Structure and Mineralization of Precambrian Rocks in the Galena-Roubaix District, Black Hills, South Dakota

By R. W. BAYLEY

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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CONTENTS

	Page
Abstract	E1
Introduction	1
Field methods	2
General geology	3
Stratigraphy	4
Metabasalt and chert	4
Graphitic schist and cherty ferruginous schist	5
Metagraywacke, schist, and slate	6
Structure	6
Distribution of gold	7
Diamond drilling	9
Magnetic survey	10
Summary	14
References	15

ILLUSTRATIONS

	Page
PLATE 1. Geologic map of the Galena-Roubaix district, Lawrence County, Black Hills, South Dakota	In pocket
FIGURE 1. Generalized geologic map of the northern Black Hills	E2
2. Magnetic survey in the vicinity of U.S. Geological Survey diamond-drill hole 1	13

TABLE

	Page
TABLE 1. Results of core-sample analyses, U.S. Geological Survey diamond-drill hole 1, Galena-Roubaix district	E11

STRUCTURE AND MINERALIZATION OF PRECAMBRIAN ROCKS IN THE GALENA-ROUBAIX DISTRICT, BLACK HILLS, SOUTH DAKOTA

By R. W. Bayley

ABSTRACT

The Galena-Roubaix district is underlain chiefly by tightly folded and moderately metamorphosed sedimentary and volcanic rocks of Precambrian age. Refolded folds, probably the result of two periods of folding, are characteristic of the district. The oldest exposed rocks, previously mapped as amphibolite and Homestake Formation, are believed to be equivalent to the multi-unit Flag Rock Formation, which lies above the Ellison Formation in the Lead district. Sparse gold occurs in ferruginous chert, vein quartz, and quartz-veined graphitic and ferruginous schist throughout the district, particularly in the crests of plunging anticlines. The Homestake Formation, if present, must lie at considerable depth beneath the crests of these plunging folds. A hole drilled 1,850 feet into one anticline passed through the Flag Rock Formation into banded garnet slate of undetermined correlation. About 250 feet of pyrrhotitic graphitic schist were penetrated near the base of the Flag Rock. Magnetic anomalies caused by the pyrrhotite are discordant with surface structures and are not understood.

INTRODUCTION

The Galena-Roubaix district lies 4–6 miles southeast of the town of Lead and the Lead mining district in the northern part of the Black Hills, S.D. (fig. 1). Precambrian rocks are plentiful and well exposed in both districts, but the area between the districts is underlain by Paleozoic sedimentary rocks and Tertiary intrusive rocks, mainly felsic laccoliths. The rocks in the Lead district, which contains the Homestake gold mine, have been intensely studied for many years by geologists and are very well known, whereas the rocks in the Galena-Roubaix district and the Precambrian rocks of the northern Black Hills in general have received a disproportionately small amount of study and thus remain poorly known. The broad aspects of the geology of the Galena-Roubaix district were defined by Darton and Paige (1925), and a detailed survey of the district was made by Berg (1946). Notable attempts to correlate the Precambrian formations across the natural barrier between the districts were made by Runner (1934) and Berg (1946).

Most of the Galena-Roubaix district was resurveyed and extensively sampled in 1966–67 as part of the Heavy Metals program of the U.S. Geological Survey. The purpose of this report is to present, in preliminary form, the resultant geologic map, the results of sample analyses, and, briefly, the geologic findings.

