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GEOLOGIC MAPS—THEIR PREPARATION AND USE

C. R. Bruce Hobbs, Jr.

Most of us have had our attention held captive by some rock or stone. Ever stop to think what it represents and why it may be important? Often this attraction to nature's most abundant creation occurred through early association with our surroundings. Initially, we were spurred by a momentary curiosity while pausing along a country road, stream, or shoreline, or resting from work in the yard or field. Rocks and stones are the foundation, floors, and walls of our earthly home; moreover they are the resources from which we provide shelter, transportation, and, in some direct or indirect way, a livelihood. Individually, the prudent man takes stock of his belongings today, and wisely plans for tomorrow. A community, state, or nation can do no less if it is to prosper.

Of concern are the methods by which we are to acquire raw materials to meet everyday needs and at the same time maintain harmony with the environment we live in. Whatever course is pursued there is the one unalterable fact—to plan for the beneficial future of our country we must know what resources are available. It is also important to know how to use them to the best advantage, when to develop them, what mining techniques to employ, and how to cope with changing demands. The geologist, who is trained to recognize and, to some extent, interpret rock structures and landforms, provides the basic framework for mineral resource studies and hence some of the essential data for land-use planning. By drawing upon many scientific techniques and by spending much time in field observations he contructs geologic maps and prepares such information that is valuable to engineers, economists, ecologists, etc.

The geologic map, to simplify a somewhat complex document, is a rock type, distribution, and structure diagram all rolled into one. At the time of preparation it is a compilation of past and present facts about rock types and limits of distribution, commonly indicated by formational boundaries. Often superposed upon such unitized data are structural symbols that indicate how the strata are folded, altered, or broken. In a practical sense, then, the geologic map at the time it is published is an up-to-date inventory of knowledge about rock characteristics for a specific area.

The first attempt to illustrate eastern United States geology, and hence Virginia, was done by William Maclure in 1809. The map from the first extensive survey of the State was made under the direction of William B. Rogers between 1835 and 1841, later published by Jed Hotchkiss in 1874. Since the early 1800's several State maps have been published, the most recent one in 1963. Interestingly enough some of the first local and regional maps were compiled to depict coal, iron, and gold resources in addition to showing distribution of various rock types. In investigations for oil, gas, limestone, clay, shale, sand, gravel, granite, feldspar, and so on, the geologic map has been and is the basic source of information.

PREPARATION OF A GEOLOGIC MAP

The geologist has a certain amount of homework to do before he sets foot in the field to record and compile new data. He determines what previous surveys were made and to what extent they were performed as such information may be useful in solving difficult problems or avoiding unnecessary duplication of effort. Acquaintance with the terrain initially comes by examination of topographic maps and aerial photographs. It is the topographic map that serves as a base upon which the geologic findings are plotted. The "mind's eye," somewhat like a camera lens, begins to imprint upon the memory the geographic location of hills, mountains, plains, valleys, streams, rivers, and man-made features. By looking closely at aerial photographs such land-form patterns as areas of low relief, extensive erosion, linear ridges, trellis-like drainage, irregular shapes, and repetitive geometric forms may be recognized and all of which are indicative of some composition, relative resistance to erosion, or structural characteristic of rocks. After the land surface has been considered, the geologist begins to study what is underneath the ground, by utilizing geophysical or aerial surveys to determine the magnetic, radiometric, and infrared properties of rock units. Again the detection of regular and irregular patterns are sought as well as anomalous measurements that reflect changes in rock type and structure. Other changes are also discernable by using additional geophysical or ground surveys in which gravity, electrical resistance, and seismic properties are measured. Although the search for meaningful data has been mostly paperwork up to this point there is still another kind of reference to be studied, rock cuttings and core obtained from wells and boreholes. This material sampled from regular intervals is prepared for examination with a microscope and then described to determine lithologic properties such as composition, texture, porosity, thickness, etc., of similar rocks. The resulting description is a lithologic, or geologic, log that is a vertical distribution record of units within a well or borehole which has been drilled from several feet to as much as a couple of miles into the ground. In having this information the geologist may be able to compare or correlate similar units from one control point to another, and by doing so, begins to learn the general arrangement of subsurface structure. Often metal "probes" are lowered into wells and boreholes to record electrical, sonic, radiometric, and other physical properties for correlation purposes.

The greatest portion of time used in preparing a geologic map may be spent outdoors in the field searching for rock exposures. They are most likely to be found along stream courses and mountain tops or in man-made features such as quarries and highway or railroad cuts. With a hammer, speical compass, topographic map, and notebook the geologist is generally equipped to gather field data necessary for the construction of the map. At rock outcrops, material can be examined on site or sampled and brought back to the laboratory for additional study. By using the compass certain measurements are taken to determine the attitudes of the strata beneath the surface, that is, whether they are flat, tilted, inverted, folded, or broken. Sediments and their hardened counterparts, sedimentary rocks, generally are deposited in a uniform manner and therefore the sequence of layering is predictable from bottom to top. It is this relationship that signifies whether strata are right side up or upside down. Nature seemingly will play tricks, however, where look-alike strata occur or where interruption of a depositional pattern may lend a reverse appearance to what looks like a normal sequence. Recognition of such conditions does take experience and awareness during field observations. Intruded igneous material formed from molten rock liquid is often more difficult to map as the location of the exposed compositional similarities are unpredictable, because of irregular occurrence. Metamorphic processes can complicate matters further where original composition and texture are altered beyond recognition.

As field measurements are plotted one by one and the location of the various rock types are recorded a picture of their distribution begins to take form. Where one rock of certain composition is adjacent to those of dissimilar character, lithologic or formational contact lines are drawn. Should these lines be offset or missing then fault contact lines are constructed to pinpoint the break. Identification and three-dimensional placement of structure is one of the biggest problems facing the geologist. Even though there are many exposures in a given area of mapping, much of the surface can be covered by soil and vegetation and, to a lesser extent, water and man-made features. Therefore from time to time during a mapping project a continuing review of geophysical surveys, geologic logs, and rock distribution is needed to solve the puzzle. In addition to the foregoing collection of facts and interpretations there is the need to geographically locate active, inactive, and abandoned quarries and mines, potential mineral resources, natural hazards, and some areas for educational purposes. This information is gathered as the geologist moves from one place to another during the mapping project.

