Bureau of Mines
Report of Investigations 4586

MAGNETIC SURVEYS IN THE IRON SPRINGS DISTRICT IRON COUNTY, UTAH

BY KENNETH L. COOK

United States Department of the Interior — January 1950

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UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

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ERRATA

Page 4. Fig. 3, A and B. Numbers giving scale of map, at top of illustration, should read "5,000 feet" instead of "500" and "10,000 feet" instead of "1,000."

Page 13. Lines 13 and 16. "Figure 38" should read "figure 37."

Page 23. Line 14. "Traverse 33.65S" should read traverse "41.00S."

Page 24. Figure 17. "H-12, H-7" should read "H-17" (these letters appear on the map at 0.00-48.45W); "H-7" should read "H-12" (these letters appear along the inclined hole at 0.00-48.45W); the words "ANOMALY GC" should be inserted on the anomaly lying 100 feet south of hole H-8.

Page 30. Line 33."N. 80° E." should read "N. 45° E." In footnote 36, "traverse 19.75" should read "traverse 19.75W."

Page 35. Line 11. "Figure 23" should be "figure 24." In footnote 48, "Peaks A and B are ..... in the holes" should read "Peak A is ... in a hole."

Page 37. Line 29. "Southward" should read "eastward."

Page 44. Line 34. ", on traverse 15.00N" should read "(on traverse 16.00N)."

Page 48. Line 37. "15.00E to 39.00E" should read "15.00W to 39.00W."

Page 49. Line 16. "Anomaly IF" should read "anomaly IE."

Page 51. Line 8, "Figure 34" should read "figure 33."

Page 62. Line 12. "Is usually the case" should read "Is the case in this area."

Page 64. Lines 3, 4, and 5, columns 5, 6, 7, and 8, should be changed to read:

300	400	600	Do.
300	500	600	Do.

Page 73. Line 20. "+1,500-gamma" should read "+2,000-gamma."

Page 75. Line 1. "Anomaly TM" should read "anomaly TN."

MAGNETIC SURVEYS IN THE IRON SPRINGS DISTRICT, IRON COUNTY, UTAH

by

Kenneth L. Cook[1]

CONTENTS

1/ Formerly geophysicist, Division of Geophysical Exploration, Mining Branch, Bureau of Mines. (Now with Geological Survey.)

CONTENTS (Cont'd.)

CONTENTS (Cont'd.)

CONTENTS (Cont'd.)

CONTENTS (Cont'd.)

TABLES

TABLES (Cont'd.)

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd.)

SUMMARY

From March 1944 to July 1945 the Division of Geophysical Exploration of the Federal Bureau of Mines made magnetometer surveys of some of the principal iron ore deposits of the Iron Springs district, Iron County, Utah. The district comprises a belt about 23 miles long and 3 miles wide. Most of the large ore bodies are found as pods of replacement ore within a favorable limestone bed lying at the margins of three separate igneous intrusions in the district. The magnetic surveys were confined chiefly to this geologically favorable zone at the margins. The iron ore is a mixture of magnetite and hematite. The magnetite content of the ore ranges from 14 to 58 percent. Magnetic anomalies of 1,250 gammas or more were usually found over the near-surface ore bodies. About 62,000 magnetometer stations were taken over a total traverse distance of about 300 miles.

Outcropping ore bodies were surveyed to determine, insofar as was possible from the magnetic data, their probable length, width, depth, extent, strike, dip, and tonnage. Geologically favorable areas where no ore is exposed were explored in an endeavor to find new ore bodies. Favorable locations were determined for exploratory diamond drilling, both in areas of exposed ore bodies and in areas of newly discovered magnetic anomalies.

Forty-five separate magnetic anomalies that indicate the possible existence of ore bodies were observed. Of these, 13 anomalies are caused by outcropping ore bodies of proved commercial size. Five are caused by nonoutcropping ore bodies of proved commercial size which were discovered, in whole or in part, as a result of the geophysical surveys. Of the remaining anomalies, which lie in virtually untested areas where few or no ore bodies are exposed, six probably are caused by large, unexposed replacement ore bodies, nine are possibly caused by large, unexposed replacement ore bodies, and six are probably caused by unexposed magnetite veins of some small commercial importance.

Ten different ore bodies were tested by 36 drill holes put down by the Federal Bureau of Mines. These holes gave helpful correlation of the geology and geophysics and served to check the qualitative interpretation and quantitative prior estimates of depths and sizes of the ore bodies.

In the district the strikes of both outcropping and nonoutcropping ore bodies were well-indicated by the trends of the anomalies. The directions of dip and rough estimates of the angles of dip can be obtained from the shapes of the magnetic response curves for outcropping ore bodies but are less reliable for nonoutcropping ore bodies. For near-surface, nonoutcropping ore bodies with steep dips, reliable estimates of the possible depths of cover and widths of the bodies for different assumed magnetite contents can be made in special cases. Estimates of only the relative thicknesses of the ore within individual near-surface ore bodies were generally possible in the district. The depth extents of the near-surface, probable ore bodies that have not been drilled can generally be predicted only qualitatively. If one drill hole has tested the down-dip extent of an ore body, however, rather accurate predictions of down-dip extent can be made for other parts of the ore body along the strike. The lengths of the near-surface ore bodies and the location of their apexes can usually be predicted accurately.

It should be emphasized that some anomalies may not be due to ore of commercial grade, but may be due to magnetite along breccia zones. It is possible that there may exist at depth ore bodies which do not produce recognizable anomalies either because they are essentially nonmagnetic or lie too deep.

The magnetic anomalies thus gave an idea of the possible sizes of the magnetic bodies and, depending on the amount of geologic control, the likelihood of finding ore. Drill holes which were located on the basis of the magnetic surveys were kept away from obviously barren zones and confined to those areas which gave some prospect of finding ore. When the drilling of one test hole proved that the ore body was of commercial grade and size, only a few additional, carefully planned, key test holes were generally needed to give a large amount of information about the ore body.

INTRODUCTION

From March 1944 to July 1945 the Division of Geophysical Exploration of the Federal Bureau of Mines, in cooperation with the Utah-Wyoming District Office of the Bureau of Mines and the Western Regional Office of the Federal Geological Survey, made magnetometer surveys of some of the principal iron ore deposits of the Iron Springs district, Iron County, Utah. The joint project was a strategic mineral investigation.

The project had been started by the Federal Bureau of Mines 2 years before the magnetic surveys were begun. During 1942-43 the Utah-Wyoming district of the Bureau of Mines carried on a drilling program which was confined largely to development drilling on two claims leased by the Defense Plant Corporation, a Reconstruction Finance Corporation subsidiary, to obtain iron ore for the government-owned Geneva steel plant at Provo, Utah. Thirty-three holes were drilled. In the spring of 1943, the Federal Geological Survey began a geological survey in the district and had field crews in continuous operation there until September 1945.

When the geophysical surveys were started, the wartime ship-building program had not yet reached its peak, and steel production in western steel plants was steadily increasing. The Geneva plant had not been entirely completed, and was not yet running at capacity. The Iron Springs district was already supplying ore at a rate of 1,542,284 tons a year to all of the principal steel plants of the West, except Kaiser's Fontana plant; and it was destined to supply the Fontana plant eventually. Although the drain on the district reserves was large, no exploratory drilling was done by the private companies during the first half of 1944; and, except for the few ore bodies in the immediate vicinity of those being exploited, little was known of the potential reserves of the entire district, one that contains some of the richest and most easily accessible ore bodies in the West.

The primary purposes of the magnetic surveys were (1) to explore outcropping ore bodies to determine, insofar as was possible, their probable length, width, depth extent, strike, dip, and tonnage; (2) to explore geologically favorable areas where no ore bodies outcrop in an endeavor to find new ore bodies; (3) to determine favorable locations for diamond drilling, both in areas of exposed ore bodies and in areas of newly discovered magnetic anomalies; and (4) to assist in obtaining eventually a

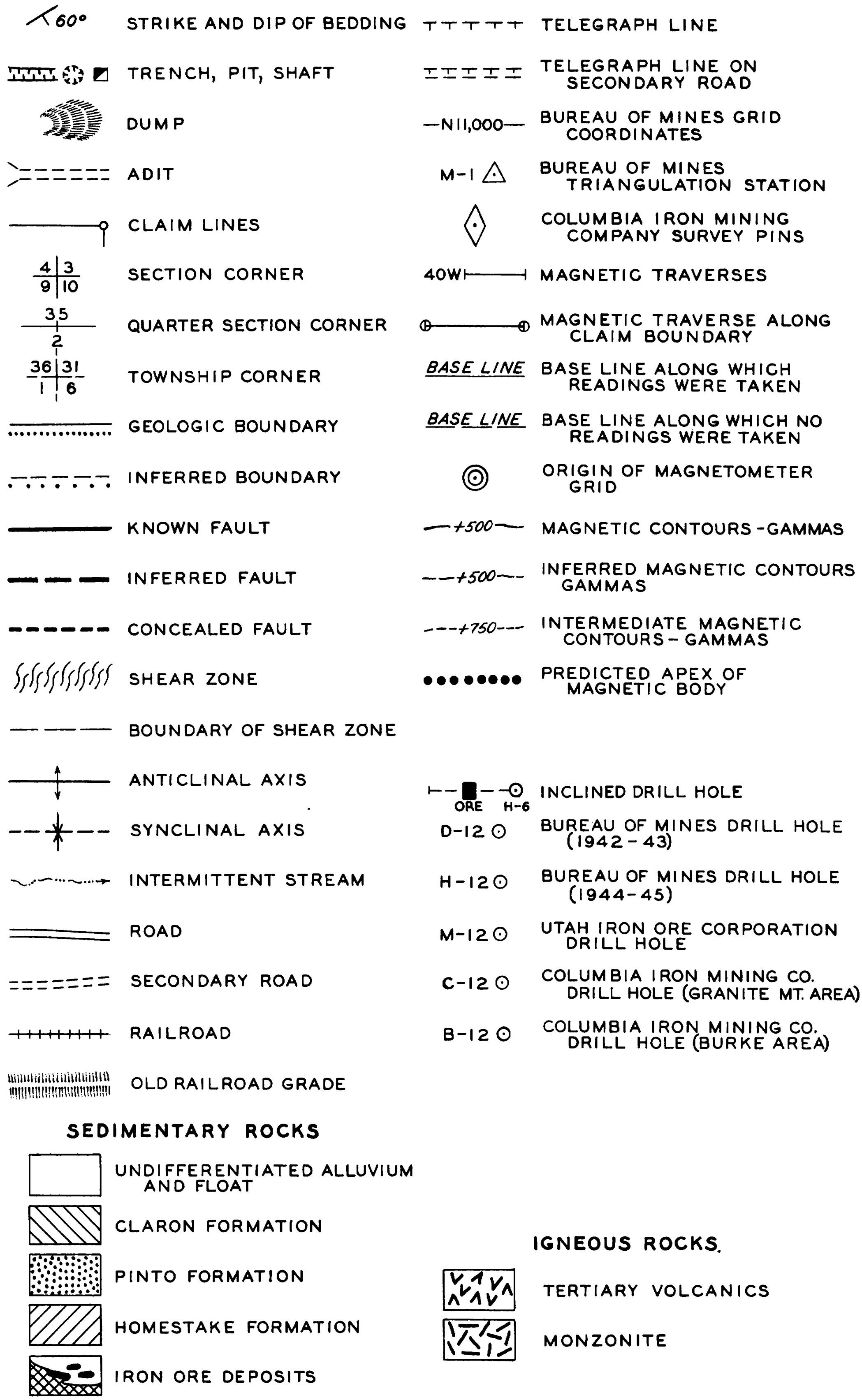

Figure 1. - Symbols used on magnetic and geologic maps.

tonnage estimate of the near-surface[2] iron-ore reserves of the entire Iron Springs district.

Conventions

Throughout this paper the following conventions are employed:

(1) The symbols used on all the magnetic and geologic maps are shown in figure 1.

(2) The convention of naming the magnetometer traverses is as follows: Traverse 8.83S means that the traverse crosses the magnetic base line at a point lying 883 feet south of the zero-zero reference point of the magnetometer grid. Ordinarily the zero-zero point is chosen to coincide with a triangulation station. To define a point on the traverse an additional coordinate, which refers to the distance east or west of the base line, is required. Thus 8.83S-2.00E are the magnetometer grid coordinates of a point lying on traverse 8.83S 200 feet east of the base line.

(3) The Bureau of Mines coordinates, to help distinguish them from the magnetometer grid coordinates, are always given in this paper with their direction letters first. Since they are given in units of feet their numbers (for example, N7,000-E16,700), usually are larger than the magnetometer grid coordinates, which are given in units of hundreds of feet (for example, 70.00N-167.00E).

(4) In naming the magnetic anomalies on the magnetic maps, those without proper names are given two-letter designations (for example, anomaly GA, anomaly IA, anomaly TA, etc.). The first letter indicates whether the anomaly exists in the Granite Mountain area (G), Iron Mountain area (I), or Three Peaks area (T). The second letter indicates its sequence in that area.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the assistance and cooperation of the personnel of the Division of Geophysical Exploration and the Utah-Wyoming district of the Federal Bureau of Mines and of the Salt Lake City office of the Federal Geological Survey.

The writer wishes to express his special debt of gratitude to W. E. Young, project engineer of the Bureau of Mines, and J. H. Mackin, geologist of the Geological Survey, for their helpful cooperation throughout the project.

Able assistance was rendered by the following magnetometer crew chief and leaders: S. H. Hoffman, M. Sirotkin, S. Liff, R. A. Rowley, A. R. Topham, and C. S. Barton.

For suggestions concerning various geophysical problems the writer wishes to thank Prof. L. B. Slichter, Dr. C. A. Heiland, and S. G. Sargis.

2/ In the present paper it will be convenient to define a "near-surface" ore body or an ore body lying "at shallow depth" in the Iron Springs district as one lying within 400 feet of the surface.

For granting rights of trespass on their claims and making available drill logs, maps, and other valuable information, appreciation is expressed to the following private companies and individuals: Charlotte Mining Co., Columbia Iron Mining Co., the Cullen-Campbell interests, J. F. Holland, H. Kearns, the Keeley estate, A. C. Milner, Milner Corp., A. E. Moreton, W. C. Murie, Mrs. R. R. Page, E. Parry, S. F. Walker, and C. S. Wilson.

The writer wishes to express his appreciation of the courtesies and assistance rendered him by the many people of Cedar City and neighboring towns who, through their efforts and interest, contributed either directly or indirectly to the results and effectiveness of the field work.

GEOGRAPHY AND TOPOGRAPHY

The principal iron ore deposits of Iron County, Utah, lie 15 to 25 miles west of Cedar City, in the Iron Springs district (see fig. 2). The district comprises a belt about 23 miles long and 3 miles wide. The elevation ranges from 5,300 to 8,000 feet. Moderate relief prevails in most of the areas that are geologically favorable for exploration. Most of the large ore bodies lie along the borders of three prominent northeastward-trending ridges, called Iron Mountain, Granite Mountain, and The Three Peaks.

Most of the areas where geophysical work was done are covered with a growth of juniper and pinon, which necessitated brushing the magnetic traverse lines. A few of the areas are covered with sagebrush, rabbit brush, and greasewood.

GENERAL GEOLOGY

The geology of the ore deposits of the Iron Springs district has been described by Leith and Harder,3/ Butler,4/ and Wells.5/ The iron-ore district contains three northeastward-trending intrusions of monzonite, which from southwest to northeast form, respectively, Iron Mountain, Granite Mountain, and The Three Peaks (see fig. 3, A, B). Each intrusion is surrounded by sedimentary rocks of Jurassic and Cretaceous age, which ordinarily dip away from the intrusion at angles that may be either steep or gentle. Originally called laccoliths by Leith and Harder, as well as by Butler, the intrusive masses are called stocks by Wells. As the bottoms of the intrusions are not known, the writer will refer to them simply as intrusions of monzonite. It is realized, however, that the intrusions may some day be proved to be true laccoliths.

A generalized geologic column of the district is given in figure 4. Mackin considers that the Homestake and the upper part of the Carmel formations are correlatives, and that the Entrada formation and at least the lower part of the Pinto formation are correlatives. In a recent publication Mackin6/ has tentatively subdivided the Pinto

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3/ Leith, C. K., and Harder, E. C., The Iron Ores of the Iron Springs District, Southern Utah: Geol. Survey Bull. 338, 1908, 102 pp.

4/ Butler, B. S., Ore Deposits of Utah: U. S. Geol. Survey Prof. Paper 111, 1920, pp. 568-580.

5/ Wells, Francis G., The Origin of the Iron-Ore Deposits in the Bull Valley and Iron Springs District, Utah: Econ. Geol., vol. 33, 1938, pp. 477-507.

6/ Mackin, J. H., Some Structural Features of the Intrusions in the Iron Springs District: Utah Geol. Soc., 1947.

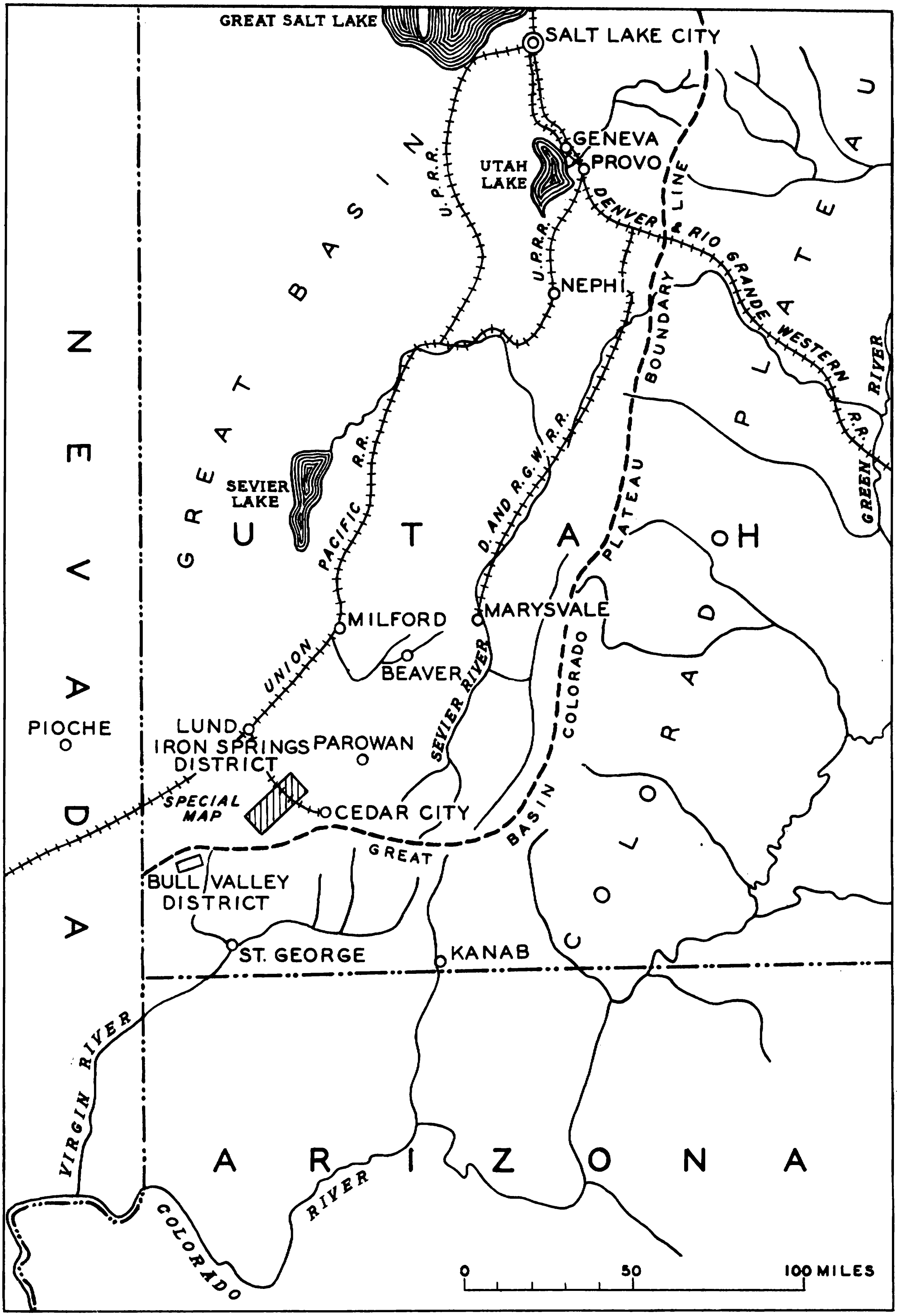


Figure 2. - Sketch map of parts of Utah, Arizona, and Nevada, showing the Iron Springs district. (After Leith and Harder.)

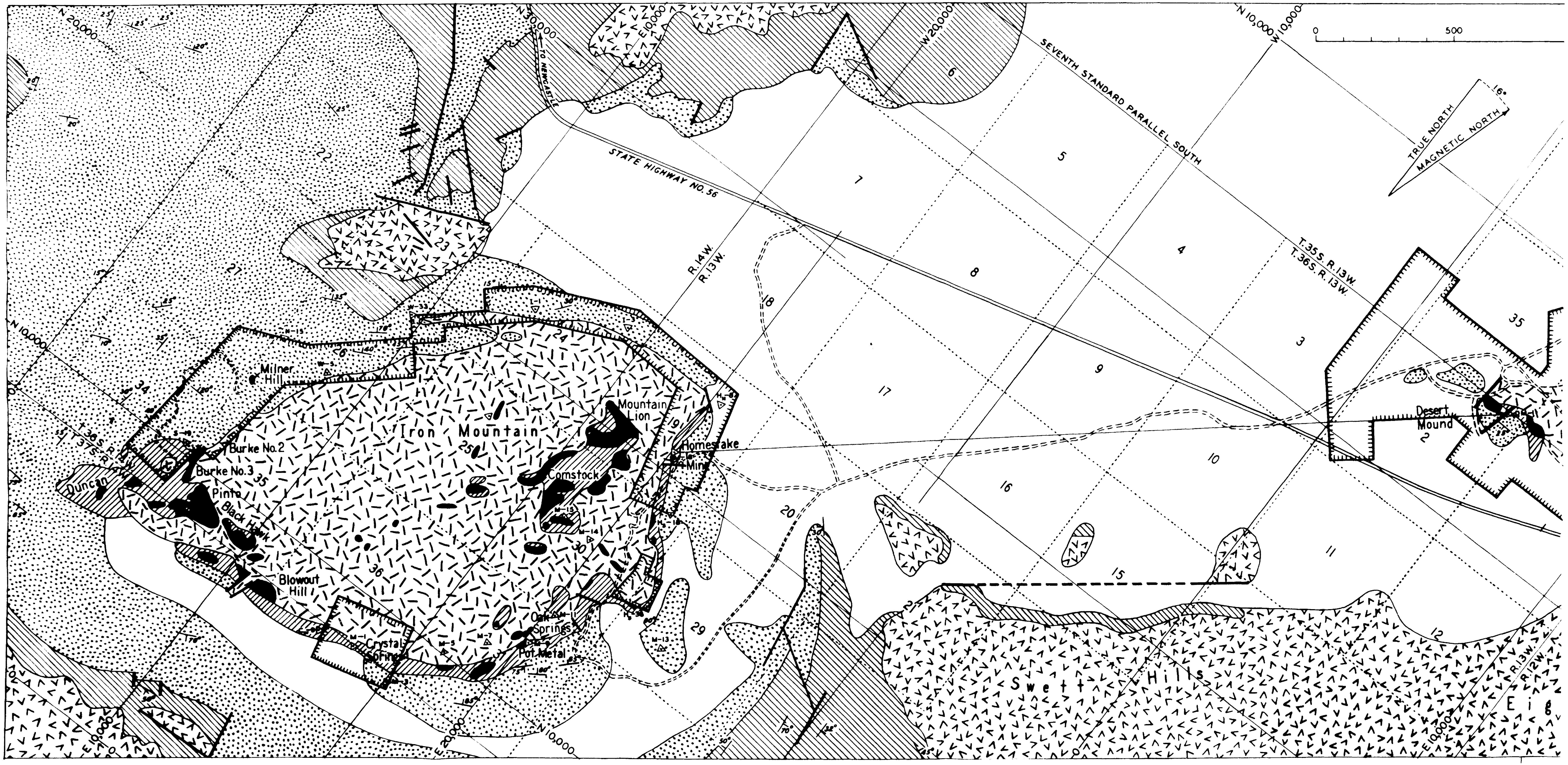


Figure 3, A. - Geologic map of the Iron Springs district, Iron County, Utah, showing areas covered by the magnetic surveys.

