Some Magnetite Deposits in New Jersey

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SOME MAGNETITE DEPOSITS IN NEW JERSEY

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ABSTRACT

The magnetite deposits of northern New Jersey are in rocks of pre-Cambrian age, which include igneous rocks, igneous and metasedimentary gneisses, and some belts of marble. The metasedimentary rocks were formed by metamorphism of a predominantly calcareous sequence of rocks, which was converted to amphibolite, skarn, and small amounts of marble. Some biotite-quartz-plagioclase gneiss, in places containing garnet and sillimanite, was formed from alumino-siliceous sedimentary rocks interbedded with the calcareous rocks. Igneous rocks, including granite, related alaskite and pegmatite, some syenite, and granitic quartz-plagioclase gneiss, invaded the metasedimentary rocks, in part at least contemporaneous with the folding and metamorphism of the sedimentary rocks. In many places, intimate penetration and modification of the metasedimentary rocks by granitic material has formed migmatites and mixed rocks.

In general the rocks strike northeast and dip moderately to steeply southeast; the gneissic foliation is parallel to the strike of the rocks. The rocks have been complexly folded, locally causing departure of the gneissic foliation from the general northeast trend. The folds are mainly isoclinal; they plunge gently to moderately northeast and are overturned to the northwest. The linear structure of the gneisses plunges northeast and is essentially parallel to the plunge of fold axes. Very few faults have been recognized except where they are exposed in underground openings and where diamond drilling has indicated their presence.

The magnetite deposits were formed by replacement of metasedimentary and granitic rocks and marble. Few are known to occur in marble, and most of the deposits described in this report are in amphibolite and skarn. The deposits are tabular or veinlike bodies, lenses, and pods that conform with the structure of the enclosing rocks; they may have a shoot structure that plunges parallel to the lineation of the adjoining rocks. The deposits are composed of magnetite and a mixture of gangue minerals. Most of the gangue is composed of unreplaced minerals of the gneisses, but some gangue minerals were formed during deposition of the magnetite.

The magnetite deposits, which were studied as part of the U. S. Geological Survey's strategic minerals program during World War II, are described. The studies were made in conjunction with dip-needle surveys and diamond-drill-hole exploration conducted by the U. S. Bureau of Mines. All the deposits described are small and generally low in grade; none is being mined at present. The principal purpose of the report is to present the new data on the possibility that the deposits may at a later time be considered as potential sources of iron ore.

INTRODUCTION

From 1943 to 1946, as part of the strategic minerals program of the United States Government, several magnetite deposits in New Jersey (fig. 30) were studied by the U. S. Geological Survey in conjunction with a program of drill-hole exploration and dip-needle surveys conducted by the U. S. Bureau of Mines. Members of the Geological Survey prepared geologic maps of the more important deposits and studied and interpreted drill cores in an effort to guide exploration and to obtain new information on the occurrence and origin of the magnetite deposits.

A. F. Buddington was responsible for general supervision of the work done by the Geological Survey. Members of the Geological Survey who took part in the study were P. E. Hotz, H. E. Hawkes, and B. F. Leonard.

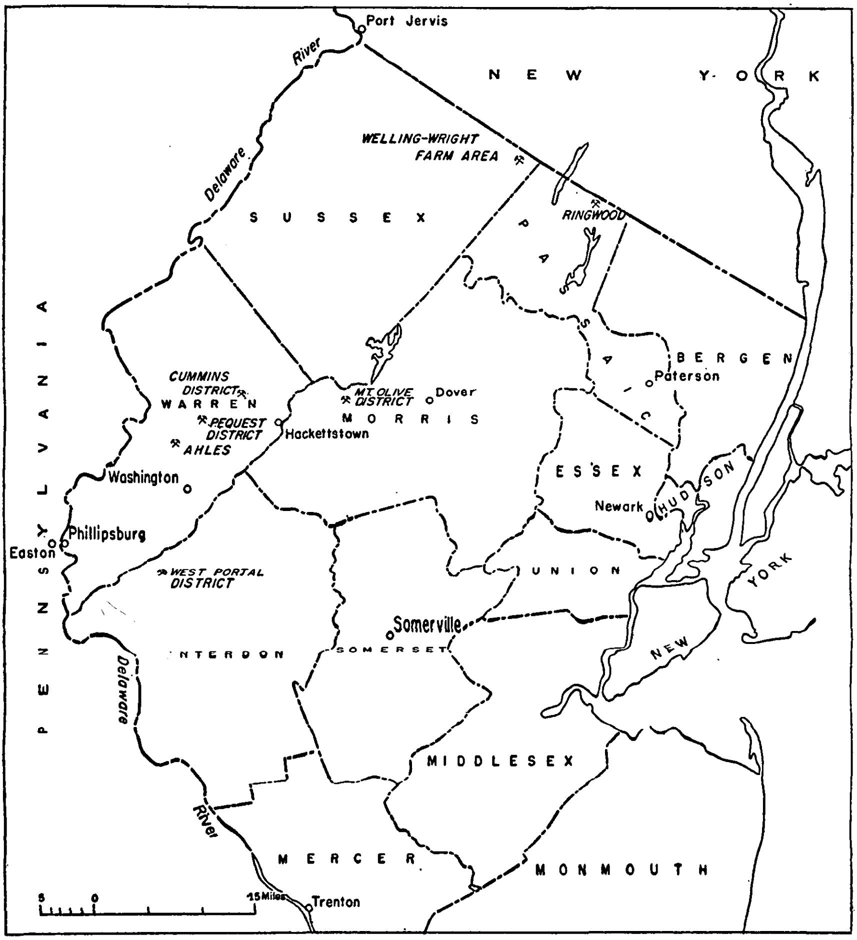

FIGURE 30. Index map of northern New Jersey, showing location of magnetite deposits discussed in this report.

The most authoritative published work on New Jersey magnetite mines is by W. S. Bayley (1910), and much of the historical data included in the present report is taken from this publication. Recent, more detailed studies have been made by Sims (1954) in the Dover district and by Hotz (1953) in the Ringwood district. A report on the Edison district by Buddington and Rogers is in preparation.

The results of drill-hole exploration and magnetic surveys of all the deposits investigated by the Bureau of Mines have been published in U. S. Bureau of Mines Reports of Investigation by Botsford (1948), Troxell (1948), Lynch (1947), Neumann and Mosier (1948), and Stampe and others (1949).

Meredith E. Johnson, New Jersey State Geologist, and Tom Myners made maps and other useful information available. The assistance and cooperation of the following engineers of the U. S. Bureau of Mines is gratefully acknowledged: G. B. Botsford, P. W. Jackson, G. L. Neumann, J. A. Stampe, J. R. Troxell, and Lloyd Williams.

GENERAL GEOLOGY

All the deposits of magnetite in New Jersey are in rocks of pre-Cambrian age. The pre-Cambrian rocks occupy a prominent belt that trends northeast through the northern part of the state, a region locally known as the New Jersey Highlands. This belt is bounded on the southeast by Triassic sedimentary rocks (the Triassic lowlands) and on the northwest by sedimentary rocks of Paleozoic age (the Ridge and Valley province). Within the area of pre-Cambrian rocks are several narrow belts of Paleozoic rocks bounded on the sides by faults.

The rocks of pre-Cambrian age include gneisses of igneous and meta-sedimentary origin and some belts of marble. Those of igneous origin are represented by a variety of granitic rocks including granite and related alaskite, and granite pegmatite, some syenite and granitic quartz-plagioclase gneiss.

The metasedimentary rocks were derived in part from calcareous sedimentary rocks that may have included some limestone or dolomite, but which probably originally consisted mostly of calcareous shales and impure carbonate rocks. Metamorphism converted most of these to amphibolite and skarn, though some of the limestone was recrystallized to marble. Some of the amphibolite may have been formed by metamorphism of mafic volcanic rocks. Alumino-siliceous rocks were metamorphosed to biotite-quartz-plagioclase gneiss and garnetiferous and sillimanite-bearing biotite-quartz-plagioclase gneisses, or were locally granitized, yielding a sillimanitic microcline-quartz gneiss with much associated granite pegmatite.

The sedimentary rocks were highly folded, metamorphosed, and intruded by granitic rocks. In part, at least, the folding and metamorphism was penecontemporaneous with the emplacement of the igneous rocks. Although the relations between the igneous rocks are not completely clear, granite and alaskite are apparently the youngest of the gneissic igneous rocks. Granite pegmatite was the latest pre-Cambrian rock of igneous origin.

DESCRIPTION OF THE PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks associated with the magnetite deposits are similar throughout the Highlands of New Jersey and have been described in the Passaic (Darton and others, 1908), Franklin Furnace (Spencer and others, 1908), and Raritan (Bayley and others, 1914) folios of the Geologic Atlas of the United States, and by Bayley (1941, p. 9–52) in a report on the Delaware Water Gap and Easton quadrangles. More recent reports by Sims (1953), on the Dover district, and by Hotz (1953), on the Ringwood district in New Jersey and the Sterling Lake district in southern New York, also describe the rocks in detail.

The following descriptions refer to the rocks of the districts in which lie the magnetite deposits described in this report, and not to the Highlands as a whole.

METASEDIMENTARY ROCKS

Limestone.—Limestone is not commonly encountered in the pre-Cambrian areas of New Jersey. In the western part of the Highlands, however, limestone underlies several areas and is mapped as the Franklin limestone. Franklin limestone occupies areas about the Ahles mine and south of the Pequest district, which are described in this report.

All the limestone is more properly termed marble because of its moderately to coarsely crystalline character. Most of it is gray to white, but some of it has a handsome salmon-pink color. Some of it is composed entirely of calcite, but most of it contains visible granules of silicate minerals, including green pyroxene and dark greenish-brown olivine. Grains of magnetite may also be present. This silicated marble represents the first step of the transformation of marble to pyroxenic and amphibolitic gneisses.

Texturally, the marble is crystalloblastic. With the addition of silicate minerals the texture may be termed porphyroblastic due to the presence of individual metacrysts and aggregates of silicate minerals.

Following are the modes of specimens of silicated limestone (marble) in a drill core from the Ahles mine:

Modal composition of silicated limestone, Ahles mine

	1	2	3	4
Plagioclase	20.2 (An_7)	--------	--------	--------
Quartz	3.3	--------	--------	--------
Olivine	--------	16.8	16.2	61.0
Pyroxene	9.7	--------	--------	--------
Calcite	43.1	82.3	74.8	24.1
Magnetite	Tr.	.8	9.0	14.9
Sphene	.9	--------	--------	--------
Tourmaline	.4	--------	--------	--------
Epidote	22.0	--------	--------	--------
	99.6	99.9	100.0	100.0

Skarn.—Skarn is an old Swedish mining term for aggregates of dark silicate minerals rich in iron, magnesia, and lime (Holmes, 1928, p. 211). In the pre-Cambrian rocks associated with the New Jersey magnetite deposits, rocks composed principally of coarsely crystalline pyroxene, with or without accompanying hornblende and garnet, are called skarn. Bodies of skarn are interlayed with the other meta-sedimentary gneisses, and are mostly thin and lenticular, though there are a few fairly continuous layers or zones.

Much of the skarn is composed mostly of pyroxene, and two kinds of pyroxene skarn have been recognized: dark pyroxene skarn, in which the pyroxene is dark green augite; and light pyroxene skarn, composed of pale green diopside. Some skarn contains notable amounts of plagioclase; in some, scapolite may be abundant. The pyroxene in many specimens is partly replaced by hornblende; some shows incipient serpentinization.

Relict grains of calcite in some specimens indicate that the skarn was formed by the metamorphism of limestone accompanied by the addition of iron, magnesium, and silica.

Most of the skarn is medium- to coarse-grained and granular. Gneissic foliation and lineation are obscure or absent in most specimens.

The following table lists the modal composition of typical specimens of skarn:

Modal composition of skarn

	1	2	3	4	5
Potash feldspar	28.6	--------	--------	--------	--------
Plagioclase	3.9 (An_{35})	--------	--------	--------	--------
Scapolite	31.8	--------	--------	5.9	40.1
Quartz	--------	1.8	--------	--------	--------
Pyroxene	12.2	92.2	38.4	88.7	57.2
Hornblende	--------	5.1	59.8	4.8	--------
Magnetite	15.8	.8	--------	Tr.	2.3
Apatite	2.3	Tr.	--------	--------	.3
Sphene	2.1	--------	--------	--------	Tr.
Calcite	--------	Tr.	--------	Tr.	Tr.
Epidote	--------	Tr.	--------	Tr.	--------
Serpentine	--------	--------	} 1.8	--------	--------
Chlorite	--------	Tr.		--------	--------
Pyrite	3.3	--------	--------	--------	--------

1. Cummins mine, drill hole 3, depth 331 feet.
2. Swayze mine, drill hole 1, depth 176 feet.
3. Turkey Hill mine, drill hole 7, depth 114 feet.
4. Turkey Hill mine, drill hole 9, depth 215 feet.
5. Ahles mine, drill hole 1.

Amphibolite and pyroxene amphibolite.—Probably the most common kind of metasedimentary rocks are amphibolite and pyroxene amphibolite, which occur as bodies that range in size from thin layers and lenses enclosed in granitic rocks to individual units hundreds of feet wide and thousands of feet long.

Typically, these rocks are dark gray, greenish gray, or black, with an equigranular medium-grained crystalloblastic texture. Foliation is best revealed in varieties that contain biotite, especially where the biotite is concentrated in thin laminae. Where platy minerals are absent the foliated structure is not readily seen, but parallel layers differing slightly in mineral composition may reveal the gneissic structure.

The principal mafic minerals are hornblende and pyroxene, which may occur separately or together, plus plagioclase feldspar and possibly some quartz. Biotite is an important mafic constituent of some of the gneisses. The usual minor constituents are magnetite, apatite, and sphene. Some specimens contain small amounts of tourmaline, which probably was introduced after the rock was formed. Scapolite may also occur in widely variable amounts. Relict grains of calcite in some specimens attest to the original calcareous nature of the rock.

The mineral composition of typical specimens of amphibolite and pyroxene amphibolite is given below:

Modal composition of amphibolite and pyroxene amphibolite

	1	2	3	4
Potash feldspar			[1] 10.8	0.6
Plagioclase	21.3 (An_{22})	53.9 (An_{38})	44.4 (An_{23})	24.1
Scapolite	[2] 33.2			
Quartz				
Pyroxene	9.3	13.3	26.9	30.0
Hornblende	33.9	28.1	15.7	14.4
Biotite		Tr.		[3] 30.2
Calcite	1.0			
Magnetite	.1	4.1	1.8	Tr.
Apatite	1.1	.2	.3	.3
Sphene		Tr.		
Zircon	Tr.	.3		
Tourmaline		Tr.		

[1] Microcline microperthite; replaces plagioclase in one part of thin section.
[2] Scapolite replaces plagioclase.
[3] Biotite, in part introduced.

1. Ahles mine, drill hole 1.
2. Ahles mine, drill hole 1.
3. Turkey Hill mine, drill hole 8, depth 483 feet.
4. Cummins mine area, outcrop.

