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IRON AND TITANIUM MINERAL PIGMENTS IN VIRGINIA

Stanley S. Johnson

Mineral pigments are produced for use in protective coatings, as coloring agents for a variety of products such as glass, floor tile, and paints, and for other commercial purposes. During the years 1960-1962 about 4 percent of the natural mineral pigments produced in the United States came from Virginia. These pigments may be divided into two types—natural crude iron oxides and titanium dioxide. Iron oxides are mined and processed at Hiwassee, Pulaski County by the Imperial Color and Chemical Department, Hercules Powder Company and processed at Henry, Franklin County by the Blue Ridge Talc Company, Inc. In 1962 Virginia ranked fifth among six states by producing 5.2 percent of the total domestic tonnage of crude iron-oxide pigments. Natural crude iron oxides were first mined commercially in Virginia in 1872 by the Bermuda Ocher Company which opened a deposit on the Coastal Plain near Bermuda Hundred, Chesterfield County. Since then at least seven other iron-oxide deposits have been exploited in Pulaski, Page, Rockingham, Augusta, Loudoun, and Bedford counties (Figure 1). Titanium-dioxide minerals for pigments are mined and processed near Piney River, Nelson County by the American Cyanamid Company and at Gouldin, Hanover County by M and T Chemicals Inc. (Figure 1). In 1962 the State was third in production of ilmenite (titanium pigments) with 3.2 percent of the national production. Titanium dioxide was first mined and processed for pigment use in Virginia by the Vanadium Corporation of America in 1931 at Piney River, Nelson County.

Natural Iron-Oxide Pigments

The chief iron-oxide minerals used for pigment purposes are limonite (hydrous iron oxide) that gives a yellow color and hematite (anhydrous iron oxide) that imparts a red color. These natural iron-oxide substances may be relatively pure or may be admixed with clay minerals. Within a single deposit, iron oxides vary greatly in color, particle fineness, texture, consistency, and purity. These oxides generally occur in a pulverulent or earthy form. The iron-oxide materials that contain clay are called ocher, sienna, and umber. Ocher contains limonite, hematite, or a mixture of both and has a yellow, red, or yellow-red color. Sienna is light brown and has a higher iron content than ocher; it may contain hydrated iron silicates and a small percentage of manganese oxide. Sienna is intermediate in color and composition between ocher and umber. Umber contains a higher percentage of manganese oxides than sienna and is dark brown to black. Table 1 shows the approximate composition of ochers, siennas, and umbers. In commercial usage, the terms ocher, sienna, and umber may be based entirely on color; thus differences in the meaning of these terms may exist from one area to another.

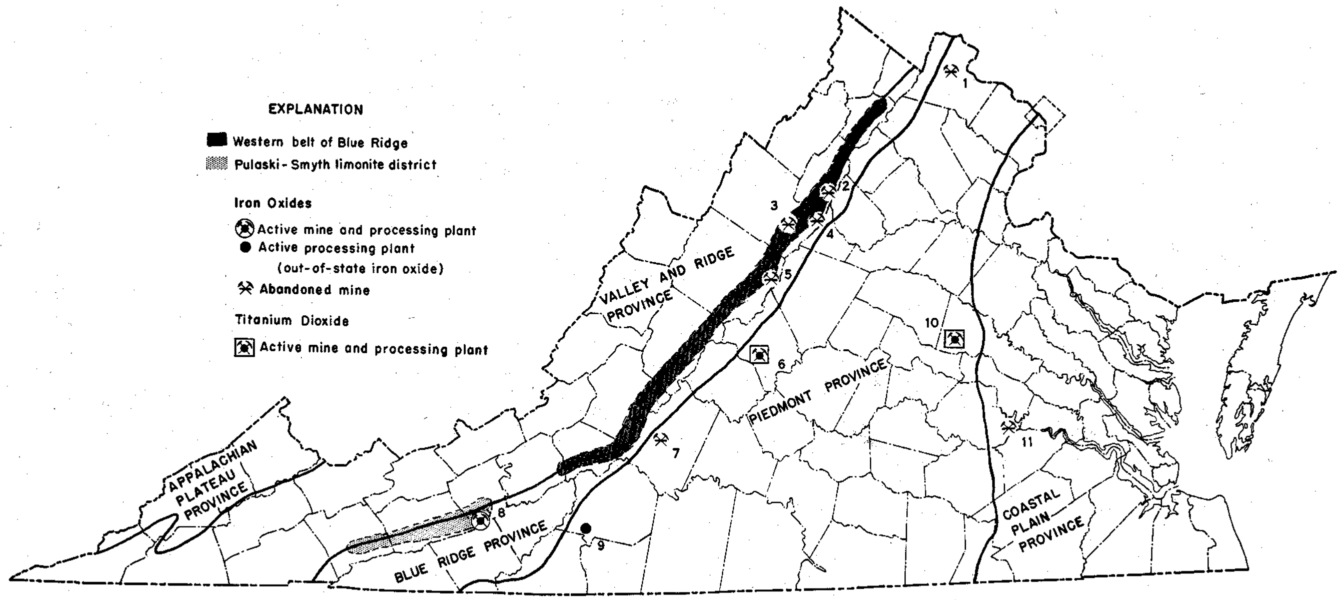

Figure 1. Map showing locations of mineral-pigment operations in Virginia.

Map Number	County	Location	Type of Pigment	Company or Status
1	Loudoun	I mile north of Leesburg, in the Little Catoctin Mountains	Iron oxide	Abandoned
2	Page	1.2 miles southwest of Stanley	Iron oxide	Abandoned
3	Rockingham	Near Keezletown at western base of Massanutten Mountain	Iron oxide	Abandoned
4	Rockingham	5 miles southeast of Shenandoah, along Naked Creek	Iron oxide	Abandoned
5	Augusta	1.3 miles north of Waynesboro	Iron oxide	Abandoned
6	Nelson	Piney River	Titanium dioxide	American Cyanamid Company
7	Bedford	Near Bedford	Iron oxide	Abandoned
8	Pulaski	Hiwassee	Iron oxide	Imperial Color and Chemical Dept., Hercules Powder Company
9	Franklin	Henry	Iron oxide	Blue Ridge Talc Company, Inc.
10	Hanover	Gouldin	Titanium dioxide	M and T Chemicals Inc.
11	Chesterfield	4 miles northeast of Hopewell	Iron oxide	Abandoned

Table 1. Approximate composition of earth pigments.

