NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
R. BRUCE ETHERIDGE, *Director*

DIVISION OF MINERAL RESOURCES
JASPER L. STUCKEY, *State Geologist*

BULLETIN NUMBER 40

MANUFACTURING CHINA CLAY OPPORTUNITIES IN NORTH CAROLINA

RALEIGH
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Raleigh, North Carolina
May 1, 1941

To his Excellency, HON. J. MELVILLE BROUGHTON,
Governor of North Carolina.

Sir: I have the honor to submit herewith, as Bulletin No. 40, a report on china clay manufacturing opportunities in North Carolina. For many years, many have held the opinion that the manufacture of china clay offers advantages in our State.

This report summarizes investigations and research directed toward leading the way to the exploitation of the mineral resources of the State which are the raw materials of the industry. It is hoped that this publication will give information which will be helpful in bringing new manufacturing enterprises to North Carolina.

Yours respectfully,
R. BRUCE ETHERIDGE,
Director.

FOREWORD

The present report entitled "Manufacturing China Clay Opportunities in North Carolina" has been prepared to set forth in brief, the possibilities of producing high-grade ceramic products from local materials in Western North Carolina. The report is not the work of any one person but rather represents a summary of the field investigations and laboratory research carried on by the Tennessee Valley Authority and the United States Bureau of Mines over a period of several years. These investigations were greatly facilitated by the friendly cooperation of the various operators of the Spruce Pine District and adjoining areas.

The investigations summarized in this report indicate that North Carolina contains large reserves of minerals and materials, to which only a minimum amount of accessory clays need be added in order to produce high-grade ceramic wares by modern methods. The close proximinity of these accessory clays to the large reserves of North Carolina raw materials and the existence of a ready market in the Southeast suggest splendid opportunities for the establishment of an industry in Western North Carolina based on the utilization of these resources.

JASPER L. STUCKEY,
State Geologist.

MANUFACTURING CHINA CLAY OPPORTUNITIES IN NORTH CAROLINA

INTRODUCTION

An ample supply of fine china clay is found in the Spruce Pine District of North Carolina. Of special interest to the ceramic industry is the extremely low iron content and the occurrence of only a trace of titanium in the kaolin. An exceptionally fine grade of kaolin is now being produced for the china clay trade by two modern refining plants and several older plants located near Spruce Pine, North Carolina. This kaolin is also being used for various fillers and special products.

Although kaolin has been produced from the Spruce Pine Area for more than a half century, its potentialities are not yet generally recognized, and the purpose of this booklet is to acquaint ceramic manufacturers with the possibilities of manufacturing chinaware in the southeast close to supplies of raw material and tapping an under-developed but growing retail market.

DESCRIPTION AND LOCATION OF MINERAL DEPOSITS

These kaolin deposits have been formed from huge bodies of coarsely crystalline, white granite, ALASKITE, containing practically no iron-bearing minerals. The Spruce Pine alaskite has its greatest development in the vicinity of Spruce Pine, Mitchell County, North Carolina, and outcrops at irregular intervals over an area of about 225 square miles. The largest unbroken body occurs two miles northwest of Micaville, Yancey County, North Carolina, and has an outcrop width of about one mile and a length of about two and one-half miles. Occasional small Spessartite-like (manganese-iron) garnets are found in the alaskite, but hornblende is entirely