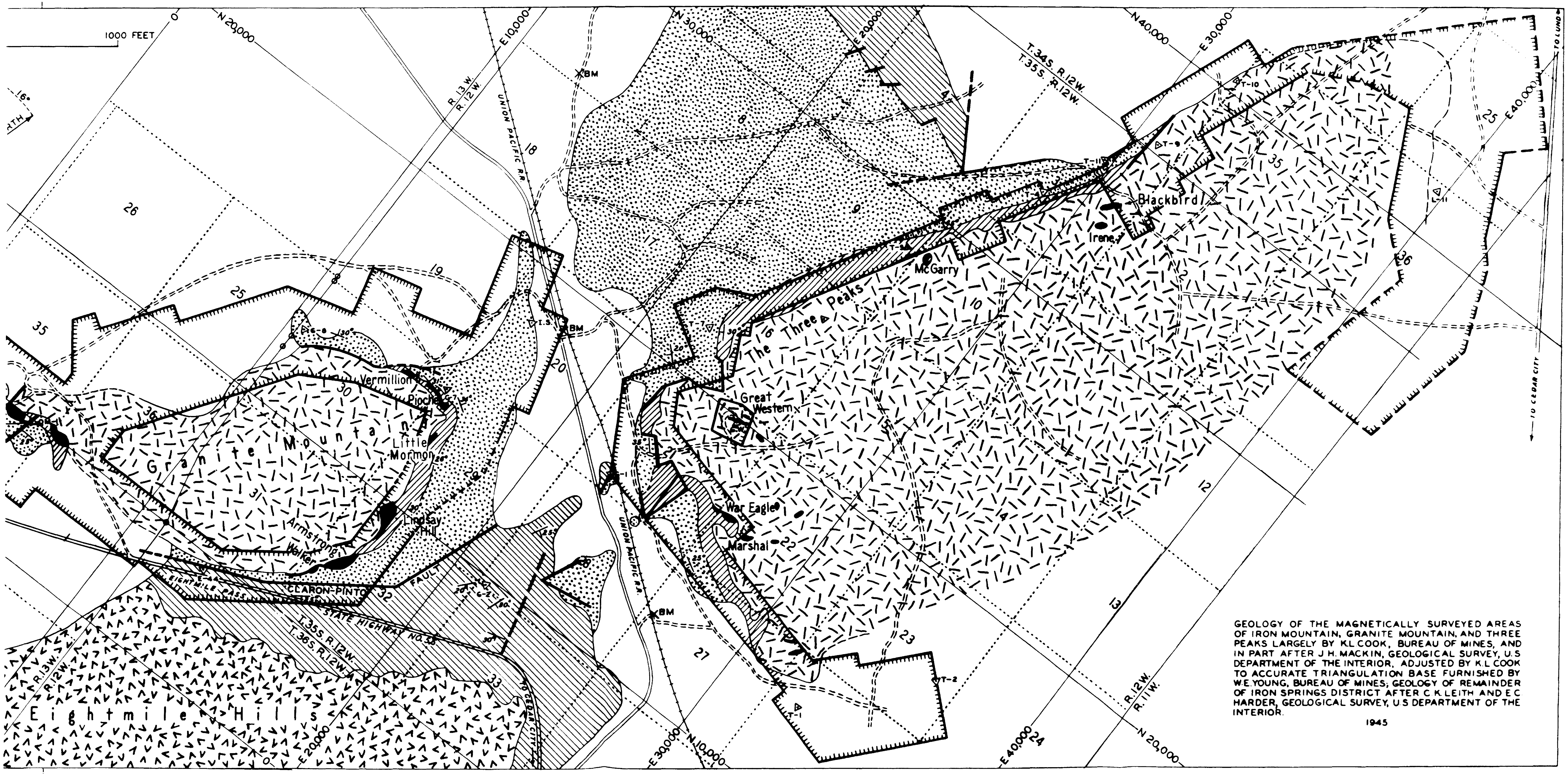
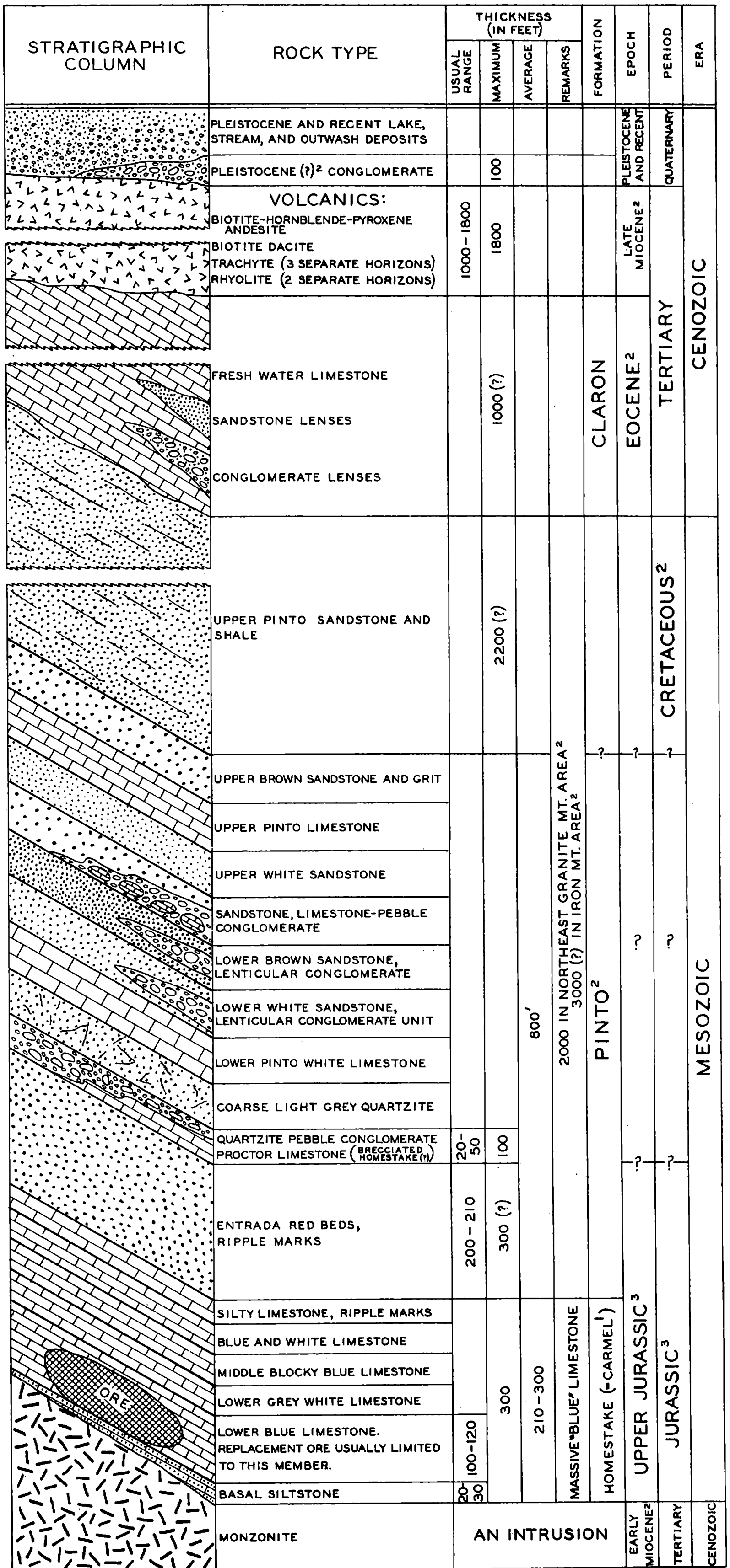


Figure 3, B. - Geologic map of the Iron Springs district, Iron County, Utah, showing areas covered by the magnetic surveys.



¹THE NOMENCLATURE OF THE MEMBERS OF THE HOMESTAKE AND PINTO FORMATIONS IS BY J. H. MACKIN.
²CORRELATION AND DATA BY LEITH AND HARDER.
³CORRELATION BY GILLULY, REESIDE, AND MOORE.

Figure 4. - Generalized geologic column of the Iron Springs district.

formation into the "Entrada" and Iron Springs formations. In this paper, however, the term "Pinto" is retained as used by Leith and Harder. Reeside, Gilluly, and Moore 7/ classify the Carmel and Entrada formations as Upper Jurassic in age. Leith and Harder classified the Pinto as Cretaceous in age, though they suggested that it is "Jurassic in part, perhaps". 8/ In the accompanying geologic column the Homestake formation and the lower part of the Pinto formation are therefore considered as Upper Jurassic, and the upper part of the Pinto formation is classified as Cretaceous.

The iron ore is found in fissure-vein deposits and replacement deposits. Although the fissure veins, which consist predominantly of magnetite, are abundant throughout the monzonite, most of them are too small to be of great economic importance. The replacement deposits, however, which consist of a mixture of hematite and magnetite, range from small replacement veins to bodies of many millions of tons. The large bodies, which are usually tabular or pod-shaped, have been formed by replacement of the Homestake limestone. In general only the "Lower Blue" limestone member of the Homestake formation has been replaced by ore, but in some instances essentially all of this formation has been replaced. 9/ As the Homestake limestone lies mainly at the borders of the intrusions, most of the replacement ore bodies also lie at the borders. Roof pendants of Homestake limestone are to be found, however, and some of them have been replaced by large bodies of ore.

The dip of the large ore bodies is usually the same as that of the limestone which they replace. For both the vein and replacement ore bodies the contact between the ore and wall rock tends to be sharp rather than gradational. Except for the deposit at Milner Hill, the known ore bodies lie at the surface or at depths of less than 500 feet. There is no reason to believe, however, that ore bodies will not be found lying at depths in excess of 500 feet.

FACTUAL MAGNETIC DATA

Magnetite Content of Ore Bodies

The iron ore is a mixture of magnetite and hematite, the ratio of these two constituent minerals varying over the district by rather large amounts. Table 1 gives a summary of the magnetite content of some of the known replacement ore bodies of the district. It is seen that, although the average magnetite content of the ore bodies ranges from 14.0 to 57.9 percent, most of the ore bodies on which assays were made have a magnetite content of less than 35 percent. The data are still too incomplete to permit making any general statement concerning the probable magnetite content of the remaining replacement ore bodies of the district, other than to say that most of them will probably average more than 10 percent in magnetite content and less than 50 percent. On the basis of present knowledge of the geology of the Iron Springs district, it seems unlikely that a purely hematite ore body of commercial size exists in the district. Nevertheless, the possibility of the occurrence of such an ore body must still be recognized.

7/ Moore, Raymond C., Historical Geology: New York, McGraw-Hill Company, Inc., 1933, p. 420.

8/ Leith, C. K., and Harder, E. C., work cited in footnote 3, p. 37.

9/ Mackin, J. H., Report on Iron-Ore Deposits in the Lindsay-Armstrong Area, Iron Springs Mining District, Iron County, Utah: Geol. Survey unpub. rept., March 1944, p. 4.

TABLE 1. - Magnetite content of ore bodies of Iron Springs district

Ore body	Drill holes on whose magnetic content average value is based	Average magnetite content (percent by weight)
Constitution 1/	H-9, H-12, H-17	57.9
Burke 2/		50.0
Milner Hill 1/	D-33	45.2
April Fool 1/	H-19, H-21, H-23	43.2
Black Hawk 2/		33.0
Armstrong 1/	H-13, H-18	30.7
Pioche 1/	H-6, H-7	28.2
Short Line 1/	H-29, H-30, H-32, H-34, H-36	25.9
Thompson 1/	H-22, H-28, H-33	25.4
Lindsay South 1/	H-4	24.8
Lindsay Hill 1/	H-1, H-2, H-10, H-11, H-14, H-15, H-16	14.2
Desert Mound 2/		14.0

1/ Computed from composite averages of magnetite content of ore in each hole taken from unpublished assay reports by H. E. Peterson, chief chemist, Bureau of Mines Assay Laboratories, Salt Lake City, Utah. In determining the magnetite ($FeO.Fe_2O_3$) content of the iron ore, Peterson determined the amount of ferrous iron contained in the ore and calculated the magnetite that would account for the ferrous iron.

2/ Wells, Francis G., work cited in footnote 5, p. 496. Wells states that his estimates of the magnetite content of the ores were determined by magnetic concentration.

The magnetite content varies by large amounts over different parts of the same ore body. On the Milner ore body at Desert Mound it ranges from about 2 percent to 23 percent, with an average content of 14 percent10/. The ore encountered in drill hole H-1, in the central part of the Lindsay Hill ore body, showed an average magnetite content of 19.5 percent, whereas the ore encountered in drill hole H-14 in the northern part of the same ore body showed 9.9 percent. The ore encountered in drill hole H-21, in the southern part of the April Fool ore body, showed 63.7 percent, whereas that encountered in drill hole H-23, in the northern part of the same ore body, showed 32.3 percent. In each of these two cases the variation is about 100 percent, although the grade of the iron ore is essentially the same. Thus the ratio of hematite to magnetite varies, so that where the ore is low in magnetite a corresponding enrichment of hematite exists.

To give some notion of how much the magnetite content may change over small distances in the same ore body, the core samples from a single hole, H-19, in the central part of the April Fool ore body, were divided into four parts as indicated in table 2. Susceptibility tests,11/ which had been made before the cores were sent to the assay

10/ Wells, Francis G., work cited in footnote 5, p. 496.

11/ The order of magnitude of the magnetic susceptibility of rocks and cores in the district was obtained by holding hand-sized specimens, all of essentially the same dimensions, at the same distance from the magnetometer and noting the change in reading.

office, had indicated that pronounced differences in magnetite content could be expected in the four units of core that were chosen. As the grade of iron ore is essentially the same within each of the four units, the zone of low magnetite content is enriched with hematite in comparison with the high magnetite zone.

TABLE 2. - Magnetite content of ore in drill hole H-19, April Fool ore body

Depth of core, feet	Length of core, feet	Fe, percent	Magnetite content, percent by weight
267-312	45	52.5	24.5
312-358	46	54.2	17.0
358-403	45	58.3	45.6
408-448	40	51.7	69.3

Magnetite Content of Monzonite

According to analyses by H. E. Peterson, two separate specimens of monzonite showed an estimated magnetite content of 2.5 percent and 2.6 percent, respectively. Although these two determinations are insufficient to permit a generalization, the true magnetite content of the monzonite in the district probably averages less than 2-1/2 percent. Within the intrusive masses of monzonite are to be found pockets that have been locally enriched in magnetite during the magmatic differentiation, and here the magnetite content may greatly exceed 2-1/2 percent.

Magnetite Content of Sedimentary Rocks

The quantity of syngenetic magnetic minerals contained within the sedimentary rocks of the Iron Springs district is so small that their magnetic response may be considered negligible.

It is thus seen that the magnetite content of the ore bodies in the Iron Springs district greatly exceeds the magnetite content of the surrounding country rock. This great contrast in magnetite content makes the ore bodies amenable to the magnetic method of geophysical exploration.

AREAS COVERED BY MAGNETIC SURVEYS

Areas Covered in Previous Magnetic Surveys by Private Parties

In 1930-32 a limited amount of magnetometer work was done in the Iron Springs district by private geophysical parties. As the work was done for private companies, the reports and magnetic maps were not published. Table 3 summarizes the areas surveyed at that time.

TABLE 3. - Areas covered by previous magnetic surveys in Iron Springs district by private parties

Area	Type of work done	Remarks
Burke No. 2 and No. 3 1/	Moderate detail	
Pinto	Detail	
Black Hawk	do.	
"A" and "B" ore body, west of Blowout	do.	
Milner Hill 1/	Moderate detail	
Blowout		
E. of Blowout 1/	Probably reconnaissance	
Duncan	At least moderate detail	
Desert Mound 1/	Moderate detail	7,000,000 tons of estimated ore originally contained within the confines of the King and Contact claims. 2/
Short Line ore body 1/	Detail	2,000,000 tons of ore estimated originally. 3/
S1/2 sec. 3, R. 13 W., T. 36 S. 1/	Reconnaissance	
Mammouth claim line 1/ a line 9,200 feet in length.	do.	

1/ Except in the areas of claims on which right of trespass was not granted, this general area was also surveyed in present work by the Division of Geophysical Exploration, Bureau of Mines.

2/ Estimate based on results of churn drilling (Wells, F. G., work cited in footnote 5, p. 492).

3/ Estimate based on geophysical measurements by private parties only and some drilling by private parties (Wells, F. G., work cited in footnote 5, p. 494).

Areas Covered in Magnetic Surveys by Division of Geophysical Exploration

Figure 3 shows the areas covered in the magnetic surveys by the Division of Geophysical Exploration. Figures 5, 6, and 7, show in greater detail the plan of the grids in the district.

On the margin of each of the three main mountains is a system of interlocking magnetometer grids. Each grid comprises a base line and magnetic traverses, which are perpendicular to the base line. Depending on the curvature of the monzonite-sedimentary rock contact, the length of the base line varies from a few thousand feet to three and a half miles.

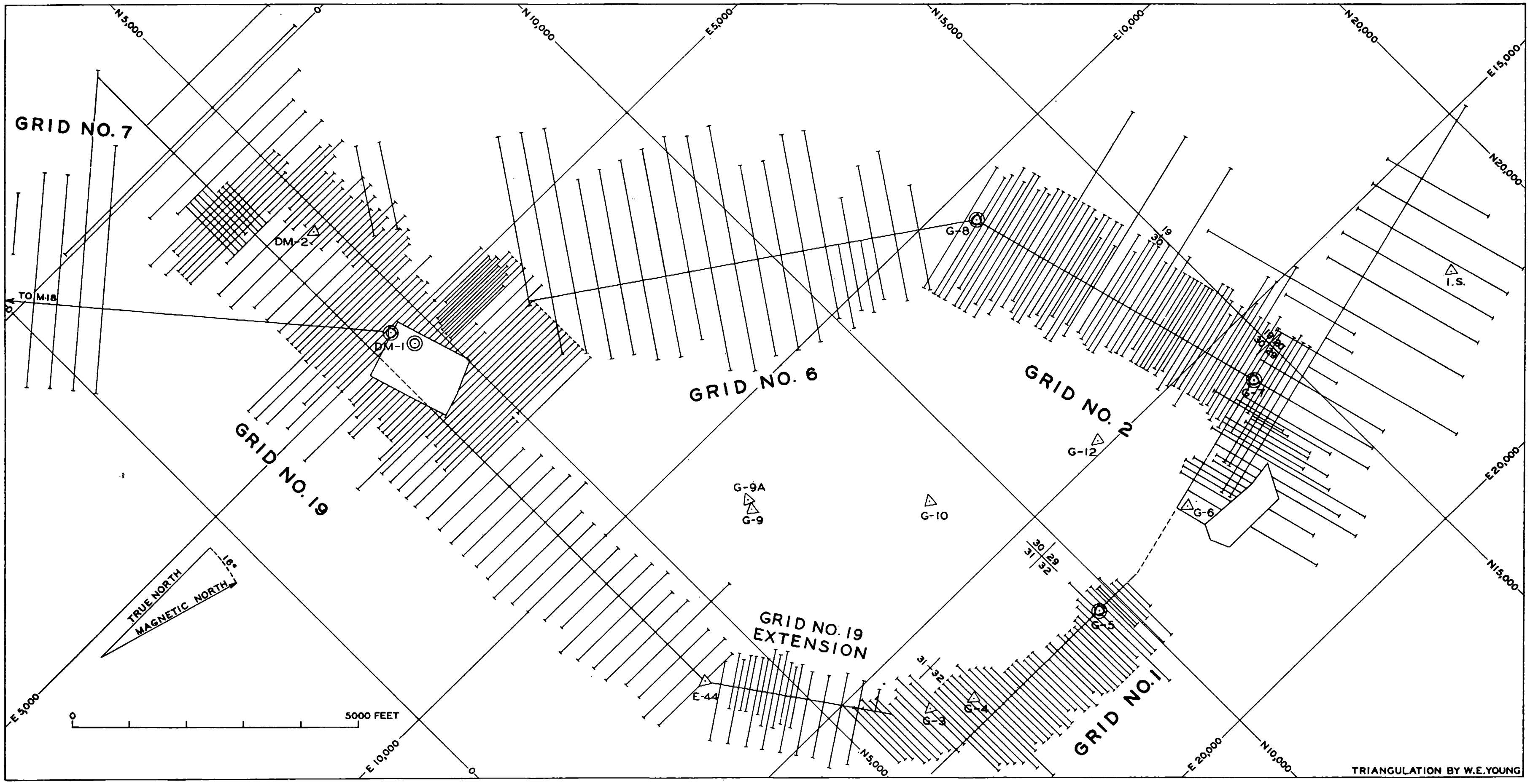


Figure 5. - Index map of the Granite Mountain area, showing location of magnetometer grids.

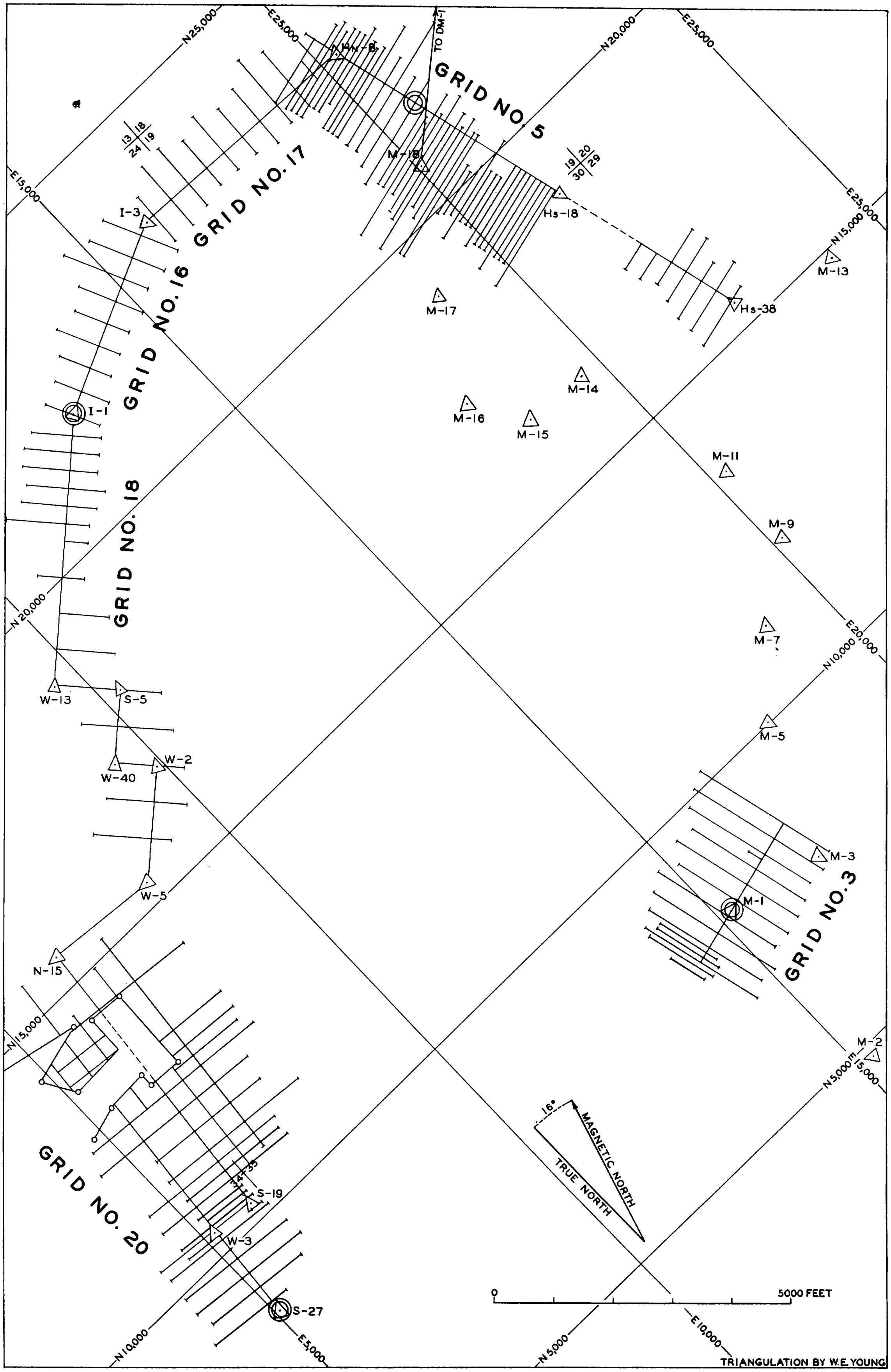


Figure 6. - Index map of the Iron Mountain area, showing location of magnetometer grids.