Biotite-quartz-feldspar gneiss.—Biotite-quartz-feldspar gneiss is perhaps less abundant than skarn and amphibolite. Generally, relatively thin sheets of biotite-quartz-feldspar gneiss are interlayered with amphibolite and skarn; in places it is interlayered with the gneissic granitic rocks.

Biotite-quartz-feldspar gneiss has a crystalloblastic texture and well-developed gneissic structure. The essential minerals are quartz and feldspar (both plagioclase and potash feldspar, generally microperthite); biotite is never more abundant than in accessory amounts. Sillimanite and garnet (almandite) are rather common accessories in addition to biotite in many places and apparently are most commonly formed where the gneiss has been penetrated by granitic material. Locally, as near the Henry tunnels in the Pequest district, tourmaline is an important constituent of the gneiss. Magnetite is mostly a minor accessory, but in the Henry tunnels area it is so plentiful that the garnet-sillimanite-biotite-quartz-feldspar gneiss is a low-grade iron ore.

The following table gives the modal composition of some specimens of biotite gneiss:

Modal composition of biotite-quartz-feldspar gneiss

	1	2	3
Potash feldspar	34.3	----------	15
Plagioclase	30.6 (An_{23})	62.9 (An_{27})	42.3 (An_{23})
Quartz	15.1	23.7	30.2
Biotite	13.6	5.6	4.0
Magnetite	6.1	6.3	8.0
Apatite	.3	1.7	----------
Garnet	----------	----------	Tr.
Sillimanite	----------	----------	.4
Zircon	----------	----------	Tr.

1. Welling-Wright farm area.
2. Welling-Wright farm area.
3. Pequest district, Henry tunnels, hole 11, depth 96 feet.

GRANITIC ROCKS

Granitic rocks, in the broad sense of the word, are interlayered with the gneisses of metasedimentary origin throughout the New Jersey Highlands. Probably more than one-half of the total bulk of pre-Cambrian rocks in the region is granitic. The bodies of granitic rock range in size from thin sheets a few feet wide interlayered with the metasedimentary gneisses, to great bodies thousands of feet wide and as much as several miles in length. The bodies are in general conformable with the structure of the older country rocks except in a few places where they show cross-cutting relationships on a small scale. Structural relations other than conformity between the granitic rocks themselves are very difficult to recognize.

Under the heading of granitic rocks are: granitic quartz-plagioclase gneiss, gneissic hornblende granite and related alaskite, and pegmatite. These look like and have the composition of true granitic rocks. The quartz-plagioclase gneiss, however, cannot be certainly distinguished from some facies of amphibolite or pyroxene amphibolite or from a similar rock of metasedimentary origin.

Age relationships between the granitic rocks are not definitely established, but all are certainly younger than the gneisses formed by metamorphism of the sedimentary rocks. The oldest of the granitic rocks is presumably the granitic quartz-plagioclase gneiss, although relations between it and the hornblende granite are not completely clear. Granite and related alaskite are next oldest, and granite pegmatite is the youngest.

Granitic quartz-plagioclase gneiss.—The quartz-plagioclase gneiss is in general a light-gray to greenish-gray granitic rock and is characterized in many of its exposures by dark mafic schlieren and large inclusions of mafic gneiss, particularly amphibolite and pyroxene amphibolite. The content of mafic minerals in the quartz-plagioclase gneiss is variable, and in places the rock is difficult to distinguish from amphibolite or pyroxene amphibolite. The rock is moderately foliated, and the gneissic structure is most apparent where the rock contains darker schlieren. In some exposures, however, foliation and lineation are difficult to recognize.

The quartz-plagioclase gneiss is medium grained and typically has a granitoid texture, though some specimens have a granoblastic appearance. Plagioclase, of about the composition of oligoclase, and quartz are the essential constituents. The plagioclase commonly has some blebs and rods of exsolved potash feldspar. Minor quantities of potash feldspar—microcline and microcline microperthite which appear to have partly replaced the plagioclase—may be present. The most common accessory mineral is pyroxene, represented by two species, augite or diopsidic augite, and hypersthene. The two varieties of pyroxene may occur singly, though more commonly both are present. Hornblende may also be an accessory mineral, though in amounts subordinate to pyroxene. Minor accessories include biotite, magnetite, apatite, sphene, zircon, and tourmaline.

Modal compositions of some specimens of quartz-plagioclase gneiss are listed in the following table:

Modal composition of granitic quartz-plagioclase gneiss

	1	2	3	4
Microcline	1.5	Tr.	3.3	5.9
Plagioclase	70.7	57.5 (An_{24})	54.3 (An_{20})	60.3
Quartz	23.1	37.4	32.8	17.6
Pyroxene	3.2	4.8	----	1.2
Hornblende	----	----	4.5	.7
Magnetite	Tr.	.5	Tr.	3.0
Sphene	----	----	----	1.2
Apatite	----	Tr.	----	Tr.
Zircon	----	----	----	Tr.
Alteration products	1.2	Tr.	[1] 5.1	[1] 1.0

1. Cummins mine area.
2. Highway 206, north of Flanders.
3. Cummins mine area.
4. Cummins mine area.

[1] Mostly after pyroxene.

Syenite.—A syenitic rock is encountered in a few places but has not been mapped separately. The rock is granitic in appearance both megascopically and under the microscope, and may have a visible planar structure. The most abundant minerals are potash feldspar, which is microperthite or microcline microperthite, and plagioclase, which has the composition of medium to calcic oligoclase (An_{20-28}). The amount of potash feldspar is greater than plagioclase. Quartz is absent or in relatively small quantities. Hornblende is the common mafic accessory, and some biotite and, uncommonly, pyroxene may also be present. Magnetite, apatite, sphene, and zircon constitute the usual minor accessories.

Following are modal compositions of some specimens of syenite:

Modal composition of syenite

	1	2		1	2
Microperthite	65	39.0	Magnetite	3.5	6.0
Plagioclase	25 (An_{20})	32.8 (An_{28})	Apatite	Tr.	1.9
Quartz	1	1.2	Sphene	Tr.	Tr.
Hornblende	3.5	12.0	Zircon		Tr.
Biotite		6.6	Pyrite		.4
Pyroxene	1				

1. Ayres mine, Cummins district.
2. Cummins mine, drill hole 2, depth 328 feet.

Hornblende granite and related alaskite.—Characteristically, fresh exposures of the hornblende granite and alaskite are pink, although some varieties are white or light gray. Most commonly they are medium- to coarse-grained and have a massive appearance; planar and linear structures are difficult to recognize. In many specimens, however, a definite parallel elongation of quartz is apparent. Unlike the granitic quartz-plagioclase gneiss, most outcrops are devoid of schlieren and inclusions of dark gneiss; in some, however, there is a segregation of the mafic minerals into poorly defined layers. The texture of most of the granite and alaskite is typically granitoid though there may be some tendency towards an elongation of the quartz and a roughly parallel orientation of the hornblende. A few specimens, however, have a true granoblastic texture due to recrystallization of the rock.

All varieties of the granite and alaskite are composed of potash feldspar, quartz, hornblende, magnetite, apatite, and sphene in varying proportions. The potash feldspar is microcline or microcline microperthite; orthoclase is generally absent or occurs in smaller amounts than microcline. Sodic, generally antiperthitic plagioclase feldspar varies rather widely in amount. Besides hornblende, the granite may contain subordinate amounts of augite and biotite. Varieties of the granite that contain less than 5 percent of mafic accessory minerals have been classed as alaskite. No attempt has been made to separate granite and alaskite on the maps.

The model composition of some typical specimens follows:

Modal composition of granite and alaskite

	1	2	3
Microcline and microcline microperthite.	55.4	70.7	34.7
Orthoclase			5.0
Plagioclase	21.2 (An_8)	2.5	11.5 (An_{11})
Quartz	13.7	22.1	36.4
Hornblende	6.2	2.7	
Pyroxene			
Biotite			
Magnetite	3.3	1.3	2.2
Sphene	.1		.2
Apatite	.1	.5	
Zircon			
Alteration products			Tr.

1. Hornblende granite from Pequest district.
2. Northeast of Highway 206—Flanders road junction, Mount Olive district.
3. Alaskite from Pequest district.

Pegmatite.—Some of the alaskite is very coarse-grained and therefore has been designated as pegmatite. The pegmatite bodies are commonly thin and lenticular and apparently are most common in the vicinity of some of the magnetite deposits.

A pink color is characteristic of the pegmatite on fresh and weathered surfaces. The texture ranges from coarse grained to pegmatitic with subhedral to idiomorphic, roughly tabular crystals of perthitic microcline and irregular bodies of white quartz. A trace of magnetite is the only visible dark accessory mineral in most specimens, though some may contain small amounts of hornblende and pyroxene. Narrow selvages of biotite may occur at the contact between pegmatite and mafic gneiss. Most of the pegmatite has no apparent gneissic structure, although in some places a faint sheeted structure and some alinement of the quartz can be seen.

Another type of pegmatite commonly occurs in the granitic quartz-plagioclase gneiss as veinlets. Quartz and white, or greenish, somewhat perthitic potash feldspar (microcline, uncommonly orthoclase), with some sodic plagioclase are practically the only mineral constituents. Some hornblende, pyroxene, or biotite, possibly derived from reworking of mafic minerals in the wall rocks, and local concentrations of magnetite have been seen in a few of these pegmatite veinlets.

MIGMATITE

At many places the metasedimentary rocks are interlayered with granitic material, and the mixture of metamorphic and granitic material may be so intimate that the rock is a migmatite. No attempt has been made to show the mixed rocks on the geologic map. Depending on the predominant component, general appearance, and relations to the surrounding rocks, migmatites were mapped as one of the metasedimentary rock units, or as granitic quartz-plagioclase gneiss, granite, or alaskite.

Many of the migmatites are mixtures of granitic quartz-plagioclase gneiss with amphibolite and pyroxene amphibolite, less commonly skarn and biotite gneiss. Migmatitization of the dark mafic rocks results in a gray gneiss having a streaked appearance due to the alternation of layers and folia of light granitic material with darker, mafic-rich layers. Much of the garnet-sillimanite-quartz-biotite gneiss in the Pequest district is migmatitic, and the granitic material, which contains potash feldspar, is regarded as belonging to the hornblende granite-alaskite unit. Most of the garnet is in aggregates next to and within the granitic leaves, where it appears to have formed by reaction between the biotite of the gneiss and the granitic material.

STRUCTURAL GEOLOGY

The gneisses generally strike northeast and dip moderately to steeply southeast; the foliation is parallel to the strike of the rock units. Many foldlike features have been recognized; locally the foliation departs from the general northeast trend. The folds, mainly isoclinal, plunge gently to moderately northeast and are overturned to the northwest.

Most of the rocks have visible foliation and lineation, though in some of the more massive types of granitic bodies either one or both structural features may be difficult to recognize. Foliation, which parallels the rock layers, may be due to (1) a rearrangement of minerals by recrystallization, resulting in parallel orientation of the platy and tabular minerals; (2) compositional layering that reflects the original bedding or layering in the sedimentary rocks; (3) migmatitic interlayering of granitic and metamorphic material; (4) flow layering induced in partly crystalline magmatic material during crystallization. Lineation in the gneisses is due to a parallel orientation of needlelike or prismatic minerals within the plane of foliation and may be due to primary flow or secondary recrystallization. At most places the lineation plunges to the northeast and is essentially parallel to the plunge of fold axes.

Joints are prominent in most places. Most common are transverse joints that are oriented about at right angles to the strike of the foliation and the plunge of the lineation and hence, in general, strike northwest; they are vertical or dip very steeply southwest. Joints that are parallel to the strike of the foliation but whose plane makes an angle with the plane of foliation are also common.

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All the faults that have been recognized are postmineralization faults and can be divided into two main types, longitudinal and cross faults. The longitudinal faults are mostly high-angle faults that are parallel to or cut across the strike of the gneisses at a small angle. Cross faults likewise dip steeply, making large angles with the strike of the foliation. Faults are not easily recognized at the surface but are seen in underground workings.

MAGNETITE DEPOSITS

The deposits of magnetite were formed by replacement of preexisting rocks. Nearly all types of gneisses may act as host rocks for the magnetite, and deposits are found in limestone, in gneisses of metasedimentary origin, and in granitic gneisses. Few are known to occur in the pre-Cambrian limestone or marble; some of the most common and largest deposits have been in amphibolite and skarn derived from calcareous sedimentary rocks; and several important deposits are found in granitic quartz-oligoclase gneiss.

FORM AND STRUCTURE

The magnetite deposits are tabular or veinlike bodies, lenses, and pods that are conformable with the structure of the enclosing rocks. Some ore bodies have definite shoot structure and are lath, pencil, cigar, or sausage shaped with the long axis parallel to the lineation of the adjoining rocks. The bodies pinch and swell. Deposits in granitic gneiss may be more irregular. Generally, the contacts between the magnetite bodies and wall rocks are fairly sharp, though some may be abruptly gradational, and a few may have indefinite or "assay" walls.

MINERALOGY

The mineralogy of the magnetite deposits is simple, and the magnetite-bearing rock has the same general features in all deposits. Magnetite is the only important ore mineral, though hematite is found with the magnetite in some deposits. Blades of exsolved ilmenite and minute rods of spinel can be seen in some polished surfaces of magnetite.

The deposits are typically composed of magnetite and a mixture of gangue minerals, most of which are original constituents of the rock that is replaced. High-grade deposits are composed of practically solid magnetite and only scattered grains of silicate gangue minerals. In deposits of lower grade, gangue minerals are more abundant and magnetite may occur as single grains.

The most common gangue minerals are hornblende, pyroxene, feldspar, quartz, apatite, pyrite, and pyrrhotite. In addition, biotite, garnet, sillimanite, calcite, and serpentine are abundant locally, and chlorite, tourmaline, epidote, fluorite, chalcopyrite, and molybdenite have been found in a few deposits. Apatite, some chlorite and biotite, tourmaline, epidote, fluorite, and the sulfide minerals formed later than the other gangue minerals and were associated with the solutions that deposited magnetite. Apatite and possibly biotite were deposited before the magnetite.

AHLES MINE

LOCATION

The Ahles mine, one of the few iron deposits that occur in limestone in New Jersey, is in Warren County (fig. 30, pl. 26) 1½ miles northwest of Oxford, 1 mile southwest of Buttzville, and about 5 miles north-northwest of Washington, the county seat. The property is readily accessible from State Route 30 by a hard-surfaced road and a short stretch of unimproved road. It can be reached from Oxford by going north on Route 30 for one-half mile to the first road on the left, thence 1 mile to a lane on the right. Three-fourths of a mile down the lane on an unimproved road, a right turn is made into a short trail that ends near the property.

A branch of the Delaware, Lackawanna, and Western railroad goes through Oxford. The old roadbed of a spur track to the nearby limestone quarry goes through the property. The rails and ties have been removed, but the grading is still in fair condition.