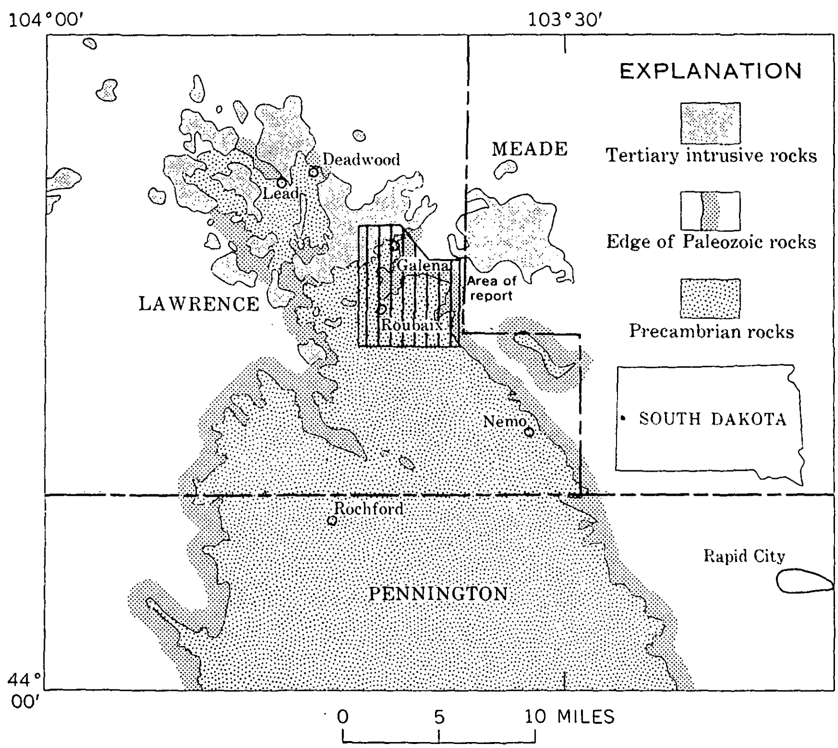

FIGURE 1.—Generalized geologic map of the northern Black Hills, showing location of the Galena-Roubaix district.

FIELD METHODS

The geologic mapping was done on 1:24,000-scale topographic base maps by pace-and-compass methods. A ground magnetometer survey was made of the central and northeast parts of the area to determine the distribution of certain Precambrian units where they are covered by Paleozoic rocks. Another magnetic survey was made in the west section to determine the shape and distribution of pyrrhotite bodies. Rock samples for analysis were collected from outcrops showing evidence of sulfide mineralization. Because most of the rocks are weathered, those showing oxides of iron and, more rarely, of copper, were sampled in greater numbers. The cherts of the district are commonly ferruginous, whether mineralized or not; thus, most samples analyzed were oxidized chert. Samples of vein quartz are next in abundance, and samples of ferruginous and carbonaceous schist are least abundant. In addition to rock samples, soil samples were collected at 200-foot intervals along the major roads and most of the trails in the district. Analyses of these soil samples generally approximate those of outcrop samples from the same locality and have revealed no soil-covered areas of potential value. Analyses were done in the field by colorimetric and atomic absorption methods.

GENERAL GEOLOGY

The Galena-Roubaix district is underlain chiefly by tightly folded and moderately metamorphosed Precambrian sedimentary and volcanic rocks. The flat-lying basal Paleozoic, Upper Cambrian, Deadwood Formation lies over part of the district. Intrusive rocks of Tertiary age, mainly dikes and laccoliths of quartz porphyry and quartz monzonite, are numerous in the Galena area, but only two small laccoliths of this suite occur in the Roubaix area. (See plate 1.) The Precambrian rocks are ellipsoidal (pillow) metabasalt, intrusive metagabbro, metachert, slate, schist, and metagraywacke. The metabasalt and chert are the oldest and form refolded anticlines flanked by refolded cynclines of metagraywacke, schist, and slate. That two distinct periods of folding took place here seems probable but is uncertain at this time. The whole district was affected by regional metamorphism of at least garnet grade, and the rocks of the northeast part of the Roubaix area and of the Galena area probably are very close to staurolite grade, although that indicator mineral has not been found. Except for very schistose rocks, primary sedimentary and volcanic features are preserved in the rocks everywhere. Sparse gold occurs in Precambrian rocks throughout the district, mainly in chert, reefs of vein quartz, and small quartz veins in ferruginous and graphitic schist. It was probably introduced during the refolding and metamorphism.

STRATIGRAPHY

Only three readily mappable Precambrian units are recognized in this district. These units and their probable correlation with stratigraphic units in the Lead district, as defined by Noble and Harder (1948), are shown below:

Galena-Roubaix district (*This report*)	*Lead district* (*Noble and Harder, 1948*)
Metagraywacke, schist, and slate	Grizzly Formation
Graphitic schist and cherty ferruginous schist	Flag Rock Formation
Ellipsoidal metabasalt and chert	Flag Rock Formation
Not exposed	Northwestern Formation Ellison Formation Homestake Formation Poorman Formation

METABASALT AND CHERT

This formation is composed predominantly of ellipsoidal metabasalt lava flows and beds of streaky ferruginous chert. These two distinct members constitute the amphibolite formation and Homestake Formation of Berg (1946), who, following Runner (1934), concluded that the amphibolites were probably derived by metamorphism from calcareous rocks. Berg attributed the unusual cherty appearance of his Homestake Formation to surface silicification. Ellipsoidal structures, though not previously recognized as such, show that these rocks were derived from mafic lava flows rather than from calcareous rocks. These metamorphosed ellipsoidal lavas are now known to occupy a considerable part of the stratigraphic interval referred to the Flag Rock Formation at Lead and at the only other place where it has been previously mapped, Rochford. At both places, the lavas are associated with one or more beds of chert similar in all respects to the cherts of the Galena-Roubaix district. Indeed, in most of the northern Black Hills, the metabasalt and chert couple seems to be the most characteristic and most easily traced element of the Flag Rock Formation.