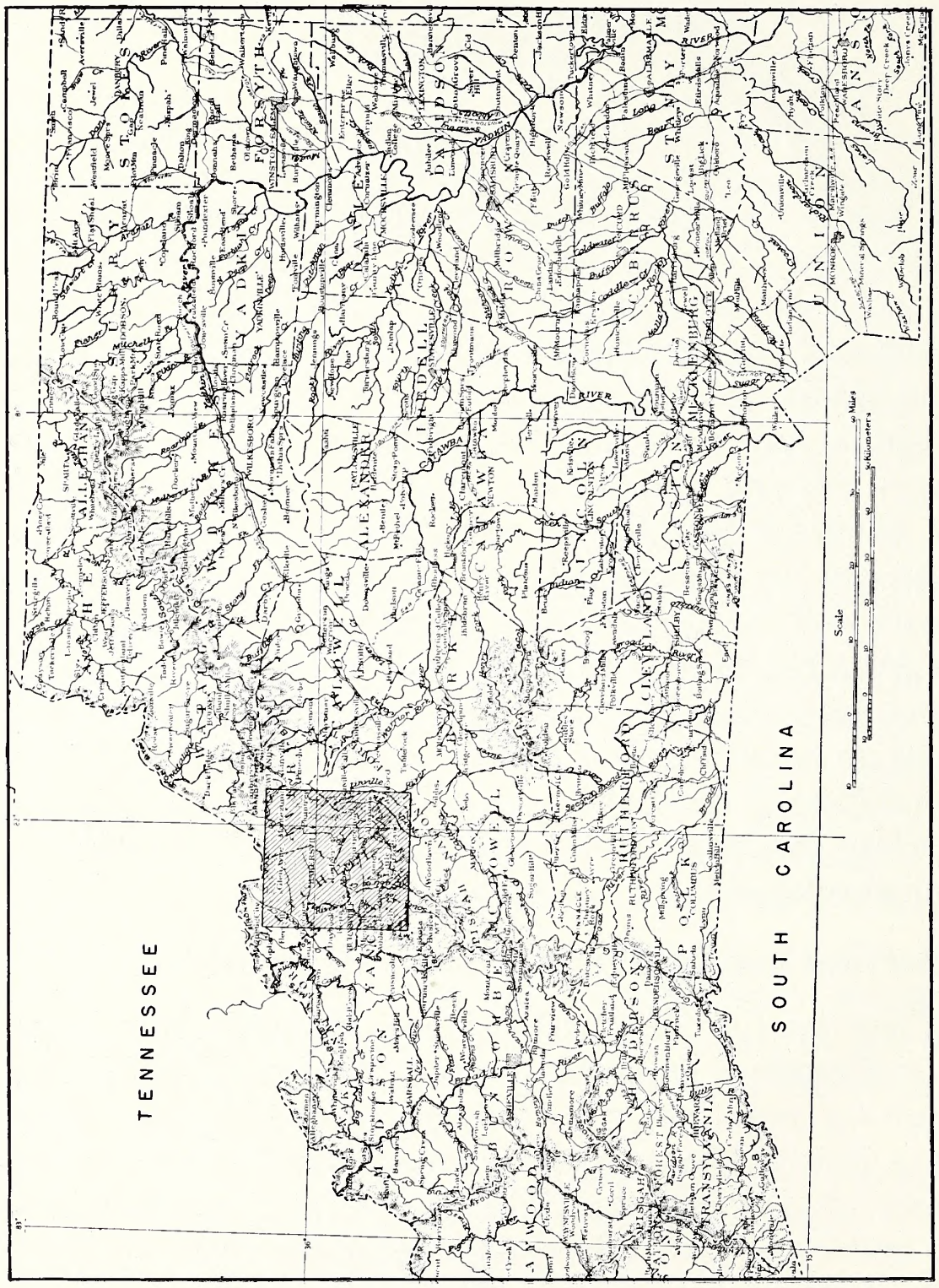

Figure 1.—Index Map Showing Location of North Carolina Kaolin Deposits.

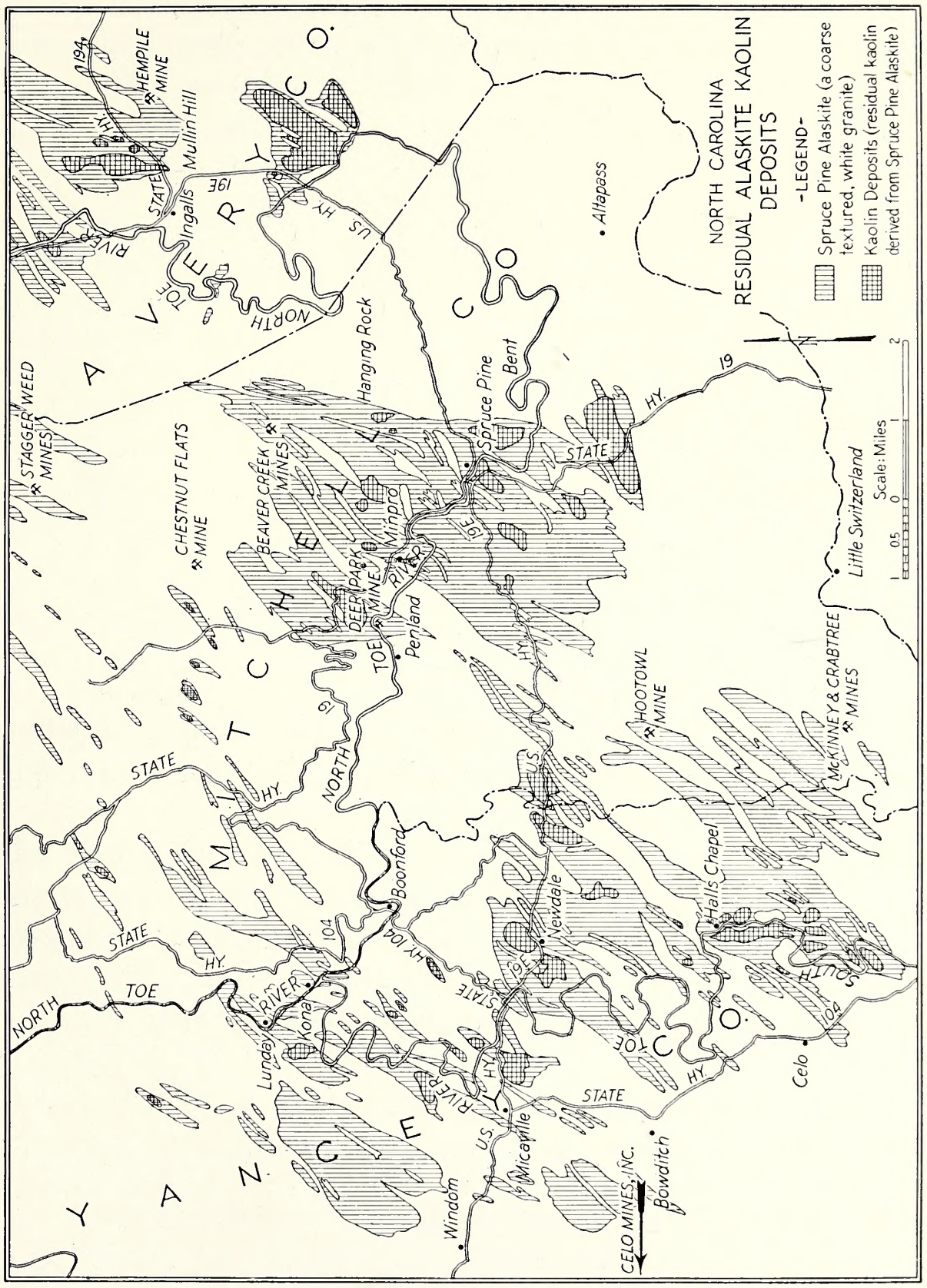

Figure 2.—North Carolina Residual Alaskite Kaolin Deposits.

absent. Biotite, the high iron mica, is rarely found in the alaskite, although frequently associated with the pegmatite cutting the alaskite. Most granites and pegmatites contain various titanium minerals, but the Spruce Pine alaskite is an exception in that it contains no noticeable titanium minerals.

