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VIRGINIA'S INDUSTRIAL SILICA RESOURCES

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Although there is an abundance of silica in the Earth's crust, only a relatively small percentage is of commercial interest as the various industrial consumers impose rigorous chemical and physical specifications. A product must generally meet a minimum silica (SiO_2) content and maximum alumina (Al_2O_3), iron (Fe_2O_3), titanium (TiO_2), and calcium and magnesium oxide (CaO and MgO) contents. Iron as Fe_2O_3, one of the main contaminants, is present from metallic particles abraded from grinding and handling equipment, from iron minerals such as limonite, magnetite, and ilmenite or as a constituent of complex silicates such as garnet, biotite, or tourmaline. Components such as arsenic, chromium, cobalt, and phosphorus are also detrimental. Tolerance on specifications for certain types of silica raw materials may vary because of proximity to markets and other factors. Some industries require a sand material while others may require sized lumps (Table).

Industrial silica is presently produced from the Valley and Ridge, Plateau, and Coastal Plain provinces in Virginia for glass manufacture, foundry and engine (traction) uses, filter beds, conversion to cristobalite, and 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 sawing. The most prevalent use of industrial sand in Virginia has been and continues to be for glass manufacture.

PRESENT AND FUTURE INDUSTRIAL SILICA OPERATIONS IN VIRGINIA

In 1985 six operations in Virginia produced industrial silica resources. Metallurgical flux material, glass, foundry and traction sand, and recrystallized silica (cristobalite) were produced in Dickenson, Frederick, Prince George, and Wythe counties and in the City of Virginia Beach (Sweet, 1985).

The outlook for additional industrial silica operations in Virginia depends on future oil and gas exploration, industrial expansion, and development of new markets and technologies. Future potential uses of silica resources from Virginia include hydraulicking (frac-propping) sand, wider markets for filter sand, and raw material for metallurgical flux and fiber optics from large quartz veins or pegmatite cores. Localities, mainly in the Valley and Ridge, Blue Ridge, and Piedmont provinces, have been investigated by several out-of-state companies. Favorable sieve and/or chemical analyses and physical properties of potential raw materials, good transportation facilities, and available markets indicate the potential for growth of the industrial silica industry in Virginia.

Following are brief descriptions of some of the better exposures, exclusive of the Antietam (Erwin) Formation of Cambrian age, that appear to be most potentially suitable for future development in Virginia.

Table. Some general specifications for silica/quartz by end use [%].

End use	min SiO_2 (percent)	max Al_2O_3 (percent)	max Fe_2O_3 (percent)	max CaO/MgO (percent)	grain size	
Glass sand						
Optical	99.5		0.008			Must be less than 6 ppm chromium and 2 ppm cobalt. 0.01.-0.05% TiO_2. Grain size and purity constant.
Colorless domestic	99.5	variable	0.013		0.1-0.5 mm	
Container/flat	98.5	0.1-0.5	0.030			
Foundry sand	88-99	—Extremely variable—			20-200 mesh	Chemical composition variable; 98-99% SiO_2 now preferred. Subangular to rounded grains.
Silica flour	97-98	0.5	0.2		micron sizing	
Silicon carbide	99.5	0.06-0.25	0.1	absent	+100 mesh	No phosphorus allowed. 0.25% Al_2O_3 sand for black SiC, 0.1% for green SiC.
Silicon	98.0	0.4	0.2	0.2 each	1 inch diameter	No phosphorus or arsenic allowed
Ferrosilicon	96	0.4	0.2		1 inch diameter	0.1% phosphorus maximum.
Silica brick	96-98	0.1		low	-8 mesh	
Sodium silicate	99	0.25	0.03	0.05	20-100 mesh	Broadly the same specifications as glass-grade sand.
Silica flux	90	1.5	1.5	0.2	40-100 mesh	

SOURCE: Industrial Minerals Magazine, May, 1976

Ridgeley Sandstone

In the extreme west-northwestern part of Virginia, the Ridgeley Sandstone of Devonian age is more than 300 feet thick in places. This unit, of high purity in places, has been quarried at several localities for use as glass sand. The rock is predominantly a white to light-tan to light-gray sandstone that in places contains a calcareous matrix. An abundance of jointing and fracturing has allowed downward-percolating waters to leach the cementing material and reduce the rock to a friable sandstone or loose sand. At some localities in the Valley and Ridge Province this rock unit may be suitable for industrial silica uses; Figure 1 notes some localities where SiO_2 content was analyzed as 99% or greater. "R" numbers refer to samples described, analyzed, and reported in Division publications (Mineral Resources Report 11 and Publication 32). Unimin Corporation in Frederick County, in northern Virginia, is presently the only active operation quarrying the Ridgeley for use as glass sand.

Tuscarora-Rose Hill (Keefer) Formations

The Clinch (Tuscarora) Formation of Silurian age consists of very fine- to very coarse-grained sandstone and quartzite with quartz pebbles in places. The rock is usually well indurated, but at some localities it is poorly cemented and weathers to sand. The Keefer Sandstone Member of the Rose Hill Formation ranges from a white to brown, very fine- to medium-grained, well indurated quartzite to a friable sandstone. Quartz grains are bonded by quartz welds and are commonly cemented by quartz overgrowths. Figure 2 indicates some locations where SiO_2 content was analyzed as 99% or greater. The Clinch has been quarried along

