Circular 54

Magnetite Taconite Rock in Precambrian Formations in Rio Arriba County, New Mexico

by William E. Bertholf II

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
E. J. Workman, President
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CAMPUS STATION SOCORRO, NEW MEXICO

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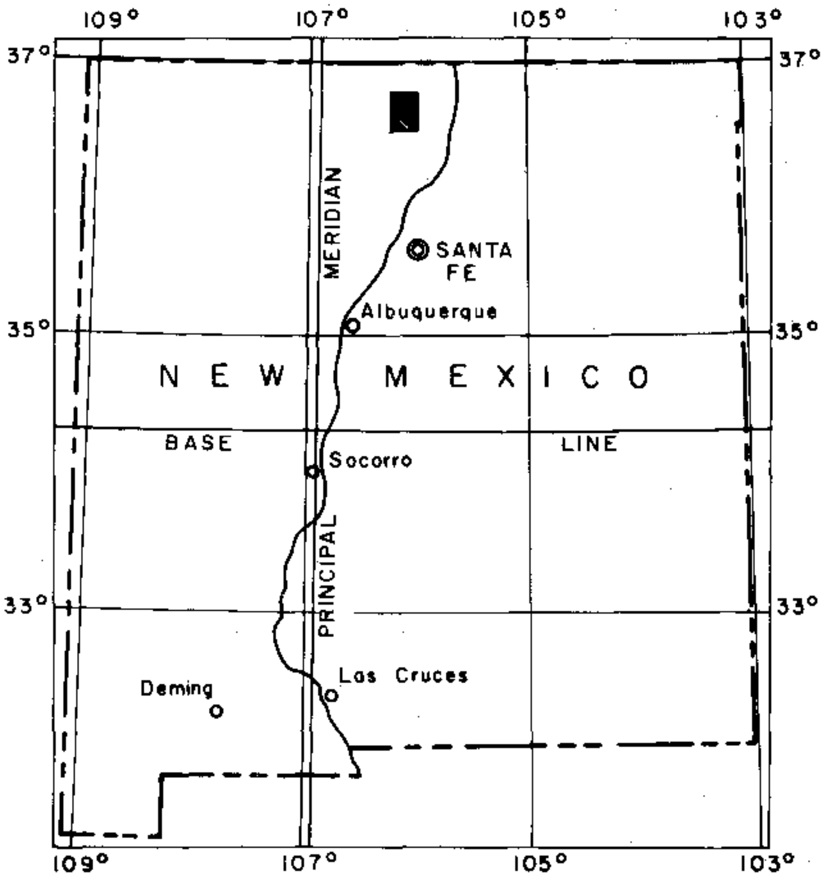

Figure 1. Location map showing Las Tablas quadrangle, Rio Arriba County, New Mexico

INTRODUCTION

In the summer of 1959 it became evident that a Precambrian magnetite taconite formation of unknown extent occurs in the Moppin metavolcanic series in Rio Arriba County, New Mexico. A geologic map of the Las Tablas quadrangle, the area within which this formation was observed, is presented by Barker (1958).

Exploratory dip-needle and magnetometer traverses were made, and sparsely distributed outcrops and float rock of the magnetite taconite rock were examined in secs. 19 and 29, T. 29 N., R. 7 E., and sec. 29, T. 28 N., R. 8 E. The aforementioned localities are on the northeast limb of a synclinal structure and are separated by approximately 10 miles. Lower Precambrian formations continue to the southeast on the same structural trend.

The magnetite taconite formation examined is within the Carson National Forest. Samples were collected in the SW1/4 sec. 29, T. 28 N., R. 8 E., and the results of the study to date are presented hereinafter. Field work was discontinued after November 29, 1959 because of frozen ground and deep snow on the back roads.

MAGNETIC MEASUREMENTS IN THE FIELD

With the use of a dip needle of the Lake Superior type, exploratory traverses were made in the sections in which Precambrian magnetite taconite rock formation was thought to occur. The results of the dip-needle survey indicated that an exploratory magnetometer survey probably would yield worthwhile data, because the area is covered with trees and bushes, and the pattern of rock outcrops leaves large areas to conjecture. It is common experience that Precambrian iron-rich formations weather down more rapidly than other Precambrian rocks.

In preparation for the magnetometer survey, a suitable area was sought for a magnetic base station, and for a traverse to establish the regional level for nonmagnetite rocks.

The base station was established at the United States Department of Agriculture, Forest Service mark R139/1955, which is located approximately 200 feet south of the northwest corner of the SW1/4 sec. 34, T. 28 N., R. 8 E., of the New Mexico Principal Meridian. Further, this mark is on a square concrete pillar 45 feet south of the centerline of the forest road at the point where the road begins to descend into Spring Creek Canyon.

From mark R139/1955, a random compass and dip-needle traverse was made to a station approximately 700 feet north and 2,000 feet west. The canyon rim trends approximately magnetic west from the mark; so the last eight stations of this traverse are away from the rim. The traverse is over rocks mapped by Barker (1958) as rhyolitic conglomerate, tuff, and sandstone of Tertiary age. It is assumed that at no great depth directly beneath the Tertiary the rocks are nonmagnetite Precambrian formations. More data will be necessary to determine whether at greater depths there are magnetite taconite formations. It is a good possibility that such occur at a depth of 2,000 feet or more.

Magnetic readings at the base station and 10 stations along the random traverse line varied from 477 to 674 gammas (relative). The temperature was approximately 20°C. The stations were read between 1300 and 1500 hours. The magnetometer was read at the base station before and after the traverse. The 1300-hour reading was 666 gammas (relative), and the 1500-hour reading was 686 gammas (relative). Three days later, at 1640 hours, the instrument reading at the base station was 645 gammas (relative), a variation of 41 gammas between the earlier high reading and the later low reading.

Traverse stations 1 and 2 had values of 674 gammas (relative) and 672 gammas (relative) respectively. The station 3 reading of 477 gammas (relative) was the low reading of the traverse. For the remaining stations (4 through 9), the high reading was 616 gammas (relative), and the low reading was 566 gammas (relative), a difference of 50 gammas.

It is assumed, therefore, in the balance of this work that for surface rock of low magnetite content, and for deeply buried magnetite taconite rock, the instrument readings would be in the range of 475 to 675 gammas relative.

On the basis of assumed models with varying horizontal two-dimensional aspect, magnetite content, and depth of burial (supplied by the author), Dr. Allan R. Sanford, of the New Mexico Institute of Mining and Technology, calculated anomaly values in the range of 60,000 to 180,000 gammas. From this calculation it was concluded that the readings observed in the field tended to be secondary highs and lows associated with a primary high-gamma-value level over the Moppin metavolcanic rocks.