(From Siegel, 1960, p. 586, copyright A.I.M.E.)

Raw: Yellow, yellow-brown Burnt: Red, red-brown, salmon		Dark brown to black
OCHERS	SIENNAS	UMBERS
Fe_2O_3 17 to 60 pct	Fe_2O_3 25 to 75 pct	Fe_2O_3 37 to 60 pct
	MnO_2, small percentage	MnO_2 11 to 23 pct
SiO_2 35 to 50 pct	SiO_2 10 to 35 pct	SiO_2 16 to 35 pct
Al_2O_3 10 to 40 pct	Al_2O_3 10 to 20 pct	Al_2O_3 3 to 13 pct
Loss on ignition 10 to 12 pct	Loss on ignition 15 to 20 pct	Loss on ignition 10 to 15 pct

Most iron-oxide pigment materials in Virginia occur in residual deposits that have been formed by removal of the relatively soluble parts of the iron-bearing rock and the concentration of the insoluble parts (clay and iron oxide). Some of the iron-oxide materials probably were formed entirely or in part by precipitation from ground water that contained large amounts of iron in solution. Deposits of these types are present along the west slope of the Blue Ridge from Warren to Roanoke counties and associated with the Pulaski-Smyth limonite district in southern Pulaski, Wythe, and Smyth counties (Figure 1). The deposits of iron oxide occurring in these belts are closely associated with gossan and occur in rocks of Cambrian and Ordovician ages. Other occurrences of iron-oxide materials are found at scattered localities in the Piedmont and Coastal Plain provinces. In the Coastal Plain the iron oxides occur in sands and gravels of Tertiary age.

To be used as a pigment material, iron-oxide pigments must reflect light well, that is they must have a high degree of brilliance; also the pigment must maintain its color when diluted in commercial products. A simple test may be performed by mixing one part powdered crude iron oxide with 10 parts of white zinc-oxide powder; a good pigment material will impart a desirable color to the mixture. The color of a pigment depends upon the relationship between particle fineness, particle shape, and type and purity of the crude iron oxide. To be suitable as a pigment in the paint industry, a material must be opaque when mixed with liquids, be able to absorb oil, and have good spreading and staining power (Table 2).

The crude iron oxides may be mixed together in various combinations in the raw state in order to obtain a wide variety of colors. The pigment material may be further processed by calcining. During calcining, the material is heated in a closed kiln in which the structural water is driven off and the iron is oxidized. The color of pigment obtained is dependent upon the temperature to which the raw material is fired and the duration of firing. Pigment from the kiln is called "burnt", for example, burnt sienna.

Iron-oxide pigments are used in paints, stains, linoleum, oilcloth, rubber, plaster, floor tile, and many other substances. Within the last few years the demand for crude iron oxide has been reduced as the marketing of synthetic iron oxides has increased. Manufactured synthetic iron oxides are generally produced from a copperas solution by adding scrap iron and then blowing in air; this causes a yellow iron oxide to precipitate from solution. Red colors are obtained by calcining the yellow iron oxides. These precipitated synthetic iron oxides are characterized by a uniform composition (approximately 97 percent iron oxide) and color, uniform particle size, high covering power, and color permanence.

Titanium-Dioxide Pigments

In Virginia titanium-dioxide pigments are obtained from two of the principal titanium minerals, ilmenite ($FeTiO_3$) and rutile (TiO_2). These minerals are mined in Virginia from titanium-rich pegmatite dikes (Figure 1, Nos. 6, 10). The pigments are generally manufactured by dissolv- titanium-rich ores are generally mined in a weathered zone where open-pit methods are employed. Since the introduction of titanium pigments in 1916, manufactured titanium-dioxide pigment has been used in producing paints, lacquers, plastics, paper, rubber, textiles, linoleum, and numerous other materials. There is an increasing demand for titanium dioxide because of its brilliant whiteness, high refractive index, low specific gravity, fine particle size, chemical stability, and high scattering qualities.

The processes employed in the production of titanium-dioxide pigments are complex and are quite different from those used to produce pigments from natural iron oxides. Titanium-dioxide ing ilmenite or titanium slag in concentrated sulfuric acid. The hard residue that is formed by this reaction is then dissolved in water or a weak

Table 2. Composition and properties of some prepared ochres, umbers, etc.

(From Johnstone and Johnstone, 1961, p. 435)

	Iron Oxide Fe_2O_3	Silica SiO_2	Alumina Al_2O_3	Lime CaO	Manganese MnO_2	Magnesia MgO	Loss on ignition	Sp. gr.	Weight (lb.) per Solid Gallon	Oil absorption	Hiding Power sq. ft. per lb.
	Percent	Percent	Percent	Percent	Percent	Percent	Percent			Percent	
French ochre, medium yellow	20.0	52.50	18.0	0.25	......	0.25	9.0	2.88	23.9	32	40
Yellow oxide (natural)	54.0	23.0	9.5	1.0	......	trace	11.0	3.4	28.3	27	125
Raw umber	50.0	13.0	3.0	5.0	15.5	2.0	13.0	3.5	29.0	44	250
Burnt umber	54.0	18.0	6.0	3.5	9.5	1.5	5.5	3.7	30.8	55	250
Raw sienna (Italian)	51.0	22.5	13.0	nil	......	nil	11.5	3.2	27.1	38	200
Burnt sienna	72.0	19.0	2.5	1.0	......	trace	5.0	3.8	31.6	35	350
Persian Gulf oxide	72.0	21.0	3.0	1.0	......	1.0	0.5	4.1	34.0	15	750
Spanish red oxide	85.0	6.5	1.0	3.0	......	1.0	3.0	4.5	37.0	14	725
Magnetite	94.0	2.2	0.9	......	......	......	......	4.7	39.4	16	......
Hematite red	56.5	17.0		8.0	......	3.5	8.0	3.6	30.0	21	350
Metallic brown (from siderite)	54.0	29.0	11.0 7.0	1.5	......	1.5	2.0	3.8	31.6	25	450