TABLE I

TYPICAL ANALYSES OF SPRUCE PINE ALASKITE

	No. 1 *Percent*	*No. 2* *Percent*
SiO_2	73.96	74.30
Al_2O_3	15.77	15.50
Fe_2O_3	0.33	0.30
CaO	1.30	0.90
K_2O	3.74	4.56
Na_2O	4.57	4.15
Ignition Loss	0.31	0.26
Total	99.98	99.97

The analyses of Table I are from the Minpro Laboratory, United Feldspar and Minerals Corporation, Spruce Pine, North Carolina.

The deposits are outstanding in the uniformity of the mineral content. All the alaskite bodies are essentially of the same composition and texture and are remarkably uniform throughout their extent. The proportions of feldspar, quartz, and mica vary only slightly within the bodies. The alaskite referred to in Table I contains 45.3 percent plagioclase feldspar, 2.12 percent microcline feldspar, 28.6 percent quartz, 2.2 percent muscovite mica, 0.5 percent garnet, 1.2 percent clays, and 1.0 percent other minerals.

PRESENT KAOLIN DEPOSITS

More than 50 geographically separate kaolin deposits associated with the Spruce Pine alaskite, have been found in Avery, Mitchell, and Yancey Counties, North Carolina.

The largest and best of these residual deposits occur under terrace levels produced by the North and South Toe Rivers and Crabtree Creek. Practically all of the deposits contain recoverable kaolin and rarely occur with objectionable mining features, such as excessive overburden and inaccessible locations. The beds are easily mined either by mechanical means or by water jets under moderate pressure. One deposit near the town of Spruce Pine is reported to have been mined to a depth of slightly more than 100 feet.

TABLE II

ANALYSES OF REFINED KAOLIN SAMPLES

	No. 1 *Percent*	*No. 2* *Percent*
SiO_2	47.94	46.18
Al_2O_3	37.02	38.38
Fe_2O_3	0.60	0.57
TiO_2	0.02	0.04
CaO	0.30	0.37
MgO	0.07	0.42
K_2O	1.25	0.58
Na_2O	0.06	0.10
ZrO_2		0.08
Ignition Loss	13.03	13.28
Total	100.29	100.00

The analyses of Table II were furnished by Kaolin, Incorporated, and Harris Clay Company, Spruce Pine, North Carolina.

AVAILABLE SUPPLY OF KAOLIN

It has been reliably estimated[1] that 51,000,000 tons of crude kaolin exist in Avery, Mitchell, and Yancey Counties, North Carolina. By crude kaolin is meant the kaolin and its accompanying matrix minerals less the

(1) Paul M. Tyler and A. Linn: *"Minerals Yearbook—United States Bureau of Mines. 1940."* Page 1255.

Figure 3. Mine of Kaolin, Inc., Spruce Pine, N. C.

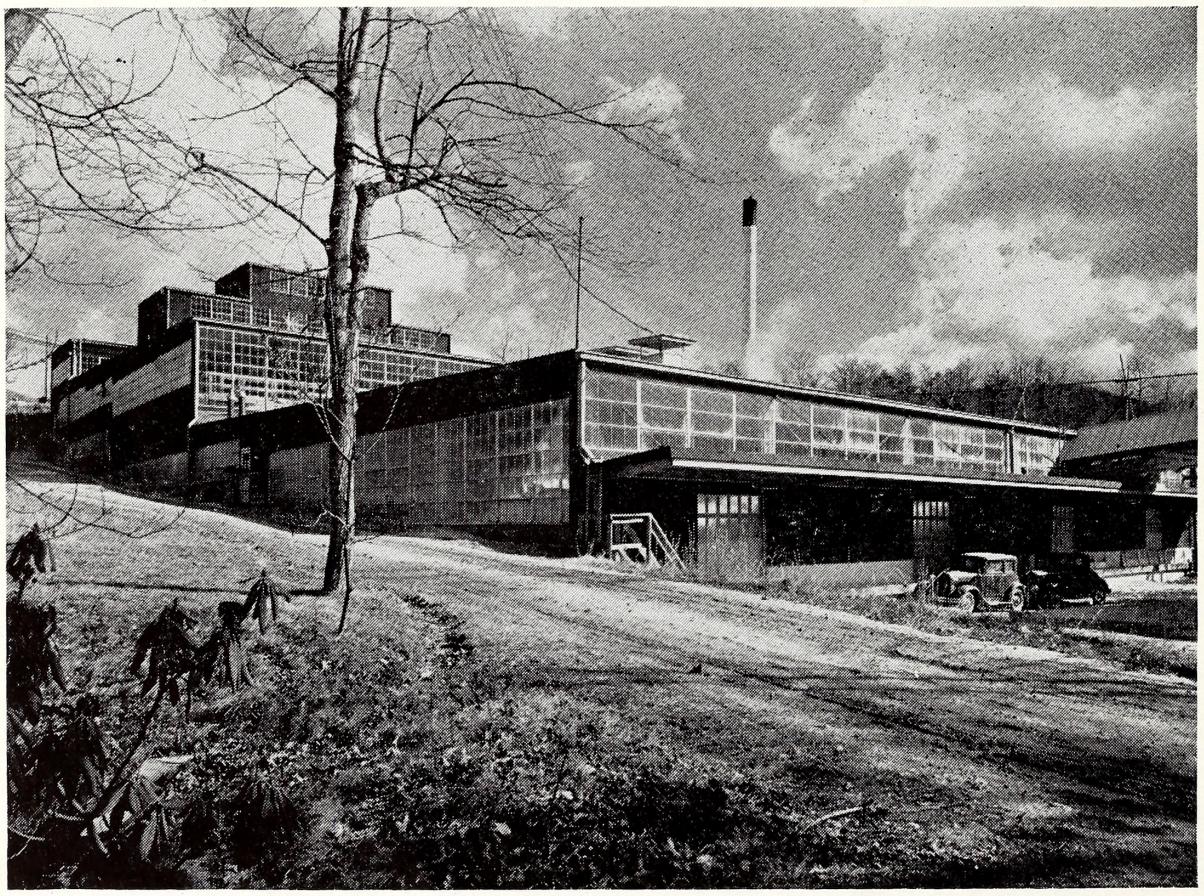

Figure 4. Plant of Kaolin, Inc., Spruce Pine, N. C.

