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THE HIGH-SILICA RESOURCES OF TENNESSEE

By

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STATE OF TENNESSEE

BUFORD ELLINGTON, Governor

DEPARTMENT OF CONSERVATION AND COMMERCE

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DIVISION OF GEOLOGY

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Preface and Acknowledgments

The Tennessee Division of Geology is continually reappraising the State's mineral resources, and this report is one of a series that presents the results of these studies. Technological advances have increased the variety of products made from high-silica raw materials, and silica industries benefited by these advances have created more markets for these raw materials. The glass industry uses by far the largest proportion of high-silica raw materials, so that compilation of data in this report was arranged in accordance with this usage.

Much of Tennessee is underlain by sands and sandstones, some of which are the high-silica variety; general usage of the term, high-silica, is a raw material that contains at least 95 percent silica (SiO_2). This is a preliminary report and is not intended to give complete coverage of the high-silica possibilities of the entire State. It includes selected representative samples only, but these probably give an indication of the possibilities. Physical and chemical analyses were made of samples from the 24 different localities selected for this investigation. Some samples did not meet requirements for glass manufacture or other high-silica products, but these were successfully beneficiated by various treatments to qualify them as commercial-grade raw materials.

Beneficiation studies were made in cooperation with the U. S. Bureau of Mines at Norris, Tennessee, under the supervision of G. D. Jermain of the Mining Branch. These studies were devised and completed by Harold L. Riley of the U. S. Bureau of Mines and by the writer. Many helpful suggestions for procedures were given by H. P. Hamlin of the Metallurgy Branch of the U. S. Bureau of Mines. All information given and work performed by the Bureau are gratefully acknowledged.

The writer wishes to acknowledge the assistance of W. D. Hardeman, State Geologist, who both supervised and worked with the writer. Other members of the Division staff aided in selecting several of the representative sample localities; chief among these are Stuart W. Maher in East Tennessee, Edward T. Luther in the Cumberland Plateau, and Richard G. Stearns in West Tennessee. Chemical analyses were made by D. F. Farrar, chemist for the Tennessee Division of Geology. The report was edited by Robert J. Floyd of the Tennessee Division of Geology.

Appreciation is given to owners and operators of the sand companies visited; much valuable data were obtained from these companies, and many courtesies were extended.

THE HIGH-SILICA RESOURCES OF TENNESSEE

By

Robert E. Hershey[1]

GENERAL SPECIFICATIONS

To date, the high-silica raw materials of Tennessee, as such, have been used in the manufacture of glass only. Tables 1 and 2 give specifications (American Ceramic Society and National Bureau of Standards) for high-silica raw materials used in the glass industry and are only a guide to general requirements. Many companies have chemical and physical tolerances different from those included in these tables.

TABLE 1. Chemical requirements for glass sand.[2]

	SiO_2 minimum %	Fe_2O_3 maximum %	Al_2O_3 maximum%	$CaO + MgO$ maximum %
First quality, optical glass	99.8	0.020	0.1	0.1
Second quality, flint glass containers and tableware	98.5	0.035	0.5	0.2
Third quality, flint glass	95.0	0.035	4.0	0.5
Fourth quality, sheet glass, rolled and polished plate	98.5	0.060	0.5	0.5
Fifth quality, sheet glass, rolled and polished plate	95.0	0.060	4.0	0.5
Sixth quality, green glass containers and window glass	98.0	0.300	0.5	0.5
Seventh quality, green glass	95.0	0.300	4.0	0.5
Eighth quality, amber glass containers	98.0	1.000	0.5	0.5
Ninth quality, amber glass	95.0	1.000	4.0	0.5

[1] Principal Geologist, Tennessee Division of Geology, Nashville, Tennessee.

[2] Percentage composition based on ignited samples.

Iron is the most objectionable of the contaminants listed in the preceding table, because it imparts color to the finished glass. Other elements such as titanium also discolor glass but are not so universally widespread as iron. Some minerals such as zircon cause undesirable physical properties in molten glass and imperfections in the finished product.

In the manufacture of glass, physical characteristics of sands are as important as the chemical content. The most important physical characteristic is uniformity of grain size. Uniformity in size is essential either in the larger grain sizes or in the smaller sizes.

The following table shows grain sizes generally in demand by the glass industry; however, several companies use much finer grain sizes, ranging from 100 mesh to 325 mesh.

TABLE 2. Grain size distribution for glass sand.

		Percent
Sand retained on	20-mesh sieve	0
Sand retained on	40-mesh sieve	40-60
Sand retained on	60-mesh sieve	30-40
Sand retained on	100-mesh sieve	10-20
Sand passing	100-mesh sieve	0-5

MARKETING

USES

The many varied uses of glass are generalized in the following list (Phillips, 1950):

- Flat glass
  - Window glass
  - Obscured glass
  - Wire glass
  - Other—including plate and glass block
- Containers
  - Food products
  - Beverage
  - Medicinal and toilet
  - General purpose
- Glassware, not containers
  - Tableware—tumblers, goblets, barware, plates, cups, saucers, bowls, vases, jugs, etc.
  - Lighting glassware—shades, globes, chimneys, reflectors, electric light bulbs, oil lamps, etc.
  - Miscellaneous glassware
    - Lenses, various but not optical
    - Tubing
    - Other technical, scientific, and individual pressed and blown ware, not specified above, including cooking utensils and ovenware; also, fiber glass products.

Other than glass, high-silica products include ferrosilicon, silicon metal, and non-ferrous silicon alloys, and are used in various metallurgical processes such as in elemental phosphorus manufacture, and for many other purposes.

PRICES

Glass sand prices have been consistent through the last several years, showing a gradual increase in price reflecting a stable industry. The following figures, from the U. S. Bureau of Mines Minerals Yearbooks, represent the average price per short ton for all grades of glass sand:

1948	$2.37
1949	$2.48
1950	$2.49
1951	$2.61
1952	$2.66
1953	$2.82
1954	$3.03
1955	$2.81
1956	$2.86
1957	$2.84

As a comparable figure, glass sand from Tennessee averaged $3.10 per ton in 1957 and $2.95 in 1958.

The total value of glass produced in the State in 1939 was $320,000, which increased to more than $700,000 by 1947 and is still increasing. The increase is due partly to population growth but mostly to increased variety of uses.

MARKETS

Present markets for glass sand in Tennessee are: the Ford Plant at Nashville, for rolled automobile window glass and safety glass; the Chattanooga Glass Company at Chattanooga, for glass containers, principally soft drink bottles; and the Blue Ridge Glass Corporation (a subsidiary of American-St. Gobain Corporation) at Kingsport, for rolled glass of many different types. American-St. Gobain Corporation is planning a new plant for the Kingsport area.

Local markets for high-silica raw materials other than glass sand are: Tennessee Products and Chemical Company at Rockwood, for ferrosilicon; phosphate plants at Columbia, in the electric-furnace manufacture of elemental phosphorus; and Tennessee Products and Chemical Corporation at Chattanooga, for the manufacture of silicon metal and aluminum-silicon alloys. These uses for high-silica raw materials require a coarse grade of silica in gravel size, ranging from $\frac{1}{2}$ inch in diameter to more than 4 inches in diameter; all are electric furnace processes and require larger size material because fine-grained sand would give too dense a charge in the furnace.

PRESENT OPERATIONS

High-silica sands have been used in Tennessee for construction, foundry, and miscellaneous purposes for many years, but the use of high-silica sands from Tennessee as raw materials in glass manufacture is relatively recent.

Two companies are now actively mining sand for glass manufacture. The Sewanee Silica Sand Company, near Monteagle (fig. 1), produces sand which is shipped to Chattanooga to make glass bottles for soft drinks. The Hardy Sand Company, near Camden (fig. 2), provides sand for the manufacture of automobile windshields and safety plate glass at the Ford Motor Company glass plant in Nashville; this sand is also used in grinding the automobile glass.

The Sewanee Silica Sand Company is mining the Sewanee conglomerate, which contains varying amounts of quartz pebbles. This sandstone is soft and easy to mine, generally requiring only mechanical loading equipment to break it into individual sand grains; however, light blasting to break up the sandstone is necessary in some areas. Coarse size sand and quartz pebbles are stockpiled and sold as road material; the finer sizes are washed until suitable for glass sand.

The Hardy Sand Company is mining the unconsolidated McNairy sand. Sand to be used for making glass is selectively mined for high quality; the remaining sand is used as grinding sand for glass, as foundry sand, and for other purposes. Most of the mining is done by power shovels, but one pit is flooded and a dredge is used to mine the sand. The glass sand is processed by washing to remove the clay and by attrition grinding to remove surficial iron stain.

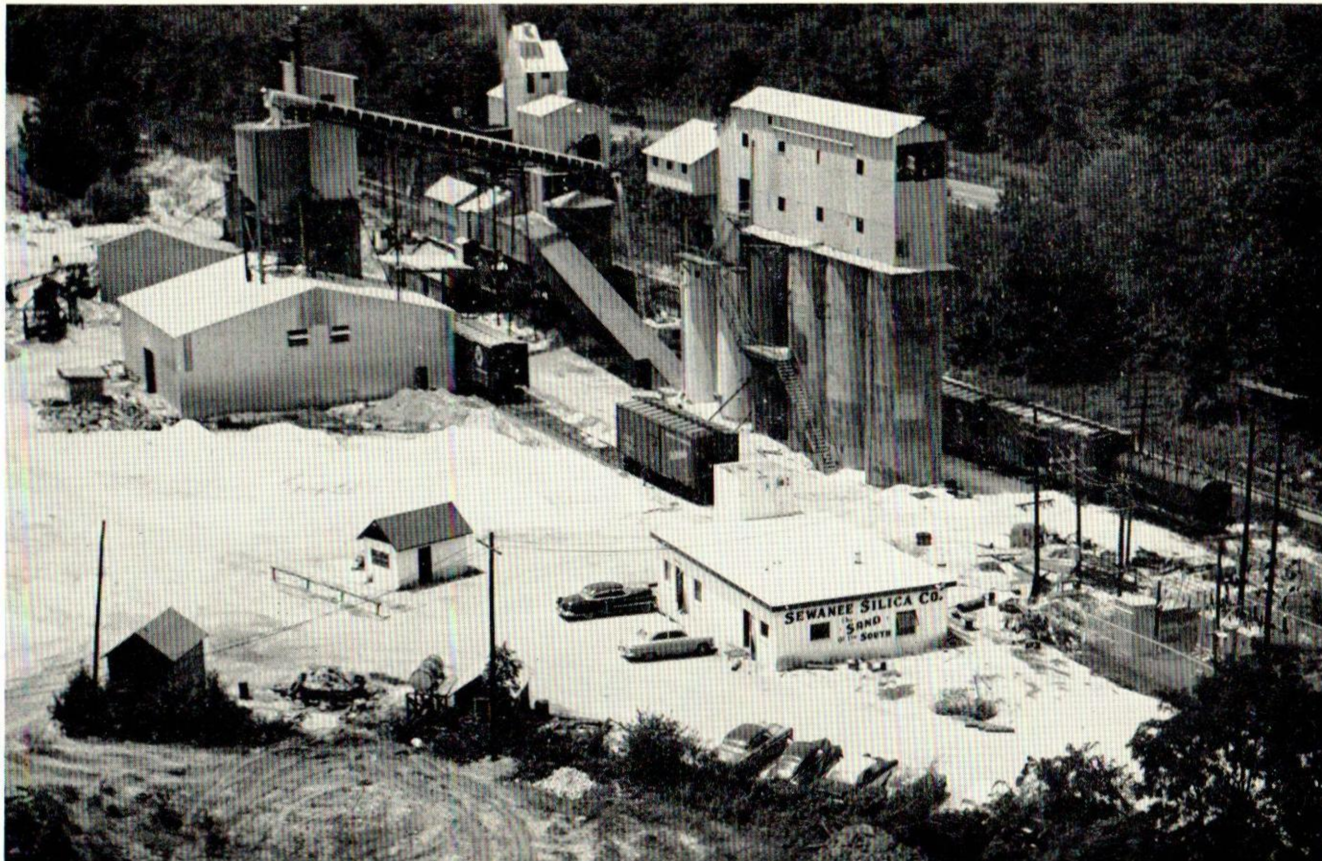


FIGURE 1. *Sewanee Silica Sand Company plant near Monteagle, Tennessee.*

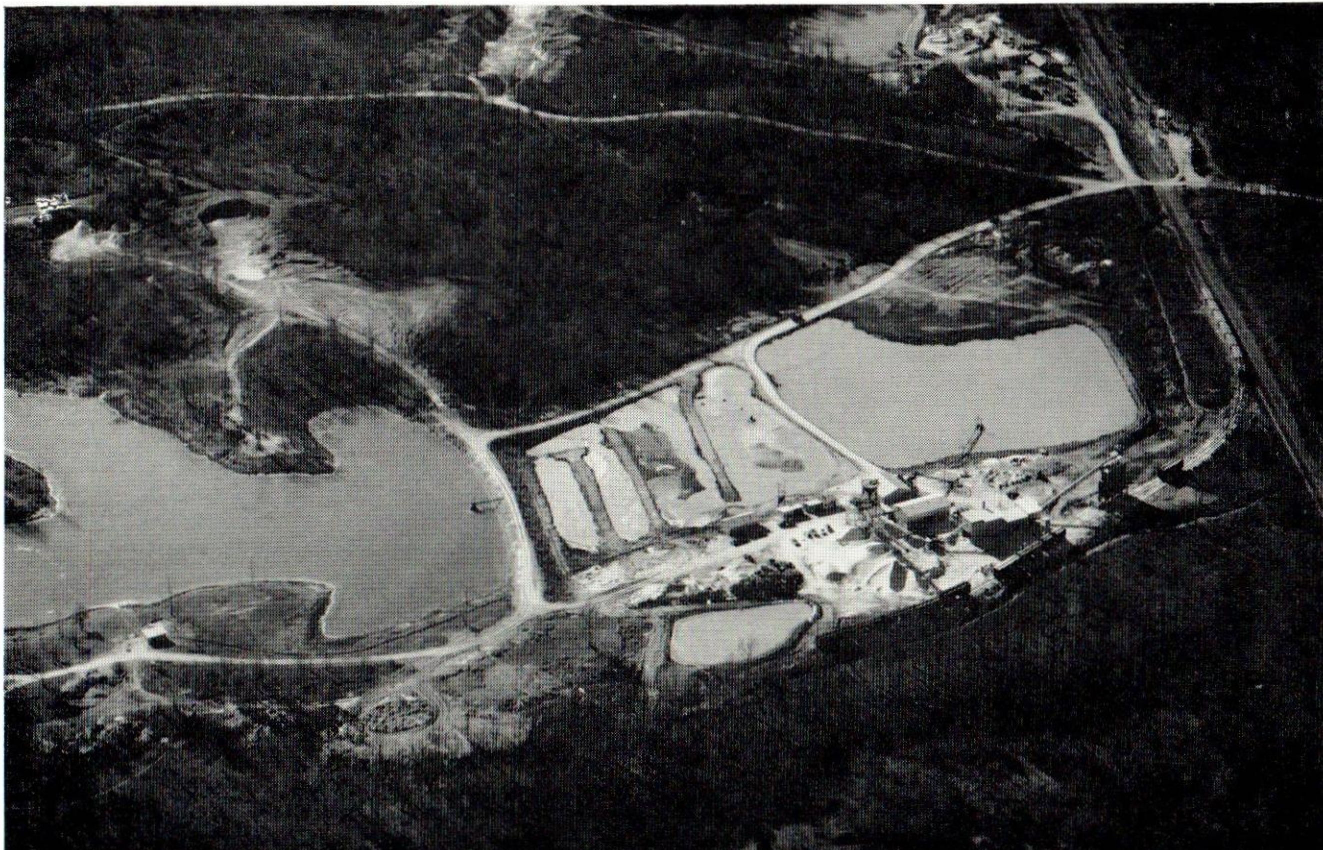


FIGURE 2. *Aerial view of the Hardy Sand Company operations near Camden, Tennessee.*

GEOLOGY OF FORMATIONS SAMPLED

Eight different formations were sampled; the formations range in age from Tertiary (Eocene) to Silurian. The younger formations are unconsolidated, and the older formations are consolidated. The consolidated deposits were sampled in areas that contain the most friable sandstone.

TABLE 3. Geologic horizons of sand and sandstone samples.

Age	*Formation*	*Thickness (feet)*
	UNCONSOLIDATED ROCKS	
Tertiary (Eocene)	Claiborne and Wilcox sand	100-1200
Late Cretaceous	McNairy sand	350-600
	Eutaw formation	0-50
	CONSOLIDATED ROCKS	
Pennsylvanian	Rockcastle conglomerate	100-300+
	Vandever formation	0-100[1]
	Sewanee conglomerate	0-160
Devonian	Camden chert	0-200
Silurian	Clinch sandstone	250-800

[1] Sandstone only; total formation thickness as much as 250 feet.

TERTIARY (EOCENE)

CLAIBORNE AND WILCOX SAND

The Claiborne and Wilcox sand is composed of unconsolidated beds of clay and sand of varying thickness. This interval is about 1,200 feet thick near the Mississippi River and thins to a feather edge eastward. It is present west of the area shown on the index map (pl. 1) but is in the subsurface. The component beds are nearly horizontal but have a gentle dip toward the west.

Sedimentary features such as sand lenses, crossbedding, and blanket-type bedding are characteristic. Grain sizes vary vertically from bed to bed, but each individual bed is composed of exceedingly well sorted grains. The sorting coefficient approaches the value of 1, which indicates well-sorted material such as marine sand or dune sand. These sediments probably were formed in several different environments of deposition. Some of the beds are definitely marine, some are probably bar deposits, some may be wind-blown beach sands, and some may be stream deposits. In all the areas sampled the total sand thickness was greater than that of clay.