The five traverses made over the suspected magnetite taconite formation were laid out on the basis of the data obtained from the earlier exploratory dip-needle survey. The distances between the lines of the traverses were spaced variously at intervals of 92 to

280 feet. The end lines were approximately 800 feet apart. The area is forested and brush covered; maximum use was made of the openings resulting from recent logging operations. The data sought at this stage of examination do not warrant the expense of brushing out a uniform grid of lines. A Ruska scout magnetometer (type S1) was used to obtain readings at stations located approximately 100 feet apart along each traverse line.

Lines 520 feet west, 280 feet west, zero, and 250 feet east were read first. On the basis of the readings and the distribution of the magnetite taconite in the float rock, line 92 east was laid out to cross the high anomaly near the footwall, and readings were made on stations spaced 25 feet apart.

For comparing airborne-magnetometer data with the ground data herein, one should fly a 2 1/4-mile south to north traverse beginning exactly 1 1/4-miles west of the Kiawa Mountain fire tower.

The instrument data are presented below (table 1).

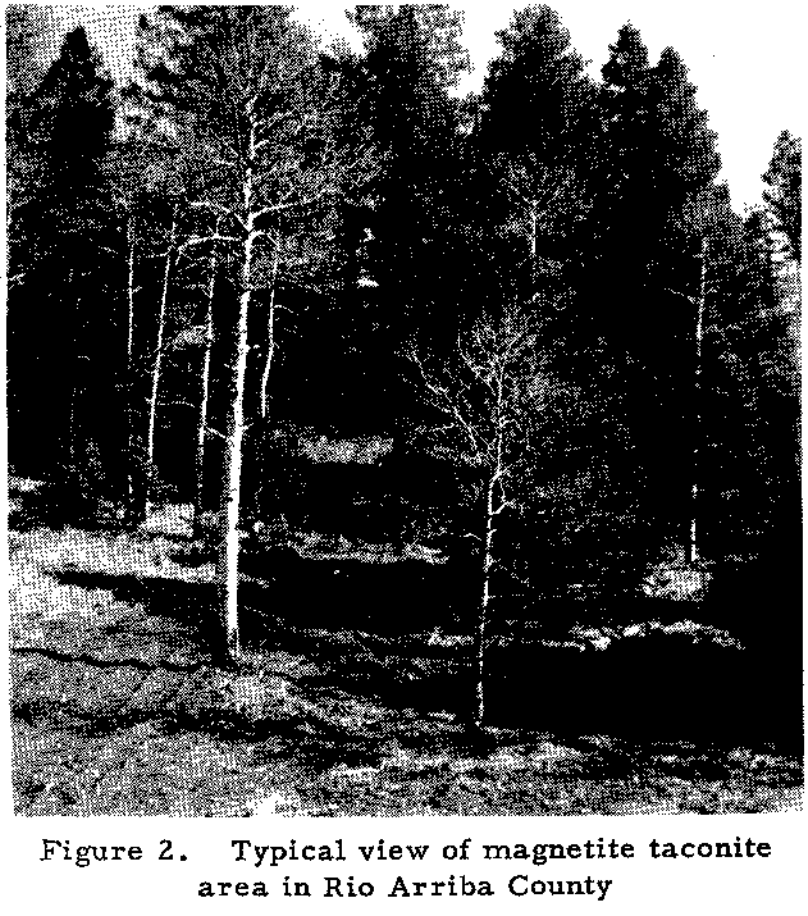

Figure 2. Typical view of magnetite taconite area in Rio Arriba County

SAMPLING AND TESTING

A channel sample of the rock under line 92 feet east was collected from between 45 feet south and 80 feet south to determine its magnetite content. At 50 feet south, a small pinnacle of magnetite taconite formation cropped out. Along the balance of the line, the overburden was 1 to 2 feet thick. The dip of the strata was approximately 80 degrees south. Weathering had penetrated deeply along the bedding planes; so the sample must be considered as being somewhat altered by weathering.

The rock collected in the sample consists of alternating layers of material rich in iron oxide and material rich in silicon dioxide. The layers are as much as 0.7 inch in thickness. See Figure 9.

In thinsection, the rock layers containing the opaque mineral are black to dark steel gray under incident light. The mineral is believed to be principally magnetite. The anisotropic layers are composed principally of quartz and have the appearance of a fine-grained quartzite.

As originally collected, the sample from the 35-foot channel was bagged as seven 5-foot samples. In the laboratory, the seven samples were washed until free of slimes, dried, and crushed in a jaw crusher. Each 5-foot sample was quartered to obtain approximately a kilogram sample. The kilogram of material from each 5-foot sample was mixed into a 7-kilogram composite sample and split into four quarters. One quarter was processed to obtain a screen analysis (table 2). With the use of heavy liquid of specific gravity 2.95, the light- and heavy-mineral fractions of the portion retained on each screen size were separated and weighed.

It was noted that some grains in the light fraction were attracted by a small hand magnet. Examination of a rock thinsection in incident light showed magnetite grains scattered throughout the silica layers.

TABLE 1. RELATIVE GAMMA VALUE OF EACH STATION ARRANGED TO SHOW COORDINATES OF EACH STATION
(In feet)

	West			East	
Coordinates	520	280	Zero	92	250
North					
700					805
600					2261
500					2775
400					1890
300			510		2863
200			6450		2487
100			3205		1870
25				2380	
Zero		1545	2745	2490	3545
25				2440	
50				3845	
60	2030				
75				6520	
100		2880	(-)327	5280	2460
125				4130	
150				3385	
160	1538				
175				3325	
200		1455	4055	3155	2082
240		859			
260	2280				
270		1445			
300		3265	2515		2605
360	1455				
400		2645	2130		4430
460	3255				
500		5025	3775		2528
560	3460				
600			1710		1595
660	3084				
700			2645		3200
760	4054				
800			2345		2055
860	1820				
900			1105		1595
960	1860				
1060	1048				
South					

TABLE 2. HEAVY-MINERAL-SEPARATION FLOWSHEET FOR THE FIRST QUARTER OF THE COMPOSITE SAMPLE

Channel sample	A 35-foot channel sample collected as seven 5-foot samples.
Crush	Each 5-foot sample deslimed, dried, and crushed in a jaw crusher set at 1/2-inch discharge opening.
Composite mixed and quartered	The 5-foot samples combined into a composite, which was quartered.
Screen analysis	First quarter processed to obtain a screen analysis.
2.95-specific-gravity separation	Each screen portion was separated into a light and heavy fraction in a liquid of specific gravity 2.95.
Microscopic examination	Thinsections and grain slides were studied to check results.
Chemical analyses	Chemical analyses were made to determine the iron and insolubles content (table 4).