dilute acid to produce a solution of basic titanium sulfate and ferric sulfate. The ferric sulfate is reduced to a ferrous state by the addition of scrap iron. After selective crystallization of the ferrous sulfate (copperas), titanium is precipitated by hydrolysis; then it is filtered, washed, calcined to the oxide, and ground to a fine white pigment. Various chemical treatments can be used at certain stages in this basic process to yield various grades and types of finished pigment products. This is a basic general process, and other modifications may be employed by various manufacturers to suit their individual raw material and products.

Producers of Mineral Pigments

Imperial Color and Chemical Department, Hercules Powder Company

At Hiwassee (Figure 1, No. 8), Pulaski County, the Imperial Color and Chemical Department, Hercules Powder Company, produces natural iron-oxide pigments from local deposits of ocher, sienna, and umber that occur near the contact of the Erwin and Shady formations of Cambrian

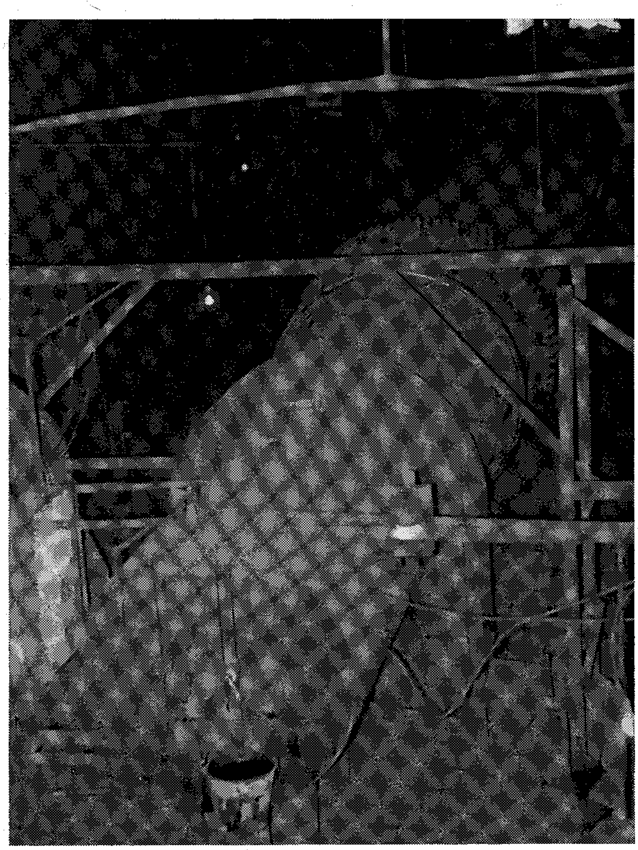

Figure 2. Rotary kiln used for calcining raw pigments at the Hiwassee plant of the Imperial Color and Chemical Department, Hercules Powder Company.

Figure 3. Blue Ridge Talc Company, Inc. processing plant at Henry.

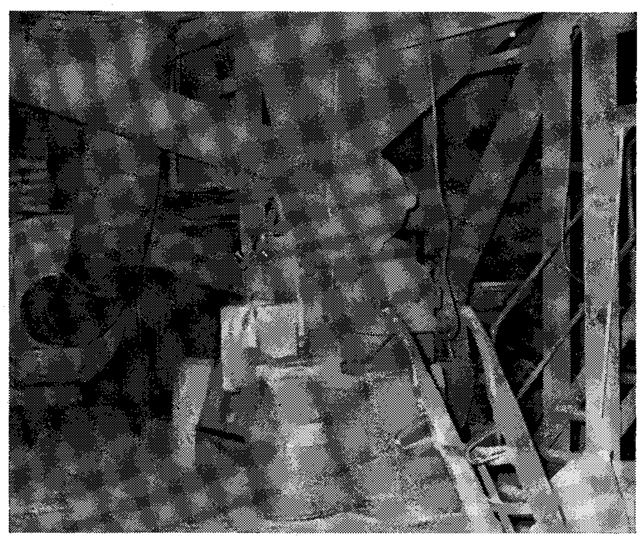

Figure 4. Bagging machine at Blue Ridge Talc Company, Inc.

age. The iron oxides are present in small stringers and pockets that occur in random fashion. Because of the nature of their occurrence the deposits are mined by hand. The pigment is separated and graded by hand at the mine site and stockpiled for later use. The material is trucked to the processing plant where it is broken in a hammermill, dried at low temperatures in a controlled steam-tube dryer, ground in Raymond impact grinders to minus 325 mesh, graded in cyclone air separators, and packaged in paper bags for shipment. Some raw iron oxides are calcined at the plant before initial grinding in the Raymond mills. The calcining process is performed in a standard rotary kiln (Figure 2), 35 feet in length, in which the various colors and grades are produced.

Problems of inconsistent colors in the raw materials are solved by blending two or more shades of pigments to a desired standard. Controlled blending is carried out by standard ribbon-type mixers. Blends are compared with set standards for both shade and tinting strength. More than a hundred different colors are produced at the Hiwassee plant by combination of raw, burnt, and blended ochers, siennas, and umbers. There are no chemicals or fillers added to the natural iron-oxide pigments. The pigments are processed to meet a particular customer's need. The finished pigments are used in paints, printing inks, fertilizers, and other products.

Blue Ridge Talc Company, Inc.

