PRODUCTION OF IRON SULFIDES IN VIRGINIA

INTRODUCTION

In the early 1900's Virginia was the leading producer of iron sulfides in the United States. These minerals were extensively used at that time in making sulfuric acid, a basic industrial chemical and two iron sulfide minerals, pyrite (FeS_2) and pyrrhotite ($Fe_{1-x}S$) were important domestic raw materials used for this purpose. These minerals are often referred to commercially as pyrites. Several relatively large deposits of iron sulfides were discovered and exploited in Virginia in the 1800's and early 1900's. During this period parts of Prince William, Stafford, Louisa, and Carroll counties were the scene of extensive mining activity. After the widespread adoption of the Frasch Process, by which elemental sulfur is obtained from the *in situ* dissolution of sulfur beds at depth, production of iron sulfides declined and currently only a small tonnage is produced in Virginia. At present iron sulfides represent less than five percent of sulfur in all forms produced in this country, whereas sulfur from the Frasch Process makes up 74 percent. Recovered sulfur (15 percent) and by-product sulfuric acid (6 percent) make up the remainder of the production of sulfur in all forms (Merwin, 1972, p. 1059-1063).

Mining operations for iron sulfides began as early as 1866 in Virginia and the State was a leading producer from 1904 to 1920. In 13 of these 16 years of greatest activity, the State produced more than 20 percent of the total annual U. S. production of pyrites (Table 1). From 1904 to 1912 Virginia produced at least 46 percent of the total U. S. production and in five years of this period production exceeded 50 percent (Table 1). The highest production was in 1917 when 170,382 long tons were produced. This increase of almost 38,000 long tons over the previous year coincides with the U. S. involvement in World War I and probably reflects the increased industrial effort brought on by a war. The lowest production of the 16-year period came in 1920 when only 100,545 long tons were recovered, corresponding to the increased production of less-expensive sulfur by the Frasch method. After the early 1920's production of iron sulfides in the United States dropped off appreciably because of this competition. In 1970 iron sulfides accounted for less than 5 percent of the total U. S. production of sulfur in all forms. Similarly, production of iron sulfides in Virginia dropped off in the early 1920's 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.

Table 1. Virginia pyrites production (U. S. Geol. Surv., 1904-1920).

Year	Quantity in long tons	Value in dollars	Percent of U. S. tonnage
1865-1903	na	na	na
1904	120,671	440,753	58.2
1905	123,183	426,008	48.6
1906	128,794	431,388	49.2
1907	124,740	372,586	50.4
1908	116,340	435,522	52.2
1909	114,176	423,238	46.2
1910	148,653	565,358	61.5
1911	150,800	558,494	50.0
1912	162,478	621,219	46.2
1913	148,259	587,041	43.4
1914	141,276	556,091	41.9
1915	145,050	729,644	36.8
1916	148,502	925,243	35.0
1917	170,382	1,378,043	36.8
1918	143,427	841,177	30.8
1919	119,164	891,308	28.3
1920	100,545	610,085	32.3
1921-1973	na	na	na
Recorded total	2,306,440	10,793,198	—

na - Not Available

Pyrite is an ubiquitous mineral that occurs in sedimentary, igneous and metamorphic rocks. Pyrrhotite is less common than pyrite and is found most frequently in basic igneous rocks and some metamorphic rocks. Pyrite and pyrrhotite are very similar in composition (Table II) but are easily distinguished. Pyrite is made up of one iron atom for every two sulfur atoms and is 53.4 percent sulfur and 46.6 percent iron by weight. Pyrrhotite has a more complex chemical composition in that the amount of iron can vary by small amounts, hence the formula $Fe_{1-x}S$, in which X ranges from 0 to 0.2. This variation causes an increase in the amount of sulfur of as much as 6 percent. The composition of pyrrhotite in which X = 0 is Fe_7S_8 or 39.6 percent sulfur and 60.4 percent iron by weight. These differences in chemical composition give pyrrhotite and pyrite different physical characteristics. Pyrrhotite is softer (hardness 3.5-4.5 on Mohs hardness scale), bronze-yellow 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.

Table II. Composition of pyrite from Louisa County (modified from Watson, 1907, p. 196).

	S%	Fe%	Zn%	Cu%	MgO%	Insoluble
Arminius mine	49.27	43.62	0.38	1.50	1.32	4.23
Sulfur mine	50.00	43.00	—	—	—	6.02

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, ~~batteries~~, paper, dyes, medicine, sugar, starch, syrup, leather and fertilizer. Other uses include the refining of precious metals and petroleum, leaching of mine dumps and cleaning (pickling) of sheet metals.