The average grain size is .82 mm at Grand Junction in the southeastern part of the area, .40 mm at Parkburg near Jackson, and .28 mm at McKenzie. The decrease in average size northward in these beds in the upper part of the formation is consistent with the Claiborne depositional pattern indicated by the sand-clay ratio maps of Stearns and Armstrong (1955). The sample from the base of the Eocene at Paris differs from the other samples in having a much greater proportion of subrounded grains, especially in the larger grain sizes. Also, this basal sample contains some brown chert grains that are not found in any of the younger samples except for rare grains in the Parkburg sample. If, as the writer believes, the main source of the sediments of the upper beds is from the south or southeast, as suggested by the northward decrease in grain size and the change from predominantly sand sediments to more clayey sediments northward, the sediments at Paris represent a change in source and are perhaps reworked older sands such as the Eutaw, which contains chert grains.

Sand from Locality No. 9 contains quartz grains that indicate three recognizable cycles of erosion (Hershey, 1959). The fourth cycle is now in progress.

Many of the sand beds are of mineable thickness and are surface or near-surface deposits. Subsurface drilling indicates considerable thicknesses of white sand, and surface banks of white sand have been reported. All the sand banks sampled were red to yellow, but sand washed down from these banks by rain is much lighter in color; thus, much of the iron content is removed by natural washing. Simple washing of these samples in the laboratory duplicated the effects of natural washing and thus indicated that most of the iron is more intimately associated with the interstitial clay portion and is not principally a hard iron stain on the individual quartz grains.

The Parkburg sample contained 90.6 percent of sand grains between minus 20 mesh and plus 65 mesh size. The Grand Junction sample contained 87.6 percent of grains in the same size range, the McKenzie sample contained 78 percent, and the Paris sample contained 79.7 percent.

Larger average grain size and uniformity of grain size in individual areas are characteristic of the Claiborne and Wilcox sands and would be an important factor to consider when large grain sizes are desired.

The chemical composition and amenability to beneficiation of the samples are discussed under Beneficiation Tests.

LATE CRETACEOUS

McNAIRY SAND

The McNairy sand is composed of beds of sand and clay. It is predominantly fine to medium sand with some coarse grains but has a fine-grained unit at its base.

Blanket-type deposition is prevalent in the lower part of the McNairy, and only small-scale crossbedding is present. Marine fossils, all replaced by "soft" silica, are found in the sediments, indicating marine or beach deposition of the lower fine sand, but the upper, coarser material may be nonmarine. The sorting coefficients of all the McNairy sands indicate well-sorted material; this is consistent with the fossil evidence of a marine or near-marine environment.

The average grain size of McNairy sand samples in the northern half of the outcrop area (pl. 1) is constant at .29-30 mm. In the southern half of the area, the average grain size ranges from .14-.45 mm. The smallest average grain size was noted at Lexington; at this locality the mica content is greatest. Beds containing sands of larger average grain sizes are present in the Lexington area but were not sampled for this report.

Heavy minerals are present in all the McNairy samples, and in some places outside the areas sampled they occur in commercial percentage concentrations. The heavy minerals—ilmenite, rutile, monazite, kyanite, zircon, and others—are very small sized; about 90 percent of them are between 170 and 200 mesh size. The bulk of the remainder are minus 200 mesh.

Mica is common in the McNairy sand and is abundant at Locality No. 8. At least some of this mica was formed after deposition of the sand beds, as illustrated by rounded quartz grain inclusions in the mica crystals. The mica is too fragile to have been transported and still retain quartz inclusions.

Clay is present interstitially throughout the McNairy sand and in many places as discrete clay beds, but the sampled areas contain little clay as beds. The amount of clay varies laterally and vertically in the sand. Some white sand now being used as glass sand contains very little clay, but other sand now being used for foundry sand has as much as 20 percent or more of interstitial clay.

Eutaw formation

The Eutaw formation consists largely of red sand, although several occurrences of white sand have been reported. The sample from Locality No. 1, an outlier in Stewart County, is red sand. The mineral content and physical characteristics of this sample are very similar to those of the Eocene sands and the McNairy. The notable difference is that the Eutaw sand contains quantities of brown chert.

The heavy-mineral suite in the Eutaw sample is the same as in the McNairy samples, but the average grain size is slightly larger.

At the locality of the Eutaw sample, as at the Eocene sample localities, sand that was washed from the sand banks was very much lighter colored than that in the sand banks.

PENNSYLVANIAN

The area shown as Pennsylvanian on the index map includes the Rockcastle conglomerate and all older Pennsylvanian formations. (For a complete description of the Pennsylvanian geology in Tennessee, the reader is referred to Wilson, Jewell, and Luther, 1956.)

Rockcastle conglomerate

The Rockcastle conglomerate is generally well indurated and in many places forms sheer cliffs, but some outcrops, principally in the area where the sample was obtained, are weathered either to sand or at least to friable sandstone. Crossbedding is common. Quartz pebbles are abundant in some areas and lacking in others.

The quartz grains in the Rockcastle are similar in shape and size to those of the other Pennsylvanian samples. The grains are subangular, and the many crystal faces are due to secondary crystallization. Heavy minerals are not common, and no magnetite was encountered.

Weathered outcrops of the Rockcastle contain more iron oxide than fresh Rockcastle obtained from drill holes.

Vandever formation

Approximately in the middle of the Vandever formation is a conglomeratic sandstone that is very similar lithologically to the Rockcastle and Sewanee conglomerates. The sample obtained from this unit had to be crushed to make sieve-size determinations. The sample is from an active "sand" pit and is crushed at the pit for use as construction sand. It can be crushed without excessive breakage of the individual grains.

The impurities in this sandstone are mainly iron oxide and clay. Very few heavy minerals and very little mica are present. The iron oxide occurs as a hard surface coating on many of the quartz crystals, and several small clusters of quartz grains are cemented by iron oxide.

Sewanee conglomerate

The Sewanee is well indurated and in many places forms sheer cliffs, but in considerable areas, in more level country, it is weathered to very friable sandstone. Crossbedding is common, and quartz pebbles are abundant in some beds. Generally there is no size gradation of grains between the quartz pebbles and the main bulk of medium-grained sandstone; that is, the quartz is either pebble size or medium grain size.

Most of the quartz grains are subangular, but a few are subrounded. The quartz is mostly clear, with a minimum of impurities in the grains. All the samples from the Sewanee were very similar in appearance. Secondary recrystallization in some cases has developed doubly terminated quartz crystals, but most of the recrystallization shows only as a multiplicity of small crystal faces on individual grains.

The CaO-MgO content is the same in fresh and weathered rock; none is gained or lost in the process of weathering. The more indurated Sewanee is due to silica cement and some iron oxide bonding.

In some areas the sand grains in the Sewanee are badly fractured owing to faulting and resultant movement within the sandstone beds.

Heavy minerals, which are sparse, occur as inclusions (probably ilmenite) in quartz crystals and as individual grains of tourmaline, rutile, and hematite.

Weathered outcrops of the Sewanee are varying shades of brown to white, depending on the iron oxide content. At several localities it was observed that the weathered Sewanee, unlike the weathered Rockcastle, contains less iron oxide than fresh samples from drill holes.

One company is now mining glass sand from the Sewanee.

DEVONIAN

CAMDEN CHERT

The Camden chert was included in this report because of its relatively high silica content, 94 percent, and because of the possibility of upgrading it to a high-silica raw material for ferrosilicon or some related metallurgical use. Some of the alumina, Al_2O_3, is in the form of small mica flakes interspersed throughout the chert and cannot be removed at a reasonable cost. Some of the alumina is clay, and part of this can be eliminated by washing.

Marine fossils are abundant in the chert, which was originally limestone. However, the sample contained only .31 percent of CaO-MgO combined.

SILURIAN

CLINCH SANDSTONE

The Clinch is a thick sandstone that forms the southeast flank of Clinch Mountain. The lower beds of the Clinch are thick-bedded, relatively pure sandstones which crop out near the crest of the mountain. The upper beds, which crop out lower on the flank of the mountain, are thin bedded and shaly. The two samples for this report were cut near the crest of the mountain, in the thicker sandstone beds.

The sedimentary beds that compose Clinch Mountain dip steeply to the southeast. Fracturing is evident, both as joints and as small faults. Slickensides from faulting are very common in the area of the Flat Gap sample but not so common in the area of the U. S. 25E sample.

The quartz grains vary from subangular to subrounded and are very similar in appearance to those of the Pennsylvanian sandstones. Recrystallization is common, as evidenced by many sharp crystal faces on the quartz grains.

The heavy-mineral content appears to be identical to that of the Pennsylvanian samples.

In some areas the Clinch sandstone is well cemented by silica and may be useful for making products that require high-silica raw material in lump form. In order to maintain a uniformly high grade of silica, one should avoid excessively faulted areas (such as the Flap Gap sample locality) where the sandstones have a high iron oxide content on slickensided surfaces.

FORMATIONS NOT TESTED

Neither the recent sands of extreme West Tennessee nor the quartzites of extreme East Tennessee were sampled for this report; however, they should not be discounted as possible sources of high-silica raw material. Reportedly, some of the sands near Memphis, Tennessee, should be high-silica sand. Binocular examination of samples of the Erwin quartzite near Erwin, Tennessee, indicate that the residual sand from this formation can be improved by beneficiation to glass sand grade or near glass sand grade.

SAMPLE LOCALITIES

The sand and sandstone samples were taken in areas as near as possible to railroad or river transportation. Localities were selected so as to give maximum geographic coverage of potential high-silica source areas. The localities are shown by number on the index map (pl. 1).

Quadrangles designated in the following list are those of the 7½-minute topographic series published by the U. S. Geological Survey and the Tennessee Valley Authority. Following the quadrangle numbers are grid locations in the 10,000-foot Tennessee coordinate system; for example, 765,150N., 1,404,000E. Grid reference coordinates are shown along margins of quadrangles.

LOCALITY NO. 1—Walnut Grove, Stewart County (small sand pit). On U. S. Highway 79, approximately 1.5 miles west of Walnut Grove Church. Paris Landing quadrangle (19-NE), 765,150N., 1,404,000E.

LOCALITY NO. 2—Paris Landing, Henry County—2 samples (highway cut). On U. S. Highway 79, approximately 0.5 mile west of Oak Hill. Paris Landing quadrangle (19-NE), 750,350N., 1,383,000E.

LOCALITY NO. 3—City of Paris, Henry County (sand pit). On U. S. Highway 641, approximately 1 mile north of the center of town in Paris. Paris quadrangle (8-SE), 707,850N., 1,314,500E.

LOCALITY NO. 4—McKenzie, Carroll County (sand pit). West of junction of U. S. Highway 79 and State Highway 22, just south of filling station. Carroll County Highway Map, 641,400N., 1,258,400E.[1]

LOCALITY NO. 5—Hardy Sand Co., Benton County (sand pit). Off U. S. Highway 70, approximately 0.4 mile north of Sawyers Mill. Bruceton quadrangle (20-SW), 607,000N., 1,350,700E.

LOCALITY NO. 6—Hardy Sand Co., Benton County (sand pit). Off U. S. Highway 70, approximately 2 miles south of Sawyers Mill. Bruceton quadrangle (20-SW), 595,150N., 1,349,400E.

[1] Approximate.

LOCALITY NO. 7—Camden, Benton County (chert quarry). On U. S. Highway 70, approximately 1 mile southeast of Camden. Camden quadrangle (20-SE), 606,800N., 1,384,300E.

LOCALITY NO. 8—Lexington Pit, Henderson County—2 samples (sand pit). On State Highway 20, 1.5 miles east of Lexington. Chesterfield quadrangle (11-SE), 462,400N., 1,296,200E.

LOCALITY NO. 9—Parkburg, Madison County (railroad cut). On G. M. & O. railroad, approximately 2 miles south of Bemis. Jackson South quadrangle (438-SE), 430,800N., 1,163,300E.

LOCALITY NO. 10—McNairy, Tennessee, McNairy County—2 samples (road cut). Approximately ¼ mile southwest of McNairy. McNairy quadrangle (12A-SW), 334,700N., 1,215,800E.

LOCALITY NO. 11—Grand Junction, Tennessee, Fayette County (highway cut). South of the Southern Railroad, at the intersection of State Highways 57 and 18 approximately 1 mile west of Grand Junction. Grand Junction quadrangle (432-SW), 253,900N., 1,039,850E.

LOCALITY NO. 12—Monterey, Putnam County, Pit No. 195—2 samples (sand pit). On U. S. Highway 70N at Sand Springs. Monterey quadrangle (331-NE), 633,750N., 2,194,900E.

LOCALITY NO. 13—Bon Air, White County—2 samples (highway cut). On U. S. Highway 70S, approximately 4.5 miles east of Sparta. Sparta quadrangle (332-NW), 560,500N., 2,183,300E.

LOCALITY NO. 14—Pleasant Hill, Cumberland County (highway cut). On U. S. Highway 70S, approximately 2 miles west of Pleasant Hill, Tennessee. Pleasant Hill quadrangle (109-NW).

LOCALITY NO. 15—Spencer, Tennessee, Van Buren County (highway cut). On State Highway 111, approximately 0.5 mile south of Spencer. Spencer quadrangle (103-NW), 490,000N., 2,159,300E.

LOCALITY NO. 16—Sewanee Silica Sand Co., Franklin County (sand pit). On U. S. Highway 64, approximately 2.7 miles west of Monteagle. Sewanee quadrangle (94-NW), 302,100N., 2,037,150E.

LOCALITY NO. 17—Roberts Gap Section, Hamilton County (road cut). At Roberts Gap. Fairmount quadrangle (105-NE), 301,250N., 2,219,500E.

LOCALITY NO. 18—Sawyer Road, Hamilton County (sand pit). On Sawyer Road, approximately 1.5 miles northeast of Fairmount. Fairmount quadrangle (105-NE), 295,400N., 2,206,250E.

LOCALITY NO. 19—Henson Gap, Sequatchie County (sand pit). At Henson Gap near Lewis Chapel. Henson Gap quadrangle (104-SE), 350,000N., 2,205,950E.

LOCALITY NO. 20—Crab Orchard, Cumberland County (sand and gravel pit). Approximately 2 miles southwest of Crab Orchard. Dorton quadrangle (117-NW), 548,000N., 2,322,400E.

LOCALITY NO. 21—Fire Tower Sample No. 1, Anderson County (road cut). On Walden Ridge half way between Laurel Grove and Dutch Valley. Clinton quadrangle (137-SW), 634,700N., 2,525,900E.

Fire Tower Sample No. 2, Anderson County (road cut). On Walden Ridge half way between Laurel Grove and Dutch Valley. Clinton quadrangle (137-SW), 634,150N., 2,526,000E.

LOCALITY NO. 22—Caryville, Tennessee, Campbell County—2 samples (sand pit). On Fork Mountain, approximately 1.5 miles northwest of Cove Lake State Park. Jacksboro quadrangle (136-SW), 710,000N., 2,519,600E.

LOCALITY NO. 23—Clinch Mountain-U. S. 25E, Grainger County (sand pit). On Clinch Mountain at Bean Gap. Avondale quadrangle (162-SW), 722,900N., 2,766,400E.

LOCALITY NO. 24—Clinch Mountain-Flat Gap, Hawkins County (road cut). On Clinch Mountain at Flat Gap. Lee Valley quadrangle (171-NW), 746,500N., 2,818,000E.

Samples 1 through 11, with the exception of No. 7, were taken from unconsolidated sand deposits; sample No. 7 is from the Camden chert. Samples 12 through 24 represent sandstones of varying friability.

DESCRIPTIONS OF SAMPLES

LOCALITY NO. 1—WALNUT GROVE

Eutaw formation

ON U. S. HWY. 79, APPROX. 1.5 MI. W. OF WALNUT GROVE CHURCH

This is a 6-foot channel sample taken in a small sand pit immediately overlying the Tuscaloosa gravel.

Quartz grains are subangular, 90 percent plus, with occasional well-rounded grains. Most of the quartz grains are clear, but some are milky. Minute black inclusions of magnetite were found in many of the quartz grains. The subangular grains have smoothly rounded facet edges and smooth faces; the rounded grains have frosted surfaces. One large subangular quartz grain was observed to be composed of five distinct well-rounded quartz grains. Two of the rounded grains included in this subangular grain contain magnetite inclusions. Some of the quartz grains show bituminous material, some of which was seen surrounding magnetite inclusions within the quartz grain. The introduction of bituminous material possibly took place simultaneously with recrystallization of the quartz. Occasional white chert grains are present; brown chert grains are common.

Clay stained by iron oxide colors the sample a brick red. Mica is present in small amounts.

Heavy minerals present are ilmenite, rutile, zircon, and some monazite, spinel, garnet, kyanite, and others. The heavy-mineral grains are larger than those from the McNairy sand; the proportions of heavies are different, but both appear to have the same suite of heavy minerals.

LOCALITY NO. 2—PARIS LANDING

McNairy sand

ON U. S. HWY. 79, APPROX. 0.5 MI. W. OF OAK HILL

Two channel samples, upper 12 feet and lower 6 feet, were taken in a highway cut. Overburden ranges from 2 feet to 20 feet or more.

Quartz grains are subangular, 90 percent plus, with several subrounded to rounded grains and some sharp, angular grains. Some quartzite fragments and occasional chert grains are present. Angular grains for the most part are clear but not so smooth sided as those in the Walnut Grove sample. Some of the larger subangular quartz grains are composed of rounded grains cemented together by silica. The rounded quartz grains are frosted. Some quartz grains contain inclusions of magnetite, which was the only heavy-mineral inclusion identified in the sample. The fact that some of the magnetite inclusions in the quartz grains are rounded suggests a sedimentary source of the magnetite prior to quartz recrystallization.

Some white clay is present, but most of the clay is stained by iron oxide which gives the sample an overall light-brown color. The sand in the bank is banded, white and light brown; the color bands range from a few inches to 2 or 3 feet thick. Mica is present throughout the sample but is not abundant.

Heavy minerals present are magnetite, ilmenite, and zircon. Other heavy minerals may be present but were not noted in the sample. The heavy minerals are not as abundant in the lower sample.

LOCALITY NO. 3—CITY OF PARIS

Claiborne and Wilcox sand

ON U. S. HWY. 641, APPROX. 1 MI. N. OF CENTER OF TOWN

This is a 20-foot channel sample taken 8 feet above the Porters Creek clay. The sample was taken in an inactive sand pit.