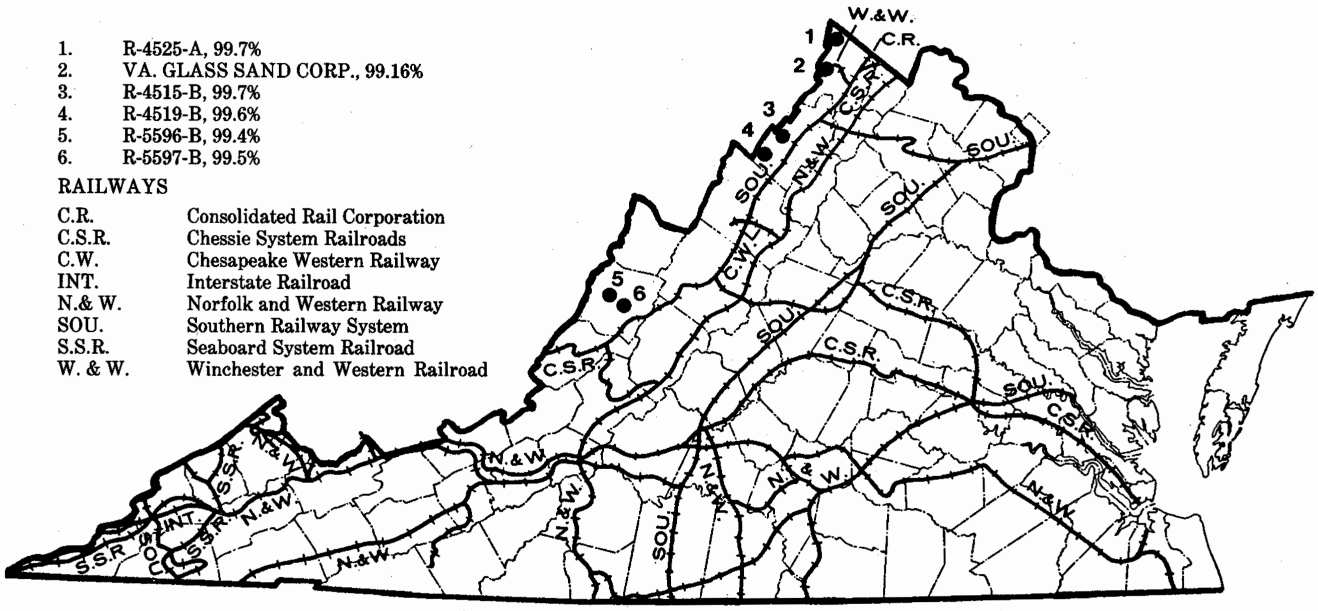

Figure 1. Locations of silica samples from the Ridgeley Sandstone.

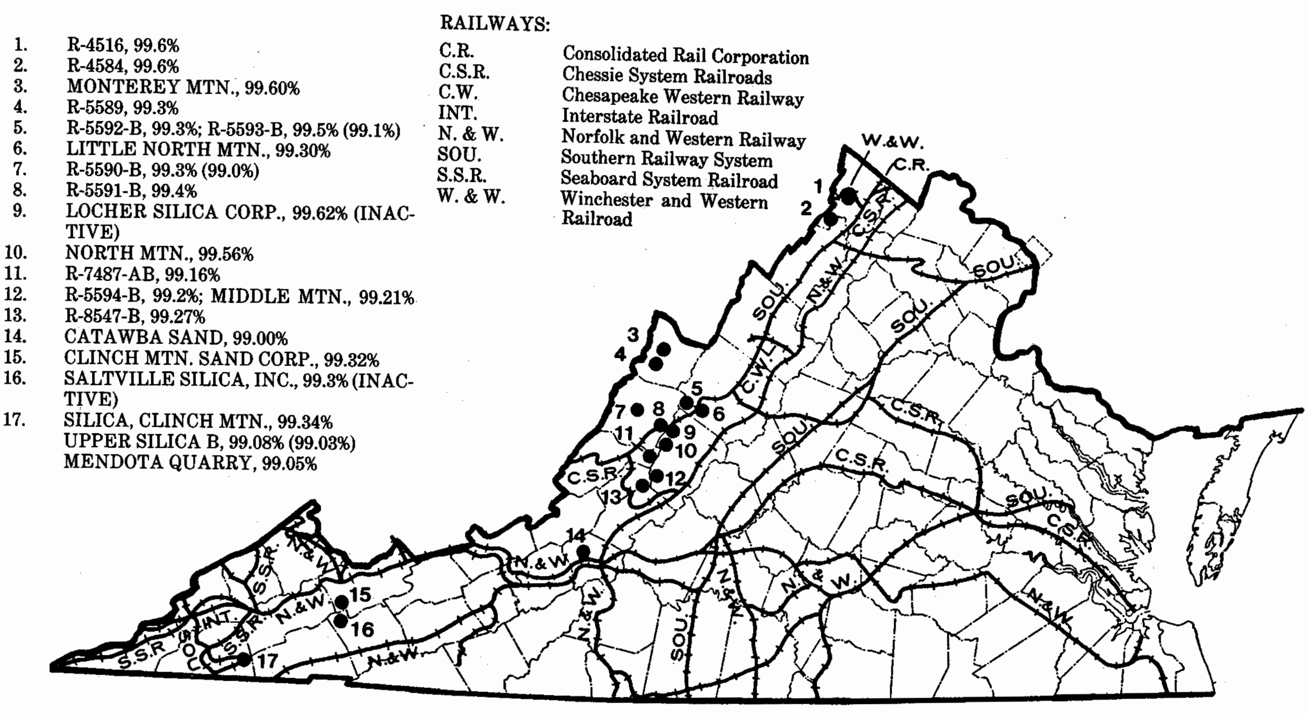

Figure 2. Locations of silica samples from the Tuscarora-Keefer Sandstone.