The metabasalts near Roubaix are typical greenstones of low metamorphic grade. In good exposures, tops of beds are readily determined from the ellipsoids (pillows), many of which still show dense glassy selvages. At Galena, the same rocks are amphibolite or hornblende schist, but some exposures, especially roadcuts along Strawberry Creek, still show pillows, though much flattened and stretched out. Because these primary volcanic features have not been described previously in this area, the locations of good exposures are listed below:

Roubaix area

NE¼NE¼ sec. 28, T. 4 N., R. 4 E., top of hill east of power line.
West-central sec. 27, T. 4 N., R. 4 E., on bluffs along both sides of Elk Creek.
NW¼SW¼ sec. 33, T. 4 N., R. 4 E., a few hundred feet northeast of road junction.

Galena area

NW¼ sec. 8, T. 4 N., R. 4 E., outcrops on north side of Strawberry Creek road.

Lead area

NW¼ sec. 34, T. 5 N., R. 3 E., north side of Whitewood Creek just east of Homestake dump and just west of (behind) motel at Pluma road junction.

Rochford area

NE¼ sec. 15, T. 2 N., R. 3 E., near hilltop east of railroad.
S¼ cor. sec. 10, T. 2 N., R. 3 E., east of railroad tracks.
Center sec. 3, T. 2 N., R. 3 E., northwest of Montana mine.

The chert beds associated with metabasalts are dense units as much as 100 feet thick. Rude, discontinuous, contorted layering can be seen in some bodies. The cherts have been called "streaky quartzites," which well describes their appearance; however, they are not clastic rocks. The streakiness is caused mainly by brown iron oxide or black carbonaceous streaks. The iron streaks are more common, and in areas of highest metamorphic grade, the iron and silica combine to form the amphibole grunerite, which is usually fine grained and inconspicuous. Most outcrops of chert have been oxidized, and because the beds resemble large quartz veins, they have been extensively prospected, unsuccessfully, for gold.

Small bodies of sheared coarse-grained metagabbro occur in the volcanic rocks at a few places but have not been mapped separately.

GRAPHITIC SCHIST AND CHERTY FERRUGINOUS SCHIST

This unit lies above the metabasalt and chert at most places but is apparently missing in a few places. The thicknesses and character of the unit are quite variable. Fissile graphitic schist is most common; some of it shows distinct bacon-stripe banding, and some of the banded rock is silicified and very hard. The cherty ferruginous schist is a thin-bedded fissile unit, is chloritic and garnetiferous in part, and contains magnetite which is oxidized red in most exposures. This magnetic member is associated with the graphitic schist on the east side of the district but is absent in the western part, where most exposures are of graphitic types. The locations of concealed contacts and structures in the northeast part of the mapped area are based wholly on the distribution of the magnetic schist as determined by magnetic survey. Berg (1946) called these schist beds Garfield Formation, a

371-691—70——2

name originally assigned to beds at Lead now included in the Flag Rock Formation. However, according to Harder (1934), the name "Garfield" was abandoned from usage at Lead before his 1934 report on the Rochford district; it is therefore not used in this report. The schist beds are known, on a regional basis, to occur above and below the volcanic rocks and are, at places, interbedded with the volcanic rocks.

METAGRAYWACKE, SCHIST, AND SLATE

This is the youngest and most widespread formation in the district and in the northern Black Hills, and it forms a geological connecting link between the several districts. It is quite variable in composition from place to place, but is everywhere predominantly of clastic origin and of one or more of the three lithologies—metagraywacke, schist, and slate. The formation is mainly thick-bedded (to 10 ft) gritty metagraywacke with thin interbeds of schist in the southeast part of the district; thinner bedded (to 3 ft) metagraywacke and mica schist in the central part of the district; and mainly mica schist in the north part of the district. These rocks are composed chiefly of quartz, plagioclase feldspar, micas, and garnet. A pervasive schistosity of northwest trend is impressed on all the rocks regardless of attitude. This strong schistosity obscures the bedding in most exposures, but in some exposures the tops of beds can still be determined from the grain-size gradations in metagraywacke. Although tops cannot be determined in enough places to completely define the structure, those that have been determined to date fit the structures as deduced from other data. These rocks correlate with the Grizzly Formation of the Lead district. They were called Roubaix Group by Berg (1946), but neither the Roubaix Group nor the Grizzly Formation is well enough known to make a formal designation.