USES OF GEOLOGIC MAPS

Once a geologic map is completed and the accompanying report is written, the combination package is ready for use. Classically this product contained descriptions and diagrams of rock types, structure, and areal coverage along with discussions of operating and potential mineral deposits. The inherent value of these maps and reports is not always recognized immediately—take for instance a bulletin published in 1913 on the occurrences of titanium and apatite in Virginia. At the time it was released to the public titanium was being used in the manufacture of steel for railroad tracks, electrodes for arc lamps, and pigments for ceramic and textile items. Little did anyone realize that about fifty years later this metal would become an essential alloy in the construction of heat shields for space capsules. Maps and reports with descriptions of the coal deposits in southwestern Virginia which were prepared between 1914 and 1925 are sought after today for exploration and reserve purposes. Geologic maps are of fundamental importance in providing a systematic knowledge of currently or potentially useful mineral raw materials, thereby directly sustaining the well-being of the State and nation. As a basic inventory of resources they are helpful in sustaining our present mineral demand in that they are used to locate new commercial orebodies and mineral deposits; guide expansion of some already-established mineral producing districts; help with mining, quarrying, or other exploitation of mineral resources; indicate sources of suitable construction materials near urban or developing areas, highway projects, and dam sites; aid in search for materials with limited specifications, such as glass sands, ceramic and cement raw materials, high-calcium limestones, metallurgical quartzite, kyanite; suggest sequences and thickness of rocks having potential for occurrence of oil and gas; aid in delineation, classification, and correlation of coal beds; and locate types of rocks and specific areas favorable to certain kinds of mineralization.

For about forty years geologists have been involved in engineering and planning projects for the municipal and private sectors. Only in the past seven years or so there has been an explosion of interest and concern about our environment. Up until then urbanization and population growth did not pose severe problems or such problems could be ignored because relatively few people were affected. Currently, efforts are being made to translate the more classical approach to dissemination of geologic data into practical everyday terms and applications. Vital to environmental studies by planning groups is the employment of geologic maps to aid in classifying available land for the greatest possible use; help in planning orderly utilization of the various existing natural resources, on the basis of mining, residential, industrial, recreational, or other human needs; aid in planning "sequential land-use" such as extraction of mineral resources where feasible prior to urban or other nonreversible land development; and aid in planning land reclamation procedures concurrent with or following mineral extraction.

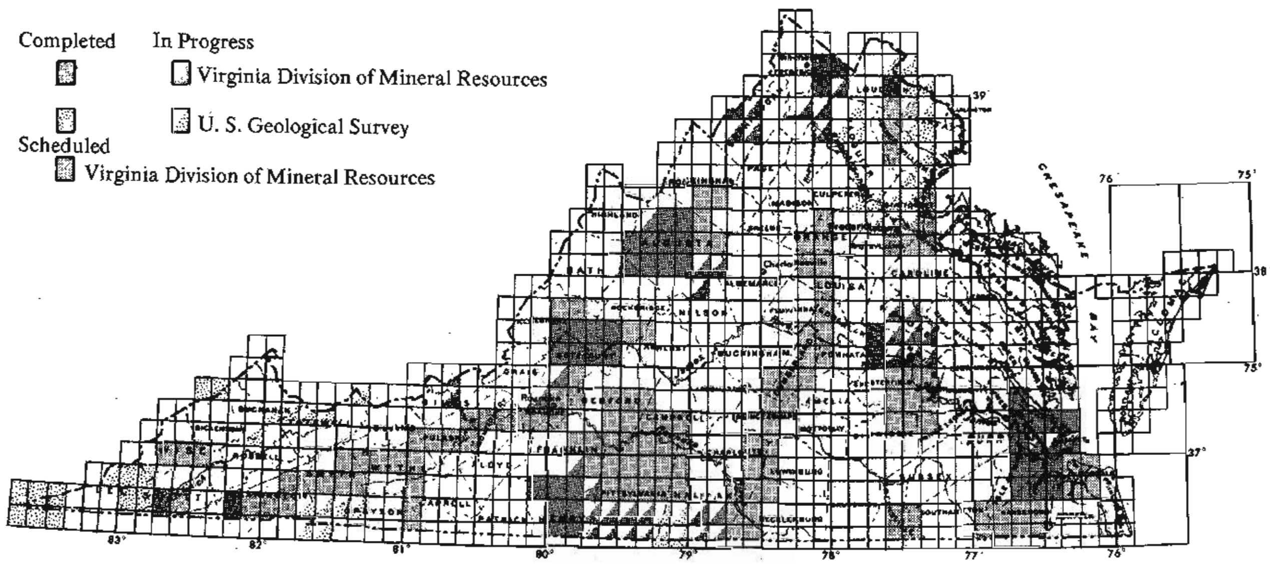
Geologic maps may be used to determine locations of bridges and buildings so that future rock and soil movement do not endanger the lives of people using them, to select areas where the ground is well drained and floods would not impair structures, to provide descriptions of rock characteristics for preparation of building material specifications, to outline areas where construction materials may be immediately available, to provide information that could be used during time of a local disaster where water supplies and underground shelters can be found, and to determine sites where specialized installations such as long range communication systems, nuclear power plants, and industrial parks could be established. For educational purposes geologic maps enhance knowledge of rock types and uses, their effect on the development of land forms, and value of raw materials having economic potential. Thus, individuals are better able to appreciate and understand the landscape around them.