HISTORY AND PRODUCTION

The date of discovery of the Ahles deposit and the conditions under which it was found are not known. In 1901 a shaft was sunk in the footwall about 30 feet from the ore body to a depth of 168 feet, and two crosscuts at 75 and 128 feet were run southwest to the ore. Two other shafts and a slope were sunk a few years later, and the ore body was thoroughly developed along its strike for about 1800 feet (Bayley, 1910, p. 210–212). Apparently, four levels were developed to a depth of about 200 feet below the surface by 1916, when operations ceased. Much of the ground above the old workings is caved, and several ponds, the largest of which is about 700 feet long and 200 feet wide, have formed above the stopes. All the shafts are flooded to their collars. All plant installations and buildings have been removed.

According to Bayley (1941, p. 69), the mine was in operation continuously for nearly 15 years and was closed down, not for lack of ore, but because of the rising costs of mining and preparing the ore for market. During its operation the mine produced about 300,000 tons of ore. Much of it was soft and consisted of soft limonite mixed with magnetite. After washing, many tons of the "hard" ore was stockpiled and the "soft" ore sold for paint pigment. In 1923 ore from the stockpile was being shipped at the rate of about 300 tons per day to the Eastern Steel Co. at Pottstown, Pa. (Bayley, 1941, p. 69). At the time of exploration in 1944 the stockpile on the property amounted to about 30,000 tons (Troxell, 1948, p. 3).

EXPLORATION

In 1944 the U. S. Bureau of Mines explored the down-dip extension of the Ahles deposit with two diamond-drill holes (Troxell, 1948, p. 6–8, fig. 3). Hole 1 was drilled from the footwall side 160 feet east of no. 3 shaft to a depth of 640 feet. The second hole, 616 feet southwest of hole 1, was drilled in the hanging wall and bottomed at 834 feet. No dip-needle work was done here.

GEOLOGY

The Ahles magnetite deposit is unique in that, unlike most New Jersey magnetite deposits, it is entirely within the Franklin limestone of pre-Cambrian age. The limestone is a lenslike body that trends northeast and is surrounded by gneiss (see inset, pl. 26). There are no exposures at the mine, as most of the region is mantled with glacial deposits which conceal the bedrock. Exposures are found in the limestone quarries northwest of the Ahles mine and in a small quarry northeast of the mine. Coarsely crystalline gneissic granite crops out at the top of a low ridge west of the mine.

The rocks of the hanging wall consist of interlayered amphibolite, pyroxene gneisses, and skarn in the upper part of drill hole 1 (pl. 26). Granitic pegmatite layers containing some magnetite interrupt the sequence in places, and there is some coarsely crystalline limestone containing scattered granules of silicate minerals. In the lower part of the drill hole (the section closest to the ore zone) the rock is predominantly coarsely crystalline limestone with some interlayered pyroxene amphibolite and skarn in which scapolite is abundant in places. There is a negligible amount of granite pegmatite. Most of the limestone contains disseminated granules of pyroxene and olivine. No chondrodite, which Bayley (1941, p. 68) reports as being present, was identified; the olivine in the limestone does not resemble chondrodite, and optical data indicate that it is an iron-rich olivine.

The rocks of the footwall, as indicated by the core from drill hole 2 (pl. 26) are predominantly lightly silicated limestone, most of which is dark gray in color. Toward the bottom of the drill section coarsely crystalline white to pink limestone free from silicate minerals, is prominent. No core was obtained in the upper part of the drill hole.

STRUCTURE

In the limestone at the quarries northwest of the Ahles mine fairly prominent color banding, which may represent bedding, strikes N. 75°–80° E. and dips steeply north or is vertical. In the small quarry northeast of the mine the limestone strikes nearly east and dips steeply south or is vertical. The foliation of the coarse-grained granite on the hill southwest of the mine also strikes nearly east and is essentially vertical. Measurements of the foliation angle in the drill cores indicate that the rocks are steeply dipping. In hole 1 the predominant direction of dips appears to be northeast; in hole 2 the dip is southwest. The attitudes derived from foliation measurements on the drill core in hole 1 may not be too reliable because there was some difficulty in drilling this hole and no measurements of the inclination of the hole were made.

According to Bayley (1941, p. 68) the ore body has a northwest trend (N. 60° W.) and dips about 80° southwest. It is noteworthy that all the exposures of limestone and gneiss have a foliation which strikes a little north of east, whereas the trend of the ore body is north-northwest. The question arises whether the ore body reflects a change in strike of the foliation or bedding of the rocks, or whether there is no change of strike of the rocks and the ore follows a transcurrent fracture zone. Plate 26 (inset) shows an abrupt change of direction in the contact between gneiss and limestone near the Ahles deposit as if there was a change in strike.

ORE DEPOSITS

From Bayley's descriptions (1910, p. 210–212; 1941, p. 68–69) and the writer's observations of drill-core and dump material, the ore occurs as a replacement of the limestone. It does not occur, except as accessory magnetite, in the amphibolite and pyroxene amphibolite or skarn. Bayley (1910, p. 210–212) describes the deposit as a tabular body that was continuous throughout its mined length and dipped southwest at a steep angle. No plunging shoot structure, such as is characteristic of the magnetite bodies in gneiss elsewhere in the Highlands, is indicated by the shape of the ore body either in plan (pl. 26) or in the way it apparently was developed in mining; neither does Bayley make any mention of a shoot structure.

The ore that was mined was a soft brown limonite containing nodules of pyrolusite and crystals of magnetite, and in many instances enclosing boulders of limestone and masses of chert or cherty limonite (Bayley, 1941, p. 68). The small amounts of ore in the drill core from hole 1 consisted of magnetite and some soft brown limonite as veinlets in the limestone. Some disseminated grains of magnetite were also seen in the limestone. No manganiferous ore mineral was identified. Apparently the pyrolusite-bearing ore occurs only in the soft, weathered ore near the surface.

Drill hole 2 penetrated soft ore just below the overburden. This material is probably similar to the weathered ore described by Bayley as being mined from the Ahles deposit.

Incomplete analyses of the ore, after Bayley (1910, p. 212), and an analysis of a stockpile sample prepared by the lessee in 1944 are as follows:

Analyses of iron ore and stockpile samples from the Ahles deposit

[In percent]

	1	2	3[1]		1	2	3[1]
Fe	46.0	47.6	49.30	S	0.0	0.04	0.04
Mn	4.0	4.3	4.00	P	.0	.09	.07
SiO_2	10.7	15.7	11.00	Ti	.0	--------	--------
Al_2O_3	--------	1.3	1.51	H_2O	10.0	--------	10.00
CaO	--------	1.3	1.40	FeS	--------	--------	.06
MgO	--------	1.6	.97				

1. Sample of ore mined in 1902 (Bayley, 1910, p. 212).
2. Sample of ore mined in 1904 (Bayley, 1910, p. 212).
3. Trench sample weighing 4,080 pounds mined in 1944 (Troxell, 1948, p. 5).

[1] Total(?) Fe.

When piled on the dumps the mixed hard and soft ore "* * * rapidly disintegrated * * * leaving a soft mass of limonite and pyrolusite enclosing the hard lumps of magnetite" (Bayley, 1941, p. 67). Washing yielded a hard and a soft ore which in the sample analysed below consisted of 63 percent hard, 15 percent soft, and 22 percent of a mixture of the two.

Analysis of "hard" and "soft" portions separated from ore of Ahles mine, Warren County, N. J.

[Analyst, E. C. Sullivan, U. S. Geol. Survey [1]]

	Hard ore	Soft ore		Hard ore	Soft ore
SiO_2	10.60	16.96	H_2O+	2.55	7.16
Al_2O_3	1.85	4.06	TiO_2	Tr.	Tr.
Fe_2O_3	7.52	50.91	P_2O_5	Tr.	.33
Fe_3O_4	70.24	--------	MnO_2	4.19	11.28
MgO	.62	1.54	BaO	.41	1.44
CaO	.29	.66	SO_3	.06	.20
Na_2O	.12 (Na₂O and K₂O)	.08		99.81	100.04
K_2O		.29			
H_2O-	1.36	5.12			

[1] After Bayley, 1941, p. 67.

RESULTS OF EXPLORATION

Neither drill hole encountered ore beneath the bodies outlined on the map (pl. 26) except for a showing of magnetite, of no economic interest, in the lower part of drill hole 1. It must be assumed, therefore, that the ore terminates between the lowermost drift and the drill holes in the area explored. The drilling was not extensive enough to disprove the downward continuation of the ore in the area to the northwest beyond drill hole 2 or southeast beyond drill hole 1.

No magnetic data are available for this property. Before additional drilling is done a dip-needle survey of the area should be made.

The presence of a body of ore southwest of the main ore zone in the section of drill hole 2 is indicated. Beneath an overburden approximately 160 feet deep a true thickness of about 25 or 30 feet of soft, weathered ore was encountered. Sludge samples were taken throughout the entire zone of soft material and analyzed by the Bureau of Mines (Troxell, 1948, p. 8). Analyses indicate a range from about 7 percent to nearly 52 percent iron. In the uppermost 65 feet the range is from about 11 percent to 52 percent iron, the average is 27.57 percent iron, and there is 0.10 percent phosphorus. The material was not analyzed for manganese. This 65 feet is drill thickness, corresponding to about 25 feet true thickness.

Further exploration might show a continuation of this body in depth and along the strike. This deposit bears the same spatial relationship to the main ore zone as does the lenticular body near the southeast end of the deposit that lies southwest of the main body.

The economic possibilities of this deposit cannot be assessed adequately without further exploratory work.

PEQUEST DISTRICT

The Pequest district includes the Pequest mine, Henry tunnel area, Hoit mine, and the Hoit farm explorations.

LOCATION

The magnetite deposits of the Pequest district (fig. 30) occur in a belt that trends north to north-northeast on the western and southern slopes of Mount Mohepinoke, north of the Pequest River and about three-fourths of a mile east of the hamlet of Pequest, Warren County. Hackettstown, the nearest large town, is about 9 miles to the east on U. S. Highway 46. The properties are close to U. S. Highway 46 and the Lehigh and Hudson River railroad.

The opencut of the old Pequest mine is only about 300 feet from the highway and is easily accessible. The Henry tunnel property is on the steep southern slope of the mountain about 800 feet northeast of the opencut and 250 feet in elevation above the highway. It can be reached either by climbing the slope or by driving around to the Hoit mine and walking south along the top of the mountain and part way down the slope. The Hoit mine is about 900 feet north of the Henry tunnel area on a broad rolling upland. It is easily reached by a road that turns north from Highway 46, 0.8 mile west of Pequest. A farm road turns east from this road about a mile from Highway 46, and after about 0.3 mile ends at a farm, from where it is a short distance on foot to the portal of the Hoit mine. The pits of the Hoit farm exploration are northeast of the Hoit mine.

HISTORY AND PRODUCTION

The following historical data are from Bayley (1910, p. 257–260). The first discovery of magnetite in this area was in 1869 at the Pequest mine. The mine was operated successfully for a few years but the ore was exhausted, and after unsuccessful attempts to locate more ore in depth the mine was permanently closed.

At about the same time as the discovery of the Pequest mine the original Henry "Tunnel" was opened. It was driven 650 feet into the hill, supposedly along the footwall of a 15-foot "vein" that dipped to the east. A second drift about 50 feet below the first was reported to have struck the vein at greater depth, and a raise was put up from the northern end of the drift to the first tunnel. A third drift, near the foot of the hill, cut across the rock structure and entered the vein about 100 feet below the uppermost workings. So far as is known, no ore was produced or shipped from this property.

The Hoit mine was first opened in 1870 by a short slope that followed down the dip of a magnetite body. A drift about 70 feet long followed the ore to the southeast. This deposit was worked until about 1875. The amount of ore removed is not known. The portal is open but the workings are flooded to within a few feet of the surface, though they were pumped out for a short time by the Bureau of Mines while the mine was being sampled.

The Hoit farm exploration consisted of a shaft and a series of pits on a line of attraction northeast of the Hoit mine. The ore which was exposed by the shaft was too lean to be considered worth working.

EXPLORATION

A dip-needle survey conducted by the Bureau of Mines covered a continuous belt about 7,100 feet long and roughly 2,000 feet wide across the mountain northward from U. S. Highway 46 (Neumann and Mosier, 1948, fig. 4, 5). Following the magnetic survey, the Hoit mine and Henry tunnel areas were drilled; four holes were drilled at the Hoit mine and one at the Henry tunnel property, a total of 1,076 feet. In addition, the two upper adits at the Henry tunnel property were repaired and samples were cut. The Hoit mine was pumped out and sampled, and six shallow pits were excavated and sampled. The writer prepared a geological map of the area, a log of the drill core, and a map of the underground workings for the U. S. Geological Survey (pl. 29).

MAGNETIC SURVEY

The belt of attraction outlined by the dip-needle survey is fairly continuous for a distance of 4,600 feet (pl. 27). In general the readings are not high, seldom much above 30°. Readings outside the belt, however, are all less than 10°. The readings above 20° are obtained in two narrow elongate belts. The zone of attraction in the vicinity of the Henry tunnel area is 1,600 feet long and averages about 125 feet in width; the other zone starts south of the Hoit mine and is 2,700 feet long and about 75 feet wide. A third small area about 400 feet long and 50 feet wide occurs over the underground workings of the Hoit mine. The elongation of the anomalies closely parallels the gneissic structure and distribution of the rocks. The belts of attraction are confined almost exclusively to a layer of garnet- and sillimanite-bearing gneiss.

GEOLOGY

The ore deposits in the Pequest district are distributed along a belt of garnetiferous biotite gneiss, part of which carries sillimanite (pl. 27). On the east this belt is limited by gneissic alaskite and hornblende granite. On the west, in the southern part of the district, the biotite gneiss is bordered by a belt of amphibolite which on its western side is in contact with another mass of granite. Farther north, in the vicinity of the Hoit mine and beyond, there is no intervening belt of amphibolite; the belt of biotite gneiss narrows to a thin strip bounded by granite on the east and west. On the south at the base of the slope the pre-Cambrian gneisses terminate against Cambrian and Ordovician sedimentary rocks. The contact possibly is a fault. On the north side of the mountain the pre-Cambrian rocks are covered by glacial deposits.

Granitic rocks.—The granitic rocks are mostly alaskitic, though in places they contain some hornblende and biotite. Slightly perthitic microcline is the principal feldspar, though there is a little sodic plagioclase which appears to be partly replaced by the microcline. The rocks are massive to moderately well foliated, and the texture is granitic, though there appears to have been some recrystallization.

Belt of biotite-quartz-feldspar gneiss.—Biotite-quartz-feldspar gneiss without garnet or sillimanite, garnetiferous biotite gneiss, and sillimanite-bearing garnet-biotite gneiss constitute the main rock types in the belt of biotite gneiss. In addition some very local areas in the vicinity of the Henry tunnels contain tourmaline as an important constituent of the garnet-biotite gneiss. Some biotite-pyroxene gneiss, with interlayered garnet-biotite gneiss and a little granitic material, occurs in the eastern part of the belt in the Hoit mine area. None is exposed at the surface, but it appears in the core from drill hole 5.