Clinch Mountain from near Wardell in southwestern Tazewell County to Mendota and Silica at the Washington-Scott county line to Kermit in Scott County. The rock is basically a gray to white, fine-grained sandstone that trends northeast with dips that range from 30°SE in Washington County to 70°SE in southern Scott County at Kermit. The sandstone varies in thickness along strike as well as in degree of consolidation, and thus reserves over a large area are hard to determine. The Clinch sandstone has a general unit thickness of approximately 360 feet; a thickness of about 25 to 50 feet of the most friable material has been quarried in the past. Reserves have been estimated by Gildersleeve and Calver (1945) at millions of tons. Part of the northern end of Clinch Mountain in Smyth County is in the Clinch Mountain Wildlife Management Area. A very friable exposure of Tuscarora from Monterey Mountain in Highland County was analyzed to contain 99.6 percent SiO_2 (Sweet, 1981).

Lee Formation

The lower sandstone unit of the Lee Formation of Pennsylvanian age crops out along Pine Mountain in northwestern Dickenson and Wise counties, and has been exploited principally at two localities. The sandstone has been quarried near the Kentucky-Virginia state line, south of Elkhorn City, Kentucky by the Silica Corporation of America; both glass sand and coal-washing sand were produced in 1960-1962. Pine Mountain here is capped by the lower unit of the Lee Formation, which is conglomeratic (pebbles up to 1 inch in diameter) at the base, and grades upward to white, fine- to medium-grained sandstone. The unit has a strike of N20°E and a dip of 30°SE at this locality.

Studies of the deposit, including test data are noted in McGrain and Crawford (1959) and Hollenbeck and others (1967). Chemical analyses of nine samples of sandstone from the quarry and the immediate vicinity range from 97.78 to 99.30 percent SiO_2, 0.022 to 0.061 percent Fe_2O_3 , and 0.08 to 1.07 percent Al_2O_3; an analysis of the basal conglomerate indicates 99.3 percent SiO_2 and 0.05 percent Fe_2O_3. Minor amounts of zircon, tourmaline, rutile, kyanite, fluorite, and opaque material were also noted. Hollenbeck and others (1967) report that a sieve analysis indicates 79.5 percent of the grains to be -40 and +100 mesh.

The Lee sandstone was also mined north of Pound in Wise County off the southeast side of Pine Mountain. This quarry was probably in the middle sandstone member and was mined for coal-washing sand. The site was last worked by Southwest Sand Company, Inc. in 1974; former operators were C. E. Robertson and Skyline Sand Company, Inc. in the early 1960's. E. E. Musgrove (personal communication, 1969) stated that the chemical analysis on this material indicated 98.5-99.2 percent SiO_2. An exposure of the upper quartz sandstone (Bee Rock Sandstone) is noted in Breaks Interstate Park, Dickenson County. The majority of the land along the southeast flank of Pine Mountain and along the northwestern Dickenson and Wise county boundaries is in the Jefferson National Forest. There are numerous privately owned tracts within these boundaries and privately-held mineral rights on some forest tracts.

Quartz Veins

Quartz veins have most recently been examined by mining companies for metallurgical flux material and, with the increasing need for transmitting light waves along thin silica strands for raw material for optical fibers. Suitable material must have the ability to withstand thermal stress or nonuniform temperature distribution. In 1983 a cable the thickness of a finger and containing 144 fibers was activated between New York and Washington. Eventually it will have the capability to carry up to 240,000 simultaneous transmissions, which is almost twice what can be carried by 2 inch standard copper cable. Both formerly mined and undeveloped quartz veins and the quartz cores of pegmatites have been examined by companies looking for silica with low Fe_2O_3 content. Quartz veins in Albemarle, Campbell, Fluvanna, and Patrick counties are of particular interest. Quartz in the cores of pegmatites may also be of interest; several such occurrences are noted in Amelia and Bedford counties.

A quartz vein on the Otter River in Campbell County appears to have minimum dimensions of 0.4 mile long, 100 feet wide and 150 feet high, and a potential tonnage more than 2.6 million short tons. Palmyra Stone Company's quarry in Fluvanna County (Figure 4) was productive in 1964, and estimates of material present in this vein are almost one million tons. A Virginia Division of Mineral Resources analysis indicates that the quartz there contains 99.05% SiO_2, 0.00% Fe_2O_3, and 0.66% Al_2O_3. The vein at this location has a strike of N15°W and a steep southwest dip; quartz is also present on the hill 0.1 mile southeast of the quarry and is probably a continuation of the vein.

A quartz vein (Figures 3 and 4) located south of Meadows of Dan, Patrick County and just off

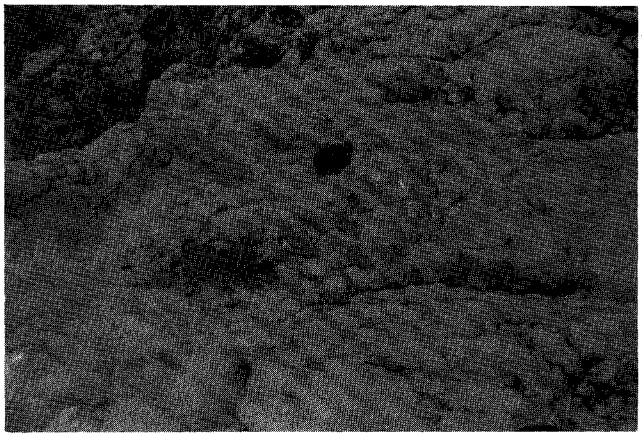

Figure 3. Drill hole in quartz vein, Meadows of Dan, Patrick County.