Processes utilized in the manufacture of sulfuric acid include: (1) the older Chamber Process, which uses iron sulfide as a source of sulfur and (2) the Contact Process, which predominantly uses native sulfur and therefore will not be discussed further. In the Chamber Process lump iron sulfide ores are usually mixed with coke and roasted in large burners in a flow of oxygen. The roasting of the sulfide drives off the sulfur dioxide (SO_2).

$$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$$

The gas is then conveyed through several chambers by pipe and mixed with steam (H_2O). Droplets of sulfuric acid (H_2SO_4) form on the inside of the pipe and are collected in a tank. Fine-size iron sulfide is also used but is roasted in a rotary burner which is designed especially for small-size material. The SO_2 is driven off and cycled similarly through the chambers (Riegel, 1942, p. 15-35). The iron-oxide residue or iron cinder, called "Blue Billy," (Fe_2O_3 - hematite) is often stockpiled and sold to iron smelters as a source of iron.

Virginia Deposits

Seven mines are known to have been operated for pyrite or pyrrhotite in Virginia (Figure 1). From northeast to southwest these are 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, frequently occur in metamorphic rocks of eugeosynclinal derivation.

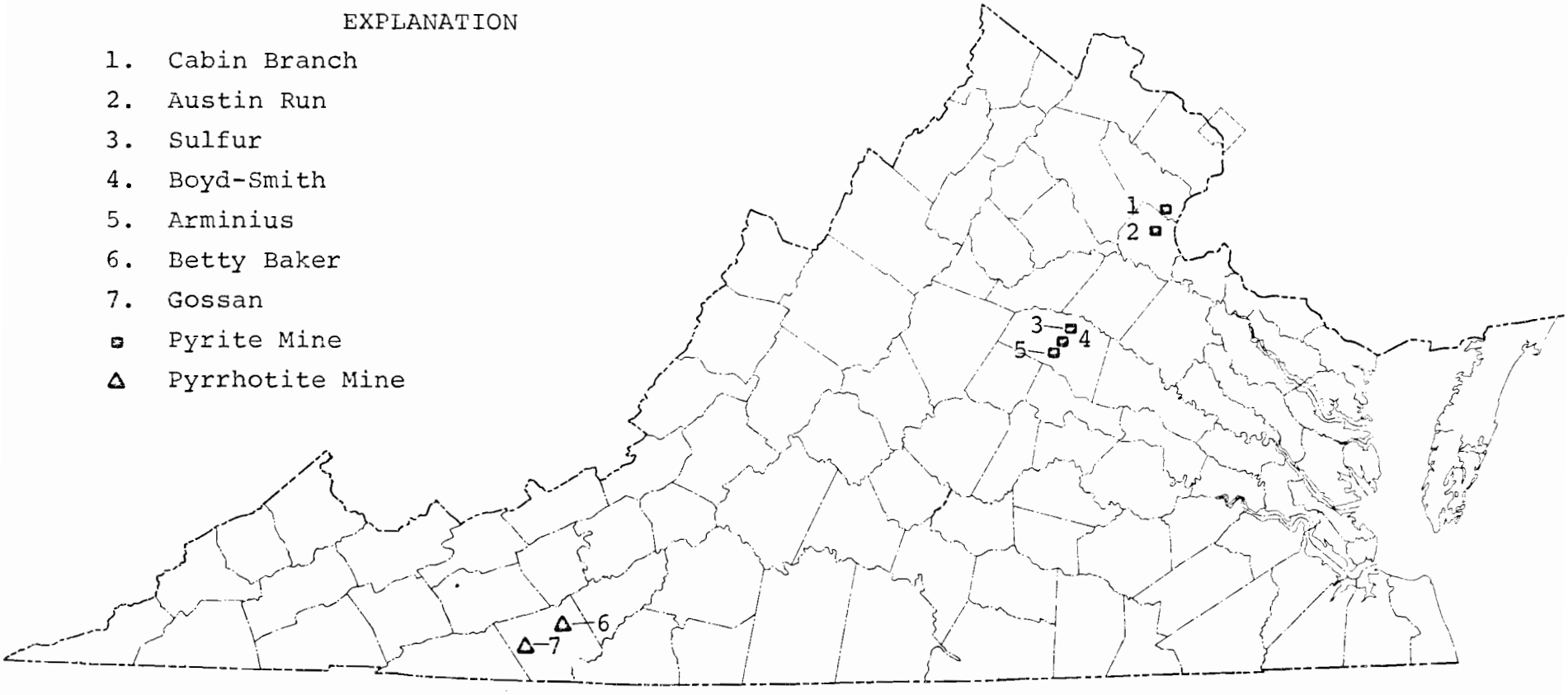
Ideas concerning the mode of origin of mineral deposits are important because they are the basis for exploration theories that may be applied in the search for new deposits. The origin of massive sulfide deposits has been a controversial subject for many years and the ideas have ranged from an epigenetic 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.