The biotite gneiss is light colored, well foliated, and locally migmatitic. Quartz and plagioclase are the principal constituents; garnet, sillimanite, and biotite are the main accessory minerals. In addition the gneiss contains magnetite which locally is sufficiently abundant for the rock to have value as ore.

Belt of amphibolite.—The rocks of this zone are not well exposed, but, judging from one outcrop and pieces of float at the surface, the belt apparently consists principally of dark amphibolite. A specimen from the only outcrop in the area consists principally of quartz and plagioclase, with hornblende as the principal accessory mineral. The amphibolite is medium grained and well foliated, and lineation of the hornblende needles is readily observed. Much of the rock is migmatitic.

The amphibolite belt may have some associated pyroxene skarn. Dark pyroxene skarn is exposed on the east wall of the Pequest mine opencut. No skarn was seen elsewhere in the belt.

STRUCTURE

Beginning at the south end of the area the foliation of the rocks strikes N. 5°–10° W. and in the vicinity of the Hoit mine strikes becomes slightly east of north. Beyond the Hoit mine the foliation continues to become more easterly and strikes N. 25°–30° E. The dip is consistently east and southeast. In the southern part of the area dips are moderate to steep and become gentler around the Hoit mine where they are 20°–25° E.

The eastern contact between the belt of biotite gneiss and granitic rocks is essentially concordant and dips east. In the vicinity of the Hoit mine and to the southwest the granite west of the belt cuts across the biotite gneiss and thins it down to less than half its width at the south. This granite also cuts off the body of amphibolite, which does not continue beyond the Hoit mine.

The lineation of the gneiss plunges east-southeast to southeast at angles of 55°–70°. In the sillimanite-garnet-biotite gneiss west of the Henry tunnel area the plunge of the lineation is the same as the dip of the foliation to the east and southeast. It should be noted that this condition is somewhat exceptional in the pre-Cambrian rocks of northern New Jersey. In most places the trend of the lineation is at a considerable angle to the direction of dip and plunges northeast.

A fault is postulated at the south end of the area where, at the bottom of the slope, the pre-Cambrian rocks are in contact with Paleozoic sedimentary rocks. A small fault in a pit of the Pequest mine cuts off the skarn from the rest of the amphibolite.

MAGNETITE DEPOSITS

OCCURRENCE

The magnetite deposits are confined to the belt of garnetiferous biotite gneiss. At the Henry tunnel area the magnetite is restricted to the west central part of the belt where much of the rock is sillimanite-bearing garnet-biotite gneiss. At the Hoit mine the magnetite is in garnet-biotite gneiss, which has some layers of sillimanitic material. North of the Hoit mine the local areas of weakly mineralized rocks are also in garnet-biotite gneiss. With the exception of the Pequest mine where the magnetite was in pyroxene skarn, there is no mineralized rock outside the belt of biotite gneiss.

The bodies of magnetite are not solid except for local thin high-grade seams. No well-defined body of magnetite was found in the Henry tunnel area. At the Hoit mine the magnetite body was a small lens with indefinite boundaries, except where pegmatite forms part of the wall rock and the distinction between "ore" and country rock is fairly sharp. Shoot structures have not been recognized, unless the small lens at the Hoit mine can be considered a shoot.

So far as could be determined, the deposits and zones of magnetite are concordant with the foliation of the host rocks. Drilling was not extensive enough to determine the continuity of the magnetite laterally or vertically.

MINERALOGY

Magnetite is the only ore mineral. The magnetite is somewhat unusual in that it seems to be almost free of titanium. Polished specimens of ore show very few exsolved blades of ilmenite, and there are no intergrown bodies of pure ilmenite. The magnetite has, however, an abundance of small rods and blebs of exsolved spinel.

Pyrite, the only metallic gangue mineral, is present in small amounts. The other gangue minerals are the normal constituents of the host rock and include biotite, garnet, some sillimanite, quartz, and plagioclase. Tourmaline, green spinel (pleonaste?), mica, and some apatite may be present as minor accessory constituents.

GRADE

No reliable analytical data on the ore of the district was available previous to the exploration by the Bureau of Mines. The results of sampling and analyses show that the ore is marginal to submarginal in grade. Phosphorus is rather high; titanium and sulfur are low. Analyses are published in Bureau of Mines Report of Investigations 4225 and are summarized in table 1.

TABLE 1.—*Analyses of drill core, Pequest district, Warren County, N. J.*

[After U. S. Bureau of Mines [1]]

	Sample (feet)	Total Fe (percent)	Magnetic Fe (percent)
Hoit deposit:			
Drill hole 1	77.4	[2] 12.8	----------
Drill hole 2	23.1	[2] 13.8	----------
Drill hole 3	32.7	[2] 19.4	----------
Hoit mine	----------	[3] 25.1	[4] 20.9
Henry tunnel area:			
Drill hole 11	131.0	[2] 16.0	----------
Henry tunnel	----------	[5] 20.3	[6] 16.7

[1] Data from Neumann and Mosier, 1948, p. 23–27, 33–34.
[2] Weighted average.
[3] Average of 16 samples.
[4] Average of 2 composite samples.
[5] Average of 39 samples.
[6] Average of 6 composite samples.

DESCRIPTION OF PROPERTIES AND RESULTS OF EXPLORATION

HENRY TUNNEL AREA

The main zone of mineralized rock at the Henry tunnel area is approximately 1,100 feet long and averages 75 feet in width. In the only hole that was drilled east of the zone the rocks also contain a small amount of magnetite. A small lenticular body of magnetite-rich sillimanite-garnet-biotite gneiss crops out about 150 feet west of the main zone.

The tunnels were reopened and the deposits sampled by the U. S. Bureau of Mines (Neumann and Mosier, 1948, p. 33–34). The underground workings were examined also by the writer. The length of the workings in the upper adit is 362 feet and in the lower adit is 319 feet. A raise connects the two levels. Plate 29 is a plan of the workings.

The rock from the mineralized zone is a foliated garnet-biotite gneiss, some of which contains sillimanite. Magnetite is dispersed throughout the rock, though there are some layers and folia that are richer in magnetite than the rest of the rock. Some of the rock consists of a mass of finely crystalline magnetite accompanied by biotite, a little quartz and feldspar, sillimanite, and knots of pink garnet. No massive solid magnetite was seen. Granitic material is very rare, though in a few places some thin layers are interleaved with the biotite gneiss. Some thin pegmatite bodies are present parallel to the foliation of the gneiss.

The average dip of the foliation of the magnetite-bearing rock is about 55° E. The attitude of the foliation is fairly consistent throughout the underground workings. There is, however, some evidence of folding in the lower adit at the end of the west drift, where the dip of the foliation is gentle and the strike is more easterly. On the west wall, near the forks of the adit, some small drag folds in the weathered gneiss can be seen. Two directions of faulting are seen underground. One system strikes and dips roughly parallel to the foliation. A second direction of faulting is represented by small, steeply dipping or vertical zones of shearing, whose strike is nearly normal to the strike of the rock foliation. The amount of movement on the faults is not known but possibly is not large. The time of movement was later than the formation of the magnetite, and in some places was certainly later than the formation of the pegmatite.

Grade.—All the material analyzed is of submarginal grade. Total Fe content ranges from 12.2 to 25.2 percent, and in composite samples magnetic Fe content ranges from 13.1 to 19.9 percent. The average content of P is 0.21 percent, TiO_2, 0.32 percent; S, 0.07 percent; and Mn, 0.19 percent (Neumann and Mosier, 1948, p. 33).

HOIT MINE

The principal working at the Hoit mine is an underground development on a small lenticular magnetite body. A short distance north a small dump in front of a cut may indicate another small caved opening. Several other shallow pits are scattered about the area, but none of these shows any ore.

The Bureau of Mines investigators partly dewatered the shallow workings of the accessible opening and cut several samples (Neumann and Mosier, 1948, p. 34), and the writer mapped the geology. A plan of the workings is shown in plate 29.

The magnetite is in garnetiferous biotite gneiss that contains a little sillimanite. The body is a thin lenticular sheet on the eastern flank of a small anticlinal roll whose axis is roughly north-south. In the upper drift, the body of magnetite pinches out against a wedge of pegmatite that comes in from the west. A wedgelike tongue of pegmatite also occurs along the northern wall of the slope. The downward continuation of the magnetite body was not recognized in any of the drill holes to the east and southeast.

Four vertical holes were drilled east and southeast of the Hoit mine shaft. Several thin mineralized zones were cut in drill holes 1, 2, and 3; hole 5 was barren. Individual seams of magnetite do not have good continuity from hole to hole, but possibly the general zone of mineralized rock in which they occur is a continuation of the zone that contains the magnetite lens at the Hoit mine (pl. 29).

Grade.—The material from the Hoit mine is of slightly higher grade than that from the Henry tunnel area. The total Fe content ranges from 17.5 to 30.5 percent; magnetic Fe is about 20.9 percent.

HOIT FARM EXPLORATION

No magnetite-bearing rocks are exposed in this area, and the few old pits do not reveal any. No drilling was done by the Bureau of Mines in this area.

CUMMINS DISTRICT

The Cummins district includes 4 magnetite deposits of which only the Cummins deposit has been actively mined. The rest, including the Ayres mine, Green farm exploration, and Scranton's lease, have attracted little attention since their initial discovery.

LOCATION

The properties of the Cummins district are in Independence Township, Warren County (fig. 30), and are alined in an east-southeasterly direction on the western ridge of Cat Swamp Mountain, about 4 miles northeast of Hackettstown, and 1 mile north of the village of Vienna on U. S. Highway 46. The Green farm exploration, Scranton's lease, and Cummins mine are easily accessible from the paved road between Vienna and Allamuchy, and the Ayres mine is about 4,000 feet east-southeast of the Cummins, within a few hundred feet of a paved road that crosses the ridge in the eastern part of the district (pl. 30).

HISTORY AND PRODUCTION

The following historical data were taken from Bayley (1910, p. 260–262).

The initial discovery of magnetite in this district was in about 1868 in the vicinity of the Shaeffer farm explorations southeast of the mapped area. Apparently little work was done there and only a small amount of ore was found.

Further exploration led to the discovery of the Cummins mine about 1882 on the north side of Cat Swamp Mountain. A shaft was sunk that exposed a breadth of from 10 to 15 feet of magnetite-bearing rock that was generally lean but contained a few rich streaks. About 20 tons a day of 40-percent ore was mined in 1882. By the end of the year (1882) the shaft had been sunk to a depth of 80 feet and 3,000 tons had been shipped. There are now two shafts and two small opencuts on the property. Apparently little or no additional work was ever done here. The two shafts are now flooded to within a few feet of their collars but the opencuts are still accessible.

Magnetite was discovered about the same time (1881) at the Ayres mine, 4,000 feet east-southeast of the Cummins, a locality situated on the extension of a belt of magnetic attraction. No record is available of the amount of work done and ore mined from here. Judging from the number of openings (4 shafts, caved or flooded, and 4 shallow opencuts) and the small size of the dumps, the work was mostly exploratory.

The Scranton's lease property consists of two caved shafts at the north base of the mountain, located on the north side of the road about

2,400 feet west of the Cummins mine. Bayley has essentially no information concerning this property except that activity here probably coincided with that at the Cummins.

The Green farm exploration consists of a shaft and two shallow pits on top of the ridge at the west end of the mountain 4,500 feet southwest of the Cummins mine. It has been referred to as the Carrol place exploration. Bayley (1910, p. 260) states that "a shaft 90 feet deep was sunk in 1882, and a vein of good quality ore 6 feet wide was found. Nothing further is known of the place." Some low-grade ore was found on the dump of a small shaft on the south side of the road about 700 feet northwest of the Green farm exploration.

EXPLORATION

A dip-needle survey of an area more than 12,000 feet long and from about 500 feet to 2,000 feet wide was made in the Cummins district by the U. S. Bureau of Mines (Neumann and Mosier, 1948, figs. 2, 3). Several minor magnetic anomalies were outlined; two of them showed a sufficiently strong attraction and were extensive enough to warrant exploration by diamond drilling. These were at the Cummins mine and the Ayres mine. Six holes that have a total footage of 2,423 feet were drilled at the Cummins anomaly, and 3 holes with a total footage of 624 feet at the Ayres.

MAGNETIC SURVEY

The largest magnetic anomaly is near the Cummins mine. Within a belt 2,500 feet long and about 400 feet wide dip-needle readings are 20° or greater. Readings over a large area south of the anomaly range between 10° and 20°, with an average of about 12°. The anomaly trends almost due east. Two fairly distinct zones of stronger attraction are found within the belt. The highest dip-needle values are at the west end over a broad area of attraction, 750 feet long and about 200 feet wide, that trends west-northwest. Readings within this area range from 30° to 60°. Another ridgelike zone of attraction that trends nearly east lies to the northeast and, beginning about at the shafts and dump of the Cummins mine, continues within the 30° contour for about 1,175 feet with a width of 100 feet. Two small "peaks" where readings of more than 40° were obtained are found at the west and east ends of this "ridge."

The anomaly next in importance is in the vicinity of the Ayres mine, about 1,300 feet east-southeast of the Cummins anomaly. The zone of attraction is a narrow belt about 150 feet wide and 1,750 feet long, within the 10° contour. In the central part of the belt there is a zone 900 feet long where dip-needle readings between 20° and 30° were taken, and in one very small area the readings attain a maximum of 55°. Over the surrounding area the magnetic attraction is very low.

GEOLOGY

The pre-Cambrian gneisses in which the magnetite deposits occur can be separated into three general lithologic units (pl. 30). These units form belts that trend in a general easterly direction. These are (1) a belt of medium-grained, well-foliated hornblende- and pyroxene-quartz-plagioclase gneiss that contains layers of metasedimentary rock and associated layers of syenite; (2) a belt of gneissic hornblende granite and alaskite; and (3) a belt of medium- to coarse-grained, slightly foliated to massive granitic quartz-plagioclase gneiss. The principal magnetite deposits are confined to the first unit where they occur in zones of skarn and amphibolite.

Sandstone beds of the Hardyston quartzite of Early Cambrian age unconformably overlie the pre-Cambrian rocks in a small area at the extreme west end of the ridge.

A rather extensive mantle of glacial debris as much as 15 feet thick covers the top and northern slope of the ridge in the central and eastern parts of the district. Alluvium and probably glacial material cover the surrounding lowlands.

Belt of metasedimentary rocks.—At the east end of the mapped area north of the Ayres mine a variety of gneisses is exposed, of which perhaps the most abundant types are granitic hornblende gneiss and pyroxene-quartz-plagioclase gneiss. Amphibolite, some skarn, and garnetiferous biotite-quartz-plagioclase gneiss are interlayered with these rocks. The amphibolite and skarn commonly occur as schlieren within the granitic quartz-plagioclase gneiss. Migmatites formed by intimate interlayering of granitic quartz-plagioclase gneiss and amphibolite are also seen. Some syenite is exposed in the southern part of the belt near the Ayres mine, and several layers of syenitic gneiss were revealed by drill cores. On the whole the rocks in this belt are well foliated. The gneisses are cut by thin veins and veinlets of granite pegmatite that are generally conformable to the foliation but cut across the gneissic structure in some places.