Quartz grains are subangular to rounded. The percentage of subrounded grains is much greater in the larger sizes than in the smaller sizes. Most of the larger grains are milky; the other larger grains and most of the small grains are quite clear. Many of the large grains are composed of two or more small, previously rounded grains. Chert grains are sparse; most of them are white, but some brown chert is present in the sample. Quartzite (?) grains are very sparse.

Clay stained by iron gives the sample an overall light-red color. Most of the iron is finely divided and intimately associated with the clay; however, some of the iron is a hard stain on the quartz grains. No iron concretions ("ironstone") were found in the sample or sample area. Thin stringers of sand high in iron oxide are present in the sand pit but are not cemented by iron. Mica is present in the sample.

Heavy minerals are sparse and, except for very occasional heavy-mineral grains, are present as magnetite inclusions in the quartz grains.

Occasional particles of woody material are present.

LOCALITY NO. 4—McKENZIE, TENN.

Claiborne and Wilcox sand

W. OF JUNCT. U. S. HWY. 79 AND STATE HWY. 22

This is an 18-foot channel sample from an abandoned sand pit. The lower 6 feet of the sample contains considerable clay. The 3 to 6 feet of sand above the sample is very dirty, containing a considerable amount of clay and organic material.

The quartz grains are subangular to subrounded with occasional angular grains and rounded grains. The only well-rounded grains are in the very small size range. The quartz grains are mostly subangular and do not have smoothly rounded edges as in the previous samples. Most of the quartz grains are clear, but some are milky. Several of the quartz grains are pitted or contain indentations in which iron oxide has penetrated. No chert grains were seen.

Not all the quartz grains are stained by iron; those that are stained are light red in color. The mixture of the two types gives the sample a speckled appearance. Small amounts of mica are present.

Heavy minerals are sparse and are present mostly as inclusions in the quartz grains. They are identified as magnetite.

LOCALITY NO. 5—HARDY SAND CO. (N. OF HWY. 70)

McNairy sand

OFF U. S. HWY. 70, APPROX. 0.4 MI. N. OF SAWYERS MILL

An 8-foot channel sample was taken from an active foundry sand pit. Some of the better quartzose sand zones are mined for glass sand.

Quartz grains are mostly subangular to subrounded, the large majority being subangular. Some angular grains and occasional rounded grains are present. Most of the quartz is clear, but some is milky. The surfaces of most of the grains are lightly pitted, which gives the visual effect of a more impure quartz. Some quartzite grains are present, but no chert grains were noted.

Clay in small quantities is interspersed throughout the sample. Iron oxide is present as small "ironstone" concretions mixed with the clay and as a constituent of some of the heavy minerals. Most of the iron stain can be easily washed from the sample, so that only a small amount of iron oxide will remain on the individual quartz grains. Some mica is present in the sample.

Several types of heavy minerals are present. The most abundant are ilmenite and rutile; monazite and zircon are present in lesser quantity; and colorless tabular crystals, probably kyanite, are present in small amounts. Other unidentified heavy minerals in very small quantity were noted. About 90 percent of the heavy minerals are minus 170 mesh and plus 200 mesh in size. A very small percentage of the heavy minerals are present as inclusions in quartz crystals, and all of these are magnetite.

LOCALITY NO. 6—HARDY SAND CO. (S. OF HWY. 70)

McNairy sand

OFF U. S. HWY. 70, APPROX. 2 MILES S. OF SAWYERS MILL

This is a 6-foot channel sample cut in an active sand pit from which glass sand, grinding sand for glass, and foundry sand are mined. The sand is of three different color types—some is pure white, another type is brown to red, and one distinctive type is "bacon striped" white and pink. The distinctive pink or rose color is caused by iron stain, which can be easily removed. Several "ironstone" concretions occur in the sand pit, but almost all of these are removed by initial screening.

The quartz grains are subangular, 98 percent or more, with a few subrounded grains. The individual quartz grains are clear internally except for a few that are milky. Most of the grains have a frosted appearance that may be due partly to abrasion and partly to incipient recrystallization. No chert or other quartz mineral varieties were found in the sample.

A small amount of clay is present in the sample and is mostly white in color. Iron oxide as stain is sparse, but iron is found in the heavy-mineral fraction as magnetite and ilmenite. Mica is present in the sample.

Two crystals of mica contain subrounded quartz grains as inclusions. This indicates that the mica was formed in situ after final accumulation of the sand.

The heavy minerals are the same type and size as those in the sample from Locality No. 5 but are slightly less abundant.

LOCALITY NO. 7—CAMDEN

Camden chert

ON U. S. HWY. 70, APPROX. 1 MILE S.E. OF CAMDEN

This is a grab sample from an active chert pit. The pit faces show blocky chert badly shattered by faulting. Interstitial material is mostly clay-sized silica with some clay minerals and mica. The sample was crushed to minus 8 mesh size for study. Only 68 percent of the sample remained after crushing and washing over a 100-mesh screen.

Some of the chert flakes are relatively fresh, but others are weathered almost to tripoli.

Many fossil molds and casts are present, and external molds of dolomite rhombs are very common. Crystalline quartz is common as fracture and cavity fillings.

Finely divided mica is common in the chert flakes. Iron oxide was the only other impurity observed in the sample.

LOCALITY NO. 8—LEXINGTON

McNairy sand

ON STATE HWY. 20, 1.5 MI. E. OF LEXINGTON

Two channel samples, upper 8 feet and lower 16 feet, were taken from an inactive sand pit. The mineral constituents and grain size relationships are essentially the same for both samples.

Most of the sand in the pit is white, but several gray bands are present which are the result of concentrations of heavy minerals in the sand.

The average grain size of these samples is .15 mm, the finest grained sample included in this report. Almost all the quartz grains are angular to subangular; only occasional rounded quartz grains were seen, and all of these were very fine grained. The quartz grains are very clear except for occasional grains that show internal fracturing. No milky quartz was found in the samples. No chert grains were noted.

Clay occurs as a white coating on individual sand grains. None was seen as distinct beds in the sand pit. Some small discontinuous stringers of iron oxide incrustation were noted along bedding planes, but iron oxide as stain is absent from the bulk of the sample. Mica is prevalent throughout the sample and is present in all size ranges. Many of the flakes are 5 or 6 times larger than the quartz grains. Two mica crystals contained rounded quartz grains as inclusions, and one crystal contained a pyrite inclusion.

The lower sample has an average of 3.4 percent heavy minerals compared with 2.3 percent in the upper sample. Ilmenite is the most abundant of the heavy minerals; others, in order of abundance, are rutile, monazite, zircon, and kyanite (?). Tourmaline, garnet, and others have been reported from the McNairy sand but were not identified in this sample. More than 90 percent of the heavy minerals are minus 170 mesh and plus 200 mesh; the major part of the remainder is minus 200 mesh.

Small fragments of marine fossils are present in the samples.

LOCALITY NO. 9—PARKBURG

Claiborne and Wilcox sand

ON G. M. & O. RAILROAD, APPROX. 2 MI. S. OF BEMIS

This is a 26-foot channel sample taken in a railroad cut. The sand is crossbedded, with one large sand lens exposed in the cut. Alternate beds of coarse-grained sand and medium- to fine-grained sand are present, and most of the coarse material is near the base of the railroad cut.

Quartz grains are mostly subangular, but a few subrounded grains and very few rounded grains are present. The subangular grains are smooth sided with gently rounded edges; the subrounded to rounded grains show surface pitting. Some of the subangular grains contain two generations of inclusions. For example, a magnetite grain was observed included in a rounded quartz grain that is an inclusion in a larger subangular quartz grain. "Bedding planes" evidenced by layers or concentrations of minute magnetite particles were found in one subangular quartz grain. Brown chert is rare, and when observed it occurs as subrounded grains.

Clay is present in small quantities interspersed with the quartz grains. Iron oxide stains the clay and sand grains a deep red. Small amounts of mica are present.

Heavy-mineral inclusions in this sample are less common and of smaller size than those in the preceding samples. Heavy minerals present not as inclusions are garnet, spinel, limonite, topaz, pyrite, rutile, ilmenite, kyanite (?), tourmaline, zircon, and others.

LOCALITY NO. 10—McNAIRY, TENN.

McNairy sand

APPROX. ¼ MI. S.W. OF McNAIRY

Two 15-foot channel samples, separated by a 12-foot covered interval, were taken in a road cut. The covered interval is probably sandy or silty clay. These upper and lower samples were found to have essentially identical characteristics.

The clay and very fine grained portions constitute about 40 percent of the samples.

Most of the quartz grains are subangular, some are subrounded, and a few are well rounded. The quartz grains vary from clear to cloudy and do not contain as many inclusions as the other McNairy sand samples. Mica is common in the samples. No chert grains were found.

Clay is abundant throughout the samples. Iron oxide is present as hematite and limonite. "Ironstone" concretions are abundant and are composed of limonite. Hematite is common as microscopic incrustations on the quartz grains; incipient botryoidal masses of hematite were present on several of the grains.

Heavy minerals are common and are the same suite that is present in the other McNairy sand samples.

LOCALITY NO. 11—GRAND JUNCTION

Claiborne and Wilcox sand

S. OF SOUTHERN RAILROAD, AT INTERSECTION STATE HWYS. 57 AND 18 APPROX. 1 MI. W. OF GRAND JUNCTION

This is a 23-foot channel sample taken in a highway cut. The sand bank is yellow in color and thus different from the usual red of most of the Claiborne sample areas. White sand banks have been reported near this sample area but were not seen by the writer.

The quartz grains are subangular to subrounded; this sample contains more subrounded grains than other Claiborne and Wilcox sand samples. The subangular grains have more surface pitting than those in the other Claiborne and Wilcox samples. The quartz grains are mostly clear to milky, but a few are yellow to brown from iron oxide stain in internal fractures of the quartz grains. No chert grains were found.

Clay interspersed with the quartz grains is present throughout the sample. Iron, as limonite, occurs mostly as stain in the clay, and some is internal stain coating fractures in the quartz grains. No mica was noted in the sample.

Magnetite is present as minute inclusions in some of the quartz grains. Rare partly oxidized pyrite also was found as inclusions. One quartz-rutile intergrowth was noted in the sample. Individual mineral grains present are rutile, ilmenite, tourmaline, and kyanite; these are the same size as the quartz grains.

LOCALITY NO. 12—MONTEREY

Sewanee conglomerate

ON U. S. HWY. 70N AT SAND SPRINGS

Stockpile sample.—This sample was obtained from the stockpile of an active sand pit. A vertical face of approximately 15 feet is being worked, in white to very light pink, friable sandstone.

The quartz grains are subangular to subrounded; no well-rounded grains are present. A large percentage of the quartz occurs as overgrowths on smaller grains and is very noticeable when observed in strong light; the quartz crystal faces reflect the light. A few grains are doubly terminated quartz crystals, and many more are well-developed singly terminated quartz crystals. The frosted surfaces on subrounded grains appear to be the result of abrasion, internal fractures, and/or incipient recrystallization. All of the quartz is clear and crystalline. Some of the finer material between the quartz grains looks like quartz flour, indicating a possibility of some crushing, but the larger grains do not show intense shattering. Several quartzite pebbles that show secondary recrystallization are present. The very few inclusions contained in the quartz grains are quite small and were not identified specifically. No chert was noted.

Clay, which is white in color, comprises less than 2 percent of the sample. Iron oxide, present only as very small flakes on the quartz crystals, gives the sample as a whole a very light pink hue.

Some magnetic particles found in the sample were iron from screening operations rather than magnetite in the sample. Occasional flakes of mica are present.

Heavy minerals are very sparse and occur mostly as inclusions in the quartz grains. Some of these inclusions have very weak magnetism and are probably ilmenite or magnetite. Some larger black or dark-green grains may be either tourmaline or smoky quartz.

Coarse sample.—This was collected from the same pit and is identical to the previous sample, except that it was taken from a stockpile containing sand selectively mined for coarser material.

The larger grain size of this sample is due to a greater percentage of quartzite grains and not to increased size of the quartz grains. However, some larger quartz grains are present, all as recrystallized grains. The quartzite grains may or may not show the outlines of the original quartz grains of which they are composed, depending on the completeness of resilicification and probably in part to the chance alignment of original crystal axes.

LOCALITY NO. 13—BON AIR

Sewanee conglomerate

ON U. S. HWY. 70S, APPROX. 4.5 MI. E. OF SPARTA

Two composite samples, an upper 10 feet and a lower 20 feet, were taken from a highway cut. The two samples are almost identical in chemical analyses and grain sizes; the lower sample has a slightly higher percentage of the coarser grain sizes.

The samples are mostly from one large sand lens which represents a channel fill. White and brown beds are present, the color varying directly with the iron oxide content.

The quartz grains are subangular to subrounded; no rounded grains are present. Most of the quartz is clear, but some milky quartz is present. Well-developed quartz crystals are common, owing to recrystallization. The crystals are short and stubby, and several show double terminations. Very few inclusions were seen in the samples. No chert was noted.

Clay and iron oxide are present in small amounts, the iron oxide giving the sample a light-yellow color. A few mica flakes are present.

Heavy minerals are rare in these samples. The only ones noted were a few as minute inclusions and one or two pieces of tourmaline or smoky quartz as individual grains.

LOCALITY NO. 14—PLEASANT HILL

Rockcastle conglomerate

ON U. S. HWY. 70S, APPROX. 2 MI. W. OF PLEASANT HILL

This is an 18-foot channel sample obtained from a highway cut.

The quartz grains are subangular to subrounded, and a few are rounded. Recrystallization is evident on many quartz grains, but the grains are not well-developed crystals as in the samples from Locality No. 13. Most of the quartz grains have very irregular surfaces, and some have hard iron stains. Most of the quartz is clear; the white color present is due to internal fractures and to surface abrasion. No chert grains were found.

Clay and iron are present as interstitial matter. The iron oxide gives the sample a light-pink to reddish-brown color. Some white beds are present. The clay content is slightly higher in the colored sediments. Some mica is present.

Heavy minerals are rare either as minute inclusions or as individual grains.

LOCALITY NO. 15—SPENCER

Sewanee conglomerate

ON STATE HWY. 111, APPROX. 0.5 MI. S. OF SPENCER

This is a 30-foot composite sample taken from an outcrop and along an adjacent road cut. The material is friable white to brown sandstone with some "ironstone" concretions.

The quartz grains are subangular to subrounded. Recrystallization is prevalent, but well-developed secondary crystals are not abundant. Many of the grains are frosted, and some are badly shattered. Nearby faulting probably caused the grain fractures. No chert grains were found.

Clay is present interstitially. Iron oxide is found as "ironstone" concretions and as a hard surface coating on some of the quartz grains. Mica is very sparse.

Heavy-mineral inclusions are rare, but some heavy-mineral grains such as ilmenite(?), rutile, tourmaline, and hematite are present. The tourmaline grains are subrounded, and the others range from angular to subangular. Magnetite was not recognized. The heavy-mineral content of this sample is not nearly so high as in the samples from West Tennessee.

LOCALITY NO. 16—SEWANEE SILICA SAND CO.

Sewanee conglomerate

ON U. S. HWY. 64, APPROX. 2.7 MI. W. OF MONTEAGLE

This is a washed sample from a stockpile of an active glass sand producer. The sandstone in the pit is white to light yellowish brown and very friable.

The quartz grains are subangular to subrounded, and some well-developed quartz crystals are present. The subrounded grains all show surface pitting, and some show internal fracturing. Grains of quartzite are present, but no chert grains were noted.

The washed sample had virtually no clay and only small amounts of iron oxide. The iron oxide occurs as a small amount of stain on the grain surfaces and in occasional internal fractures. No mica was noted.

Heavy minerals were not observed in this sample except for a few as minute inclusions in some of the quartz grains. Examination of the magnetically separated material from this sample showed only extraneous iron picked up in the sand-cleaning process and no magnetite or ilmenite.

LOCALITY NO. 17—ROBERTS GAP

Sewanee conglomerate

AT ROBERTS GAP

This is a 38-foot composite sample from a road cut. The sample was crushed in a jaw crusher to break the sandstone into individual sand grains.

The quartz grains in this sample are subangular to subrounded; well-developed secondary quartz crystals are present. The cementing material between some of the individual quartz grains is silica, but the silica cementation is not well developed enough to make this a quartzite. No chert was seen in the sample.

Some clay is present, and iron oxide occurs as coating on the quartz grains. Mica is very sparse.

Heavy minerals, except for some hematite, were not found in the sample.

LOCALITY NO. 18—SAWYER ROAD

Vandever formation

ON SAWYER RD., APPROX. 1.5 MI. N.E. OF FAIRMOUNT

This is a stockpile sample of crushed sandstone from a 15-foot face in a small active sand pit.

The quartz grains are subangular to subrounded. Most of the grains are clear internally, but their surfaces are frosted, in part by incipient recrystallization and/or erosional pitting and by mechanical crushing. Several of the grains show secondary crystal development, but the crystal faces are marred by pitting and/or corrosion. Several quartzite grains are present. No chert was found in the sample.

Clay is present as thin films over the quartz grains and as interstitial material. Iron oxide is present mixed with the clay (giving it a light-brown color), as a hard stain on some of the quartz grains, and as a cement in small clusters of quartz grains. Some mica was noted.

Heavy minerals are found only as very small inclusions in some of the quartz grains.

LOCALITY NO. 19—HENSON GAP

Sewanee conglomerate

AT HENSON GAP NEAR LEWIS CHAPEL

This is a 28-foot composite sample from an active sand pit. The pit is in a shattered sandstone bed which has been disturbed by faulting. A few discontinuous stringers of very plastic clay are present. Some clay gall zones are found as continuations of the clay stringers. A few conglomerate beds are present. Areas of white sandstone are conspicuous at several places in the pit.

The quartz grains are subangular to subrounded. Recrystallization is indicated by small, well-developed crystal faces on many of the grains. Numerous grains are intensely shattered and will break apart with moderate pressure. Some of the grains are transparent, and others are white as a result of shattering. Quartzite grains and pebbles are present. No chert was noted.