schist and gneiss inclusions. The percentage of recoverable kaolin varies with the various deposits. Many deposits have been worked on a 10 percent or greater recovery basis. A higher percentage than 10 percent of recoverable kaolin, however, occurs in many deposits.

In addition to kaolin, these deposits yield valuable by-products from the kaolin refining process, such as high-grade muscovite mica used in the manufacture of roofing and as fillers, and semi-kaolinized feldspar and quartz. The quartz is milky white, free from iron stains, and near the specifications for high-grade glass sand, although little use has so far been made of it for this purpose.

REFINING KAOLIN

In 1936, the Tennessee Valley Authority established a ceramics laboratory at Norris, Tennessee, to work out methods of refining North Carolina kaolin in order to produce all-American clay bodies suitable for the manufacture of high-grade and medium-grade chinaware, and to replace imported kaolin. These experiments were carried out jointly with the U. S. Bureau of Mines and the Harris Clay Company of Spruce Pine, North Carolina, and in 1938 a new modern kaolin refinery was built in the Spruce Pine District. About the same time Kaolin, Incorporated, also of Spruce Pine, North Carolina, set up a large plant to refine kaolin by a process developed in Czecho-Slovakia. Both companies are now supplying a blended kaolin of uniform quality to the trade which is equal to the best imported kaolin.

The TVA process is available to other prospective producers or manufacturers. Shipments of over 12,000 tons of refined kaolin per year are now being made to northern potteries.

In addition to the kaolin, there are potash, soda, and blended feldspars produced in the area which are used

Figure 5. A Mine of Harris Clay Co., near Spruce Pine, N. C.

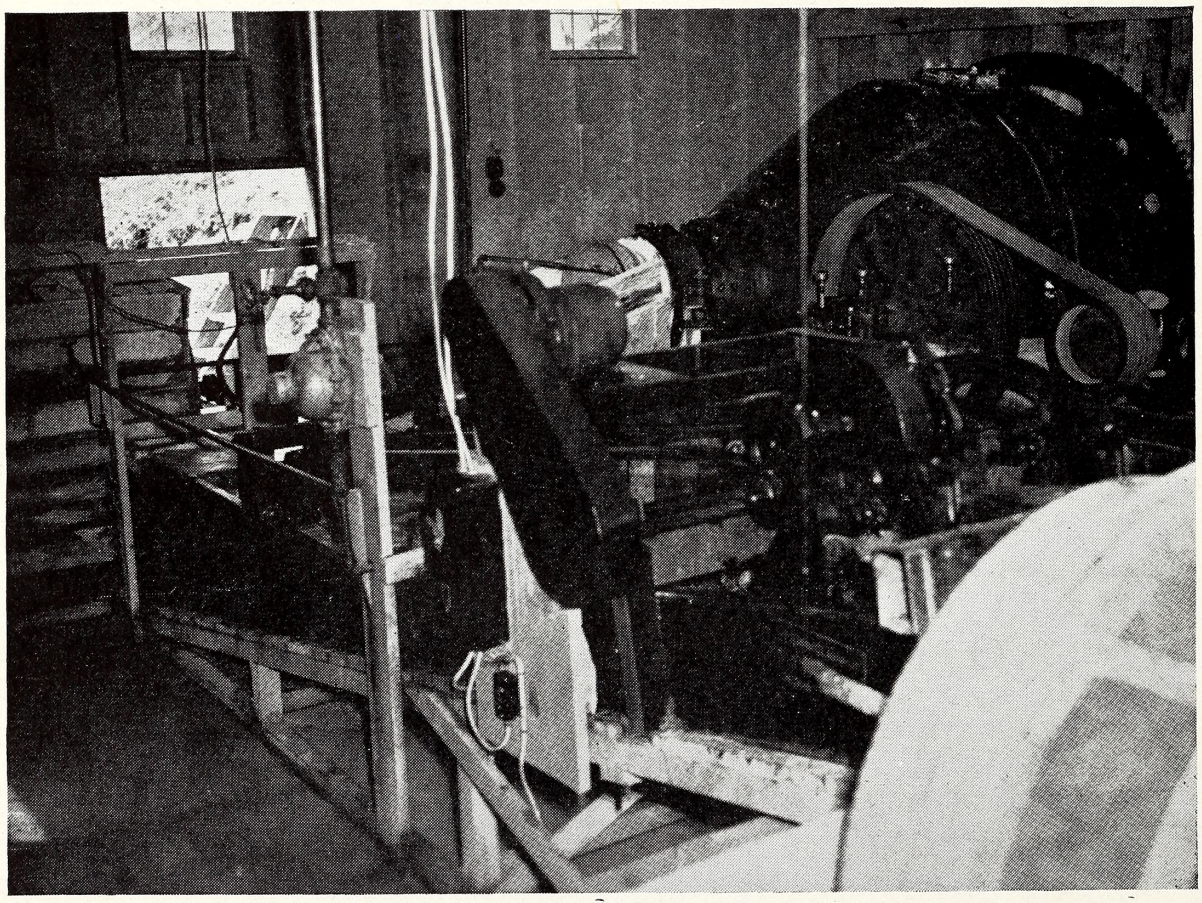

Figure 6. Clay Preparation Machinery, Harris Clay Company Plant near Spruce Pine, N. C.

