



# HIGH-SILICA RESOURCES IN ALLEGHANY, BOTETOURT, CRAIG, AND ROANOKE COUNTIES, VIRGINIA

Palmer C. Sweet and Gerald P. Wilkes



COMMONWEALTH OF VIRGINIA

DEPARTMENT OF MINES, MINERALS AND ENERGY  
DIVISION OF MINERAL RESOURCES

Robert C. Milici, Commissioner of Mineral Resources and State Geologist

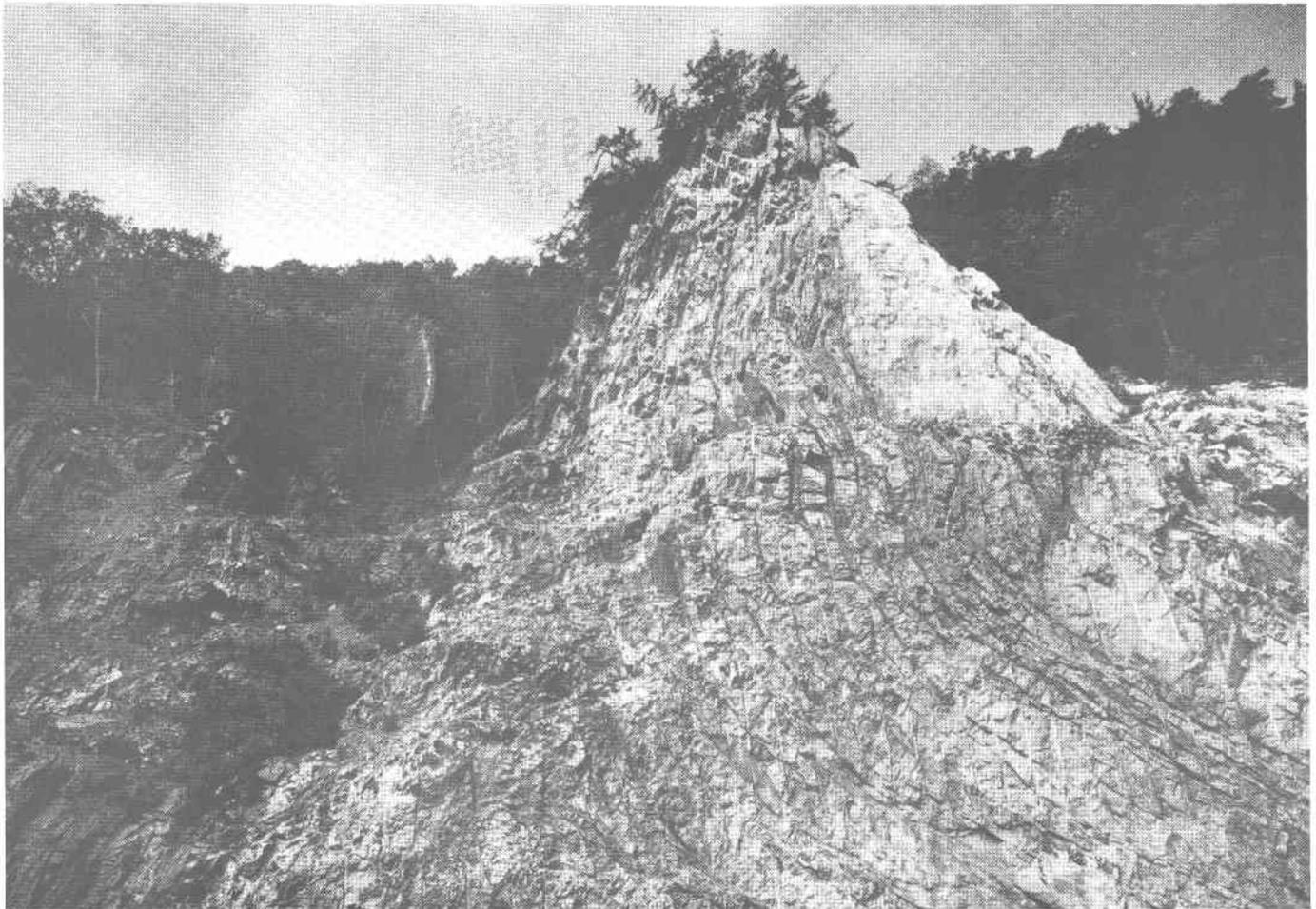
CHARLOTTESVILLE, VIRGINIA

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**FRONT COVER:** Eagle Rock from U.S. Highway 220 north of Roanoke,  
Botetourt County (Photograph by T. M. Gathright, II).

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**DEPARTMENT OF MINES,  
MINERALS AND ENERGY**

Richmond, Virginia

**O. GENE DISHNER, Director**

**COMMONWEALTH OF VIRGINIA  
DEPARTMENT OF PURCHASE AND SUPPLY  
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# HIGH-SILICA RESOURCES IN ALLEGHANY, BOTETOURT, CRAIG, AND ROANOKE COUNTIES, VIRGINIA

Palmer C. Sweet and Gerald P. Wilkes

## ABSTRACT

The principal high-silica resources of Alleghany, Botetourt, Craig, and Roanoke counties in the central and south-central Valley and Ridge province of Virginia are in the Antietam (Erwin) and Rose Hill formations and the Tuscarora, Keefer, and Ridgeley sandstones. Physical descriptions, sieve analyses, and chemical test data are presented so that the commercial potential of high-silica resources can be evaluated.

Composite samples from each of the principal resource units at selected localities were analyzed for silica content in a raw or unbeneficiated condition; silica content of the units ranges from 96.05 to 98.74 percent. The percentage of silica in beneficiated splits of the samples ranges from 97.29 to 99.27 percent for the same samples. A general decrease in percentage of  $Al_2O_3$  and  $Fe_2O_3$  upon sample beneficiation indicates that much of the clay and silt-size particles, as well as iron-oxide coating on the quartz grains, were effectively removed. Grain-size distribution, average grain size, and degree of sorting for most samples is shown by histograms and cumulative frequency curves.

## INTRODUCTION

A study of potential high-silica resources in the Valley and Ridge province was begun by the Virginia Division of Mineral Resources in November, 1970. Reports on the high-silica resources in Clarke, Frederick, Page, Rockingham, Shenandoah, and Warren counties (Harris, 1972) and Augusta, Bath, Highland, and Rockbridge counties (Sweet, 1981) have been published.

In the four counties included in this present report, more than 150 sandstone and quartzite localities were examined. Sixteen samples from fourteen of these localities warranted further study and were evaluated physically and chemically. Physical and chemical analyses were performed at the Virginia Division of Mineral Resources. Samples are designated by numbers preceded by "R" (R-7488) and are on file in the Virginia Division of Mineral Resources rock repository, where they are available for examination. Two samples were taken at each of two localities; these are designated

"A" and "B" and "A" and "C" respectively. The designations "R" and "B" after the repository number (A-7487-AR, R-7487-AB) are for "raw" and "beneficiated". Distributions of formations and samples are shown in Figure 1. Locations of sample sites are designated by Universal Transverse Mercator coordinates (UTM). There are descriptions of many other sandstone and quartzite localities within the study area on open-file, and hand samples for all localities are retained at the Virginia Division of Mineral Resources in Charlottesville.

## PROCEDURES

Exposures of sandstone and quartzite were measured and sampled at one- to three-foot intervals to form composite samples consisting of 10 to 20 pounds. Material from each sampled interval was crushed by hand with a porcelain mortar and pestle if the rock was friable. Samples were broken into fragments if tight cementation hindered disaggregation of the grains and passed through a jaw crusher and then further ground with a Bico Pulverizer or the mortar and pestle. The individual samples were then mixed on a rolling cloth to form a composite sample, which was split and prepared for chemical and sieve analyses and beneficiation. Approximately 450 grams of each of the composite samples were sieved on a Ro-Tap for 10 minutes. If microscopic examination of the resulting individually sieved fractions revealed a large percentage of grain aggregates, those fractions were recrushed and the entire sample re-sieved for 10 additional minutes.

The degree of sorting for the composite samples is based upon the Inclusive Graphic Standard Deviation which includes 90 percent of the size-distribution of the total (Folk, 1968, p. 46). Beneficiation consisted of agitating material in water in a Waring Blender for 15 minutes and then decanting. The samples were then oven dried at 100° C. Beneficiated samples were sieved for 10 minutes on the Ro-Tap for grain-size distribution.

Tightly cemented quartzite from one locality was considered for possible metallurgical use. Hand samples of the quartzite were chemically analyzed and studied in thin section to determine quartz content, sorting, cementation, and impurities.

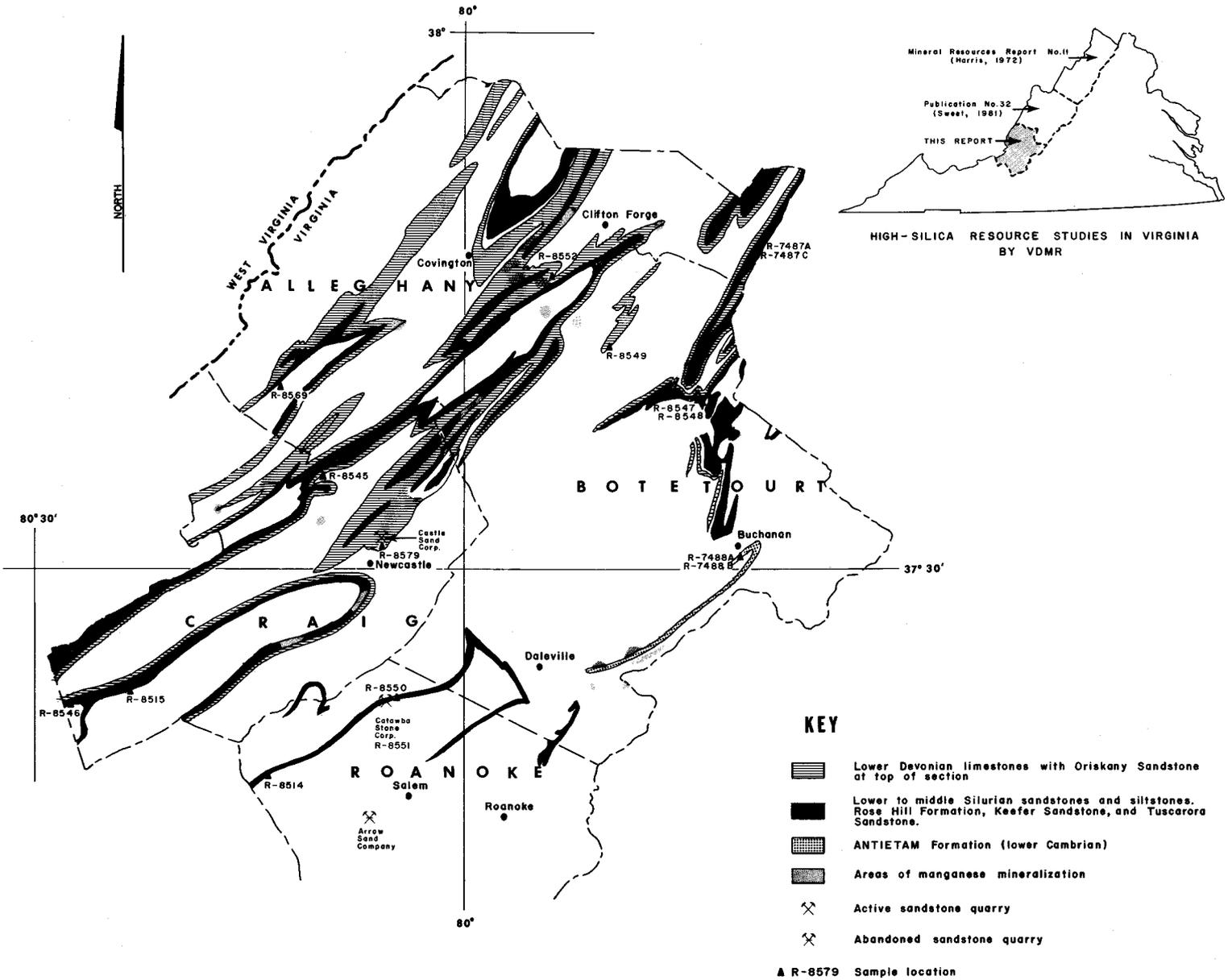


Figure 1. Outcrop map and sample locations of High-Silica Rocks in Alleghany, Botetourt, Craig and Roanoke counties, Virginia.

## SILICA-SAND INDUSTRIAL ACTIVITY IN THE STUDY AREA

Castle Sands Company, which began operations in 1960, is presently producing masonry sand from residual Ridgeley Sandstone northeast of New Castle in Craig County. Filter bed sand and sand, utilized by cement and brick companies, have been produced in the past. There may be a potential market for foundry sand from this area.

Friable sandstone of the Tuscarora Sandstone was produced from Catawba Mountain, Roanoke County, by Catawba Silica Company from around 1913 into the 1920's for a glass sand material. Material from the lower quartzitic unit was marketed as building and flagging stone from 1955-1964 by Catawba Stone Company of Roanoke.

Masonry and concrete sand were produced by the Arrow Sand Company from the Unicoi Formation on Twelve O'Clock Knob, southeast of Salem, Roanoke County from 1973-1975.

## USES OF HIGH-SILICA RESOURCES

Sweet (1984) notes that industrial silica is presently produced in the Valley and Ridge, Plateau, and Coastal Plain provinces of Virginia for glass manufacture, foundry and engine (traction) uses, for filter beds, conversion to cristobalite, and for a metallurgical flux. Additional uses in the past include electrical porcelain, oscillator grade quartz crystals, coal washing, ferrosilicon, silica flour as a component in fiberglass, cleansers, and as an abrasive for sandblasting and stone cutting. The most prevalent use of industrial sand in Virginia has been, and continues to be, for glass manufacture.

McLaws (1971) reports the following special commercial uses of material produced from high-silica resources:

- Abrasive sand, for blasting, glass grinding, sandpaper, scouring, stonegrinding — marble grinding and stone cutting
- Building products sand, for asbestos cement pipe, asphalt roofing tile, and sand-lime brick.
- Glass sand
- Hydraulic fracturing sand
- Refractory sand, for foundry moldings, coring, lining furnaces (fine sand), pottery moldings, and silica brick.
- Miscellaneous sand, for chemical processes, coal washing, traction, filtering, source of silica, and metallurgical processes.

A general discussion of sand and gravel resources in Virginia and specifications for some uses of high-silica resources is provided in Sweet (1978a). With newer technologies, more markets are developing for finer ground silica in fillers and extenders.