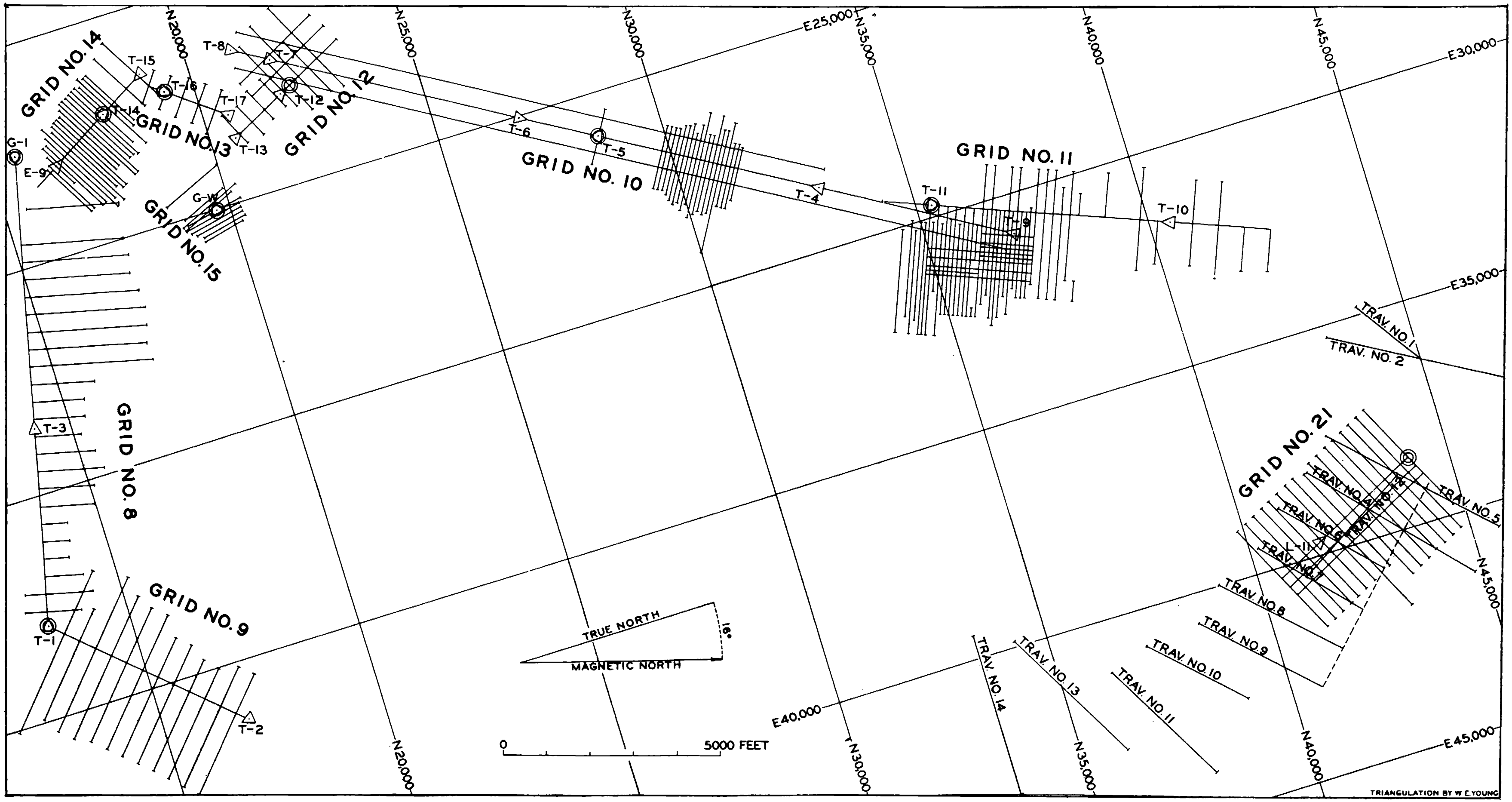


Figure 7. - Index map of the Three Peaks area, showing location of magnetometer grids.

The margin of Granite Mountain is completely covered by grids 1, 2, 6, and 19. Grid 7 lies in the desert alluvium between Granite Mountain and Iron Mountain. Over half of the border of Iron Mountain is covered by grids 20, 18, 16, 17, 5, and 3.[12] Over half of the margin of the Three Peaks area is covered by grids 9, 8, 14, 13, 12, 10, 11, and 21. Grid 15 covers the area of the Great Western vein deposit.

In general, each of the 21 grids may be considered a separate unit with its own geological and magnetic peculiarities and problems, and each was surveyed by using field techniques which were best-suited to these individualities. In some areas a large amount of detail work was done; in others only reconnaissance work was done, owing either to the absence of an important anomaly or to termination of the survey before the desired detail work could be done.

Table 4 shows the amount and type of work done on each grid, including the distance between successive traverses, the common station intervals along the traverses, the total number of magnetometer stations taken within the confines of the grid, and the total traverse distance surveyed within the grid.

Summary of Statistics

During 383 crew-days of magnetometer operation in the Iron Springs district, 62,205 magnetometer stations were occupied over a total traverse distance of 1,587,215 feet, or 300 miles. In addition, 1,746 base stations were taken.

PLAN OF OPERATION OF MAGNETIC SURVEYS

Organization of Field Work

Nearly forty years ago, Leith and Harder[13] suggested that in exploring for iron ore in the Iron Springs district the monzonite-Homestake limestone contact at the margins of the intrusions should be followed. This general principle was adopted in the geophysical exploration program. Though some surveys were made over the ore bodies of the fissure vein type, the main efforts of the geophysical work were spent in a search for ore bodies of the replacement type.

The choice of areas surveyed within the district and the priority given to different areas depended on several factors: whether rights of trespass had been granted by the claim owners; the accessibility of the areas; the size of the exposed ore bodies; the amount of geologic control of the areas; how far the geophysical work was ahead of the drilling program. Measurements were omitted where rights of trespass were not available. Claims which were not surveyed for this reason are left blank on the magnetic and geologic maps accompanying this report.

In each area the best disposition of the traverses was determined by a study of the geologic data and a preliminary reconnaissance on the ground to determine additional geologic, topographic, vegetative, and other factors affecting the lay-out of the grid. As the margins of the intrusions are gently curved, successive grids were overlapped as needed to give more complete coverage. The base line was generally laid out

12/ The remainder of the margin of Iron Mountain lies within claims on which rights of trespass for geophysical exploration were not given to the Bureau of Mines.

13/ Leith, C. K., and Harder, E. C., work cited in footnote 3, p. 88.

in a direction approximately parallel to the strike of either the ore bodies or of the monzonite-sedimentary rock contact. Measurement traverses were laid out at right angles to the base line.

The distance between individual traverses varied in accordance with the principal objective of the survey in each area under study. In areas of exposed ore, where additional detail work was very likely, the reconnaissance traverses were usually spaced 300 feet apart; in areas where nonexposed ore at shallow depth was possible, 300 or 400 feet apart; in areas where ore at only great depth was probable, 600 or even 1,000 feet apart. These rules, which were generally followed except in a few instances, proved useful and reliable in exploring for the large replacement ore bodies in the Iron Springs district.

After the grid had been laid out, magnetometer readings were taken along both base line and traverses. In those areas where the reconnaissance magnetic survey revealed significant anomalies, additional traverses were laid out. In general, the successive traverses in a detail survey were not spaced closer than 100 feet.

Distances between traverses were measured as horizontal distances by transit and steel tape. Distances along traverses between magnetometer stations were, in general, measured by a 100-foot cloth tape. In gentle terrain such station intervals were measured as slope distances. In steep terrain horizontal distances were approximated by a rough empirical correction.

Geologic notes were taken by the magnetometer crews along traverses and base lines giving the location of all exposures that could be seen from a given magnetometer station. Locations of claim posts were also recorded. Except for grids 1 and 2, the geologic maps in this report were compiled largely from the geologic data taken by the magnetometer crews.

Triangulation Control and Bureau of Mines Coordinates

Much of the triangulation work, which was under the supervision of W. E. Young of the Bureau of Mines, was done by the brushing crew when the magnetometer grids were being laid out. Usually the base lines of the grids lie between triangulation stations placed on prominent hills.

Good triangulation control was established throughout the Granite Mountain area, in the southern and southwestern parts of the Three Peaks area, and in the southern and eastern parts of the Iron Mountain area. In the remainder of the district the surveying control was by transit traverse only.

Two sets of coordinates were used by the Bureau of Mines in the triangulation work: (1) A southwestern system covering the Iron Mountain area only; and (2) a northeastern system covering the Granite Mountain and Three Peaks areas (see fig. 3, A and B). These two coordinate systems are tied together accurately by the line from triangulation station M-18 at the Homestake mine to triangulation station DM-1 on Desert Mound.

TABLE 4. - Summary of magnetic surveys made in the Iron Springs district by the Division of Geophysical Exploration

Area	Grid No.	Description	Type of work done	Distance between traverses (feet)	Station intervals (feet)	No. of magnetometer stations	Total traverse distance (feet)
Granite Mountain	1	Lindsay Hill deposit Lindsay South deposit Armstrong deposit Walker deposit	Detail	100	10,25,50	7,154	121,700
	2	Little Mormon deposit Pioche deposit Iron Springs Arch Vermillion deposit Constitution claim area	Do.	100	20,25,50	8,764	240,405
	6	Between G-8 and DM-1, Desert Mound	Reconnaissance	400	25,50,100	1,440	65,000
	19 and	Milner deposit, Desert Mound Short Line deposit Thompson deposit	Detail	100	20,25,50 100	11,321	296,530
	19 ext'n	Southeast Granite Mountain area	Reconnaissance	300	25,50		
	7	Between DM-1, Desert Mound, and M-18, Iron Mountain	Reconnaissance mostly-one 5-1/2-mile-long line & some traverses	400	50,100	787	45,950
Iron Mountain	20	Milner Hill area Burke deposits	Moderate detail	100,200 300,400	25,50	3,628	90,300
	18	Northwest Iron Mountain area	Reconnaissance	300,600	25,50	660	25,000
	16	North Iron Mt. area	Do.	300	25,50	513	14,075
	17	North Iron Mt. area	Do.	300	25,50	593	15,900
	5	Homestake Mine area	Detail in northern part of grid. Reconnaissance in southern part of grid.	100 300	20,25,50	5,966	79,525
	3	Blowout-Crystal Springs area	Moderate detail	100,300	20,25,50	3,080	56,300
Three Peaks	12	Southwest Three Peaks area	Detail	100,300	25	914	24,000
	13	Do.	Reconnaissance	300	25	152	6,600
	14	Do.	Detail	100	25,50	2,329	59,700
	8	South Three Peaks area	Reconnaissance	400	25,50	1,418	38,200
	9	Southeast Three Peaks area Marshal deposit	Do.	400	25,50,100, 200	318	42,480
	10	Northwest Three Peaks area	Reconnaissance mostly-3 long parallel lines 400 feet apart.		25,50	2,949	90,095
		April Fool claim area	Detail in April Fool claim area only	100	20,25,50		
	11	Northwest Three Peaks area	Detail in southern part of grid. Reconnaissance in northern part of grid.	100 300,600	20,25,50 25,50	5,317	118,910
	21	North Three Peaks area	Detail	250	25,50	2,165	70,350
		Northeast Three Peaks area	Large-scale reconnaissance	1,000	100	667	51,600
	15	Great Western area	Detail	100	10,20,25	1,038	12,670
		Base stations and other				2,778	21,925
		Grand Total				63,951	1,587,215 (296.5 miles)

Instruments

A standard, temperature-compensated, Askania vertical magnetometer was used throughout most of the work. As standard practice its absolute sensitivity was determined at least once every 2 months and more frequently if necessary. By using a small auxiliary magnet, daily checks of the approximate sensitivity of the magnetometer were made both in the morning and late afternoon to insure that the instrument was operating properly over its normal range of readings. The auxiliary magnets were calibrated bimonthly. During the survey the sensitivity of this instrument varied less than 2 percent from an average value of 51.0 gammas per scale division. As the instrument was read to the nearest tenth of a scale division for both the direct and reverse positions, the readings at each station were within about 5 gammas. Occasionally, when two magnetometer crews were operating, an earlier-built Askania vertical magnetometer without temperature compensation and with a sensitivity of about 30 gammas per scale division was used. With this instrument, the value at each station could be read within about 3 gammas. The anomalies discovered with this instrument were of sufficient magnitude to permit neglecting the temperature corrections.

Although the normal diurnal variations of 10 to 20 gammas could be neglected in the Iron Springs district, where the anomalies are generally large, readings at base stations were taken four or more times daily, usually in the early morning, noon (two readings, 1 hour apart), and late afternoon, to detect any magnetic storm.

Geophysical Interpretation in the Field

Magnetic profiles plotted daily from the traverse measurements were used to great advantage in the detail planning of the surveys and in preliminary field interpretations. Any area that showed in profile a magnetic response larger than 1,250 gammas invariably justified detail investigation, and some areas showing much smaller magnetic response warranted further work. As soon as the detailed work in an area was completed, preliminary magnetic and geologic maps were compiled. Diurnal corrections were not made in the field for magnetic profiles or magnetic maps, since their values were found negligible in comparison with the magnitude of significant anomalies.

Quantitative determinations of the depth of cover and size of the magnetic bodies were made in the field for the magnetic anomalies in the Constitution and April Fool claim areas.

THEORETICAL CONSIDERATIONS[14]

Quantitative Determinations

Certain characteristics of tabular magnetic bodies can be calculated directly from field response curves and are independent of the specific magnetic properties of

14/ For many of the ideas advanced in this section the writer is greatly indebted to Prof. L. B. Slichter and S. G. Sargis, who, in their personal and written communications with the writer, assisted materially in several phases of the geophysical interpretation of the district. However, the writer is alone responsible for the statements of opinions and conclusions that are advanced.

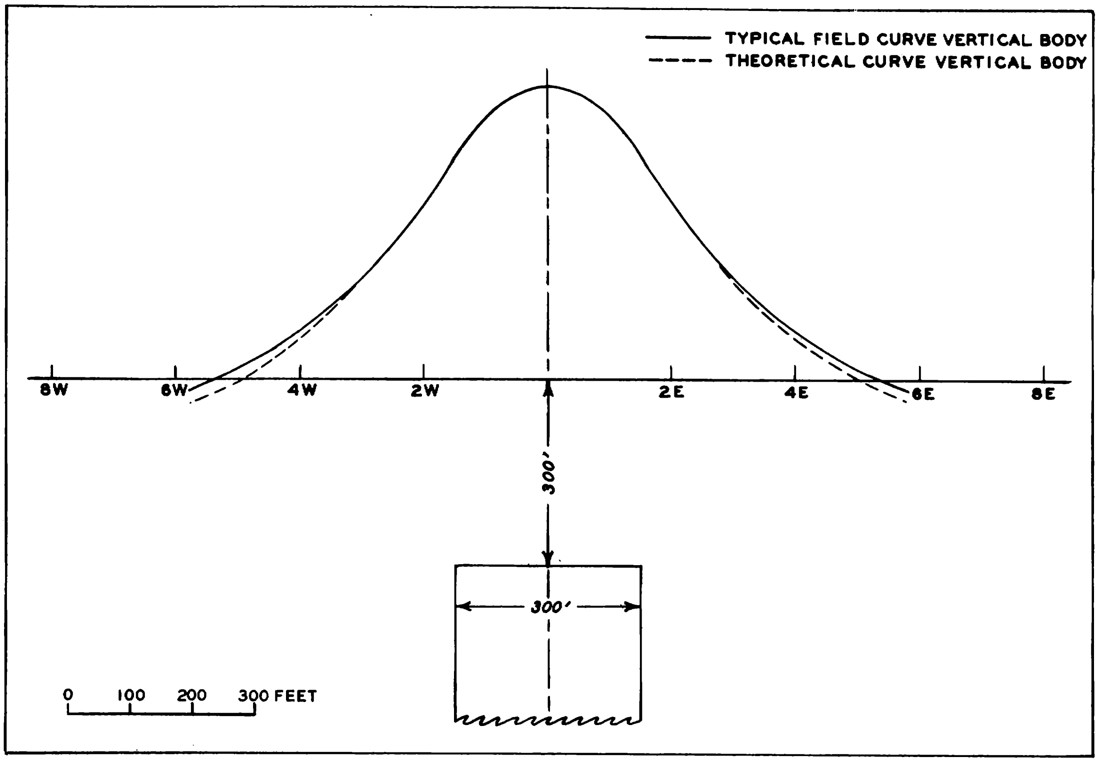


Figure 8. - Comparison of typical field and theoretical curves for a body with vertical dip.

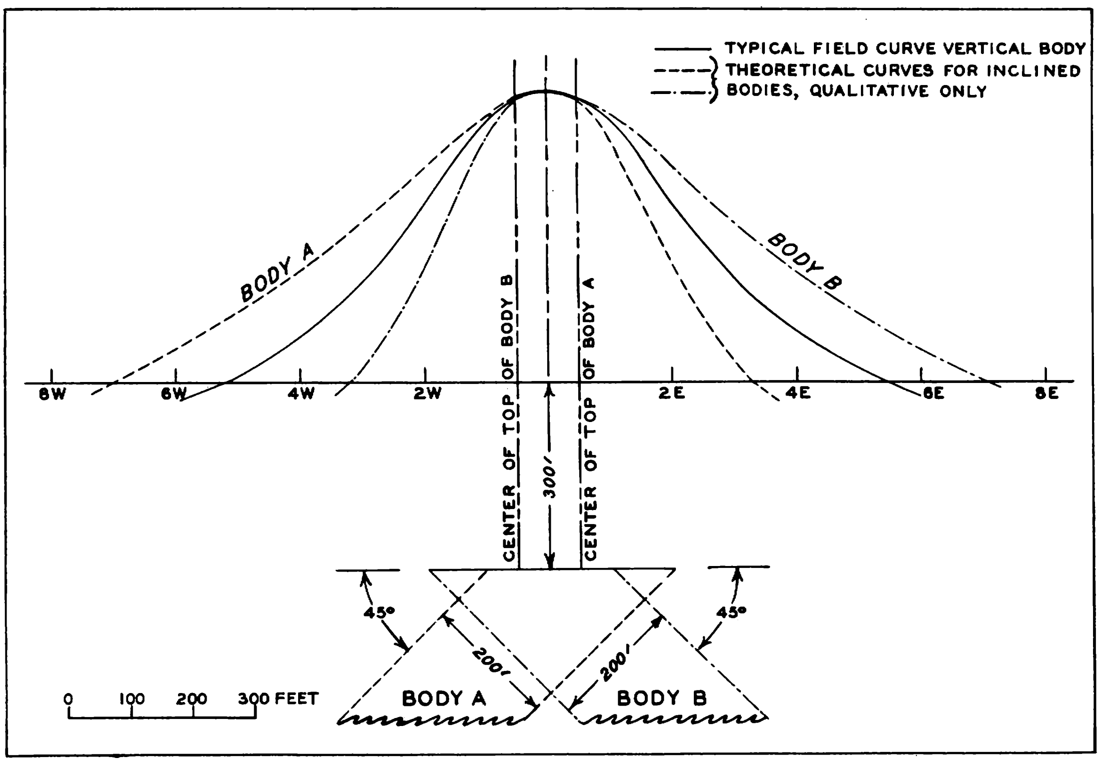


Figure 9. - Comparison of typical field and theoretical curves for bodies with dips of 45°W. (body A) and 45°E. (body B), respectively.

the ores of the district. The position of the apex may be inferred from the position of the maximum positive response whether the response be large or small. Similarly, the dip of the body may usually be estimated from the shape of the curve and is but slightly allied with the maximum value of the response. It will be seen in the three cases shown in figures 8 and 9 that, if the necessary assumptions as to the size of the ore body are made so that the theoretical curves fit the typical field curve vertically, the shape of the curve for the vertical body is much closer to that of the typical field curve than are the theoretical curves for bodies dipping to either side of the vertical. It will be noted that for a vertical ore body with a strike of magnetic north, the response curve is a symmetrical curve. Curves computed for lesser dips than 45° to the east and west would show increasing variance with the indicated typical field curve.

Curve A of figure 38 is the observed field magnetic response curve for traverse 26.00N across the buried April Fool ore body in grid No. 10. It was correctly predicted before the discovery hole that this curve indicates a vertical or steeply dipping magnetic body with an apex as shown on the magnetic map in figure 38, whatever may be its width, depth of cover, or magnetite content.15/

The iron ore of the Iron Springs district is a mixture of magnetite and hematite. Because the magnetic response is due wholly to magnetite in the ore, and not to hematite, the correlation between magnetic response and commercial ore is not a direct one, but must necessarily involve accurate knowledge of the percentage of magnetite in the bodies under consideration and of the magnetic susceptibility of this constituent mineral as found in the ores of the district.

In the calculations made incident to their discovery of the Short Line ore body in the Iron Springs district, Slichter and Sargis used a susceptibility value of 0.25 for pure magnetite. Because of the success attained in their predictions of depth and width for this ore body the writer has also assumed this value as the susceptibility of pure magnetite, and calculated the susceptibility of an assumed ore body on the basis of Slichter's empirical rule16/ that the susceptibility is proportional to the amount of magnetite by volume contained in the ore. For example, if the susceptibility of the magnetite is 0.25, the assumed succeptibility of an ore containing 30 percent magnetite by volume, would be 0.30 x 0.25, or 0.075.

Assuming that a postulated tabular ore body contains 30 percent magnetite by volume it is possible with these assumptions to calculate the depth of cover, width, and depth extent17/ of a buried ore body accurately enough to estimate the economic importance of the body, provided that the remaining 70 percent by volume may be assumed from mining experience in the district to be hematite. In the Iron Springs district the problem is complicated because the ratio of magnetite to hematite varies over the district by rather large amounts. Therefore, in analyzing a newly discovered anomaly whose size suggests a buried ore body, several different magnetite contents, 10, 20, 30, 40, 50, and 100 percent, should be assumed. Each of these percentages

15/ Certain minor qualifications of this statement are given later in the detailed discussion of the April Fool ore body.

16/ Nettleton, L. L., Geophysical Prospecting for Oil: New York, McGraw-Hill Book Co., Inc., 1940, p. 201.

17/ Estimates of depth extent are far less reliable than estimates of depth of cover or width.

leads to a postulated ore body of different size and depth. In general the smaller the assumed magnetite content, the larger and shallower the postulated ore body must be to obtain the best fit between the field response curve and the theoretical response curve. If the assumed magnetic susceptibility of the magnetite is correct, the calculated depth for a body with 100 percent magnetite content provides a definite depth limit within which the magnetic body must lie.

Obviously all of the geological complexities cannot be taken into consideration when computing theoretical curves, and a fit of the curves, as in figure 39, for example, is therefore considered as quite satisfactory.

If the calculated size of the postulated ore body is one that would be unquestionably of economic value, even if a high magnetite content is assumed (for example, 40 percent or 50 percent), and if the anomaly occurs in an area where the geologic control suggests that it may be due to replacement ore, the prospect can be regarded as favorable for test drilling.18/ If the magnetite causing the anomaly is merely disseminated magnetite unaccompanied by hematite, the magnetic body may not be of commercial grade. The magnetic response of such a magnetic body cannot necessarily be differentiated from the magnetic response of an ore body. Therefore, in the absence of good geologic control, the magnetic results cannot positively fortell the existence of an iron ore body of commercial grade. Nonetheless, experience in interpreting the anomalies of the district permits rather accurate appraisals of the economic potentialities of the anomalies and decreases the drilling risks.