TABLE 3. SCREEN ANALYSIS AND HEAVY-MINERAL-SEPARATION DATA FOR THE FIRST QUARTER OF THE COMPOSITE SAMPLE

Retained on screen				Gram wt.		Wt. %
Inches	Mm	Gram wt.	Wt. %	Light	Heavy	Heavy fraction
.624	15.9	148.7	9.4	13.0	136.1	91.5
.500	12.7	315.9	19.85	59.0	257.9	81.6
.375	9.52	378.9	23.7	83.8	296.0	78.2
.250	6.35	243.4	15.3	33.8	208.4	85.8
.187	4.76	109.7	6.9	19.7	89.3	81.4
.132	3.36	83.5	5.25	13.7	70.0	83.8
.093	2.38	53.2	3.4	9.7	43.6	82.0
.066	1.68	37.0	2.3	5.6	31.5	85.2
.046	1.19	27.5	1.7	4.2	23.3	84.8
.033	0.84	18.0	1.1	(2.7)	(14.9)	85.0
	Pan (-0.84)	174.4	10.95	(71.7)	(96.1)	57.3
		1590.2	99.85	316.9	1267.1	

TABLE 4. CHEMICAL ANALYSES OF THE COMPOSITE AND SELECTED FRACTIONS OBTAINED FROM THE LIGHT- AND HEAVY-MINERAL-SEPARATION PROCEDURE

	Composite		Light fraction		Heavy fraction	
Size Range	Iron	Insolubles	Iron	Insolubles	Iron	Insolubles
Composite	35.6					
15.9 mm			22.8	65.6	38.2	43.9
9.52 mm			14.9	77.1	39.2	42.4
0.84 mm			10.0	82.0	42.6	36.8
Pan (-0.84 mm)			6.0	88.5	51.4	24.0

TABLE 5. DRY-MAGNETIC-SEPARATION FLOWSHEET FOR THE SECOND QUARTER OF THE COMPOSITE SAMPLE ROLLED TO -0.84-MM (20 mesh) SIZE

Crushing rolls	The second quarter of the composite sample was crushed between rolls until all of it screened -0.84 mm (20 mesh).
Magnetic separator	The -0.84-mm material was then processed on a Stearns type D belt magnetic separator set at 192 volts and 0.2 ampere. The feed was adjusted so that the belt was covered with a thin film. A first concentrate (C_1) and tailing (T_1) were obtained.
Tailing reprocessed	The first tailing product was reprocessed to give a second concentrate (C_2) and a second tailing (T_2).
Concentrate reprocessed twice	The concentrates were mixed and reprocessed twice to obtain a final concentrate (C_3) and a third tailing (T_3).

TABLE 6. CHEMICAL ANALYSES OF THE PRODUCTS OF THE DRY-MAGNETIC-SEPARATION PROCESS

Dry magnetic separation			Chemical analysis	
Product	Gram wt.	Wt. %	Iron	Insolubles
T_2	445.0	27.15	14.0	75.0
T_3	213.8	13.10	21.3	33.3
C_3	978.5	59.75	46.4	65.8
	1637.3	100.00		

CORRIGENDUM

Page 7, Table 6. The chemical analysis should read:

	Iron	Insolubles
(T_2)	14.0	75.0
(T_3)	21.3	65.8
(C_3)	46.4	33.3

TABLE 7. WET-MAGNETIC-SEPARATION FLOWSHEET FOR A 500-GRAM SAMPLE OF THE DRY-MAGNETIC-SEPARATION FINAL CONCENTRATE (C_3) GROUND IN A BALL MILL FOR 15 MINUTES

Ball mill	The dry magnetic concentrate C_3 was halved, and one portion ground in a laboratory ball mill for 15 minutes (load ratio approximately 1 to 10).
Wet magnetic separation	(a) The ball-mill product was mixed in a laboratory flotation cell, and a 250-ml glass beaker containing a magnet was immersed in the agitated pulp to collect magnetite on the glass. (b) The beaker and adhering magnetite were withdrawn from the pulp and the magnetite collected. (c) Magnetic extraction was repeated until substantially all the magnetite obtainable by this method was collected from the pulp. The tailing and concentrate were dried, weighed, and analyzed.

TABLE 8. CHEMICAL ANALYSES OF THE PRODUCTS OF THE WET-MAGNETIC-SEPARATION PROCESS

Wet magnetic separation			Chemical analysis	
Product	Gram wt.	Wt. %	Iron	Insolubles
Tailing	223.6	41.6	24.6	60.5
Concentrate	313.9	58.4	62.0	12.7
	537.5	100.0		