## DESCRIPTIONS OF SAMPLES FROM HIGH-SILICA RESOURCES

### ANTIETAM FORMATION

Quartzites and well-indurated sandstones cemented by secondary silica characterize the Antietam Formation of Cambrian age. In Botetourt County southeast of Buchanan, this unit consists of thin- to medium-bedded, poorly sorted dirty sandstones that have an abundance of iron-oxide stain and a few *Skolithos* burrows. The unit at this locality is 845 feet thick (Spencer, 1968, p. 10) and is in contrast to the massive beds of well sorted light bluish-gray sandstone and quartzite near Balcony Falls in Rockbridge County to the northeast. The Antietam is cleaner just to the southwest (Sample R-7488-A, C) at "The Gorge"; exposures are scarce in Roanoke County.

### Sample R-7488-A

*Location:* The Antietam Formation was sampled 1.4 miles south of Buchanan, Botetourt County, along Dry Run at "The Gorge", 0.35 mile off the northwest side of State Road 625 approximately 0.9 mile by road southwest of its intersection with Virginia Highway 43 in the Buchanan 7.5-minute quadrangle (UTM: N4,151,940, E 616,510; Zone 17).

*Description:* The quartzite is medium gray with medium subangular to subrounded grains. The quartzite is very indurated and has minor iron-oxide staining. Bedding varies from 12 to 24 inches. This upper unit is 19 feet thick and a ledge former. The strike is N55° E with a dip of 38° SE; major jointing is developed along a N28° W plane.

*Laboratory analyses:* The quartzite consists of medium, subangular to subrounded quartz grains, whose boundaries are tightly bonded by a simple quartz weld. The quartzite at this locality is too indurated to be crushed for sieve determination of grain size distribution.

The chemical analyses of a hand sample is shown in Table 1.

Table 1. Chemical analyses of Sample R-7488-A, Antietam Formation.

Constituents	Percent
SiO <sub>2</sub>	96.47
Al <sub>2</sub> O <sub>3</sub>	1.86
Fe <sub>2</sub> O <sub>3</sub>	0.03
MgO	0.01
CaO	0.00
Na <sub>2</sub> O	0.02
K <sub>2</sub> O	1.08
TiO <sub>2</sub>	0.14
MnO	0.00
P <sub>2</sub> O <sub>5</sub>	0.02
Cr <sub>2</sub> O <sub>3</sub>	0.003
CoO	0.004
LOI	0.36

#### Sample R-7488-B

*Location:* Same as for R-7488-A

*Description:* This sample is similar to R-7488-A except there is visibly less iron-oxide staining. Exposed thickness of the lower unit is 21 feet; shaly siltstone (4 feet) at the top was not sampled. The attitude is the same as for R-7488-A.

*Laboratory analyses:* The quartzite at this locality consists of medium, subangular to subrounded quartz grains, whose boundaries are bonded by a simple quartz weld. The material is too well cemented to be crushed for sieve determination of grain-size distribution. A chemical analysis of a hand sample is shown in Table 2.

Table 2. Chemical analysis of Sample R-7488-B, Antietam Formation.

Constituents	Percent
SiO <sub>2</sub>	98.62
Al <sub>2</sub> O <sub>3</sub>	0.72
Fe <sub>2</sub> O <sub>3</sub>	0.01
MgO	0.02
CaO	0.00
Na <sub>2</sub> O	0.01
K <sub>2</sub> O	0.31
TiO <sub>2</sub>	0.11
MnO	0.00
P <sub>2</sub> O <sub>5</sub>	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003
CoO	0.004
LOI	0.19

#### TUSCARORA SANDSTONE

The Tuscarora Sandstone of Silurian age consists of fine- to coarse-grained sandstone with the quartz grains generally bonded by a simple quartz weld. In Botetourt County the unit consists of white to tan, medium- to coarse-grained conglomeratic orthoquartzite and ranges up to 120 feet thick. It weathers to a gray sandy soil. On Catawba Mountain in Roanoke County, the sandstone is white to light gray and medium to thick bedded with subangular to subrounded quartz grains. Some medium- to coarse-grained conglomeratic sandstone is also present in the exposure. The sandstone is about 45 feet thick in that area.

#### Sample R-7487-A

*Location:* The Tuscarora Sandstone (Figure 2) was sampled 2.0 miles east of Longdale Furnace, Alleghany County, on the south side of State Road 770 approximately 2.6 miles by road east of its intersection with U. S. Highway 60 in the Longdale Furnace 7.5-minute quadrangle (UTM: N4,186,110, E618,940; Zone 17).

*Description:* This sandstone is white to light tan, with medium coarse to subrounded grains. This unit is friable, especially toward the top where the grains are coarser. Some iron-oxide staining is present on the medium bedding. The strike is N28° W with a dip of 78° SW on the sampled unit, which has a thickness of 34 feet.



Figure 2. Tuscarora Sandstone, Alleghany County, east of U. S. Highway 60 (sample R-7487-A).

Table 1. Chemical analyses of Sample R-7488-A, Antietam Formation.

Constituents	Percent
SiO <sub>2</sub>	96.47
Al <sub>2</sub> O <sub>3</sub>	1.86
Fe <sub>2</sub> O <sub>3</sub>	0.03
MgO	0.01
CaO	0.00
Na <sub>2</sub> O	0.02
K <sub>2</sub> O	1.08
TiO <sub>2</sub>	0.14
MnO	0.00
P <sub>2</sub> O <sub>5</sub>	0.02
Cr <sub>2</sub> O <sub>3</sub>	0.003
CoO	0.004
LOI	0.36

#### Sample R-7488-B

*Location:* Same as for R-7488-A

*Description:* This sample is similar to R-7488-A except there is visibly less iron-oxide staining. Exposed thickness of the lower unit is 21 feet; shaly siltstone (4 feet) at the top was not sampled. The attitude is the same as for R-7488-A.

*Laboratory analyses:* The quartzite at this locality consists of medium, subangular to subrounded quartz grains, whose boundaries are bonded by a simple quartz weld. The material is too well cemented to be crushed for sieve determination of grain-size distribution. A chemical analysis of a hand sample is shown in Table 2.

Table 2. Chemical analysis of Sample R-7488-B, Antietam Formation.

Constituents	Percent
SiO <sub>2</sub>	98.62
Al <sub>2</sub> O <sub>3</sub>	0.72
Fe <sub>2</sub> O <sub>3</sub>	0.01
MgO	0.02
CaO	0.00
Na <sub>2</sub> O	0.01
K <sub>2</sub> O	0.31
TiO <sub>2</sub>	0.11
MnO	0.00
P <sub>2</sub> O <sub>5</sub>	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003
CoO	0.004
LOI	0.19

#### TUSCARORA SANDSTONE

The Tuscarora Sandstone of Silurian age consists of fine- to coarse-grained sandstone with the quartz grains generally bonded by a simple quartz weld. In Botetourt County the unit consists of white to tan, medium- to coarse-grained conglomeratic orthoquartzite and ranges up to 120 feet thick. It weathers to a gray sandy soil. On Catawba Mountain in Roanoke County, the sandstone is white to light gray and medium to thick bedded with subangular to subrounded quartz grains. Some medium- to coarse-grained conglomeratic sandstone is also present in the exposure. The sandstone is about 45 feet thick in that area.

#### Sample R-7487-A

*Location:* The Tuscarora Sandstone (Figure 2) was sampled 2.0 miles east of Longdale Furnace, Alleghany County, on the south side of State Road 770 approximately 2.6 miles by road east of its intersection with U. S. Highway 60 in the Longdale Furnace 7.5-minute quadrangle (UTM: N4,186,110, E618,940; Zone 17).

*Description:* This sandstone is white to light tan, with medium coarse to subrounded grains. This unit is friable, especially toward the top where the grains are coarser. Some iron-oxide staining is present on the medium bedding. The strike is N28° W with a dip of 78° SW on the sampled unit, which has a thickness of 34 feet.



Figure 2. Tuscarora Sandstone, Alleghany County, east of U. S. Highway 60 (sample R-7487-A).

*Laboratory analyses:* The sandstone consists of medium to coarse, subrounded to rounded, iron-oxide stained quartz grains bonded by a tangential quartz weld. The grain weld is very weak as demonstrated by the ease of disaggregation.

Sieve and chemical analyses of the raw material (R-7487-AR) and beneficiated material (R-7487-AB) are shown in Table 3. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 3 and 4. Both the raw and beneficiated material are moderately well sorted.

Table 3. Sieve and chemical analyses of sample R-7487-A, Tuscarora Sandstone.

SIEVE ANALYSES			
U. S. Standard Sieve Mesh No.	SAMPLE R-7487-AR		SAMPLE R-7487-AB
	Percent Retained		
10	0.00	0.00	
35	15.51	5.30	
60	58.92	51.54	
80	17.37	24.41	
100	4.18	5.55	
120	1.90	4.62	
140	0.54	1.45	
200	0.03	2.76	
Pan	1.50	4.24	

CHEMICAL ANALYSES

Constituents	Percent	
SiO <sub>2</sub>	98.74	99.16
Al <sub>2</sub> O <sub>3</sub>	0.54	0.40
Fe <sub>2</sub> O <sub>3</sub>	0.14	0.06
MgO	0.01	0.01
CaO	0.00	0.00
Na <sub>2</sub> O	0.02	0.01
K <sub>2</sub> O	0.04	0.01
TiO <sub>2</sub>	0.03	0.01
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.03	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.007
CoO	0.004	0.004
LOI	0.46	0.33

Sample R-7487-C

*Location:* The Tuscarora Sandstone (Figure 5) was sampled 2.1 miles east of Longdale Furnace, Alleghany County, on the east side of State Road

770 approximately 2.7 miles by road east of its intersection with U. S. Highway 60 in the Longdale Furnace 7.5-minute quadrangle (UTM: N4,186,220, E618,990; Zone 17).

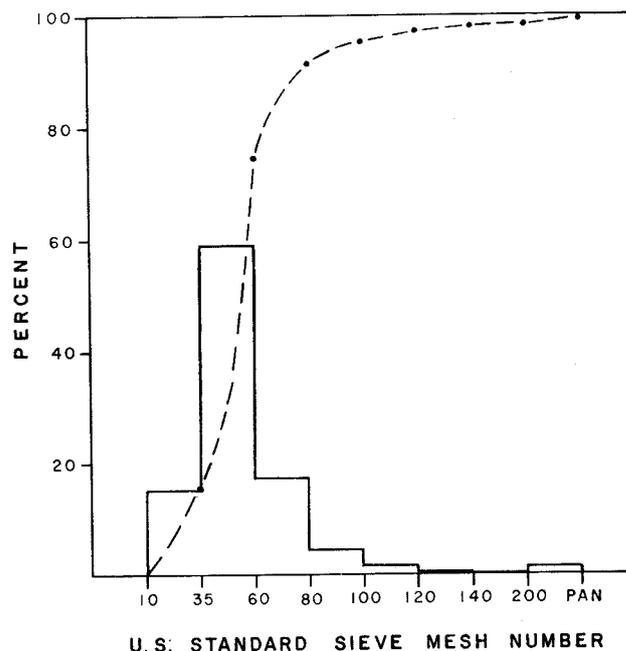


Figure 3. Histogram and cumulative frequency curve of sample R-7487-AR, Tuscarora Sandstone.

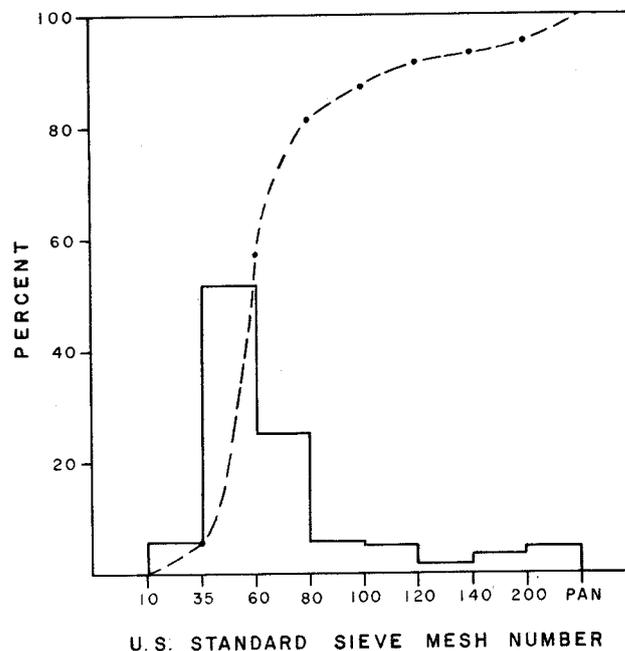


Figure 4. Histogram and cumulative frequency curve of sample R-7487-AB, Tuscarora Sandstone.

*Description:* This sample is sandstone, white to light tan, with very fine to medium subrounded grains. The unit is friable except for a few indurated beds (a total of less than 2 feet thick). Ripple marks and cross-bedding occur on medium beds; some iron-oxide staining is present. The unit has a thickness of 33.5 feet; the strike is N25° W with a dip of 70° SW.

*Laboratory analyses:* The sandstone consists of fine to medium, subrounded to rounded, slightly iron-oxide stained quartz grains bonded by a tangential quartz weld.

Sieve and chemical analyses of the raw material (R-7487-CR) and beneficiated material (R-7487-CB) are shown in Table 4. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 6 and 7. The raw material is moderately sorted; after beneficiation the material is well sorted.

Table 4. Sieve and chemical analyses of sample R-7487-C, Tuscarora Sandstone.

SIEVE ANALYSES			
U. S. Standard Sieve Mesh No.	SAMPLE R-7487-CR	SAMPLE R-7487-CB	
	Percent Retained		
10	0.91	0.00	
35	4.92	0.19	
60	7.51	3.83	
80	22.92	21.10	
100	20.72	21.72	
120	20.31	25.49	
140	6.84	7.98	
200	11.76	15.33	
Pan	4.06	4.31	

CHEMICAL ANALYSES			
Constituents	Percent		
	SiO <sub>2</sub>	98.70	98.81
Al <sub>2</sub> O <sub>3</sub>	0.64	0.66	
Fe <sub>2</sub> O <sub>3</sub>	0.06	0.06	
MgO	0.03	0.02	
CaO	0.00	0.00	
Na <sub>2</sub> O	0.01	0.01	
K <sub>2</sub> O	0.05	0.03	
TiO <sub>2</sub>	0.04	0.03	
MnO	0.00	0.00	
P <sub>2</sub> O <sub>5</sub>	0.01	0.00	
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.004	
CoO	0.004	0.004	
LOI	0.45	0.39	

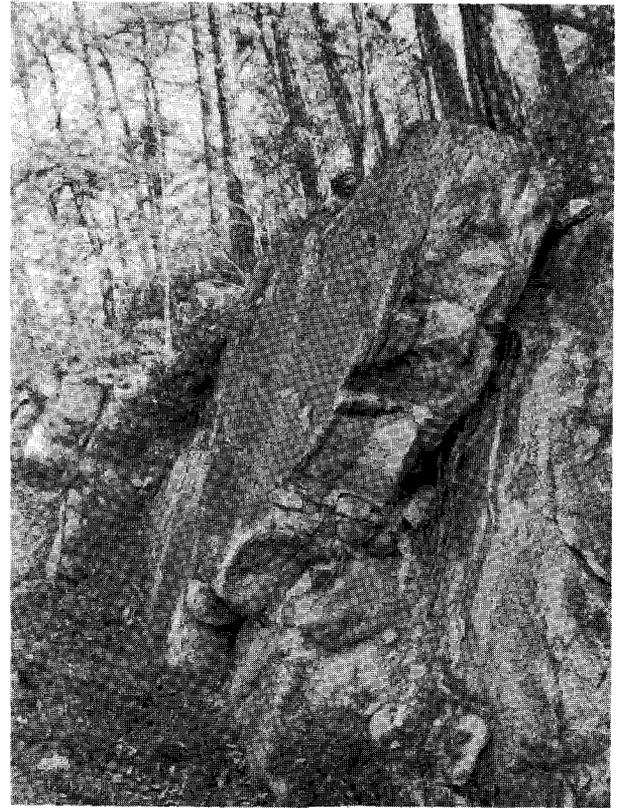


Figure 5. Tuscarora Sandstone, Alleghany County, east of U. S. Highway 60 (sample R-7487-C).