With the undoubted increase in population, the environment in which we live and grow comes more sharply into focus. The well-being and safety of Virginia's citizens is paramount and to this end a practical understanding of our surroundings is essential. Examples of continually reoccurring problems include loss of natural resources through urban development, natural hazards, air and water pollution, development of open space, programs related to the acquisition of land, multiple use potential, home mortgage difficulties, and complex growth of the central city. We are concerned with modern and complicated engineering problems. Rocks and their structure may be either the cause of such problems or the means of resolving them. Geologic information can be most effective in the early stages of land-use planning and development when some problems can be anticipated and avoided before they occur unexpectedly during later stages of commitment. In the later stages alterations are costly and often difficult to resolve. Where there is some degree of flexibility in planning, it is much better to try to fit the uses required to the framework of the land available, rather than to make the land fit the uses.

MAPPING STATUS

The first 1:24,000-scale geologic quadrangle map of Virginia was printed on a modern topographic base which was published by the State 10 years ago, and since that time a total of 44 have been completed. These are color illustrations for 6.5 percent of the approximately 40,000 square-mile area in Virginia. By adding work done by the United States Geological Survey, the total completed coverage is 7.4 percent. As a quadrangle area averages 59 square miles, there are then some 675 "equivalent area" maps that can be used to depict the State. Additionally, there are over 75 geologic quadrangle maps being prepared at the present time (11.5 percent coverage). Areas for which there are geologic maps are referred to in the May 1963 issue of Virginia Minerals, Volume 9, Number 2 for the period 1931 through 1960 and in the November 1972 issue of Virginia Minerals, Volume 18, Number 4 for the period 1961 through 1971. Maps and accompanying geologic reports may be procured from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903 at a cost noted in a list of publications available upon request.

GEOLOGIC MAPPING PROGRAM
STATUS OF 1:24,000 SCALE MAPPING
JUNE 30, 1973



NEW PUBLICATIONS

Bulletin 82. POST-MIOCENE STRATIGRAPHY AND MORPHOLOGY, SOUTHEASTERN VIRGINIA, by Robert Q. Oaks, Jr. and Nicholas K. Coch; 135 p., 2 maps, 33 figs., 6 tables. Price: $2.50.

Mineral Resources Report 12. ANALYSES OF CLAY, SHALE, AND RELATED MATERIALS—SOUTHERN COUNTIES, by Palmer C. Sweet; 183 p., 13 figs. Price: $2.50.

Report of Investigations 32. BOUGUER GRAVITY, NORTHEASTERN VIRGINIA AND THE EASTERN SHORE PENINSULA, by Stanley S. Johnson; 48 p., 2 maps (1 in color), 2 figs. Price: $2.00.

Report of Investigations 33. GEOLOGY OF THE SNOW CREEK, MARTINSVILLE EAST, PRICE, AND SPRAY QUADRANGLES, VIRGINIA, by James F. Conley and William S. Henika; 71 p., 5 maps (3 in color), 30 figs., 1 table. Price: $5.50.

DIRECTORY OF THE MINERAL INDUSTRY IN VIRGINIA—1973, by D. C. Le Van; 51 p. Price: $0.25.

LIST OF PUBLICATIONS (1973), 51 p. No charge.

Note: A four percent (4%) sales tax is required on all publications mailed to Virginia addresses.

IRON SULFIDE MINES IN VIRGINIA

James L. Poole

INTRODUCTION

In the early 1900's Virginia was a leading United States producer of the iron sulfide minerals *pyrite* and *pyrrhotite* that were used extensively in making sulfuric acid, a basic industrial chemical. Several deposits of iron sulfides were discovered and mined in Virginia from 1865 through the early 1920's and Prince William, Stafford, Louisa, and Carroll counties were the scene of extensive mining activity. From 1904-20, Virginia produced 2,306,440 tons of pyrite and pyrrhotite (U. S. Geological Survey, 1904-20). During this period, the State's part of the total annual U. S. production ranged from 28.3 to 61.5 percent. After the widespread adoption of the Frasch Process in the early 1920's by which elemental sulfur is obtained from the *in situ* dissolution of sulfur beds at depth, production of iron sulfides in Virginia dropped off until the Gossan mine in Carroll County was the only producer. Large-scale production ceased at the Gossan mine in 1966, but smaller, intermittent production has continued to the present time at a nearby surface pit. In 1970, iron sulfides accounted for less than 5 percent of total U. S. production of sulfur in all forms.

Pyrite (FeS_2) is an ubiquitous mineral that occurs in sedimentary, igneous, and metamorphic rocks. Pyrrhotite ($Fe_{1-x}S$) is less common than pyrite and is found most commonly in basic igneous and some metamorphic rocks. Pyrite and pyrrhotite are similar in composition but are easily distinguished. Pyrrhotite is softer (hardness 3.5-4.5 on Mohs hardness scale), bronze - to light-yellow with a metallic luster, and is usually fine grained with little or no apparent crystal structure. The mineral is often slightly magnetic, this characteristic varying with the iron content. Pyrite is measurably harder (6-6.5), bright brassy yellow in color (hence the name *Fool's Gold*), non-magnetic, and commonly occurs as small individual cubic crystals or masses of crystals.

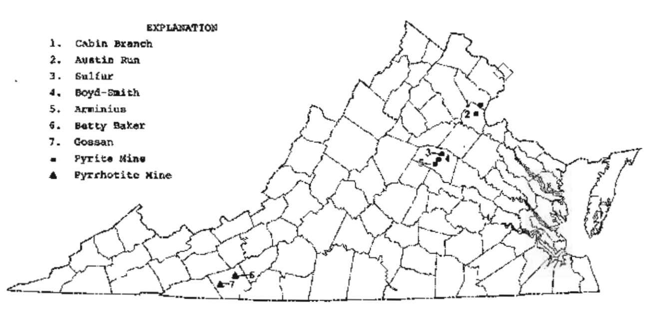


Figure 1. Iron sulfide mine locations in Virginia.

Sulfuric acid is a basic industrial chemical that has a very wide range of uses. It is used in manufacturing most sulfate compounds, glass, soap, bleaches, many industrial acids, textiles, paper, dyes, medicine, sugar, rubber, starch, syrup, leather, and fertilizer. Other uses include the refining of precious metals, uranium, and petrolem; leaching of mine dumps; and cleaning (pickling) of sheet metals.