Some clay occurs as interstitial material, and some is present as occasional stringers and galls. The interstitial clay is stained light tan by iron oxide. Most of the iron oxide occurs as stain on the clay; a washed sample showed only rare iron stain on individual quartz grains. Mica is sparse.

Heavy minerals are sparse. Some occur as minute inclusions in the quartz grains and some as individual grains. The only heavy mineral grains identified were tourmaline.

LOCALITY NO. 20—CRAB ORCHARD

Sewanee conglomerate

APPROX. 2 MI. S.W. OF CRAB ORCHARD

This sample was taken from a stockpile at a small sand pit in conglomeratic sandstone.

The individual quartz grains are considerably larger than those of the other Sewanee conglomerate samples. They are mostly subangular to subrounded, but some rounded grains are present. Most of the quartz is transparent; the apparent white color is due to surface abrasion. Several quartzite grains are present. No chert was observed in the sample.

Clay is found only as thin surface coatings on the quartz grains. Iron oxide stains the clay very light tan or cream. A very small amount of iron oxide occurs as surface stain on the quartz grains. Some mica is present. One mica crystal was developed partly around a quartz grain, indicating that the mica was formed after the sand was deposited.

Heavy minerals are sparse as inclusions and rare as individual grains.

LOCALITY NO. 21—FIRE TOWER

Sewanee conglomerate (?)

ON WALDEN RIDGE HALF WAY BETWEEN LAUREL GROVE AND DUTCH VALLEY

Upper sample.—This represents a 13-foot composite section from a sandstone bluff. The beds may be overturned. Part of the section contains well-indurated beds of sandstone; other beds are friable. The sample had to be crushed for analysis.

The quartz grains are mostly subangular, but a few are subrounded. Recrystallization is evidenced by the presence of small crystal faces on many of the grains. The quartz grains in this sample are very similar to those of the other Pennsylvanian samples. No chert was noted.

Approximately 4 percent of interstitial clay is present throughout the sample. Iron oxide colors the clay light brown and is also present as a hard stain on many of the quartz grains. Iron oxide was also noted cementing sand grains, forming small clusters of grains. Mica flakes are common.

Lower sample.—This is a 20-foot composite sample in a road cut. It is quite different in grain size and chemical content from the upper sample.

The quartz grains are subangular to subrounded. The subangular grains have some well-developed crystal faces formed by recrystallization. The subrounded grains and some subangular grains have frosted surfaces. This sample contains more subrounded grains than most of the Pennsylvanian sandstone samples. Some quartzite grains are present. No chert was observed.

Clay and iron oxide occur in minor amounts. Some of the iron oxide adheres to the quartz grains as stain; some occurs as a cementing material and forms isolated clusters of quartz grains. Part of the iron oxide is intermixed with the clay. Mica is sparse.

Heavy minerals are rare.

LOCALITY NO. 22—SILICA SAND CO.

Sewanee conglomerate (?)

ON FORK MTN., APPROX. 1.5 MI. N.W. OF COVE LAKE STATE PARK

The sandstone beds at this locality are steeply dipping, and the "upper" and "lower" samples were therefore obtained from approximately equal elevations. Both beds are being actively mined.

Upper sample.—This is a 12-foot channel sample cut in the upper sandstone bed. It is a white sandstone with some thin beds and stringers of conglomerate. Quartzite pebbles more than one-half inch in diameter are present.

The quartz grains are subangular to subrounded with some rounded grains present. Secondary recrystallization is evident as shown by the sharp, well-developed crystal faces on some of the quartz grains. The subrounded grains have frosted surfaces. Many of the quartz grains are fractured internally, probably because of movement from faulting in the immediate vicinity. No chert grains were found.

Small amounts of iron are dispersed throughout the sample. The iron oxide content in the raw sample is very low, .03 percent, very little of which is stain on the quartz grains. Mica is sparse.

Heavy minerals are very sparse. Very few inclusions were seen in the quartz, and the only heavy mineral grains noted were tourmaline.

Lower sample.—The "lower" sample was taken along a 25-foot channel. The physical and chemical descriptions of the upper and lower samples are almost identical; the only difference noted was that the lower bed contains more clay as finely divided particles and has a slightly higher iron content.

LOCALITY NO. 23—CLINCH MTN. (U. S. 25E)

Clinch sandstone

ON CLINCH MTN. AT BEAN GAP

This is a 10-foot composite sample from a "sand" pit. The sandstone is blasted loose and then crushed, in a jaw crusher, to be used as sand. This sandstone is friable in small pieces, but larger pieces are tough and some are almost quartzitic.

The quartz grains are subangular to subrounded with some sharp quartz fragments present. Well-rounded quartz grains are sparse. Recrystallization is evident from small well-developed crystal faces on the quartz grains. The quartz grains in this sample are almost identical to those of the Pennsylvanian sandstone samples. No chert was noted.

Clay and iron oxide are present in small amounts. Part of the iron oxide is present as a hard surface stain on some of the quartz grains. Mica is sparse.

Heavy minerals are sparse; a few well-rounded grains of ilmenite and rutile (?) were seen.

LOCALITY NO. 24—CLINCH MTN. (FLAT GAP)

Clinch sandstone

ON CLINCH MTN. AT FLAT GAP

A 65-foot composite sample was taken from a highway cut. This sample was collected to see if it would be a possible source for large, lump-size silica; it was crushed to ½-inch mesh. The sandstone is well indurated.

Several small faults are present in this sandstone, and the fault surfaces are well cemented by iron oxide and silica. In areas where these faults are not present, the iron oxide content should be lower.

The individual quartz grains appear to be more rounded than those in the other Clinch sandstone sample. Well-defined crystal faces are not as common. No chert grains were noted.

Clay is present interstitially and as fillings of small fractures in the rock. Some selected fragments from the sample were almost entirely free of clay. Iron is found both as interstitial iron and as hard crusts on slickensided surfaces. Some mica and heavy minerals are present.

RAW MATERIAL ANALYSES

Chemical analyses of the raw materials are included in table 4. A very few of the sands are high-silica glass sand grade with no beneficiation necessary except washing to remove excess clay and some of the iron. The other sands require beneficiation of different degrees to be suitable as high-silica raw materials. These types of beneficiation are discussed under Beneficiation Tests.

Sieve analyses of the raw samples and cumulative analyses are included in table 5. Histograms, figures 3-20, give a visual guide to grain size distribution; frequency distribution curves are included to show the average grain size of the samples as well as the degree of sorting or the sorting coefficient. Frequency distribution curves also may be used to compute blending of different sands to get specific sand sizes in case of narrow size tolerance ranges.

TABLE 4. Chemical analyses of raw samples.

Locality number		*% SiO_2*	*% Fe_2O_3*	*% Al_2O_3*	*% $CaO+MgO$*	*% Ignition loss*
1		93.88	1.20	3.49	.17	1.23
2	Upper	92.67	1.20	4.10	.19	1.86
	Lower	98.48	.48	.66	.13	.27
3		93.80	.96	3.58	.34	1.30
4		95.44	.80	2.36	.28	1.10
5		97.91	.47	.95	.21	.47
6		97.71	.052	1.41	.23	.57
7		93.40	.56	4.01	.31	1.70
8	Upper [1]	91.41	.56	5.34	1.21	1.40
	Lower [2]	91.34	.67	5.58	.80	1.57
9		92.90	1.10	3.85	.62	1.50
10	Upper	79.26	4.95	9.85	1.38	4.44
	Lower	81.00	3.51	9.89	1.45	4.10
11		92.65	1.28	4.24	.10	1.75
12	Stockpile	97.35	.060	1.76	.20	.65
	Coarse	97.99	.053	1.32	.13	.53
13	Upper	97.50	.32	1.38	.27	.50
	Lower	96.90	.31	1.67	.46	.62
14		95.56	.56	2.69	.36	.82
15		95.70	.80	2.28	.33	.88
16 [3]		—	—	—	—	—
17		95.90	.80	1.86	.55	.85
18		96.31	.81	1.81	.26	.79
19		96.57	.28	2.02	.28	.85
20		98.10	.28	.62	.36	.60
21	Upper	92.46	1.16	4.06	1.05	1.22
	Lower	97.77	.39	.92	.51	.38
22	Upper	97.72	.031	1.57	.14	.52
	Lower	97.94	.079	1.31	.27	.41
23		98.66	.084	.75	.25	.20
24		97.32	.070	1.82	.10	.62

[1] Analyses of sand fraction (97.7%) after removal of heavy minerals (2.3%) by bromoform separation.

[2] Analyses of sand fraction (96.6%) after removal of heavy minerals (3.4%) by bromoform separation.

[3] Raw sample not collected.

TABLE 5. Sieve analyses of raw (dry) samples.

(Cumulative figures in parentheses)

Number	Locality	Geologic horizon	% plus 20 mesh	% plus 40 mesh	% plus 65 mesh	% plus 100 mesh	% plus 120 mesh	% plus 140 mesh	% plus 170 mesh	% plus 200 mesh	% minus 200 mesh	Total %	Remarks
1	Walnut Grove, Stewart County	Eutaw	2.5	40.6 (43.1)	33.3 (76.4)	17.4 (93.8)	3.8 (97.6)	1.1 (98.7)	0.6 (99.3)	0.1 (99.4)	0.6 (100.0)	100.0	6′ channel
2	Paris Landing	McNairy	2.0	26.7 (28.7)	54.8 (83.5)	11.9 (95.4)	1.3 (96.7)	0.6 (97.3)	0.6 (97.9)	0.5 (98.4)	1.6 (100.0)	100.0	Upper 12′ channel
	Do.	do.	0.8	11.0 (11.8)	68.0 (79.8)	17.3 (97.1)	1.7 (98.8)	0.5 (99.3)	0.4 (99.7)	0.1 (99.8)	0.2 (100.0)	100.0	Lower 6′ channe
3	City of Paris	Claiborne and Wilcox	10.7	47.2 (57.9)	32.5 (90.4)	6.0 (96.4)	1.1 (97.5)	0.5 (98.0)	0.6 (98.6)	0.3 (98.9)	1.1 (100.0)	100.0	20′ channel
4	McKenzie	do.	0.4	12.7 (13.1)	63.3 (76.4)	15.4 (91.8)	3.5 (95.3)	1.2 (96.5)	1.3 (97.8)	0.7 (98.5)	1.5 (100.0)	100.0	18′ channel
5	Hardy Sand Co.	McNairy	0.3	18.1 (18.4)	67.3 (85.7)	11.9 (97.6)	0.9 (98.5)	0.3 (98.8)	0.4 (99.2)	0.2 (99.4)	0.6 (100.0)	100.0	9′ channel
6	Hardy Sand Co.	do.	Trace	19.7 (19.7)	61.0 (80.7)	17.6 (98.3)	0.9 (99.2)	0.1 (99.3)	0.2 (99.5)	0.1 (99.6)	0.4 (100.0)	100.0	8′ channel
7	Camden	Camden	....	....	....	....	....	....	....	....	....	....	No grain size determinations. Raw sample crushed.
8	Lexington	McNairy	0.4	2.1 (2.5)	35.1 (37.6)	37.4 (75.0)	13.6 (88.6)	6.2 (94.8)	3.3 (98.1)	0.8 (98.9)	1.1 (100.0)	100.0	Upper 8′ of 24′ channel
	Do.	do.	0.5	1.2 (1.7)	8.7 (10.4)	36.2 (46.6)	31.4 (78.0)	11.6 (89.6)	7.1 (96.7)	1.8 (98.5)	1.5 (100.0)	100.0	Lower 16′ of 24′ channe
9	Parkburg	Claiborne and Wilcox	5.9	59.7 (65.6)	30.9 (96.5)	2.1 (98.6)	0.5 (99.1)	0.1 (99.2)	0.3 (99.5)	0.1 (99.6)	0.4 (100.0)	100.0	26′ channel
10	McNairy, Tenn.	McNairy	19.6	37.9 (57.5)	29.8 (87.3)	5.7 (93.0)	1.4 (94.4)	0.8 (95.2)	1.3 (96.5)	0.9 (97.4)	2.6 (100.0)	100.0	Upper 15′ channe
	Do.	do.	18.3	39.0 (57.3)	25.3 (82.6)	4.5 (87.1)	2.2 (89.3)	0.8 (90.1)	1.7 (91.8)	1.1 (92.9)	7.1 (100.0)	100.0	Lower 15′ channe
11	Grand Junction [1]	Claiborne and Wilcox	26.7 (28.3)	60.9 (89.2)	7.8 (97.0)	1.3 (98.3)	0.2 (98.5)	0.2 (98.7)	0.3 (99.0)	0.3 (99.3)	0.7 (100.0)	100.0	23′ channel
12	Monterey, Pit #195	Sewanee	1.6	7.6 (9.2)	73.5 (82.7)	11.6 (94.3)	2.1 (96.4)	0.6 (97.0)	1.5 (98.5)	0.5 (99.0)	1.0 (100.0)	100.0	Stockpile

	Do.	do.	15.8	48.1 (63.9)	25.5 (89.4)	6.0 (95.4)	1.4 (96.8)	0.9 (97.7)	1.1 (98.8)	**0.3 (99.1)**	0.9 (100.0)	100.0	Stockpile (selectively mined for coarser sizes)
13	Bon Air	do.	2.5	16.1 (18.6)	68.3 (86.9)	9.4 (96.3)	1.2 (97.5)	0.5 (98.0)	0.6 (98.6)	**0.4 (99.0)**	1.0 (100.0)	100.0	Upper 10′ of section, composite
	Do.	do.	1.4	8.6 (10.0)	71.9 (81.9)	11.5 (93.4)	2.2 (95.6)	0.9 (96.5)	1.2 (97.7)	**0.5 (98.2)**	1.8 (100.0)	100.0	Lower 20′ of 30′ section, composite
14	Pleasant Hill	Rockcastle	0.0	0.7 (0.7)	55.3 (56.0)	28.8 (84.8)	6.1 (90.9)	2.1 (93.0)	2.9 (95.9)	**1.1 (97.0)**	3.0 (100.0)	100.0	18′ channel
15	Spencer, Tenn.	Sewanee	4.5	5.1 (9.6)	54.6 (64.2)	21.0 (85.2)	6.3 (91.5)	2.3 (93.8)	2.5 (96.3)	**0.9 (97.2)**	2.8 (100.0)	100.0	30′ composite
16	Sewanee Silica Sand Co.	Sewanee	....	....	....	....	....	....	....	....	....	....	No samples taken; sizes from company data shown on histograms of Sewanee Silica Sand Co. (Glass sand sizes #20, #40, and #80).
17	Roberts Gap	do.	41.1	21.9 (63.0)	28.6 (91.6)	4.8 (96.4)	0.7 (97.1)	0.5 (97.6)	0.7 (98.3)	**0.3 (98.6)**	1.4 (100.0)	100.0	38′ composite
			0.0	37.2	48.6	8.1	1.2	0.8	1.2	**0.5**	2.4	100.0	Theoretically crushed to minus 20 mesh
18	Sawyer Road	Vandever	9.5	37.1 (46.6)	41.2 (87.8)	6.5 (94.3)	1.6 (95.9)	0.9 (96.8)	1.4 (98.2)	**0.6 (98.8)**	1.2 (100.0)	100.0	Stockpile sample, crushed, from 15′ face
19	Henson Gap	Sewanee	8.2	28.1 (36.3)	48.5 (84.8)	8.4 (93.2)	2.1 (95.3)	0.7 (96.0)	1.6 (97.6)	**0.8 (98.4)**	1.6 (100.0)	100.0	28′ composite
20	Crab Orchard	do.	[2]35.8	32.7 (68.5)	25.7 (94.2)	2.9 (97.1)	0.5 (97.6)	0.3 (97.9)	0.7 (98.6)	**0.4 (99.0)**	1.0 (100.0)	100.0	Stockpile
21	Fire Tower #1	Sewanee (?)	30.3	14.9 (45.2)	30.6 (75.8)	15.4 (91.2)	3.2 (94.4)	1.5 (95.9)	1.7 (97.6)	**0.6 (98.2)**	1.8 (100.0)	100.0	Upper sample, crushed. 13′ composite
			0.0	21.4	43.8	22.0	4.7	2.3	2.4	**0.8**	2.6	100.0	Theoretically crushed to minus 20 mesh.
	Fire Tower #2	do.	5.1	37.3 (42.4)	52.9 (95.3)	3.0 (98.3)	0.3 (98.6)	0.2 (98.8)	0.3 (99.1)	**0.2 (99.3)**	0.7 (100.0)	100.0	20′ bed, composite, dip 60°
22	Silica Sand Co. Southeast Pit	do.	0.2	10.7 (10.9)	76.1 (87.0)	5.9 (92.9)	1.7 (94.6)	1.1 (95.7)	1.2 (96.9)	**0.6 (97.5)**	2.5 (100.0)	100.0	Upper sandstone, 12′ channel
	Northwest Pit	do.	6.9	26.0 (32.9)	54.1 (87.0)	5.9 (92.9)	1.6 (94.5)	1.1 (95.6)	1.5 (97.1)	**0.9 (98.0)**	2.0 (100.0)	100.0	Lower sandstone, 25′ channel
23	Clinch Mtn., U. S. 25E	Clinch	5.8	35.7 (41.5)	49.5 (91.0)	6.1 (97.1)	1.0 (98.1)	0.5 (98.6)	0.5 (99.1)	**0.1 (99.2)**	0.8 (100.0)	100.0	10′ composite
24	Clinch Mtn., Flat Gap	do.	....	....	....	....	....	....	....	....	....	....	Quartzite-like; no grain size determinations. Would have to be crushed if used as glass sand. 65′ composite section

[1]1.6% of sample is plus 16 mesh.
[2]Quartzite pebbles up to ½″ diameter.