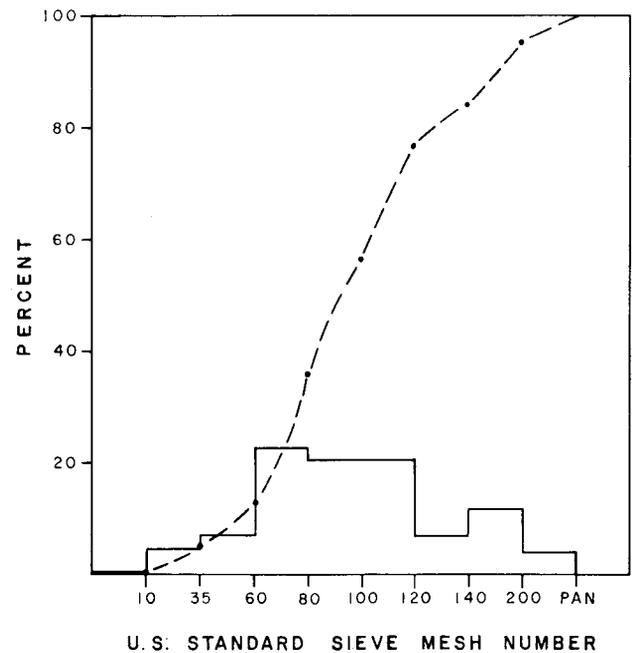


Figure 6. Histogram and cumulative frequency curve of sample R-7487-CR, Tuscarora Sandstone.

*Description:* This sample is sandstone, white to light tan, with very fine to medium subrounded grains. The unit is friable except for a few indurated beds (a total of less than 2 feet thick). Ripple marks and cross-bedding occur on medium beds; some iron-oxide staining is present. The unit has a thickness of 33.5 feet; the strike is N25° W with a dip of 70° SW.

*Laboratory analyses:* The sandstone consists of fine to medium, subrounded to rounded, slightly iron-oxide stained quartz grains bonded by a tangential quartz weld.

Sieve and chemical analyses of the raw material (R-7487-CR) and beneficiated material (R-7487-CB) are shown in Table 4. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 6 and 7. The raw material is moderately sorted; after beneficiation the material is well sorted.

Table 4. Sieve and chemical analyses of sample R-7487-C, Tuscarora Sandstone.

SIEVE ANALYSES				
U. S. Standard Sieve Mesh No.	SAMPLE R-7487-CR		SAMPLE R-7487-CB	
	Percent Retained			
10	0.91	0.00		
35	4.92	0.19		
60	7.51	3.83		
80	22.92	21.10		
100	20.72	21.72		
120	20.31	25.49		
140	6.84	7.98		
200	11.76	15.33		
Pan	4.06	4.31		

CHEMICAL ANALYSES			
Constituents	Percent		
	SiO <sub>2</sub>	98.70	98.81
Al <sub>2</sub> O <sub>3</sub>	0.64	0.66	
Fe <sub>2</sub> O <sub>3</sub>	0.06	0.06	
MgO	0.03	0.02	
CaO	0.00	0.00	
Na <sub>2</sub> O	0.01	0.01	
K <sub>2</sub> O	0.05	0.03	
TiO <sub>2</sub>	0.04	0.03	
MnO	0.00	0.00	
P <sub>2</sub> O <sub>5</sub>	0.01	0.00	
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.004	
CoO	0.004	0.004	
LOI	0.45	0.39	

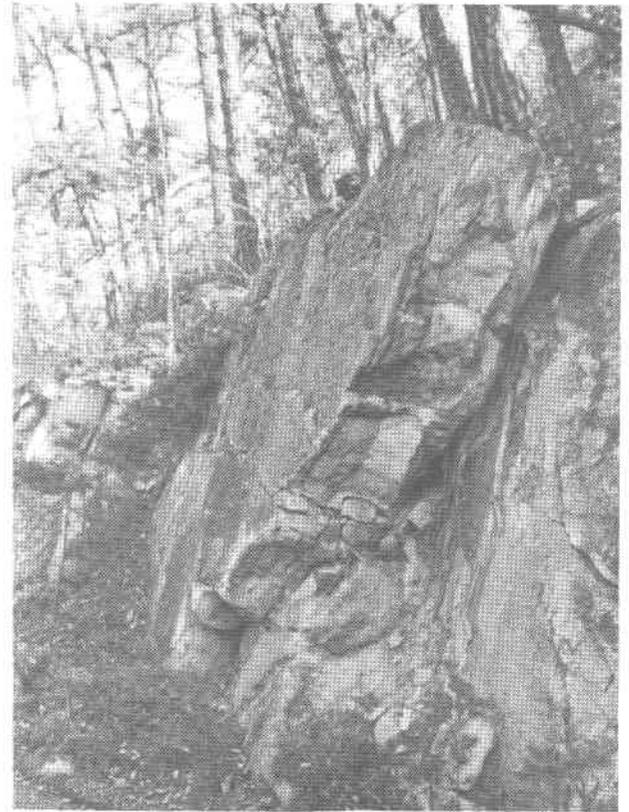


Figure 5. Tuscarora Sandstone, Alleghany County, east of U. S. Highway 60 (sample R-7487-C).

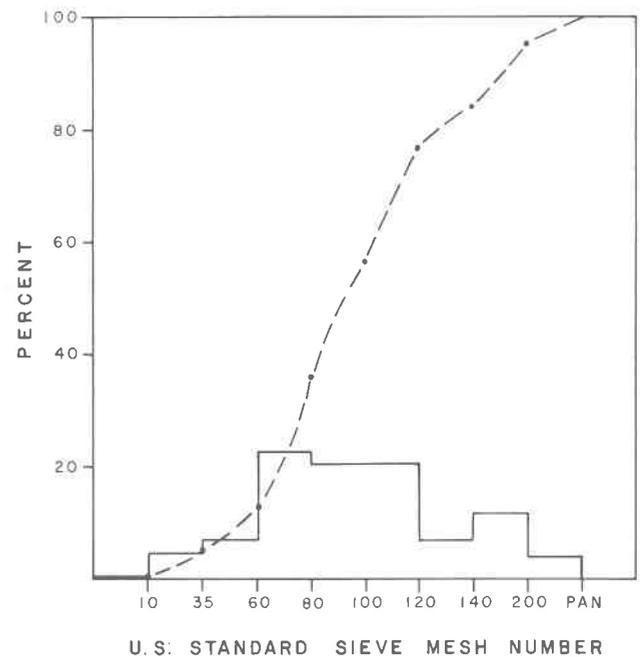


Figure 6. Histogram and cumulative frequency curve of sample R-7487-CR, Tuscarora Sandstone.

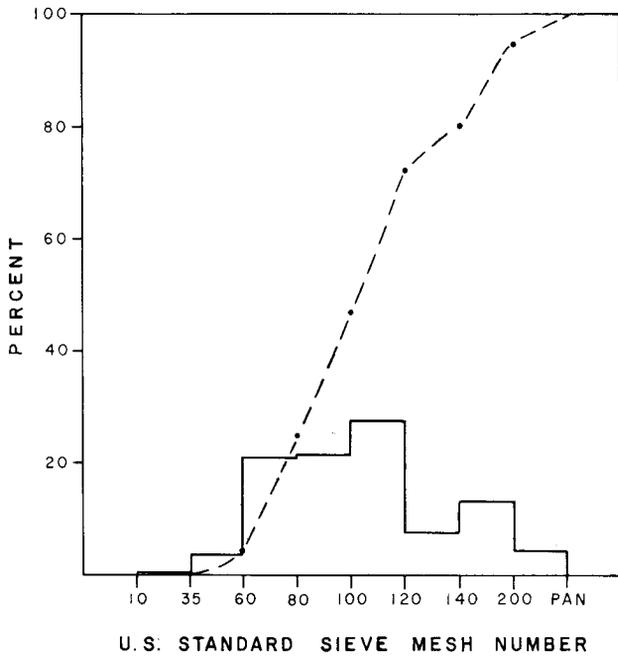


Figure 7. Histogram and cumulative frequency curve of sample R-7487-CB, Tuscarora Sandstone.

**Sample R-8514**

*Location:* The Tuscarora Sandstone (Figure 8) was sampled 5.8 miles northwest of Glenvar, Roanoke County, off the northeast side of State Road 727 approximately 1.4 miles by road northwest of its intersection with State Road 622 in the Glenvar 7.5-minute quadrangle (UTM: N4,129,050 E567,880; Zone 17).

*Description:* This sample is sandstone which is white to light gray, fine- to medium- grained with subrounded to rounded grains. It is friable but has a few indurated zones. The exposed sandstone is 27 feet thick. There is a small zone of 0.23-inch pebbles near the top of the exposure. Iron-oxide staining is present as grain coating.

*Laboratory analyses:* The sandstone consists of white to light gray, medium to coarse, rounded, iron-oxide stained quartz grains that are bonded by a simple tangential quartz weld. Minor amounts of clay are also present.

Sieve and chemical analyses of the raw material (R-8514-R) and beneficiated material (R-8514-B) are shown in Table 5. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 9 and 10. Both the raw and beneficiated material are poorly sorted.



Figure 8. Tuscarora Sandstone, Roanoke, County, northwest of Glenvar (sample R-8514).

Table 5. Sieve and chemical analyses of sample R-8514, Tuscarora Sandstone.

SIEVE ANALYSES		
U. S. Standard Sieve Mesh No.	SAMPLE R-8514-R	SAMPLE R-8514-B
	Percent Retained	
10	3.53	0.29
35	21.15	12.22
60	14.93	13.27
80	18.82	15.91
100	20.81	26.40
120	12.85	19.08
140	2.63	4.56
200	2.59	5.56
Pan	2.64	2.67

CHEMICAL ANALYSES		
Constituents	Percent	
SiO <sub>2</sub>	98.45	98.77
Al <sub>2</sub> O <sub>3</sub>	0.83	0.76
Fe <sub>2</sub> O <sub>3</sub>	0.08	0.03
MgO	0.02	0.03
CaO	0.00	0.00
Na <sub>2</sub> O	0.07	0.02
K <sub>2</sub> O	0.06	0.03
TiO <sub>2</sub>	0.05	0.04
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.00	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.44	0.33

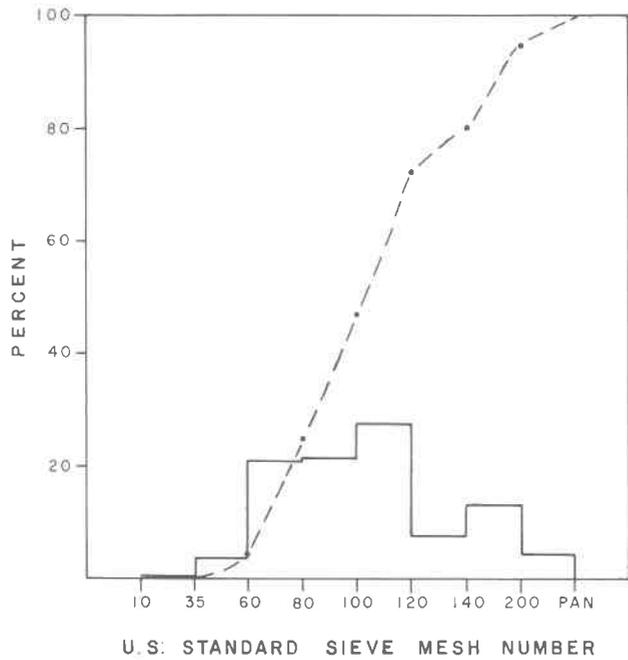


Figure 7. Histogram and cumulative frequency curve of sample R-7487-CB, Tuscarora Sandstone.

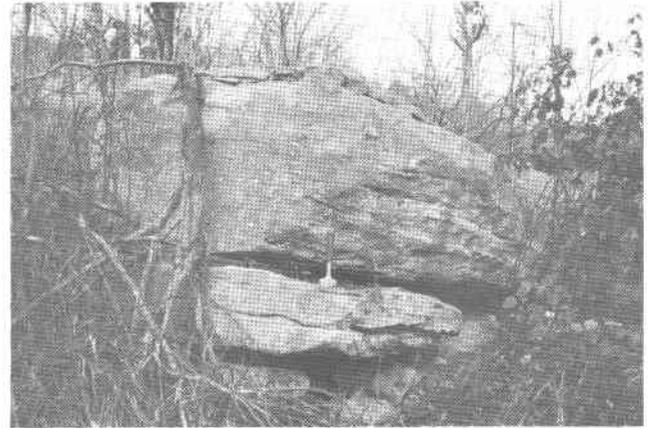


Figure 8. Tuscarora Sandstone, Roanoke, County, northwest of Glenvar (sample R-8514).

Sample R-8514

*Location:* The Tuscarora Sandstone (Figure 8) was sampled 5.8 miles northwest of Glenvar, Roanoke County, off the northeast side of State Road 727 approximately 1.4 miles by road northwest of its intersection with State Road 622 in the Glenvar 7.5-minute quadrangle (UTM: N4,129,050 E567,880; Zone 17).

*Description:* This sample is sandstone which is white to light gray, fine- to medium- grained with subrounded to rounded grains. It is friable but has a few indurated zones. The exposed sandstone is 27 feet thick. There is a small zone of 0.23-inch pebbles near the top of the exposure. Iron-oxide staining is present as grain coating.

*Laboratory analyses:* The sandstone consists of white to light gray, medium to coarse, rounded, iron-oxide stained quartz grains that are bonded by a simple tangential quartz weld. Minor amounts of clay are also present.