VIRGINIA DEPOSITS

Seven prominent mines have been operated for pyrite or pyrrhotite in Virginia (Figure 1): the Cabin Branch, Austin Run, Sulfur, Boyd-Smith, and Arminius mines in the Piedmont province, and the Betty Baker and Gossan mines in the Blue Ridge province. The deposits are similar in that they are massive sulfides that occur as veins or lens-shaped bodies that are generally parallel to the local foliation or schistosity of the country rock. A massive sulfide may be defined as ". . . any solid compact mass of pyrite and/or pyrrhotite commonly containing one or more sulfides of copper, lead and zinc." (Anderson, 1969, p. 130). Massive sulfides, such as those in Virginia, commonly occur in metamorphic rocks.

Ideas concerning the mode of origin of mineral deposits are important because they are the basis for exploration theories that may be applied in the search for new deposits. The ideas have ranged from an epigenetic origin, in which the sulfide deposits are considered to have formed after the enclosing rock, to syngenetic origins, in which the sulfides are believed to have formed simultaneously with the enclosing rock.

From the viewpoint of the epigeneticist there have been two predominant theories for the origin of Virginia massive sulfides. One formation has been attributed to the replacement of limestone by sulfides (Watson, 1907, p. 197). Precipitation of sulfides from hydrothermal (warm, aqueous) solutions derived from intrusives of Cambrian age is suggested by Lonsdale (1927, p. 96-101) for those deposits in the northern portions of the state. The opposing view of the syngeneticist is well exemplified by the statement of Kinkel (1967, p. 55) ". . .the similarity of all Appalachian sulfide deposits, the parallelism of many deposits to bedding, the lack of correlation between sulfide-rich areas and intrusive rocks, and the presence of layers of sulfide-rich sediments in the eugeosynclinal rocks of the Appalachian mineral belts suggest primary deposition with the sediments."

PYRITE—PRINCE WILLIAM, STAFFORD, AND LOUISA COUNTIES

The general geology of the ore bodies that were mined in Prince William, Stafford, and Louisa counties is very similar, so that similar mining techniques were employed. An inclined shaft was sunk in the ore body and changes in attitude of the body resulted in a corresponding change in shaft attitude. Drifts (tunnels or levels) were driven from the shaft into the ore parallel to the strike or long horizontal dimension of the ore body. The individual drifts were connected by raises or winzes for passage between levels. The most common mining method was overhand stoping. By this method ore was worked from below and mining proceeded upward, the broken rock being removed by car to the shaft where it was hoisted to the surface. In 1907, Watson (p. 204) reported that timbering was not commonly needed in these mines because the rock was strong enough to support mining activity. The Cabin Branch mine, however, required timbering in stopes (areas of extracted ore) where the country rock was weak.

Cabin Branch mine, also known as the Dumfries mine (Luttrell, 1966, p. 30), is located approximately 1.5 miles northwest of Dumfries on Quantico Creek in Prince William County (Figure 1). It was opened in 1889 but did not attain continuous production until 1908. The mine ceased production in 1920 and was abandoned. After the mine closed the property changed ownership and was later sold to the National Park Service, and became part of the Prince William Forest Park. During the early period of the park the Civilian Conservation Corps dismantled most of the old mine buildings and used the dump and tailings as road metal. As a result, there is little to show for the one-time large mining operation. Four caved shafts, however, can be seen downstream along Quantico Creek.

Three major shafts were used in the mining operations. Two of the shafts were vertical and the third was inclined 25°-55° depending on the dip of the ore. The vertical shafts were shallow but the inclined shaft reached a depth of 1000 feet.

The mineralization of the mine consists of a lens of pyrite, which ranges in thickness from 5 to 10 feet, exceeds 1000 feet in length, and is concordant with the schistosity of the enclosing rock. The strike of the lens is N.10-20°E. and the dip is to the northwest at 25-55°. Contacts of the ore with the wallrock are sharp on both the footwall and hanging wall (Lonsdale, 1927, p. 86). The ore mineral at this mine was predominantly pyrite, with very minor pyrrhotite. Other sulfide minerals present are chalcopyrite, galena, and sphalerite with small amounts of gold and silver determined by assay. Gangue (waste) minerals are hornblende, chlorite, biotite, epidote, garnet, quartz, tourmaline, and calcite. Pyrite, quartz, and tourmaline were formed at the same time and postdate the schistose country rock (Lonsdale, 1927, p. 86-87).

The pyrite obtained from the Cabin Branch mine was used exculsively for the manufacture of sulfuric acid. The average grade of the pyrite ranged from 43 to 45 percent sulfur (Watson, 1907, p. 196). From 1908-20, a recorded total of 207,262 tons of pyrite was produced. Some copper was produced as a copper matte from hand-picked chalcopyrite (Lonsdale, 1927, p. 87). Copper was also recovered from the mine waters by submerging scrap iron and plating copper onto the surface.

Austin Run mine, also known as the Garrisonville, Fer-Sul, or Old Dominion mine (Luttrell, 1966, p. 12), is located in Stafford County approximately 1.75 miles southeast of Garrisonville (Figure 1). The Austin Run mine was opened in 1906 and was worked intermittently until 1920.

The mine was reportedly developed from one shaft 650 feet deep. A shaft, with a concrete collar, can be seen 40 feet west of State Road 684 on top of a hill. From 1908-20, a recorded total of 3876 tons of pyrite was produced (Lonsdale, 1927, p. 10).