LOCALITY NO. 1

Walnut Grove 6' Channel

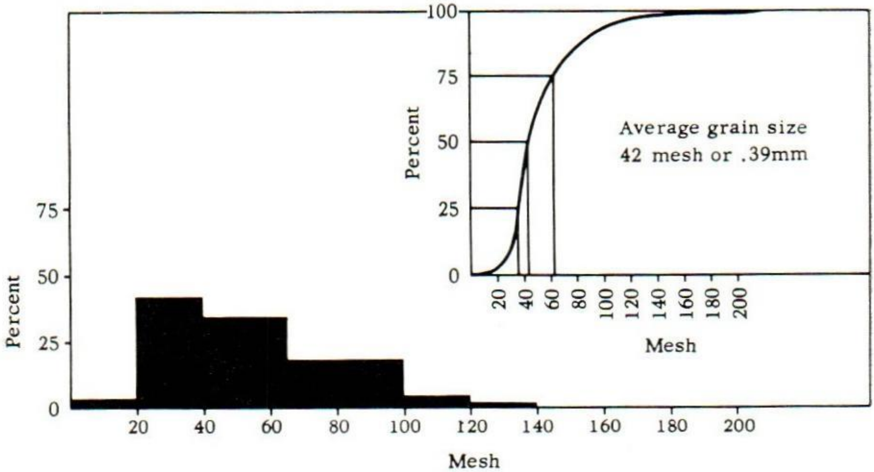
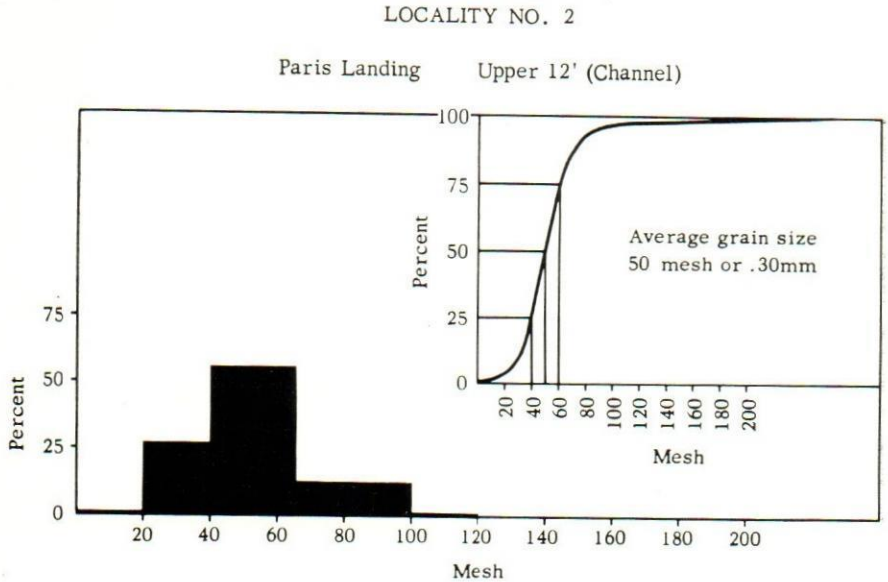


FIGURE 3. *Histogram and cumulative curve, Eutaw formation, Locality No. 1.*



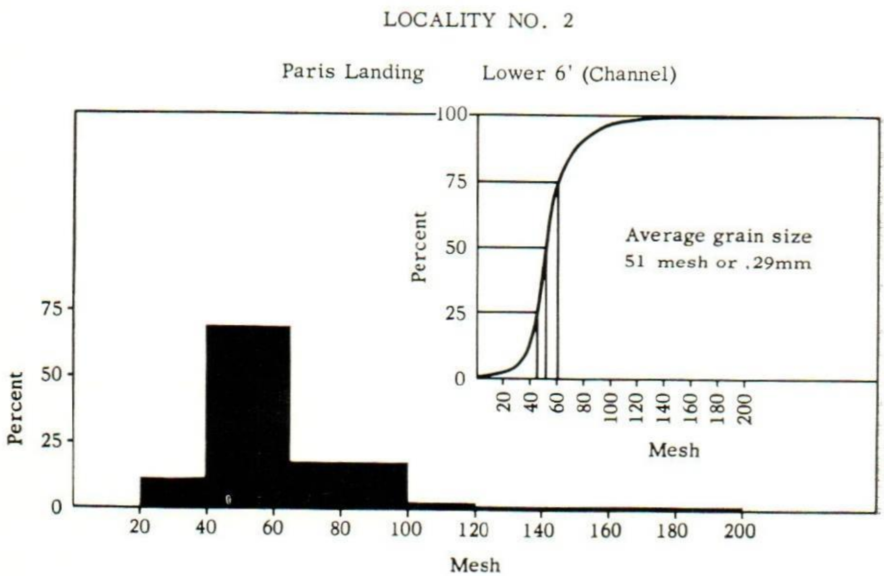
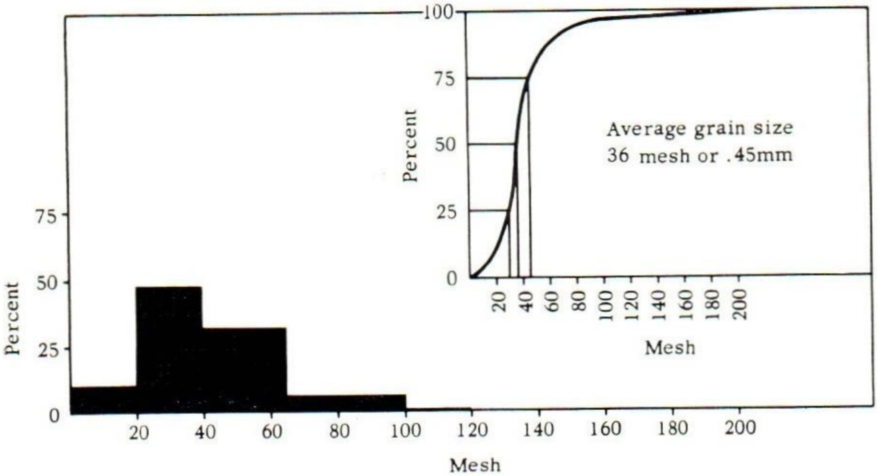


FIGURE 4. *Histograms and cumulative curves, McNairy sand, Locality No. 2.*

LOCALITY NO. 3

Paris 20' Channel



LOCALITY NO. 4

McKenzie 18' Channel

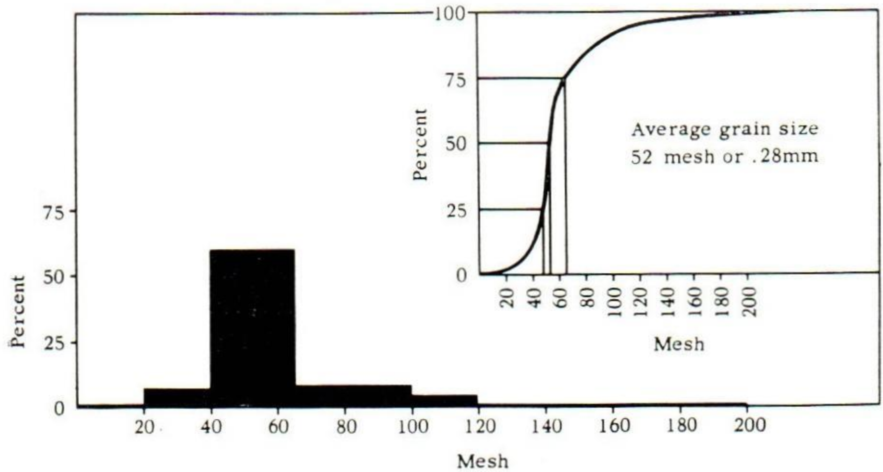
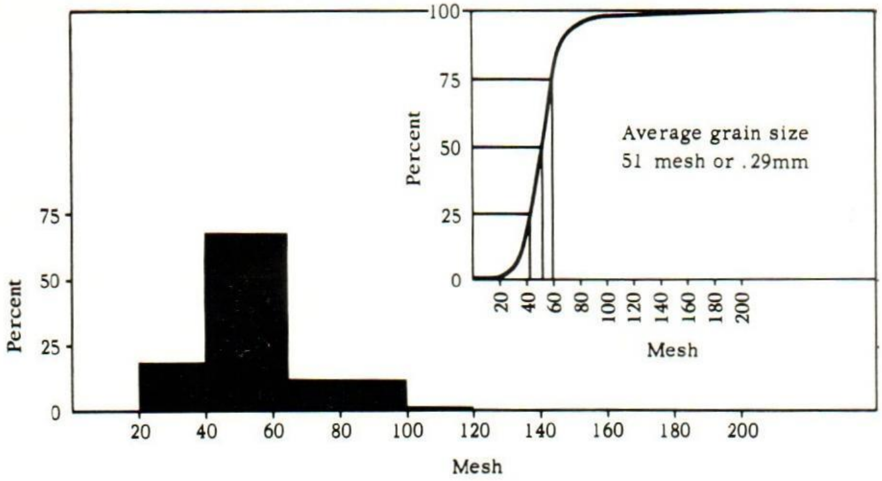


FIGURE 5. *Histograms and cumulative curves, Claiborne and Wilcox sand, Localities No. 3 and No. 4.*

LOCALITY NO. 5

Hardy Sand Co. (Pit North of Highway) 9' Channel



LOCALITY NO. 6

Hardy Sand Co. (Pit South of Highway) 8' Channel

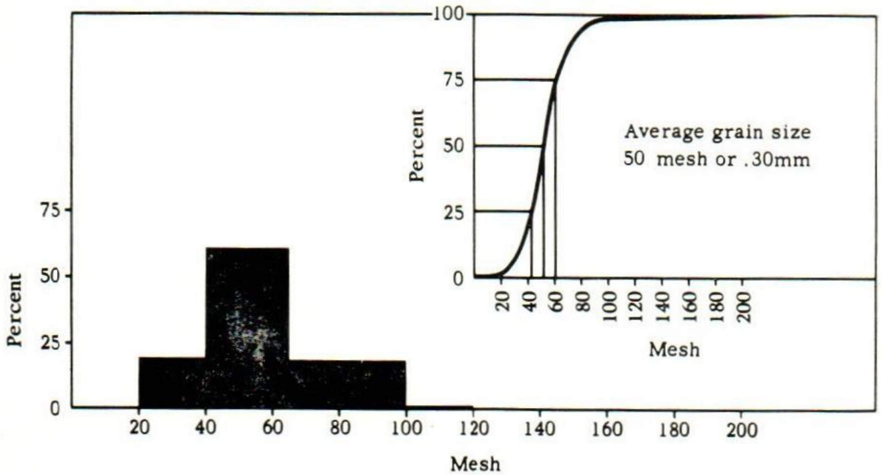
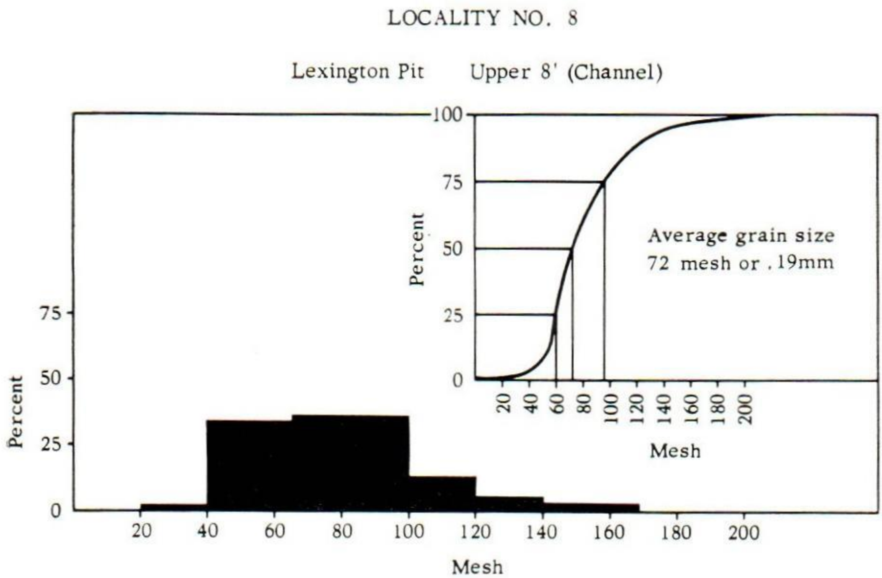


FIGURE 6. *Histograms and cumulative curves, McNairy sand, Localities No. 5 and No. 6.*



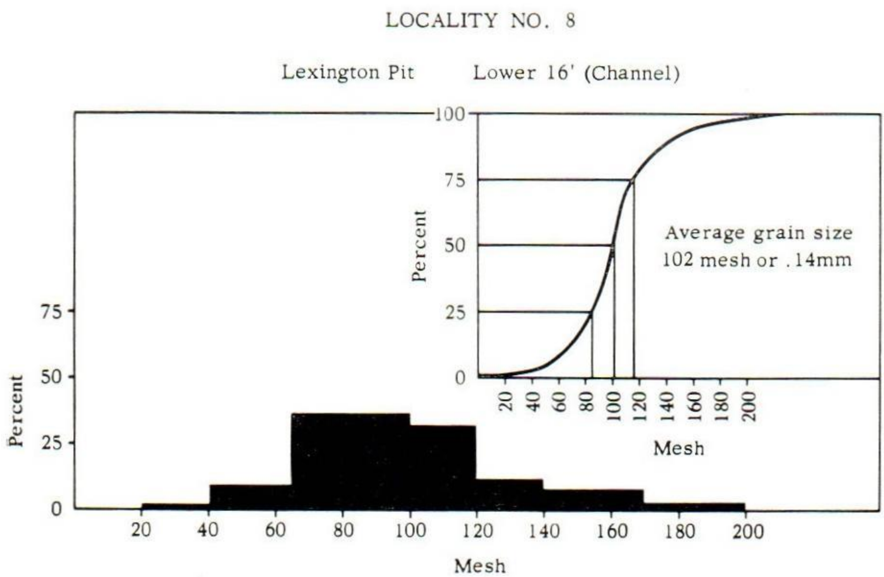


FIGURE 7. *Histograms and cumulative curves, McNairy sand, Locality No. 8.*

LOCALITY NO. 9

Parkburg 26' Channel

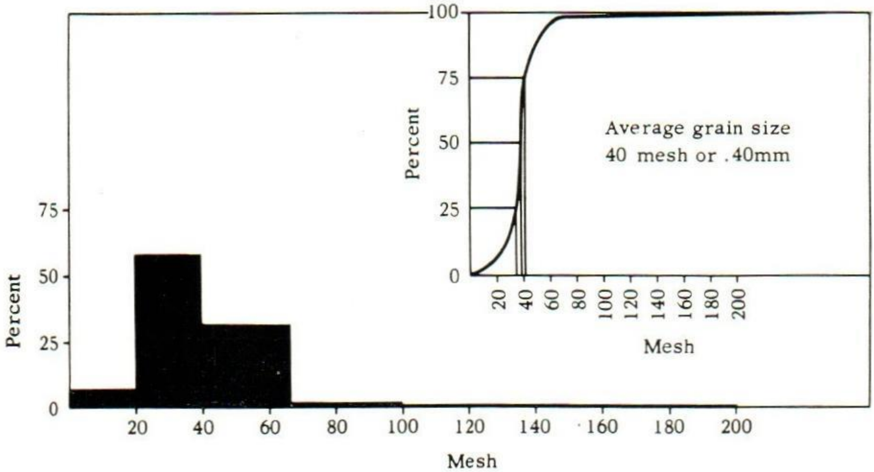
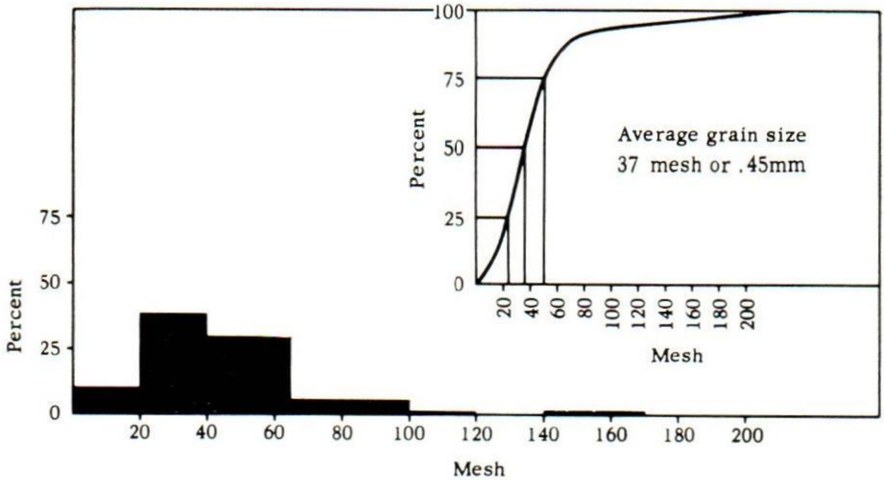


FIGURE 8. *Histogram and cumulative curve, Claiborne and Wilcox sand, Locality No. 9.*

LOCALITY NO. 10

McNairy Upper 15' (Channel)



LOCALITY NO. 10

McNairy Lower 15' (Channel)