Sieve and chemical analyses of the raw material (R-8514-R) and beneficiated material (R-8514-B) are shown in Table 5. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 9 and 10. Both the raw and beneficiated material are poorly sorted.

Table 5. Sieve and chemical analyses of sample R-8514, Tuscarora Sandstone.

SIEVE ANALYSES		
U. S. Standard Sieve Mesh No.	SAMPLE R-8514-R	SAMPLE R-8514-B
	Percent Retained	
10	3.53	0.29
35	21.15	12.22
60	14.93	13.27
80	18.82	15.91
100	20.81	26.40
120	12.85	19.08
140	2.63	4.56
200	2.59	5.56
Pan	2.64	2.67

CHEMICAL ANALYSES		
Constituents	Percent	
	SiO <sub>2</sub>	98.45
Al <sub>2</sub> O <sub>3</sub>	0.83	0.76
Fe <sub>2</sub> O <sub>3</sub>	0.08	0.03
MgO	0.02	0.03
CaO	0.00	0.00
Na <sub>2</sub> O	0.07	0.02
K <sub>2</sub> O	0.06	0.03
TiO <sub>2</sub>	0.05	0.04
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.00	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.44	0.33

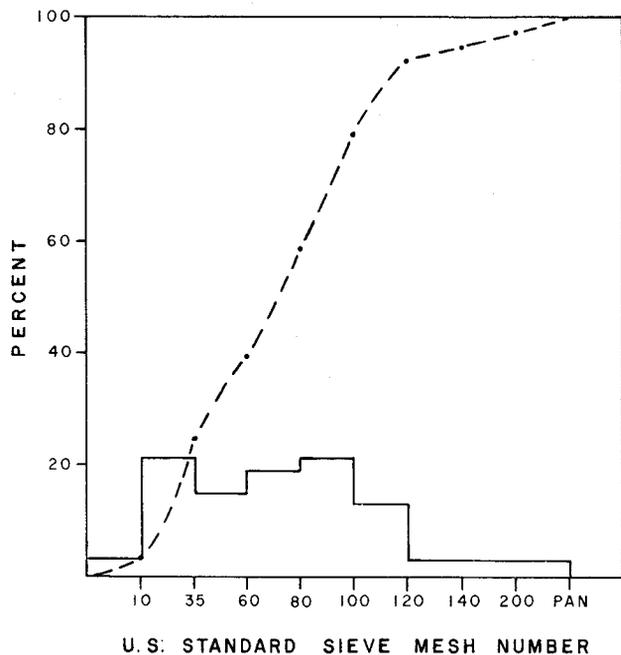


Figure 9. Histogram and cumulative frequency curve of sample R-8514-R, Tuscarora Sandstone.

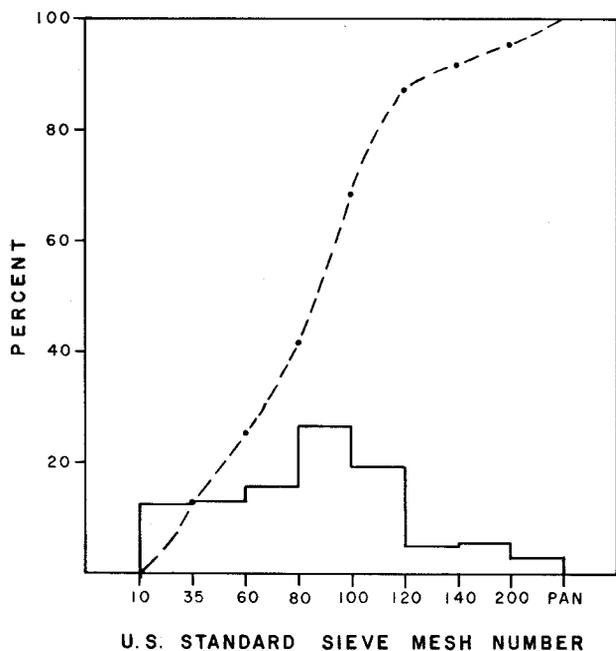


Figure 10. Histogram and cumulative frequency curve of sample R-8514-B, Tuscarora Sandstone.

#### Sample R-8547

*Location:* The Tuscarora Sandstone was sampled 1.2 miles west of Sugarloaf Mountain, Botetourt County, on the south side of a logging road approximately 1.3 miles by road east of its intersection

with State Road 622 in the Sugarloaf Mountain 7.5-minute quadrangle (UTM: N4,168,930, E613,200; Zone 17).

*Description:* This sample is sandstone, white to light gray, with fine to medium, subrounded to rounded iron-oxide stained quartz grains present in a 35-foot exposure. The sandstone is friable and contains several occasional thin zones of rounded quartz pebbles. The strike is N74° E with a dip of 47° SE.

*Laboratory analyses:* The sandstone consists of very fine to coarse, subrounded to rounded grains with some pinkish-red iron-oxide staining. The quartz grains are bonded by a tangential quartz weld.

Sieve and chemical analyses of the raw material (R-8547-R) and beneficiated material (R-8547-B) are shown in Table 6. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 11 and 12. Both the raw and beneficiated material are moderately well sorted.

Table 6. Sieve and chemical analyses of sample R-8547, Tuscarora Sandstone.

SIEVE ANALYSES		
U. S. Standard Sieve Mesh No.	SAMPLE R-8547-R	SAMPLE R-8547-B
	Percent Retained	
10	0.80	0.15
35	11.58	5.55
60	54.67	45.50
80	19.05	25.97
100	6.34	10.41
120	3.62	6.60
140	1.11	2.07
200	1.27	2.21
Pan	1.51	1.51
CHEMICAL ANALYSES		
Constituents	Percent	
SiO <sub>2</sub>	98.35	99.27
Al <sub>2</sub> O <sub>3</sub>	0.95	0.35
Fe <sub>2</sub> O <sub>3</sub>	0.05	0.02
MgO	0.01	0.03
CaO	0.00	0.00
Na <sub>2</sub> O	0.02	0.00
K <sub>2</sub> O	0.17	0.06
TiO <sub>2</sub>	0.04	0.03
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.00	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.40	0.27

Sample R-8551

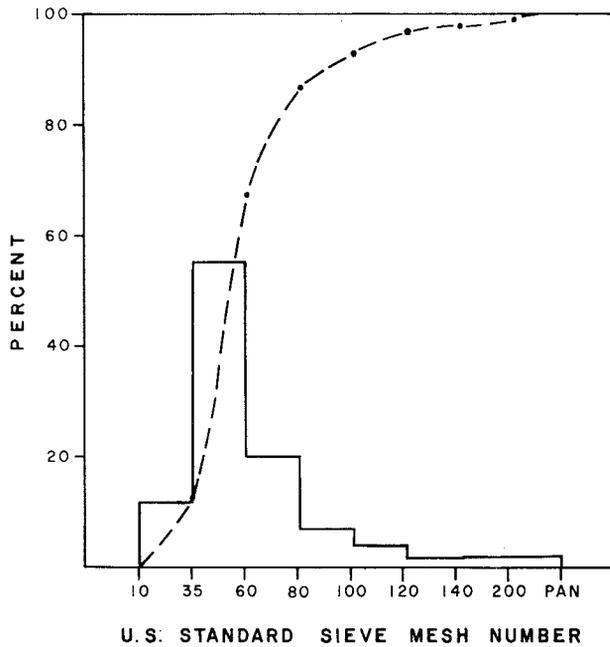


Figure 11. Histogram and cumulative frequency curve of sample R-8547-R, Tuscarora Sandstone.

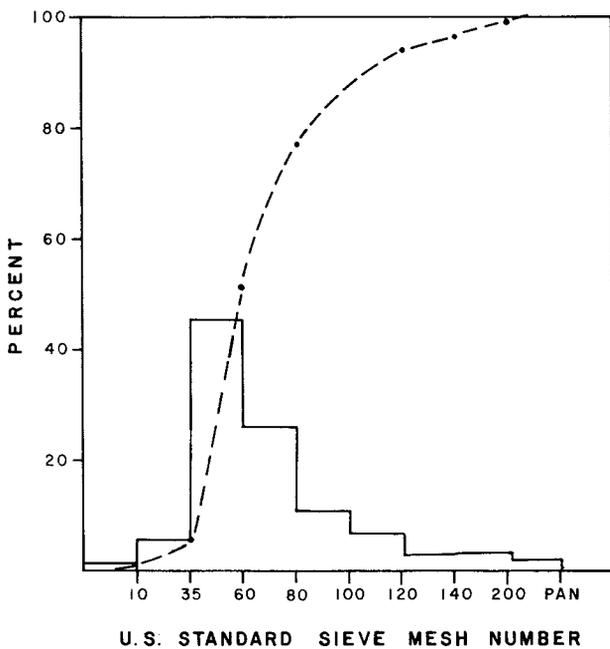


Figure 12. Histogram and cumulative frequency curve of sample R-8547-B, Tuscarora Sandstone.

*Location:* The Tuscarora Sandstone (Figure 13) was sampled at the edge of an abandoned sandstone quarry 1.5 miles east of Catawba, Roanoke County, on the north side of State Road 864 approximately 0.95 mile by road east of its intersection with Virginia Highway 311 in the Catawba 7.5-minute quadrangle (UTM: N4,137,250, E581,180; Zone 17).

*Description:* Sandstone is white to light gray, with medium, subrounded to rounded iron-oxide stained grains. The base of the 13-foot exposure is very quartzitic and probably only suitable for building and flagging stone. The sampled unit is very friable; the strike is N68° E with a dip of 30° SE.

An adjacent quarry was last operated by Catawba Stone Company (inactive in the early 1960's) for use as building flagging material. Quarrying was first done at the site around 1913 by Catawba Silica Company for glass-grade sand which was utilized by Salem Glass Company. Analyses of material reported to have come from this site, indicates 98.8% SiO<sub>2</sub>, with iron content around 0.4%.

*Laboratory analyses:* The sandstone consists of medium, subrounded to rounded iron-oxide stained quartz grains bonded by a simple quartz weld. Sieve and chemical analyses of the raw material (R-8551-R) and beneficiated material (R-8551-B) are shown in Table 7. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 14 and 15. The raw material is moderately sorted; after beneficiation the material is moderately well sorted.



Figure 13. Tuscarora Sandstone, Roanoke County, dip-slope in abandoned stone quarry of Catawba Stone Company (20 feet below sample R-8551).

Sample R-8551

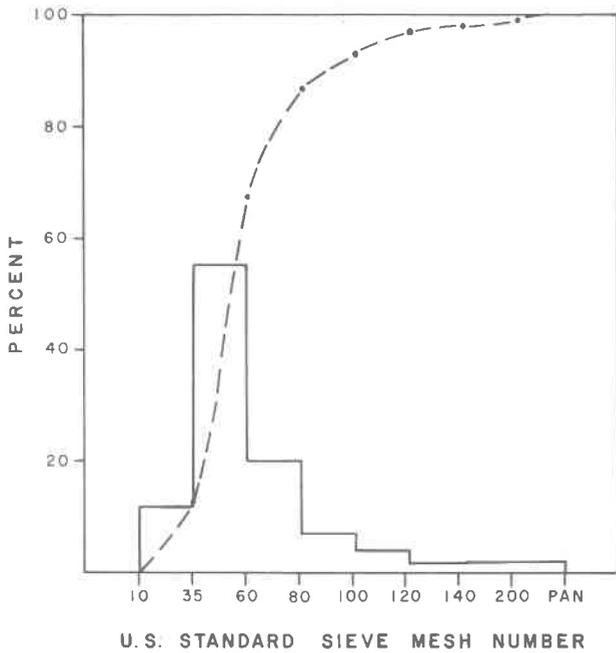


Figure 11. Histogram and cumulative frequency curve of sample R-8547-R, Tuscarora Sandstone.

*Location:* The Tuscarora Sandstone (Figure 13) was sampled at the edge of an abandoned sandstone quarry 1.5 miles east of Catawba, Roanoke County, on the north side of State Road 864 approximately 0.95 mile by road east of its intersection with Virginia Highway 311 in the Catawba 7.5-minute quadrangle (UTM: N4,137,250, E581,180; Zone 17).

*Description:* Sandstone is white to light gray, with medium, subrounded to rounded iron-oxide stained grains. The base of the 13-foot exposure is very quartzitic and probably only suitable for building and flagging stone. The sampled unit is very friable; the strike is N68° E with a dip of 30° SE.

An adjacent quarry was last operated by Catawba Stone Company (inactive in the early 1960's) for use as building flagging material. Quarrying was first done at the site around 1913 by Catawba Silica Company for glass-grade sand which was utilized by Salem Glass Company. Analyses of material reported to have come from this site, indicates 98.8% SiO<sub>2</sub>, with iron content around 0.4%.

*Laboratory analyses:* The sandstone consists of medium, subrounded to rounded iron-oxide stained quartz grains bonded by a simple quartz weld. Sieve and chemical analyses of the raw material (R-8551-R) and beneficiated material (R-8551-B) are shown in Table 7. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 14 and 15. The raw material is moderately sorted; after beneficiation the material is moderately well sorted.

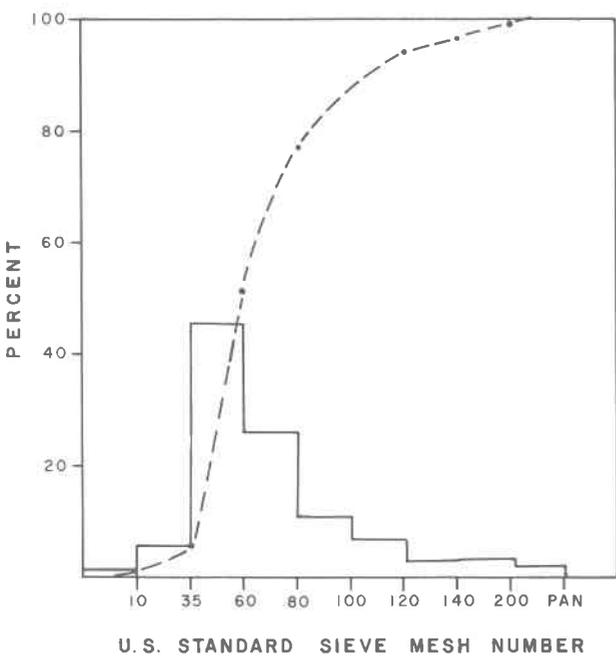


Figure 12. Histogram and cumulative frequency curve of sample R-8547-B, Tuscarora Sandstone.



Figure 13. Tuscarora Sandstone, Roanoke County, dip-slope in abandoned stone quarry of Catawba Stone Company (20 feet below sample R-8551).