At Henry (Figure 1, No. 9), Franklin County, the Blue Ridge Talc Company, Inc. (Figure 3) produces an iron-oxide pigment from hematite that is mined in Minnesota and shipped to the plant by railroad. The ore has a ferric oxide content of approximately 81 to 84 percent and is in the form of lumps that are approximately 3

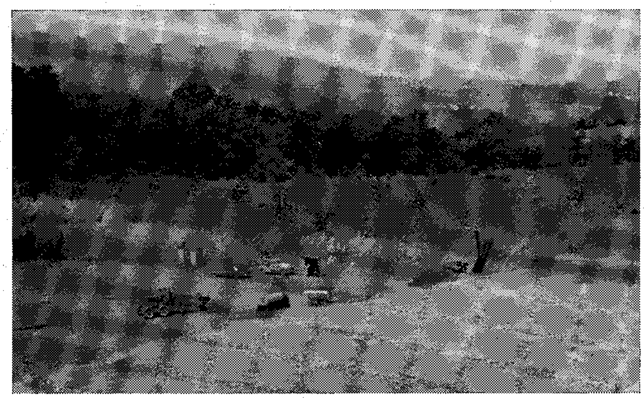

Figure 5. American Cyanamid Company open-pit mine in Amherst County. The saprolitic material is easily removed by mechanical shovel.

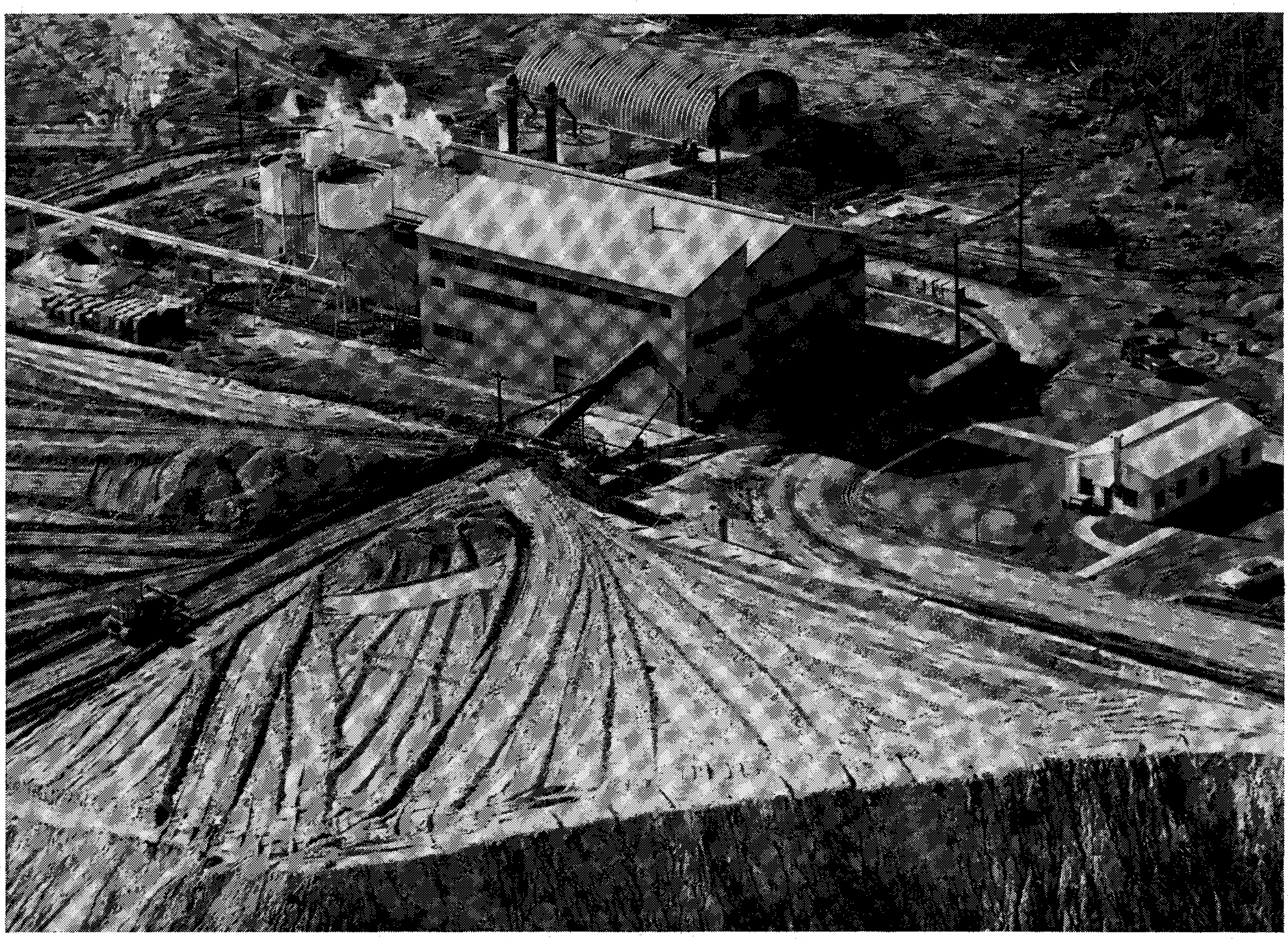

Figure 6. Processing plant of M and T Chemicals Inc. at Gouldin. Ore stockpile is in the foreground. (Photograph taken in 1960).

inches in size when shipped. The 3-inch lumps are crushed to less than 0.5 inch in a hammermill, dried in a rotary dryer, ground in a Raymond impact grinder, graded in a cyclone air separator, and packaged in paper bags (Figure 4). Of the finished bulk material, approximately 80 percent is finer than 200 mesh, and the remainder is finer than 325 mesh. The ground hematite pigment is used in foundry facings, paint, fertilizer, cement, and other products. In addition to the mineral-pigment operation, the company has for many years produced and processed soapstone that is mined near Henry.