The ore at the mine, as described by Lonsdale (1927, p. 90), "occurred in lenses and stringers over a width of several feet. In some places small areas were composed almost entirely of pyrite, but for the most part the ore was a mixture of schist and pyrite in which the whole mass was mined." The mineral occurs as fine disseminations in the country rock and as medium-grained euhedral to subhedral crystals in a quartz matrix. In the latter occurrence pyrite constitutes as much as 50 percent of the rock. The origin of this quartz-pyrite assemblage is unknown. Two rock types were found to predominate on a dump (Kinkel, 1967, p. 39-40). The most common type is chlorite-sericite schist containing randomly oriented hornblende crystals lying across schistosity. The second type is described as a quartz-sericite schist with lenticular, blue to glassy quartz grains that is believed to represent a sheared rhyolite or rhyolitic crystal tuff.

Sulfur mine, also known as the Crenshaw or Victoria Furnace mine (Luttrell, 1966, p. 125), is in Louisa County, 4 miles northeast of Mineral (Figure 1). Activity at the Sulfur mine began with the production of gossan iron ore in 1840. Gossan mining continued at the site until 1877, with some pits as much as 60 feet deep and some underground workings. In 1881 the first shaft was developed for underground mining of pyrite and by 1884 mining had attained a large scale with the addition of several new shafts. The mine, however, was forced to close in 1922 (Luttrell, 1967, p. 125) when sulfur produced on the Gulf Coast became too competitive.

The Sulfur mine consisted of eight shafts, with a mine depth of 720 feet, and other extensive underground works. The main shaft, sunk in 1882, was a 6 x 14-foot, dual-compartment shaft for dual hoisting. Several more shafts were subsequently developed along the ore zone, all on the east side of Contrary Creek.

The ore at the Sulfur mine occurs in lenses that are concordant with the foliation and lineation of the country rock. The lenses are several hundred feet long, 40 to 50 feet thick, and occur next to and overlapping one another. The strike of the lenses is generally N. 25°E., and surface dips of 65°SE decrease in the mine to 35°SE (Katz, 1961, p. 12). The ore minerals at Sulfur mine were pyrite and minor pyrrhotite. Chalcopyrite, sphalerite, and galena occur in minor amounts but were not generally recovered. As at the other mines, the chief product was pyrite for the manufacture of sulfuric acid. Small amounts of copper in the mine water were plated on scrap iron. The gangue minerals were quartz, chlorite, magnetite, calcite, amphibole, and feldspar. The country rock near the mine is a quartz-sericite schist with some layers of chlorite schist. The schists are probably metamorphosed sedimentary rocks, although some layers appear to be water-lain rhyolitic and mafic tuffs. The beds are isoclinally folded and there appear to be two periods of metamorphism of the ore and a period of post-ore faulting (Kinkel, 1967, p. 36).

Remnants of the former activity at the Sulfur mine can be found for approximately 1100 feet on both sides of Contrary Creek. At least five shafts can be easily found; Katz (1961, p. 29), however, reports eight to be present. Foundations for several buildings and the remains of several wooden structures such as the tramway, tipple, and mill buildings can be seen (Figure 2). A water-filled hole near the main shaft is approximately 225 feet long and 150 feet wide and is believed to be an extension of the gossan pit or a collapsed section of old mine workings. A steep-sided trench, from which gossan was mined, extends through most of the mine area, with parallel trenches occurring within 150 feet. Waste rock and tailings are present on both sides of Contrary Creek although the mining was done on the south side of the creek.

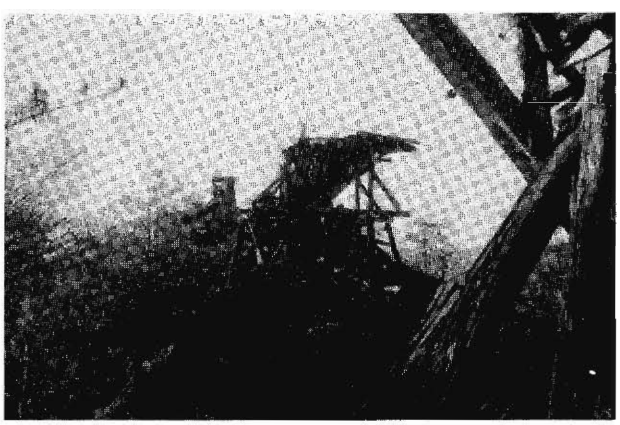


Figure 2. Wooden structures near the main shaft, Sulfur mine, Louisa County.

Boyd-Smith mine, also known as the Smith, Lennig, or Groome mine (Luttrell, 1966, p. 24), is in Louisa County approximately 2.25 miles northeast of Mineral and 1300 yards southwest of the Sulfur mine (Figure 1). Gossan iron ore was mined as early as 1845. The 1880's saw the advent of pyrite mining from the Boyd-Smith mine and it was operated continuously from 1886 to 1906 for pyrite and some copper but was closed because of litigation. The mine was sold in 1913 and reopened in 1915. It was closed again in 1922 (Luttrell, 1966, p. 24-25). In 1946 the U. S. Bureau of Mines drilled a 400-foot vertical exploratory hole on the Boyd-Smith property but encountered only disseminated pyrite. The low mineralization in the first hole precluded drilling a second (Hickman, 1947, p. 2).

Very little is known about the mine workings at the Boyd-Smith but in 1906 the mine was operated from three shafts, with a mining depth of 300 feet, five working levels, and a surface mill (Watson, 1907, p. 201). Two caved shafts, one wooden structure, several foundations, a waste dump, and the former tailings pond are all that remain of the operation.

The sulfide minerals are similar in appearance both mineralogically and texturally to those at the Arminius and Sulfur mines. The predominant sulfide is pyrite with lesser amounts of chalcopyrite, sphalerite, and galena. The sulfides occur as medium-grained masses that commonly comprise 90 percent of the rock. Samples of waste rock on the dump range from schist to gneiss; nonmetallic minerals include quartz, feldspar, amphibole, biotite, chlorite, and sericite.