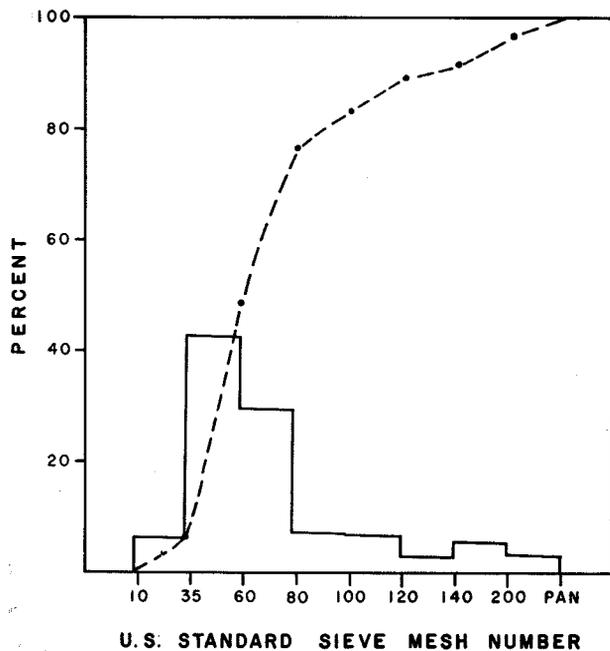


Figure 14. Histogram and cumulative frequency curve of sample R-8551-R, Tuscarora Sandstone.

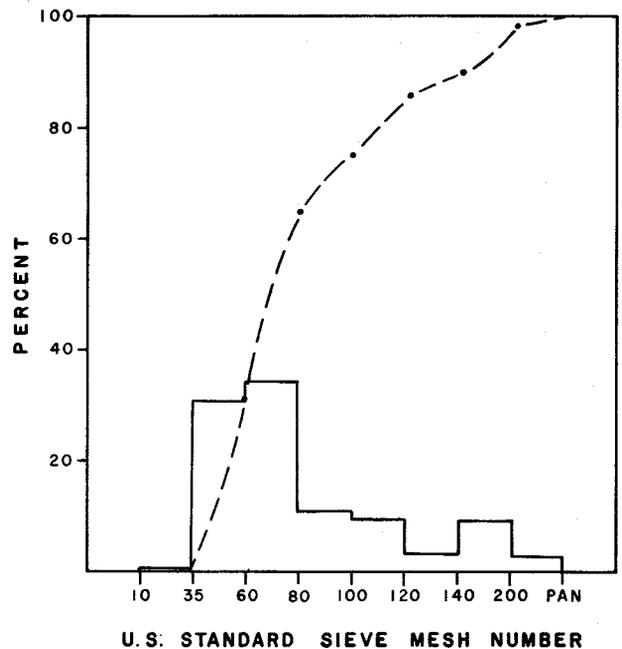


Figure 15. Histogram and cumulative frequency curve of sample R-8551-B, Tuscarora Sandstone.

Table 7. Sieve and chemical analyses of sample R-8551, Tuscarora Sandstone.

SIEVE ANALYSES		
U. S. Standard Sieve Mesh No.	SAMPLE R-8551-R Percent Retained	SAMPLE R-8551-B Percent Retained
10	0.00	0.00
35	5.52	0.19
60	41.95	30.65
80	28.45	34.32
100	6.54	10.53
120	6.36	9.28
140	2.05	3.34
200	5.69	9.11
Pan	3.43	2.56

CHEMICAL ANALYSES		
Constituents	Percent	
SiO <sub>2</sub>	97.02	98.86
Al <sub>2</sub> O <sub>3</sub>	1.45	0.64
Fe <sub>2</sub> O <sub>3</sub>	0.18	0.01
MgO	0.04	0.03
CaO	0.00	0.00
Na <sub>2</sub> O	0.02	0.02
K <sub>2</sub> O	0.22	0.04
TiO <sub>2</sub>	0.08	0.05
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.01	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.97	0.34

#### KEEFER SANDSTONE

The Keefers Sandstone of Silurian age consists of pinkish-white to tan, fine- to coarse-grained, medium- to thick-bedded orthoquartzite and friable sandstone. This unit differs from the Tuscarora Sandstone in that overall it is finer grained and pinkish in color. In Botetourt County the unit is 200-250 feet thick, around Roanoke it is 260 feet thick and in Alleghany County it is about 220 feet thick. The thickest section in the study area is along Johns Creek in Craig County, where the Keefers Sandstone is 320 feet thick.

#### Sample R-8515

*Location:* The Keefers Sandstone was sampled 2.8 miles south of Maggie, Craig County, on the east side of State Road 658 approximately 0.6 mile by road west of its intersection with State Road 662 on Johns Creek Mountain, in the Waiteville 7.5-minute quadrangle (UTM: N4,137,440, E553,660; Zone 17).

*Description:* This sample is a white to tan sandstone with fine to medium and minor coarse sub-rounded to rounded grains. The unit is semifriable to friable with thin to thick bedding. Reddish iron-oxide staining is present near the top of the exposure which is about 26 feet thick. The strike is N80° E with a dip of 28° N.

*Laboratory analyses:* The sandstone consists of medium, subrounded to rounded, iron-oxide stained quartz grains bonded by a simple tangential quartz weld.

Sieve and chemical analyses of the raw material (R-8515-R) and beneficiated material (R-8515-B) are shown in Table 8.

Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 16 and 17. The raw material is moderately sorted, after beneficiation the material is moderately well sorted.

Table 8. Sieve and chemical analyses of sample R-8515, Keefer Sandstone.

SIEVE ANALYSES			
U. S. Standard Sieve Mesh No.	SAMPLE R-8515-R		SAMPLE R-8515-B
	Percent Retained		
10	1.20	0.02	
35	18.85	3.86	
60	40.07	34.97	
80	23.69	29.42	
100	7.25	11.68	
120	4.10	8.65	
140	1.30	3.18	
200	1.80	4.89	
Pan	1.71	3.28	

CHEMICAL ANALYSES

Constituents	Percent	
SiO <sub>2</sub>	97.96	98.80
Al <sub>2</sub> O <sub>3</sub>	0.96	0.57
Fe <sub>2</sub> O <sub>3</sub>	0.20	0.09
MgO	0.01	0.02
CaO	0.00	0.00
Na <sub>2</sub> O	0.01	0.02
K <sub>2</sub> O	0.13	0.04
TiO <sub>2</sub>	0.05	0.03
MnO	0.01	0.01
P <sub>2</sub> O <sub>5</sub>	0.00	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.007
CoO	0.004	0.004
LOI	0.68	0.42

Sample R-8545

*Location:* The Keefer Sandstone was sampled 3.1 miles southeast of Potts Creek, Alleghany County, on the north side of Cove Trail approximately 0.3 mile by road west of its intersection with Forest Service Road 176 in the Potts Creek 7.5-minute quadrangle (UTM: N4,159,750, E574,650; Zone 17).

*Description:* The sandstone is white to medium gray, with fine to coarse, rounded grains. The unit is thick bedded and the material is very friable near the base and also near the top of this 22-foot exposure. Iron-oxide staining is common near the middle of the exposure. The strike is N29° E with a dip of 12° NW.

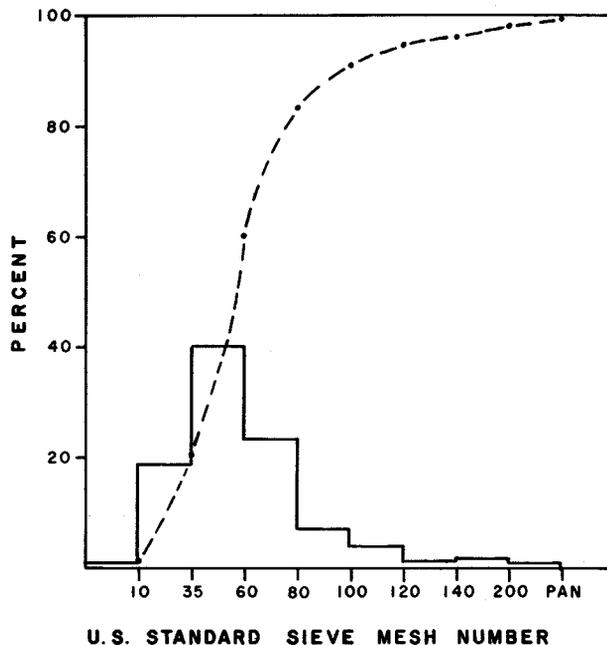


Figure 16. Histogram and cumulative frequency curve of sample R-8515-R, Keefer Sandstone.

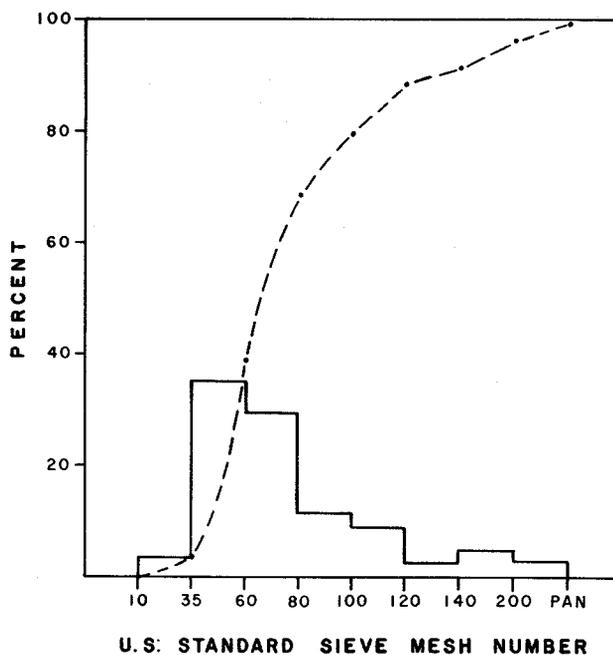


Figure 17. Histogram and cumulative frequency curve of sample R-8515-B Keefer Sandstone.

**Laboratory analyses:** The sandstone consists of fine to medium and some coarse subrounded to rounded grains. The quartz grains are bonded by quartz; other constituents include some minor mica and clay.

Sieve and chemical analyses of the raw material (R-8545-R) and beneficiated material (R-8545-B) are shown in Table 9. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 18 and 19. Both the raw and beneficiated material are moderately sorted.

Table 9. Sieve and chemical analyses of sample R-8545, Keefer Sandstone.

SIEVE ANALYSES			
U. S. Standard Sieve Mesh No.	Percent Retained		
	SAMPLE R-8545-R	SAMPLE R-8545-B	
10	0.00	0.00	
35	14.27	6.65	
60	30.72	22.80	
80	22.21	25.62	
100	9.76	12.22	
120	10.47	13.83	
140	4.11	6.24	
200	5.99	9.35	
Pan	2.46	3.29	

#### CHEMICAL ANALYSES

Constituents	Percent	
SiO <sub>2</sub>	98.22	98.90
Al <sub>2</sub> O <sub>3</sub>	0.77	0.50
Fe <sub>2</sub> O <sub>3</sub>	0.11	0.05
MgO	0.02	0.02
CaO	0.00	0.00
Na <sub>2</sub> O	0.01	0.01
K <sub>2</sub> O	0.08	0.02
TiO <sub>2</sub>	0.06	0.04
MnO	0.01	0.00
P <sub>2</sub> O <sub>5</sub>	0.01	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.71	0.45

#### Sample R-8546

**Location:** The Keefer Sandstone was sampled 4.7 miles southwest of Maggie, Craig County, on the south side of State Road 601 approximately 1.0 miles by road south of its intersection with State Road 632, on Johns Creek Mountain in the Waiteville, Virginia-West Virginia 7.5-minute quadrangle (UTM: N4,137,090, E548,910; Zone 17).

**Description:** This sample is a white to tan sandstone with fine to medium grains. A coarse grained interval is located near the middle of the 19.5-foot exposure and has a reddish-orange iron-oxide coating. Bedding varies from thin to medium near the top, to thick lower in the section. The unit varies

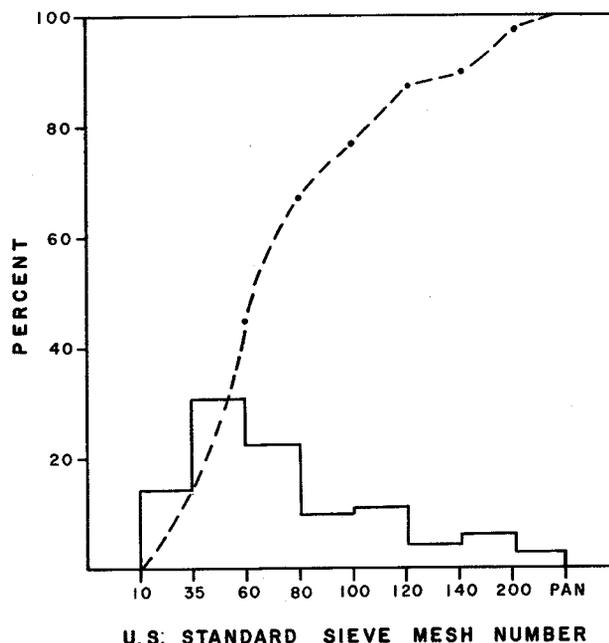


Figure 18. Histogram and cumulative frequency curve of sample R-8545-R, Keefer Sandstone.

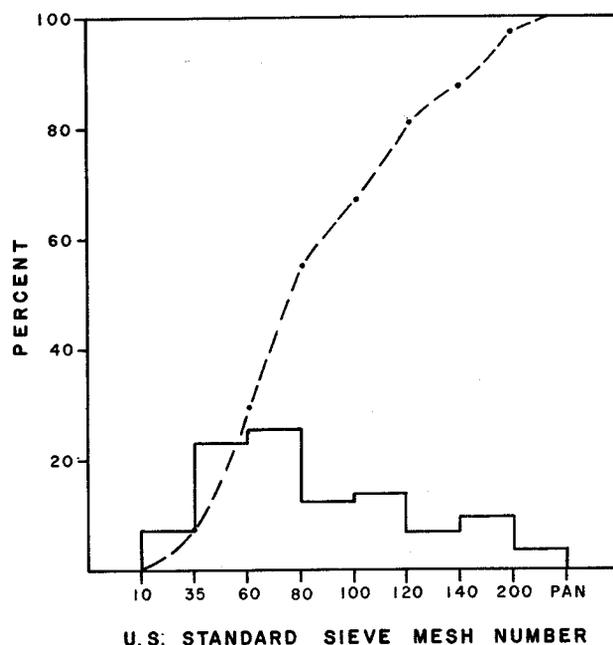


Figure 19. Histogram and cumulative frequency curve of sample R-8545-B, Keefer Sandstone.

from slightly indurated at the top and bottom to friable in the middle of the exposure. Strike of the rock is N75° E with a dip of 53° NW.

*Laboratory analyses:* The sandstone consists of fine to medium, subrounded to rounded, iron-oxide stained quartz grains bonded mainly by a simple quartz weld although some secondary silica cement is present.