in the ceramic industry. This area contains the largest reserves of high-grade feldspar known in the United States, and has produced an average of 82,700 tons annually for the past decade. This material is produced by three large, modern grinding plants in the Spruce Pine area. One of these plants produces ground quartz in addition to the feldspar. It might also be of interest to the ceramist to know that the only pyrophyllite ($H_2Al_2(SiO_3)_4$) mines and grinding plants in the United States are located in North Carolina. This industry is located in Moore and Randolph Counties, about 200 miles east of the Spruce Pine District, where three modern grinding plants are in operation. In these counties there are large reserves of high-grade crystalline pyrophyllite. Both foliated and fibrous or radiating varieties are abundant. Another important ceramic mineral in the Spruce Pine District is kyanite (Al_2SiO_5), which occurs commonly throughout most of the Mountain and much of the Piedmont sections of the State. The most important deposits are found on the western edge of the Spruce Pine District, in a belt 6 to 8 miles wide, extending from near Burnsville, Yancey County to Swannanoa, Buncombe County. The mineral occurs in metamorphosed acid rocks and in pegmatite dikes and quartz veins, inclosed in these rocks. There are ample reserves of kyanite-bearing gneisses and schists which contain from 5 to 40 percent of kyanite. A modern beneficiation plant, capable of producing a 98 percent kyanite concentrate is in operation near Burnsville.

ELECTRIC FIRING

In order to test fully the use of North Carolina kaolins for high-grade dinnerware, the TVA built and operated at Norris, Tennessee, a small experimental or pilot plant in which was installed a continuous electric kiln. Different types of ware of good commercial quality

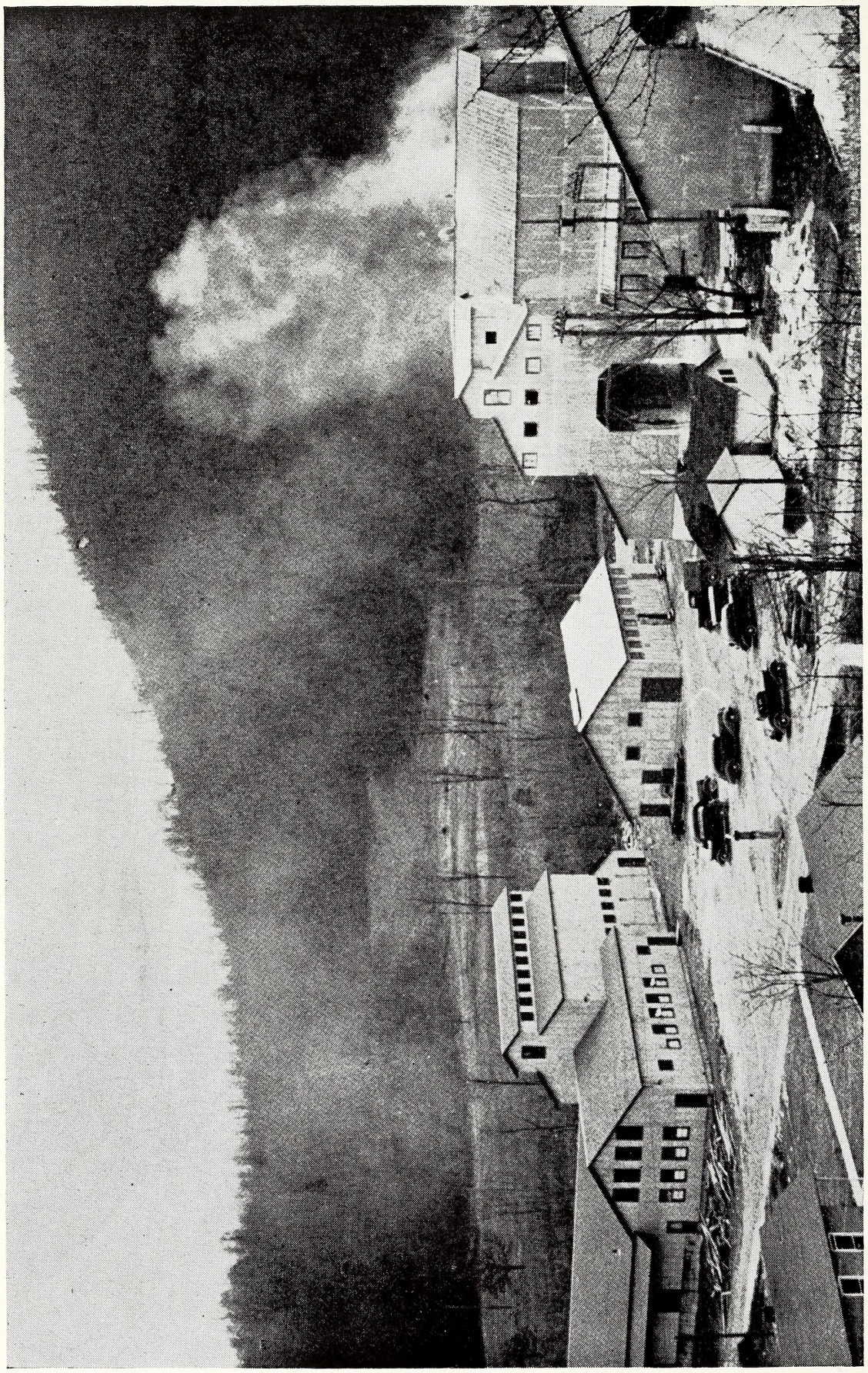

Figure 7. A Feldspar Plant in North Carolina.

were made using domestic materials only and fired electrically. Kaolin from North Carolina was blended with that from Florida to give an all-American all-kaolin mixture. A high-grade, vitreous, translucent dinnerware was made in order to test thoroughly the best methods of blending the clay bodies and of molding and firing the ware. Best results seem to be obtained when approximately 12 percent of Florida kaolin or ball clay from Tennessee or Kentucky are added. The proximity of the Florida kaolins and the Tennessee and Kentucky ball clays to the Spruce Pine District make possible in this area the manufacture of an all-Southern body without the necessity of transporting these accessory clays great distances.