STRUCTURE

The Galena-Roubaix district is an area of sinuous refolded folds. For this reason the district was thought to be unique in the region, but recent work in the Rochford district has revealed similar folds, and minor refolds have been reported from the Lead district. The structures in the vicinity of Roubaix, though remapped with minor modifications, are shown as depicted by Berg (1946), differences in stratigraphy notwithstanding. These structures are regarded as basically sound, however perplexing in terms of origin. The Hay Creek syncline (pl. 1) separates the Galena-Roubaix district from the Nemo district, which lies to the southeast. The Hay Creek syncline is a refolded structure crossed perpendicularly by southeast plunging fold axes and associated parallel axial-plane cleavage. All linear structures plunge toward the Hay Creek syncline from at least 10 miles away on both flanks, indicating that it is a dominant structure in the regional framework. The metabasalts and cherts exposed on the southeast limb represent the northwest limit of the Nemo district. These units pass beneath the Hay Creek syncline, which contains mainly thick-bedded graywacke and schist, and emerge on the northwest limb as refolded anticlines in the Roubaix area. The latter folds are separated from similar folds in the Galena area by another syncline which divides the district into two distinct areas. The refolded anticlines have been defined mainly on the basis of the distributions of the metabasalt, chert, and overlying graphitic and ferruginous schist, and on top directions determined from pillow structures and graded beds. Inasmuch as the volcanic pile does not conform strictly to layer-cake stratigraphy, there are numerous apparent disconformities between the metabasalt and the overlying schists; overall, however, the data best fit the structures as shown on plate 1. In general, south and southeast limbs of anticlines are right side up and opposite limbs are overturned. Axial planes of folds dip south or southeast, and axes plunge southeastward toward the Hay Creek syncline. It is postulated (1) that these refolded folds were originally east to northeast trending—that is, parallel to the northwest edge of the Nemo district, which is a relatively immobile, basement-rooted block—and (2) that the northwest-trending crossfolds formed under southwest to northeast compression with relatively unlimited freedom of movement with respect to the Nemo block. Our regional mapping suggests that all refolding may be related to several large right-lateral wrench faults. This view of the origin of the crossfolds is tentative and will doubtless be modified as fieldwork in the northern Black Hills continues.

DISTRIBUTION OF GOLD

The distribution of analyzed samples (pl. 1) reflects the sampling bias previously mentioned under "Field Methods"—that is, rocks showing macroscopic signs of mineralization were most frequently sampled. Thus, most samples are of ferruginous chert and schist and vein quartz. The younger graywacke and schist seem least mineralized, although they are cut by numerous quartz veins in several localities.

Results of sampling show that gold mineralization was extensive but lean. Most samples contain between 0.02 and 0.20 ppm (parts per million) gold; about 40 percent of the samples contain 0.05 to 0.20 ppm. Precambrian rocks containing more than 1.0 ppm gold were found at only three places, each on the crest of a plunging anticline. Sampling was concentrated in such structures because most show macroscopic evidences of mineralization and because similar structures in the Lead district localized the Homestake ore bodies. The sampling procedure, therefore, was further biased. Six of these anticlinal areas will be described here, in order from south to north. The anticlines are indicated on the map (pl. 1) by roman numerals.

I. This south-plunging anticline contains a core of pillow metabasalt and is enveloped by graphitic schist on the south end. There are several test pits in the schist, and a sample of rusty vein quartz from the dump of one of these (east of the road) contains 1.10 ppm gold. The soil near the pit also contains a small amount of gold.

II. North along the same fold is a refolded anticlinal bow which plunges about 70° to the southeast. The chert in this fold is ferruginous and oxidized and is penetrated by several large test pits. The gold content of the chert is anomalously high, as much as 0.20 ppm. Some samples contain as much as 600 ppm arsenic, which suggests that the unoxidized rock contained sparse arsenopyrite. On the inside of the anticlinal bow, between the metabasalt and graywacke, is a mass of white quartz which appears to have the configuration of a saddle reef. The quartz was sampled in numerous places and yielded rather consistent analytical results. The gold content ranges from 0.06 to 0.20 ppm, and the arsenic content from 300 to 800 ppm, suggesting again the presence of arsenopyrite.