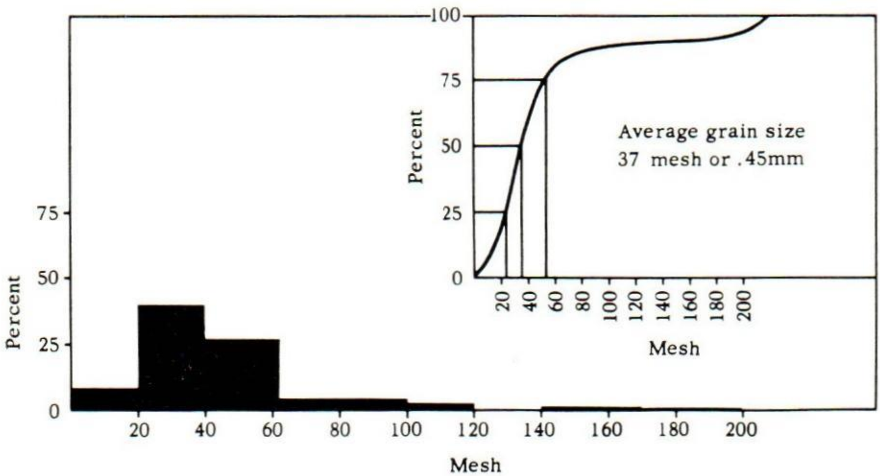


FIGURE 9. *Histograms and cumulative curves, McNairy sand, Locality No. 10.*

LOCALITY NO. 11

Grand Junction 23' Channel

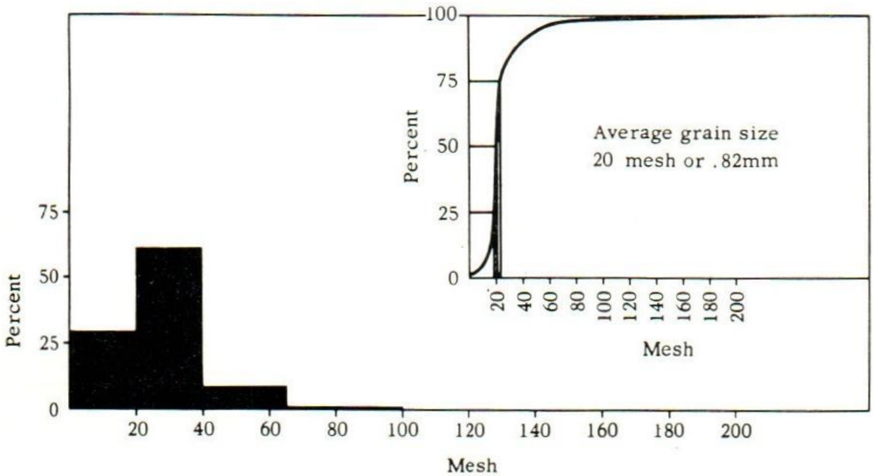
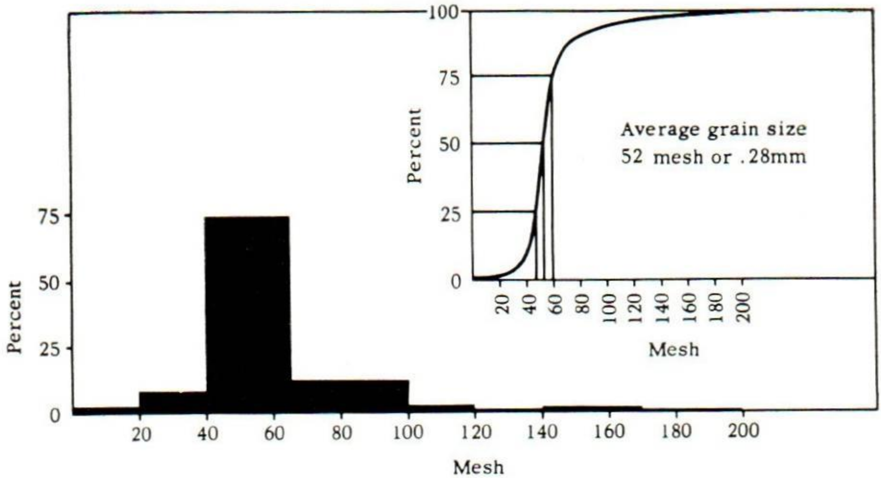


FIGURE 10. *Histogram and cumulative curve, Claiborne and Wilcox sand, Locality No. 11.*

LOCALITY NO. 12

Monterey, Pit #195 (Stockpile)



LOCALITY NO. 12

Monterey, Pit #195 (Stockpile)
Selectively Mined for Coarse Size

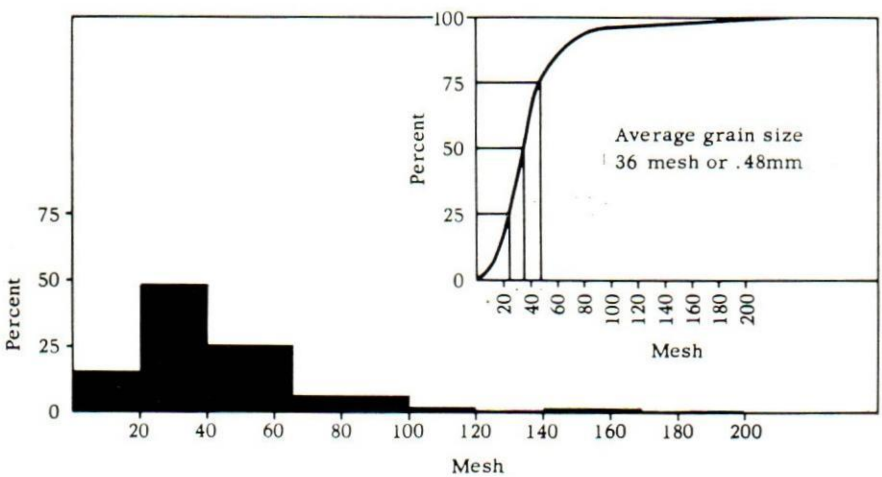
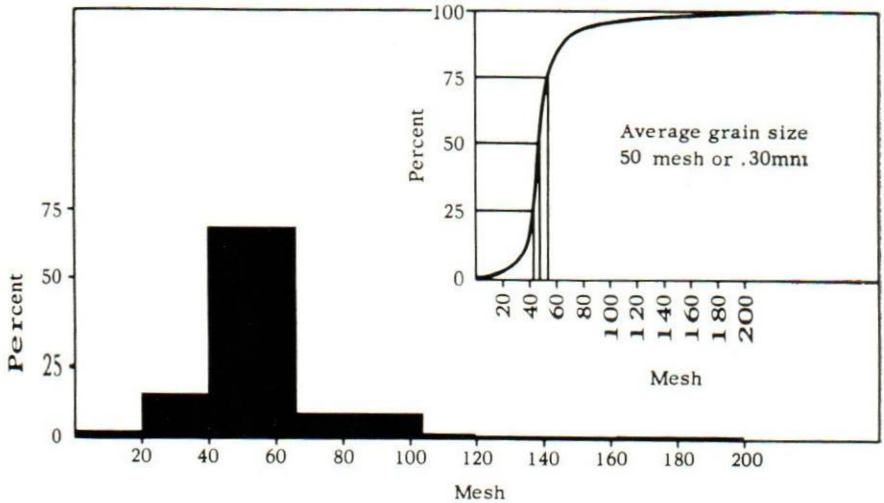


FIGURE 11. *Histograms and cumulative curves, Sewanee conglomerate, Locality No. 12.*

LOCALITY NO. 13

Bon Air Upper 10' (Composite)



LOCALITY NO. 13

Bon Air Lower 20' (Composite)

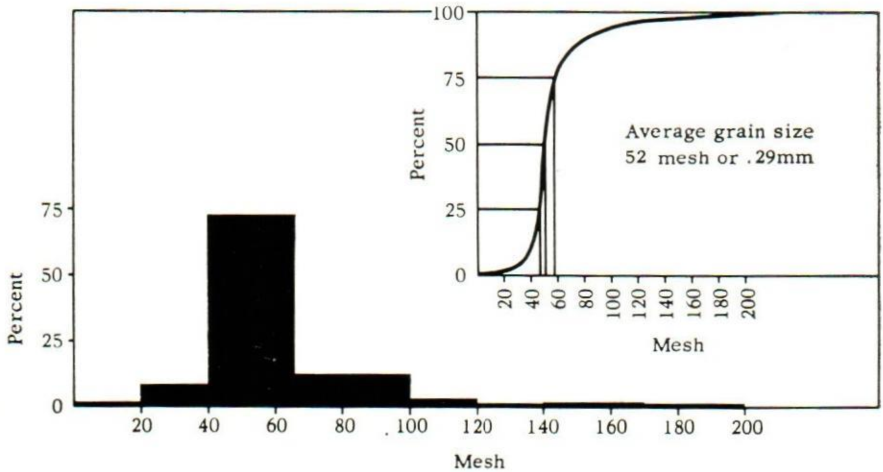
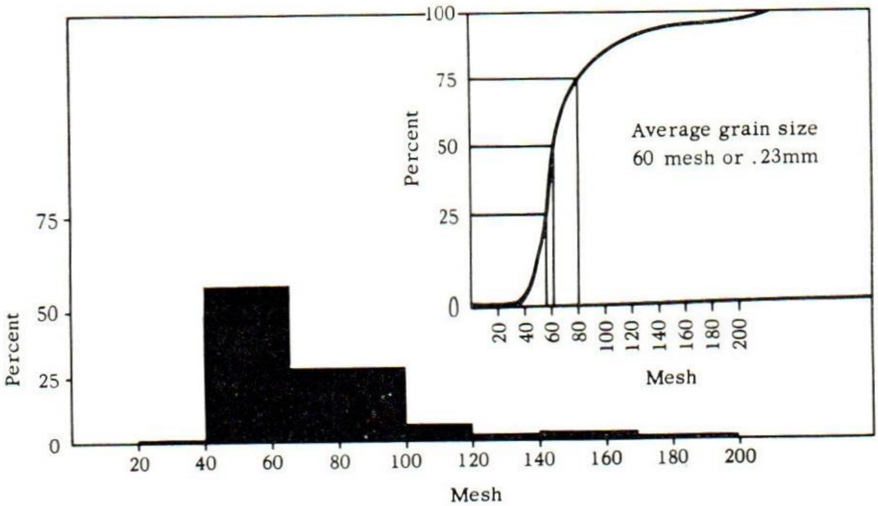


FIGURE 12. *Histograms and cumulative curves, Sewanee conglomerate, Locality No. 13.*

LOCALITY NO. 14

Pleasant Hill 18' Channel



LOCALITY NO. 15

Spencer 30' Composite

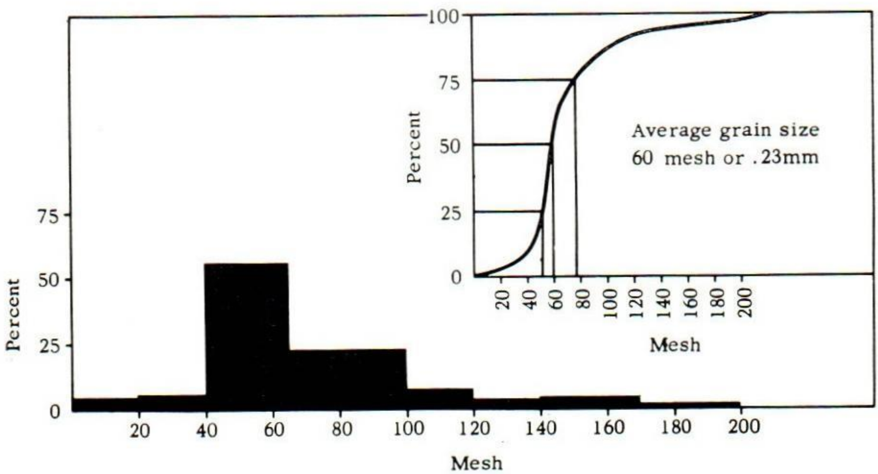
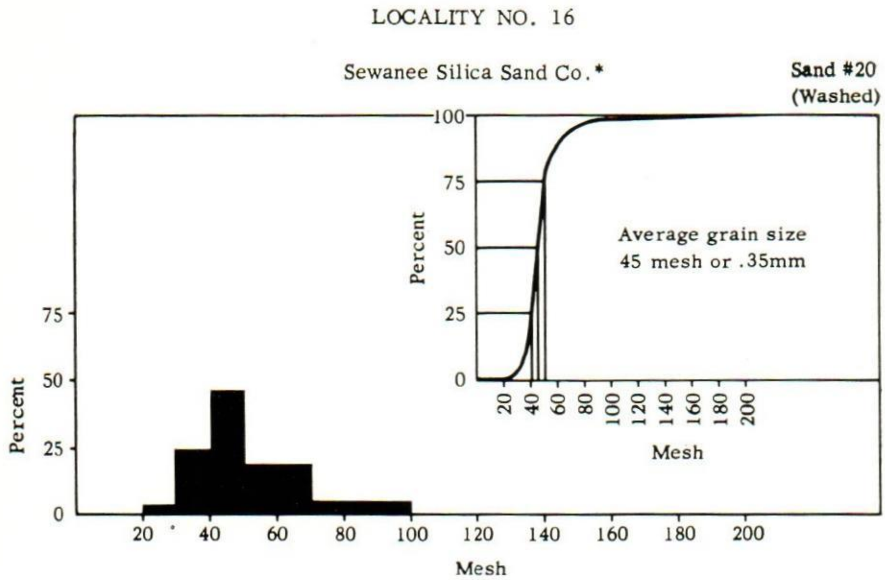
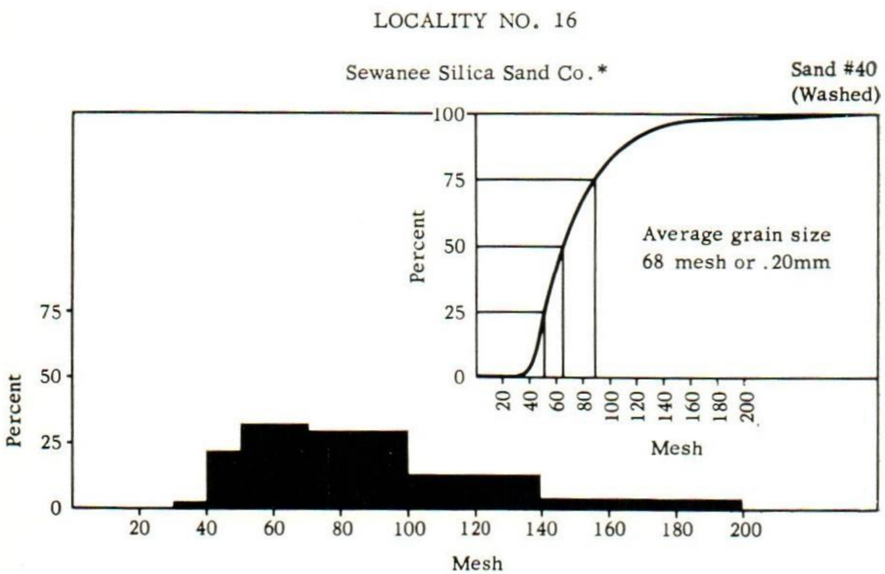


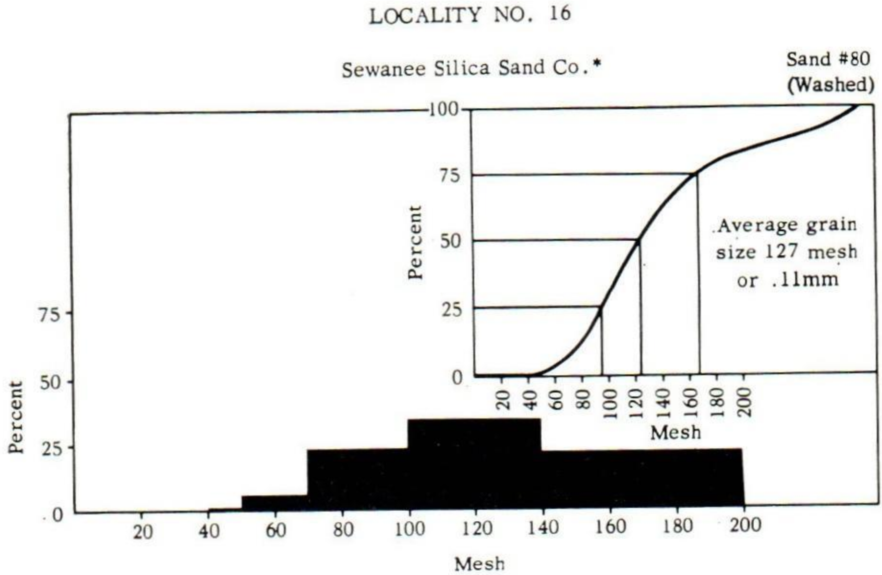
FIGURE 13. *Histograms and cumulative curves, Rockcastle conglomerate, Locality No. 14, and Sewanee conglomerate, Locality No. 15.*

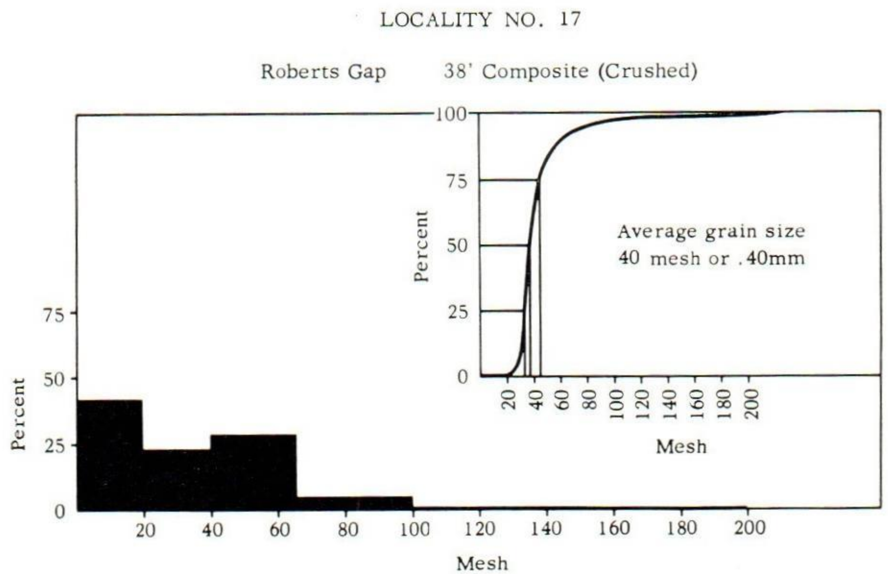




*Sand sizes from company data.