Arminius mine is located in Louisa County approximately 1.5 miles northeast of Mineral and 1200 yards southwest of the Boyd-Smith mine (Figure 1). The Arminius mine was first opened in 1834 as a gossan iron-mining operation, the ore being smelted at the Rough and Ready Furnace located on the property. Copper mining began in 1847 with the extraction of the copper-enriched zone at the base of the gossan. Pyrite and some copper were produced from 1865 to 1888 and 1894 to 1921 (Luttrell, 1966, p. 11). The U. S. Bureau of Mines conducted a self-potential geophysical survey of the property in the mid-1940's but no follow-up work was done (Hickman, 1947, p. 2). The New Jersey Zinc Company purchased the property in 1953 and conducted a geochemical and geophysical program with some diamond drilling.

The mine was worked from four steeply inclined shafts. The main shaft was reported to be 1060 feet deep with eight working levels. Pyrite occurs in lens-shaped bodies that are generally concordant with the schistosity of the country rock and have a strike of N.20°E. and a general dip of 63° to the southeast. Individual lenses are generally large, averaging 20 feet thick and several hundred feet long; the largest is 61 feet thick and 700 feet long (Watson, 1907, p. 200).

The sulfide mineralization consists of coarse-grained subhedral to euhedral pyrite and sphalerite grains with irregular shaped masses of galena and chalcopyrite. Gangue minerals include calcite, quartz, amphibole, garnet, biotite, and feldspar. All but biotite and feldspar are common interstitial minerals in the ore and comprise from less than 10 to more than 70 percent of the rock. The main country rock of the area is described by Kinkel (1967, p. 37-38) as gray mica gneiss that changes mineralogy across strike but is consistent along strike. He believes these lithologies to be metamorphosed sediments with possible interbedded tuffs.

Three small buildings can be found at the Arminius mine, two of which are located near the shaft. One of these served as the hoist building and the concrete foundations for the hoist drum can be seen in the floor. The shaft is covered and the foundation for the head-frame and shaft collar are intact. Settling ponds on three levels are present just north of the mine and the dump surrounds the mine on three sides.

PYRRHOTITE—GOSSAN LEAD DISTRICT

The Gossan Lead occurs in the Lynchburg Gneiss of the Blue Ridge province in Carroll and Grayson counties. These sulfide deposits are a series of veins or lenses that occur along a northeast trend for more than 17 miles. The predominant sulfide in the lenses is pyrrhotite with some pyrite, sphalerite, chalcopyrite, and galena. Corriveau (1956, p. 15) estimated the total reserves of sulfide and included gangue in the Gossan Lead District to be 180 to 200 million tons.

Two mines in the Gossan Lead produced pyrrhotite: the Betty Baker prior to 1907 and the Gossan continuously from the early 1900's to 1962. Since that time pyrrhotite for captive use has been produced from a small surface opening south of the underground workings of the Gossan mine.

Betty Baker mine is in Carroll County approximately 6.5 miles north of Hillsville (Figure 1). The mine was first operated in 1854 for copper. As with most mines in the Gossan Lead the copper ore was obtained from the zone of secondary enrichment at the base of the gossan and above the primary sulfide zone. The mine was worked intermittently for gossan iron ore after the Civil War. Prior to the mine closing in 1900, about 1800 tons of pyrrhotite ore were shipped to Winston-Salem, North Carolina, to produce sulfuric acid (Weed, 1911, p. 122). The property was later purchased by the Virginia Iron, Coal and Coke Company, which drilled 24 holes totaling 9277 feet in 1927-28. The U. S. Bureau of Mines drilled seven core holes totaling 3838 feet in 1947 to further determine the extent of the deposit along strike and to the southeast (Kline and Ballard, 1949, p. 11). Several more holes were drilled by the Virginia Iron, Coal and Coke Company in 1947 and 1948, which extended the sulfide deposit along strike. Reserve calculations done by Corriveau (1956, p. 15) showed that the Betty Baker property contained a maximum of 7,500,000 tons of sulfide and contained gangue.

Most of the mining done at the Betty Baker was open-cut or trench mining for gossan. In 1905 the Virginia Iron, Coal and Coke Company developed an inclined shaft 84 feet deep at the base of the lens. Two levels were driven out from the shaft at the 40- and 80-foot levels. These workings, tunnels in the gossan, and various pits and trenches are the known extent of mine workings on the property.

The Betty Baker mine is on the northeasternmost extension of the Gossan Lead mineralized zone. The deposit has a strike of N.45 E. and southeast dips of 40° to 60°. The sulfide minerals are very fine-grained pyrrhotite, and minor amounts of pyrite, sphalerite, chalcopyrite, and galena. The country rock is generally a fine to medium-grained quartz-mica schist, probably of sedimentary origin. The nonmetallic minerals include quartz, feldspar, biotite, sericite, amphibole, chlorite, and spessartite (garnet).

Very little can be seen on the property today except for a northeast-trending trench that ranges in depth from 5 to 35 feet and is 2 to 15 feet wide at the bottom. The trench is essentially continuous for 5600 feet except where interrupted by two roads and a stream. Iron gossan is found at several sites in the trench and primary sulfides can be seen at two sites.

Gossan mine, also known as the Chestnut Yard, Great Outburst, Iron Ridge, or Monarat mine (Luttrell, 1966, p. 70) is on Iron Ridge in Carroll County approximately 3.5 miles north of Galax (Figure 1). The site of the Gossan mine was first opened in the 1780's for gossan iron ore, which was smelted at a nearby furnace. From 1850-59 supergene copper ore was mined at the Great Outburst mine. Gossan iron-ore mining was resumed in the 1880's and the mine soon became one of the largest iron-mining operations in Virginia (Luttrell, 1966, p. 71). In 1892 iron ore production is reported to have reached 800 to 1000 tons per day from a series of open cuts extending 1500 feet along strike. By 1900 the operations were forced to cease because the mining had reached the primary sulfide under the iron gossan (General Chemical Division, 1962, p. 2).