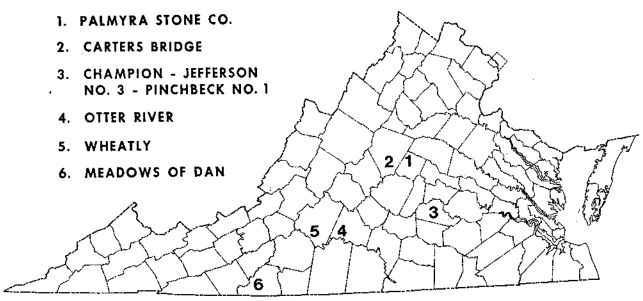

Figure 4. Vein and pegmatite quartz localities in Virginia.

the Blue Ridge Parkway was operated in 1964 for metallurgical material that was utilized in the Pittsburgh area. The vein is exposed for 400 feet, with a width of 75 feet; soil cover is over an additional 900 feet of vein material. The vein has a strike of N35°E and a dip of 60°SE. An analysis of this quartz by the Virginia Division of Mineral Resources indicates 99.10% SiO_2, 0.00% Fe_2O_3, and 0.57% Al_2O_3. A quartz vein west of Carters Bridge in Albemarle County (Figure 4) has a strike of N60°E and is exposed discontinuously for about 0.3 mile with a visible width of about 70 feet.

Quartz from the core of pegmatites ranges from clear to milky. Locations that may be of interest include the Champion, Jefferson No. 3, and Pinchbeck No. 1 mines in Amelia County (Chula 7.5-minute quadrangle) and the Wheatly mine in Bedford County (Moneta 7.5-minute quadrangle) (Figure 4).

Annual demand for industrial silica resources has increased from 25 million to 33.5 million tons from 1975 to 1979 mainly because of the increased demand for glass and foundry sand. As the unit price of most of the speciality sands precludes distant transport, the delivered price is very important. Thus, competition is stiff and industry is secretive about production capabilities, grades, and prices. The major markets for silica sand are the industrialized areas of the north-central and southern parts of the country. Transportation of sand more than 200 miles is rare.

USES AND SPECIFICATIONS FOR SILICA RESOURCES

Glass Sand

High silica content is important; iron content may be as low as 0.008% or as high as 1% depending on whether the final product will be optical or amber glass. Iron oxides may form crusts or coatings on quartz grains, which are usually removed by washing, scrubbing, or flotation. Grain-size specifications require all material to pass through a 30-mesh screen with only a small amount passable through a 100-mesh sieve. Uniformity of grain size may actually be more important than the size of the grains themselves. Grain shape is not critical and can range from round to angular. The majority of fines are lost through washing; too many fine grains result in a rapid first reaction and liberation of carbon dioxide which will cause the glass batch to foam excessively. Too fine a material may also form a fine persistent seed in the glass. If the sand has a few coarse grains, it will not flux readily; oversize grains may remain unmelted. High alumina (Al_2O_3) is a detriment for optical glass, and six parts per million (ppm) of chromium is the maximum allowed in the melt. Sweet (1978) notes that 0.0002 percent cobalt oxide will produce a distinct tint in the glass.

There have been many producers of glass-grade material in Virginia in the past. The only presently-active operation, Unimin Corporation near Gore, Frederick County, is quarrying the Ridgeley (Oriskany) Sandstone. Glass sand producers in the past have been located in the Valley and Ridge, Plateau, and Piedmont provinces. The container glass industry was the largest national domestic consumer of silica sand in 1982 (8,865,000 short tons). Competition from cans, plastics, and paper cartons will probably affect the glass container market in the future. Flat-glass markets tend to follow the economy. Prices of glass sand vary from \$8-\$13 per short ton FOB.

Abrasive Sand

Basically, all natural sands are suitable for grinding. Requirements for the size and shape of the grains depend on the specific job, whether sandblasting, stonesawing, glass grinding, or banding (second grinding of plate glass). Some of the abrasive, grinding and airblasting sands can be recycled. Material from the Tuscarora Formation at Clinch Mountain Silica Sand Corporation was marketed in 1930 as abrasive material for cutting marble (Gildersleeve and Calver, 1945).

Because of regulations regarding siliceous materials over the last several years, the trend is toward use of other materials for abrasive purposes, for example, nepheline syenite from Ontario, Canada. Hardness and durability are being sacrificed for material that is more easily accepted by industry.

Metallurgical Flux

Silica raw materials are used as a fluxing agent for basic oxides in various smelting operations, as a source of silicon in ferrosilicon alloy manufacture, and for making metallic silicon. The iron and basic oxides react with the silica to form a silicate slag. Users generally prefer quartzite with a purity of at least 98% SiO_2 with only small amounts of iron and alumina and traces of other oxides. The iron, alumina, and other oxides reduce the percentage of available silica. Compounds of arsenic, phosphorous, or sulfur are objectionable because of poisonous gases they create in the furnace. Alumina is difficult to reduce in the electric furnace and usually a sticky slag that may contaminate the product is produced. The silica should be a tough material that does not crumble and that contains no fine material; metallurgical-grade material has size requirements of 1 to 4 inches.

Raw material for ferrosilicon was produced in 1918 at the Reynolds Quarry in Washington County. Production of 5000 tons of quartzite containing 98 percent SiO_2 occurred at the Archer Quarry on Lick Mountain, south of Wytheville, in 1941. Reserves of metallurgical-grade material are estimated at 2 million long tons on Lick Mountain. Material is presently being produced by Locher and Company, Inc., at Lots Gap, Wythe County (Figure 5). Good grade metallurgical quartzite is also present along the west flank of the Blue Ridge mountains near Waynesboro, Augusta County and near Greenlee in southeastern Rockbridge County.