The belt of metasedimentary rocks cannot be traced continuously westward to the Cummins mine, because the intervening area is concealed by a cover of glacial material. A few exposures in the vicinity of the Cummins mine and the sections revealed by the drill cores indicate, however, that this general unit is probably the same as that in which the magnetite deposits occur.

Belt of granitic quartz-plagioclase gneiss.—A belt of granitic quartz-plagioclase gneiss occupies most of the top and all of the south side of the ridge. This rock forms prominent cliffs all along the southern slope of the mountain. The rock is medium- to coarse-grained and massive to slightly foliated. Some schlieren and larger lenticular bodies of amphibolite occur within it, and veinlets of granite pegmatite cut it in places. In general the rock is alaskitic, the dark minerals seldom accounting for more than a few percent of the mineral content. Pyroxene and hornblende may be present as well as magnetite. At places this rock is weakly magnetic, owing, probably, to an increase in the amount of accessory magnetite or, possibly, to small concealed lenses of mineralized amphibolite or skarn.

Belt of hornblende granite and alaskite.—A belt of gneissic hornblende granite and alaskite is fairly well exposed in the vicinity of the Green farm exploration and at the northwest end of the ridge. Depending on their content of mafic accessory minerals, the rocks range from hornblende granite to alaskite. The rock contains abundant thin hornblende-rich streaks or schlieren, and some of the gneiss appears to be contaminated by the incorporation of amphibolite. In general the granite and alaskite are well foliated and under the microscope crushed and granoblastic textures are visible.

Pegmatite.—Granite pegmatite is fairly common but is erratically distributed, and individual bodies are too small to be mapped separately. In a few places it contains coarsely crystalline magnetite. A pink pegmatite containing coarse, shreddy pyroxene is exposed along the road 2,000 feet west of the Green farm exploration, where it intrudes hornblende granite and alaskite.

STRUCTURE

The strike of the foliation ranges from west to west-northwest. The distribution of the lithologic units conforms to the foliation trends. An exception to the persistent westerly trend is found in the western part of the area where the foliation has an east-northeast to northwest strike. Over most of the area the foliation dips steeply south or is essentially vertical. In the western end of the ridge the foliation dips 45° to 50° in a southeasterly direction. Linear structures that are shown by alinement of prismatic minerals in the plane of the foliation plunge southeast to east-southeast at an average angle of 45°.

MAGNETITE DEPOSITS

OCCURRENCE

The host rock for the magnetite deposits is amphibolite and pyroxene amphibolite. The deposits are not massive bodies but are characteristically streaked. Thin, magnetite-rich layers alternate with weakly mineralized or barren rock. The deposits are restricted to zones of mafic pyroxene gneiss and skarn. In addition, there are some interlaminated thin sheets or lenses of granite pegmatite. Footwall and hanging-wall boundaries cannot be clearly delimited. The rocks outside the mineralized zones, however, include a greater amount of granitic gneiss and pegmatite.

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The magnetite layers and the enclosing rocks are nearly vertical or dip very steeply north or south. They strike nearly east or slightly north of east. The general form of the deposits is that of tabular zones of mineralized rock in which magnetite-rich layers alternate with barren or weakly mineralized rock. The presence of shoot structures has not been definitely established in this district.

MINERALOGY

Magnetite is the only ore mineral. No hematite was seen in polished specimens. Under the microscope a very few exsolution blades of ilmenite were seen in the magnetite. Some of the magnetite contains minute oriented rods of an undetermined nonmetallic mineral, possibly spinel.

Some pyrite and chalcopyrite usually accompany the magnetite. Pyrite ranges in amount from less than 1 percent to 5 percent, with a possible average of 2 percent. Chalcopyrite is much less abundant and more sporadic in distribution.

Other gangue minerals are the normal constituents of the host rock—feldspar and pyroxene, less commonly hornblende, and a little biotite. Apatite, most of which probably was introduced during the period of mineralization, is associated with the magnetite and may occur in amounts greater than 3 percent by volume.

GRADE

Previous to the drilling on the Cummins and Ayres properties by the Bureau of Mines investigators, no good analytical data on grade were available. Bayley (1910, p. 262) gives the following analysis of "an average sample of the washed ore" from the Cummins mine: SiO_2, 16.31; Fe, 56.54; Mn, 1.77; S, 2.80; P_2O_5, td.; TiO_2, 0.0.

During the recent investigation no material approaching this in possible Fe content was seen on the dumps, in the old openings, or in the drill core. Possibly it represents ore from a local high-grade seam, or the sample may have been taken from ore hand picked for shipment.

Analytical data from the drill cores at the Cummins mine are given by Neumann and Mosier (1948, p. 7–22) and are summarized here in table 2. These analyses show that the grade of ore in the drill holes is low to submarginal. No data on the sulfur, phosphorous, manganese, or titanium content are available.

DESCRIPTION OF PROPERTIES AND RESULTS OF DRILLING

CUMMINS MINE

In the small opencut a little less than 400 feet east of the shafts and just south of the road, the foliation of the gneiss strikes east and dips very steeply south or is essentially vertical. The mineral lineation plunges 45° ESE. Amphibolite is on the footwall while the hanging wall is a medium-grained gneissic hornblende-biotite granite. A dike of granite pegmatite 2 feet wide transects the amphibolite at a slight angle. The mineralized zone is from 2 to 3 feet wide and is a garnetiferous biotite-hornblende-pyroxene skarn containing more or less evenly disseminated magnetite that amounts to approximately 20 percent of the rock. The zone is stained with iron oxide caused by oxidation and leaching of pyrite, which is present in small amounts.

The rock on the dumps at the shafts is mostly dark, medium-grained pyroxene gneiss with a little magnetite. A less abundant rock is coarse-grained garnet-biotite skarn in which some magnetite is present.

Massive medium-grained altered granite gneiss with conspicuous pyrite is exposed in a cut on the north slope, about 400 feet south-southwest of the shafts. Megascopically and under the microscope it can be seen that the rock has been somewhat crushed and rather strongly chloritized. Some of it contains disseminated magnetite. Pieces of hornblende-pyroxene skarn containing some magnetite occur on the dump. A thin section of a specimen of feldspathic skarn showed complete serpentinization of the original pyroxene.

The two magnetic anomalies at the Cummins mine suggest the presence of two mineralized zones—a western one that strikes about N. 60° W. and an eastern belt that trends nearly east. This suggestion is borne out by the differences in the rocks exposed by the drill holes. The footwall rocks north of the western ore zone are pink gneissic granite. On the north side of the eastern zone there are several garnetiferous units, amphibolite, and thin skarn layers in addition to layers of granitic rock.

Results of drilling.—Holes 1, 2, 3, and 6 were drilled to check the western anomaly at the Cummins mine. Of these, only hole 2 (pl. 31) intersected material which was of sufficient grade and thickness to be considered marginal. In hole 2 a mineralized zone was encountered that was about 60 feet thick and had an average total iron content of about 25 percent. The zone consists of layers of magnetite-rich gneiss 2–5 feet wide that alternate with mixed pegmatite and barren or weakly mineralized pyroxene gneiss. Such material might be of economic importance if the zone has sufficient vertical and lateral continuity. Hole 1, however, drilled at a lower angle in the same vertical plane as hole 2, cut only a small amount of magnetite, part of which appears to be continuous with the magnetite zone in hole 2. Hole 3 was drilled to explore the same anomaly at a greater depth and should have intersected the extension down the plunge of the zone found in hole 2. A zone of pyroxene gneiss, amphibolite, and skarn was encountered that is probably the same as the mineralized belt in hole 2, but on the whole the zone was weakly mineralized, the average total iron content being only about 21 percent. Of course it is possible that drill hole 3 passed above or below a small shoot.

Hole 6 encountered a zone of weakly mineralized gneiss. This is probably the same zone that was cut by holes 1, 2, and 3, but, owing to the plunge of the linear structure, the section drilled would be above the downward extension of the zone in hole 2.

Holes 4 and 5 were drilled to test the narrow east-west anomaly east of the Cummins mine. Hole 4 intersected a zone about 50 feet wide that contained several layers of magnetite-bearing gneiss 2 to 5 feet thick, separated by thicker layers of barren or weakly mineralized rock. This mineralized zone is undoubtedly the continuation of the belt on which the Cummins shafts were sunk. Drill hole 5 cut a 30-foot zone of slightly mineralized rock and a few thin weakly mineralized layers.

TABLE 2.—*Analyses of drill core, Cummins mine, Warren County, N. J.*

[After U. S. Bureau of Mines [1]]

Depth from surface (feet)	Thickness (feet)		Total Fe [2] (percent)	Magnetite [2 3] (percent by weight)	Magnetic Fe [3] (percent)
	Apparent	True			
Drill hole 1:					
154–159.5	5.5	3.2	30.5	42.5	30.8
224–239	15.0	11.7	26.7		
240–242.5	2.5	1.9	21.1	22.4	16.2
243.5–256.5	13.0	11.0	25.3		
256.5–275	18.5	14.4	18.7		
280.0–288.0	8.0	6.2	22.9		
Drill hole 2:					
129–159	30.0	15.4	[4] 28.0	34.1	24.7
162.7–179	16.3	8.3	[4] 28.1	36.5	26.4
201–229	28.0	14.4	[4] 33.9	23.1	16.7
Drill hole 3:					
315.3–345.3	30.0	22.3	21.9	21.9	15.9
345.3–367.3	22.0	16.4	24.1		
379.5–480.8	86.8	64.5	19.8	18.5	13.4
Drill hole 4:					
272–277	5.0	3.9	21.9		
277–292	15.0	11.7	37.0		
292–312	20.0	15.6	17.5	19.1	13.8
312–317	5.0	3.9	26.2		
317–342	25.0	19.5	17.8		
Drill hole 5:					
264–294	30.0	21.2	18.1		
294–314	20.0	14.1	26.0	26.1	18.9
314–324	10.0	7.1	16.1		
Drill hole 6:					
128–153	25.0	14.7	20.9	26.4	19.1
173–193	20.0	11.8	21.7		
199–202	5.0	2.9	27.7		

[1] Neumann and Mosier, 1948, p. 7–19.
[2] Weighted average.
[3] Based on visual estimates of magnetite in core.
[4] Based on sludge analyses because of poor core recovery.

AYRES MINE

The mineralized zone at the Ayres mine trends nearly east, according to the shape of the magnetic anomaly and the distribution of the pits and shafts, and is in general agreement with the strike of the foliation in the adjacent gneiss, which ranges from N. 80° E. to N.

80° W. From data on the foliation angle observed in the drill cores and observations on surface exposures the dip is vertical or very steeply inclined (85°–90°) to the north. Lineation is well shown in the cut on Ryan road at the east end of the belt where it plunges 45°–50° S. 60° E.

Drilling shows the magnetite to be in a zone of skarn and pyroxene gneiss 20 to 50 feet thick with granitic gneiss containing schlieren of amphibolite on the hanging wall and footwall. Tourmaline is abundant in two layers of syenitic gneiss near the ore zone in Ayres drill hole 1.

The mineralized zone consists of thin layers of rock 1–3 feet thick, which contain as much as 25 percent magnetite, and, locally, a rare high-grade seam of magnetite. Analyses of drill-core samples by the Bureau of Mines show a consistently low total iron content. The highest analysis was 22.9 percent total iron from a 0.4-foot sample; other samples are considerably lower. Furthermore, pyrite is abundant in all specimens in the mineralized zone, ranging in amount from 5 to 20 percent by volume. A little chalcopyrite is also present. Judging from the material on the dumps the ore taken from the old openings was generally of this kind, though a few small fragments of coarse magnetite were also seen.

GREEN FARM EXPLORATION

The dumps at the Green farm exploration show mostly amphibolite and some coarse-grained gneiss that carries a little magnetite. In a shallow pit, hornblende granite and amphibolite are cut by a narrow pegmatite in which there is magnetite.

SCRANTON'S LEASE

There are no exposures here. Some magnetite in pyroxene gneiss and some amphibolite were seen on the dumps.

MOUNT OLIVE DISTRICT

The Mount Olive district (fig. 30, pl. 32) includes a large area in southwestern Morris County, within which there are two general belts of magnetic attraction and, according to Bayley's report on the iron mines of New Jersey (Bayley, 1910, p. 324–331), at least 12 known magnetite deposits. The U. S. Bureau of Mines made an extensive dip-needle survey of the district and selected one area for drill-hole exploration (Neumann and Mosier, 1948, p. 27–32, fig. 6). Private companies have also conducted magnetic surveys of many parts of the area and have done considerable diamond drilling. Geologic mapping of the area, examination of the old mine pits and dumps, and logging of drill core were done by the U. S. Geological Survey.

LOCATION

The Mount Olive district includes parts of Mount Olive, Roxbury, and Washington Townships, Morris County, and is south-southwest of Lake Hopatcong and southeast of Budd Lake. The area trends about N. 40° E. and extends nearly 7 miles southwestward from U. S. Highway 46 near Ledgewood. It is from 0.75 to 2.25 miles wide, with the villages of Mount Olive and Flanders on the northwest and southeast boundaries, respectively (pl. 32). All parts of the district are easily accessible by automobile. U. S. Highway 206 passes through the middle of the area, and there are many other paved and hard surfaced dirt roads lacing the district. Flanders is a station on a branch of the Central Railroad of New Jersey, and the main line of the Delaware, Lackawanna, and Western Railroad runs within a half mile of the northeastern end of the district. Dover and Hackettstown are the nearest large towns.

HISTORY

According to Bayley (1910, p. 324–331) the initial discoveries of ore in the district were made about 1848, when several deposits were opened. Subsequently, shallow shafts were sunk on the more promising properties and considerable activity was seen until about 1880 when exploration and development virtually ceased. Practically no production data are available for the district, but apparently the properties referred to by Bayley as the Mount Olive mines were the most vigorously exploited. Total production to 1880 was about 22,400 tons.

The ore encountered was reportedly in "veins" 3 to 15 feet wide, the majority being between 5 and 10 feet. The veins dipped southeast at moderate to steep angles, and a plunging shoot structure was recognized in some of the deposits. The plunge of the ore bodies was to the northeast.

The Mount Olive district apparently was never a large producer of iron ore. The ore bodies on which openings were made, though of a good grade, were all small. It seems doubtful that the production from the entire district exceeded a few hundred thousand tons.

EXPLORATION

The dip-needle survey of the Mount Olive district conducted by the Bureau of Mines covered two previously known belts of magnetic attraction. The total length of the area covered was approximately 37,000 feet and the width ranged from 500 to about 1,500 feet.