III and IV. Graphitic schist and some metabasalt and chert are exposed in this anticline. Gold has been detected in soils and in the south part of this structure; and rock samples, mainly chert and oxidized schist, also contain minor gold, to 0.20 ppm, and anomalously high arsenic.

The Clover Leaf mine (IV) is in a thick U-shaped quartz saddle reef on a minor anticline which plunges about 40° to the southeast. The ore consists mainly of quartz, streaks of galena, sphalerite, pyrite, and native gold; some pyrrhotite and arsenopyrite occur in schist near the quartz reef (Irving, 1904; Connolly and O'Harra, 1929; and Allsman, 1940). The north limb of the quartz reef averages about 20 feet thick, the south limb about 12 feet, and the crown 30–50 feet (Allsman, 1940, fig. 3, p. 16). The length of the stopes on both limbs increases with depth.

The mine was opened in 1878 and has changed hands several times. It was idled several times because of excessive water and was closed last in 1937 by the Anaconda Mining and Milling Co., probably because of excessive water and because it was no longer economical to operate (Allsman, 1940, p. 14). The plunging reef has been mined to about the 700-foot level. Irving (1904), who visited the Clover Leaf when its depth was about 200 feet, noted that "the average value of the ore is stated to have been $40 to $400 to the ton". Later statistics by Allsman

(1940) indicate that the average value of the ore was only about $7 to the ton, although some ore in the crown of the reef was of much higher value, about $190 to the ton on the 700-foot level. During the last 2 years (1936–37) of operation of the Clover Leaf, the Anaconda Mining and Milling Co. amalgamated about 5,635 tons of ore and recovered about $1.75 gold per ton. About 75 percent of the gold was lost, and although the tailings were stored, they were never treated. According to Allsman (1940, p. 14), the average value of the tailings (estimated to be about 27,840 tons) is about $5.84 per ton. Total production of the mine, from discovery to 1937, was 43,884.84 ounces of gold from 220,931 tons of ore (Allsman, 1940, p. 15). The statistics for 1878–1937 indicate that the value of the ore has probably not diminished with depth, although free-milling recovery is less for the deeper sulfide ores. On the basis of what is known about this mine, it seems likely that the ore will increase in quantity at greater depth at about the same average value.

V. This anticline, though only partly exposed, apparently is similar to those previously described. Greenstone and ferruginous chert are exposed in the crest and are overlain by graphitic schist which wraps around the west end of the structure. The chert beds all dip south, which indicates that the anticline is overturned. Linear features plunge steeply southeast. The cherts are oxidized and appear slightly mineralized. Test pits and short adits penetrate the chert in several places, and the broken rock on some test-pit dumps shows a little copper bloom. Of seven samples of chert analyzed, three show about 0.20 ppm gold, and the other four show trace amounts. Arsenic is anomalously high in all samples and very high in two samples. Soils downslope from the chert outcrops show uncommonly high gold. There is no evidence of mineralization in the greenstone and overlying rocks.

VI. This is a very narrow anticline which trends diagonally across the bottom of Strawberry Gulch. It consists of a narrow rib of amphibolite (metabasalt) flanked on both sides by ferruginous chert which wraps around the southeast-plunging anticlinal nose. Four samples of oxidized chert from the north limb contain 0.10–0.20 ppm gold, and one sample of unoxidized pyritic chert from the plunging nose of the fold contains 1.30 ppm gold. Pyrite-gold deposits occur in Tertiary porphyries nearby, so that in this particular location it is not possible to be sure whether the mineralization of the chert is of Precambrian or younger age.

DIAMOND DRILLING

In 1968, a diamond-drill hole was put down in anticline V in the NW¼NW¼ sec. 20 to learn something about the underlying rocks in that structure. (See pl. 1 for location.) The hole was directed

S. 20° E. at an 85° angle, which flattened to about 50° during the course of drilling. After drilling started, the direction of the hole was never certain because magnetic rocks rendered the in-hole compass useless. A simplified log of the hole follows:

	Depth (feet)
Surface rubble	0–35
Greenstone. Normal amphibolitic metabasalt to about 866. Heavy alteration below 866. Chloritization and biotization with some tourmaline, disseminated pyrrhotite, and numerous quartz veins. Interbedded thin units of pyrrhotitic graphitic schist below 847. Disseminated pyrrhotite deformed in schistosity. Schistosity in greenstone strikes approximately east and dips 60° S. near surface; it is approximately perpendicular to core in lower part of greenstone and to bottom of hole. Lower part of greenstone magnetic	35–1, 004
Banded graphitic schist with disseminated pyrrhotite. Becomes interlayered with chloritic schist downward. Magnetic	1, 004–1, 100
Banded graphitic and chloritic schist with pyrrhotite mainly in schistosity partings. Numerous quartz veins and pyrite veinlets. Magnetic	1, 100–1, 184
Banded schistose slate. Gray chlorite-biotite layers alternate with black graphitic layers containing small garnets. Minor sulfides in schistosity and veinlets. Pyrrhotite to about 1,200; all pyrite below 1,200. Slightly magnetic	1, 184–1, 850

The correlation of the units below the greenstone is uncertain. The graphitic schist looks most like the so-called iron dike or former Garfield Formation at Lead, which is now included in the Flag Rock Formation. The underlying banded schists could possibly represent the Northwestern Formation or a schist part of the Ellison Formation (quartzite), but there is no way to be sure which, if either.

The altered greenstone and extensive quartz-sulfide veining indicate that the drilled rocks have been slightly mineralized; however, the mineralization does not seem to be of the type which produced Precambrian gold deposits in this region, as indicated by the nearly complete lack of arsenic (table 1). The abundant iron sulfide in the graphitic schists is most likely indigenous, as it very commonly is in rocks of this type.

MAGNETIC SURVEY

After the pyrrhotite rocks were encountered in the diamond-drill hole, a ground magnetic survey was made to determine the distribution of the pyrrhotite-bearing rocks. The results of the survey are shown in figure 2. The survey results are not understood in that the magnetic trends do not fit the surface structures on the Precambrian rocks as they do in nearby areas surveyed previously. Anomaly I is a possible exception; it seems to conform to an altered ferrugi-

TABLE 1.—*Results of core-sample analyses, U.S. Geological Survey diamond-drill hole 1, Galena-Roubaix district*

[Au, Ag, and Cu by atomic absorption methods; As by colorimetric method; analyses data in parts per million. Abbreviations: alt, altered; amph, amphibolite; bio, biotite; carb, carbonate; chlor, chlorite; graph, graphite; qtz, quartz; sch, schist; sulf, sulfide(s); and tour, tourmaline]

Depth (feet)	Material	Au	Ag	Cu	As
650	Pyrite veinlet	<0.02	0.8	29	------
665	do	<.02	.9	60	------
790	Carb-sulf vein	<.02	.3	100	60
847	Vein qtz with pyrite	<.02	<.2	13	60
849	do	.02	1.2	110	------
851	do	1.0	1.7	81	<10
852	do	.09	.9	58	------
854	do	.08	.8	220	<10
856	do	.11	<.2	63	------
858	do	.04	.2	280	120
859	do	<.02	<.2	200	------
860	Graph sch, vein qtz, sulf	<.02	2.7	220	<10
861	do	<.02	<.2	440	------
861.5	Pyrrhotite in vein qtz	.09	1.5	63	<10
864.5	Sulf vug	<.02	<.2	32	------
865	Chlor-graph sch with sulf	<.02	<.2	61	40
866	do	.19	1.5	230	------
867.5	Bio sch & vein qtz	<.02	.9	<10	60
868.5	Graph sch with sulf	<.02	<.2	51	------
869.5	Bio-qtz sch with actinolite	<.02	.8	34	120
870.5	Graph-chlor sch with sulf	<.02	.4	71	------
871.5	Bio sch with actinolite rosettes	<.02	.5	16	100
874.5	Carb vein	<.02	.7	28	------
878	Carb-tour-sulf vein	.02	.4	73	150
880	Bio alt amph with sulf	<.02	.5	48	------
880.5	Amph with pyrrhotite	<.02	<.2	53	120
885	Qtz-tour vein	.02	.9	120	------
889.5	Bio alt amph	<.02	<.2	41	------
913	do	<.02	<.2	<10	------
930	Bio alt amph with pyrrhotite	<.02	<.2	83	------
948	do	.03	.6	180	150
958	do	<.02	1.5	95	------
974	Vein qtz	<.02	<.2	27	------
980	Bio alt amph with vein qtz	.25	<.2	69	------
986	Bio-graph sch with pyrrhotite	<.02	<.2	99	<10
987.5	do	.22	.6	14	------
989	do	.02	<.2	62	10
993.5	Bio-pyrrhotite sch	<.02	<.2	48	------
999	Vein qtz	.03	<.2	73	150
1002	do	.02	<.2	66	150
1004.5	do	<.02	<.2	44	------
1010	Bio rock with pyrrhotite	<.02	.9	27	120
1013.5	Vein qtz	.16	.6	250	------
1022.5	Graph sch	<.02	.8	160	80
1017.5	Vein qtz	<.02	<.2	350	------