FIGURE 14. *Histograms and cumulative curves, Sewanee conglomerate, Locality No. 16.*



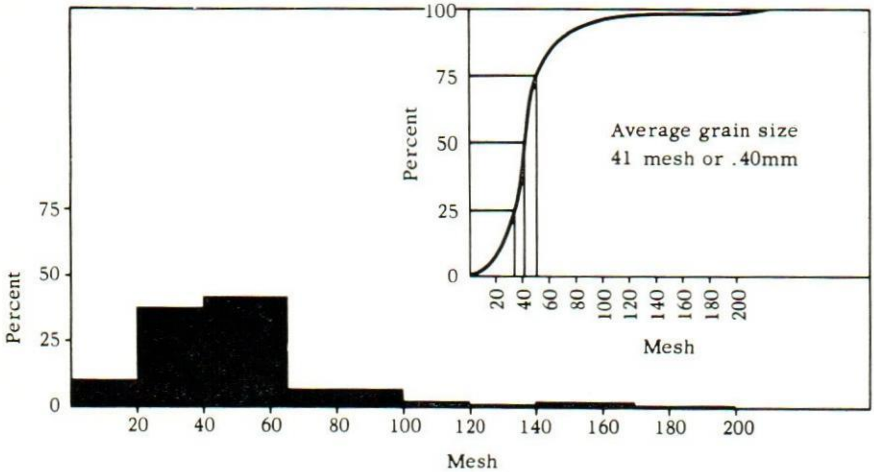


*Sand sizes from company data.

FIGURE 15. *Histograms and cumulative curves, Sewanee conglomerate, Localities No. 16 and No. 17.*

LOCALITY NO. 18

Sawyer Road Stockpile Sample (Crushed)



LOCALITY NO. 19

Henson Gap 28' Composite

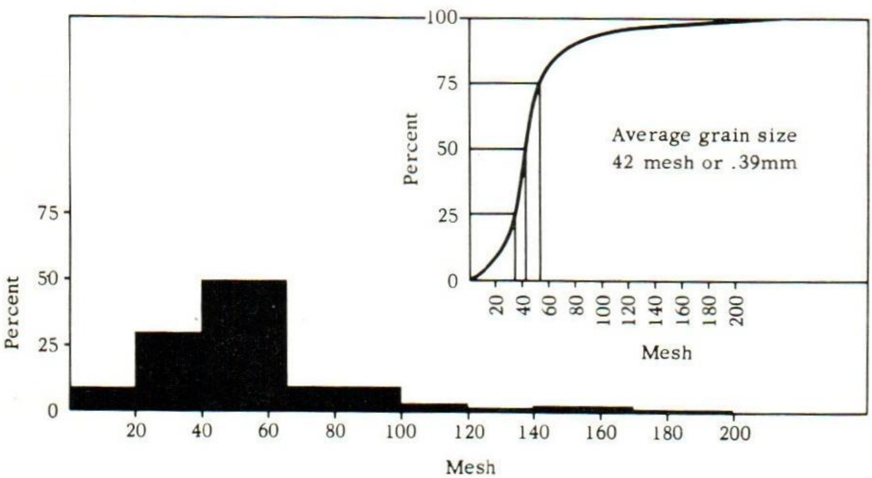
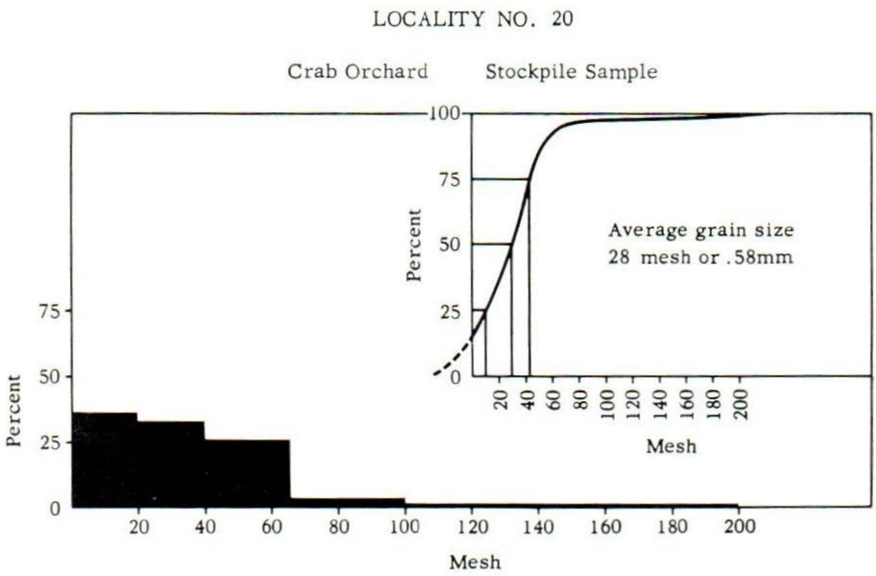


FIGURE 16. *Histograms and cumulative curves, Vandever formation, Locality No. 18, and Sewanee conglomerate, Locality No. 19.*

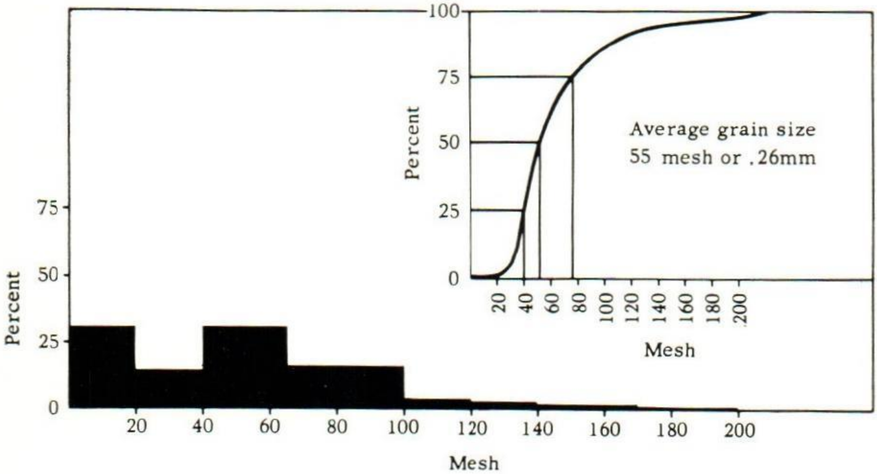


Note: The plus 20 mesh size material is quartz and quartzite pebbles and not smaller sizes cemented together by iron or other material.

FIGURE 17. *Histogram and cumulative curve, Sewanee conglomerate, Locality No. 20.*

LOCALITY NO. 21

Fire Tower, Oliver Springs
Upper Sample (Crushed) 13' Composite



LOCALITY NO. 21

Fire Tower, Oliver Springs
Lower Sample 20' Composite

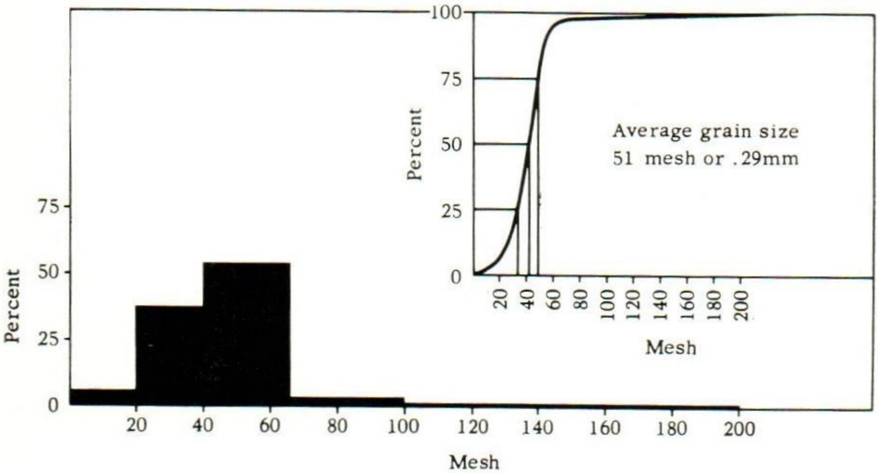
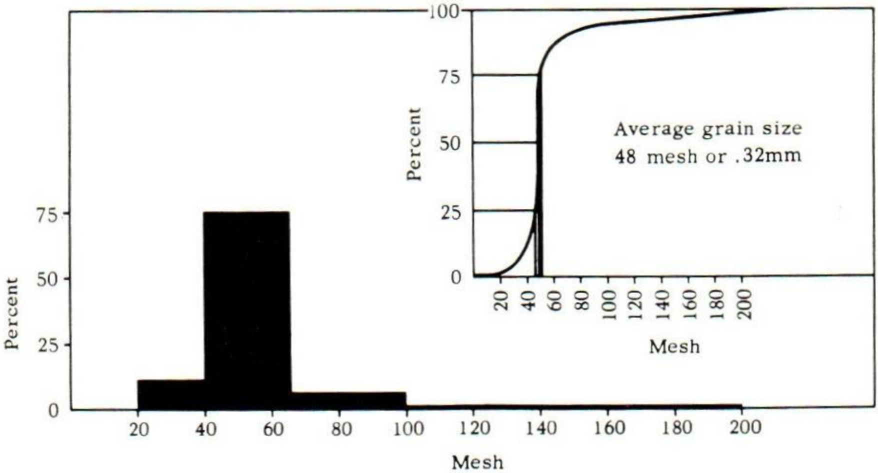


FIGURE 18. *Histograms and cumulative curves, Sewanee conglomerate (?), Locality No. 21.*

LOCALITY NO. 22

Silica Sand Co., Caryville
SE Pit (Upper Bed) 12' Channel



LOCALITY NO. 22

Silica Sand Co., Caryville
NW Pit (Lower Bed) 25' Channel

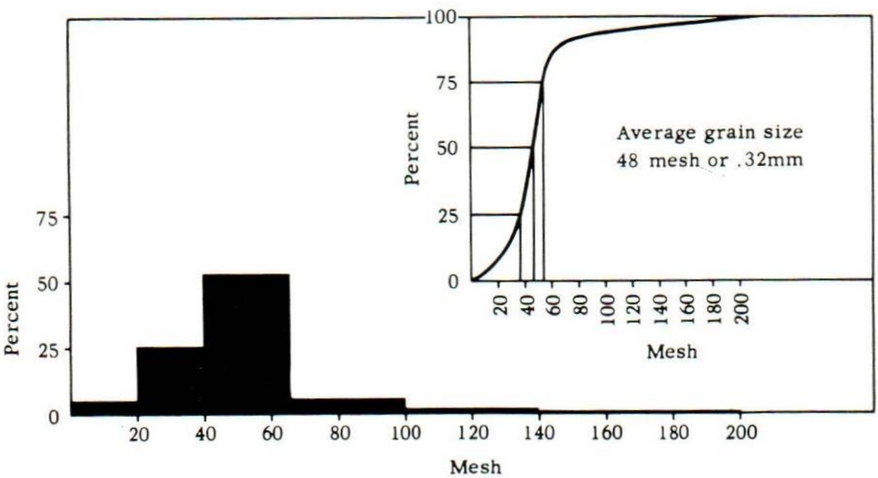


FIGURE 19. *Histograms and cumulative curves, Sewanee conglomerate (?), Locality No. 22.*

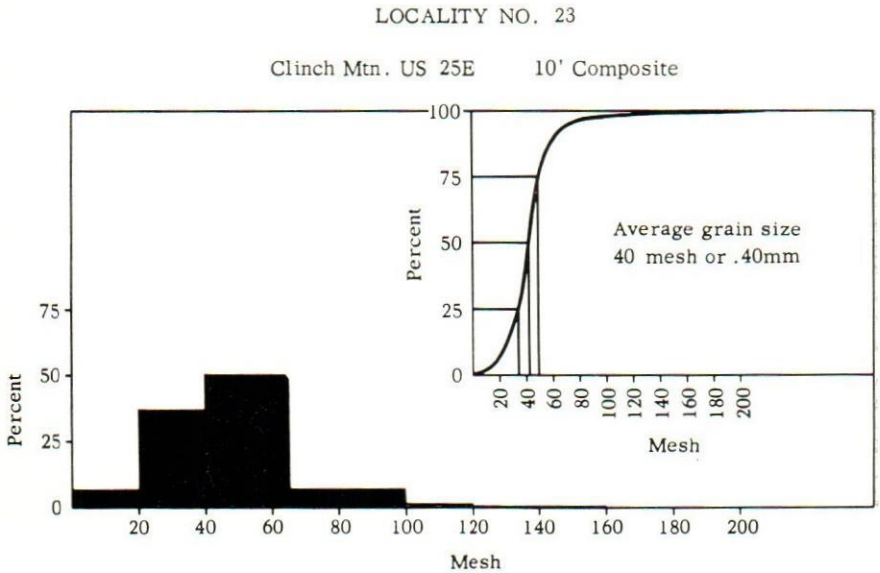


FIGURE 20. *Histogram and cumulative curve, Clinch sandstone, Locality No. 23.*

BENEFICIATION TESTS

PROCEDURES

Almost all the samples taken for this report contained too many impurities to be used directly as high-silica raw material. Consequently, different types of beneficiation were used in an effort to upgrade them.

Some of the sandstone samples did not break down into sand when collected, and these were crushed in a jaw crusher to minus 8 mesh size. The Crab Orchard sample contained a considerable amount (35.8 percent) of quartz pebbles, which were not crushed for inclusion in beneficiation tests. These quartz pebbles if crushed and included would probably not change the chemical analysis of the beneficiated sample.

Ten- to fifty-pound samples were collected from the different localities. Each sample was run through a sample splitter until it was reduced to 500 grams. The 500-gram samples were screened through an 8-mesh sieve, and all material not passing 8 mesh was discarded. The remaining material was blunged in a 1-gallon straight-walled porcelain jar containing 1,000 cc of tap water. Agitation was supplied by an impeller driven by a $\frac{1}{4}$-hp motor. The speed of the impeller was approximately 640 rpm. Three wooden baffles were clamped to the sides of the jar to add turbulence to the mixture and thus give the sand grains a greater abrasive effect. Length of blunging time varied according to the amount of impurities in the samples, either 5, 10, or 20 minutes.

When the blunging was completed, the samples were washed over a 100-mesh screen, and all material passing 100 mesh was discarded. The washed samples were examined with the aid of a binocular microscope to determine if additional beneficiation was necessary. If the sample did not appear to need additional treatment it was dried and sieved for grain size percentages (tables 6 and 7), and a portion was taken for chemical analysis.

Two methods of abrasion were tried to remove clay and iron stain from the sands after washing. The first was by tumbling the sand samples in an Abbe Mill charged with flint pebbles; the second by tumbling the samples in an Abbe Mill charged with weighted rubber balls. The first method was abandoned because the flint pebbles crushed the sand grains to a smaller average grain size and increased the amount of quartz "flour." The second method did not substantially improve the samples even after a 1-hour period of tumbling.

Most of the raw samples tested contained 1 percent or more of clay, and binocular examination showed that the iron was more intimately associated with the clay than as a hard iron stain on the individual quartz grains. Consequently, a detergent[1] was added to disperse the clay particles, and the samples were blunged in the same apparatus previously described for blunging. After blunging with detergent the sample was washed over a 100-mesh screen and examined. Most of the iron and clay was removed by the detergent. A commercial operation using a continuously moving stream of water over the sample would probably remove more of the clay, iron, and mica than was accomplished in the laboratory process used.

The samples that contained heavy minerals were further beneficiated, by magnetic methods, in a Frantz Isodynamic Separator. Fifty grams of the blunged samples were screened over a 40-mesh screen, and all material passing 40 mesh was run through the separator; the separated samples then were analyzed chemically. In some samples the alumina content appears abnormally high, because it is concentrated in the fine fraction which is used in this type of beneficiation. Materials removed by magnetic separation consisted of iron-stained quartz grains, limonite grains, mica, and several heavy minerals of which ilmenite was the most prevalent. Practically no magnetite was encountered except for the small inclusions in the samples from West Tennessee. Heavy minerals were more abundant in samples from the McNairy sand than in any of the other samples.

Table 8 includes the type of beneficiation given to each sample.

[1] Sodium hexametaphosphate.