Four drill holes, which had a total footage of 1,412 feet, were drilled by the Bureau of Mines at the east end of the north belt in the vicinity of the Baptist Church and Hilt mines (fig. 31). Private companies

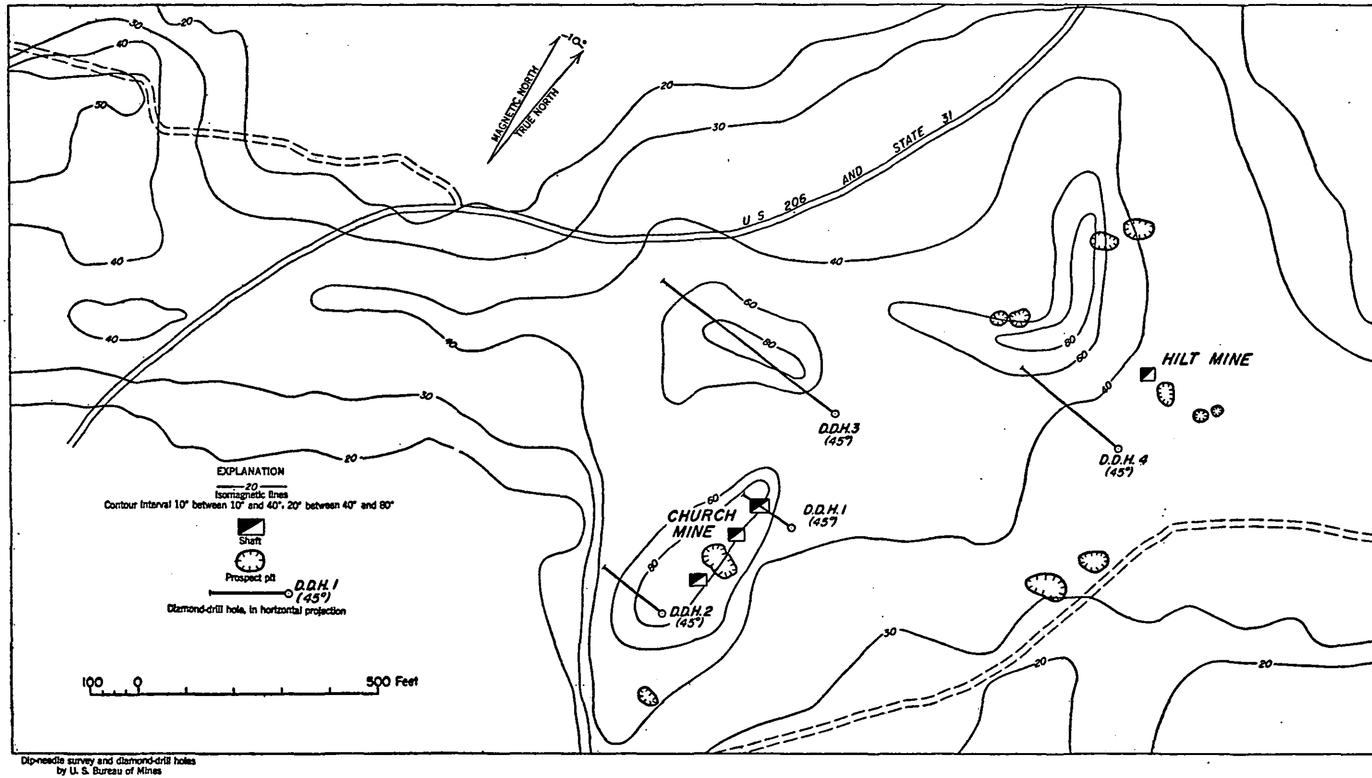

FIGURE 31. Map of the Baptist Church and Hilt mine areas, Mount Olive district, Morris County, N. J.

have also drilled several thousand feet of holes elsewhere in the district.

MAGNETIC SURVEY

Earlier dip-needle surveys outlined two parallel belts of attraction in the district and exploration and mining were conducted along these zones. The magnetic survey by the Bureau of Mines was confined to these belts. The northern belt trends roughly northeast; it has a fairly continuous width of about 800 feet and is about 5 miles long, extending from near the South Branch of the Raritan River, 1.25 miles northwest of Bartley to about U. S. Highway 46 northwest of Ledgewood. The second belt is roughly parallel to the northern belt; it has an average width of 1,000 feet and extends from about 1.5 miles southwest of Bartley to a point just south of the Baptist Church mine, a distance of about 4.75 miles.

The general attraction over the northern belt is considerably greater than over the southern belt. Both are characterized by dip-needle readings above 10°, ranging from 10° to 90°. Within each belt are many small areas of strong attraction, generally 40° and higher in the northern belt, and greater than 30° in the southern belt. Such areas of attraction constitute small "prominences" within a region of lower attraction. Many of the old mines and prospects are within these local areas of higher attraction which have served to guide the location of drill holes. The prominences are from 100 to about 500 feet long and from 50 to 150 feet across, and they are generally symmetrical about the longer axis. In general the elongation is at an angle to the northeasterly trend of the belt. In the northern belt the prominences strike north-northwesterly at an average angle of 40° to the strike of the belt. In the southern belt they trend about north, making angles of about 30° to the trend of the belt except in the central part, where they trend northeasterly and are parallel with the belt.

GEOLOGY

Bed rock exposures are scanty in most of the Mount Olive district because of the deep cover of soil and glacial debris. Along the steep slopes in the eastern edge of the district good outcrops can be found. There are also a few exposures in road cuts along U. S. Highway 206 near Flanders, on U. S. Highway 46 northwest of Ledgewood, and along the road a half mile northwest of Bartley.

The district is entirely within an area of pre-Cambrian gneisses forming a broad, gently rolling upland that trends northeast and is bounded on the southeast by a lowland underlain by Paleozoic rocks. The southeast boundary is marked almost everywhere by a steep slope.

Hornblende granite and alaskite.—The predominant rocks exposed at the surface and in drill holes are hornblende granite and alaskite. These are pinkish to buff granitic rocks ranging from medium- to coarse-grained and, in most exposures, are only slightly foliated to massive. Most of the rock outside the ore zones is alaskite with less than 5 percent of mafic accessories. Locally, however, it may contain a few percent of dark minerals of which hornblende and magnetite are the principal minerals.

Belt of granitic quartz-plagioclase gneiss and mafic gneisses.—Near Bartley and Flanders and at the northern end of the district near Ledgewood there are some outcrops of granitic hornblende- and pyroxene-quartz-plagioclase gneiss associated with amphibolite and pyroxene amphibolite. A layer of garnetiferous biotite-pyroxene-quartz-plagioclase gneiss was also seen near Flanders. These more mafic gneisses apparently are in a belt that more or less conforms to the southern belt of magnetic attraction.

Granitic quartz-plagioclase gneiss is not plentiful in the Mount Olive district. The amphibolitic rocks occur as layers and schlieren in the granitic quartz-plagioclase gneiss and locally in hornblende granite and alaskite.

A narrow layer of biotite-quartz-plagioclase gneiss with conspicuous metacrysts of pink garnet occurs in the zone of mafic gneiss and granitic quartz-plagioclase gneiss near Flanders.

This belt of mafic gneisses, in part at least, probably is a remnant of metasedimentary rocks that were preserved in a large body of granite and alaskite.

Diabase.—Some diabasic dike rock has been cut in the drill holes, and diabase float is found near the Hopler mine at the south end of the district.

STRUCTURE

The strikes of the foliation, which are more or less parallel to the trend of the magnetic belts, range from about N. 50° E. to N. 25° E. Dips are consistently to the southeast and east-southeast and range from 55° to vertical; the average is about 65°. Lineation, where observable, plunges about 30° NE. (pl. 32).

The eastern boundary of the district marked by the contact between pre-Cambrian and Paleozoic rocks is probably a fault. No faults were recognized within the pre-Cambrian rocks, though they may well be present.

MAGNETITE DEPOSITS

OCCURRENCE

No ore is exposed and the nature of the deposits must be inferred from material on the dumps and from drill-hole data.

The predominant rocks of the ore zones, as in the rest of the area, are granitic. In the Baptist Church and Hilt mine areas hornblende granite and alaskite, pegmatite, some granitic quartz-plagioclase gneiss, and a little syenite occur with the ore. A few thin layers of biotite gneiss and amphibolite also are present. At the Hopler mine, near the southwest end of the southern belt, biotite gneiss and garnetiferous biotite gneiss are plentiful, and some pyroxene amphibolite is present; but granitic rocks are rare in core from holes drilled by the Pittsburg Coke and Iron Co.

In places where there are layers or lenses of amphibolite and pyroxene amphibolite the magnetite apparently tends to be concentrated in the mafic zones. The granitic rocks also contain magnetite, however, and it may be present in sufficient amount to constitute ore. In the area drilled by the Bureau of Mines the magnetite is in gneissic granite.

Bayley's description (1910, p. 324–331) suggests that the deposits are discrete ore bodies. The drilling has shown that the ore seldom has sharp boundaries with the adjacent rock. Several layers or zones of magnetite-bearing rock may occur together, separated by barren or weakly mineralized rock. The layers of magnetite lack good continuity down dip and along their strike. Nothing is known about possible shoot structure.

MINERALOGY

Only ore from the drill cores in the area drilled by the Bureau of Mines was studied in detail.

The magnetite is fairly pure and has only a few blades of exsolved ilmenite. Some microscopic blebs, dashes, and laths of a nonmetallic mineral, possibly spinel or rutile, can be seen arranged along octahedral planes in the magnetite.

Besides the exsolved laths of ilmenite in magnetite, the ore contains considerable pure ilmenite. The pure ilmenite has the same habit as the magnetite and may be intergrown with it or may occur independently.

Pyrite is present as irregular masses and less commonly as veinlets. Mostly it occurs in the silicates where it typically enters on or near the border with magnetite, and some apparently occurs along boundaries between silicate grains.

A very little chalcopyrite is present in tiny irregular bodies. The age relationship with respect to pyrite is not known.

The silicate gangue minerals are the normal rock constituents of the host. In the ore from the Baptist Church and Hilt mines microperthite, quartz, and lesser amounts of plagioclase and mafic minerals are the principal silicates. The mafics include biotite, pyroxene, and hornblende. Apatite, normally amounting to little more than a fraction of one percent, is commonly present. In addition there may be some chlorite and a little epidote in the magnetite-bearing rocks. Elsewhere, as at the Hopler mine, where the host rocks are gneisses, the chief gangue mineral may be pyroxene.

GRADE

In Bayley's (1910, p. 324) account of the Mount Olive mines he states that in the north belt "* * * on the whole the ore was lean * * *" though "* * * some of the openings were important mines * * *". Ore found in the south belt "* * * was so lean as to be unmerchantable * * *". This is in accordance with the results of drilling by private companies and by the Bureau of Mines. Although all the analyses given by Bayley of ore from some of the early mines indicate around 60 percent iron content, these were probably from small, extremely local, rich seams or pockets of ore. Analyses of ore intersected in the holes drilled by the Bureau of Mines at the Baptist Church mine and Hilt mine properties are given in the Bureau of Mines Report of Investigation 4225 and are summarized in table 3. On the average the ore is of marginal to submarginal grade, seldom exceeding 20 percent total iron, which is somewhat less than the magnetic or recoverable iron. Although the Bureau of Mines analyses do not show it, some of the ore contains considerable sulfur in the form of pyrite.

TABLE 3.—*Analyses or drill core, Baptist Church and Hilt mines, Mount Olive district, Morris County, N. J.*

[After U. S. Bureau of Mines [1]]

Depth from surface (feet)	Thickness (feet)		Total Fe [2] (percent)	Depth from surface (feet)	Thickness (feet)		Total Fe [2] (percent)
	Apparent	True			Apparent	True	
Drill hole 1:				Drill hole 3—Continued			
57.0–72.0	15.0	14.3	27.0	270–290	20.0	15.1	17.2
82–97	15.0	14.3	20.2	290–308	18.0	13.6	22.4
Drill hole 2:				324–329.2	5.2	3.9	15.6
71–90.5	19.5	17.7	19.1	382–387	5.0	3.8	23.5
Drill hole 3:				414–418	4.0	3.0	28.3
44–54	10.0	--------	18.2	491–509	18.0	13.7	21.4
173–183	10.0	--------	16.7	Drill hole 4:			
200–203	3.0	--------	19.6	134–160	26.0	18.4	28.2
244–270	26.0	19.5	24.0	240–250	10.0	7.1	21.3

[1] Neumann and Mosier, 1948, p. 7–22.
[2] Weighted average.

DESCRIPTION OF PROPERTIES AND RESULTS OF DRILLING

During the preliminary study of the Mount Olive district the sites of most of the old mines were visited. All of them are now represented by overgrown pits and dumps and a few open shafts from which very little important geologic data can be obtained. Descriptions of the old mines, more complete than it is now possible to give are available from Bayley's account of the Mount Olive district (Bayley, 1910, p. 324–331). As only the Baptist Church and Hilt mines were drilled by the U. S. Bureau of Mines, discussion here will be limited to these properties.

Bedrock does not crop out in the Baptist Church-Hilt mine area, but all the surface float is gneissic granite and pegmatite. The rock on the dumps appears to be mostly granite and pegmatite containing 20–30 percent of accessory magnetite and considerable pyrite. There are also a few fragments of biotite-rich gneiss. It is impossible to obtain any structural data, but according to Bayley (1910, p. 330) a 5- to 6-foot vein at the Hilt mine dipped 75° SE.

Results of drilling.—Holes 1 and 2 were drilled to check the Baptist Church mine anomaly; hole 3 was drilled on an anomaly midway between the Baptist Church mine and Hilt mine; and hole 4 was drilled at the Hilt mine (fig. 31). All 4 holes were drilled due west at an inclination of 45°, the assumption being that the strike of the ore zones, as indicated by the trend of the anomalies, was north.

Some ore was encountered in each of the drill holes (pl. 33). The rocks penetrated by the drills are mostly granite and alaskite, syenite, and some granitic quartz-plagioclase gneiss. In addition, there are some thin layers of biotite gneiss and amphibolite. Diabasic dike rock occurs in core from holes 1, 3, and 4.

Syenite is possibly more plentiful than granite or alaskite. Both types occur together, but syenite is commonly associated with the ore though it also occurs away from the mineralized rock. In the few available exposures, most of which are outside the ore zones, no syenite was recognized. Possibly, considering that all the rocks intersected by the drill holes may be within a general belt of mineralized rock, the syenitic gneisses occur only in the ore zone. Much of the granite and syenite appears to be contaminated and has blotches and streaks of hornblende and pyroxene. Some granitic quartz-plagioclase gneiss was recognized, but it does not seem to be plentiful.

Magnetite is a minor constituent of the granitic rocks, but where it is locally abundant the rock is considered low-grade or marginal ore. The boundaries of the ore layers are seldom well defined; the magnetite content gradually decreases away from the ore into the country rock. Seams of nearly pure magnetite are rare. Much of the rock in which the ore occurs is chloritized.

Ore was encountered in each of the 4 drill holes. The drilling was not extensive enough, however, to delineate any definite mineralized zones. The dip of the foliation and the ore layers, as indicated by the angles in the core, is steeply inclined in hole 2 and is essentially vertical in holes 1, 3, and 4. It appears that the whole area is mineralized and the rock contains magnetite-rich zones which are probably discontinuous vertically and horizontally.