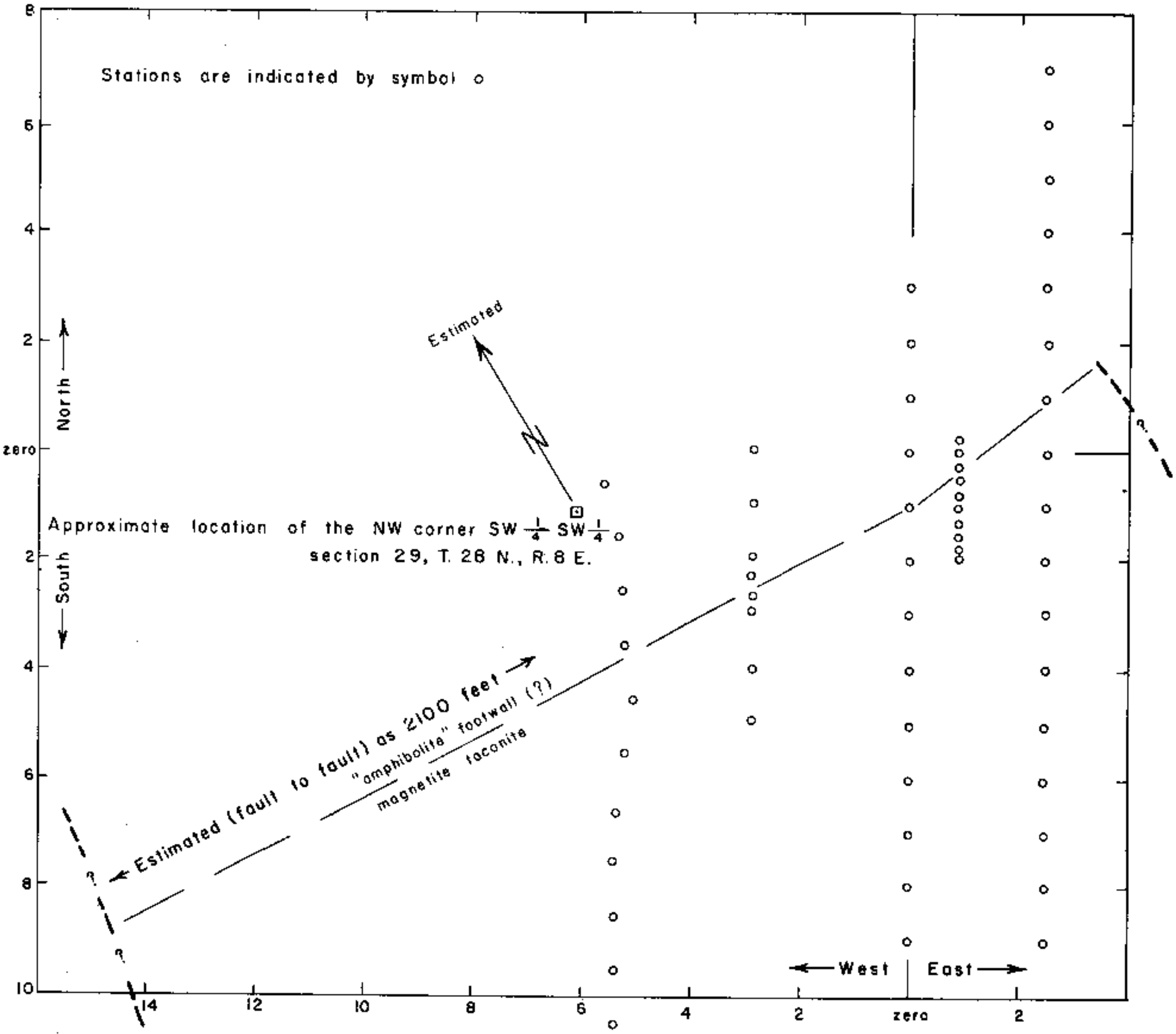

Figure 3. Magnetic traverse lines

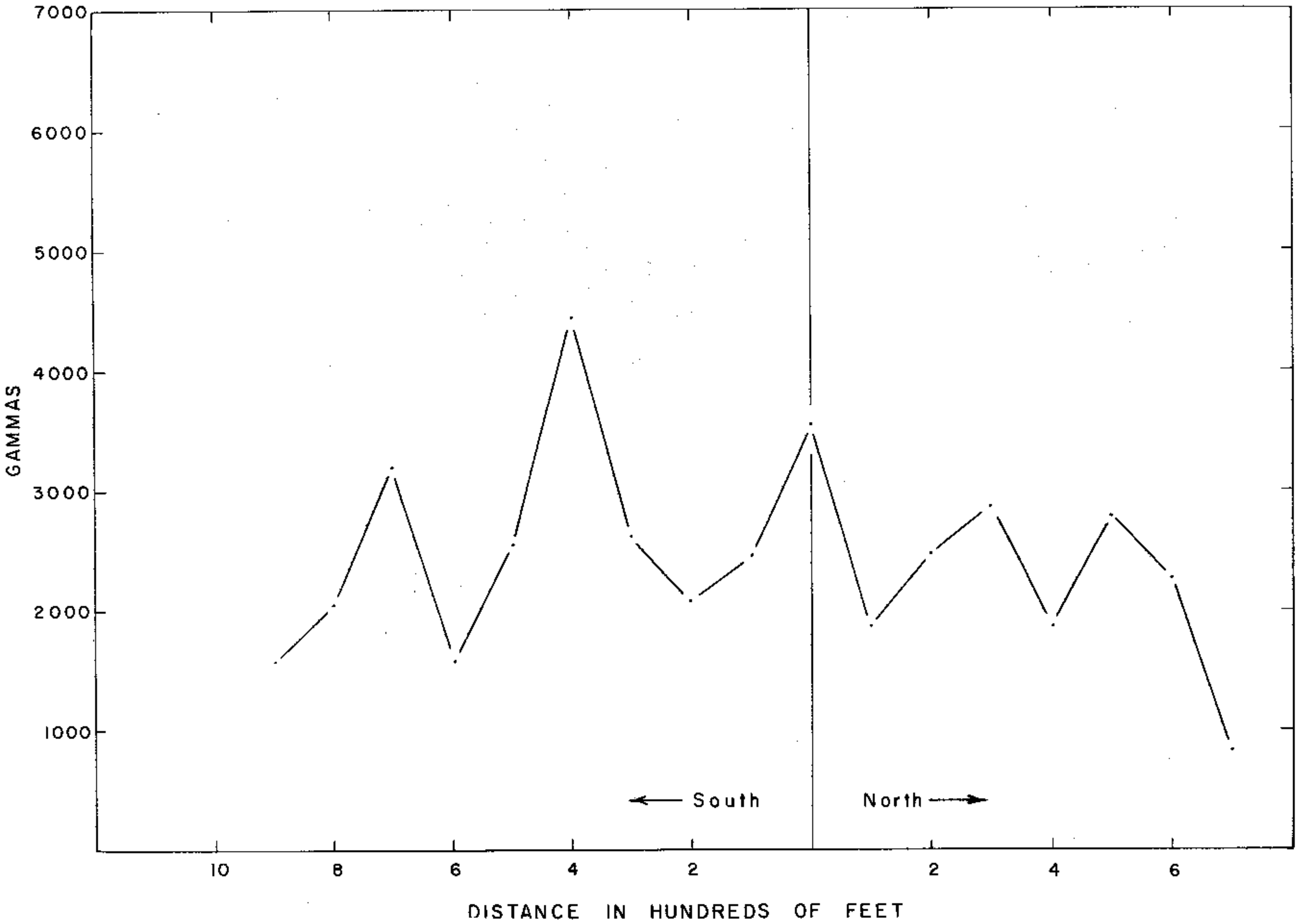

Figure 4. Magnetic profile along line 250 feet east (relative values)