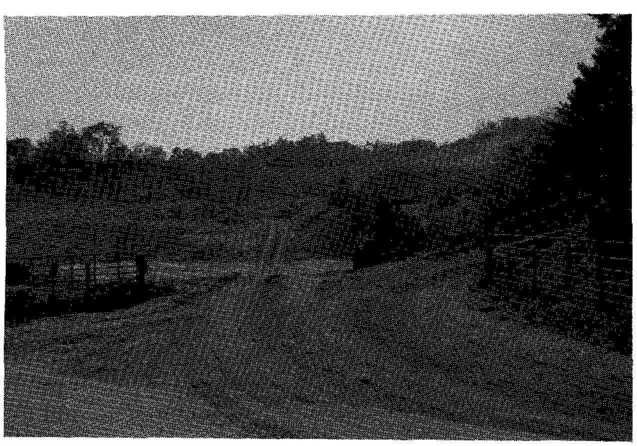

Figure 5. Locher and Co., Inc. quarry operation, Lots Gap, Wythe County.

Filter Sand

Filter sand is used to remove sediment, suspended matter, and bacteria from municipal and industrial water supplies, for sewage treatment, and to purify swimming pools. The sand is used as the upper layer in a filter bed succession (the upper layer performs the filtering function while the lower coarse layers act as a support).

Uniform grain size (usually between 25 and 45 mesh) is very important, but grain-shape requirements are not critical as angular to rounded grains are permitted; however, flat or elongated grains must be less than one percent. Specifications for filter sand set by the Virginia Department of Health are 98-100% of the sand passing through the #4 sieve, 0-2% -80 mesh and 0-1% -100 mesh. The sand should be high in silica and free of grain coatings such as iron and manganese, which would react with chemicals used in the water treatment. The material should also be free of clay, silt, or organic matter. The solubility (usually less than 5% in hydrochloric acid) of the sand is governed by the pH of the water to be filtered. Material marketed for filtration purposes is produced by a sand and gravel operation east of Petersburg.

Engine (Traction) Sand

This material is used on slippery rails for traction of locomotives and to remove soot from the flues of oil-burning locomotives. Clean silica sand, with round to subrounded grains between 20 and 80 mesh and with very low clay content, is required so that there will be no caking to inhibit free running of sand onto the rails.

An operation near Oceana in eastern Virginia markets the sand material from their pit that is retained on a 60 mesh sieve to a major railroad. River sand in southwest Virginia is also used as a traction material on the rails for mine cars in the coal mines. In the early 1940's Clinch Mountain Sand Corporation, located on Short (Beartown) Mountain (part of Clinch Mountain in southern Tazewell County near Wardell) produced a "friction" sand to be used on mine haulage systems.

Engine sand was formerly produced by Locher Silica Corporation at Goshen in Rockbridge County. Other counties with production in the past include Giles, Hanover, Rockingham, Scott, and Spotsylvania.

Furnace (Fire) Sand

This sand is used to line the walls and floors of open-hearth steel furnaces. Material should be clean and of high-silica content (95%+) to obtain the necessary refractory properties. Variable grain size and a small amount of bonding clays are necessary to hold the sand in place in the furnace and make the hearth more impervious. Spent molding sand is also used as furnace sand and in many cases may be preferable to new sand because of the increase in fines from the molding sand bond. In Virginia furnace sand has been produced in Hanover, Henrico, New Kent, Pulaski, and Wythe counties.

Foundry (Molding) Sand

This product is used in foundries to make cores and molds for casting of common metals and as a component of refractory products. Four to five tons are utilized per ton of metal poured.

Raw material for foundry sand is required to have a minimum SiO_2 content of 95-96 percent; however, the standard specification is increasing towards 98-99%. Allowable amounts of Al_2O_3 are 6-10% and of Fe_2O_3 4%; loss on ignition should be less than 0.4%. The percent of clay and iron is also important. If this is too high, the mold will shrink and crack, if too low, the mold will dry and crumble. The material must have refractoriness to withstand heat and enough cohesiveness to hold together. The sand should have the strength to resist the pressure from the molten metal being poured, and must be porous enough to allow gases to escape. The texture and composition of the sand allows the mold to be smooth.

Material of lacustrine or marine origin as well as dune sands may be suitable. An operation located in Virginia Beach produces a material that passes through a 60 mesh screen and has the correct amount of fines. In the past, molding sand was produced by Locher Silica Corporation in Rockbridge County. Some other localities with past production include the City of Alexandria, and Augusta, Campbell, Caroline, Charles City, Chesterfield, Dinwiddie, Giles, Henrico, Prince George, Pulaski, Rockingham, Scott, and Spotsylvania counties.

The foundry sand market suffered during the recent recession as consumption dropped about 3 million tons from almost 10 million tons in 1981. The market, following the economy, is expected to recover slowly in the mid 1980's. Prices for foundry sands are normally less than glass sands; finely ground sand for core facings averages $17-18 per short ton.

Hydraulic Fracturing (Frac or Propping) Sand

Hydraulic fracturing utilizes a sand-water mixture, forced into wells under high pressure, to break up hydrocarbon-bearing formations and open bedding planes so that the oil or gas can move more freely. Approximately 1,470,000 tons of industrial-quality frac silica sand were mined from a select group of sandstone formations in the U. S. in 1981.

For early fracturing treatments, construction sand from gravel pits was used as a propping to hold open the fractures in the rocks that had been enlarged by the pressurized fluids. Later, propping agents such as crushed and rounded walnut hulls, high strength glass beads, aluminum pellets, steel shot and other materials were evaluated. It was eventually discovered, however, that certain sandstone formations yielded silica grains that performed reliably in well stimulation. Such characteristics as particle-size distribution (90 percent of the material between 20 and 40 mesh), roundness and sphericity, solubility in hydrochloric acid (less than 5 percent), and crushing resistance must be evaluated. A uniformly graded sand gives a better permeability in the rock strata. Whether mined from open pits or underground, frac sand must be washed and processed to ensure that clean, unconsolidated quartz grains are the final result.