American Cyanamid Company

American Cyanamid Company produces titanium pigments from ilmenite in the plant at Piney River (Figure 1, No. 6), Nelson County. The ilmenite is mined near Lowesville, Amherst County from a weathered nelsonite dike. A zone of saprolitic "soft ore" extends to a depth of approximately 100 feet; this ore is easily removed by mechanical shovel (Figure 5). The ore is trucked approximately 4 miles to the plant where it is stockpiled. Concentration and preparation processes are carried out at the plant. The method of beneficiation presently used involves crushing, washing, grinding, concentration in Humphrey spirals, flotation of apatite from the ilmenite, and finally dewatering and drying the ilmenite concentrate. This concentrate is then processed into titanium-dioxide pigment.

M and T Chemicals Inc.

At Gouldin (Figure 1, No. 10), Hanover County, M and T Chemicals Inc. (Figure 6) produces a finely ground rutile pigment from material obtained by open-pit mining from a weathered titanium-rich pegmatite dike. The titanium ore is trucked approximately 0.3 mile to the plant where it is crushed in a hammermill, ground into small particles, separated by water using spiral separators, concentrated on shaker tables, and dried in a standard rotary dryer. The ilmenite-rutile concentrate is then separated by electrostatic and magnetic separators and stored for future use. A wet-milled rutile product, 5 microns and less in size, is used in selected pigment applications. A dry-milled rutile product, approximately 400 mesh, is generally used in floor tile, ceramics, and other fired products. Titanium is also utilized in welding-rod coatings, and aplite is recovered for use by the glass industry.

References

Johnstone, S. J., and Johnstone, M. G., 1961, Ochre, iron oxide, sienna, umber and other mineral colours, *in* Minerals for the chemical and allied industries: New York, John Wiley and Sons, p. 432-445.

Siegel, Alfred, 1960, Mineral pigments, *in* Industrial minerals and rocks: Am. Inst. Mining Metall. Petroleum Engineers, p. 585-593.

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News Notes

The Buena Black Granite Corporation, producers of dimension stone, made the first shipments of diabase from their new quarry located near Rapidan, Culpeper County, during June 1964 to their plant facilities in Elberton and Mt. Airy, Georgia. The stone will be marketed primarily for building and monumental purposes.

The M. J. Grove Lime Company recently opened a quarry in limestone near their underground limestone mine at Stephens City, Frederick County. The stone is crushed for aggregate purposes in a new plant located adjacent to the quarry. Functions of the quarry and plant are independent of the company's adjacent mine and lime-plant operations.

Progress of Topographic Mapping

The following compilation and maps (Figures 7-10) indicate the progress of the topographic mapping program through June 30, 1964.

	No. of Quadrangles	% of State
Total number of 7.5′ quadrangles	799	100.0
Number of 7.5′ quadrangles of recent aerial photography	367	45.9
Number of 7.5′ quadrangles in progress	475	59.5
Number of 7.5′ stereocompilations	78	9.8
Number of 7.5′ composites	12	1.5
Number of 7.5′ published modern maps, 7/1/63 to 6/30/64	20	2.5
Number of 7.5′ published modern maps	119	14.9
Total number of 7.5′ stereocompilations, composites, and published maps	208	26.0

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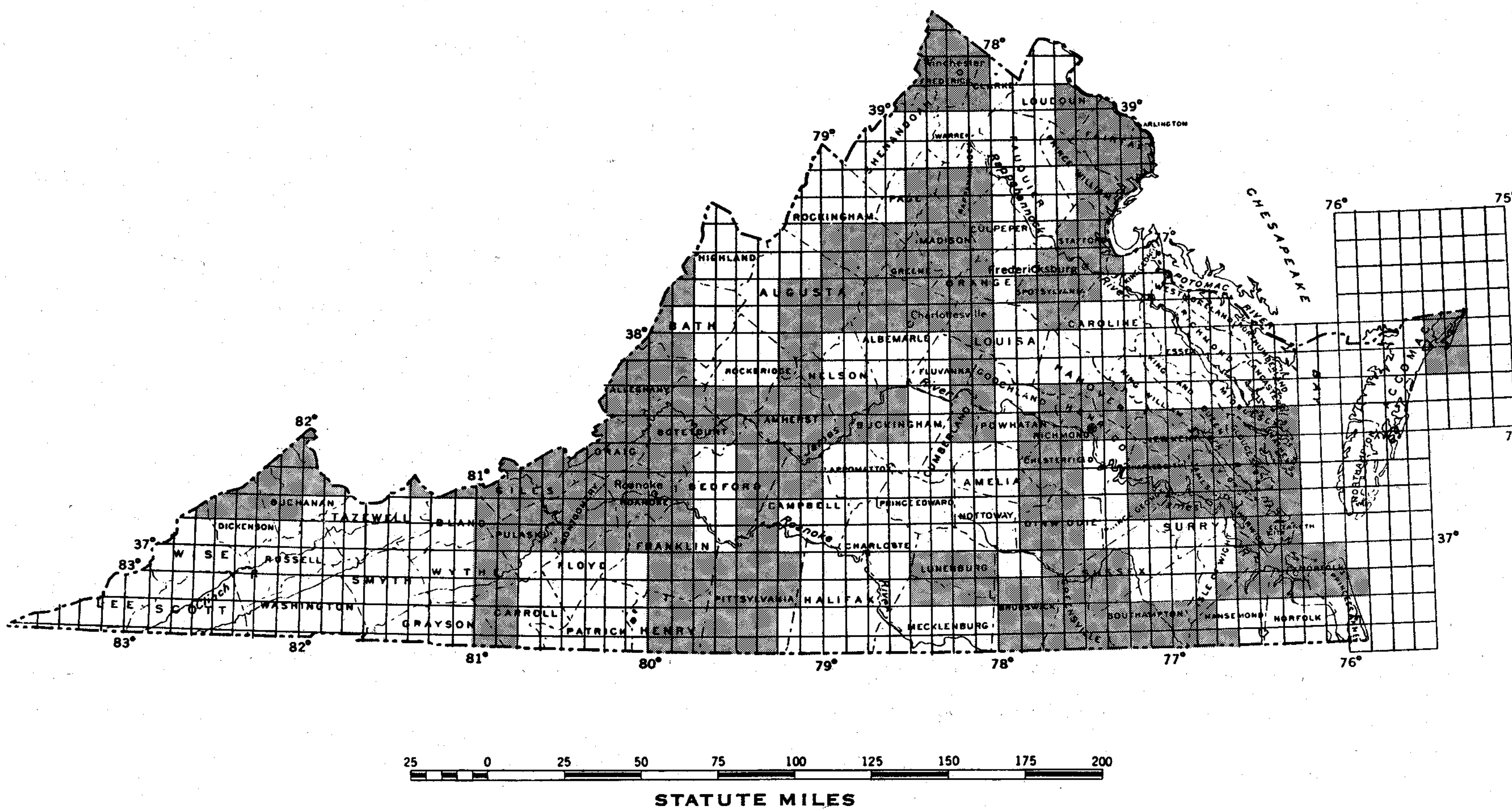