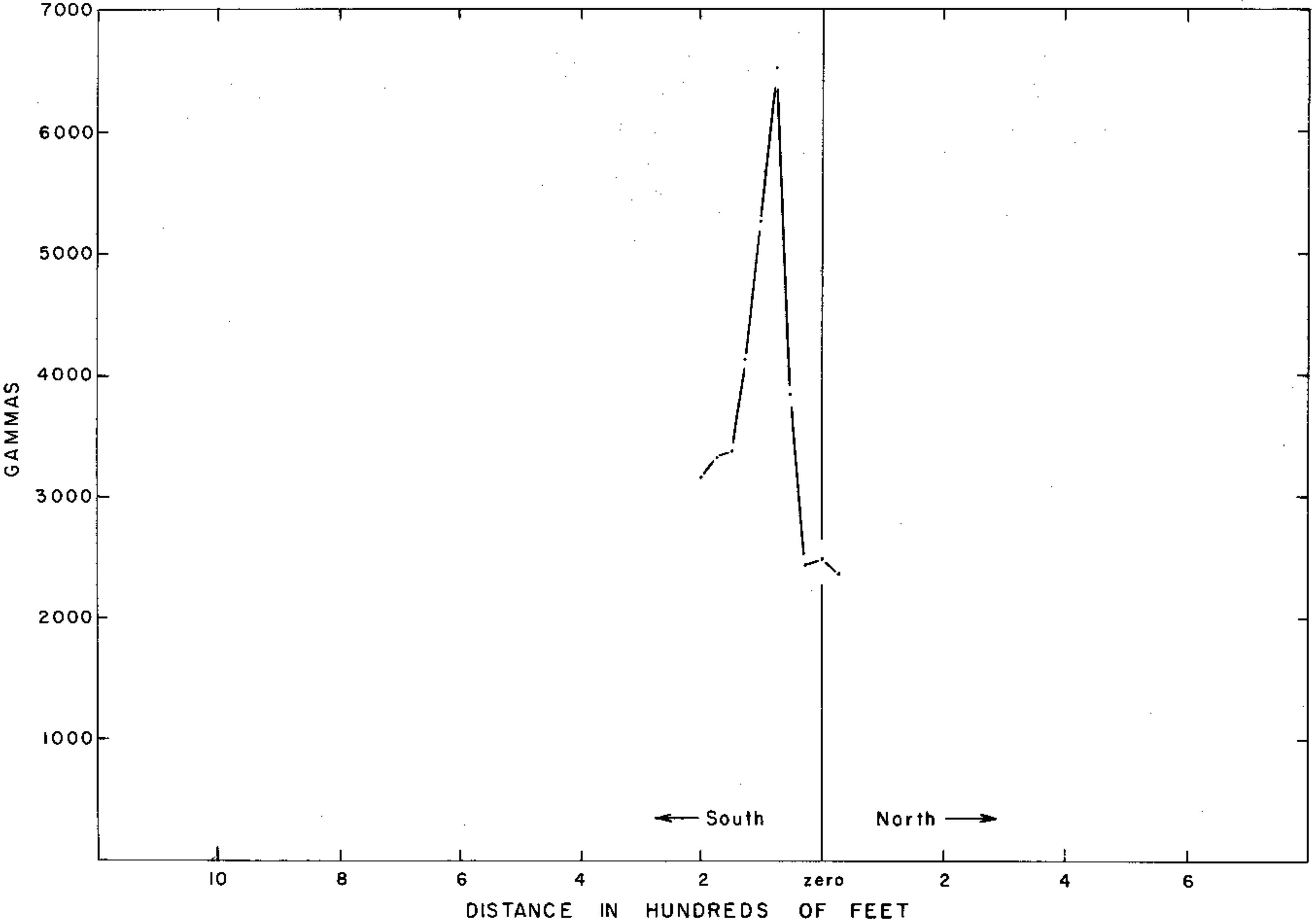

Figure 5. Magnetic profile along line 92 feet east (relative values)

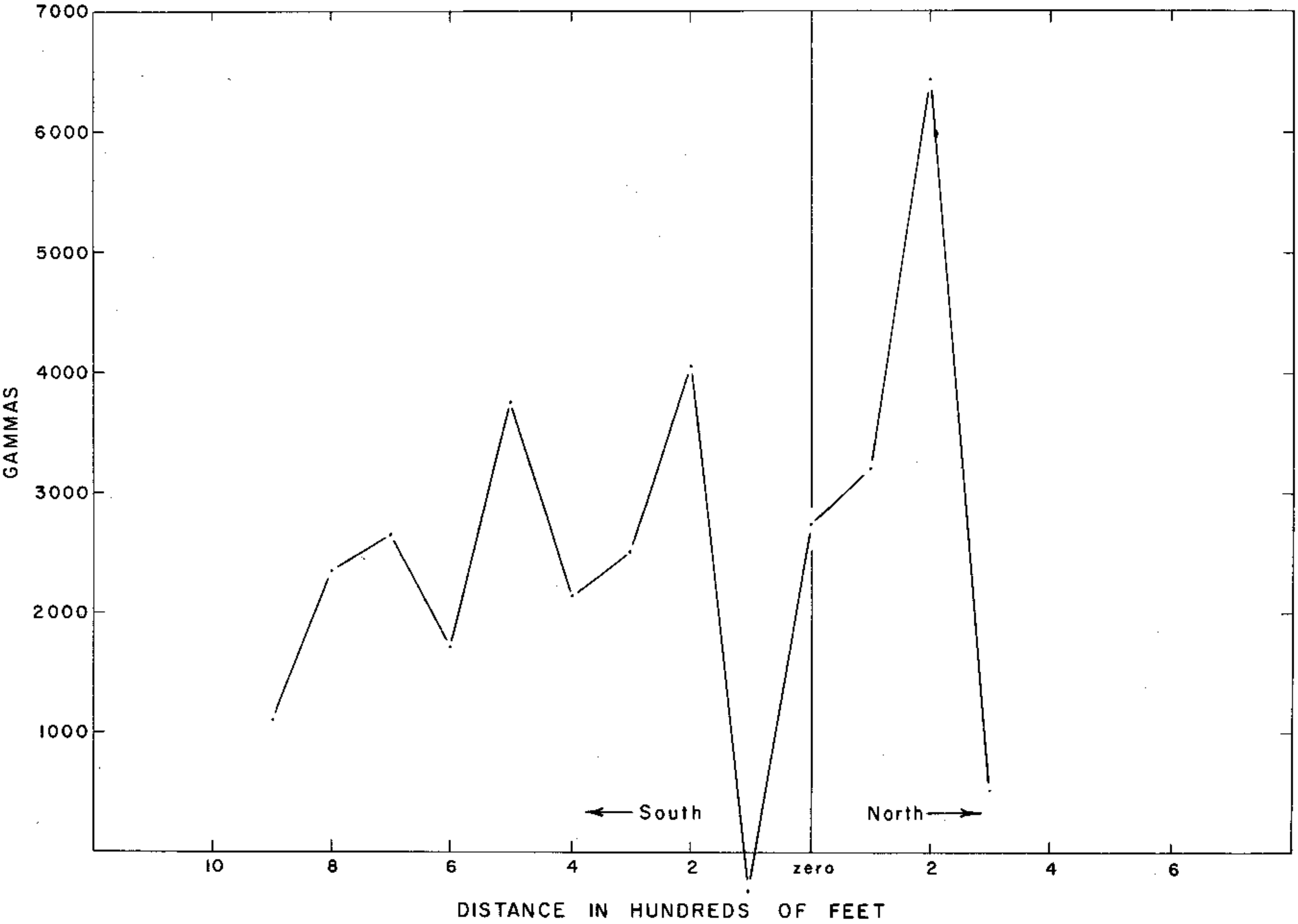

Figure 6. Magnetic profile along line zero (relative values)