Method of Analysis

The writer has applied ordinary methods of induction theory in computing theoretical response curves for magnetic bodies assumed in interpretation studies. Such methods had proved useful in a previous survey of certain ore deposits in the Iron Springs district. As most of the known ore bodies of the district are elongate and roughly tabular, bodies of infinite length whose cross sections are shaped in the form of parallelograms could be safely assumed for the preliminary quantitative calculations. Equations developed by Haalck19/ and Heiland20/ were available for vertical and inclined bodies.

Assuming that α is the angle, measured counterclockwise from the direction of magnetic north to the direction of strike of an infinitely long dike and that the direction of the theoretical magnetic profile is taken at right angles to the strike of the dike, the vertical component of the magnetic anomaly at point P for an inclined dike (see fig. 10) is21/

18/ For a more detailed discussion of an application of this method of analysis, the reader is referred to the section on the April Fool ore body.

19/ Haalck, H., Handbook of Experimental Physics: Vol. 25 (3), 1930, pp. 230-347.

20/ Heiland, C. A., Geophysical Exploration: New York, Prentice-Hall Inc., 1940, pp. 394-398.

21/ This formula, which was suggested in a letter from Dr. C. A. Heiland, was obtained by applying twice the formula for the vertical intensity over an inclined medium (Heiland, C. A., work cited in footnote 20, p. 397).

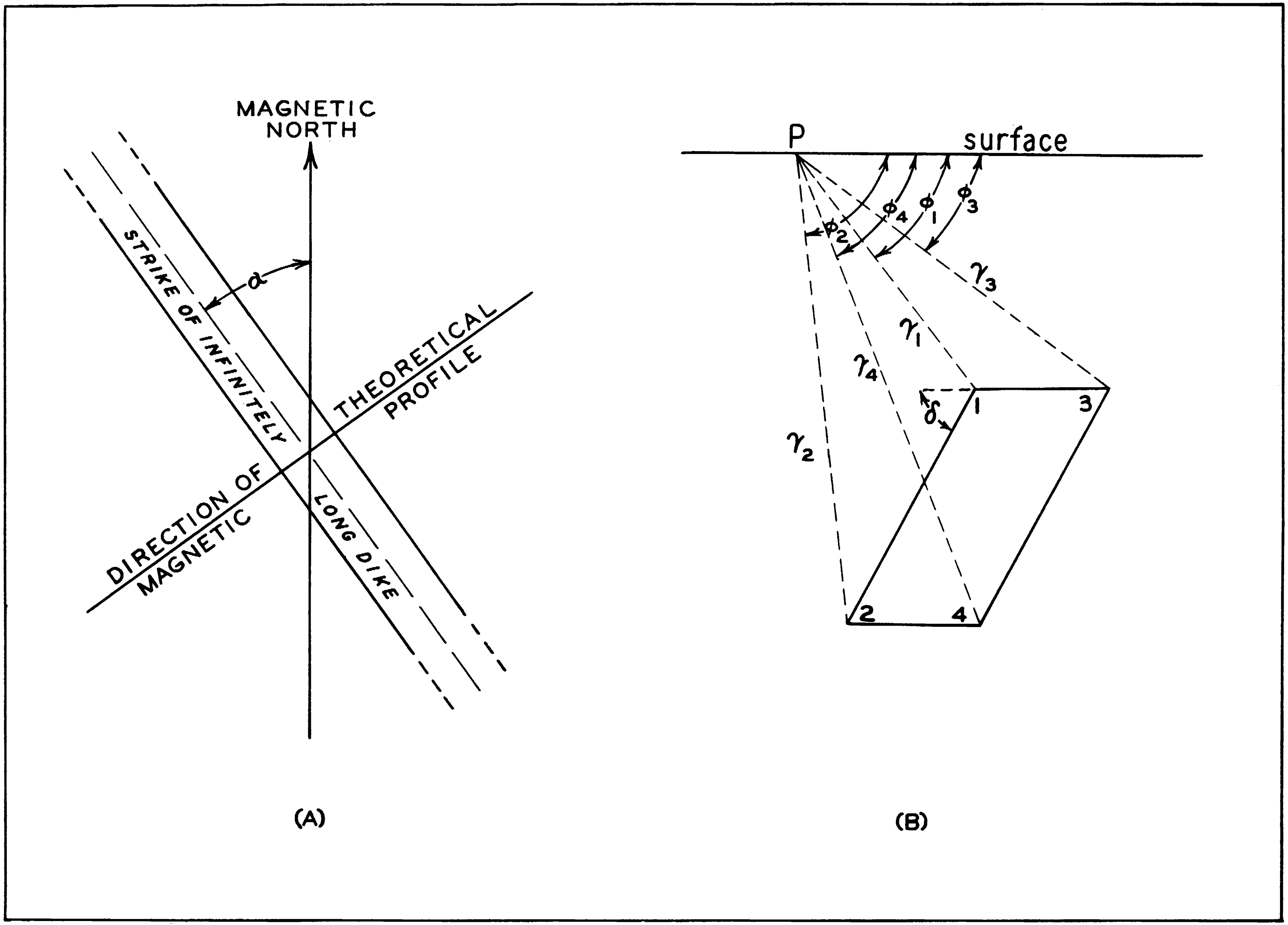


Figure 10. - Diagrammatic plan view (A) and vertical section (B) through an infinitely long dike, showing angles and distances involved in theoretical computations.

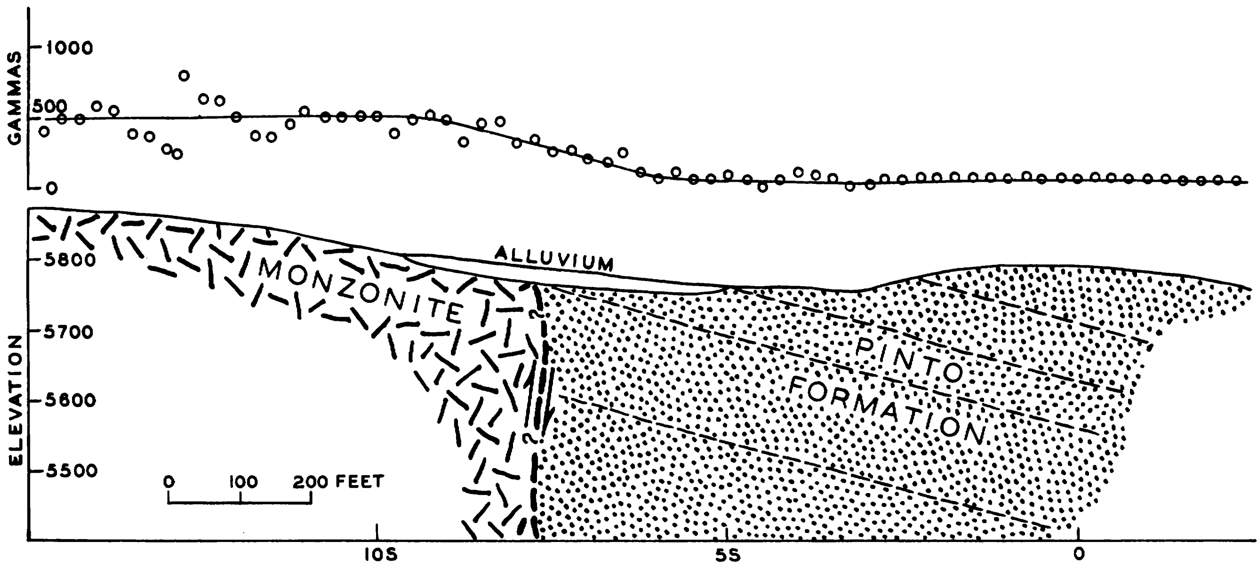


Figure 11. - Magnetic profile and geologic cross section across monzonite-pinto contact along traverse 57.00 W, grid 2, showing typical difference in regional values of monzonite and sedimentary rock in barren areas in the Iron Springs district. (Topography and geology in part after J. H. Mackin.)

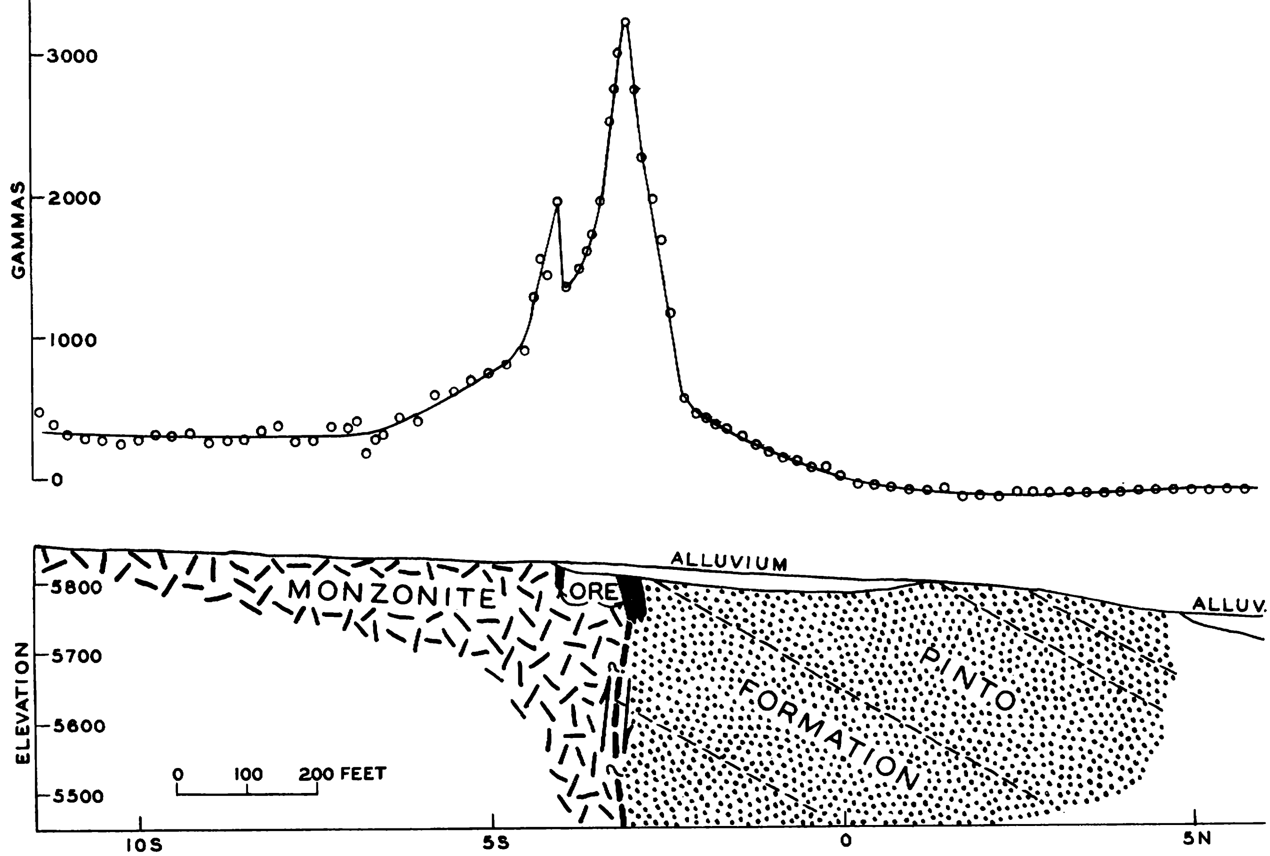


Figure 12. - Magnetic profile and geologic cross section across monzonite-pinto contact along traverse 40.00 W, grid 2, showing typical difference in regional values of monzonite and sedimentary rock in mineralized areas in the Iron Springs district. (Topography and geology in part after J. H. Mackin.)

$$\Delta Z = 2K \sin\delta \{(H_0 \sin\alpha \sin\delta + Z_0 \cos\delta) \log_e \frac{r_2 r_3}{r_1 r_4} + (H_0 \sin\alpha \cos\delta - Z_0 \sin\delta)(\varphi_2 - \varphi_1 + \varphi_3 - \varphi_4)\}, \quad (1)$$

where H_0 and Z_0 are, respectively, the horizontal and vertical components of the intensity of the earth's normal magnetic field in the area; K is the difference between the magnetic susceptibilities of the dike and the adjacent rock; δ is the angle of dip of the dike; r_1, r_2, r_3, and r_4 are the radial distances from point P and φ_1, φ_2, φ_3, and φ_4 are the angles measured in a clockwise direction from the horizontal to the four corners of the cross sectional parallelogram as measured in a vertical plane perpendicular to the strike of the dike.

For a steeply dipping dike whose width is small compared with its depth extent, the vertical anomaly, when the transverse magnetization is neglected ($\alpha = 0$), is

$$\Delta Z = 2K \sin\delta \, Z_0 \left[\cos\delta \log_e \frac{r_2 r_3}{r_1 r_4} - \sin\delta (\varphi_2 - \varphi_1 + \varphi_3 - \varphi_4)\right]$$

For a vertical dike of limited depth extent, $\delta = \pi/2$ and the equation reduces to

$$\Delta Z = 2K Z_0 (\varphi_1 - \varphi_2 - \varphi_3 + \varphi_4).$$

Concept of Regional Value

Figure 11 shows the magnetic profile and geologic cross section taken across the monzonite-sedimentary rock contact in a barren area. It is seen that, in the area lying north of the contact, the magnetometer readings decrease gradually until they reach an essentially constant value, which, because it remains constant throughout large areas of barren sedimentary rock, is called the regional value of the sedimentary rock. Similarly, in the area lying south of the contact the readings gradually increase to an essentially constant value, which, because it remains moderately constant throughout large areas of barren monzonite, is called the regional value of the monzonite. Owing to the small pockets of magnetite that were segregated during the magmatic differentiation, the response over the monzonite is usually somewhat erratic.

Throughout the Iron Springs district the differences of regional values of the monzonite and sedimentary rocks is generally about 400 gammas, though locally it may be as low as 250 gammas or as high as 750 gammas or more.

The difference in regional value is caused by a difference in the magnetic susceptibilities of the sedimentary rock and the monzonite. As the susceptibility of the monzonite is greater than that of the sedimentary rocks, in all barren areas greater magnetic response is observed over the monzonite. Accordingly, if no magnetite mineralization exists at depth, the readings ordinarily rise gradually in going from the sedimentary rocks onto the monzonite. The gradient of the rise and the point of inflection of the magnetic response curve depend on local geological and physical conditions, such as the dip of the monzonite-sedimentary rock contact, the quantity of monzonite float overlying the sedimentary beds, the slope of the bedrock beneath the alluvium, the depth to bedrock, and the magnetic susceptibility of the monzonite in the area. Experience gained by running hundreds of magnetic traverses over areas where the monzonite-sedimentary rock contact is known permits one to predict rather accurately from the response curve the position of the contact in areas covered with alluvium, provided that the alluvium is not too thick.

Necessary Adjustments

Figure 12 shows the magnetic profile and geologic cross section taken across the monzonite-sedimentary rock contact in a mineralized area. Here the observed-field magnetic-response curve is the combined effect of the response due to the ore body and the response due to the different susceptibilities of the monzonite and sedimentary rock. To obtain the true magnetic-response curve, due solely to the magnetic body at depth, the observed curve must be adjusted in the area of the monzonite and in the area of the monzonite-sedimentary rock contact by subtracting the response due to the monzonite alone. As this adjustment is an approximation made empirically in the most critical part of the response curve, the power of the analytic method is correspondingly limited, especially for anomalies less than 1,500 gammas in size. For large anomalies of 2,500 gammas or more, however, the necessary adjustments do not impose severe limitations on the analytic method in the Iron Springs district.

Limitations of Quantitative Determinations

Though the assumptions concerning susceptibilities made for quantitative determinations are reasonable for the Iron Springs district, they are nontheless subject to large uncertainties; and it should be recognized that the resulting estimates of dimensions of the magnetic bodies are subject to corresponding errors. Nevertheless, such quantitative determinations are helpful when their basis is recognized and properly evaluated.

MAGNETIC SURVEYS OF GRANITE MOUNTAIN AREA

Introduction

Of the areas surveyed, the Granite Mountain area affords the best information on the correlation between the geophysical results and the known surface and subsurface geology, primarily because more exploratory test drilling has been done within the grids lying along the margin of this mountain than within the grids on the other two mountains.22/ For this reason the magnetic surveys of the Granite Mountain area are discussed first.

Magnetometer Grids in Granite Mountain Area

Granite Mountain was completely encircled by a system of over-lapping magnetometer grids, which lie chiefly along the monzonite-sedimentary rock contact. Starting with grid 1, which lies in the Lindsay Hill area, and going counterclockwise around Granite Mountain, the successive grids are to be found in the order listed below (see fig. 5):

Grid 1
Grid 2
Grid 6
Grid 19
Grid 19 extension

22/ A large amount of exploratory and development drilling has been done by private companies within restricted areas along the margin of Iron Mountain, but these areas were not surveyed by the Division of Geophysical Exploration.

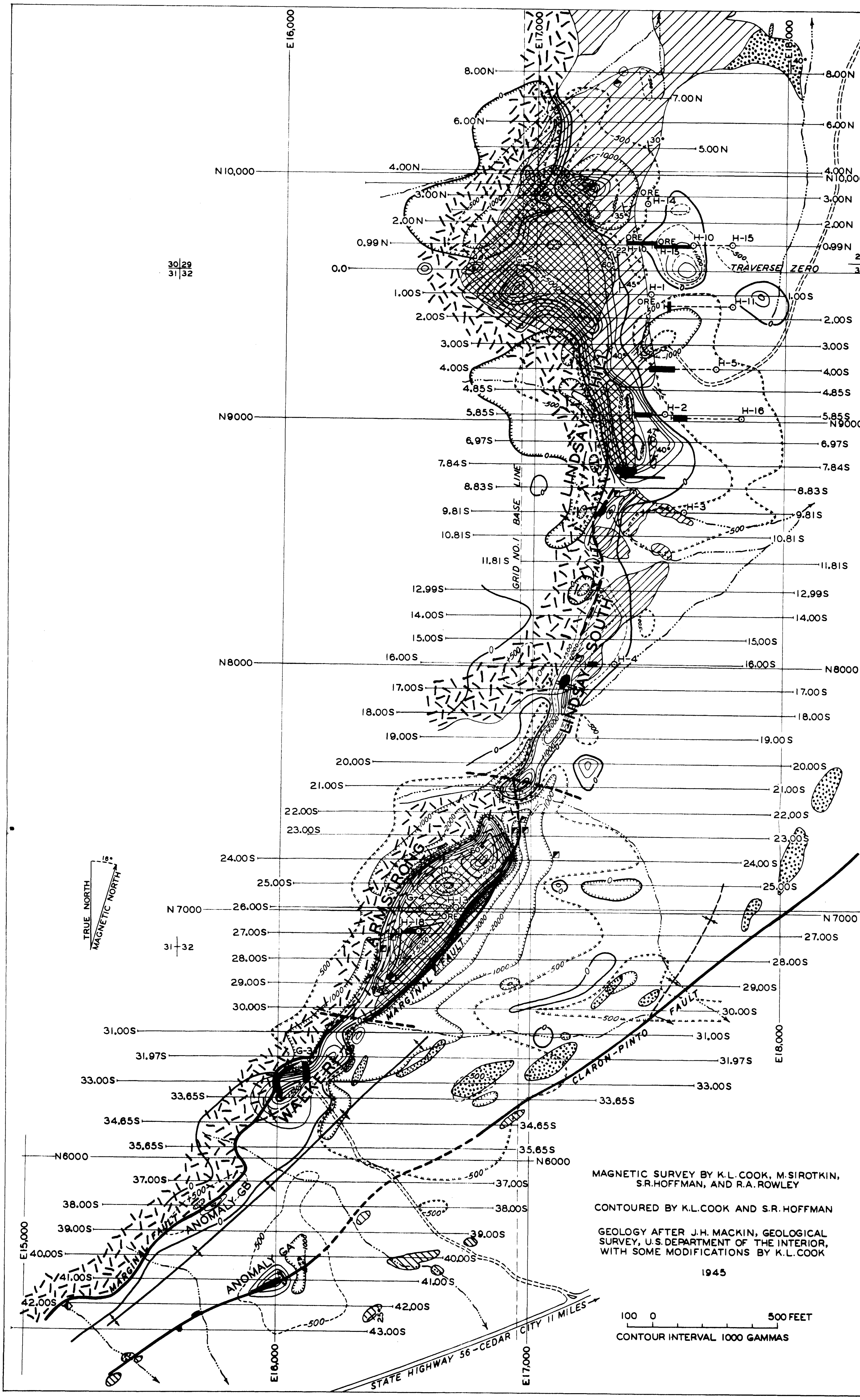


Figure 13. - Magnetic and geologic map of grid 1, Lindsay Hill area, Granite Mountain.

General Geology of Granite Mountain Area

The sedimentary rocks that immediately surround the Granite Mountain intrusion (see fig. 3) are as follows: Pinto sandstone on the south, southeast, and northwest; Homestake limestone on the east and north; and desert alluvium on the west and southwest. Desert Mound, a hill lying less than 1 mile southwest of Granite Mountain proper, is surrounded by monzonite and desert alluvium on the north and by Homestake limestone, Pinto sandstone, and desert alluvium on the south and west.

The main ore bodies that are exposed around the periphery of Granite Mountain are the Walker, Armstrong, Lindsay South, Lindsay Hill, and Little Mormon deposits on the east and southeast; the Pioche and Vermillion deposits on the northeast and north; and the Desert Mound ore bodies on the extreme west. The nonoutcropping ore bodies originally discovered by geologic evidence and magnetometer surveys are the Short Line deposit, lying northwest of Desert Mound at a depth of about 100 feet; the newly discovered Constitution deposit, lying along the north margin of Granite Mountain at a depth of about 300 feet; and the newly discovered Thompson deposit, lying half a mile west of Desert Mound at a depth of about 100 feet.

In the past the Pioche, Vermillion, and Desert Mound deposits have been mined to some extent. In 1944-46 the Lindsay Hill ore body was mined by the Utah Construction Co., and the ore was shipped to Kaiser's Fontana plant.

Magnetometer Grid 1

Magnetometer grid 1 covers about 5,700 feet of the east border of the Granite Mountain intrusion (see fig. 13). It includes, from north to south, the Lindsay Hill, Lindsay South, Armstrong, and Walker iron deposits. In the Lindsay Hill and Lindsay South areas the Homestake formation, which dips east, is in contact with the monzonite; but in the Armstrong and Walker areas the Homestake formation has been faulted down to a depth exceeding 1,300 feet along a marginal fault, and the exposed Pinto formation lies in contact with the monzonite. In the southern part of the grid is to be found the Claron-Pinto fault, which extends southwestward and essentially parallels the marginal fault. Detail magnetometer work was done throughout the grid.

Lindsay Hill Deposit

Geology. - The Lindsay Hill ore body outcrops along its strike for about 1,300 feet northward between traverses 4.00N and 8.83S. The main mass of exposed ore lies north of traverse 3.00S, and the remainder consists of a narrow tail extending southward. In its widest part, along traverse 0.00 between the points 2.00W and 4.00E, the ore outcrop is about 600 feet wide. Monzonite and basal siltstone lie to the west of the ore body, and the upper members of the Homestake formation lie to the east, the limestone striking approximately north and dipping 40° -60° E. to form a monocline. The dip of the ore is essentially the same as that of the limestone. On the east edge of the ore body the contact between the ore and the unreplaced limestone is a sharp contact.

In the area beginning about 200 feet east of the east edge of the main northern mass of exposed ore and extending eastward is to be found float consisting of large ore boulders. Many of the boulders are 1 to 2 feet in diameter, some are 3 feet, and a few are 4 to 5 feet. The float thickens eastward so that in the general area of 7.00E it locally attains a thickness of 25 feet or more. Similarly, thick float consisting of equally large ore boulders lies in the general area east of the tail of the ore deposit.23/

The main problem at Lindsay Hill was to delineate the horizontal extent of the ore body at either end and to determine the depth extent of the ore. Mackin's study of the Lindsay Hill area led him to predict correctly that if the ore body extends down-dip, it would probably be monoclinal in shape.