Figure 7. Areas of recent aerial photography by the U. S. Geological Survey. Information concerning aerial photographs may be obtained from the U. S. Geological Survey, Aerial Photography Section, G.S.A. Building, Washington 25, D. C.

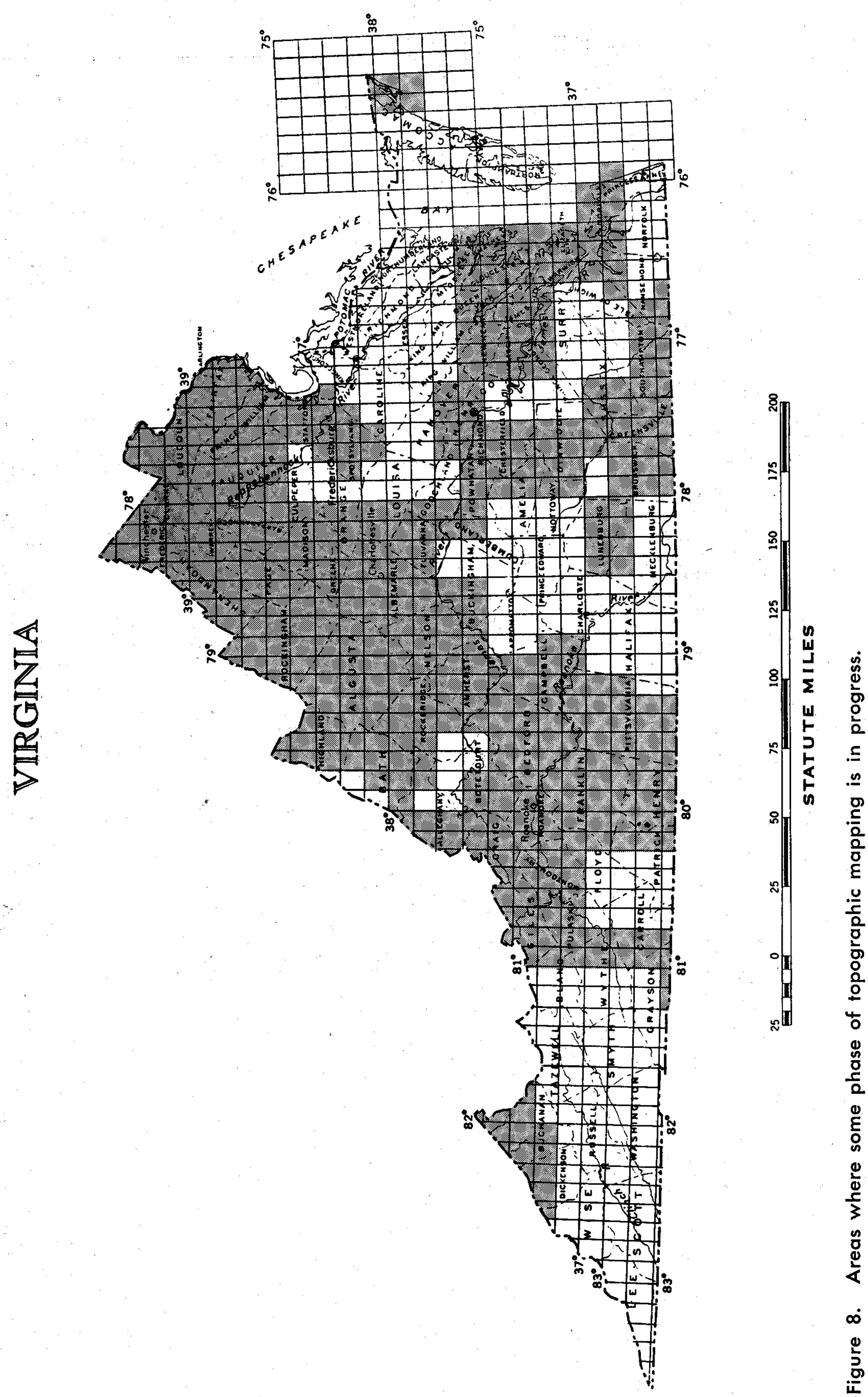

Figure 8. Areas where some phase of topographic mapping is in progress.