BUREAU OF MINES

The Norris Ceramic Laboratory was recently turned over to the U. S. Bureau of Mines, who are continuing the experiments on electric firing and the development of southern raw materials for ceramic and other uses. The Bureau of Mines is also testing the production of large sanitary ware on a small commercial scale using all American materials under methods of electric firing.

The Bureau of Mines reports that "The North Carolina kaolins correspond most closely of those tested to the English kaolins in physical and chemical properties, but as now prepared by improved methods, are finer grained, more plastic and stronger than English clays."

The Bureau also reports that "North Carolina Alaskite was found to represent a satisfactory and enormous potential source of white-firing, mixed potash and soda feldspar (plus flint) for many future generations."

RESISTOR

In order to retard oxidation and prolong the life of the heating element, the ceramic laboratory developed a

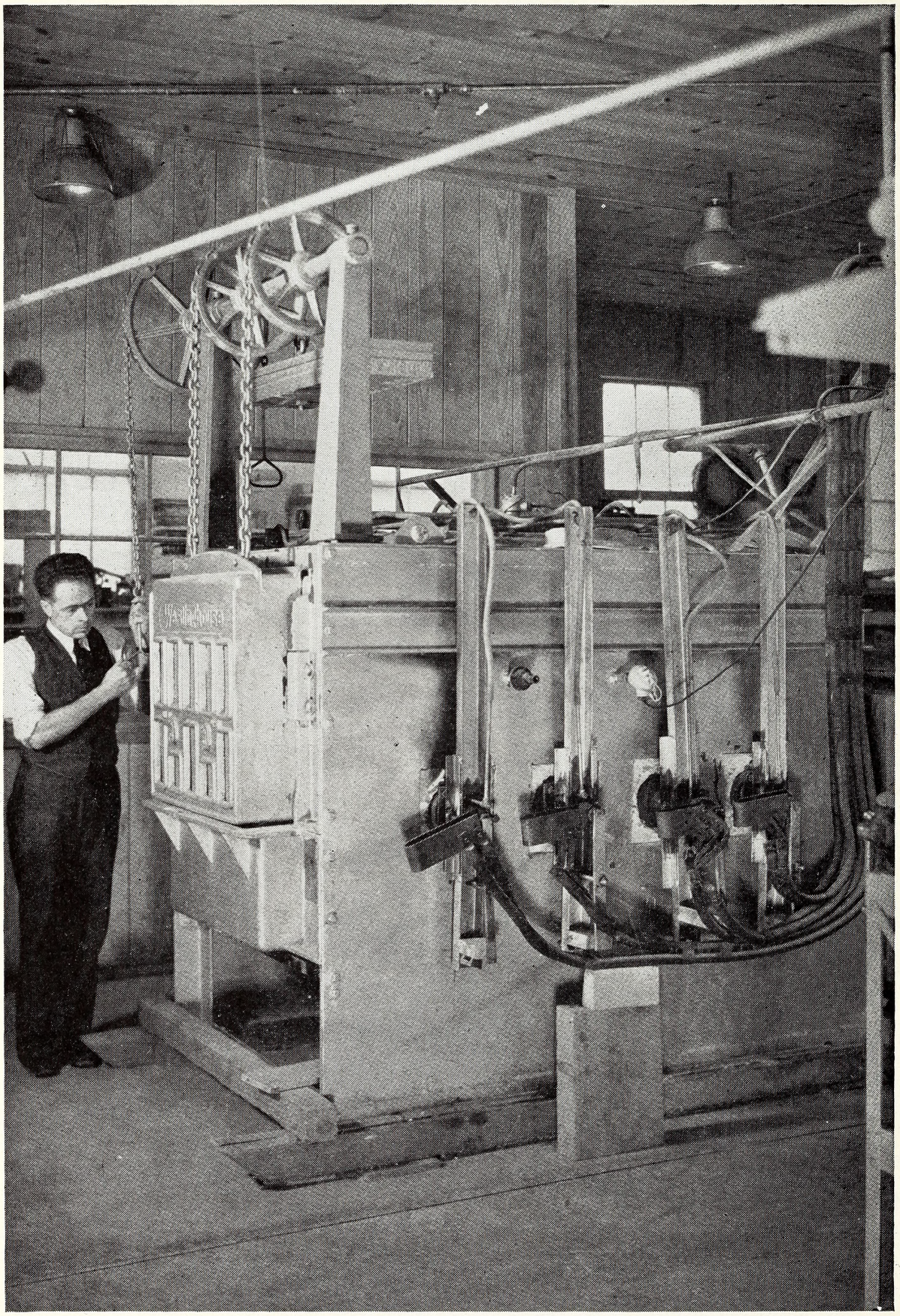

Figure 8. Electric Periodic Kiln at Electrotechnical Laboratory of U. S. Bureau of Mines, Norris, Tennessee.

graphite core resistor enclosed in a refractory tube of silicon carbide, in which hydrocarbon gas (propane) was held under a slight pressure.