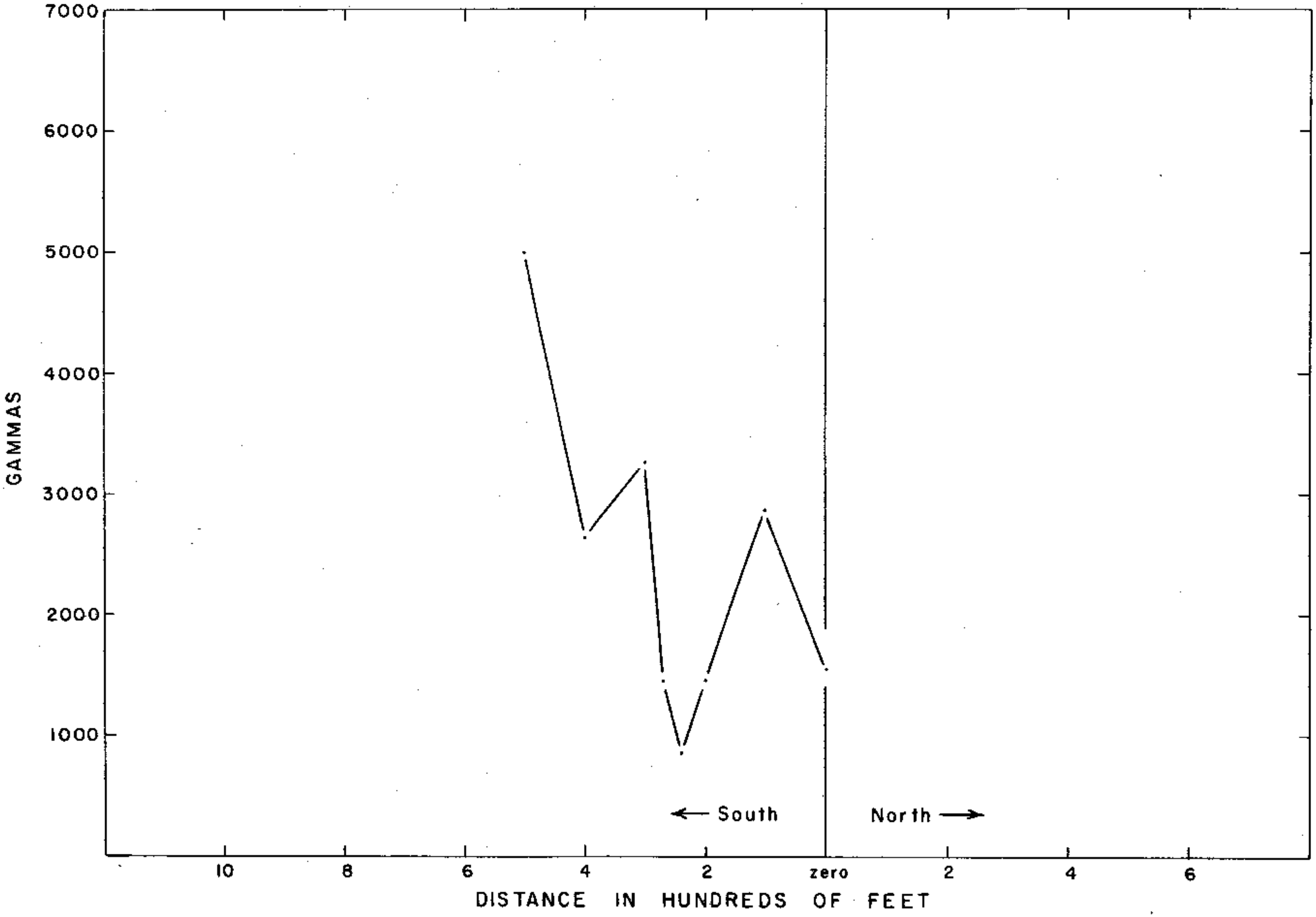

Figure 7. Magnetic profile along line 280 feet west (relative values)

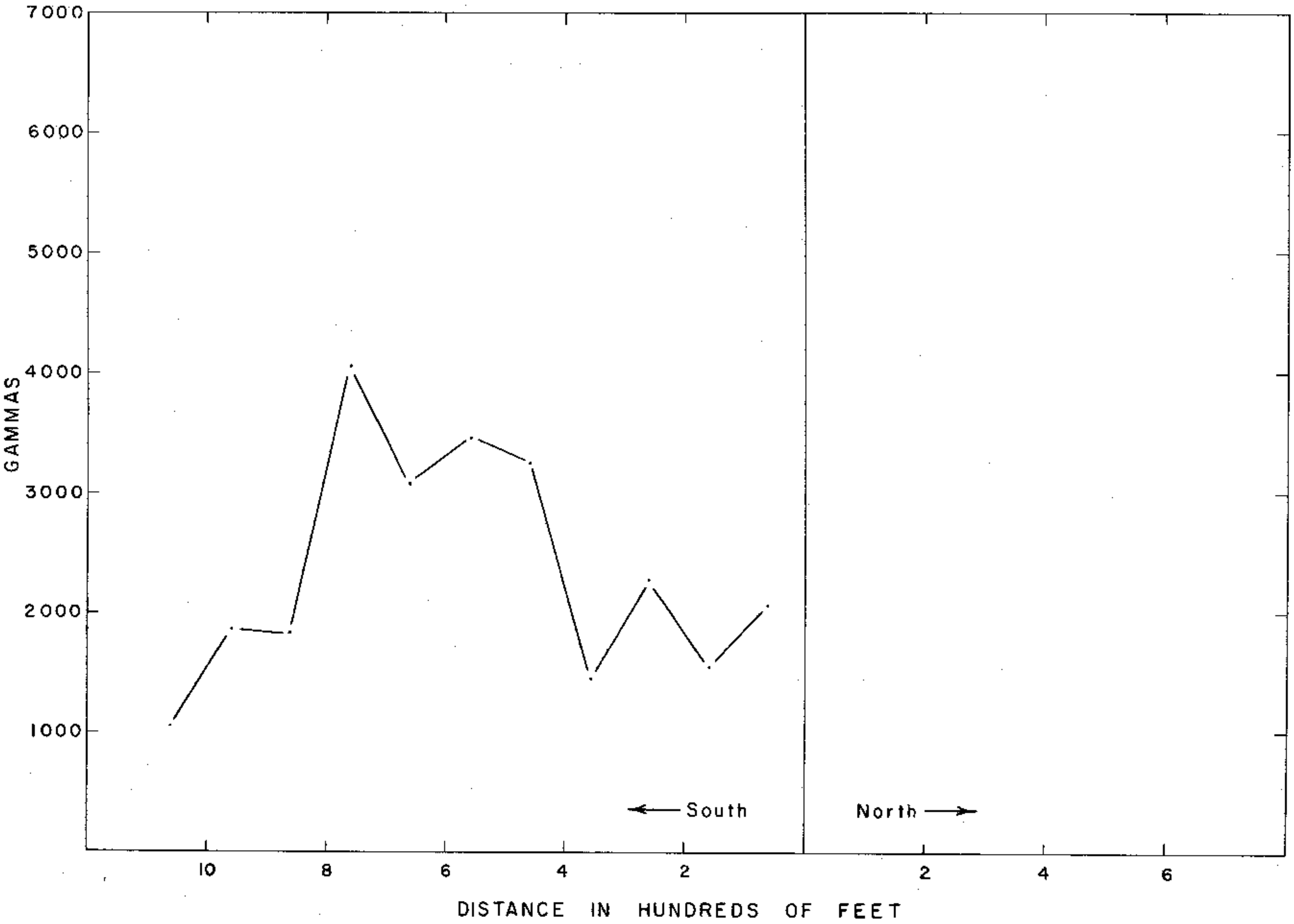

Figure 8. Magnetic profile along line 520 feet west (relative values)