The use of sand grains in hydraulic fracturing treatments is continually being studied to improve efficiency. New fracturing fluids, surfactants, emulsions, and other substances serviced with even more sophisticated equipment should result in more commercial oil and gas fields in the future. Suitable resources may be present in the Ridgeley Sandstone or the Erwin Formation where the sandstone is coarse grained.

Coal-washing Sand

A washed and graded silica sand (minimum specific gravity of 2.64, with grains which must be subangular to round, is mixed with water to form a slurry in a conical separating chamber into which raw coal is fed. By movement of a revolving agitator, the sand is kept in suspension; the coal, with a specific gravity of 1.50 (bituminous coal), floats near the surface of the fluid mixture and circulates around the cone until it reaches the discharge point. The heavier impurities sink.

Sand should be free from clay and organic matter and have a grain size that ranges between -30 mesh and +140 mesh, with at least 90 percent between -3 and +100 mesh. Raw material from the Lee Formation of Pennsylvanian age was produced in 1960-1962 by the Silica Corporation of America from a quarry in Kentucky just west of the Dickenson County line.

Sand-lime Brick

These white standard-size bricks used for ornamental facing are composed of silica (80-85%) and lime which react under heat (steam) and pressure to form a hydrous calcium silicate bond. Ten percent of the sand should pass a 140 mesh sieve, with all passing the 20 mesh sieve. The sand may contain no more than 5% clay; it should be angular, clean, and free from organic matter. The most attractive brick is made of white sand free from dark-colored grains. A company in Princess Anne County (now City of Virginia Beach) was a sand-lime brick producer in 1915.

Refractory Brick

Silica (refractory) bricks are made from silica sand or quartzite (96-98% SiO_2) fired with lime for bond. Specifications note that alkalies should be less than 0.3 percent with less than 1 percent Al_2O_3 and combined iron and alumina under 1.5 percent. A suitable grain-size range has 55 percent between 4 and 30 mesh, 20 percent between 30 and 70 mesh, and 25 percent finer than 70 mesh. Refractory ganister refers to fine-grained quartzite, and refractory pebble includes granule to pebble (2 mm-64 mm) size material.

The most important property is the ability of the brick to support loads at high temperatures. Uses include roofs for basic open-hearth steel furnaces and glass melting tanks, lining of coke ovens, and refractory and other types of furnaces. Raw material for refractory brick was supplied by Saltville Silica, Inc., Smyth County, in the early 1980's. Sand from this operation was first melted so that expansion and contraction properties would be lessened and made acceptable.

Ground Silica (Silica Flour, Ground Quartz)

A representative chemical analysis (McLaws, 1971) for ground silica is as follows: SiO_2, 99.80%; Fe_2O_3, 0.02%; Al_2O_3, 0.06%; TiO_2, 0.013%; and L.O.I., 0.09%. Raw material should be angular and fine-sized with better grades having more than 95% finer than -325 mesh.

Raw material is sand, quartzite, or sandstone ground to micron sizes, usually in a ball mill. The material is used as an extender in paint and varnish, as a filler in insecticides and fertilizers, in fiberglass, cement mixtures, tile, plastic, and rubber, and as an abrasive ingredient in soaps and scouring powders. It is used in the preparation of gypsum plaster (wallboard) where desirable properties are refractoriness, whiteness, and chemical inertness. It is also an ingredient in ceramic bodies for making earthenware, porcelain (electrical), and sanitary ware where it is employed basically to reduce the drying and firing shrinkage and deformation. Material for electrical porcelain was produced in 1930 by the Clinch Mountain Silica Sand Corporation in Scott County; similar material was produced from the Reynolds Quarry in adjacent Washington County around 1918.

Silica flour was marketed in the mid 1960's by Locher Silica Corporation at Goshen, Rockbridge County, for use in fiberglass. In 1982 fiberglass markets consumed 1,457,000 short tons of sand. The market is now rebuilding after a drop from the upsurge in the mid 1970's when fuel prices rose and government incentives to upgrade existing insulation as well as new insulation specifications were being introduced. Average prices for fiberglass sands are about $23 per short ton.

Miscellaneous

Cristobalite, a crystalline form of silica, is produced by CED Process Minerals at a plant near Gore, Frederick County. Ridgeley (Oriskany) Sandstone from an out-of-state quarry is heated to 1500-2950°F to recrystallize the quartz; impurities are removed with magnets. The material, in 90-mesh and 325-mesh sizes, is bagged and shipped by rail to the Great Lakes area and to the port of Baltimore. End uses for the product include fillers for paint and lime.

Crystal Quartz

Quartz crystals have been utilized as oscillators, in telephone resonators, and more increasingly as timing devices in watches. Oscillator-grade quartz crystals are sliced into thin plates and used to stabilize the frequency of electric waves that are being radiated from transmitters. Crystal production occurred in Virginia in 1943 during World War II when the material was utilized in radio transmitters in airplanes, tanks, and ships. Almost 135 pounds of quartz crystals were produced from Carroll, Floyd, Patrick, and Pulaski counties at a 1943 total value of $830.70 (Mertie, 1959). A large quartz crystal is present in the rock wall of the Buffalo Mountain Church, Carroll County (Figure

Figure 6. Quartz crystal, wall of Buffalo Mountain Church, Carroll Co.

6). Reserves of crystal quartz are probably small with only low grades present in scattered occurrences.

There is no active U. S. production of natural quartz suitable for electronic or optical applications, although lasca was produced from Arkansas. Lasca is a natural non-electronic-grade quartz that is used as a feed stock for growing cultured quartz crystals. Domestically grown or cultured quartz crystals (the U. S. is the world leader in production) have taken over much of the former demand for natural quartz crystals. Natural quartz is still required for specific electronic applications requiring an extremely high Q-factor. Main uses for quartz crystals remain in frequency controlled oscillators, and future uses include timing devices for microprocessors and clocks and in video games.