TABLE 1.—*Results of core-sample analyses, U.S. Geological Survey diamond-drill hole 1, Galena-Roubaix district*—Continued

Depth (feet)	Material	Au	Ag	Cu	As
1026.5	Graph sch with pyrrhotite	<.02	<.2	100	150
1034.5	do	<.02	<.2	190	------
1049	do	<.02	<.2	140	<10
1051	do	.02	.8	150	<10
1052	Graph sch with vein qtz	<.02	1.7	300	------
1057.5	do	<.02	.9	79	<10
1065.5	do	.03	1.7	210	------
1073	Graph sch, vuggy	<.02	.8	110	120
1080	do	.02	.9	210	------
1089	do	<.02	.9	110	40
1090.5	do	<.02	.5	88	------
1093	do	<.02	.4	92	10
1097	Vein qtz, pyrrhotite	<.02	<.2	24	------
1103	Chlor sch with pyrrhotite	<.02	<.2	62	<10
1104	do	.02	<.2	59	------
1109	do	<.02	<.2	17	40
1109.5	Vein qtz, pyrite	.02	<.2	16	------
1111.5	do	<.02	.6	32	<10
1114	Rock, pyrite	<.02	.4	83	------
1116.5	Vein qtz	<.02	<.2	35	<10
1122	Graph sch with pyrite	<.02	.9	120	------
1124	Chlor sch with pyrrhotite & pyrite (late).	<.02	<.2	24	<10
1127.5	Chlor sch with pyrrhotite	<.02	<.2	19	------
1135	Graph sch with pyrite	<.02	.5	100	<10
1137.5	Graph sch with pyrrhotite	<.02	<.2	110	------
1149	Graph sch with pyrite	<.02	1.0	230	<10
1151.5	do	<.02	<.2	210	------
1159	Chlor sch with pyrrhotite & pyrite	<.02	<.2	50	<10
1190	Chlor-bio sch	.03	.8	46	------
1200	Chlor-bio sch with pyrite	<.02	.8	45	<10
1220	Bio sch with pyrite	<.02	1.4	54	------
1232	do	<.02	1.1	38	10
1246	Sch, vein qtz	<.02	1.4	74	------
1246.5	do	.03	1.4	23	40
1251	Vein qtz	.04	.8	160	------
1274	Sch with pyrite	<.02	1.3	96	<10
1334	Vein qtz with pyrite	<.02	<.2	12	------
1346.5	do	.03	1.6	170	<10
1437	do	.02	.5	52	------
1447	do	.03	<.2	100	<10
1534	do	.06	.7	110	------
1598	Sch, vein qtz, pyrite	.02	.8	21	<10
1732	Vein qtz	<.02	<.2	<10	<10
1760	do	.08	1.0	<10	------