Results of Magnetic Survey. - As shown in figure 13, a pronounced positive magnetic anomaly was found over the Lindsay Hill ore body. In plan view the general shape of the outline of the anomaly is very similar to that of the exposed ore. In the general area of the northern mass of exposed ore, the major positive anomaly terminates abruptly at or near the east edge of the ore outcrop. An abrupt termination of this kind might at first suggest that the ore at depth does not extend very far east of the outcrop. However, two other possible interpretations are: (1) Magnetic polarization effects may exist at the east edge of the ore body and produce an apparent sharp magnetic change there, and (2) for such a monoclinal ore body, especially if the thickness of its upper limb greatly exceeds that of its central part (point of maximum flexure), an abrupt diminution of the vertical magnetic intensity could be expected. Drill hole H-1 proved that the ore at depth dips east and extends east of the surface outcrop.

It is reported that, in a test hole recently drilled by a private company within the large mass of ore constituting the upper limb of the monocline, about 200 feet of ore was encountered. Thus it now appears that the latter of these three interpretations is the most plausible reason for abrupt termination of the positive anomaly.

In the northern part of the main positive anomaly, starting at traverse 0.99N, the anomaly narrows gradually to a nose at a point on traverse 2.50N, which lies about 150 feet south of the north edge of the ore outcrop. In addition, on either side of the north end of the exposed ore is seen an elongate negative center.24/ On the basis of these features, it was correctly predicted (1) that the area between 2.50N and 4.00N constitutes a transition zone in which magnetic manifestations of the north end of the large ore body are clearly recognized; (2) that north of traverse 0.99N the ore body at depth is thinning in either width or depth extent, or both, in comparison with its dimensions along, and immediately south of, traverse 0.99N; and (3) that the bulk of the Lindsay Hill ore body does not extend appreciably north of traverse 4.00N, the small amount of ore lying north of this traverse constituting an elongate finger of little economic importance.

Termination of the positive magnetic anomaly at a point essentially coincident with the south end of the exposed tail indicates that the bulk of the ore probably

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23/ At 5.00S-5.50E and 8.00S-8.10E were found ore boulders with diameters of 20 feet and 25 feet, respectively.

24/ Within the easternmost negative center of these two lies a small positive center.

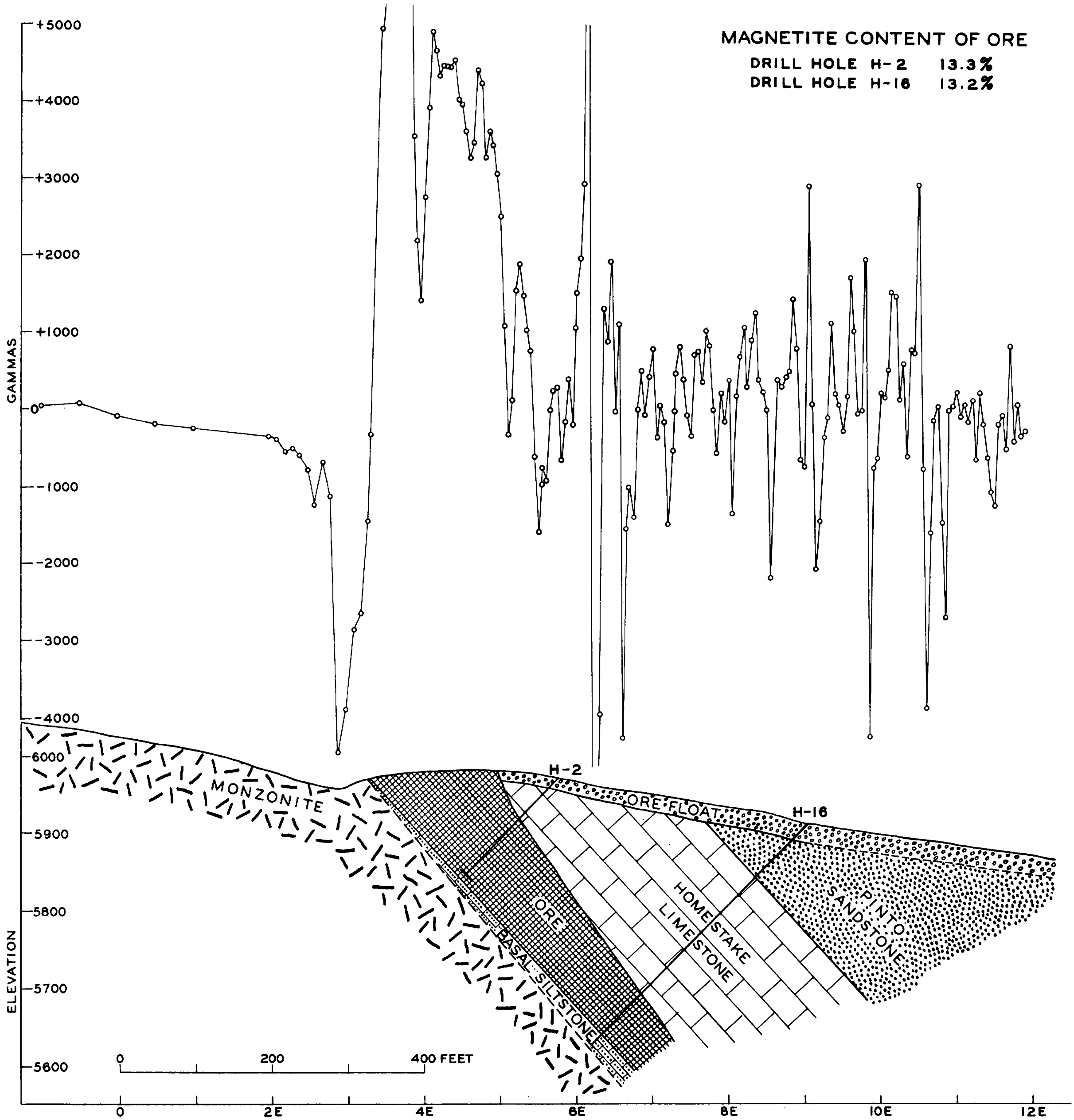

Figure 14. - Magnetic profile and geologic cross section along traverse 5.85S, Lindsay Hill ore body, grid I. (Topography and geology after W. E. Young.)

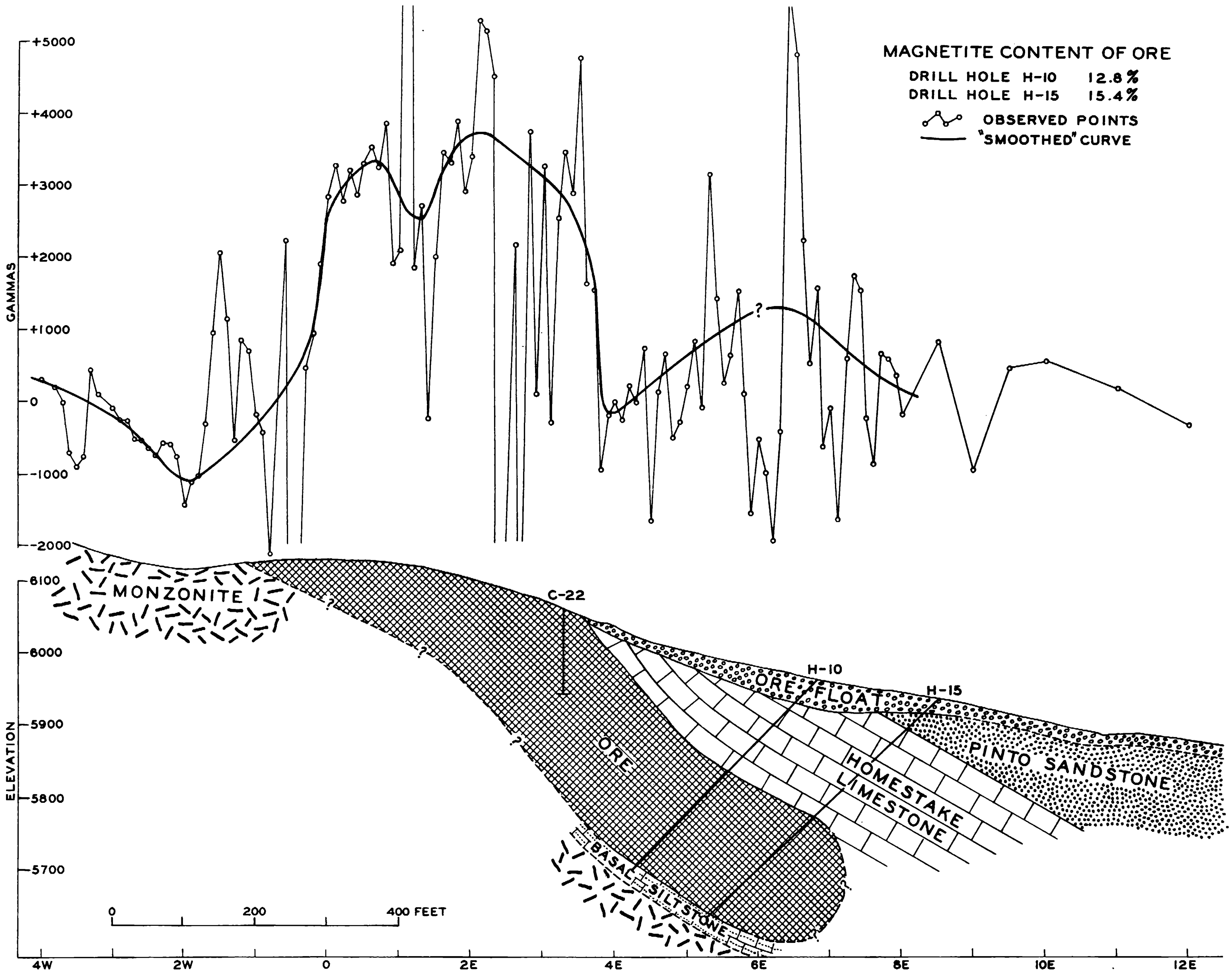

Figure 15. - Magnetic profile and geologic cross section along traverse 0.99N, Lindsay Hill ore body, grid I. (Topography and geology after W. E. Young.)

does not extend south of this point. A small pod of ore, which at depth is probably a minor continuation of the tail, extends southward to about traverse 10.81S. The absence of any anomaly along traverse 11.81S led to the prediction, supported by later drilling of hole H-3, that the area in the immediate vicinity of this traverse probably was barren.

In the area of the tail, a continuous negative zone lies west of the ore outcrop, and over the outcrop is seen a strongly positive anomaly which extends eastward with decreasing intensity to an area more than 100 feet east of the east edge of the ore outcrop. Each magnetic profile across the tail is thus asymmetrical, with a steep slope and negative low on the west side and a gentle slope on the east (see fig 14). These features indicate an easterly dip. The thick ore float produces an erratic magnetic response in the critical part of the curve so that reliable estimates of the depth extent of the ore body could not be made. In this respect the ore float masks the magnetic effect of the main ore body at depth.

An elongate, seemingly separate positive anomaly lies about 650 feet east of triangulation station G-5. In view of the possibly thick ore float known to lie in this general area, and in view more especially of the apparently isolated position of the anomaly in relation to the main positive anomaly to the west, from which it is separated by a negative zone, the significance that could be attached to this isolated anomaly was questionable. It was not known until the late stages of the drilling program on Lindsay Hill that this anomaly is probably caused by the eastward, down-dip extension of the northern part of the Lindsay Hill ore body (see fig. 15). This part of the ore body constitutes the lower limb of the monocline and is much thicker than the down-dip extension of the southern part of the ore body. Figure 15 shows how the thick ore float, by producing an erratic response, tends to mask the magnetic effect of the ore existing down-dip.

Drilling Results. - Holes H-1 and H-2 penetrated about 100 feet of ore and thus established the fact that the ore body dips east and at depth extends more than 135 feet east of the east edge of the ore outcrop.

The pronounced change in character of the magnetic profiles on traverses 9.81S and 10.81S as compared with those over the mass of known ore lying to the north indicated that no great amount of ore could be expected in the general area of traverse 9.81S. Hole H-3 encountered only 2 feet of low-grade ore, which supported this conclusion. Hole H-5, located to test the down-dip extent of the southern part of the ore body, penetrated 161 feet of ore beginning at a hole depth of 220 feet.

The main contribution of geophysics to the drilling program on the Lindsay Hill ore body was in helping to locate the test holes that delineated the northern extent of the bulk of the ore. The magnetic survey indicated that the best drilling strategy in testing the area north of hole H-1 would be to drill first a hole that would encounter the ore body down-dip at relatively shallow depth along traverse 0.99N. This traverse was chosen because all those magnetic contours lying north thereof which are associated with the main positive anomaly, narrow into a nose. Following this procedure, hole H-10 penetrated 176 feet of ore, beginning at a depth of 185 feet. Hole H-14 was drilled to edge the ore body at its north end. The magnetic survey indicated that the hole would lie at or near the north edge of the ore body at depth and that any ore penetrated would be thinner by a rather large amount in either width or depth extent, or both, than that found at the same depth in the area of traverse 0.99N. The hole penetrated 74 feet of ore beginning at a depth of 102 feet, which means that the thickness of the ore here is about one-third as great as that in the area of traverse 0.99N.

Holes H-11, H-15, and H-16 were drilled to test further the down-dip extent of the ore body.

Lindsay South Deposit

Geology. - In the Lindsay South area, which is arbitrarily defined as that area lying between traverses 11.81S and 20.00S, the ore exposed on traverse 17.00S and the ore encountered in several shafts and an adit indicate a strongly mineralized zone. In the northern part of the area, the Homestake limestone is well-exposed and dips 45°-55° E., but no ore is exposed. The extreme southern part of the area is covered with alluvium. The problem of the Lindsay South area was to ascertain whether a continuous ore body of commercial size exists between the several shafts and the adit, and whether such an ore body at depth is continuous with the Lindsay Hill ore body to the north and the Armstrong ore body to the south.

Results of Magnetic Survey. - A continuous magnetic anomaly was observed throughout the Lindsay South area between traverses 12.99S and 20.00S; therefore the Lindsay South ore body probably is continuous between these traverses over a distance of about 700 feet along the strike. Although the ore extends northward to a point where it lies beneath the exposed limestone in the area of traverses 14.00S and 15.00S, the ore body probably is not continuous with the Lindsay Hill ore body, for the absence of any anomaly along traverse 11.81S suggests that a barren area exists between these two ore bodies. As the south end of the anomaly over the Lindsay South ore body is continuous with the north end of the anomaly associated with the Armstrong ore body lying to the south, these two ore bodies probably are continuous beneath the alluvium.

In the northern part of the Lindsay South area the asymmetry of the magnetic profiles, with a steep slope on the west and a gentle slope on the east, indicates that the ore body dips east and extends down-dip far enough to make the body of economic importance. In the southern part of the area the sharp peaks indicate near-surface ore, and the absence of any gentle slope on the east side of the anomaly makes it improbable that any great eastward extension of the ore body will be found.

Drilling Results. - As indicated both by the geology and by the magnetic survey, the northern part of the Lindsay South ore body apparently has a larger economic potentiality than the southern part. Hole H-4 was drilled in this area and penetrated 42 feet of ore, beginning at a hole depth of 105 feet. Throughout its length, the ore body at depth probably does not greatly exceed 50 feet in width. This single hole, in conjunction with the geophysical results and the geologic evidence, was sufficient to establish the existence of a near-surface ore body of economic importance.

Armstrong Deposit

Geology. - The lens-shaped Armstrong ore outcrop, which extends southwestward between traverses 22.00S and 30.00S, is 1,000 feet long and 270 feet wide at its widest part. Monzonite and basal siltstone, according to Mackin,25/ lie to the west of the ore and Pinto sandstone to the east. The existence of basal silstone, which is the lowest member of the Homestake formation, indicates that the deposit is a replacement ore body. In this case the ore has apparently replaced a large part of the Homestake formation rather than the Lower Blue member only.26/ Relict bedding and the few outcrops of basal siltstone indicate that the strike of the ore bed is essentially parallel to the strike of the original limestone and that the dip varies from 50° to 80° east.27/ Coincident with the east edge of the ore outcrop is a marginal fault along which the Homestake limestone has been faulted down on the east relative to the block of ore on the west. Owing to the large amount of sandstone and ore float lying in the area east of the ore outcrop, reliable measurements of the strike and dip of the Pinto formation cannot be made. The problems of the Armstrong area were to delineate the horizontal extent and depth extent of the outcropping ore body, noting especially whether at depth the ore is terminated by the fault, and to ascertain whether the underlying, down-faulted block of Homestake limestone is mineralized east of the fault plane.

On the basis of the convergence of the monzonite-ore contact toward the marginal fault plane, which can be seen on the north and south slopes of the hill, Mackin concluded that the Armstrong ore body, in cross section perpendicular to the strike, is shaped like a wedge, narrowing downward.28/

Results of Magnetic Survey. - A large positive anomaly which extends between traverses 22.00S and 30.00S and whose shape conforms closely with that of the ore outcrop was found over the Armstrong ore body. In the general area of traverse 22.00S, the main positive anomaly narrows to a nose, and the negative centers on both sides of the ore converge in a manner similar to that seen on the north end of the Lindsay Hill ore body. These effects probably are manifestations of the north end of the ore body, and therefore the main ore body probably does not extend appreciably north of traverse 21.00S, although some of the ore presumably is continuous with the south end of the Lindsay South deposit. The abrupt contrast in character of the magnetic profiles along traverses 20.00S and 21.00S, respectively, gives strong support to the possible existence of a cross fault lying between these two traverses. As the intensity of mineralization on the south side of this fault probably will be found to be much greater than that on the north side, this postulated fault may be the actual line of demarcation between the Armstrong and Lindsay South ore bodies.

At the south end of the main positive anomaly, the high-valued magnetic contours extend southward to a point essentially coincident with the south tip of the ore outcrop. Therefore the bulk of the ore does not extend south of traverse 30.00S. A small anomaly does continue south of this traverse and extends all the way to the Walker vein deposit. As ore that has replaced Pinto sandstone is to be found in an adit at 31.00S-6.50W, this anomaly, in the area between the Armstrong and Walker deposits, is thought to be caused by a body of replacement ore in the Pinto sandstone, which is probably of little commercial importance.

25/ Mackin, J. H., work cited in footnote 6, p. 10.
26/ See footnote 25.
27/ See footnote 25.
28/ Mackin, J. H., work cited in footnote 6, p. 12.

Thus the Armstrong ore body at depth probably is continuous over a horizontal distance of about 1,100 feet between traverses 21.00S and 30.00S.

On either side the main positive anomaly is terminated abruptly at or near the east and west edges of the ore outcrop, where a strong negative zone is found over the country rock immediately adjacent to the ore. These features may be explained on the basis of a wedgeshaped ore body which is narrowing downward and whose depth extent probably is less than its greatest width (see fig. 16). It seems unlikely that abrupt termination of the positive anomaly is caused solely by polarization effects at the edge of this ore body.

In the northern part of the ore body, the symmetrical position of the two negative centers relative to the outcropping ore suggests that here the cross section of the ore body may be shaped like a rather symmetrical wedge, whereas in the southern part of the ore body the lack of a strong negative center lying west of the ore body suggests that here the cross section may be shaped like an asymmetrical wedge.

Drilling Results. - In selecting a site for a vertical hole in the central part of the Armstrong ore body, the negative center on traverse 25.00S was avoided, as such a center can be caused by reverse polarization effects and thus have no bearing on the thickness of the ore or may be due to a horse of unreplaced sedimentary rock within the ore body. Test hole H-13 was placed somewhat east of the center of the exposed ore outcrop in order to penetrate the ore and the suspected fault plane, and to continue until the Homestake formation was penetrated at depth beneath the Pinto sandstone (see fig. 16). The hole penetrated 166 feet of ore, including a partly mineralized zone at a depth of 145 to 166 feet. After penetrating the marginal fault zone at a depth of 170 feet, the hole was continued in the Pinto sandstone to 1,306 feet. Because this was the maximum depth obtainable with available equipment, the hole stopped short of the geological objective, namely, the possible mineralized Homestake limestone in the down-thrown block. The hole shows that the east edge of the ore body is terminated by the fault and the throw of the marginal fault exceeds 1,306 feet.

Hole H-18, located on the basis of geologic and magnetic considerations, was drilled to determine the west edge of the ore body at depth.

Walker Deposit

Geology. - The crescent-shaped Walker ore body, a vein deposit of almost pure magnetite and lodestone, is exposed between traverses 31.97S and 34.00S at the contact of the monzonite and Pinto formation. The ore outcrop is about 250 feet long and 30 feet wide.

Results of Magnetic survey. - On its southern part, the bulk of the Walker vein probably extends under the monzonite and ore float for about 50 to 100 feet south of the southernmost ore exposure. On its northern part, as already noted, a continuous shallow band of ore probably extends between the north end of the Walker vein and the south end of the Armstrong ore body. Presumably in the general area of traverse 31.00S the ore changes from pure magnetite and lodestone, which is characteristic of the Walker vein deposit, to a mixture of hematite and magnetite, which is characteristic of the Armstrong replacement ore body. It is not known whether the change is

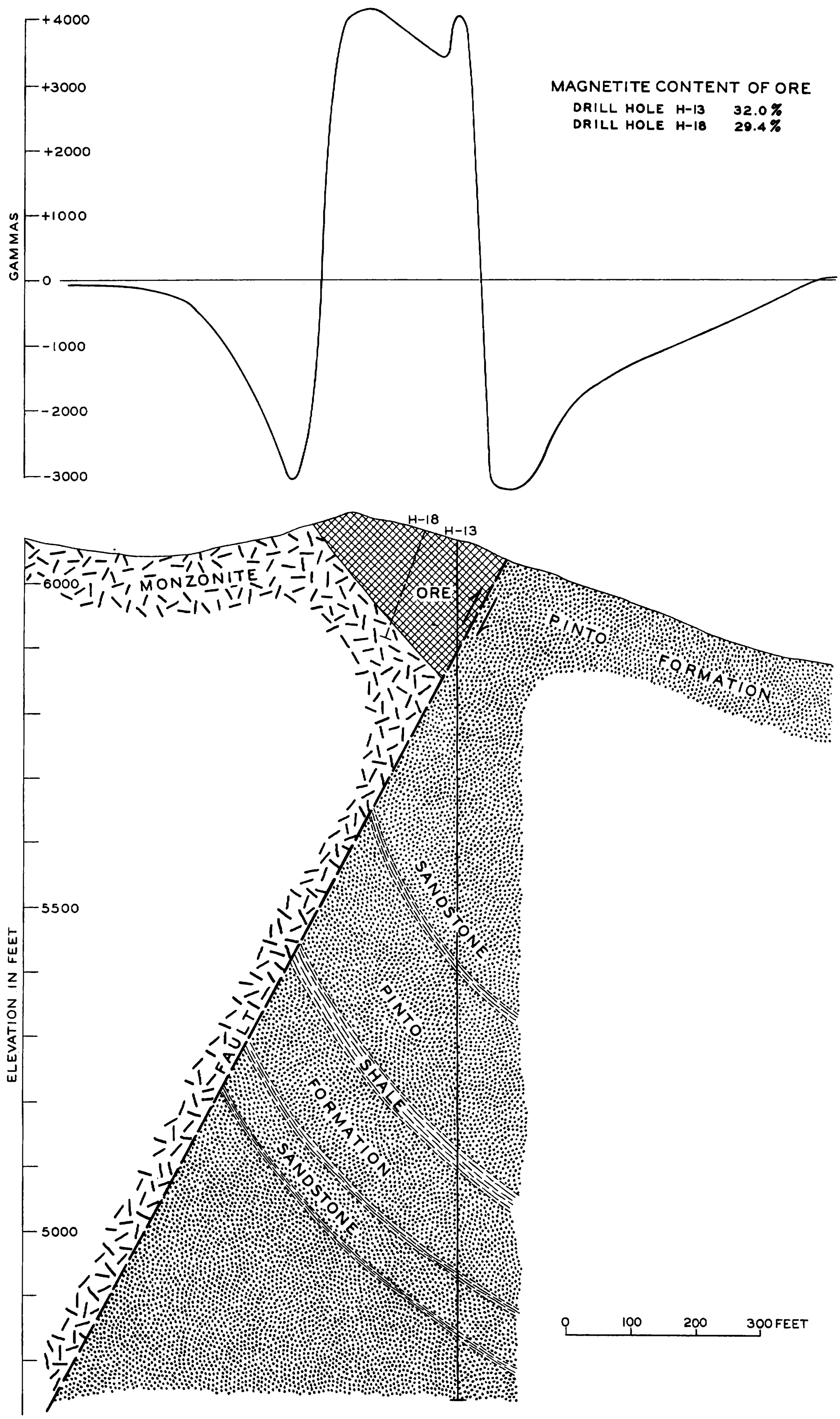

Figure 16. - Magnetic profile and geologic cross section along a line bearing N. 55° W. through hole H-13, Armstrong ore body, grid No. 1. (Topography and geology after W. E. Young.)

abrupt or gradational. The Walker vein as such - that is magnetite and lodestone - probably extends less than 50 feet north of traverse 31.97S. Thus the main part of the ore in the Walker vein probably is confined to a distance of about 350 feet along its general strike.