EXPLANATION

1. Cabin Branch
2. Austin Run
3. Sulfur
4. Boyd-Smith
5. Arminius
6. Betty Baker
7. Gossan

▫ Pyrite Mine

△ Pyrrhotite Mine



From the viewpoint of the epigeneticist there have been two predominant theories for the origin of Virginia massive sulfides. Ore 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 Mines of Prince William, Stafford and Louisa Counties

The five mines in these counties are discussed together because of their geographic proximity and the similarity of mining and milling techniques.

Mining Technique

The general geology of the ore bodies that were mined in these three counties is very similar, so that the same mining techniques were employed. An inclined shaft was sunk

in the ore body and change 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. 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.

Milling Technique

Milling is the process by which ore is physically beneficiated (crushing, jigging, sieving, etc.) to bring up the grade for final processing. The milling is usually done at the mine and should not be confused with smelting, roasting or other extractive procedures.

The pyrite was prepared in three sizes, termed lump, spall and fine. Lump ore was ore broken in the mine and free from all low-grade material. Spall was lump ore that passed through a 2 1/2-inch ring but not a 3/8-inch ring. Fine ore passed through a 3/8-inch ring and was cleaned by washing and jigging to bring up the grade (Watson, 1907, p. 205). The specific milling practice at each mine in these three counties was varied according to the condition of ore recovered. Some of these mines produced only fine-sized ore because broken ore in the mine was essentially all in the fine-size range. At others, milling practices were determined by the type of material required by the sulfuric-acid plant to which the ore was sold. Some ores were beneficiated by hand-sorting and often lump or spall were crushed to produce finer size ore for the acid plants. The milled product was then loaded into railroad cars and shipped to ~~roasters~~ where it was sold according to sulfur content. The average sulfur content of ores from the northern Virginia area was 40 to 45 percent (Watson, 1907, p. 196).

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). This mine was first opened in 1889 but did not attain continuous production until 1908. The mine

ceased production in 1920 and was abandoned and the equipment sold. Ore shipment from the mine was done by connection to the Richmond, Fredericksburg and Potomac Railway at Barrow Siding. A wharf on the Potomac River was also available for barge transportation (Lonsdale, 1927, p. 85-89). After the mine closed the property changed ownership and was later sold to the National Park Service. Under this agency the property eventually 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 in the Park. As a result, there is little to show for the one-time large mining operation. During a field visit by the author in 1973 the main mine site was found to be overgrown but four caved shafts could 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° to 55° depending on the dip of the ore. The vertical shafts were shallow but the inclined shaft reached a depth of 1000 feet. The mining method was as described above

The mineralization at the mine occurs as a lens of pyrite, that 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 to 20°E and the dip is to the northwest at 25° to 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 (copper-iron sulfide), galena (lead sulfide) and sphalerite (zinc sulfide) with small amounts of gold and silver determined by assay. Gangue (waste) minerals are hornblende, chlorite, biotite, epidote, garnet, quartz, tourmaline and calcite. Apparently pyrite, quartz and tourmaline were formed at the same time and post-date the schistose country rock (Lonsdale, 1927, p. 86-87).

The pyrite obtained from the Cabin Branch mine was used exclusively for the manufacture of sulfuric acid. The average grade of the pyrite ranged from 43 to 45 percent sulfur (Watson, 1907, p. 196). Table 3 gives the production of pyrite at this mine from 1908 to 1920. 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 first opened in 1906 and was worked intermittently until 1920. The mine was involved in several periods of litigration and financial troubles causing the property to change ownership at least three times during these 14 years.

Little is known concerning the mine workings at the Austin Run mine but the mining method utilized was probably the same as described above. The mine was reportedly developed from one shaft 650 feet deep (Lonsdale, 1927, p. 89-90). Annual production figures are given in Table 4. A small dump was present at the time of a field visit by the author in 1973; most of the dump, however, has apparently been removed for local road construction. A shaft, with a concrete collar, was found ~~on top~~ of the hill (Figure 2) and two dams were seen north of the mine.

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 present author noted two modes of occurrence for pyrite. The mineral occurs

Table 4. Pyrite production, Austin Run Mine, Stafford County (modified from Lonsdale, 1927, p. 10).