TABLE 6. Sieve analyses of beneficiated samples.[1]
(Cumulative figures in parentheses)

Locality	*Sample number*	*% plus 20 mesh*	*% plus 40 mesh*	*% plus 65 mesh*	*% plus 100 mesh*	*% minus 100 mesh*	*Total %*
No. 1—Walnut Grove	4B	0.6	37.0 (37.6)	39.3 (76.9)	16.8 (93.7)	6.3 (100.0)	100.0
No. 2—Paris Landing							
Upper 12′	10B	0.5	15.6 (16.1)	62.9 (79.0)	17.3 (96.3)	3.7 (100.0)	100.0
Lower 6′	15B	0.2	6.6 (6.8)	68.3 (75.1)	22.1 (97.2)	2.8 (100.0)	100.0
No. 3—City of Paris	32B	8.9	44.0 (52.9)	37.9 (90.8)	8.1 (98.9)	1.1 (100.0)	100.0
No. 4—McKenzie	18B	0.4	7.8 (8.2)	64.7 (72.9)	22.5 (95.4)	4.6 (100.0)	100.0
No. 5—Hardy Sand Co.							
N. of highway	19B	0.3	16.7 (17.0)	67.7 (84.7)	13.7 (98.4)	1.6 (100.0)	100.0
Do.	34B	0.2	16.0 (16.2)	67.8 (84.0)	14.2 (98.2)	1.8 (100.0)	100.0
No. 6—Hardy Sand Co.							
S. of highway	2B	Trace	19.4	59.1 (78.5)	20.0 (98.5)	1.5 (100.0)	100.0
No. 7—Camden	27B	62.8	21.7 (84.5)	11.7 (96.2)	3.6 (99.8)	0.2 (100.0)	100.0
No. 8—Lexington							
Upper 8′	8B	0.4	1.7 (2.1)	20.2 (22.3)	43.8 (66.1)	33.9 (100.0)	100.0
Lower 16′	40B	0.3	0.7 (1.0)	4.5 (5.5)	22.7 (28.2)	71.8 (100.0)	100.0
No. 9—Parkburg	3B	4.1	53.9 (58.0)	39.2 (97.2)	2.6 (99.8)	0.2 (100.0)	100.0
No. 10—McNairy							
Lower 15′	25B	6.7	30.2 (36.9)	50.7 (87.6)	10.4 (98.0)	2.0 (100.0)	100.0
Upper 15′	35B	4.7	30.2 (34.9)	52.7 (87.6)	10.7 (98.3)	1.7 (100.0)	100.0
No. 11—Grand Junction	9B	18.0	66.9 (84.9)	12.0 (96.9)	2.5 (99.4)	0.6 (100.0)	100.0
No. 12—Monterey							
Stockpile	7B	0.2	5.4 (5.6)	74.2 (79.8)	15.6 (95.4)	4.6 (100.0)	100.0
Coarse	38B	11.0	50.0 (61.0)	27.6 (88.6)	7.3 (95.9)	4.1 (100.0)	100.0

TABLE 6. Sieve analyses of beneficiated samples.[1] (Continued)
(Cumulative figures in parentheses)

Locality	*Sample number*	*% plus 20 mesh*	*% plus 40 mesh*	*% plus 65 mesh*	*% plus 100 mesh*	*% minus 100 mesh*	*Total %*
No. 13—Bon Air							
Upper 10′	1B	Trace	12.3	73.3 (85.6)	11.7 (97.3)	2.7 (100.0)	100.0
Lower 20′	31B	0.3	9.6 (9.9)	73.3 (83.2)	13.3 (96.5)	3.5 (100.0)	100.0
Do.	36B	0.4	9.5 (9.9)	72.7 (82.6)	13.0 (95.6)	4.4 (100.0)	100.0
No. 14—Pleasant Hill	17B	Trace	0.2	55.5 (55.7)	33.7 (89.4)	10.6 (100.0)	100.0
No. 15—Spencer	37B	0.9	3.4 (4.3)	59.7 (64.0)	24.4 (88.4)	11.6 (100.0)	100.0
No. 16—Sewanee Silica Sand Co.			Not included in beneficiation tests				
No. 17—Roberts Gap	16B	10.1	22.9 (33.0)	54.6 (87.6)	10.5 (98.1)	1.9 (100.0)	100.0
No. 18—Sawyer Road	6B	4.7	37.3 (42.0)	46.6 (88.6)	7.7 (96.3)	3.7 (100.0)	100.0
No. 19—Henson Gap	11B	3.7	23.6 (27.3)	56.0 (83.3)	11.4 (94.7)	5.3 (100.0)	100.0
No. 20—Crab Orchard	23B	14.1	46.6 (60.7)	34.0 (94.7)	4.8 (99.5)	0.5 (100.0)	100.0
No. 21—Fire Tower							
Upper 13′	24B	3.7	4.5 (8.2)	49.6 (57.8)	31.7 (89.5)	10.5 (100.0)	100.0
Lower 20′	33B	1.4	30.7 (32.1)	62.5 (94.6)	4.5 (99.1)	0.9 (100.0)	100.0
No. 22—Silica Sand Co.							
Lower 25′	5B	2.3	29.4 (31.8)	56.9 (88.6)	7.3 (95.9)	4.1 (100.0)	100.0
Upper 12′	39B	Trace	11.9	78.5 (90.4)	7.4 (97.8)	2.2 (100.0)	100.0
No. 23—Clinch Mtn.							
U. S. 25E	26B	5.6	35.7 (41.3)	49.9 (91.2)	7.6 (98.8)	1.2 (100.0)	100.0
No. 24—Clinch Mtn.							
Flat Gap	46B			Crushed to ½ inch			

[1] All minus 8 mesh and washed over 100 mesh.

TABLE 7. Percentage of samples in grain size range from minus 20 mesh to plus 65 mesh and percent recovery of beneficiated samples.

Locality	—20 mesh to + 65 mesh (percent) Raw sample	Beneficiated sample	Percent recovery [1]	Geologic horizon
No. 1	73.9	[2] 76.3	[3] 80+	Eutaw
No. 2				
Upper	81.5	78.5	[3] 90+	McNairy
Lower	79.0	74.9	94	Do.
No. 3	79.7	[2] 81.9	87	Claiborne and Wilcox
No. 4	76.0	72.5	85	Do.
No. 5	85.4	84.4	92–95	McNairy
No. 6	80.7	78.5	[3] 90	Do.
No. 7	——	[4] 33.4	68	Camden
No. 8				
Upper	37.2	21.9	[3] 80	McNairy
Lower	9.9	5.2	[3] 80	Do.
No. 9	90.6	[2] 93.1	85	Claiborne and Wilcox
No. 10				
Upper	67.7	[2] 82.9	47	McNairy
Lower	64.3	[2] 80.9	41	Do.
No. 11	68.7	[2] 78.9	[3] 90	Claiborne and Wilcox
No. 12				
Stockpile	81.1	79.6	[3] 90+	Sewanee
Coarse	73.6	[2] 77.6	93	Do.
No. 13				
Upper	84.4	[2] 85.6	[3] 90	Do.
Lower	80.5	[2] 82.5	90–92	Do.
No. 14	56.0	55.7	85	Rockcastle
No. 15	59.7	[2] 63.1	85	Sewanee
No. 16 [5]	——	——	——	Do.
No. 17	50.5	[2] 77.5	[3] 90	Do.
No. 18	78.3	[2] 83.9	[3] 90	Vandever
No. 19	76.6	[2] 79.6	[3] 90	Sewanee
No. 20	58.4	[2] 80.6	91	Do.
No. 21				
Upper	45.5	[2] 54.1	77	Sewanee (?)
Lower	80.2	[2] 93.2	93	Do.
No. 22				
Upper	86.8	[2] 90.4	91	Do.
Lower	80.1	[2] 86.3	[3] 90	Do.
No. 23	41.5	[2] 85.6	96	Clinch
No. 24 [6]	——	——	——	Do.

[1] Percent recovery of the total sample after beneficiation, not including electromagnetic separation.
[2] Grain size more uniform after beneficiation.
[3] Estimated.
[4] Sample crushed to 8 mesh.
[5] Not collected; 3 size grades reported by company.
[6] Massive sandstone; later crushed to ½ inch.

TABLE 8. Chemical analyses of beneficiated samples.[1]

Locality	Sample number	Type of benefi-ciation[2]	SiO_2	Fe_2O_3	Al_2O_3	CaO-MgO	Ignition loss
No. 1—Walnut Grove	4B	2	99.30	.054	.48	.05	.10
Do.	12B	4	99.52	.006	.39	.03	.06
No. 2—Paris Landing							
Upper 12′	10B	2	99.25	.069	.53	.05	.11
Lower 6′	15B	2	99.16	.044	.50	.05	.24
No. 3—City of Paris	32B	2	99.15	.061	.62	None	.12
Do.	43B	4	99.38	.046	.47	None	.12
No. 4—McKenzie	18B	2	99.37	.063	.44	None	.12
Do.	42B	4	99.36	.050	.36	.12	.08
No. 5—Hardy Sand Co.							
N. of highway	19B	2	99.60	.049	.25	None	.10
Do.	20B	4	99.60	.009	.25	.05	.08
Do.	34B	1	99.12	.086	.55	.05	.15
No. 6—Hardy Sand Co.							
S. of highway	2B	1	99.16	.024	.28	.22	.24
Do.	14B	3	98.88	.004	.79	.12	.22
		[3] 3	99.04	.004	.68	.10	.20
No. 7—Camden	27B	2	99.00	.091	.30	.17	.42
No. 8—Lexington							
Upper 8′	8B	1	95.03	.61	3.35	.55	.43
Do.	13B	3	97.64	.062	1.64	.47	.21
Lower 16′	40B	1	94.33	.56	4.00	.39	.66
Do.	41B	3	95.88	.28	3.16	.22	.40
No. 9—Parkburg	3B	2	98.71	.063	.88	.10	.22
No. 10—McNairy							
Upper 15′	35B	2	96.83	.90	1.58	.18	.48
Lower 15′	25B	2	97.70	.75	1.30	None	.24
No. 11—Grand Junction	9B	6	98.80	.067	.94	.10	.12
No. 12—Monterey							
Stockpile	7B	1	99.35	.024	.36	.10	.18
Coarse	22B	3	99.40	.016	.39	.05	.14
Do.	38B	1	99.51	.026	.16	.15	.12

[1] All minus 8 mesh and plus 100 mesh, except in types 3 and 4 where minus 40 mesh and plus 100 mesh material was used.

[2] Types (1) 10-minute blunge in water.
(2) 5-minute blunge in water plus 10-minute blunge with detergent solution.
(3) 10-minute blunge in water plus electromagnetic separation.
(4) 5-minute blunge in water, plus 10-minute blunge with detergent solution, plus electromagnetic separation.
(5) 30 minutes in Abbe mill with detergent solution.
(6) 5-minute blunge in water plus 20-minute blunge with detergent solution.

[3] Recheck on 14B.

TABLE 8. Chemical analyses of beneficiated samples.[1] (Continued)

Locality	*Sample number*	*Type of benefi-ciation*	SiO_2	Fe_2O_3	Al_2O_3	*CaO-MgO*	*Ignition loss*
No. 13—Bon Air							
Upper 10′	1B	1	99.23	.053	.39	.14	.17
Lower 20′	30B	4	98.76	.046	.98	None	.17
Do.	31B	2	98.84	.064	.72	.26	.10
Do.	36B	1	98.81	.064	.81	.18	.11
No. 14—Pleasant Hill	17B	2	98.00	.107	1.24	.28	.35
Do.	44B	4	98.72	.079	.74	.18	.23
No. 15—Spencer	21B	3	98.47	.22	.93	.15	.20
Do.	37B	1	98.10	.39	.97	.25	.28
No. 16—Sewanee Silica Sand Co. Not included in the beneficiation tests							
No. 17—Roberts Gap	16B	2	97.67	.34	1.44	.20	.32
No. 18—Sawyer Road	6B	2	98.78	.150	.42	.46	.20
No. 19—Henson Gap	11B	1	99.08	.024	.34	.40	.14
No. 20—Crab Orchard	23B	2	99.25	.049	.43	.10	.14
Do.	28B	4	98.74	.027	.62	.37	.22
No. 21—Fire Tower							
Upper 13′	24B	2	95.97	.67	2.47	.24	.63
Lower 20′	33B	2	98.96	.106	.35	.30	.24
No. 22—Silica Sand Co.							
Upper 12′	39B	1	99.35	.033	.29	None	.28
Do.	45B	3	99.18	.008	.45	.14	.20
Lower 25′	5B	1	99.63	.023	.07	.15	.10
No. 23—Clinch Mtn.							
U. S. 25E	26B	2	99.50	.026	.29	.05	.11
Do.	29B	4	99.15	.024	.40	.05	.35
No. 24—Clinch Mtn.							
Flat Gap	46B	5	98.54	.066	.70	.37	.30

[1] See footnotes on preceding page.

RESULTS

Simple washing was sufficient to upgrade some of the Sewanee sandstone and McNairy sand samples to a fairly high degree of purity. The addition of detergent solution upgraded the remaining samples from other formations to at least ninth quality glass. The detergent solution was efficient in removing much of the clay and iron, some of which was colloidal size, from the quartz grains.

Very little or no iron was taken into solution by the detergent. If the detergent solution used for washing were to be recycled, the clay and iron would have to be removed from suspension before re-use by adding a sequestering agent and allowing the fine material to settle out in a tailings pond.

Electromagnetic separation was: (1) very efficient in removing most of the remaining iron after washing from the Eutaw sand sample and the McNairy sand samples; (2) fairly efficient in removing iron from the Sewanee conglomerate samples except the "upper" sample from Locality No. 22, in which it was very efficient; (3) not very efficient on the Claiborne and Wilcox, Clinch, and Rockcastle samples. Magnetic separation was not tried on the sample of sandstone from the Vandever formation, but the results would be very similar to those of the Sewanee and Rockcastle.

The average percentage recovery for all the samples after beneficiation was 84 percent. If samples containing large amounts of material finer than 100 mesh and material that was crushed by a jaw crusher are discounted, the average recovery was 89 percent. The 80 percent estimated recovery of minus 20 to plus 65 mesh material for Locality No. 8 is abnormally high because it includes a considerable amount of minus 100 mesh material that was not removed by wet screening.

After beneficiation the effective recovery of material in sizes minus 20 mesh to plus 65 mesh was 98 percent or greater in all samples except the Lexington sample, Locality No. 8.

In most of the samples tested, 75 percent or more of the sand grains met the size requirements for glass sand as indicated by table 2. (Also see table 7.)

Of the 24 localities all contained material that was beneficiated to a high-silica, chemical classification. (See tables 2 and 8.)

One locality, No. 22 (lower), contained sand that might be beneficiated to first quality optical grade glass; this sample, beneficiated by washing only, contained .023 percent iron or .003 percent more iron than the maximum iron content for first quality optical glass, and .05 percent more than maximum CaO-MgO. Other impurities are within the tolerance ranges. Results of further beneficiation on similar samples, by addition of detergent and/or by electromagnetic separation, suggest that both the iron and CaO-MgO content of this sample could be reduced to within the requirements for first quality optical glass. The "coarse" sample from Locality No. 12 is also near the requirements for first quality optical glass.

The sample from Locality No. 22 (lower) contained 86.3 percent sand grains between minus 20 mesh and plus 65 mesh, with an estimated percentage recovery after beneficiation of 90 percent. Locality No. 12 ("coarse") contained 77.6 percent sand grains within the same size range and a calculated percentage recovery of 93 percent. Samples from 5 localities, including the 2 previously mentioned, were upgraded to second quality flint glass, by washing only—Localities 6, 12, 16[1], 19, and 22; by the addition of detergent, the sample from Locality Number 23 obtained the same classification. By adding electromagnetic separation, samples from three other localities—1, 5, and 20—fit the chemical requirements for second quality flint glass. In all of these samples, 76.3 percent to 90.4 percent of the sand grains were between minus 20 mesh and plus 65 mesh. The percent recovery after beneficiation ranged from 80 to 96 percent and averaged 90.6 percent.

Four samples, from Localities 2, 3, 4, and 13, were beneficiated to fourth quality sheet glass; samples from Localities 18 and 21 were beneficiated to sixth quality green glass.

None of the samples had the specific chemical requirements for third quality flint glass or fifth quality sheet glass.

Samples from the remaining nine localities were beneficiated to at least ninth quality amber glass as far as chemical requirements are concerned.

Locality No. 7, which is in the Camden chert, yielded a massive sample that was crushed to minus 8 mesh. The large loss through washing, 32 percent, would preclude the use of this material for glass sand, but the resultant high silica content, 99.00 percent, and relatively low iron content, .091 percent, are sufficient justification for further consideration of this material for large size, ½ inch to 4 inch, high-silica uses.

The sample from Locality No. 24, which is in an area of hard, well-indurated sandstone, contained less iron by analysis than visual observation indicated. This 65-foot composite sample contained .070 percent iron, which was not materially reduced by beneficiation, but the alumina content was lowered from 1.82 percent to .70 percent. The sample would be suitable for some uses of large-size high-silica raw materials.

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[1] Company data.

POTENTIAL OF THE INDUSTRY

RAW MATERIALS

The glass sand industry in Tennessee is relatively recent. At present two companies are mining and processing sand for the glass industry. The trend is toward expansion and diversification. The Sewanee Silica Sand Company has just completed a silica grinding plant to produce exceedingly fine grained high-silica material for many uses. The volume of raw materials needed for glass manufacture has increased steadily, which indicates a growing and very stable industry with no radical price or volume fluctuations.

The variety of uses for high-silica raw materials has expanded greatly in the past several years and is expected to expand more in the immediate future. Users now depending on coarse-size (gravel) high-silica raw materials from more distant areas for electric furnace processes may use some of the local high-silica sand by bonding it to obtain the proper charging characteristics. Heretofore overlooked Mississippian chert formations are another possible source of coarse-size high-silica raw material.

The sands and sandstones tested for this report are relatively uniform, in each horizon from area to area, in chemical composition and physical properties. This uniformity in composition indicates that as a whole large quantities of like material would be available in the vicinity of tested areas. Local variation in composition does occur, however, and location of pits would be dependent on adequate exploration.

Each sand or sandstone horizon showed like characteristics of amenability to beneficiation to give uniformity of beneficiation types for each sand. All the samples tested showed some degree of improvement in chemical characteristics after beneficiation, all of them adequate to be classified as high silica.

Thus, Tennessee has large quantities of high-silica raw materials, some of which may be used for glass manufacture and some of which may be beneficiated to a high degree of purity for small quantities of optical glass.

BY-PRODUCTS

One valuable source of by-products from the sands could be the heavy minerals, principally ilmenite for titanium and monazite for thorium, from the sands of West Tennessee; some of the rare earths may also be developed from this source. The process of separating heavy minerals from sand could be combined with preparation of small quantities of high-grade special purpose glass sands.

Heavy mineral grains, reported by M. V. Denny[1], in the Parkburg sample, were: garnet, monazite, zircon, spinel, limonite, topaz, ilmenite (including leucoxine), mica, pyrite, tourmaline, and traces of other minerals. Most of the inclusions in the quartz grains were magnetite; less common were bituminous material and pyrite or pyrrhotite.

Heavy minerals appear to be much more abundant in the Cretaceous sands than in the Eocene sands.

The samples from Locality No. 8 contained more heavy minerals than any of the other samples. The upper 8 feet of the 24-foot channel contained 2.3 percent heavy minerals, and the lower 16 feet contained 3.4 percent.

The heavy minerals can be separated from the sand by size differentiation, the heavy minerals being much smaller than the bulk of the sand. After screening the sample on a 170-mesh screen, more than 90 percent of the heavy minerals are retained on a 200-mesh screen; this fraction also contains about 10 percent of quartz grains.

One reported percentage distribution of the heavy minerals in the McNairy sand is as follows: ilmenite 30-35 percent; rutile 8-10 percent; zircon 15-18 percent; leucoxine 15 percent; monazite 2-3 percent; xenotime ½-1 percent; and others, including kyanite but principally iron oxide. The samples tested for this report did not seem to have the zircon content indicated in the above analysis. The Walnut Grove sample contained the most zircon, which was identified by brilliant yellow fluorescence under ultraviolet light.

[1] Mineralogist, U. S. Bureau of Mines, Norris, Tennessee.

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