The dip of the vein probably is vertical or steeply dipping. The size of the anomaly suggests that the vein, though small, may extend downward far enough to have economic importance.

Anticlinal Zone

Beginning in the area lying southeast of the Armstrong deposit an anticline in the Pinto sandstone extends, as mapped by Mackin, southwestward throughout the southern part of grid 1. No anomaly was observed in this area that suggests a large body of ore at shallow depth.

The intense, near-surface mineralization along the Claron-Pinto fault apparently is restricted to the general area of traverse 33.65S; and the small magnetic anomaly (anomaly GA) here indicates that the ore body exposed in several pits in this area is too small to be commercially important.

Limitations of Geophysical Survey in the Southern Part of Grid 1

Hole H-13 shows that the Homestake limestone in the southern part of grid 1 has been faulted down more than 1,300 feet and that the dip of the marginal fault plane is west. Accordingly, any ore body that has been formed by replacement of this limestone can be expected to lie at a corresponding depth, and such a deep ore body in the Armstrong-Walker area could lie directly beneath these two exposed ore bodies. In such a case, the small magnetic response of the deep ore would be so masked by the strong magnetic effects of these two exposed ore bodies that a magnetometer survey could not detect the deep ore.

Within the anticlinal zone, the Homestake limestone probably lies at a depth exceeding 1,000 feet. It is therefore conceivable that the magnetometer would not detect a deep replacement ore body of economic size because the small magnetic effect of such a deep ore body would be masked by the erratic response caused by ore float and minor near-surface mineralization in the area. That some mineralizing solutions have penetrated the general area is evidenced by mineralization to be found locally not only along the Claron-Pinto fault but also along the monzonite-Pinto contact (anomaly GB).

Magnetometer Grid 2

Magnetometer grid 2 covers the northeastern and northern parts of the border of the Granite Mountain intrusion. Because the strike of the monzonite-Homestake contact swings nearly 90° within the area, the grid consists of two parts (see fig. 5), but all coordinates are referred to a single zero-zero point at triangulation station G-7. The eastern part, in which magnetometer traverses were run on a bearing of about N. 75° E., covers, from south to north, the area north of the Lindsay Hill deposit (northern part of grid 1), the Little Mormon deposit, part of the Pioche deposit, and the Iron Springs Arch. The western part, in which the traverses were run on a bearing of about N. 15° W., covers, from east to west, the rest of the Pioche deposit, the Vermillion deposit, and the area westward to triangulation station G-8, including the newly discovered Constitution deposit. The magnetic data of grid 2 are shown on two magnetic maps, (fig. 17 and fig. 18). Detail magnetometer work was done throughout the grid except in the extreme southern part and in the area of the Iron Springs Arch, where reconnaissance work only was done.

Throughout most of the area of the monzonite-Homestake contact lying between the Vermillion and Little Mormon deposits, the Homestake limestone and monzonite are well-exposed. In addition, the Vermillion, Pioche, and East Pioche pits, from which approximately 600,000 tons of ore was removed in 1924-27 by the Columbia Iron Mining Co., provide excellent exposures that show the detailed geologic relations of the replacement ore bodies.29/ Test holes C-2 to C-21, inclusive, whose approximate locations are shown in figure 17 and whose results are given in table 5, were drilled in this area in the 1920's by the Columbia Iron Mining Company.

Within grid 2 in the general area lying between the Vermillion deposit and triangulation station G-8 a northeastward-trending marginal fault brings the Pinto formation into direct contact with the monzonite. In the vicinity of triangulation station G-8 the block of sedimentary rock on the north side of the fault has been displaced downward relative to the monzonite block on the south side a vertical distance of about 600 feet.

Little Mormon Deposit

The Little Mormon ore outcrop is 350 feet long and 80 feet wide at its widest part. Columbia test holes C-19, C-20, and C-21 indicate that the ore body at depth is probably about 45 feet thick in its central part. In the direction along the strike of the ore body, the magnetic anomaly terminates on traverses 17.95S and 20.26S, which suggests that the bulk of the ore lies between these two traverses. The steepness of the magnetic response curve across the ore body, together with lack of a broad response on the east side, suggests that the bulk of the ore probably does not extend far down-dip. Thus the main ore body in depth probably does not greatly exceed 350 feet in length, 45 feet in true width (in a direction perpendicular to the bedding plane), and 100 feet in down-dip extent.

In the surveyed area south of Little Mormon, magnetometer readings along reconnaissance traverses show no magnetic anomaly suggestive of an ore body of economic size.

29/ Mackin, J. H., Preliminary Report and Drilling Recommendations, Northeastern Granite Mountain Area, Iron Springs Mining District, Iron County, Utah: Geol. Survey report (unpublished), August 1944, p. 2.

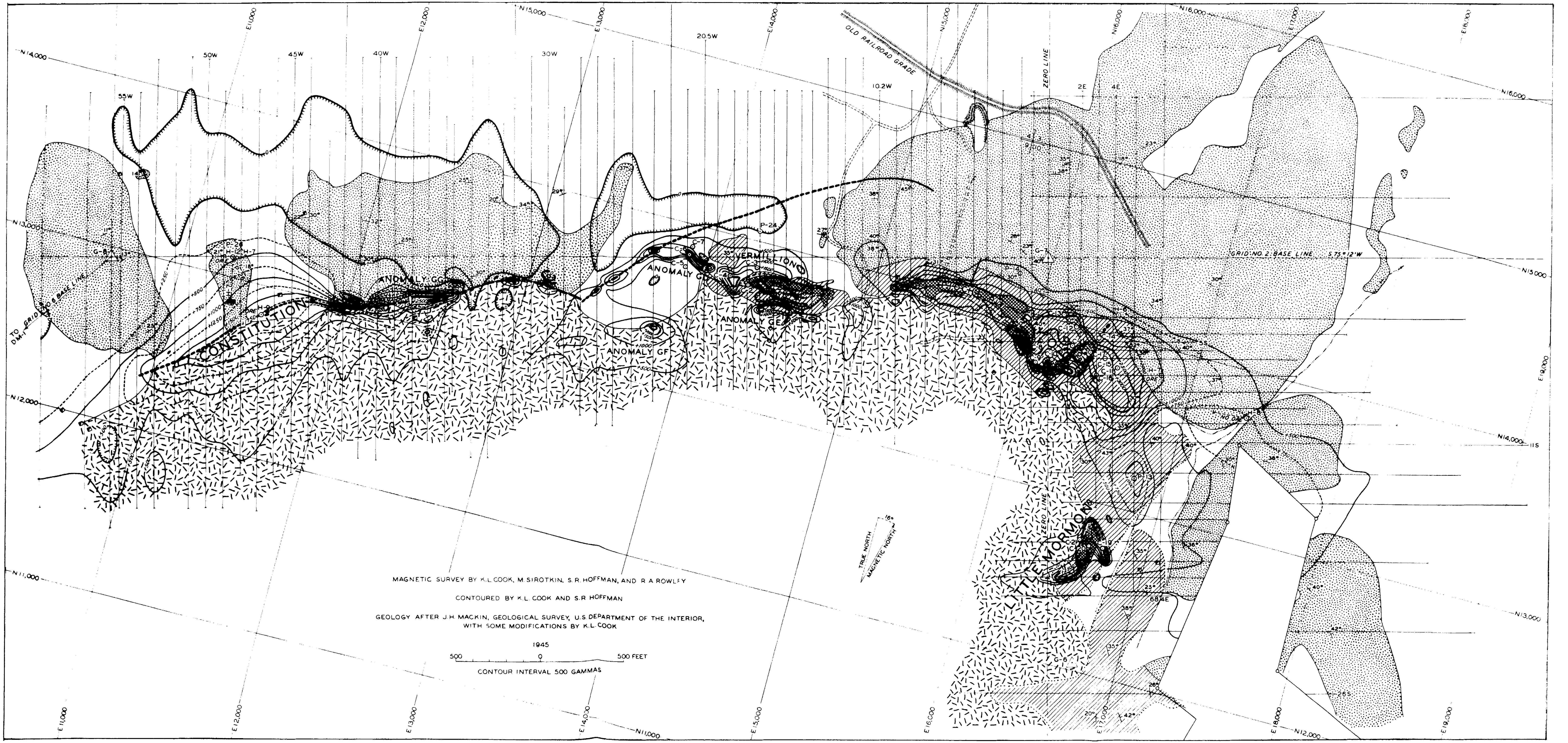

Figure 17. - Magnetic and geologic map of grid 2, Granite Mountain.

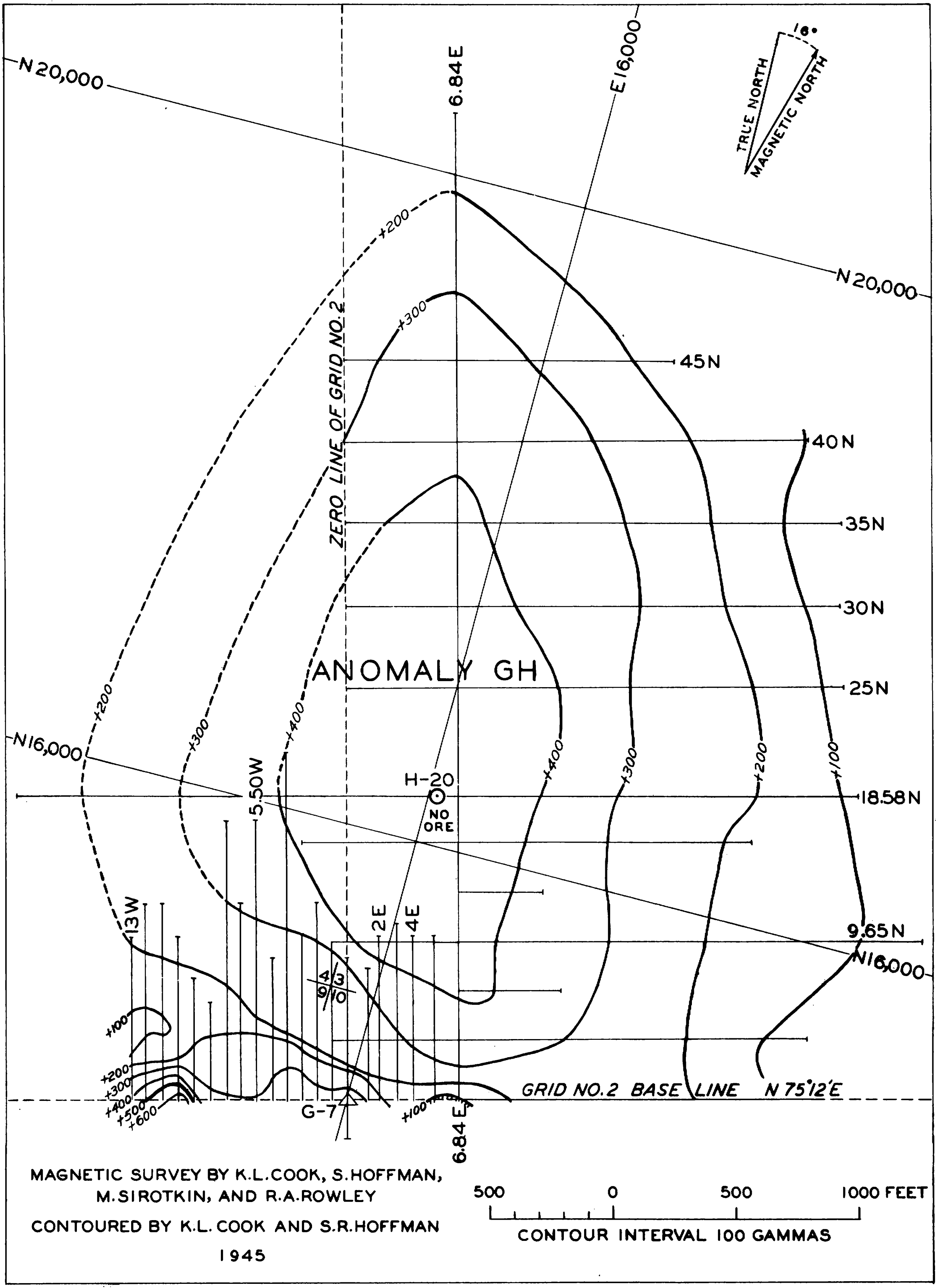

Figure 18. - Magnetic map of the Iron Springs Arch area, northern part of grid 2, Granite Mountain.

TABLE 5. - Drilling results of columbia Iron Mining Co. test holes in east and northeast Granite Mountain area

Area	Hole-	Location B.M. coordinates	Collar elevation (feet)	Drilling results (depths in feet)				
				Alluvium	Limestone	Ore	Monzonite	stopped in-
Vermillion	C-2	N13700-E14240	5645		30-75	0-30.	75-80	Monzonite
	C-3	N13825-E14260	5630		0-50	50-76		Ore
	C-4	N13730-E14110	5640	0-7	7-47		47-50	Monzonite
	C-5	N13715-E14040	5645	0-5			5-45	Do.
	C-6	N13792-E13842	5635	0-10	10-35	35-54	54-60	Do.
	C-7	N13840-E13842	5632	0-8	8-80	80-94	94-97	Do.
Pioche	C-8	N13870-E16050	5672	0-5	5-58 89-111	58-89	111-116	Do.
	C-9	N13725-E16050	5665		0-12 32-80	12-32		Limestone
	C-10	N13775-E16150	5655		0-15 32-55	15-32		Do.
	C-11	N13860-E16260	5818		0-37 88-94	37-88	94-95	Monzonite
	C-12	N14000-E16240	5615		0-40 96-110	40-96		Limestone
	C-13	N14050-E16150	5640		0-55	55-110		Ore
	C-14	N13960-E16385	5590		0-17 27-58	17-27		Limestone
	C-15	N13845-E16450	5610		0-42	42-105		Ore
	C-16	N13760-E16420	5635		0-23 105-108	23-105	108-110	
	C-17	N13860-E16365	5610		98-100	0-98		Limestone
	C-18	N13815-E16535	5625		0-147	147-208	208-210	
Little Mormon	C-19		5688		40-55	0-40		Limestone
	C-20		5706		45-59 61-100	0-45 59-61		Do.
	C-21		5723		0-10 22-55	10-22		Do.
Lindsay Hill	C-22					0-100		Ore

Pioche Deposit

Geology. - The Pioche ore body, which is well-exposed in the Pioche and East Pioche pits, lies in the general area where the trend of the monzonite-Homestake contact, as well as the strike of the Homestake formation, changes gradually from southeast to east in going from south to north. Throughout most of the area, the dip of the limestone is 30°-45° NE. Most of the exposed Homestake formation in the area constitutes the high side of a marginal monocline, which extends almost continuously along the northeast margin of Granite Mountain from Lindsay Hill to the Vermillion deposit.30/

Columbia test holes C-8 to C-13, inclusive, as well as surface croppings and underground workings, prove that the Pioche ore body at depth is continuous in the area lying between the Pioche and East Pioche pits and that in this area the ore body thickens down-dip so that its thickness exceeds 55 feet (holes C-12 and C-13). The ore is exposed throughout the length of the Pioche pit and extends westward to the vicinity of traverse 9.17W. Here, as seen both on the surface and underground, the ore body terminates westward against the east side of a 300-foot-wide, northeastward-trending, barren breccia zone lying between the Vermillion and Pioche pits.

Test holes C-15, C-16, and C-18 prove that the ore at depth extends eastward to a point at least 150 feet east of the east edge of the East Pioche pit, although in this area no ore is exposed in the limestone lying in an up-dip direction from this proved ore.

The problem in the Pioche area was to delimit the extent of the Pioche ore body in a down-dip direction and along the strike to the southeast. The earlier drilling and underground workings had failed to provide this information.

Results of Magnetic Survey. - A 2,300-foot-long, crescent-shaped magnetic anomaly was found over the Pioche ore body. The anomaly is characterized by (1) a narrow finger that constitutes the western part of the anomaly overlying the Pioche pit, (2) a broad, positive center which lies over and adjacent to the East Pioche pit and which, though showing a southeast trend, bulges pronouncedly eastward, and (3) a much smaller positive center which, though partly separated from the main positive center by a saddle, constitutes the southern part of the Pioche anomaly.

The strong anomaly over and adjacent to the East Pioche pit indicates that the bulk of the Pioche ore body lies immediately north, east, and southeast of this pit. The eastward bulge of the anomaly suggests that the ore extends a considerable distance down-dip in the area due east of the East Pioche pit. The southeast trend of the main part of the anomaly indicates that the main ore body probably extends to a point lying about 300 feet southeast of the southeast edge of the East Pioche pit. Here, in the general area of traverse 9.00S, the down-dip extent of the ore body probably diminishes greatly in going from north to south. In spite of the magnetic saddle along traverse 11.00S, some ore probably exists here beneath the exposed limestone and extends southward beneath the oval anomaly constituting the southern tip of the Pioche anomaly. This local magnetic high, whose peak lies about 400 feet east of the monzonite-Homestake contact, apparently is not continuous with the anomaly associated with the Little Mormon ore deposit; rather, the Little Mormon ore

30/ Mackin, J. H., work cited in footnote 29, p. 5.

body is offset about 200 feet west of the southern tip of the Pioche ore body and separated from it by a barren zone along the offset.

In the area lying west of the East Pioche pit the main positive magnetic anomaly narrows gradually westward until, in the vicinity of the east tip of the Pioche pit, the narrowing of the anomaly is so pronounced that a major structural change is suggested in the general area of the Bureau of Mines coordinate line E16,000. Here, according to Mackin,31/ is to be found a north-northeastward-trending shear zone, with the block of rock exposed in the main Pioche pit to the west having been uplifted relative to the block in the East Pioche area to the east.

The probability of some down-dip extension of the Pioche ore body in the area of the Pioche pit, and particularly in the area lying north of the east half of the pit, appears great enough to justify testing. The continued narrowing of the anomaly in a westward direction in the west half of the Pioche pit indicates that here the ore probably does not extend far down-dip. The termination of the anomaly along traverse 9.17W indicates that the bulk of the ore does not extend west of that line.

Thus the Pioche ore body is one of major size, which, with the possible exception of a lean area in the vicinity of traverse 11.00S, is continuous along its curving strike for a distance of about 2,200 feet.

Drilling Results. - In testing the Pioche anomaly, holes H-6 and H-7 were drilled first in the general area of the main positive center.

Columbia test hole C-14 penetrated first 18 feet of limestone, then 10 feet of ore, then 30 feet of limestone, and was then abandoned. The size of the anomaly and geologic evidence indicated that, had it been continued, it would have encountered additional ore. Therefore, inclined hole H-6 was drilled and penetrated 77 feet of ore, beginning at an inclined depth of 145 feet.

To test the down-dip extension of the ore body in the area east of the East Pioche pit, vertical hole H-7, which is in the central part of the eastward bulge of the anomaly, was drilled, penetrating 47 feet of ore, beginning at a depth of 271 feet.

Beginning at 10.00E on traverse 9.00S, anomaly GC extends southeastward about 700 feet over the Pinto formation. Because of the possibility that this 600-gamma anomaly might indicate that a thin tongue of ore extended southeastward from the main Pioche ore body, hole H-8, an inclined hole chosen as a compromise between the geological and magnetic interpretations, was drilled. The hole encountered monzonite at a depth of 404 feet but penetrated no ore. Magnetic susceptibility tests made on the core from this hole show three narrow zones between 320 and 375 feet in which the susceptibility is considerably higher than that of the normal Homestake and Pinto members constituting the remainder of the core. Although these zones of extraordinarily high magnetic susceptibility in the sedimentary rocks, together possibly with an unusually high susceptibility of the underlying monzonite, may possibly account for the observed anomaly, further drilling will be necessary to prove it.

31/ Mackin, J. H., work cited in footnote 29, p. 14.

Iron Springs Arch

Geology. - An anticlinal arch extends about 1 mile northward from the Pioche and East Pioche pits on the northern margin of Granite Mountain. The arch is cored by monzonite and roofed by Homestake under a cover of Pinto sandstone that has been mineralized with chlorite and specularite along its axis and flanks.32/ Mackin regards the arch as a buried nose of monzonite that resembles the southwest nose of Iron Mountain and the Desert Mound nose, both of which have large tonnages of iron ore.

Results of Magnetic Survey. - A magnetometer survey of the arch was made along traverses spaced 500 feet apart, and the results are shown in figure 18. A small (350-gamma), broad, magnetic anomaly (anomaly GH), which trends northward in a direction essentially parallel to the axis of the arch, was observed.

The stratigraphy and lithology suggested that a replacement ore body in the Homestake limestone could lie possibly as deep as 500 to 600 feet. Accordingly, calculations were made to determine the magnetic response of economic-size ore bodies lying at a depth of about 500 feet. The calculations indicate that, for an economic-size ore body with 10 percent magnetite and whose top is 500 feet below the surface, the maximum magnetic response could be as small as the anomaly actually observed. Thus the magnitude of the observed magnetic anomaly can be reconciled with an ore body at depth.

If, for the purposes of discussion, the observed magnetic anomaly is assumed to be due to ore at depth, the broadness of the anomaly suggests either (1) a blanket of ore having a far greater horizontal extent than any ore body in the Iron Springs district whose horizontal limits are known at present33/ or (2) a series of ore pods at depth. As the ore bodies in the district ordinarily exist as pods or segments, Mackin suggests that, if any ore is found beneath the arch, it may be expected to exist as pods rather than as a continuous blanket.34/ Under such geologic conditions the usefulness of a magnetometer in the area is limited by the resolving power of magnetic observations. For two cylindrical pods of ore having a magnetite content of 10 percent, measuring 1,000 feet in length and 200 feet in diameter and lying with their central axis parallel at a depth of 500 feet and less than 500 feet apart horizontally, it would be essentially impossible with the magnetometer used in the present survey to distinguish them from a continuous blanket of ore. Accordingly, if this single broad anomaly were due to ore pods at depth, there is considerable risk that the first few vertical drill holes within the anomaly might miss even large pods of ore.

32/ Mackin, J. H., work cited in footnote 29, p. 17.

33/ Not enough information has yet been obtained on either the geology or geophysics of the Milner Hill area to compare the anomaly over the arch with that at Milner Hill.

34/ Mackin, J. H., work cited in footnote 29, p. 17.

There are other equally plausible interpretations for the observed magnetic anomaly over the arch which need not assume the presence of any ore:

(1) The anomally can be attributed to the part of the monzonite that came nearer to the surface in the arching of the sedimentary beds. The general trend of this anomaly can be reconciled in part with the trend of the arch as evidenced by the surface geology.

(2) A slight variation of the magnetic susceptibility of the underlying sedimentary or igneous rocks, due to disseminated magnetite, may account for the observed anomaly. Some support to this interpretation is given by the results of hole H-8. In this case, no ore was found and susceptibility tests suggest that zones of extraordinarily high magnetic susceptibility in the sedimentary rocks, together possibly with an unusually high susceptibility of the underlying monzonite, may give rise to the anomaly GC. The observed anomaly over the arch may be due to the same causes.