Year	Quantity produced long tons	Quantity sold long tons	Value
1906-1907	na	na	na
1908	None	None	None
1909	na	na	na
1910	500	None	None
1911	None	None	None
1912	Development work		
1913	None	None	None
1914	None	None	None
1915	na	na	na
1916	Development work		
1917	1,932	1,932	$15,630
1918	844	844	8,106
1919	None	None	None
1920*	600	300	2,400
Recorded total	3,876	3,076	$26,136

na - not available

*Production ceased

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 the 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. From 1889 to 1906 the property was involved in litigation problems but by 1906 mining was up to full scale once again and the Sulfur mine reached its most extensive degree of development ~~(Katz, 1961, p. [illegible])~~. At this time the cost of mining and milling at the

Sulfur mine was about $1.64 per hoisted ton and the pyrite was sold at $4.00 per ton (Katz, 1961, p. 20-31). 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 was comprised 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 N25°E, and surface dips of 65°SE flatten in the mine to 35°SE (Katz, 1961, p.). The ore minerals at Sulfur mine were pyrite ~~with some~~ 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 are 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).

The Sulfur mine was apparently one of the largest pyrite mines in Virginia. This mine, and the nearby Boyd-Smith and Arminius mines, created a boom-time atmosphere in Louisa County in the early part of the twentieth century. At one time over 2000 people were employed at the three mines and there were at least three banks in the area, two at Tolersville (Mineral) and a third at the Sulfur mine (Katz, 1962, p. 31).

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 (1962, p. 27), 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 3). 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 by some and a collapsed section of old mine workings by others (Figure 4). 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.

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 at the Groome mine. 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 then contributed to the "boom atmosphere" of the Louisa County area for a number of years but was closed again in 1922 and has not reopened (Luttrell, 1966, p. 24-25). In 1946 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). During a field visit in early 1973 the author noted two caved shafts, one wooden structure (Figures 5 and 6) and several foundations.

The wooden building was probably either part of the structure for hoisting or the tramway because of its proximity to a caved shaft. A waste dump extends westward from the mine area and the former tailings pond extends from the mine dump to Contrary Creek.

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 make up 90 percent of the rock. Samples of waste rock on the dump range from schist to gneiss. Non-metallic minerals present 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. Mining for pyrite and some copper began in 1865 and continued for 23 years. The mine was purchased by the Arminius Chemical Company in 1894 and was worked until closing in 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.). The New Jersey Zinc Company purchased the property in 1953 and conducted a geochemical and geophysical program with some diamond drilling; results were not released.

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 N20°E and a general dip of 63° to the southeast. Individual lenses (Figure 1) 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 found are calcite, quartz, amphibole garnet, biotite and feldspar. All but biotite and feldspar are common interstitial minerals in the ore and make up 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 and 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 immediately north of the mine and the dump surrounds the mine on three sides.

Pyrrhotite Production in the Gossan Lead District

The (Great) Gossan Lead occurs in the Lynchburg Gneiss of the Blue Ridge Province in Carroll and Grayson counties, Virginia. 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.

U. S. Bureau of Mines drilled 7 core holes totaling 3,838 feet in 1947 to further determine the extent of the deposit to the southeast (Kline and Ballard, 1949, p.). This drilling was followed by several more drill holes 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 N45°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. Table 5 gives the average grade of primary ore from drill-hole samples (Kline and Ballard, 1949, p. 8). The country rock is generally a fine to medium-grained, quartz-mica schist, probably of sedimentary origin. The non-metallic minerals include quartz, feldspar, biotite, sericite, amphibole, chlorite and spessartite (garnet).

Table 5. Average Grade of Primary Ore from the Betty Baker Property, Carroll County (Kline and Ballard, 1949, p. 8).

Element	Percent
Iron	33
Sulfur	21
Copper	0.4
Zinc	2.0

Very little can be seen on the property today except for a northeast-trending trench (Figure 7) 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. In 1850 supergene copper ore was mined at the Great Outburst mine but within nine years copper production on the property had ceased. 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 (G. C. D., 1962, p. 2).

The General Chemical Division ~~of~~ (now Allied Chemical ~~Company~~ Corporation) acquired the property in 1905 and began pyrrhotite mining by open-pit methods. The mining from 1905 to 1935 was 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. In room and pillar mining, pillars of rock are left in the mined areas to support the back (roof). Shrinkage stoping is very similar to room and pillar mining and varies only with the position of the pillars. 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 and this brought large scale iron-sulfide mining in Virginia to an end. 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 at the Gossan mine 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 (G. C. D., 1962, p. 1-11).

Like other sulfide bodies of the Gossan Lead the deposit at the Gossan mine is lensoid shaped and has a strike of approximately N45°E and a dip of 30° to 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 8). 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 (Figure 9), 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.

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