The latest tests on graphite resistors protected by a bonded silicon carbide tube, show a life of from 3,120 to 4,872 hours of continuous firing and an average life of about 3,800 hours or about 6 months' operations. The use of these resistors is available under license for other purposes in the fields of heat treatment, metallurgy, electro-chemistry, etc.

RESULTS OF ELECTRIC FIRING TESTS

The results obtained by firing large sanitary wares and masses of full size brick, substantiated by theoretical calculations, have shown that

1. Radiated heat is the major method of transmission at incandescent temperatures.
2. Firing schedules similar to those in combustion fired kilns can be maintained by electric firing.
3. Commercial requirements for quality and uniformity of vitrification can easily be met if time is given for "soaking" or completing the reactions at the maximum temperatures.

These results also substantially confirm the experience in firing thin translucent dinnerware.

RATE OF FIRING

High grade dinnerware has been bisque-fired satisfactorily in 18-hour cycles for the open setting to 36-hour cycles for plate bungs and heavy ware. The experimental kiln at the Norris Laboratory measures 55 feet long, 2 feet and 11 inches wide, and 1 foot high to the spring of the arch (the kiln has two tunnels each with 1 foot by 1 foot loading cross section), with a total of 14 heating elements, requires 85 to 110 kw. input, depending upon operating temperature, and has operated for over 8,500

Figure 9. Casting Room at Electrotechnical Laboratory of U. S. Bureau of Mines, Norris, Tennessee.

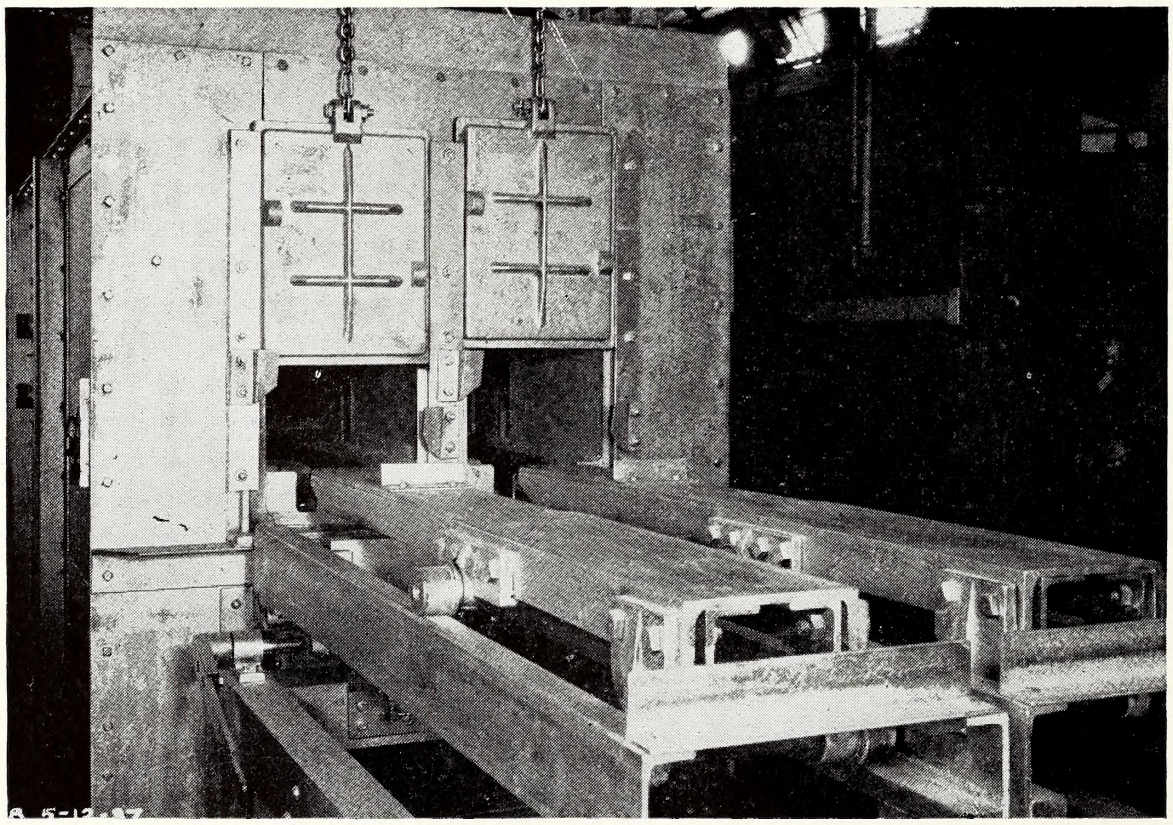

Figure 10. Electric Tunnel Kiln at Electrotechnical Laboratory of U. S. Bureau of Mines, Norris, Tennessee.

hours on all types of ware from fine china to face brick with ranges of temperature up to cone 14, 2550° F. The rates of firing used were faster than those now employed in the larger commercial, combustion-fired kilns, but these undoubtedly can be met in other small kilns.

ECONOMICS OF ELECTRIC FIRING

At present with electric energy at 2 mills per KWH the equivalent electrical energy consumed is comparable in fuel cost of natural gas at $0.58 per M feet, fuel oil at 8.4 cents per gallon, and coal at $16.25 per ton.