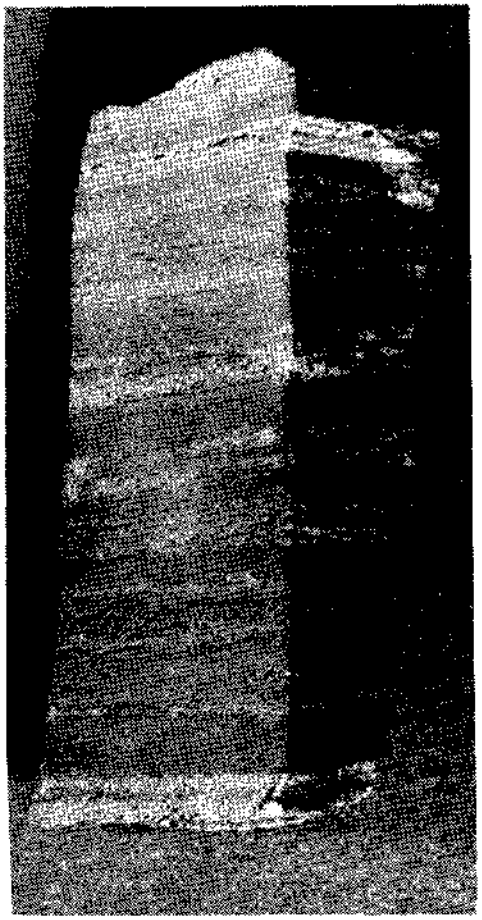

Figure 9. Typical magnetite taconite rock

Dark layers are rich in magnetite.

ESTIMATE OF THE IRON POTENTIAL IN RIO ARRIBA COUNTY, NEW MEXICO

Precambrian rocks have been reported (Lindgren et al., 1910, p. 48–51, 125) as cropping out in Rio Arriba County, New Mexico. The Precambrian is exposed where streams have eroded through the overlying Tertiary volcanic rocks and sediments. Precambrian porphyritic intrusive rocks, of various compositions from diorite to quartz monzonite and granite, are reported as present in the immediate vicinity of mineral deposits containing metallic elements. Iron oxide, carbonate, and sulfide are noted as accessary minerals, but the only mention of an occurrence of magnetite sufficiently extensive to be called a deposit is in the Hopewell district, approximately "2 miles a little west of north from Hopewell":

> On the small elevation known as Iron Mountain, a short distance south of the Jaw Bone mine, a moderate amount of work has been done on a deposit of iron ore. A slaty schist, striking somewhat north of west and dipping 65° N., about parallel to the Jaw Bone vein, holds an interfoliated band of iron ore. To judge from the pits sunk upon it, it is about 6 or 8 feet wide and, instead of having definite walls, grades off into the inclosing schist. The ore, which is mostly magnetite, is slaty in structure and fairly rich in iron. The microscope shows that it is a mixture of minute grains and cubes of magnetite mingled with quartz and perhaps a little feldspar. (Lindgren et al., 1910, p. 128.)

In 1937, Just mapped the rocks in the Hopewell-Cleveland Gulch structure as the oldest Precambrian rock sequence in the area, designating it the Hopewell series. The series, according to Just (1937, p. 42):

> . . . contains rocks of sedimentary origin interspersed with volcanic rocks. . . . The series consists principally of dark hornblende-chlorite schist . . . some of the Vallecitos rhyolite flows are included . . . .

> A small part . . . is composed of quartzite and quartz-mica schist of sedimentary origin. The Cleveland Gulch quartzite is a particularly prominent member that is exposed between Tusas and Kiawa mountains. Its position in the series suggests that it may correlate with the Badito quartzite of the Picuris area [approximately 40 miles east of south from Cleveland Gulch.]

Just placed his Ortega quartzite stratigraphically above the Hopewell. Both the Hopewell and the Ortega formations are intruded by the Proterozoic Tusas granite. The Proterozoic formations are now exposed where erosion has removed the Tertiary Carson conglomerate, which was deposited on the eroded Proterozoic land surface. West of the Rio Grande River, the Hopewell series is exposed in various outcrops from north of Hopewell to Ojo Caliente, a distance of 40 miles measured along the probable strike of the Hopewell series. The series is reported to have an average thickness of 5,000 feet or more. East of the Rio Grande River, the Hopewell series, the Ortega quartzite, and the Hondo slate are described by Just (1937, p. 23) as present in the area northeast of Dixon:

> The Hondo slate is characteristically black and has well-developed schistosity. In places a rather high iron content causes it to weather to a rusty color. In a few spots, zones are exposed that resemble streaks of "iron formation" in the Proterozoic rocks of the Lake Superior region. The most conspicuous of these noted was just east of the exposure on the Dixon-Penasco road. However, the ferruginous beds are scarcely well enough developed to warrant hopes of finding exploitable bodies of iron ore.

Further, Just (1937, p. 42 f.) recognized that the quartzite members could change appearance and composition as a result of changes in geophysical and geochemical environment.

Jahns (1946, p. 19) reported that the Ortega quartzite exhibited a phase that is "rich in coarse magnetite where exposed in cliffs along the Tusas River Canyon 4 miles south of Petaca." Further, with respect to the Petaca-schist phase of the Ortega quartzite, Jahns (p. 20) agreed with Just on the general idea that the Tusas granite "provided the materials and possibly the physical conditions that permitted the formation of schist."

Barker (1958, p. 10-11) redefines the Ortega as mapped by Just and places it, along with the Petaca schist, as the oldest rock in his stratigraphic section. Just's Hopewell series, less the Cleveland Gulch quartzite, becomes Barker's Moppin metavolcanic series and includes "several thousand" feet of greenschist and amphibolite (p. 10), and "a number of thin, discontinuous beds of conglomerate, phyllite, gneiss, and schist" (p. 21). Barker notes that iron oxide minerals occur in accessory amounts in many parts of the Precambrian stratigraphic section.

From the results of the present and previous studies, it appears that:

1. A magnetite taconite rock would result from a substantial intrusion of magnetite into the Moppin, Cleveland Gulch, Ortega, Petaca, Badito, and Hondo siliceous or quartzite phases.
2. The quartzitic rock belt in the Hopewell to Dixon area can be traced (or inferred under Tertiary rocks) over a linear strike distance of more than 40 miles, and has a thickness in excess of 5,000 feet.
3. Such an extent of potential quartzitic host rock represents a major environment for the development of magnetite-rich rock masses.
4. In the Hopewell-Kiawa area, the various porphyry intrusives associated with the Tusas granite probably constitute the source of the magnetite.
5. The pattern of outcroppings shown on the regional map suggests that the Tusas granite is present under the whole area at moderate depth.
6. Stated simply, an extensive geophysical and geochemical environment exists that is favorable for the impregnation of large quartzitic rock masses with iron minerals.