Based on the magnetic survey, no information was obtained to encourage drilling at any specific location.

Drilling Results. - The arch was tested by vertical hole H-20, in which no ore was found. The top of the Homestake formation and monzonite were encountered at depths of 470 and 801 feet, respectively. The top of a possible replacement ore body in the Lower Blue member of the Homestake formation would be expected to lie at a depth of 650 to 700 feet. Because of poor core recovery, the monzonite may lie at a depth of 772 to 801 feet. The drilling of this one hole has neither confirmed nor disproved the possible occurrence of ore in the broad area of the arch or on its flanks.

Vermillion Deposit

Geology. - The Vermillion ore body is exposed throughout the length of the Vermillion pit. The east end of the ore body grades eastward into ore consisting of replaced Homestake breccia within the breccia zone.35/ The Homestake limestone is exposed throughout the Vermillion area, but in the area lying about 650 feet west of the west end of the Vermillion pit, it is faulted down along a marginal fault which brings the beds of the Pinto formation in direct contact with the monzonite along the entire west end of grid 2. The underground workings indicate that the Vermillion ore body dips gently north and extends down-dip at least several scores of feet. As the geological relations alone indicate that the ore body probably does not extend far east of the east edge of the pit, the main problem of the Vermillion ore body is to delimit its extent down-dip and west-ward along the strike.

Results of Magnetic Survey. - The absence of any significant anomaly in the area between the Vermillion and Pioche pits indicates that this area is barren and that the bulk of the Vermillion ore body does not extend east of traverse 14.75W. In the area between traverses 18.75W and 19.75W the abrupt closing of the magnetic contours

35/ Mackin, J. H., work cited in footnote 29, p. 15.

associated with the main ore body indicates that the bulk of the ore does not extend west of traverse 19.75W. Columbia hole C-4, which encountered no ore although it was continued until monzonite was encountered, substantiates this interpretation, for this hole lies along the trend of the anomaly in the area of the abrupt terminations of the Vermillion anomaly.36/ Comparison of the Vermillion and Pioche magnetic anomalies shows that the Vermillion ore body is much smaller than the Pioche ore body in length, thickness, and depth extent.

Anomaly GE, which lies about 100 feet south of the Vermillion pit within the breccia zone, represents a small mineralized zone that is too small to be commercially important.

Anomaly GD lies in the general area of the monzonite-Homestake contact immediately west of the Vermillion anomaly and is the manifestation of a small body of ore which, though probably connecting with the Vermillion ore body, is much smaller. Columbia holes C-6 and C-7, which penetrated 19 and 14 feet of ore, respectively, prove the existence of this small ore body, which probably has only relatively little economic importance. This small pod of ore extends westward as far as the general area of traverse 26.00W, where it ends. The west end of anomaly GD swings southwestward and thus conforms to the direction of the marginal fault lying in this area.

In the area of the monzonite-Pinto contact lying between traverses 28.97W and 34.50W west of anomaly GD, strong mineralization exists locally at the contact, but no anomaly suggestive of a large, near-surface ore body was found.

Anomaly GF, which was found about 500 feet southwest of the Vermillion pit, lies in an area covered with monzonite float. Any possible ore body here will have small economic importance and may be of the vein type.

Constitution Claim Area

Geology. - The Constitution claim area comprises the western part of grid No. 2. Here the eastward-trending marginal fault is the outstanding structural feature. The Pinto formation, which lies in contact with the monzonite, is locally well-exposed, strikes N. 43°-60° E., and dips 11°-30° NW.

Results of Magnetic Survey. - In the area between traverses 43.00W and 54.00W was found a large magnetic anomaly, called the Constitution anomaly,37/ which extends 1,200 feet along the strike (see fig. 17 and fig. 19). The strike of the magnetic anomaly is about N. 80° E., which is essentially parallel to the strike of the Pinto formation in the area. Most of the area beneath the anomaly is covered with monzonite float and Pinto float, so that the location of the marginal fault can be

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36/ The area beneath traverse 19.75 is not completely barren, however, and hole C-4 probably would have encountered some ore if it had been located about 40 feet farther north.

37/ As the main part of the anomaly covers the Clive, rather than the Constitution, claim, the anomaly should properly be called the Clive anomaly. However, the misnomer, which was due originally to an error in claim recognition, has come into common usage in the district and will be followed by the writer.

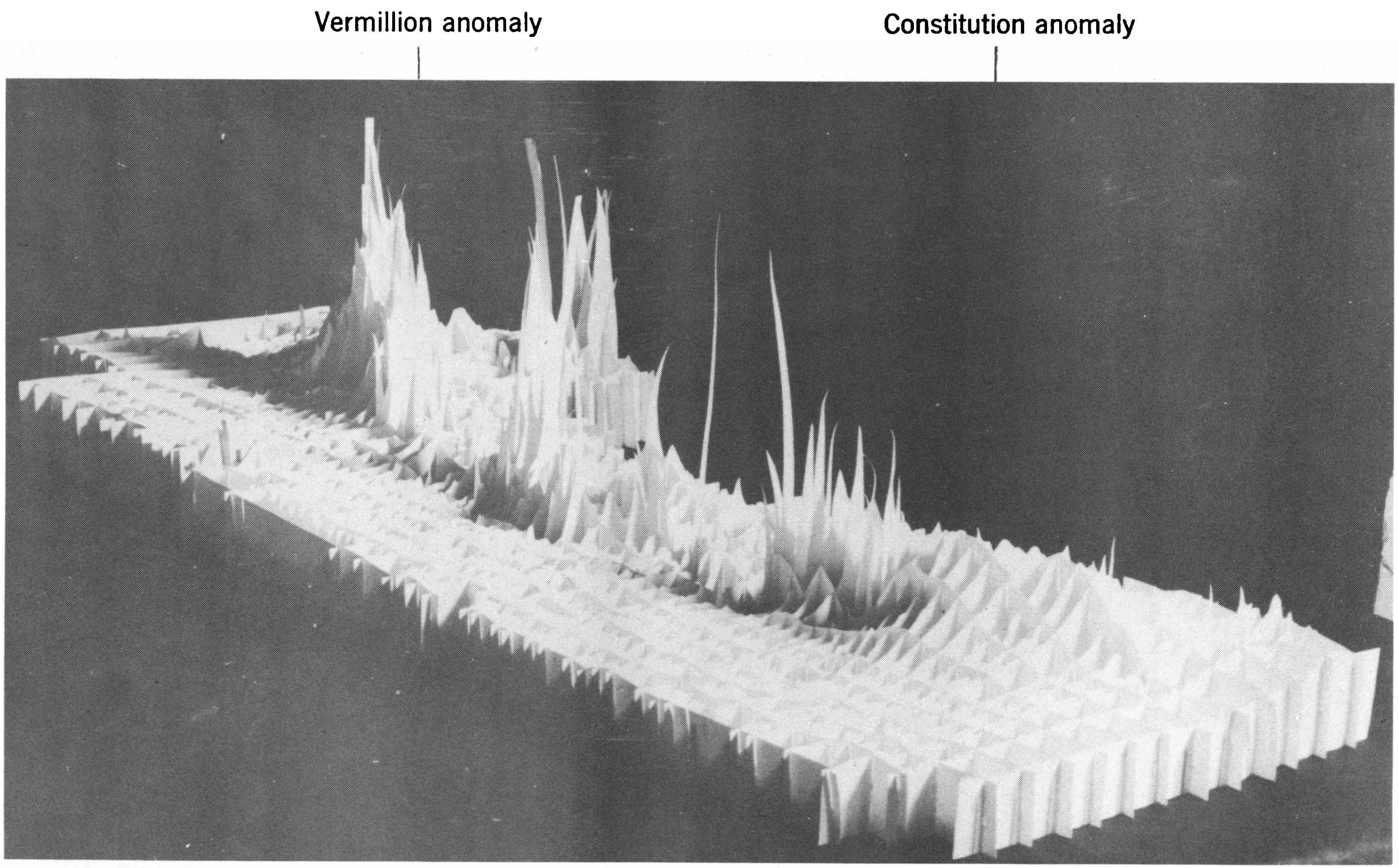

Figure 19. - Egg-crate model showing magnetic anomalies in western part of grid 2.

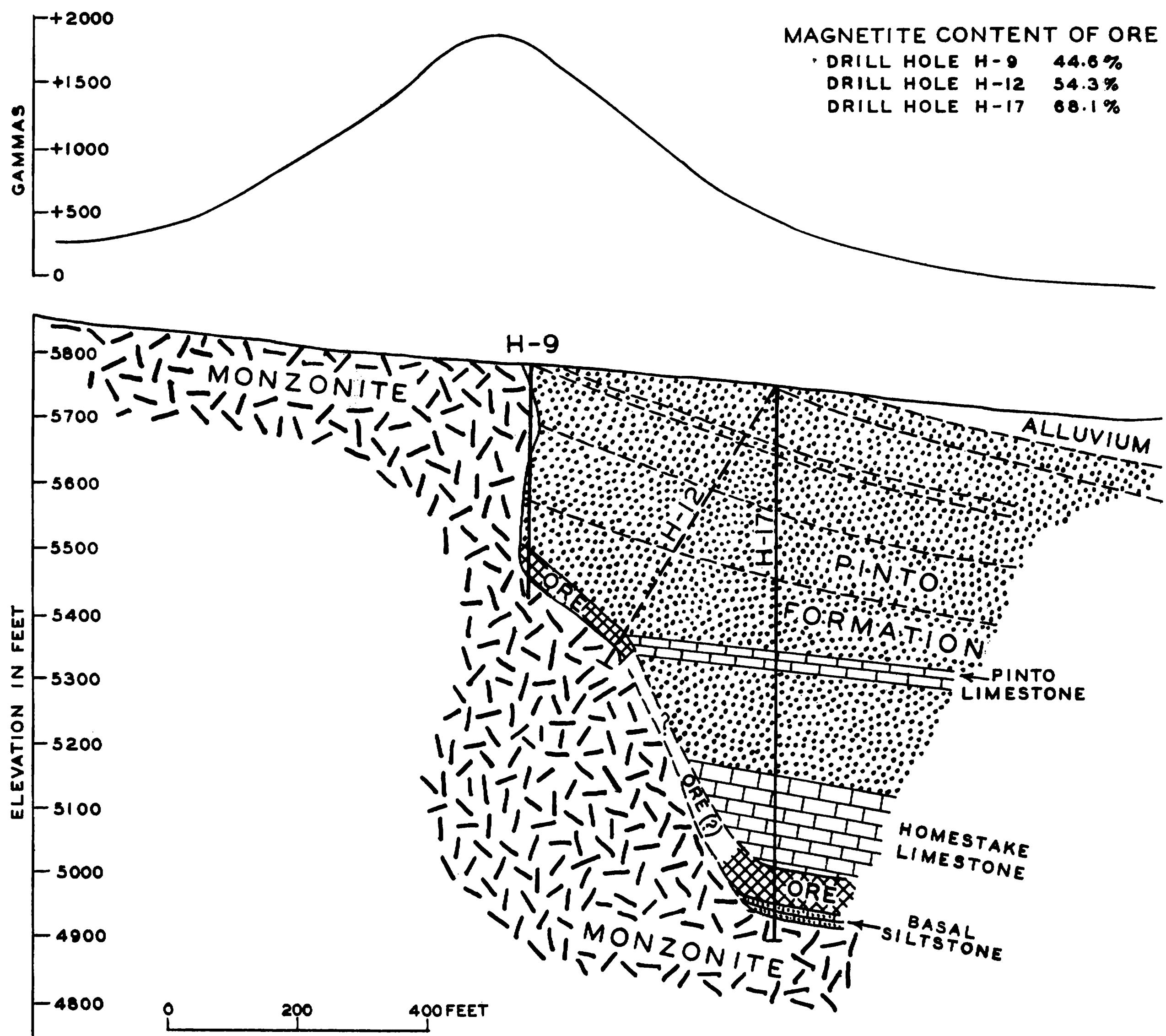

Figure 20. - Magnetic profile and geologic cross section along a line bearing N. 39° W. through vertical drill holes H-9 and H-17, Constitution ore body, Granite Mountain. (Topography and geology in part after W. E. Young and J. H. Mackin.)

inferred to within only 25 to 50 feet. Within the area underlying the Constitution anomaly Mackin38/ found geological evidence of mineralization, which consisted of pronounced alteration of the siltstones to a dark gray to black spotted and mottled hornfels. As none of the magnetic response curves along traverses 45.00W to 53.00W, inclusive, indicate strong mineralization at or near the fault contact within depths of about 30 feet of the surface, the magnetic data offer little help in choosing the fault contact, except in so far as the trend of the anomaly aids in giving the probable strike of the fault.

In making the theoretical calculations for the eastward-striking Constitution ore body, theoretical magnetic bodies with parallelogram-shaped cross sections were assumed, and the transverse horizontal magnetization effect on the vertical intensity was taken into consideration. The character of the field response curves along the traverses indicated that the top of the main mass of magnetite was probably 100 to 300 feet below the surface, the actual depth obviously depending on the mass distribution of the magnetite. One of the serious problems regarding the interpretation before the drilling was the fact that a large part of the anomaly, including its peak, lies south of the inferred location of the fault contact and thus lies over the monzonite. In view of the exposures of magnetite-impregnated breccia that are to be found along the fault contact in the area east of the Constitution anomaly, it was possible that the anomaly might be due to magnetite disseminated in the breccia at depth. In such a case, the magnetic body might not be of commercial grade because the over-all iron content might be too small.

From lithologic and stratigraphic studies Mackin suggested that, in the Constitution area near the fault contact, the top of the Homestake limestone probably would lie about 200 to 250 feet below the surface.39/ In this case any replacement ore within the Homestake formation could be expected at a depth of about 300 feet or more. When the large uncertainties of the factors involved were taken into account, the geological and geophysical estimates apparently correlated well enough to assume that, insofar as depth was concerned, the Constitution anomaly could be reconciled with a replacement ore body. Nevertheless, the existence of replacement ore beneath the anomaly was still apparently predicated on the dip of the fault plane; and before the drilling it was not known whether the dip was south, vertical, or north. Provided that the dip were south and the shape of the ore body due to vagaries of the replacement process had taken a symmetrical form about a vertical axis, the symmetry of the response curve is reconcilable with the possible existence of a large replacement ore body with a vertical or steep dip, even though the dip of the Homestake limestone does not exceed 30°. This contention is supported by the geological and geophysical relations known to exist in the case of the Short Line ore body prior to testing the Constitution anomaly.

Drilling Results. - Hole H-9 (see fig. 20) penetrated a total thickness of 35 feet of replacement ore in limestone, beginning at a depth of 287 feet. The hole encountered first approximately 30 feet of Pinto quartzite and siltstone, which means that the hole started at a point lying north of the monzonite-Pinto contact; then

38/ Mackin, J. H., work cited in footnote 29, p. 16

39/ In view of the difficulty of correlating thicknesses of individual beds along the strike in the Pinto formation, rather large uncertainties in estimates of thickness are to be expected.

about 100 feet of monzonite followed by 150 feet of Pinto sandstone, which means that the monzonite-Pinto fault contact is ragged and irregular, and probably dips, on an average, essentially vertically or to the south down to a depth of about 300 feet. The hole showed further (1) that, although the monzonite at a depth of 227 to 257 feet is impoverished of magnetite, the monzonite encountered from depths of 40 to 132 feet is heavily enriched with magnetite in places, and (2) that rather strong mineralization exists locally in some of the members of the Pinto formation overlying the massive ore. These facts suggested that the more favorable Lower Blue member of the Homestake formation, if encountered by drilling, might be mineralized.

Holes H-12 and H-17 penetrated 19 feet and 55 feet of ore, respectively, at depths of 463 and 738 feet. Hole H-17, which was originally recommended by Mackin as the best first hole to test the Constitution claim area, is the only hole that penetrated the Homestake limestone and ore that has definitely replaced this limestone. The replacement ore encountered in holes H-9 and H-12 is apparently either replaced Pinto limestone or replaced Homestake limestone which exists as dragged and sheared material in or adjacent to the fault zone.

Most of the observed magnetic response is apparently a manifestation of replaced limestone along the narrow, steeply dipping fault zone encountered in holes H-9 and H-12 and the magnetite impregnating the adjacent country rock at depths of 40 feet or more. In spite of the unusually high magnetite content (68.1 percent) of the ore penetrated by hole H-17, only a small part of the observed magnetic response probably is caused by this ore, as it lies relatively deep. The peak of the anomaly lies more nearly vertically over the narrow, mineralized fault zone than over the deeper ore because the shallower ore exerts a greater magnetic effect on the magnetic field of the earth as measured at the surface than does the deeper ore.

Anomaly GG, which lies between traverses 35.44W and 41.00W in the general area of the marginal fault, may be caused largely by near-surface magnetite disseminated in the fault breccia, as evidenced by several ore exposures within the area of the anomaly. However, if enough replacement of the Pinto formation has taken place to make the magnetic body of ore grade, it may have some small commercial importance.

Magnetometer Grid 6

Magnetometer grid 6, which covers essentially all of the west margin of Granite Mountain, extends for 1-1/4 miles in the area between Bureau of Mines triangulation station G-8, near the west end of grid 2, and triangulation station DM-1, on Desert Mound (see fig. 21). The grid consists mainly of reconnaissance magnetic traverses spaced 400 feet apart.

Geology. - The grid lies in an area that is covered largely with alluvium. Monzonite is exposed along the east border of the grid only, and most of the traverses extend eastward onto outcropping monzonite. With the exception of the extreme northeast and southwest ends of the grid, where the Pinto formation is exposed, no outcrop of sedimentary rock is to be found in the area; nor is any replacement ore body known to exist in the area. In the south end of the grid the monzonite-alluvium geologic boundary has been mapped as lying west of all three shafts in which monzonite was

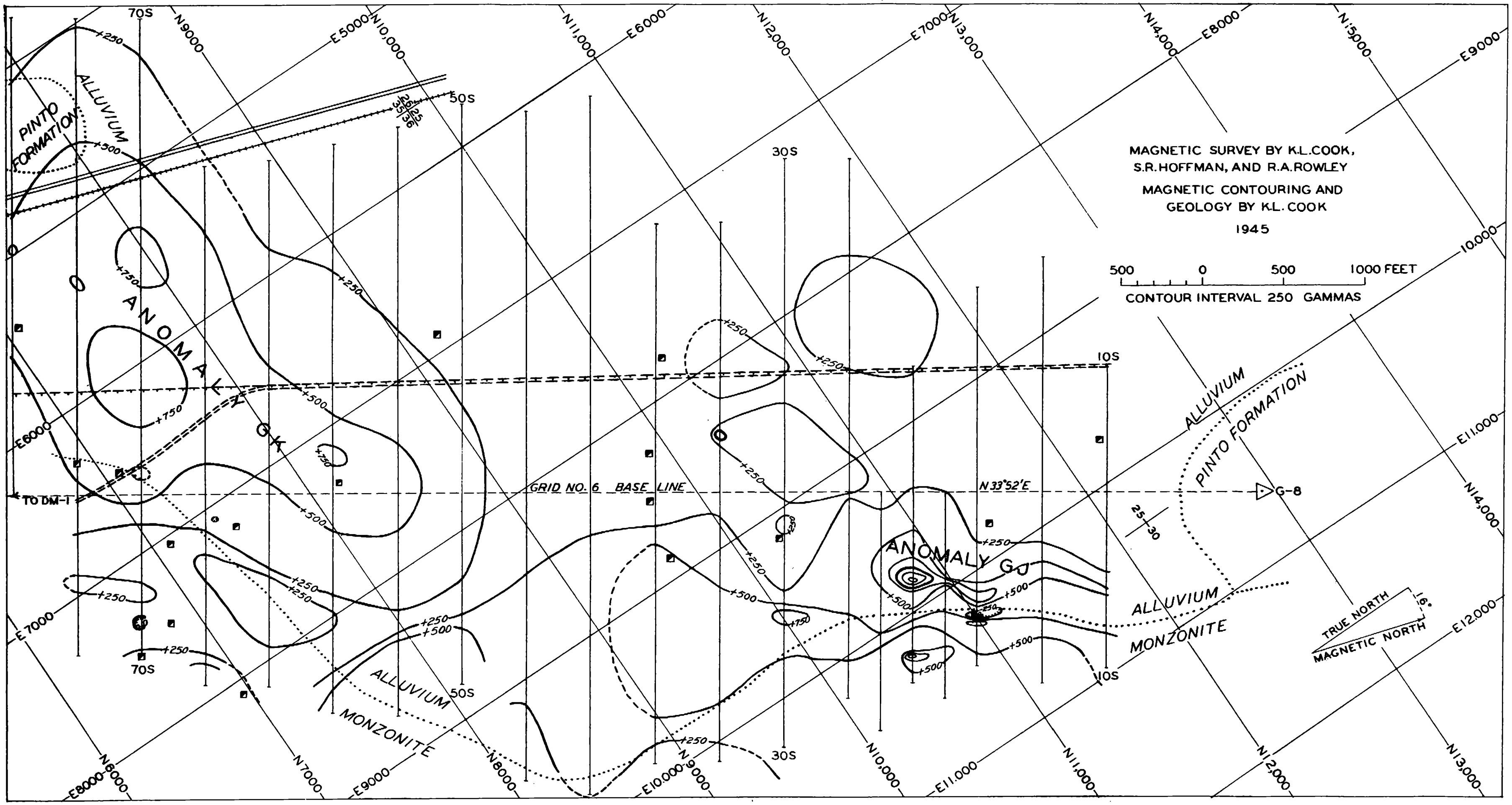

Figure 21. - Magnetic and geologic map of a reconnaissance survey of grid 6, Granite Mountain.

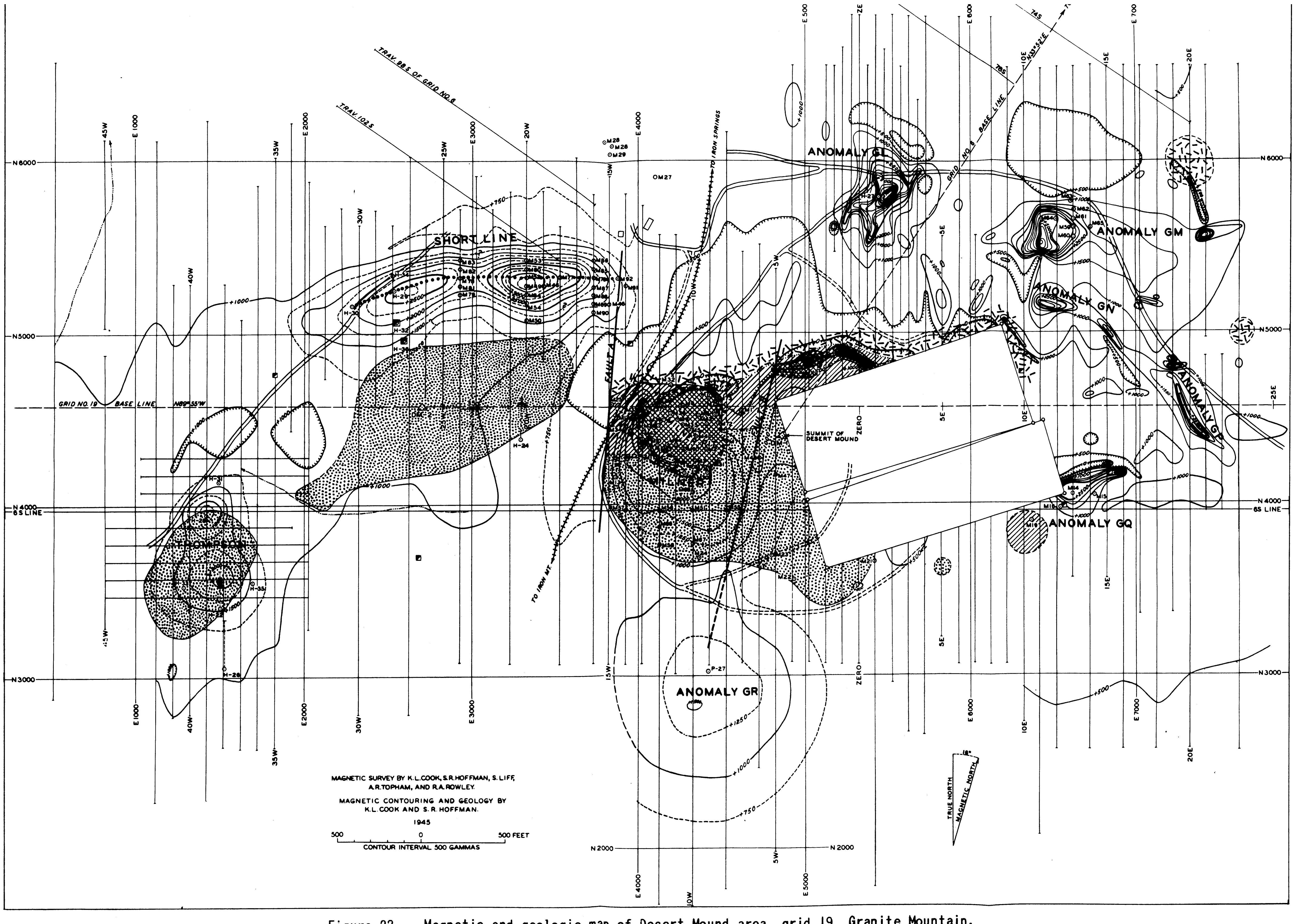

Figure 22. - Magnetic and geologic map of Desert Mound area, grid 19, Granite Mountain.