Ornamental Aggregate

Over the years many silica raw materials have been produced in Virginia for use as exposed aggregate and terrazzo. In the early 1960's, the majority of the material was produced by two companies that opened numerous quarries in quartz veins, mainly in the Piedmont Province. Economy Cast Stone Company set up two plants around Richmond, and over a period of 15 years, operated four quarries. Stone and Mineral Corporation of Warrenton set up a crushing plant in Madison County and has operated eleven quarries over the years. Records indicate that approximately 50,000 short tons of material valued at more than $600,000 was produced. More recently, the use of exposed-aggregate panels has decreased. Some white quartz pebbles, mainly from sand and gravel operations in Caroline County, have been utilized over the last few years.

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SALTPETRE STUDY

The Virginia Division of Mineral Resources is seeking information on saltpetre mining and production in Virginia. Production of saltpetre occurred from just prior to the Revolutionary War, through the War of 1812, and again during the Civil War and commonly involved caves. Saltpetre, also termed "petre" and niter was used in production of gunpowder. Any information on mining sites, powder mills or artifacts (including digging tools, paddles, troughs, vats, and boiling kettles) would be appreciated. Documented information, observations, old stories or hearsay are solicited.

Please report information to:

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Charlottesville, VA 22903

SESQUICENTENNIAL CELEBRATION

D. Allen Penick, Jr.

The 150th anniversary of the geological survey in Virginia was observed by the Division of Mineral Resources with a series of events beginning in May of 1984 and concluding in November, 1985. The geological survey in Virginia was initiated in 1835 by William Barton Rogers who was consequently named the first State Geologist. The events are listed below as they occurred:

1. A symposium, entitled *The Mineral Industries of Virginia* , was held in conjunction with the annual meeting of the Virginia Academy of Science in May, 1984. This meeting, organized by G. Wilkes of the Division and held on the University of Richmond campus, was attended by approximately 80 people. The program consisted of eleven speakers representing several mineral industries currently active in the State.
2. A symposium, *Quaternary of Virginia* , was held in Charlottesville during September, 1984. This symposium was organized by Dr. S. O. Bird of the Division staff. The principal speaker, Dr. Silvio A. Bedini, is currently Keeper of Rare Books at the Smithsonian Institution. The title of his presentation was "Thomas Jefferson and American Vertebrate Paleontology". This paper has recently been made available as Division Publication 61. The meeting was followed by a field trip to Saltville to view vertebrate fossils.
3. The 16th Annual Virginia Geological Field Conference originated in Covington in October, 1984. This two-day field trip was led by Tom Gathright and Gene Rader of the Division staff and focused on stratigraphy and structural geology of western portions of Alleghany and Bath counties.
4. In November, 1984, the Association of American State Geologists (AASG), in conjunction with Minerals Management Service (MMS), held a one-day symposium in Charlottesville. The meeting was hosted by the Division and attended by 36 geologists from nine eastern coastal states, the U. S. Geological Survey, and MMS. During the meeting representatives from the eastern coastal states which had received grants for offshore mineral projects from MMS presented some of their preliminary findings.
5. In a special event (March 1985) Dr. Douglas Bassett, Director of the Natural Museum of Wales, presented a talk entitled "In Celebration of the Geologic Map". The talk was held in Clark Hall and was followed by a banquet at the Rotunda, University of Virginia.
6. The July-August, 1985 issue of *Rocks and Minerals* magazine was entirely devoted to Virginia in a special commemorative publication. This publication contained articles by Division staff members, D. Allen Penick, Jr. and S. O. Bird, on the diverse minerals and fossils found in Virginia and an article by Dr. C. R. Hobbs entitled "The Virginia Division of Mineral Resources", a history of the Survey.
7. To help commemorate the 150th anniversary, mineral cards were produced and distributed at the various meetings, to office visitors, and school groups. Each card has a sample of a mineral from Virginia and information which includes name, location, use, and chemical composition.
8. Displays of Virginia products were placed at the following meetings: Highways Conference (Lexington), Social Teachers Conference (Charlottesville), Science Teachers Conference (Virginia Beach), and Virginia Academy of Science (Williamsburg).
9. The Eastern Section of the American Association of Petroleum Geologists held their annual meeting in Williamsburg during November, 1985. The meeting was preceded by five field trips to: Great Dismal Swamp, Southern Delmarva Peninsula, Western Virginia - eastern West Virginia, Taylorsville Basin (Richmond), and Pamunkey River.

PUBLICATION 55

Geologic Features Related to Coal Mine Roof Falls—A Guide for Miner Training, by Robert C. Milici and Thomas M. Gathright, II; 13 p., 1985

$3.00

The purpose of this publication is to help miners and their supervisory personnel recognize some of the geologic factors which have caused roof control problems in the southwest Virginia coal fields. Immediate roof types are classified and potentially hazardous conditions are described. The publication contains photographs of different roof conditions, generalized diagrams of roof types, and a glossary of significant words.

It can be purchased at the Division for $3.00.

MINERAL UPDATE-VIRGINIA (TROLLEITE)

William F. Giannini, D. Allen Penick, Jr.
and
Oliver M. Fordham, Jr.

The rare mineral trolleite, previously unreported from Virginia, has recently been discovered in Buckingham County. This occurrence of the hydrous aluminum phosphate, $Al_4(PO_4)_3(OH)_3$, is only the second reported in the United States and the fourth worldwide. Trolleite had previously been reported from the White Mountains, Mono County, California, at Westano near Kristianstad in Skane, Sweden (Moore and Araki, 1974), and Rwanda, Africa (von Knorring, 1972). The mineral from Buckingham County was positively identified by X-ray diffraction and X-ray fluorescence analyses.