Sieve and chemical analyses of the raw material (R-8546-R) and beneficiated material (R-8546-B) are shown in Table 10. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 20 and 21. The raw material is moderately sorted; after beneficiation the material is moderately well sorted.

intersection with State Road 622 in the Sugarloaf Mountain 7.5-minute quadrangle (UTM: N4,169,150, E612,480; Zone 17).

*Description:* The sandstone is white to maroon with very fine to fine, subrounded to rounded quartz grains. Thin to thick bedding is dominant in the 59-foot exposure. Some thin interbedded gray

Table 10. Sieve and chemical analyses of sample R-8546; Keefer Sandstone.

SIEVE ANALYSES			
U. S. Standard Sieve Mesh No.	SAMPLE R-8546-R		SAMPLE R-8546-B
	Percent Retained		
10	0.00	0.00	
35	2.54	0.42	
60	14.96	12.41	
80	24.01	27.45	
100	11.16	14.08	
120	16.73	18.39	
140	10.90	7.81	
200	13.89	15.59	
PAN	5.80	3.86	

CHEMICAL ANALYSES			
Constituents	Percent		
	SiO <sub>2</sub>	98.44	98.93
Al <sub>2</sub> O <sub>3</sub>	0.74	0.44	
Fe <sub>2</sub> O <sub>3</sub>	0.04	0.01	
MgO	0.03	0.01	
CaO	0.00	0.00	
Na <sub>2</sub> O	0.01	0.00	
K <sub>2</sub> O	0.05	0.02	
TiO <sub>2</sub>	0.05	0.04	
MnO	0.00	0.00	
P <sub>2</sub> O <sub>5</sub>	0.00	0.00	
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003	
CoO	0.004	0.004	
LOI	0.63	0.14	

Sample R-8548

*Location:* The Keefer Sandstone was sampled 1.7 miles west of Sugarloaf Mountain, Botetourt County, on the southeast side of a logging road approximately 0.65 mile by road northeast of its

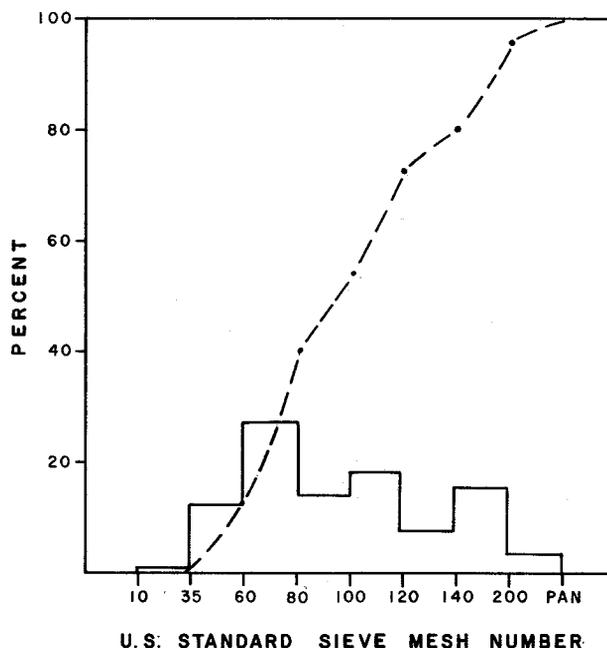


Figure 20. Histogram and cumulative frequency curve of sample R-8546-R, Keefer Sandstone.

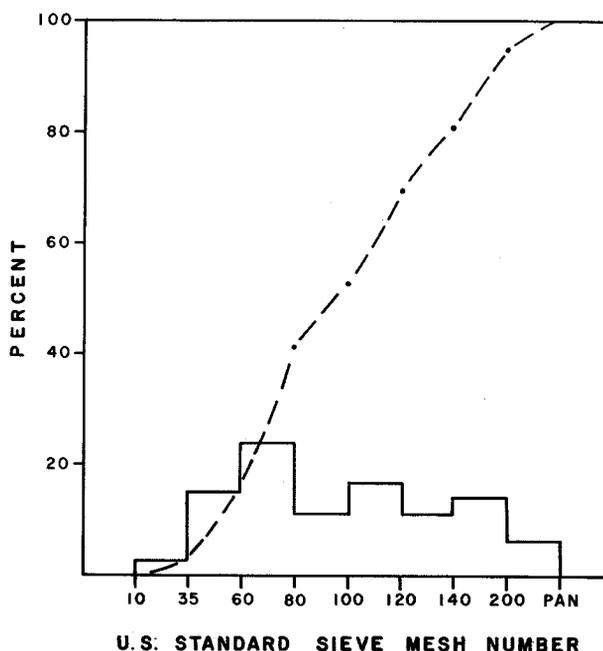


Figure 21. Histogram and cumulative frequency curve of sample R-8546-B, Keefer Sandstone.

shale and a 3-foot-thick bed of quartzite are present near the middle of the exposure and were not sampled. Overall the unit is friable and ripple-marked; some thin indurated zones are present near the top of the unit, which is in contact with a maroon sandstone. The strike is N58° E with a dip of 50° SE.

**Laboratory analyses:** The sandstone consists of very fine to medium, subrounded to rounded, slightly iron-oxide stained quartz grains bonded by a tangential quartz weld. Minor clay material is present in the matrix.

Sieve and chemical analyses of the raw material (R-8548-R) and beneficiated material (R-8548-B) are shown in Table 11. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 22 and 23. Both the raw and beneficiated material are moderately sorted.

Table 11. Sieve and chemical analyses of sample R-8548, Keefer Sandstone.

SIEVE ANALYSES			
U. S. Standard Sieve Mesh No.	SAMPLE R-8548-R	SAMPLE R-8548-B	Percent Retained
10	0.00	0.00	
35	10.94	4.52	
60	28.32	24.23	
80	21.64	21.99	
100	6.35	13.02	
120	6.62	9.09	
140	3.39	6.25	
200	13.63	16.04	
Pan	9.12	10.91	

CHEMICAL ANALYSES			
Constituents	Percent		
SiO <sub>2</sub>	96.05	97.29	
Al <sub>2</sub> O <sub>3</sub>	2.00	1.31	
Fe <sub>2</sub> O <sub>3</sub>	0.34	0.24	
MgO	0.10	0.07	
CaO	0.00	0.00	
Na <sub>2</sub> O	0.02	0.02	
K <sub>2</sub> O	0.39	0.23	
TiO <sub>2</sub>	0.17	0.15	
MnO	0.00	0.00	
P <sub>2</sub> O <sub>5</sub>	0.01	0.00	
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.005	
CoO	0.004	0.004	
LOI	0.91	0.67	

Sample R-8550

**Location:** The Keefer sandstone (Figure 24) was sampled 1.5 miles east of Catawba, Roanoke

County, on the north side of Virginia Highway 311 approximately 0.3 mile by road east of its intersection with State Road 864 in the Catawba, Virginia 7.5-minute quadrangle (UTM: N4,137,410, E581,170; Zone 17).

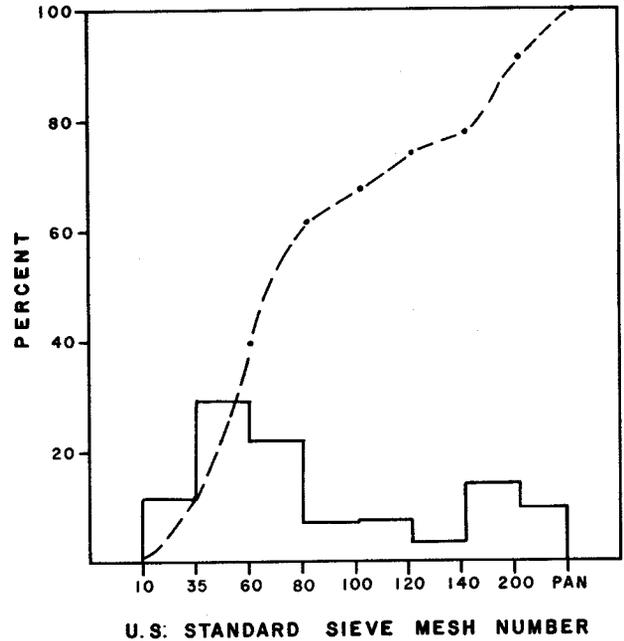


Figure 22. Histogram and cumulative frequency curve of sample R-8548-R, Keefer Sandstone.

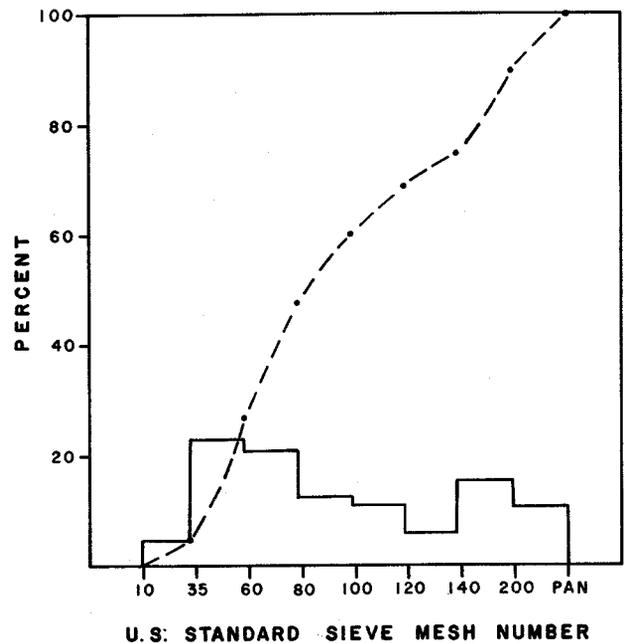


Figure 23. Histogram and cumulative frequency curve of sample R-8548-B, Keefer Sandstone.

*Description:* This sandstone is white to tan with rounded to coarse fine grains. The top and bottom of the unit is fine grained and slightly indurated. A friable sandstone, cemented with noncalcareous cement, which contains some rounded white pebbles occurs near the middle of the exposure. Iron-oxide stain is present on some grains near the middle of the exposure. Bedding ranges from thick to about 4 inches with some dark reddish-brown surfaces. Some cross-bedding is present and joints are basically perpendicular to bedding. The strike is N9° E with a dip of 21° SE.

*Laboratory analyses:* The sandstone consists of medium to coarse, subrounded to rounded, iron-oxide stained quartz grains bonded by a simple quartz weld. Minor clay material is present in the matrix. Sieve and chemical analyses of the raw material (R-8550-R) and beneficiated material (R-8550-B) are shown in Table 12. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 25 and 26. Both the raw and beneficiated material are moderately well sorted.

Table 12. Sieve and chemical analyses of sample R-8550, Keefer Sandstone.

SIEVE ANALYSES

U. S. Standard Sieve Mesh No.	SAMPLE R-8550-R	SAMPLE R-8550-B
	Percent Retained	
10	0.22	0.00
35	30.55	19.70
60	55.19	63.03
80	6.72	8.55
100	1.60	1.92
120	1.40	1.88
140	0.81	1.02
200	1.98	2.58
Pan	1.53	1.32

CHEMICAL ANALYSES

Constituents	Percent	
SiO <sub>2</sub>	98.23	98.96
Al <sub>2</sub> O <sub>3</sub>	1.05	0.61
Fe <sub>2</sub> O <sub>3</sub>	0.01	0.00
MgO	0.01	0.01
CaO	0.00	0.00
Na <sub>2</sub> O	0.01	0.01
K <sub>2</sub> O	0.06	0.02
TiO <sub>2</sub>	0.05	0.03
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.01	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.57	0.36

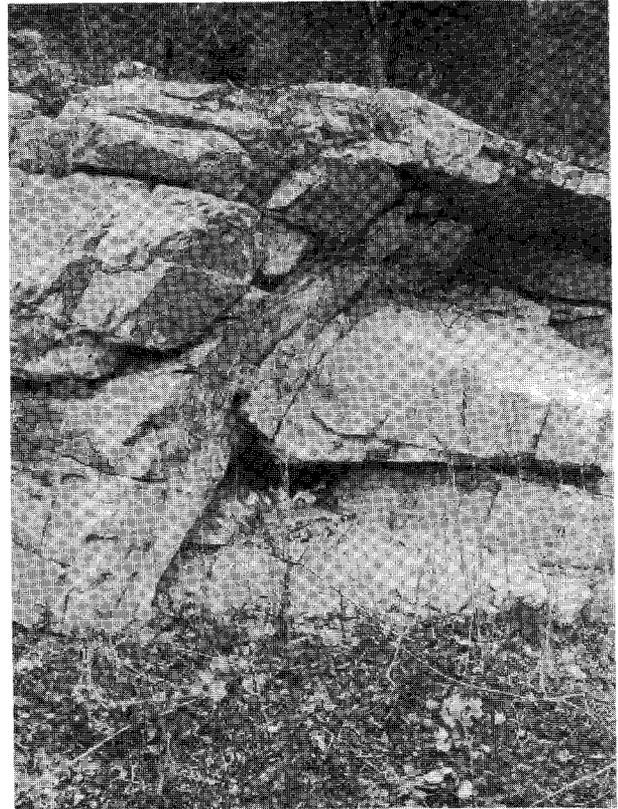


Figure 24. Keefer Sandstone, Roanoke County, on the north side of Virginia Highway 311 on Catawba Mountain (sample R-8550).

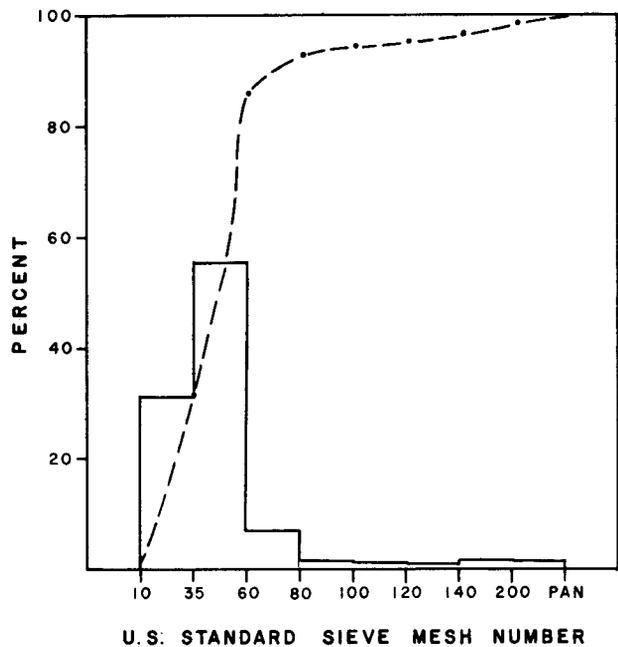


Figure 25. Histogram and cumulative frequency curve of sample R-8550-R, Keefer Sandstone.