The General Chemical Company (now Allied Chemical Corporation) mined pyrrhotite from 1905-35 from two open pits, the Huey and the Bumbarger. In 1925 underground mining began and by 1962 there were seven working levels with a total mining depth of approximately 700 feet. The mining was by the room and pillar method and by shrinkage stoping. Most of the ore was shipped to a company plant in Pulaski, Virginia, to be used in the manufacture of sulfuric acid. Underground mining operations ceased in 1962. Since that time the Allied Chemical Corporation has worked a surface pit intermittently for pyrrhotite as required for captive use. In the 57 years of mining, 5,807,000 tons of pyrrhotite ore were extracted. The ore assayed between 26 and 28 percent sulfur until the last few years when the sulfur content dropped to 24 percent. After milling the concentrate grade was a consistent 33.2 to 33.5 percent sulfur. The copper and zinc values of crude ore ran 0.50 to 0.55 percent and 0.40 to 0.45 percent respectively, but these metals were not extracted as byproducts (General Chemical Division, 1962, p. 1-11).

Similar to other sulfide bodies of the Gossan Lead, the deposit at the Gossan mine is lensoid-shaped and has a strike of approximately N.45°E. and a dip of 30°-60° to the southeast. The lens is concordant with surrounding country rock which is predominantly gneiss and mica schist. The principal sulfide minerals are very similar in texture to those at the Betty Baker mine and are pyrrhotite, pyrite, chalcopyrite, sphalerite, and galena. The major gangue minerals are quartz, feldspar, biotite, chlorite, garnet, kyanite, and amphibole.

The mine area on Iron Ridge has five distinct openings into the sulfide body. The southwesternmost opening is the present-day open pit which is relatively small. The Huey and Bumbarger pits were opened prior to 1925 and can still be seen. The Huey pit, which is the closer to the present-day pit, is approximately 100 feet deep with vertical walls. The sulfide lens can be seen in one face of the pit and there are several adits in this face that follow the lens underground (Figure 3). The Bumbarger pit, further northeast, is closer to the Gossan mine (underground mine) and the sulfide lens is exposed in two faces and the floor of the pit; adits in two faces follow the sulfide underground. Extensive tailings and dump cover most of the area in the vicinity of the underground mine. Several concrete foundations are present and the old hoist building is intact with two hoisting drums in place. The northeasternmost section of the Gossan mine is an adit at Chestnut Yard. The ore body is not exposed here but a small dump evidences the adits use as an opening to the ore body. Throughout most of the area on Iron Ridge old gossan trenches can be seen, most commonly in the mine area and around the open pits. The trenches are generally not more than 10 feet deep and are 15 to 25 feet wide at the bottom.

Figure 3. Adits at the Huey pit, Gossan mine, Carroll County.

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OIL AND GAS DEVELOPMENT IN VIRGINIA DURING 1972[1]

A total of 2,801,913 Mcf (thousand cubic feet) of natural gas was produced in Virginia during 1972, which is an increase of 168,937 Mcf from 1971 production. Reported production was from five counties: Buchanan County, 1,084,366 Mcf; Dickenson County, 400,460 Mcf; Russell County, 4,535 Mcf; Tazewell County, 1,305,093 Mcf; and Wise County, 7,459 Mcf. Oil production in Lee County was 97 barrels from one well.

Twenty-three tests were drilled during the year. Columbus Gas Transmission Corporation drilled twenty of these wells in Buchanan and Dickenson counties with combined footage of 93,139 feet. One test was drilled by Ashland Oil, Inc. in Buchanan County, and two tests drilled in Charles City County by Ernest Lippert, bringing the total footage drilled during 1972 to 101,329 feet.

Of the twenty wells drilled by Columbia Gas Transmission Corporation, thirteen were completed in 1972 and early 1973 with a combined total openflow of 25, 172 Mcf after treatment of Berea, Maxon, and Ravencliffe sands and Big Lime (Greenbrier). As of June 8, 1973, four wells were still waiting on fracture treatments, and one test drilled to the Clinton Formation was temporarily abandoned after treatment. Two wells were plugged and abandoned during 1972 and 1973.

Four operators in Buchanan County produced 1,084,366 Mcf of gas: Ashland Oil, Inc., 513,294 Mcf; Cabot Corporation, 34,061 Mcf; Columbia Gas Transmission Corporation, 489,758 Mcf; and P & S Oil and Gas Corporation, 47,253 Mcf. Seventeen wells were drilled in Buchanan County by Columbia Gas Transmission Corporation with a combined total openflow of 18,770 Mcf. One well drilled by Ashland Oil, Inc. had an openflow of 1700 Mcf. Footage drilled totaled 98,079 feet.

In Dickenson County the Clinchfield Coal Company delivered 346,263 Mcf of gas to lines of the Kentucky-West Virginia Gas Company and used 390 Mcf in field operations. Columbia Gas Transmission Corporation produced 53,807 Mcf to give Dickenson a total production of 400,460 Mcf. Three new wells were completed in Dickenson County by the Columbia Gas Transmission Corporation with an openflow after fracture of 5,757 Mcf. Total footage drilled was 12,054 feet.

In Lee County oil production totaled 97 barrels from one well in the Rose Hill field. There was no drilling or workover activity in Lee County during 1972, although a few wells are still waiting on stimulation attempts or plugging.

The Clinchfield Coal Company used 4,535 Mcf from one of their wells in Russell County at their Carbo Lightweight Aggregate plant.

Tazewell County continued as the leading gas producer in Virginia during 1972 with a total of 1,305,093 Mcf as reported by two operators: Consol-Ray Resources, 914,374 Mcf, and Columbia Gas Transmission Corporation, 390,719 Mcf. There was no drilling activity during the year. The Westmoreland Coal Company produced 7,459 Mcf of gas for local use from two wells in Wise County.

In 1972 Ernest Lippert drilled two test wells in Charles City County southeast of Richmond to depths of 850 feet and 2,426 feet. Both wells were plugged and abandoned.

[1] Information supplied by Everett J. Dishman, Jr., Virginia Division of Mines and Quarries.