The pale green, monoclinic mineral, 8.5 hardness on Mohs scale, was found in the Willis Mountain quarry of the Kyanite Mining Corporation, 3.9 miles south of Dillwyn, and 0.5 mile east of U. S. Highway 15 (Figure). It occurs in milky to pale gray translucent quartz as masses to 1.25 inches long by 0.5 inches wide with conchoidal fracture. Eight specimens of quartz that contained trolleite were collected from a block of kyanite quartzite blasted from the west face of the quarry at a depth of approximately 50 feet below the original land surface.

Additional new minerals noted from the Willis Mountain site include apatite, native sulfur, crandallite-florencite and lazulite-scorzalite series minerals. The apatite, associated kyanite, and some of the crandallite-florencite minerals fluoresce under ultra-violet light. These minerals are of scientific value and may contribute towards the further understanding about the origin of the kyanite deposit.

We wish to acknowledge Mr. Gene Dixon, owner of Kyanite Mining Corporation, for allowing us entry to his property and for his enthusiastic support, and also Dr. Richard S. Mitchell, Department of Environmental Sciences, University of Virginia, for his advice and assistance.

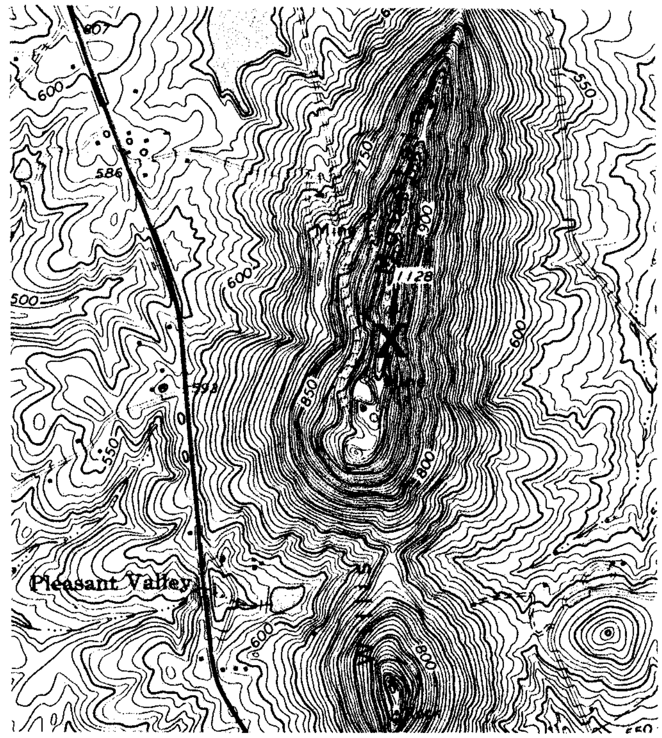

Figure. Location of the Willis Mountain quarry, Kyanite Mining Corporation, Buckingham County, discovery site of trolleite.

REFERENCES

Moore, P. B. and Araki, T., 1974, Trolleite, $Al_4(OH)_3(PO_4)_3$: a very dense structure with octahedral face-sharing dimers: American Mineralogist, Vol. 59, p. 974-984.

von Knorring, O., 1972, Notes on phosphate minerals from Buranga pegmatite, Rwanda; 16th Annual Report, Research Institute African Geology, Univ. of Leeds, p. 56-57.

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NEW PUBLICATIONS

PUBLICATION 56

Eden in Peril: The Troubled Waters of the Chesapeake Bay, by S. O. Bird; 27 p., 1985.

$4.00

Publication 56 is an assessment of the health of the Chesapeake Bay, which is presented in a question and answer format. Some of the topics include the effects of toxic substances such as kepone and heavy metals and nutrients such as phosphorous and nitrogen on the Bay. The formation of the Bay, and its circulation pattern and ecosystem are also discussed. The immediate plans of the State for attacking the Bay's problems are addressed and summarized. Twenty-one illustrations accompany the text.

Eden in Peril is sold by the Division for $4.00. A four percent sales tax will be added to in-State orders.

PUBLICATION 57

Post-Martinsburg Ordovician Stratigraphy of Virginia and West Virginia, by Richard J. Diecchio; 77 p., 1985.

$8.00

This publication is an investigation of the uppermost Ordovician strata within the Central Appalachian basin in Virginia, West Virginia, and Maryland. The strata included in this report are contained in the upper portion of the Martinsburg and Reedsville formations, the Oswego Sandstone, and the Juniata Formation. Diecchio describes the lithology, bedding characteristics, paleontology, and sedimentologic features of the units based on 43 sample localities. Measured sections are presented from each of these localities. Thirteen geophysical logs of the area and their interpretations are also included in this text.

Publication 57 can be ordered from the Division for $8.00. Add 4 percent State sales tax for Virginia addresses. An additional charge for postage ($1.25 for third-class and $2.75 for first-class) should also be included.

PUBLICATION 58

Simple Bouguer Gravity Anomaly Map of the Danville — Dan River Basin and Vicinity, Virginia — North Carolina and the Scottsville Basin and Vicinity, Virginia, by Stanley S. Johnson, Leonard S. Wiener, and James F. Conley; one sheet, 1985.

$3.00

On this map, Bouguer gravity contours are shown for the western belt (Danville — Dan River and Scottsville basins) of Triassic rocks. The geology of these two major basins is described in a text and also shown on the map (scale 1:125,000). A location map shows the position and names of Mesozoic basins in the central, eastern, and western belts of Virginia.

Publication 58 can be ordered from the Division for $3.00. Add $1.25 for third-class postage ($2.75 for first-class postage) and 4 percent sales tax for Virginia addresses.