*Description:* This sandstone is white to tan with rounded to coarse fine grains. The top and bottom of the unit is fine grained and slightly indurated. A friable sandstone, cemented with noncalcareous cement, which contains some rounded white pebbles occurs near the middle of the exposure. Iron-oxide stain is present on some grains near the middle of the exposure. Bedding ranges from thick to about 4 inches with some dark reddish-brown surfaces. Some cross-bedding is present and joints are basically perpendicular to bedding. The strike is N9° E with a dip of 21° SE.

*Laboratory analyses:* The sandstone consists of medium to coarse, subrounded to rounded, iron-oxide stained quartz grains bonded by a simple quartz weld. Minor clay material is present in the matrix. Sieve and chemical analyses of the raw material (R-8550-R) and beneficiated material (R-8550-B) are shown in Table 12. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 25 and 26. Both the raw and beneficiated material are moderately well sorted.

Table 12. Sieve and chemical analyses of sample R-8550, Keefer Sandstone.

SIEVE ANALYSES		
U. S. Standard Sieve Mesh No.	SAMPLE R-8550-R	SAMPLE R-8550-B
	Percent Retained	
10	0.22	0.00
35	30.55	19.70
60	55.19	63.03
80	6.72	8.55
100	1.60	1.92
120	1.40	1.88
140	0.81	1.02
200	1.98	2.58
Pan	1.53	1.32

CHEMICAL ANALYSES		
Constituents	Percent	
SiO <sub>2</sub>	98.23	98.96
Al <sub>2</sub> O <sub>3</sub>	1.05	0.61
Fe <sub>2</sub> O <sub>3</sub>	0.01	0.00
MgO	0.01	0.01
CaO	0.00	0.00
Na <sub>2</sub> O	0.01	0.01
K <sub>2</sub> O	0.06	0.02
TiO <sub>2</sub>	0.05	0.03
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.01	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.57	0.36

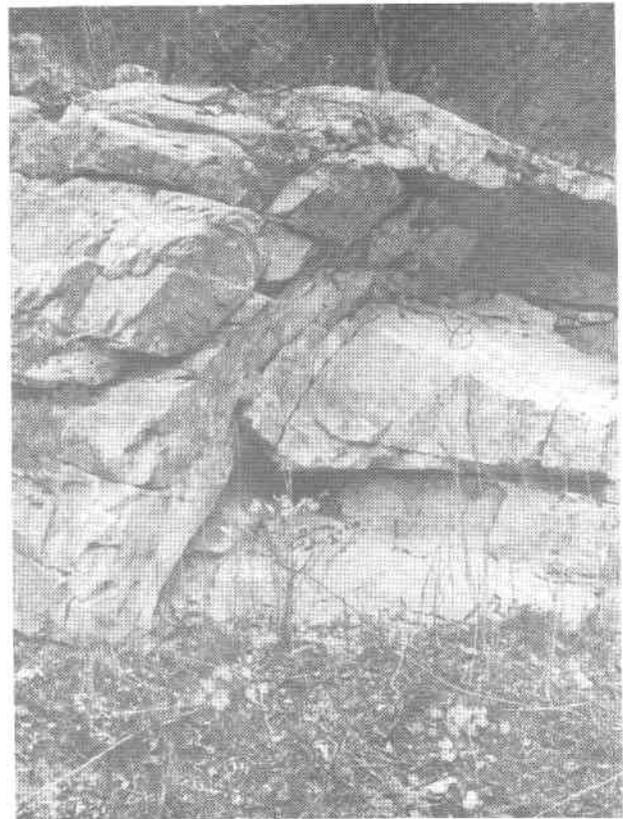


Figure 24. Keefer Sandstone, Roanoke County, on the north side of Virginia Highway 311 on Catawba Mountain (sample R-8550).

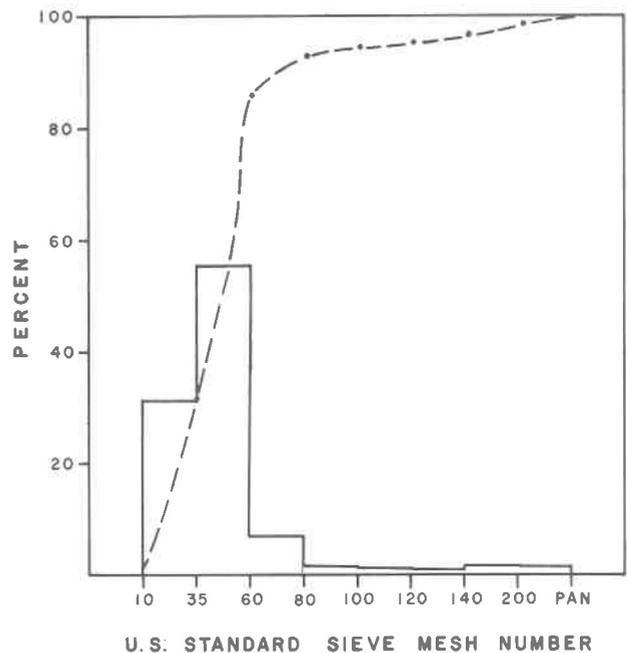


Figure 25. Histogram and cumulative frequency curve of sample R-8550-R, Keefer Sandstone.

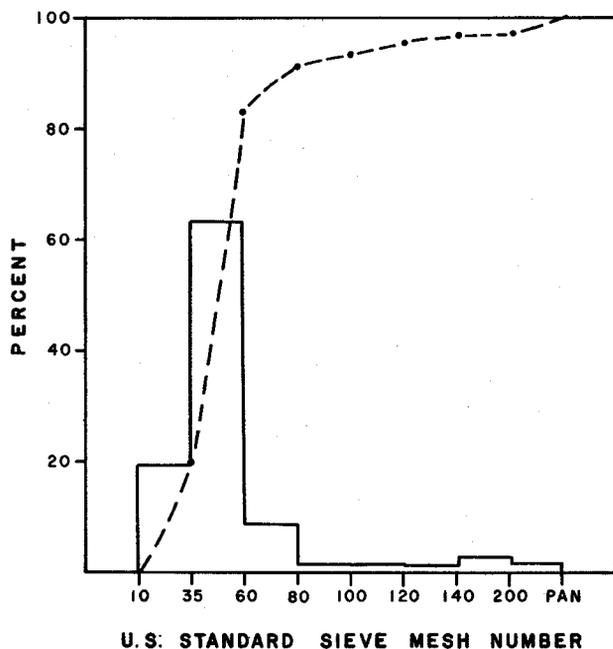


Figure 26. Histogram and cumulative frequency curve of sample R-8550-B, Keefer Sandstone.

#### Sample R-8569

*Location:* The Keefer Sandstone was sampled 2.3 miles north of Sweet Chalybeate, Alleghany County, on the northeast side of State Road 604 approximately 0.6 mile by road southeast of its intersection with Virginia Highway 311 in the Alleghany 7.5-minute quadrangle (UTM: N4,169,750, E568,430, Zone 17).

*Description:* This sample is a white to tan sandstone with medium-rounded to subrounded grains with some yellowish-orange to black iron-oxide stains. Bedding is thin to thick and the sandstone is highly fractured and ranges from friable to partly friable. The unit has a thickness of approximately 20 feet. The strike is N35° E with a dip of 77° NW.

*Laboratory analyses:* This sandstone consists of medium to fine rounded to subrounded quartz grains with some iron-oxide coating. The quartz grains are bonded by a simple quartz weld; some siltstone grains and clay are also present.

Sieve and chemical analyses of the raw material (R-8569-R) and beneficiated material (R-8569-B) are shown in Table 13. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 27 and 28. The raw material is poorly sorted; after beneficiation the material is moderately well sorted.

Table 13. Sieve and chemical analyses of sample R-8569, Keefer Sandstone.

#### SIEVE ANALYSES

U. S. Standard Sieve Mesh No.	SAMPLE R-8569-R	SAMPLE R-8569-B
	Percent Retained	
10	0.00	0.00
35	13.66	5.67
60	8.95	5.79
80	8.02	5.88
100	14.26	16.62
120	26.36	32.80
140	6.40	28.64
200	13.08	0.001
Pan	9.26	4.51

#### CHEMICAL ANALYSES

Constituents	Percent	
SiO <sub>2</sub>	98.41	98.89
Al <sub>2</sub> O <sub>3</sub>	0.82	0.40
Fe <sub>2</sub> O <sub>3</sub>	0.24	0.04
MgO	0.01	0.03
CaO	0.00	0.00
Na <sub>2</sub> O	0.01	0.01
K <sub>2</sub> O	0.07	0.02
TiO <sub>2</sub>	0.08	0.05
MnO	0.00	0.00
P <sub>2</sub> O <sub>5</sub>	0.03	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.32	0.56

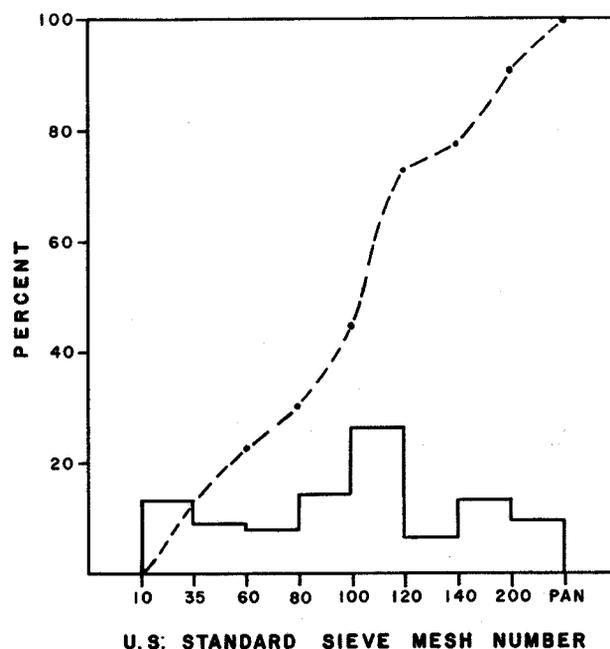


Figure 27. Histogram and cumulative frequency curve of sample R-8569-R, Keefer Sandstone.

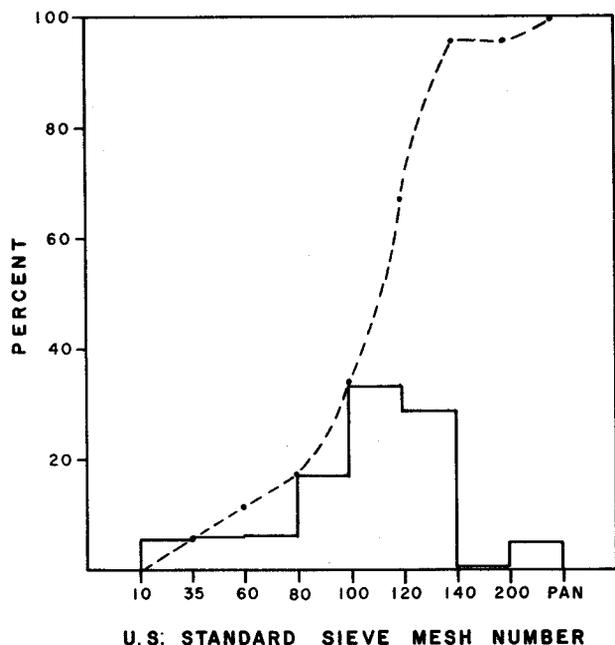


Figure 28. Histogram and cumulative frequency curve of sample R-8569-B, Keefer Sandstone.

RIDGELEY SANDSTONE

The Ridgeley Sandstone of Devonian age is white to light-gray to dark-gray, medium to coarse grained, with subrounded to rounded grains. A clayey carbonate matrix and hematitic cement are present near the lower part of the unit. The rock is very friable where the carbonate has been leached out, and where it is indurated the grains are also bonded by a simple quartz weld. Brachiopods (*Spirifers*) are present at most localities. Yellowish-brown to gray iron-oxide stains occur on most weathered surfaces. In the Rich Patch area of Alleghany County, the unit is about 25 feet thick.

Sample R-8549

*Location:* The Ridgeley Sandstone was sampled 1.75 miles northwest of Gala, Botetourt County, on the east side of State Road 622 approximately 0.4 mile by road south of its intersection with State Road 702 in the Eagle Rock 7.5-minute quadrangle (UTM: N4,174,100, E603,420; Zone 17).

*Description:* The sandstone is tan and light gray, with very-fine to medium-grained subrounded grains; the unit ranges from indurated to friable sandstone that exhibits some iron-oxide staining

throughout. Bedding in the exposure of 22 feet ranges from thin at the top to massive at the base. Six feet of siltstone with brachiopods, cephalopods and some crinoid stems is present at the base of the exposure. The strike is N45° W with a dip of 25° SW.

*Laboratory analyses:* The sandstone consists of fine to coarse grains, which are subround and coated by iron-oxide stain. The grains are bonded dominantly by a tangential weld. In some beds the grain weld is very weakly bound with a calcareous cement. Clay material is also present in the grain matrix.

Sieve and chemical analyses of the raw material (R-8549-R) and beneficiated material (R-8549-B) are shown in Table 14. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 29 and 30. Both the raw and beneficiated material are poorly sorted.

Table 14. Sieve and chemical analyses of sample R-8549, Ridgeley Sandstone.

SIEVE ANALYSES		
U. S. Standard Sieve Mesh No.	SAMPLE R-8549-R Percent Retained	SAMPLE R-8549-B Percent Retained
10	4.94	18.31
35	36.94	17.36
60	25.22	18.59
80	11.05	14.30
100	4.19	6.86
120	3.44	6.61
140	1.99	3.19
200	4.12	7.47
Pan	8.08	7.19

CHEMICAL ANALYSES		
Constituents	Percent	
SiO <sub>2</sub>	96.59	98.33
Al <sub>2</sub> O <sub>3</sub>	1.46	0.77
Fe <sub>2</sub> O <sub>3</sub>	0.56	0.15
MgO	0.11	0.03
CaO	0.00	0.00
Na <sub>2</sub> O	0.02	0.03
K <sub>2</sub> O	0.27	0.10
TiO <sub>2</sub>	0.08	0.05
MnO	0.04	0.02
P <sub>2</sub> O <sub>5</sub>	0.02	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.85	0.51

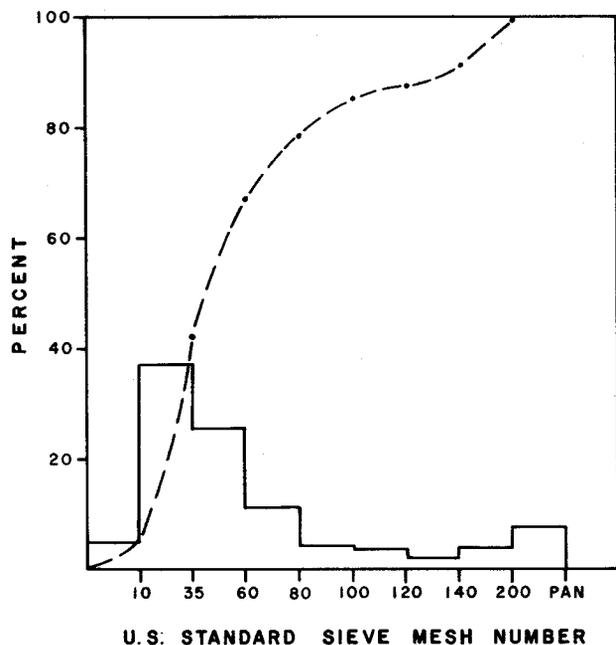


Figure 29. Histogram and cumulative frequency curve of sample R-8549-R, Ridgeley Sandstone.