WELLING-WRIGHT FARM DEPOSIT

LOCATION

The Welling-Wright farm deposit is in Vernon Township, Sussex County (fig. 30) on the east side of the Upper Greenwood Lake road (pl. 34). Some of the old shafts are as far north as 1,000 feet south of the New York-New Jersey State line. To reach the Wright farm from State Route 45, turn right 2.3 miles north of the New York-New Jersey line or 1.7 miles north of New Milford, N. Y. A farm road turns left from the Upper Greenwood Lake road, 1.8 miles from the junction with Route 45. The deposits are easily reached on foot by an old road and trails from the Wright farm.

HISTORY

Little is known of the history of this area. Bayley (1910, p. 317) says in regard to the Welling mine that "* * * a strong line of attraction was opened at five points about 1855, and a lean ore was uncovered at each. Some of it was sent to the Wawayanda furnace. Additional exploratory work was done between 1873 and 1876. In 1879 a number of new openings were made in the neighborhood of the old ones and 400 tons of ore was mined. It was, however, not shipped."

The Wright farm property was discovered and operated about the same time as the Welling mine. The belt of attraction was explored with prospect pits, and several shafts were sunk to mine the ore. The extent of the workings and amount of ore shipped is not known, but it is doubtful if any extensive operations were carried on.

EXPLORATION

A dip-needle survey by the U. S. Bureau of Mines covered an area about 5,800 feet long and 2,000 feet broad (Stampe and Mosier, 1949). No drill-hole exploration was carried on in the area.

MAGNETIC SURVEY

Two general belts of attraction that strike slightly east of north were outlined by the dip-needle survey and are shown on the geologic map (pl. 34). The eastern and western belts are about 1,200 feet apart. Low and negative dip-needle readings were obtained in the intervening area except for a few local anomalies in the central and northern part.

Of the two belts, the eastern one is the more continuous. Beginning about 800 feet south of the New York-New Jersey State line, dip-needle readings along the eastern belt are consistently greater than 20° for a distance of over 2,000 feet. Two other anomalies, 1,000 feet and 600 feet long, give readings higher than 20° south of the eastern belt. The average width of the belt is nearly 200 feet. In it are magnetic peaks that give dip-needle readings as high as 80°.

The western belt is less sharply defined. In it are several anomalies more or less alined but separated from one another by distances of from 100 to 200 feet. The individual anomalies in general have a weaker attraction (20°–60°) and are narrower (seldom more than 100 feet) than in the western belt. The zone over which the anomalies are found is from 200 to 500 feet wide. In contrast to the eastern belt, the areas of magnetic attraction are in the granitic rock close to the west contact of the mafic rocks.

The two belts are connected at their north ends by a broad zone of attraction. There is no similar connecting belt of attraction at the south end.

GEOLOGY

About half the area is covered by stream and glacial deposits as much as 10 or 15 feet thick, which conceal much of the bedrock.

Most of the exposures are of pinkish to white alaskitic granite that apparently occupies the area between the two magnetic belts and extends an unknown distance to the west. Within the granite are thin discontinuous inclusions and schlieren of biotite gneiss and amphibolite. In places the granite contains fragments of dark green pyroxene skarn.

Within the granite in the western part of the area and bounding it on the east are two narrow zones of skarn and amphibolite. No outcrops are found along these zones, but boulders and dump material indicate the presence of rocks of this type. These belts of mafic rock follow closely the eastern and western belts of magnetic attraction. The western belt is marked by a narrow trenchlike topography; the limits of the eastern zone are vague.

Biotite-quartz-feldspar gneiss lies east of the eastern skarn-amphibolite belt. Its eastern limit is not known. Some layers of alaskite and granite pegmatite occur in the biotite gneiss parallel to the foliation. Locally the gneiss is migmatitic. Another area of biotite-quartz-feldspar gneiss borders the granite in the northwestern part of the area. This gneiss is similar in appearance to the gneiss in the eastern belt; but when the rocks are compared in thin section, it is seen that the gneiss from the eastern belt contains potash feldspar and plagioclase, in contrast to that from the northwestern area, which contains only the plagioclase feldspar. A small body of biotite gneiss apparently occurs as an inclusion in alaskite at the Welling mine.

STRUCTURE

The structure cannot be clearly delineated, but it appears to be an asymmetric syncline plunging gently south. A broad zone of magnetic attraction at the north end of the area may be continuous with the eastern and western zones of attraction, and the two belts of skarn and amphibolite may be continuous to the north beneath the cover of alluvium.

Over most of the area the gneissic foliation dips 50°–60° E., but the foliation of the biotite-quartz-feldspar gneiss east of the eastern skarn and amphibolite belt dips west. In the northern part of the area, near what may be the axis of the syncline, the foliation dips east more gently (20°). In exposures northwest of the Welling mine the strike of the foliation in the alaskite and the northwest area of biotite-quartz-feldspar gneiss becomes more easterly and dips southeast. The plunge of the structure is not known.

MAGNETITE DEPOSITS

OCCURRENCE

Information on the mode of occurrence of the magnetite was gained entirely from observation of material on the dumps around old shafts and prospect pits. The magnetite apparently has two modes of occurrence: in the skarn-amphibolite belts and in biotite-quartz-feldspar gneiss inclusions in the alaskite.

The eastern belt of mineralized rock, which includes the Wright farm deposits, appears to be entirely within the skarn-amphibolite belt. The magnetite on the dumps is coarse grained and granular and the host rock is green pyroxene skarn. Coarse-grained, biotite-rich rock is apparently associated with the ore. Judging from one or two poor exposures in shafts and from the size of the prospect pits, the magnetite bodies are no more than 5 or 6 feet wide. Possibly they are discontinuous bodies of different size and grade. Foliation attitudes in gneisses adjacent to the mineralized zone indicate that the zone dips steeply west in the central and southern parts and is vertical or dips steeply east at the northern end. The strike of the zone is about N. 15° E. except at the north end where it is approximately north.

The western skarn-amphibolite belt apparently contains very little magnetite, but it is characterized by pyrite in several places. The magnetite is mostly in small bodies in the alaskite outside the belt. Some of the magnetite occurs as thin seams and lean disseminations in the alaskite. Coarse, disseminated magnetite in pegmatite also occurs locally along this zone. At the Welling mine and a few other places in the northern part of the area magnetite is associated with biotite-quartz-feldspar gneiss inclusions in the alaskite. The biotite gneiss in this association exhibits more or less chloritic alteration of the mica. The deposits are erratic and probably have little lateral or vertical persistance.

In the extreme southwest part of the district some magnetite occurs in folia of pyroxene skarn in the alaskitic granite.

MINERALOGY

Magnetite is the principal ore mineral. No hematite has been seen in the specimens collected. Polished surfaces indicate that some of the magnetite is pure; ilmenite is intergrown with it in other specimens. Locally pyrite is abundant. Other gangue minerals are those of the host rock.

GRADE

No data on the tenor of the "ore" are available. Some high-grade material can be found on the dumps, but much of it contains a high percentage of silicate gangue. Two analyses of samples from the Welling mine are given by Bayley (1910, p. 317) as follows:

	Fe	P	SiO_2	Ti	Mn	S
1	33.91	0.028	[1] c. a. 50			
2	54.23	.033		Tr.	Tr.	Tr.

[1] Estimated.

SUGGESTIONS FOR EXPLORATION

The persistent eastern belt of magnetic attraction is the most favorable area for diamond drilling. Over the rest of the area mineralized zones are extremely local, and there is no indication that the deposits persist either laterally or vertically. The broad area of lower magnetic attraction at the north, between the Welling mine and the eastern belt of anomalies, should be investigated to discover if the magnetite that causes the anomaly is present in commercial quantities.

It seems doubtful that a continuous belt of commercial ore underlies the eastern anomaly. Probably there are several bodies or shoots of ore. Drilling in the area of the magnetic peaks along the mineralized zone would afford evidence as to the presence of ore of commercial grade. Further drilling would then be necessary to test the extent of any ore bodies, laterally and in depth, and to determine their structure.

WEST PORTAL DISTRICT

The Swayze and Turkey Hill magnetite mines near West Portal, Hunterdon County (fig. 30) were explored by the U. S. Bureau of Mines from August 1943 to April 1944, (Botsford and Mosier, 1948, p. 5–11). In addition to dip-needle surveys, 11 diamond-drill holes, which have a combined depth of 4,910 feet, were put down to explore the property. H. E. Hawkes of the U. S. Geological Survey was responsible for most of the geological studies and interpretation of the drill core during the exploration. Much that follows was taken from an unpublished report by Hawkes on the results of exploration.

LOCATION

The Swayze and Turkey Hill mines are on the summit and northwest slope of Musconetcong Mountain, near West Portal, Bethlehem Township, Hunterdon County. West Portal is 12 miles east of Easton, Pa., and about 60 miles west of New York City. The Turkey Hill deposit is approximately 1½ miles S. 65° W. of the Swayze mine (fig. 32). The magnetite deposits are accessible all year, by dirt and graveled roads leading from U. S. Highway 22, from Easton, Pa., and Phillipsburg, N. J. The area is served by the Lehigh Valley Railroad and the Central Railroad of New Jersey.

HISTORY AND PRODUCTION

The Swayze mine, formerly the Bethlehem mine, was operated prior to 1868, idle from 1868 to 1871, and was operated again from 1871 to 1875. It was reopened in 1879, operated for 10 years, and abandoned in 1889. The history of production is very hazy, but the total tonnage shipped from the Swayze mine was about 253,000 tons.

The Turkey Hill mine, formerly the West End mine, was discovered in 1872 and was operated intermittently until 1884 when a labor strike and mine fire resulted in its closing. In 1885 the mine was reopened, but in 1887 it was closed again. The total production (1872–1887) was 184,000 tons. In 1939 the West Portal Mines, Inc., H. M. Roche, president, was organized, and a magnetic concentrator was erected in 1941 to work the dumps. Some concentrates were shipped, but the amount is not known.

EXPLORATION

The U. S. Bureau of Mines made a dip-needle survey of a belt approximately 10,200 feet long and from 600 to 2,000 feet wide connecting the Turkey Hill and Swayze properties (Botsford and Mosier, 1948, fig. 2). Eleven diamond drill holes, which had a total footage of 4,910 feet, were put down to test the extent of the magnetite deposits beyond the old mine workings. Five holes were drilled at the Turkey Hill mine and five were drilled at the Swayze mine. No areas of magnetic attraction that seemed to warrant exploration by drilling were found in the belt joining the Turkey Hill and Swayze mines.

GEOLOGY

The Turkey Hill and Swayze deposits are in the northeast-trending belt of gneiss that makes up Musconetcong Mountain. The Musconetcong Valley on the northwest is in sedimentary rocks of Paleozoic age, and Triassic red beds limit the gneiss on the southeast. Exposures are

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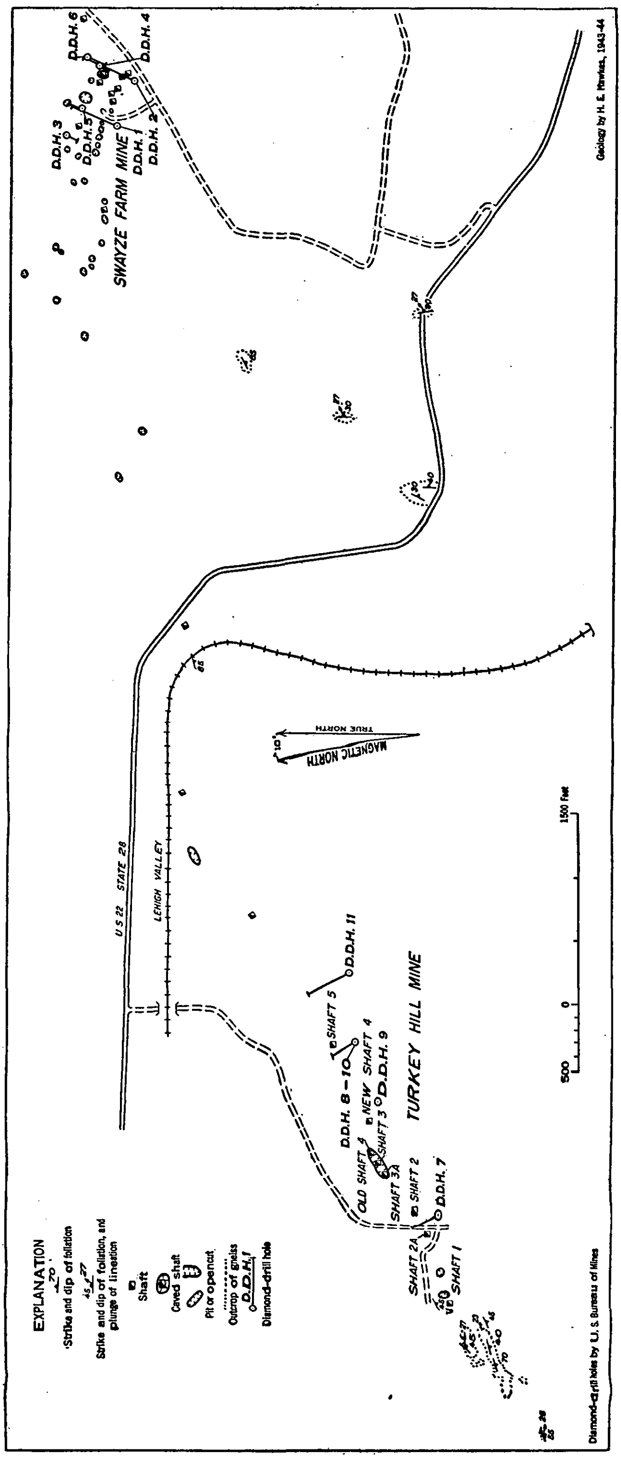

FIGURE 32.—Map of the West Portal district, Hunterdon County, N. J.

scanty and poor in the vicinity of the mines because of an overburden of glacial deposits and alluvium as much as 30 or 40 feet thick. The magnetite deposits apparently are along a zone of metasedimentary rocks interlayered with gneissic granite and alaskite, and granite pegmatite.

The strike of the mineralized zone at Turkey Hill, when extended to the northeast, passes very close to the Swayze mine. Prospect pits and minor magnetic anomalies are also situated along the line between the two mines. Possibly the two deposits are joined by a continuous belt in which scattered mineralized zones occur. There is, however, a difference in the attitude of the gneisses at the two deposits. The average strike of the gneissic foliation and layering is N. 65° E. at Turkey Hill and the dip is 50° SE. (fig. 32); whereas at the Swayze mine, as indicated by drill-hole data, the gneissic foliation and layering is about N. 70° W. and the dip 83° N. Lack of outcrops prevents detailed structural analysis in this area.

Observations at the surface and data from the drill-hole exploration suggest that these deposits may conform to the idealized pencil- or cigar-shaped shoot structure that is characteristic of many of the New Jersey magnetite bodies. More detailed analysis of this structural possibility is reserved for discussion under the descriptions of the individual mines, but, in general, the data suggest that at the Turkey Hill mines a well-developed ore shoot may be found which plunges east or slightly north of east at about 33°, more or less in conformity with the plunge of the lineation in the gneiss. The evidence is less definite for a similar structure at the Swayze mine.