GUIDES TO THE UTILIZATION
OF POTENTIAL TACONITE RESERVES

The percentage of iron in a rock does not necessarily indicate its marketability. A rock containing 51.50 percent natural iron ordinarily is a good direct-shipping iron ore; if, however, it contains appreciable amounts of phosphorous or sulfur, it probably would not be marketable as direct-shipping ore. In the case of taconite rock, which is usually thought of as containing from 25 to 50 percent natural iron, the problem is to remove and concentrate the iron minerals into a marketable product.

After the iron-rich rock types have been mapped in the field, metallurgical testing of a large, carefully collected sample is necessary before it can be determined that a particular iron-rich rock can be worked profitably as direct-shipping ore or can be upgraded to a marketable concentrate. At present, magnetite taconite can be processed more readily and cheaply than hematite taconite to produce a high-grade iron concentrate.

If a geological map has been prepared showing the rock outcrops that contain magnetite, the metallurgical characteristics of the magnetite rock have been established, and a process for reducing the magnetite to metallic iron has been decided upon, the rock that will be considered to constitute taconite can be determined and its volume estimated.

The process of estimating ore volume can be compared with that of estimating economic-resource potential. It is important to note the context, purpose, and program of data collection. The context of an estimate of ore volume is a mine site; the context of an estimate of economic-resource potential is a district, range, or region. An ore body is associated with a purely local geologic structure, whereas economic-resource potential is associated with regional geologic and economic structures. The purpose of an estimate of ore volume is to undertake mining;the purpose of an estimate of resource potential, on the other hand, is to undertake exploration. The data-collection program for an estimate of ore volume is designed to measure the size, shape,and quality of a particular ore mass and is a highly objective process, whereas the data-collection program for an estimate of economic-resource potential is designed to measure the probabilities attending geophysical, geochemical, and geoeconomic conditions and is a highly subjective process.

For the efficient economic utilization of taconite deposits, the following conditions should be fulfilled:

1. The iron content should be 25 percent or higher.
2. The iron should be substantially in the form of magnetite.
3. The magnetite grain size and shape should be such that the magnetite grains are liberated from the rock without expending a large amount of physical or chemical energy in the process.
4. The process required to form a high-grade concentrate (60 percent or above) should be simple and inexpensive.
5. The concentrate should be amenable to direct reduction, because new blast-furnace capacity is expensive.
6. The taconite rock should be minable by open-pit methods, and it is generally desirable that the waste rock be not in excess of three times the amount of taconite mined.

In forming an estimate of the taconite rock potential of the Hopewell-Cleveland Gulch structure, the following should be noted:

1. The surface measurements are exploratory and should be used only to evaluate the risks involved in expending capital on additional exploration.
2. More geologic mapping, magnetic data, trenching, and drilling must be accomplished before tonnage figures for taconite can be more than inferred.
3. At least three magnetic highs were observed within a distance of approximately 300 feet measured at a right angle to the assumed strike.
4. On line 92 feet east, a 35-foot trench (channel) sample, collected to correspond to the magnetic high adjacent to the assumed footwall contact, yielded the metallurgical data presented above.
5. Within the area of the three magnetic highs, amphibolite and quartzite rock with low magnetite content is inferred to be present from consideration of the pattern of the float rocks and occasional outcrops.
6. On the Hopewell (Jaw Bone-Iron Mountain) end of the Hopewell-Cleveland Gulch structure, the trend of a magnetic high and the accompanying magnetite taconite float rock was traced with a dip needle for a distance estimated as one-half mile. Both ends of the trend were open. The trend is southeastward through the S1/2 sec.

19 and the N1/2 sec. 29, T. 29 N., R. 7 E. The taconite rock was scattered over an area approximately 100 feet wide and appeared to be of the same character as the taconite rock on the Cleveland Gulch end of the structure.

7. Coal, gas, limestone, an iron and steel scrap-collection center, and potential iron and steel producing and consuming centers are located within a 150-mile radius of the Hopewell-Cleveland Gulch structure.

In conclusion, a conservative estimate of the magnetite taconite resource potential of the Hopewell-Cleveland Gulch structure would be: Depth, 500 feet; width, 300 feet; length, 6,000 feet. This would give a volume of 900 million cubic feet of magnetite taconite rock.

No attempt should be made to convert the volume figure to tonnage until more is determined concerning variations in the metallurgy of the magnetite taconite rock of the structure as a whole. The common variations can change the tonnage estimate by as much as 100 percent. Conversion factors vary considerably, ranging from 8 to more than 16 cubic feet per ton.

ACKNOWLEDGMENTS

As with most projects, this study has received the help and suggestions of several persons. The writer is especially grateful to Mr. Clarence M. Harrer, of the United States Department of the Interior, Bureau of Mines, Region III, Denver, Colorado, for discussions and suggestions during an examination of this and other selected localities of iron occurrences in New Mexico in October 1959.

At the New Mexico Institute of Mining and Technology, Dr. Allan R. Sanford gave valuable help on the geophysical problems; Dr. Rousseau H. Flower prepared the rock photograph; Dr. Ming-Shan Sun helped with the preparation and examination of thinsections and grain slides; Dr. Roshan B. Bhappu made the chemical analyses and helped with the initial planning of the metallurgical test work; Dr. Frank Bowdish helped with the planning of the metallurgical test program and supervised the metallurgical test work carried out by Mr. Ronald Borys and Mr. Edward Bingler. Suggestions by Mr. Alvin J. Thompson, director of the Bureau of Mines and Mineral Resources Division of the Institute, helped materially in completing the project. Dr. Edmund H. Kase, Jr. aided in preparing the manuscript for publication.

No less appreciated is the unsung work of the writer's field companions.

GLOSSARY

(From Fay, 1920)

TACONITE. See Taconyte. Also called Jasper, and Iron formation.

TACONYTE. A name proposed by H. V. Winchell for the cherty or jaspery, but at times calcareous or more or less quartzitic rock, that incloses the soft hematites of the Mesabi Range, Minn. . . . The term is current in the Mesabi iron range. The name is derived from Taconic, E. Emmons' rejected geological system.

TACONIC. The principal iron-ore-bearing system of the Lake Superior region.

TACTITE. A rock of more or less complex mineralogy formed by the contact metamorphism of limestone, dolomite or other calcareous rocks into which foreign matter from the intruding magma has been introduced by hot solutions. It does not include the inclosing zone of tremolite, wollastonite and calcite. A group name similar to gneiss, schist or porphyry.

SCHIST. A crystalline rock that can be readily split or cleaved because of having a foliated or parallel structure, generally secondary and developed by shearing and recrystallization under pressure.

GNEISS. A layered crystalline rock with a more or less well-developed cleavage, but without the fissility of schist.

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