VIRGINIA GEOLOGY FIELD CONFERENCE

The fifth annual Virginia Geology Field Conference will be held in the Martinsville area on November 2-4, 1973. J. F. Conley and W. S. Henika will be field trip leaders. Rocks of the western Piedmont, including the Blue Ridge anticlinorium, Smith River allochthon, and Sauratown Mountains anticlinorium, will be examined. This conference is sponsored by the geology section of the Virginia Academy of Science for all people interested in earth science of the Commonwealth. To be placed on the mailing list to receive later information about this conference, contact H. W. Webb, Conference Secretary, at the Virginia Division of Mineral Resources, Box 3667, Charlottesville, Virginia 22903.

Table 1.—Summary of Virginia drilling during 1972.

Operator	Lease	Well No.	Total Depth (feet)	Status (6-1-73)
Buchanan County				
Ashland Oil, Inc.	Lon B. Rodgers	5054	4,923	Gas well
Columbia Gas Transmission Corp.	H. Claude Pobst	9638	4,056	Gas well
"	J. L. Elswick	9646	3,860	Gas well
"	Bull Creek Coal Co.	9678	2,440	Gas well
"	H. Claude Pobst	9679	4,031	Gas well
"	The Pittston Co.	9680-T	5,760	Gas well
"	H. H. Deel	9681	4,645	Gas well
"	G. P. Belcher	9685	3,965	Gas well
"	J. L. Elswick	9686	5,156	Plugged and abandoned
"	J. L. Elswick	9687	4,230	Gas well
"	R. C. and D. H. Bell	9688	4,345	Waiting on testing
"	The Pittston Co.	9690	4,545	Waiting on testing
"	The Pittston Co.	9691	4,542	Waiting on testing
"	G. C. Charles	9692	4,412	Gas well
"	Sidney Looney	9701	4,302	Gas well
"	John W. Pobst	9719-T	6,772	Waiting on testing
"	L. R. Wyatt	9721-T	6,740	Plugged and abandoned
"	John W. Pobst	9722-T	7,296	Temporarily abandoned
Charles City County				
Ernest Lippert	Clarence D. Gaddy	1-A	850	Plugged and abandoned
"	Clarence D. Gaddy	1-B	2,426	Plugged and abandoned
Dickenson County				
Columbia Gas Transmission Corp.	The Pittston Co.	9644	3,988	Gas well
"	The Pittston Co.	9689	4,561	Gas well
"	The Pittston Co.	9714-T	3,493	Gas well

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CALVER PRESIDENT-ELECT

Dr. James L. Calver was chosen President-elect of the Association of American State Geologists meeting on May 30, 1973 at Stone Mountain, Georgia. The annual meeting of the Association was attended by the State Geologists of 43 states. Dr. Calver, head of the Division of Mineral Resources of the Department of Conservation and Economic Development, has been State Geologist of Virginia since 1957. The Association meets yearly with members of Federal agencies to be informed of plans and projected work schedules of the U. S. Geological Survey, U. S. Bureau of Mines, Department of Housing and Urban Development, and other Federal agencies. Key topics of discussion during the four-day meeting included topographic and geologic mapping, evaluation of high altitude and space photography, energy, conservation of the environment, and computer methods for recovery, analysis, and dissemination of geological and mineral resources data.

Dr. Calver served as Editor of the Association's Journal from 1965 to 1971. That publication is devoted to the organizational structure, facilities, activities, accomplishments, and publications of the various State geological surveys and their cooperative programs with Federal agencies.

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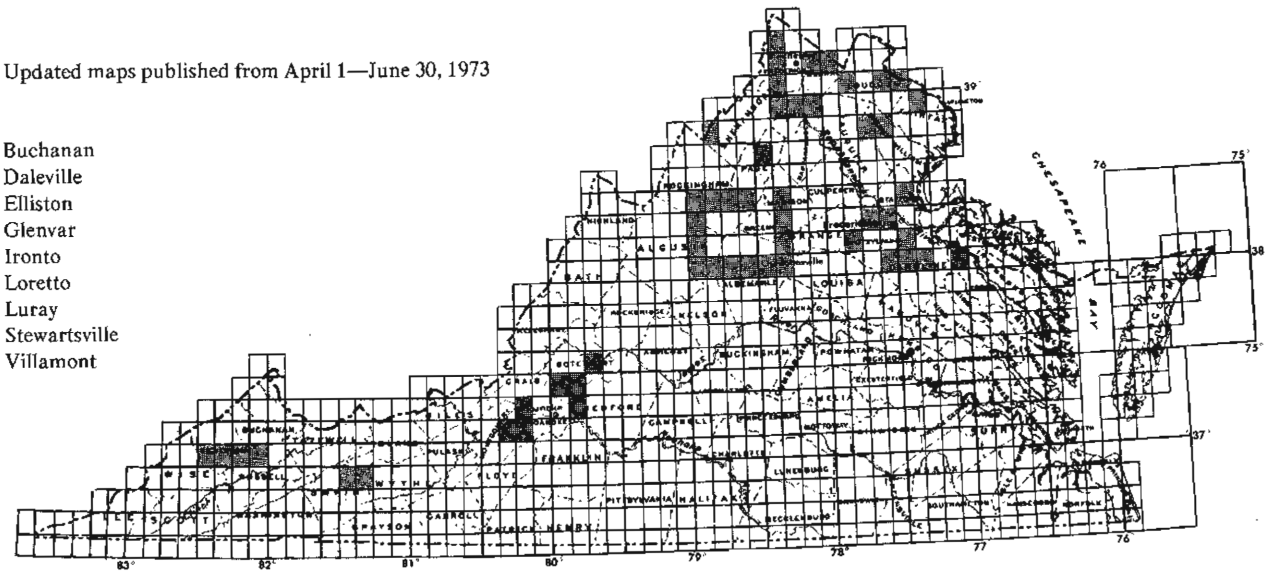

PUBLISHED MAPS

State index is available free. Updated maps, on which recent cultural changes are indicated, are now available for certain areas of industrial, residential, or commercial growth. Published maps are available at 75 cents each (plus 4 percent state sales tax for Virginia residents) from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903.