TURKEY HILL MINE

Prospect pits and old shafts are situated along the strike of the Turkey Hill zone for a distance of more than one mile, indicating a mineralized belt of considerable persistence. Deposits along this zone probably are small and spotty, however, except at the southwest end at the Turkey Hill mine (fig. 32) where information from old reports and the arrangement of pits and shafts indicate that a fairly continuous body of magnetite extended from shaft 1 as far as the large caved pit at shaft 4. Apparently this part of the belt marks the trace at the surface of an ore shoot whose bottom is about at shaft 1 and the top of which is at shaft 4.

According to a private unpublished report the thickness of the "vein" ranged from 12 feet to 15 feet and the ore lay in "pockets." Whether the 12- to 15-foot thickness applies to the ore in the pockets or to the average thickness is not known, but it is reasonable to assume that the thickness is variable. By analogy with other New Jersey deposits, the pockets probably are shoots elongated in the direction of plunge of the lineation. The large caved pits in the vicinity of shafts 3, 3*A*, and 4 probably reflect an especially large pocket or "swell" in the ore shoot that is immediately beneath the top rock.

From a study of the drill core it was possible to recognize several rock units which enabled correlation between drill holes (pl. 35). The most distinctive lithology is in a unit that is characterized by pyroxene skarn and some marble. This unit is above the zone in which magnetite occurs and is separated from that unit by a layer of predominantly light-colored gneissic granite and pegmatite. Beneath the magnetite-bearing zone the gneiss consists of mixed or interlayered amphibolite, granitic quartz-plagioclase gneiss, and biotite gneiss, with some pegmatite. The zone or unit in which the magnetite deposits are found is characterized by an abundance of amphibolite and pyroxene amphibolite in which there is some interlayered granite and granite gneiss, and pegmatite. Magnetite is not found throughout this zone but occurs as local concentrations or layers or as scattered granules. The skarn and light gneiss unit above the "ore" zone are thickest northeast of hole 9. To the southwest they become thinner; the skarn and marble unit, which is about 110 feet between holes 9 and 11, is only about 40 feet thick in hole 7; the unit between the ore zone and the skarn is from 120 to 130 feet thick in holes 8, 10 and 11, but in hole 9 it is 63 feet and in hole 7 only 15 feet thick. The magnetite-bearing unit likewise becomes thinner to the southwest; it is about 80 feet thick in holes 8, 10, and 11; 65 feet in hole 9, and 10 feet in hole 7.

The average strike of the gneiss measured on outcrops southwest of shaft 1 is N. 65° E.; the dip is 50° SE. The average strike of the gneiss as determined in the drill holes is N. 60° E.; the dip is 47° SE.

The probable plunge of the ore structure is indicated by the plunge of the lineation in the outcrops southwest of the Turkey Hill workings. The lineation in these exposures plunges toward the east at a gentle angle, the inclination from the horizontal ranging from 20° to 30°.

Mylonites and breccias encountered in the upper parts of holes 8 and 10 indicate a certain amount of faulting. The lithologic units do not appear to be appreciably displaced, however, and the component of movement normal to the planar structure of the rocks is apparently negligible. The amount of movement parallel to the layering may have been large but cannot be determined without more data.

RESULTS OF EXPLORATION

Although all the drill holes intersected the zone or unit in which magnetite deposits occur, ore was encountered only in holes 9 and 10 (fig. 33; pl. 36). Hole 7 (fig. 34) appears to have been drilled through an old stoped area. Hole 9 cut a thick section of magnetite;

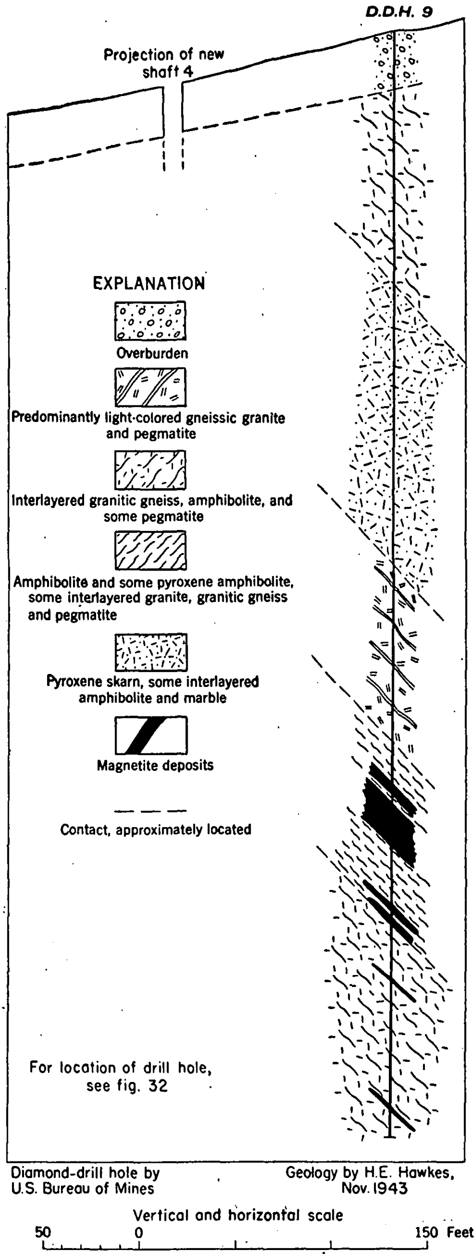

FIGURE 33. Section through diamond-drill hole 9, Turkey Hill mine, Hunterdon County, N. J.

and in hole 10 a smaller amount of magnetite, about 5 feet thick, was penetrated by the drill. Analyses of core samples are as follows:

TABLE 4.—*Analyses of drill core, Turkey Hill mine, West Portal district, Hunterdon County, N. J.*

[After U. S. Bureau of Mines [1]]

Depth from surface (feet)	Thickness (feet)		Chemical composition (percent)						
	Apparent	True	Fe	P	SiO_2	TiO_2	CaO	MgO	S_2
Drill hole 9:									
381-386	5	3.47	17.7	0.055	40.2				
392-395	3	2.08	48.2	.014	17.0				
395-399	4	2.77	54.0	.024	11.8				
399-404	5	3.47	55.5	.008	9.8	0.24	2.72	5.85	0.049
404-409	5	3.47	55.0	.010	10.8	.16	3.14	5.54	.026
409-414.6	5.6	3.9	52.7	.004	11.8				
	27.6	19.16							
445-450	5	3.47	18.4	.006					
450-454	4	2.77	24.5	.022					
		6.24							
Total thickness		25.40							
Drill hole 10:									
308.3-314.0	5.7	5.4	50.4	.008	13.6	.1	.5	.5	.033

[1] Botsford and Mosier, 1948, p. 9.

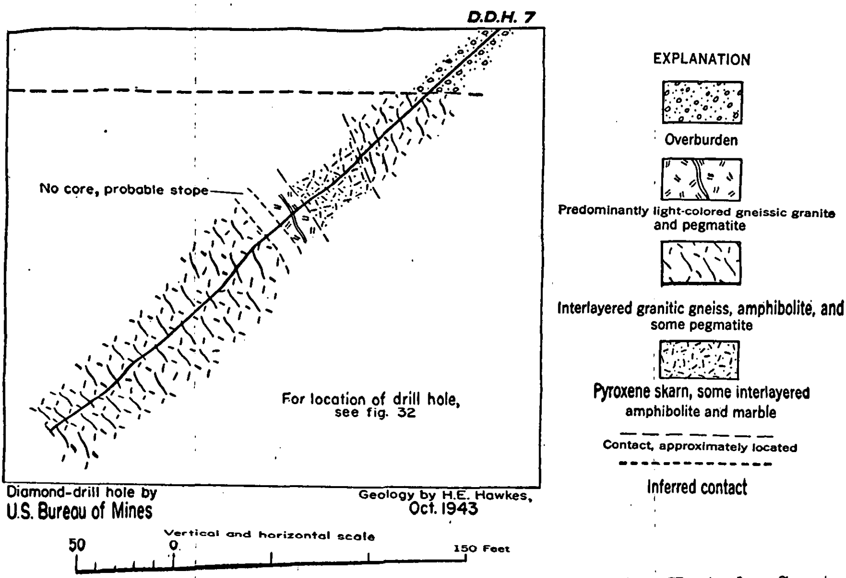

FIGURE 34. Section through diamond-drill hole 7, Turkey Hill mine, Hunterdon County, N. J.

The section of magnetite cut in hole 9 is interpreted to be a "swell" on the Turkey Hill ore shoot. In all probability the large caved pits at shafts 3 and 4 are located at the outcrop of a swell on the ore shoot—now mined out an indefinite distance. If it is assumed that this swell plunges eastward in the same direction as the observed lineation, its downward extension passes directly under the site of hole 9 at a depth corresponding closely with the magnetite encountered at about 400 feet. The ore in hole 9, therefore, is probably the downward extension of that mined in shafts 3 and 4. Measured in a vertical section through shaft 3 and hole 9, the plunge of this swell is 33° E. These features are shown on the block diagram (pl. 35) of the Turkey Hill mine.

Holes 8 and 11 intersected the "ore zone" but did not encounter any mineralized rock, apparently because they cut the zone in the area above the "top rock" of the main ore shoot. The smaller section of magnetite cut in hole 10 is probably part of an isolated deposit or shoot not connected with the main body. The absence of anomalous dip-needle readings in the area where the assumed plunge of this body projects to the surface indicates that it probably pinches out between the intersection of hole 10 with the ore and the surface.

SWAYZE FARM MINE

As no bedrock is exposed within a half mile of the Swayze farm mine, all geological deductions are based on interpretations of drill core, study of the arrangements of old pits and shafts, and information obtained from discussions with individuals who have had personal knowledge of the mine.

Apparently, there were two ore bodies in parallel zones about 150 feet apart, striking about N. 70° W. and dipping steeply northeast to vertical. The north ore body contributed the bulk of the production, though the south ore body was also extensively explored and mined. The inferred outline and position of the north ore body based on meager data is shown in plate 37, a section drawn through diamond-drill holes 1 and 5. No information concerning the plunge or direction of elongation of the ore shoot is available but in accordance with the general behavior of the New Jersey deposits it is assumed that the body plunged gently eastward.

The purpose of the drilling campaign was to explore for possible downward or lateral extensions of the mined-out ore body.

Drilling revealed a characteristic rock assemblage which enabled the establishment of distinctive units that could be correlated from hole to hole. The zone containing the north ore body is a unit that consists predominantly of amphibolite and pyroxene amphibolite with some interlayered pegmatite and light granitic gneiss. The unit interpreted as the south mineralized zone is characterized by an abundance of pyroxene skarn, considerable amphibolite and some pegmatite and granitic gneiss. Between the zone of skarn and the zone of amphibolite is a unit containing granitic rocks and interlayered amphibolite and some pegmatite. The unit north of the amphibolite zone is composed predominantly of pegmatite and light-colored granite. The zone of amphibolite is 25 to 35 feet thick, the skarn zone is 75 to 95 feet thick, and the intervening unit ranges from 95 to 130 feet in thickness.

The strike and dip of the gneiss as determined from study of the drill core is about N. 70° W., 83° N. The dip was obtained by measurements on sections constructed from the drill-hole data and from measurements of foliation angles on the drill core. The strike was derived by projecting the various units to the surface along the dip, and joining the points thus established.

An important feature is the failure of the amphibolite—the zone containing the north ore body—to appear in hole 2. Correlation with the stratigraphy in holes 1, 5, and 6 fails to apply below a depth of 357 feet in hole 2. High core loss at this depth in hole 2 indicates a zone of broken or weakened rock. These facts indicate a fault at this place which brings a thick section of light gneisses into the position where the amphibolite would be expected. No inferences as to the strike, dip, or relative displacement on this fault can be made on the basis of information available. Perhaps it is significant, however, that the lateral termination of the north ore body is close to this drill section. The possibility remains, therefore, that the north ore body on the southeast end was faulted off rather than pinched out. A possible interpretation of the structure at the east end of the Swayze deposit is offered in the generalized block diagram, plate 38.

RESULTS OF EXPLORATION

Results of drill-hole exploration at the Swayze mine were disappointing. A little magnetite was cut in the skarn zone in drill holes 1 and 2. Analyses of core samples of magnetite from these holes are recorded in table 5. The downward extension of the north ore body was not discovered.

TABLE 5.—*Analyses of drill core, Swayze farm mine, West Portal district, Hunterdon County, N. J.*

[After U. S. Bureau of Mines [1]]

Depth from surface (feet)	Thickness (feet)		Chemical composition (percent)						
	Apparent	True	Fe	P	SiO_2	TiO_2	CaO	MgO	S_2
Drill hole 1: 146.5–149.0	2.5	1.8	45.80	0.008	20.8	0.27	1.41	9.45	0.37
Drill hole 2: 123.7–124.5	.8	.5	33.5	.011	29.6	.08	10.7	7.8	.027

[1] Botsford and Mosier, 1948, p. 6.

The north ore body may have been a simple kidney-shaped pod that did not continue in depth. A characteristic of the Highlands type magnetite deposits, however, is that they extend in depth along the plunge for considerable distances with not much change in cross section.

Possibly, the plunge is such that the extensions of the ore body were not explored by drilling; the plunge is not accurately known, and no indication of the angle of plunge could be obtained from measurements of lineation in the enclosing gneiss because there are no outcrops in the mine area. If the plunge were horizontal, hole 6 might have gone under the ore body; this is not likely, as dip-needle observations east of the east drill section failed to disclose a sufficiently intense magnetic effect. If the plunge were steep to the southeast, hole 1 might have gone under the ore body while hole 2 went over it; this is not likely in view of the limited space allowed in this section and the lack of any indication in hole 2 of the amphibolite zone above the shoot. If the plunge were to the northwest, all the holes would have missed the ore body; this is not likely inasmuch as reports of the shape of the north ore body, as it was developed, suggest a progressive shallowing of the deposit west of the main shaft; this is also contrary to observations of plunge on outcrops within a three-mile radius of the mine, which are consistently inclined to the east at a gentle angle.

It seems most likely that the north ore body is cut off on the east by a fault. As described previously, there is considerable evidence that hole 2 encountered a fault at depth. The persistence of moderately high dip-needle readings (5°–10°) east of the east drill section indicated that the horizontal component of the displacement is probably not more than 100 feet. A fault of this magnitude would still be sufficient to account for the absence of the amphibolite zone in hole 2. On this assumption the gneiss below 375 feet in hole 2 must correspond with the gneiss in the hanging wall of the amphibolite zone (pl. 38), and the relative movement of the fault is right-handed—the east segment moved south relative to the west.

Even though the apparent horizontal separation at the surface were only 100 feet, the vertical displacement parallel to the dip of the gneissic layering might be very great, and the extension of the amphibolite zone that contains the north ore body might be located a considerable distance from the surface.

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