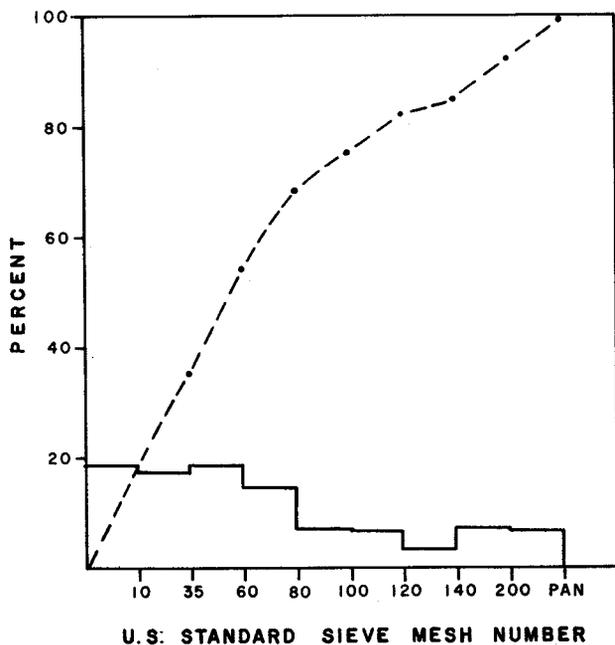


Figure 30. Histogram and cumulative frequency curve of sample R-8549-B, Ridgeley Sandstone.

#### Sample R-8552

*Location:* The Ridgeley Sandstone was sampled 1.1 miles southwest of Lowmoor, Alleghany County, off the west side of State Road 616 approximately 0.25 mile by road north of its intersection with State

Road 623 in the Covington 7.5-minute quadrangle (UTM: N4,182,190, E597,300; Zone 17).

*Description:* This sample is a white to light gray sandstone with fine to medium subrounded grains. The unit is mainly friable, although indurated in places. Bedding ranges from thin up to 2 feet in thickness; some cross-bedding is present. Iron oxide staining is present throughout the exposed thickness of 30 feet. Strike is N20° W with a dip of 23° SW.

*Laboratory analyses:* The sandstone consists of light-gray medium to coarse, subrounded to rounded grains with some iron-oxide coating. The quartz grains are bonded by a simple quartz weld. Minor constituents include siltstone grains, hematite and clay detritus.

Sieve and chemical analyses of the raw material (R-8552-R) and beneficiated material (R-8552-B) are shown in Table 15. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 31 and 32. The raw material is poorly sorted; after beneficiation the material is moderately sorted.

Table 15. Sieve and chemical analyses of sample R-8552, Ridgeley Sandstone.

#### SIEVE ANALYSES

U. S. Standard Sieve Mesh No.	SAMPLE R-8552-R Percent Retained	SAMPLE R-8552-B Percent Retained
10	6.94	0.00
35	29.26	24.64
60	18.47	17.70
80	20.38	29.87
100	6.67	10.24
120	5.23	7.94
140	2.07	3.00
200	4.83	5.36
Pan	6.16	1.25

#### CHEMICAL ANALYSES

Constituents	Percent	
SiO <sub>2</sub>	96.15	97.84
Al <sub>2</sub> O <sub>3</sub>	1.73	0.96
Fe <sub>2</sub> O <sub>3</sub>	0.50	0.22
MgO	0.16	0.11
CaO	0.00	0.00
Na <sub>2</sub> O	0.02	0.03
K <sub>2</sub> O	0.37	0.23
TiO <sub>2</sub>	0.13	0.11
MnO	0.02	0.00
P <sub>2</sub> O <sub>5</sub>	0.01	0.01
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.91	0.49

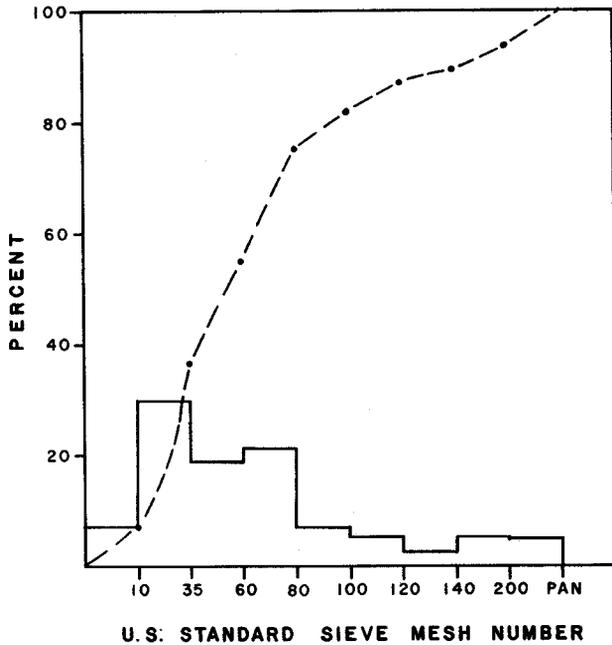


Figure 31. Histogram and cumulative frequency curve of sample R-8552-R, Ridgeley Sandstone.

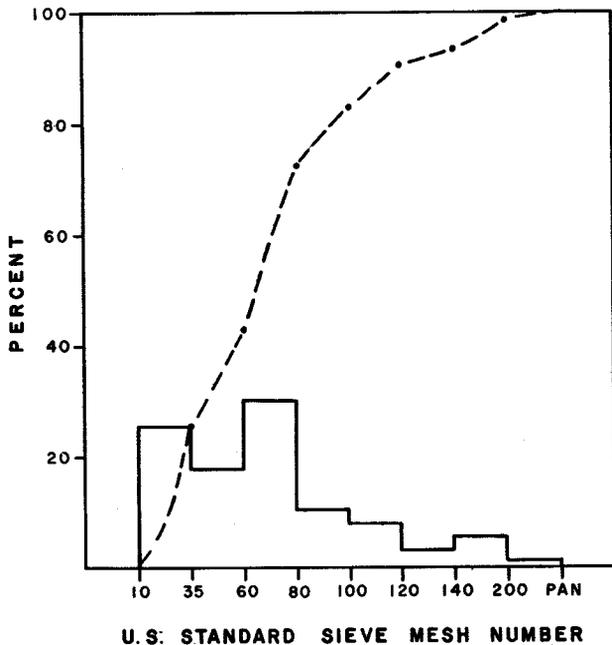


Figure 32. Histogram and cumulative frequency curve of sample R-8552-B, Ridgeley Sandstone.

Sample R-8579

*Location:* The Ridgeley Sandstone was sampled 1.2 miles northeast of New Castle, Craig County, on the north side of State Road 615 approximately 0.15 mile by road northeast of its intersection with

State Road 689 in the New Castle 7.5-minute quadrangle (UTM: N4,151,960, E579,970; Zone 17).

*Description:* This sandstone is light-gray to orange with medium grains which are rounded and coated with brown and black iron-oxide stain. Cross-bedding is present and bedding ranges from thin to thick; the thicker bedded material is harder. The sandstone grades to very friable in the eastern part of the exposure. The sandstone has an attitude of N86° E with a dip of 18° S; north-south jointing is present. The dips decrease toward the eastern part of the exposure.

*Laboratory analyses:* The sandstone consists of medium to coarse, subrounded to rounded, iron-oxide stained quartz grains bonded by a simple tangential quartz weld. Minor clay detritus and sericite are contained in the matrix.

Sieve and chemical analyses of the raw material (R-8579-R) and beneficiated sample (R-8579-B) are shown in Table 16. Histograms and cumulative frequency curves of the sieve analyses are shown in Figures 33 and 34. The raw material is moderately well sorted; after beneficiation the material is well sorted.

Table 16. Sieve and chemical analyses of sample R-8579, Ridgeley Sandstone.

SIEVE ANALYSES		
U. S. Standard Sieve Mesh No.	SAMPLE R-8579-R	SAMPLE R-8579-B
	Percent Retained	
10	0.46	0.24
35	26.80	13.37
60	64.90	75.65
80	4.17	7.25
100	0.69	1.30
120	0.58	0.84
140	0.34	0.43
200	0.93	0.65
Pan	1.77	0.28

CHEMICAL ANALYSES		
Constituents	Percent	
SiO <sub>2</sub>	97.56	98.93
Al <sub>2</sub> O <sub>3</sub>	1.06	0.61
Fe <sub>2</sub> O <sub>3</sub>	0.37	0.02
MgO	0.04	0.02
CaO	0.00	0.00
Na <sub>2</sub> O	0.01	0.02
K <sub>2</sub> O	0.10	0.04
TiO <sub>2</sub>	0.04	0.02
MnO	0.06	0.00
P <sub>2</sub> O <sub>5</sub>	0.01	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.003	0.003
CoO	0.004	0.004
LOI	0.75	0.34

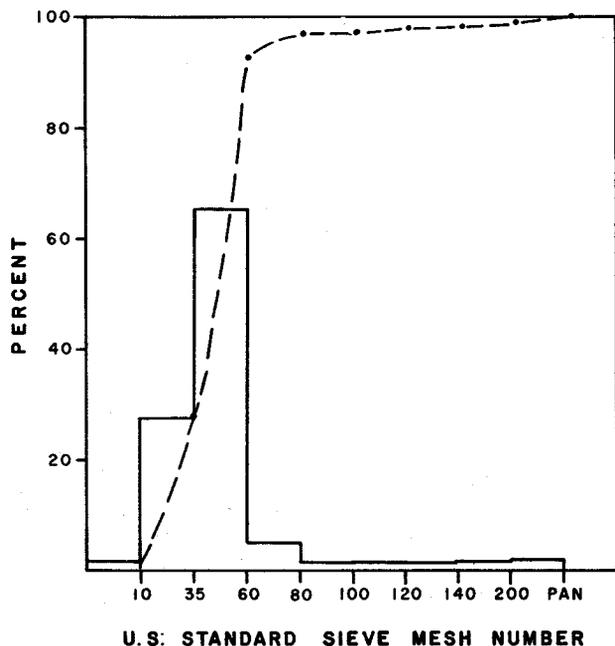


Figure 33. Histogram and cumulative frequency curve of sample R-8579-R, Ridgeley Sandstone.

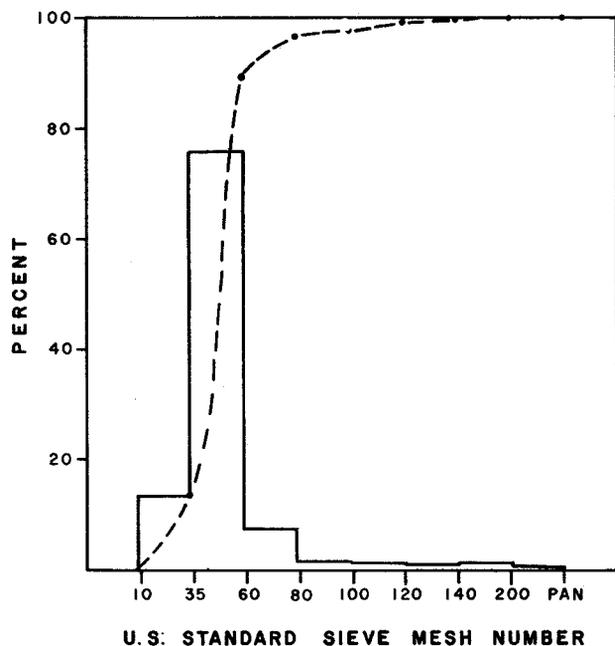


Figure 34. Histogram and cumulative frequency curve of sample R-8579-B, Ridgeley Sandstone.

### MANGANESE MINERALIZATION

Mining and prospecting for manganese ore have been conducted in the past at several localities in the study area. Most of the zones of mineralization are in sandstones and quartzites. The largest concentrations of manganese are present in Ridgeley

Sandstones in the eastern part of Alleghany County around Clifton Forge and Covington. Manganese is also present in the Silurian sandstones in the western part of Botetourt County and in the Antietam Formation in the southern part of the county. The manganese mineralization is probably of secondary origin associated with groundwater flow. Varying amounts of cobalt are associated with iron and manganese prospects along the Blue Ridge. Manganese and associated cobalt mineralization may decrease or preclude use for certain high-silica requirements. McLaws (1971, p. 7) reports that as little as 0.0002 percent cobalt produces a distinct tint in glass. Specifications of one glass manufacturer state that the weight of coloring oxides other than  $Fe_2O_3$  (e.g. oxides of chromium, manganese, nickel, cobalt, copper) is not to exceed 0.0001 percent.

### CONCLUSIONS

Four formations in Alleghany, Botetourt, Craig, and Roanoke counties have potential economic value as high-silica resources. Chemical and physical analyses of selected sandstone and quartzite samples in the study area reflect this potential.

The Antietam Formation (Cambrian) contains thin to medium-bedded, poorly sorted dirty sandstone with shale interbeds in Botetourt County. Chemical analyses of two Antietam samples show silica to be 98.62 and 96.47 percent at the sampled locations.

The Tuscarora Sandstone (Silurian) consists of fine- to coarse-grained, subrounded to subangular grains with predominantly quartz cement. Five chemical analyses of the unbeneficiated samples show a range from 98.35 to 98.74 percent silica. Simple beneficiation raises the range to 98.77 to 99.27 percent silica.

The Keefer Sandstone (Silurian) is a fine- to coarse-grained, medium to thick-bedded orthoquartzite and friable sandstone. Six unbeneficiated Keefer samples have a range of 96.05 to 98.41 percent silica; simple beneficiation raises the range to 97.29 to 98.96 percent silica.

The Ridgeley Sandstone (lower Devonian) is a medium- to coarse-grained sand with subrounded to rounded grain shape. Three unbeneficiated samples have a range from 96.05 to 97.56 percent silica. Simple beneficiation raised the range to 97.29% to 98.93%  $SiO_2$ .

Physical and chemical analyses of the samples collected in this study indicate a definite potential use as a glass sand as defined by criteria set by the sand industry (Sweet, 1978).

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