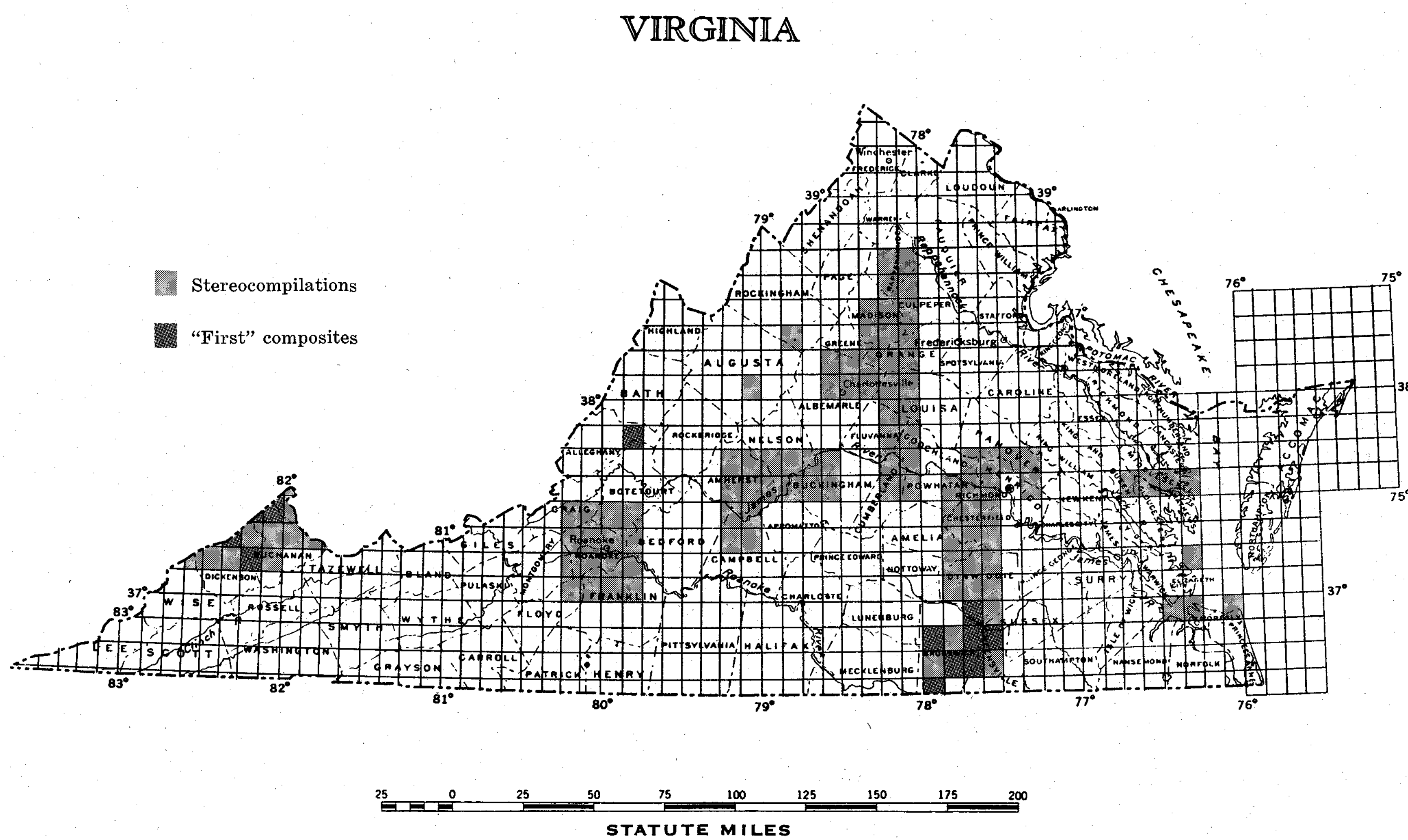

Figure 9. Areas where advance maps are available. Stereocompilations are advance maps that have not been field checked and have no names. "First" composites are advance maps that have been field checked and have names. Advance prints (blue line) of topographical maps are available at 50 cents each from the U. S. Geological Survey, Topographic Division, 1109 N. Highland St., Arlington, Virginia.