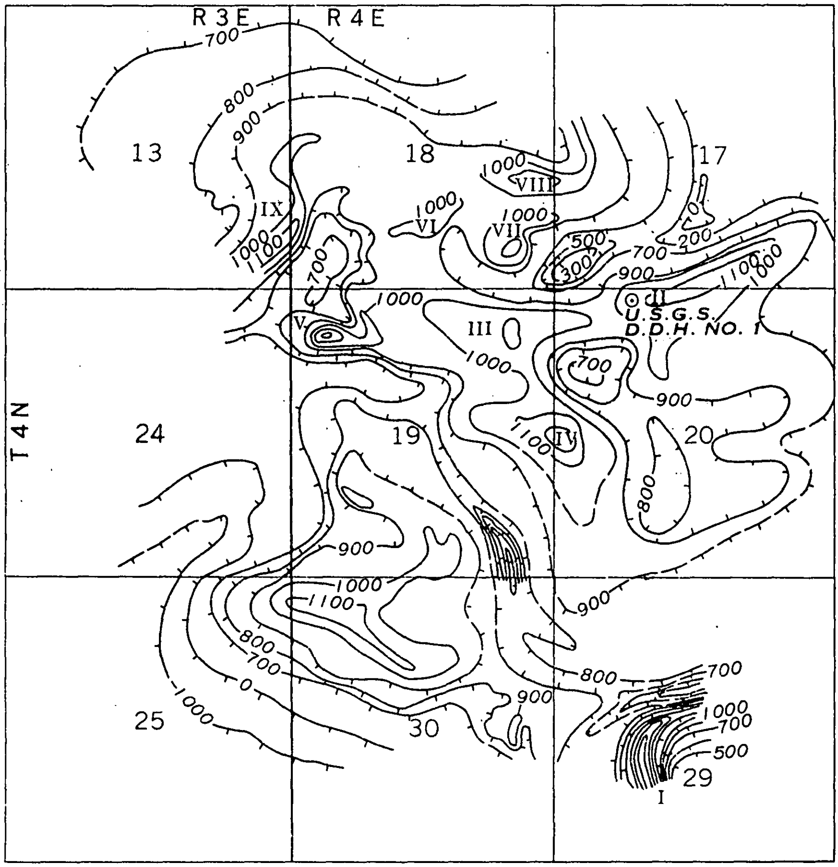

FIGURE 2.—Magnetic survey in the vicinity of U.S. Geological Survey diamond-drill hole 1. Roman numerals inidicate anomalies referred to in text. Values in gammas above an arbitrary datum. Contour interval irregular.

nous schist unit exposed at the surface. This schist is assumed to overlie the greenstone (pl. 1). Anomaly II at the drill-hole site obviously reflects the pyrrhotite in the graphitic schist below the greenstone. Thus, there are at least two magnetic units represented in the survey area. Anomalies III and IV are off the greenstone over rocks assumed to be above the greenstone. Some of the exposed rock is graphitic schist which could be pyrrhotitic; however, no sulfides were seen in the exposures. Anomaly V also crests over graphitic schist bedrock which could be pyrrhotitic below the surface oxidation level. Anomalies VI, VII, VIII, and IX are in graywacke schist terrane and trend perpendicular to the strike of the exposed beds. These anomalies seem related to the others; hence, they are presumed to reflect a pyrrhotized graphitic schist unit beneath the graywacke schist and separated from it by an unconformity or thrust fault. Anomaly X also seems to be discordant to surface structures, and its source may lie beneath the graywacke schist. Overall, the survey shows a block of country characterized by positive anomalies surrounded by country characterized by negative anomalies. In general, all such magnetically positive areas in this region are anticlinal and underlain by Flag Rock Formation volcanics and older rocks, whereas the negative areas are synclinal and underlain by Grizzly Formation graywackes and schists.

Anomaly IX of the present report (fig. 2) is shown on the aeromagnetic map of Meuschke, Philbin, and Petrafeso (1962) to diminish in value westward to a saddle in the NW¼ sec. 14, T. 4 N., R. 3 E., and there to join another positive anomaly which rises in value northwestward to crest over Grizzly Gulch and approximately over the deep workings of the Homestake mine, in sec. 3, T. 4 N., R. 3 E. It seems safe to assume that at least part of the anomaly over Grizzly Gulch is caused by pyrrhotite in the Homestake Formation, which is present 5,000 feet or more below the Gulch. Folds in the Homestake Formation under the Gulch plunge southeasterly at about 35°. This plunge could account for the southeastward decrease in value of Grizzly Gulch anomaly. The coincidence of the magnetics and structure suggests that the magnetic saddle in sec. 14 is also a structural saddle from which point the Homestake and other formations ascend upward, eastward, to the Galena-Roubaix district. If the plunge angle is assumed to flatten a little as the structural saddle is approached, the depth to the Homestake Formation in the structural saddle will be 10,000 to 12,000 feet. The degree of ascent of the rocks eastward from the saddle cannot be worked out from the available data.

SUMMARY

Volcanic rocks, not previously recognized in the Galena-Roubaix district, and cherts occur extensively and consistently in the stratigraphic interval assigned to the Flag Rock Formation of the Lead area. The volcanic rocks and cherts are the oldest exposed rocks in the Galena-Roubaix district, and they form plunging anticlines, some of which are mineralized in the crests. A straightforward geologic projection will place the older formations of the Lead sequence—the Northwestern, Ellison, Homestake, and Poorman Formations—beneath these anticlines. The Homestake Formation is the host rock for the gold deposits at the famous Homestake mine. Rocks possibly equivalent to the Northwestern Formation or the Ellison Formation

were cut in a diamond-drill hole in the crest of an anticline north of Roubaix. The Homestake Formation, if present at all, must lie at depth below the bottom of this hole, and its presence can only be verified by deep drilling.

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