COMPARATIVE ENERGY COSTS

100% Electricity	*100% ratio to electricity*[1] Oil	Gas	Coal
2 mill	8.4¢	58¢	$16.25
100%	*80% ratio to electricity*		
2 mill	6.7¢	46.5¢	$13.00
3 mill	10¢	70¢	19.50
100%	*60% ratio to electricity*		
2 mill	5¢	35¢	$ 9.75
3 mill	7.5¢	52.5¢	14.60
4 mill	10¢	70¢	19.50
100%	*40% ratio to electricity*		
2 mill	3.4¢	23¢	$ 6.50
3 mill	5.1¢	35¢	9.75
5 mill	8.4¢	58¢	16.25

Electricity: cost in mill per kwh = 3412 B.t.u.
Oil: cost per gallon, 142,000 B.t.u. per gallon.
Gas: cost per thousand cubic feet, 1000 B.t.u./cu. ft.
Coal: cost per ton, 14,000 B.t.u./lb.

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1 Different types of kilns operate at different degrees of efficiency. The above table gives cost comparisons for different efficiency ratios as compared to electricity. For example, in a kiln with an 80 percent ratio of efficiency as compared to electricity, electricity at 3 mills per KWH would represent the same energy cost as fuel oil at 10 cents a gallon, natural gas at 70 cents per M feet, or coal at $19.50 a ton.

Figure 11. Test Ware Produced Experimentally at TVA Ceramic Laboratory. Made Exclusively of North Carolina Kaolins and Other Domestic Materials.

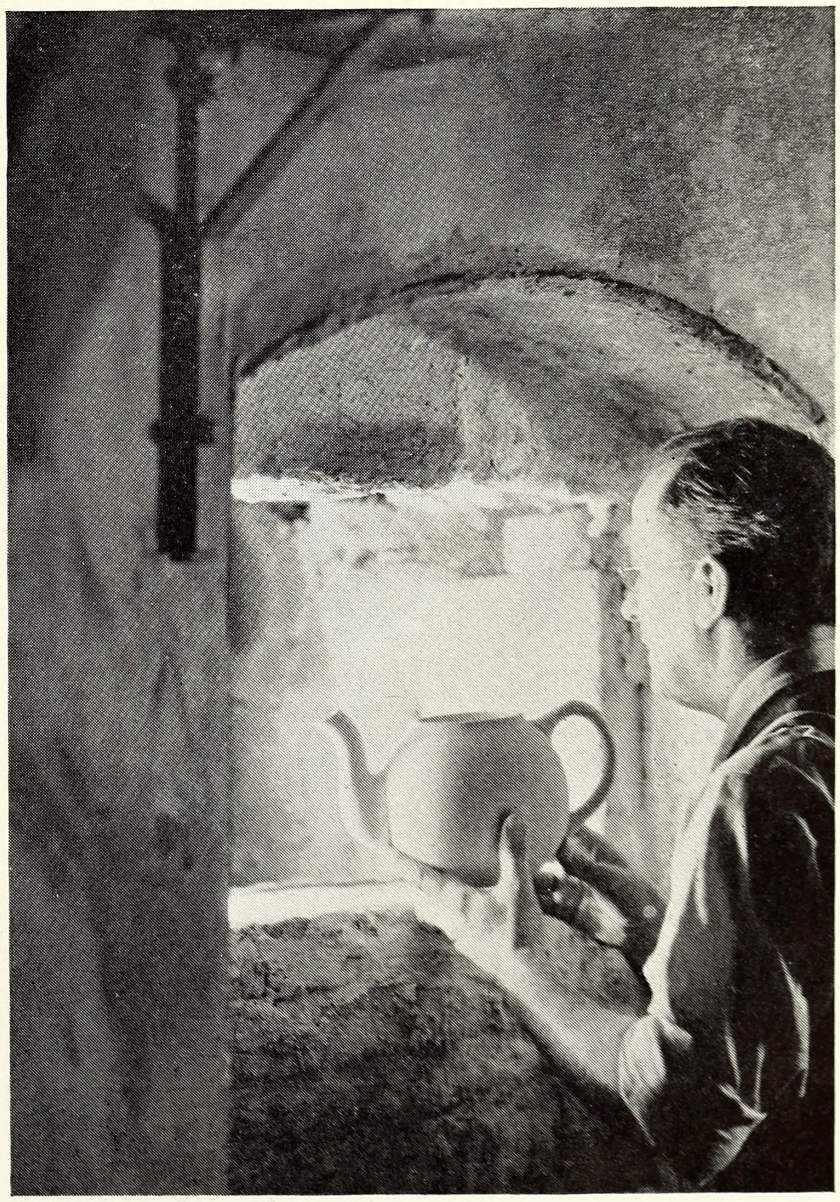

Figure 12. Test Ware Produced Experimentally at TVA Ceramic Laboratory. Made Exclusively of North Carolina Kaolins and Other Domestic Materials.

Electric firing offers:

1. The clean oxidizing atmosphere of the best muffle kiln designs.
2. The most efficient methods of temperature control.
3. The most efficient use of energy since there are no losses of heat from stacks nor radiation from open, exposed fire boxes.
4. Possible savings in fuel costs in those districts having high oil or gas prices and low electricity rates.
5. The opportunity of using multiple tunnel kilns with more uniform distribution of heat units and greater savings.

AVAILABILITY OF FURNACE

The use of the electric tunnel kiln at Norris, Tennessee, is available to ceramic manufacturers desiring to conduct their own tests of electric firing. Electricity will be supplied by the TVA at standard commercial rates. Extra labor, supplies, repairs, and miscellaneous expenses of operation can be supplied at actual cost plus a small percentage for overhead and handling.

PRESENT SOUTHEASTERN MARKET

Based on 1935 Census of Manufactures, the estimated annual market for whiteware in the nine southeastern states is $10,361,000, of which $9,770,000 worth is produced outside the area. This includes not only chinaware, but sanitary and plumbing ware.

The market for chinaware in the Southeast not covered by production in the area and sold through department stores and five and ten stores is conservatively estimated to be about $3,325,000 annually.