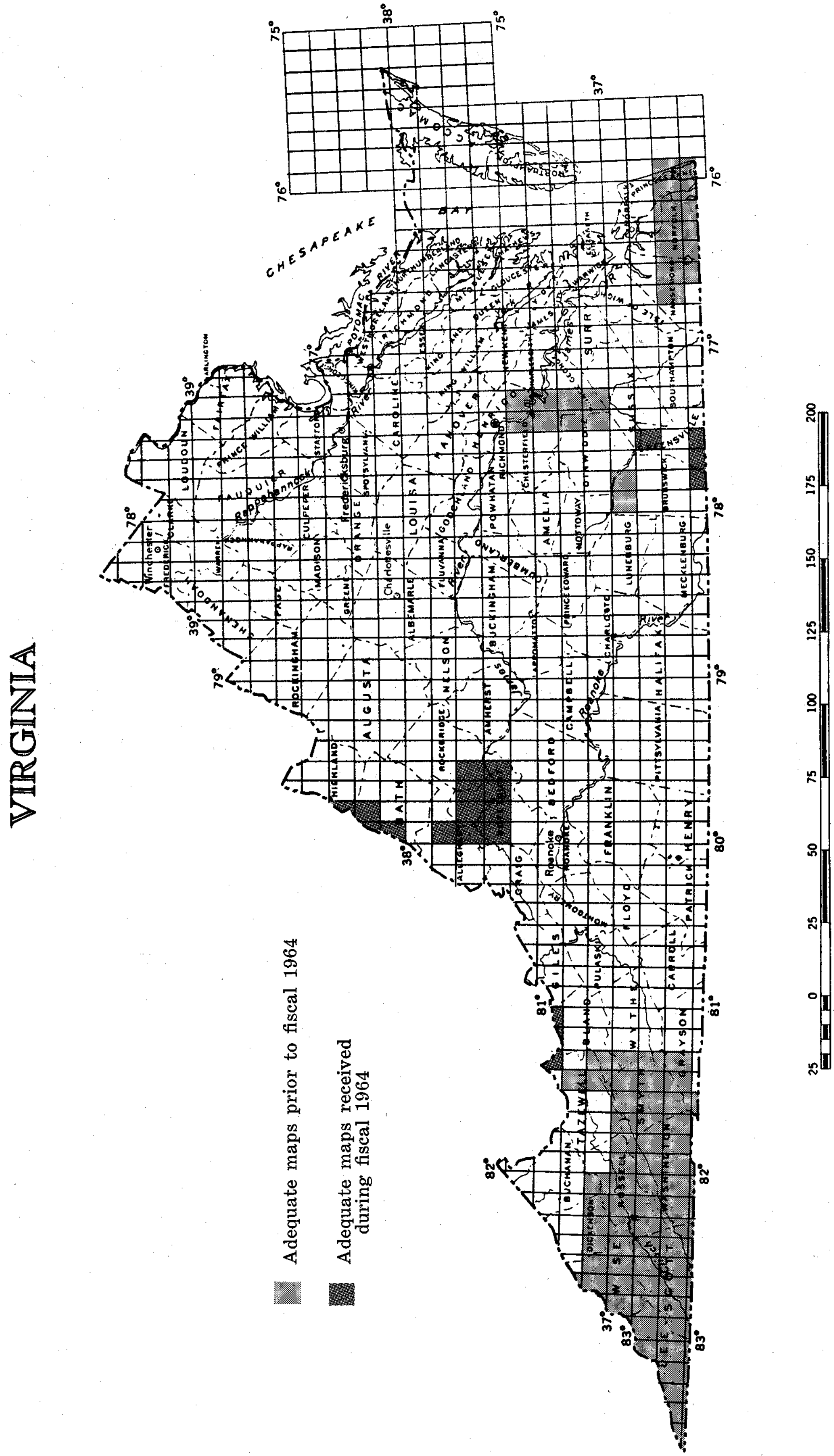

Figure 10. Areas where modern maps are available. Published maps are available at 30 cents each from the Virginia Division of Mineral Resources, Box 3667, University Station, Charlottesville, Virginia. A State index to topographic maps is available free.

New Publications

Bulletin 79. GEOLOGY AND MINERAL RESOURCES OF FLUVANNA COUNTY by James W. Smith, R. C. Milici, and S. S. Greenberg. 62 p., with geologic map in color.

Price: $3.50

Fluvanna County is situated in the central Virginia Piedmont on the southeast limb of the Blue Ridge anticlinorium. The rocks range from the Cambrian or Precambrian Catoctin Formation through the Upper Ordovician Arvonia Formation. The aggregate thickness of this metamorphosed sequence is about 21,000 feet. The lower 13,000 feet of strata are composed of paragonite phyllites and chlorite-muscovite- or muscovite-bearing graywackes, subgraywackes, argillites, phyllites, and quartzose phyllites interbedded with minor amounts of greenstone (metabasalt). The upper 8,000 feet of strata consist of a metamorphosed volcanic and sedimentary rock unit and the Arvonia Formation.

The sequence was folded into asymmetrical and overturned anticlines (Rivanna River, Hardware) and synclines (Columbia, Arvonia, Long Island) near the end of Ordovician time, and the granodiorite batholith was intruded between the time of folding and the end of the Devonian Period. All units were subjected to regional metamorphism near the end of the Mississippian Period. In the western portion of Fluvanna County formations are within the greenschist facies, and in the eastern portion formations are within the almandine-amphibolite facies. Metamorphic grade generally increases from west to east across the county; biotite and garnet isograds were mapped. Triassic diabase dikes generally trend northwestward across northeastward-trending Paleozoic structures. The dikes are composed principally of labradorite, pyroxene, and olivine.

Stone, talc, asbestos, quartz, garnet, gemstones, iron minerals, vermiculite, sand and gravel, clay, and gold occur within the area.

Mineral Resources Report 5. ANALYSES OF CLAY, SHALE AND RELATED MATERIALS—WEST-CENTRAL COUNTIES by James L. Calver, C. E. Smith, and D. C. Le Van. 230 p.

Price: $1.00

This report contains results of tests and determinations of properties required to evaluate the potential ceramic and nonceramic uses of 151 samples of clay, shale, mudstone, slate, phyllite, and schist. A total of 131 localities in Albemarle, Alleghany, Augusta, Bath, Botetourt, Buckingham, Craig, Fluvanna, Highland, Louisa, Montgomery, Nelson, Roanoke, and Rockbridge counties, Virginia are represented.

Information Circular 7. GUIDE TO FOSSIL COLLECTING IN VIRGINIA by Eugene K. Rader. 45 p., with geologic map in color.

Price: $0.75

This publication is designed to serve as a basic introduction to fossils and fossil collecting in Virginia. Twenty-four fossil groups are discussed, and representative specimens from each group are illustrated. Information about equipment, specimen preparation, identification, and classification is included to aid those who wish to assemble fossil collections. Modes of fossil preservation are discussed, and a selected list of books about fossils is included. In addition, a small geologic map in color and a table showing the distribution of fossils by geologic age are provided.

A revised LIST OF PUBLICATIONS AND MAPS is now available from the Division at no cost. This revision contains a listing of all the Division's publications and maps as of July 1, 1964, an index to these publications, and selected other publications on Virginia geology published outside of the Division. Certain price changes have been made in the new list.

Division of Mineral Resources
Box 3667
Charlottesville, Virginia

Form 3547 Requested

Additions to Staff

Mr. T. M. Gathright II joined the Division on June 16, 1964, to assist in ground-water studies. One of his first projects will be to investigate the ground-water conditions in Rockingham County. He received a B.S. degree in geology from Virginia Polytechnic Institute in 1962 and is currently completing his M.S. degree in geology at the same school. While there he worked as a research assistant in seismology. Mr. Gathright is married and has three sons.

Mr. Garnett A. Gatlin was employed by the Division on June 2, 1964, to assist in ground-water studies. Initially he will be concerned with an investigation of ground-water conditions in the Shenandoah National Park area. He received a B.A. degree from the University of Virginia in 1963 and is writing the thesis for his M.A. degree at the present time. Mr. Gatlin previously worked for the Virginia Council of Highway Research and Investigation. He is married and has one son.

Rock and Mineral Collections Available

To promote and stimulate interest in Virginia's mineral resources that are utilized as basic raw materials in industrial processes, the Division is making available a rock and mineral collection similar to that prepared in 1959 for school use. Each set contains 25 specimens of rocks and minerals packed in an attractive display box, a booklet with a description of each specimen, and a general location map. These collections may be purchased at a cost of $5.00 each by residents of Virginia. Order from the Division of Mineral Resources, Box 3667, University Station, Charlottesville, Virginia.