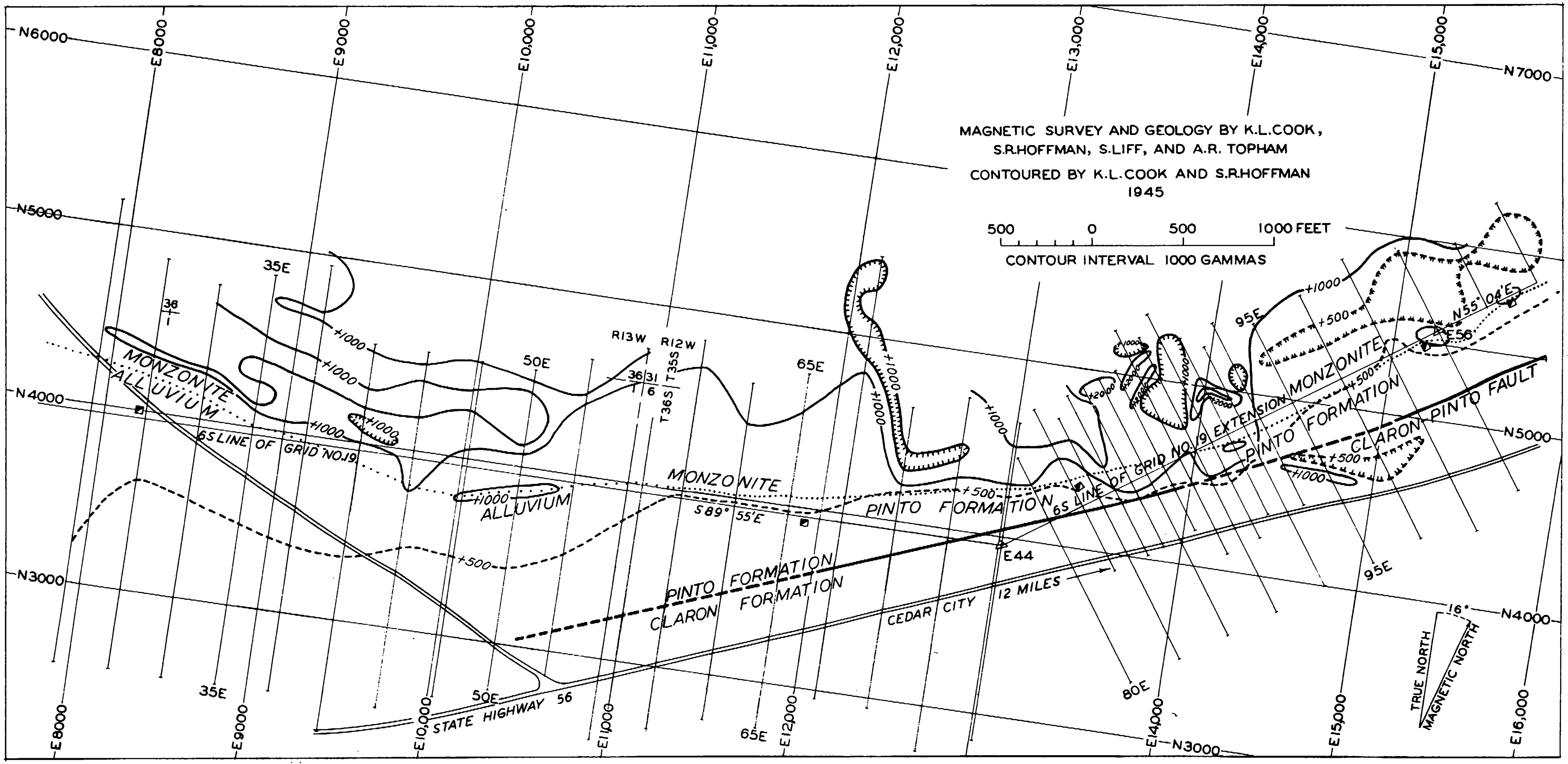

Figure 23. - Magnetic and geologic map of a reconnaissance survey of the eastern part of grid 19, Granite Mountain.

encountered,[40] even though a thin veneer of alluvium, about 5 or 10 feet thick, exists in the area of the shafts. The location of the monzonite-sedimentary rock contact beneath the alluvium is not known in the area of the grid. The traverses extend westward far beyond the point where the assumed regional value of the sedimentary rocks was found; and the contact was presumably crossed by the traverses. The difference in regional values of the monzonite and assumed sedimentary rocks was not as pronounced in this area as in most other areas in the district.

Results of Magnetic Survey. - The general trend of the magnetic contours suggests, though it does not indicate conclusively, that the monzonite-sedimentary rock contact in the northern part of the grid extends in a direction essentially parallel to the indicated monzonite-alluvium boundary and lies possibly east of the magnetic base line. Anomaly GJ, which lies about 600 feet east of the base line and between traverses 18.00S and 24.00S, may be caused by mineralization along the monzonite-sedimentary rock contact, although it could also be caused by either a magnetite vein or a small, mineralized roof pendant. The anomaly is too small to indicate ore of much commerical importance. Thus within the northern part of the grid was found no magnetic anomaly suggestive of a large, near-surface ore body.

Anomaly GK, which lies between traverses 50.00S and 78.00S in the southern part of the grid, is a low (500 gammas), broad, northeastward-trending anomaly extending 4,000 feet along its strike. If the interpretation already given concerning the possible location of the monzonite-sedimentary rock contact to the north is correct, the general trend of anomaly GK conforms well with the expected trend of the contact, which presumably swings westward in this general area to form the north edge of the Desert Mound nose. If the anomaly is due to an economic-size ore body, the body would necessarily be deep, probably 500 to 1,000 feet or more. The main positive center in the southern part of the anomaly lies between an exposure of Pinto formation to the west and exposures of monzonite in shafts to the southeast.

Without knowing the approximate location and dip of the monzonite-sedimentary rock contact beneath the anomaly, together with the possible depth to the Homestake formation, the anomaly cannot at present be sufficiently reconciled with the possible existence of a replacement ore body at depth to recommend test drilling. Additional geologic control is desirable to appraise better the economic potentiality of the anomaly and the drilling risks involved in the testing.

Magnetometer Grid 19

Magnetometer grid 19 covers the general area of Desert Mound and the south margin of Granite Mountain. For convenience in map compilation the grid is divided into two parts: (1) A western part (see fig. 22), which extends, respectively, about 1 mile west and 1/2 mile east of the summit of Desert Mound; and (2) an eastern part (see fig. 23), which extends about 1-3/5 miles along the south border of the Granite Mountain intrusion. The western part of the grid overlaps traverses belonging to the south end of grid 6, and the eastern part overlaps the south end of grid 1. Most of the western part was surveyed in detail along traverses spaced 100 feet apart, whereas the eastern part was surveyed largely along reconnaissance traverses spaced

40/ Small veins of ore in the monzonite were also encountered in 2 of these shafts.

300 feet apart. The western part includes (1) several mineralized zones within the monzonite, (2) the ore blocks on Desert Mound proper, (3) the Short Line ore body, and (4) the newly discovered Thompson ore body. Within the eastern part no ore bodies are known to exist. In the early 1930's a large amount of drilling was done in the western part by the Utah Iron Ore Corporation,41/ and a large amount of ore was mined from the Milner pit, the C. F. and I. pit, and the intervening Upper pit, all of these pits lying on Desert Mound proper.

Geology

Desert Mound Proper. - The Homestake and Pinto formations, which strike east and dip 20°-35° S. along the Desert Mound ridge, constitute the south slope and top of the ridge, and the underlying monzonite forms the north slope. Leith and Harder42/ show that the ridge has been cut by two main northward-trending faults, and Wells43/ suggests that movement along these and other faults has resulted in the formation of large, separate blocks of ore, which are displaced north or south relative to each other. Wells does not state his opinion as to whether the faults are premineralization or post-mineralization. After mapping the Desert Mound area, Mackin44/ concludes that the ridge is divided by northward-trending faults45/ and shear zones into four geologic blocks, each of which is mineralized in varying degrees of intensity. He postulates that here the cross faulting and shearing occurred before the mineralization and that the faults and shear zones tend to control the mineralization. He notes, for example, that while within the westernmost or Milner block essentially the full thickness (200 feet) of Homestake formation is replaced by ore, in the adjacent Contact block the exposed ore is confined to the lower part of the Homestake formation. These two blocks are separated by fault B in figure 22.

West Extension of Desert Mound. - West of Desert Mound proper, a lower, separate ridge of Pinto sandstone extends westward about 1,500 feet. Here the sandstone, which strikes east and dips south, overlies Homestake limestone encountered in shafts at the north base of the ridge. Leith and Harder46/ originally showed that the sandstone constituting the ridge has been offset northward along a major northward-trending fault lying immediately west of the present Milner pit and designated as fault A (see fig. 22) by the writer. Mackin47/ considers this ridge to be a continuation of the Desert Mound structure, though offset by fault A. He names it the West Extension ridge.

41/ The coordinates of grid No. 19 were chosen so that they coincide with those used by this company. As the base line extends over the deep pits, the 6.00S line was used as the main survey line in laying out the magnetometer grid. Contrary to the usual procedure, and only in the case of grid No. 19, the extreme east end of the grid was turned about 35° northward at triangulation station E-44 to form grid No. 19 extension, which is considered part of the eastern part of grid No. 19.
42/ Leith, C. K., and Harder, E. C., work cited in footnote 3, plate V.
43/ Wells, Francis G., work cited in footnote 5, p. 491.
44/ Mackin, J. H., Preliminary Statement; Drilling Recommendations in the Desert Mound Area: Unpub. Geol. Survey Mem., February 1945, p. 1.
45/ Not all of the faults are shown in figure 22.
46/ Leith C. K., and Harder, E. C., work cited in footnote 3, plate V.
47/ Mackin, J. H., work cited in footnote 44, p. 3.

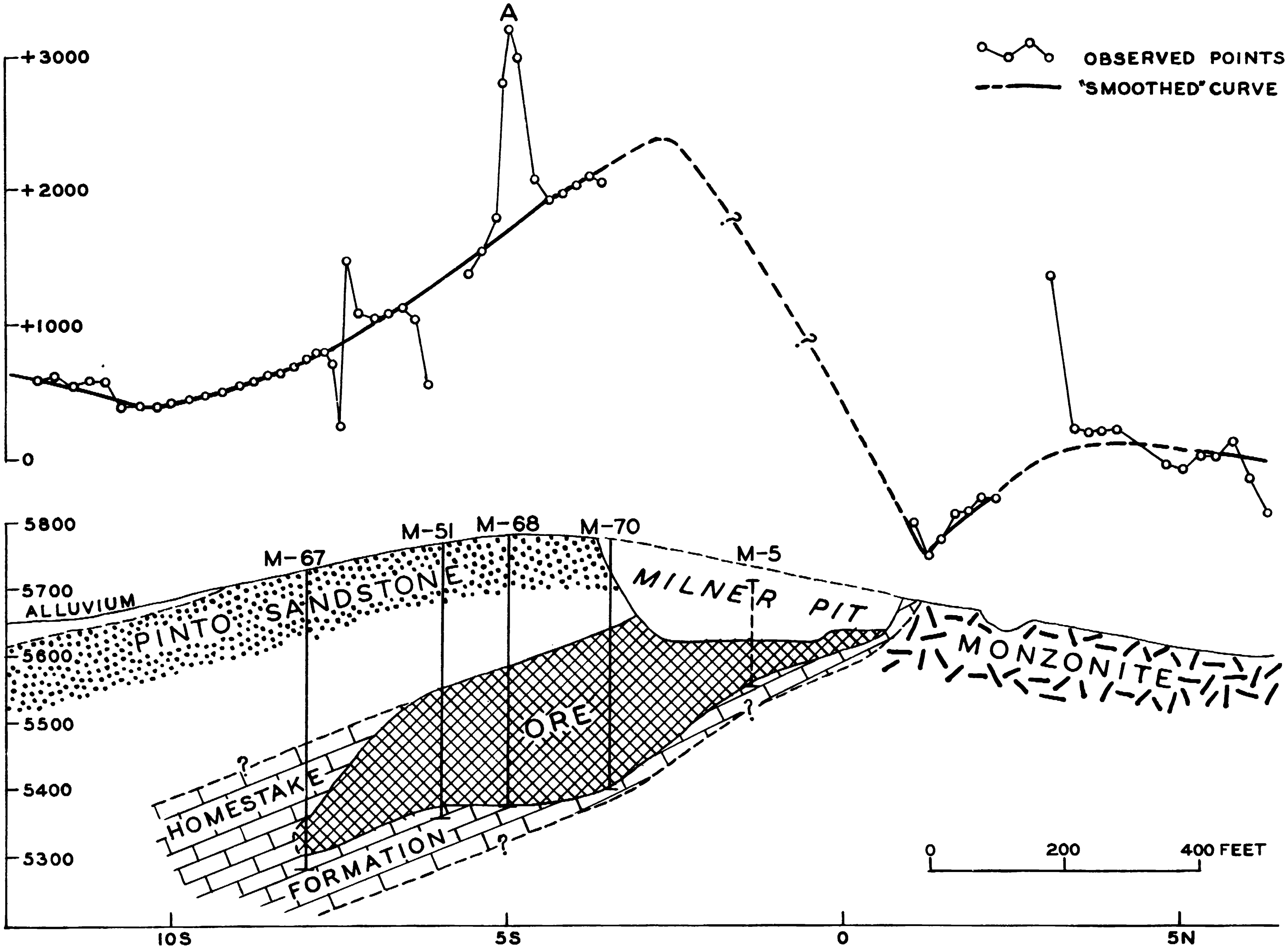

Figure 24. - Magnetic profile and geologic cross section along traverse 10.00 W, Milner ore body, Desert Mound area, grid 19.

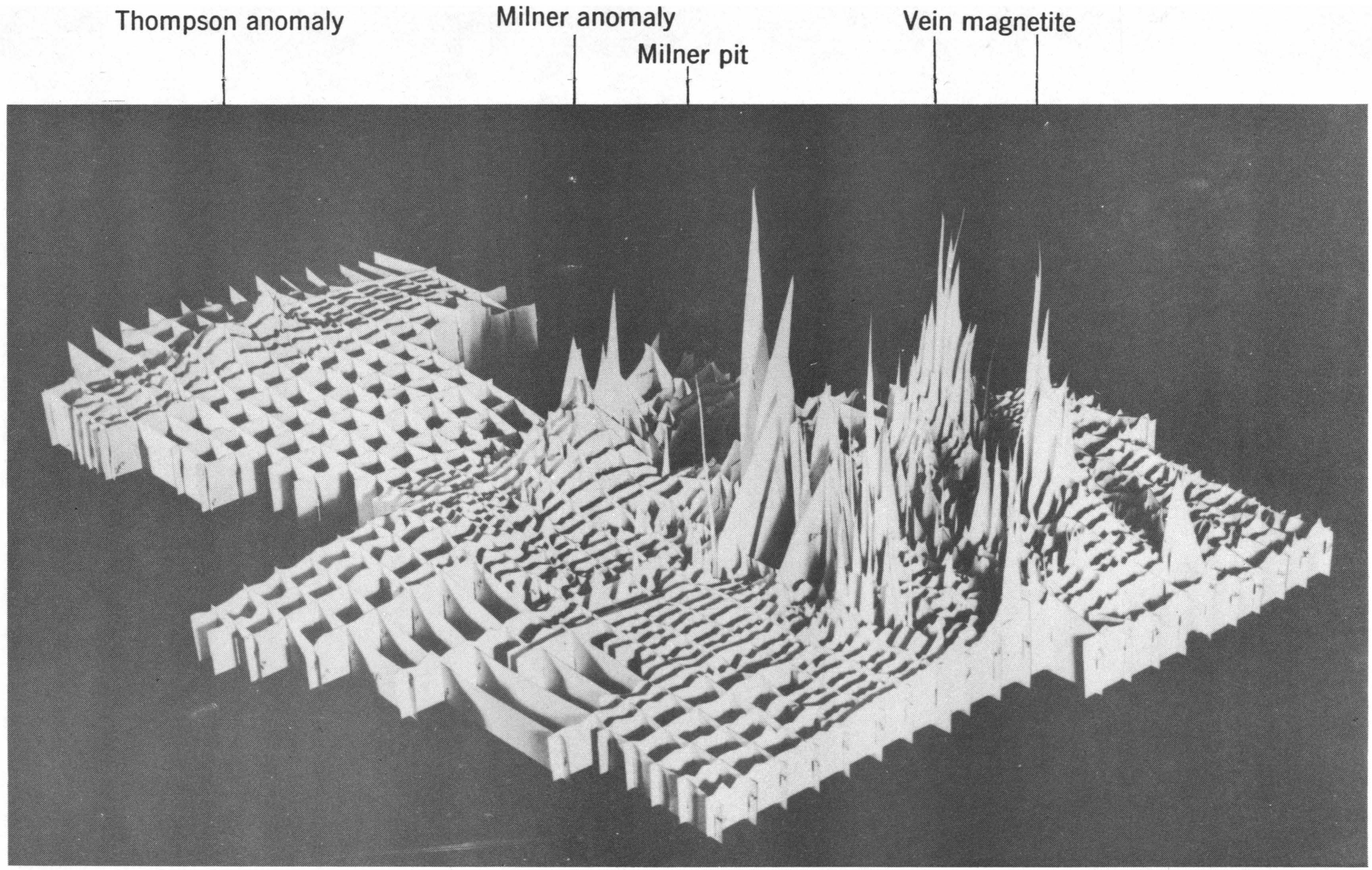

Figure 25. - Egg-crate model showing magnetic anomalies in western part of grid 19.

Eastern Part of Grid 19 .- The extreme eastern part of grid 19, including the grid 19 extension, lies in Eightmile Pass, where exposures of the Pinto and Claron formations are to be found. The Pinto formation lies in contact with the monzonite. The major Claron-Pinto fault is also present here. Westward from Eightmile Pass the Claron and Pinto formations, as well as the Claron-Pinto fault, disappear under the alluvium, which covers the area east of Desert Mound.

Milner Deposit

Geology. - The Milner block, by definition, is confined between faults A and B (see fig. 22), and the Milner ore body lies within this block. Extensive drilling by the Utah Iron Ore Corp. shows that the ore body strikes east, dips 20° S., and extends down-dip at least 800 feet in its central part (see fig. 23).

Results of Magnetic Survey. - The magnetic anomaly associated with the Milner ore body terminates abruptly in the general area of fault A, which indicates that the main ore body at depth probably does not extend west of this fault. Similarly, the abrupt convergence of the magnetic contours in the general area of fault B makes it unlikely that the bulk of the ore at depth extends east of this fault, with the exception of the area beneath and immediately adjacent to triangulation station DM-1. The magnetic profile along traverse 10.00W is shown in figure 24.48/ The down-dip extent of the bulk of the ore body to the southwest is approximately marked by hole M-57, which in 400 feet penetrated only 7 feet of ore. Hole M-67, near the center of the ore body, in 449 feet penetrated about 50 feet of medium-and high-grade ore.

Wells reported that an estimated 7,000,000 tons of ore was originally contained within the confines of the King and Contact claims.49/ The magnetic results indicate that essentially all of the tonnage found within these two claims probably lies in the Milner block as an aggregate part of the Milner ore body.

The Milner anomaly is shown in the egg-crate model of the magnetic anomalies in the western part of grid 19, figure 25.

Importance of Critical Dip. - In 1928 Stearn50/ emphasized that the attitude of the body plays an important role in exploration for magnetic iron ore bodies of tabular shape. A maximum effect arises for bodies striking in a magnetic east direction and dipping against the earth's magnetic field at the so-called critical dip, which is an angle whose value is approximately equal to the complement of the magnetic inclination of the area. In such a special case, because of nearly compensating polarities, the ore body lying at depth might give no observable magnetic anomaly.

In the Iron Springs district the critical dip would be expected to be about 26° in a magnetic south direction. As this value approximates the dip of the Milner ore body, as well as that of any ore body that might conceivably exist in the West Extension area of Desert Mound, the problem caused by the critical dip must be considered in the geophysical interpretation of the Desert Mound area.

48/ Peaks A and B are caused by buried well casing left in the holes.
49/ Wells, Francis G., work cited in footnote 5, p. 492.
50/ Stearn, Nole H., A Background for the Application of Geomagnetics to Exploration: Am. Inst. Min. and Met. Eng., Geophysical Prospecting, 1929, p. 335.

Despite this difficulty, however, an Askania magnetometer with a sensitivity such as that used in the present surveys probably would detect any ore body of economic size lying within 400 feet of the surface in the Desert Mound area for the following reasons:

(1) The strike of an ore body in the West Extension area would be geographic east rather than magnetic east. Because the magnetic declination of the Iron Springs district is about 16°, the horizontal magnetization effects of a large ore body should be large enough to be reflected in the vertical magnetometer readings.

(2) The Milner ore body, even though it dips at or near critical dip, gives a pronounced anomaly.

Although a near-surface ore body can probably be detected, the southerly dip and easterly strike of any ore body in this area probably will conspire to diminish greatly the magnitude of the anomaly. Accordingly, a small anomaly which might be disregarded in other areas must be interpreted cautiously in this area.

Drilling Results. - In the area lying immediately west of the Milner ore body and of fault A no anomaly was found that would suggest the existence of a commercial-size ore body within 400 feet of the surface. However, on the strength of geologic interpretation inclined hole H-24 was drilled and encountered 15 feet of ore at a hole depth of 457 feet, or a vertical depth of about 400 feet.

Anomaly GR

The circular anomaly GR (see fig. 22) is a newly discovered anomaly lying about 1,400 feet south of the Milner pit in an area completely covered with alluvium. It may or may not be significant that fault B, if extended southward, passes along an apparently local magnetic spur of the anomaly and then through the central part of the anomaly. The lack of geologic control in the area makes testing of the anomaly risky. In particular, it is not known whether the anomaly lies north or south of the possible westward continuation of the Claron-Pinto fault. However, in the later development of the district, if a search is being made for deep-lying ore bodies, this area might be attractive.

Anomaly GQ

Anomaly GQ lies in the general area of traverse 14.00E, which is covered with alluvium. Two shafts and Utah Iron Ore Corp. hole M-14 encountered ore beneath the anomaly, which indicates that the anomaly is caused by replacement ore lying at or near the monzonite-Homestake contact. Though small, the ore body probably has some commercial importance.

Anomalies Over Monzonite

Anomalies GN and GP. - The area lying northeast and east of the base of the main Desert Mound ridge is covered largely with a thin veneer of alluvium, although in places small exposures of monzonite are to be found. Anomalies GN and GP lie along a southeastward-trending mineralized zone in the monzonite and probably are caused by very shallow magnetite veins of doubtful commercial importance.

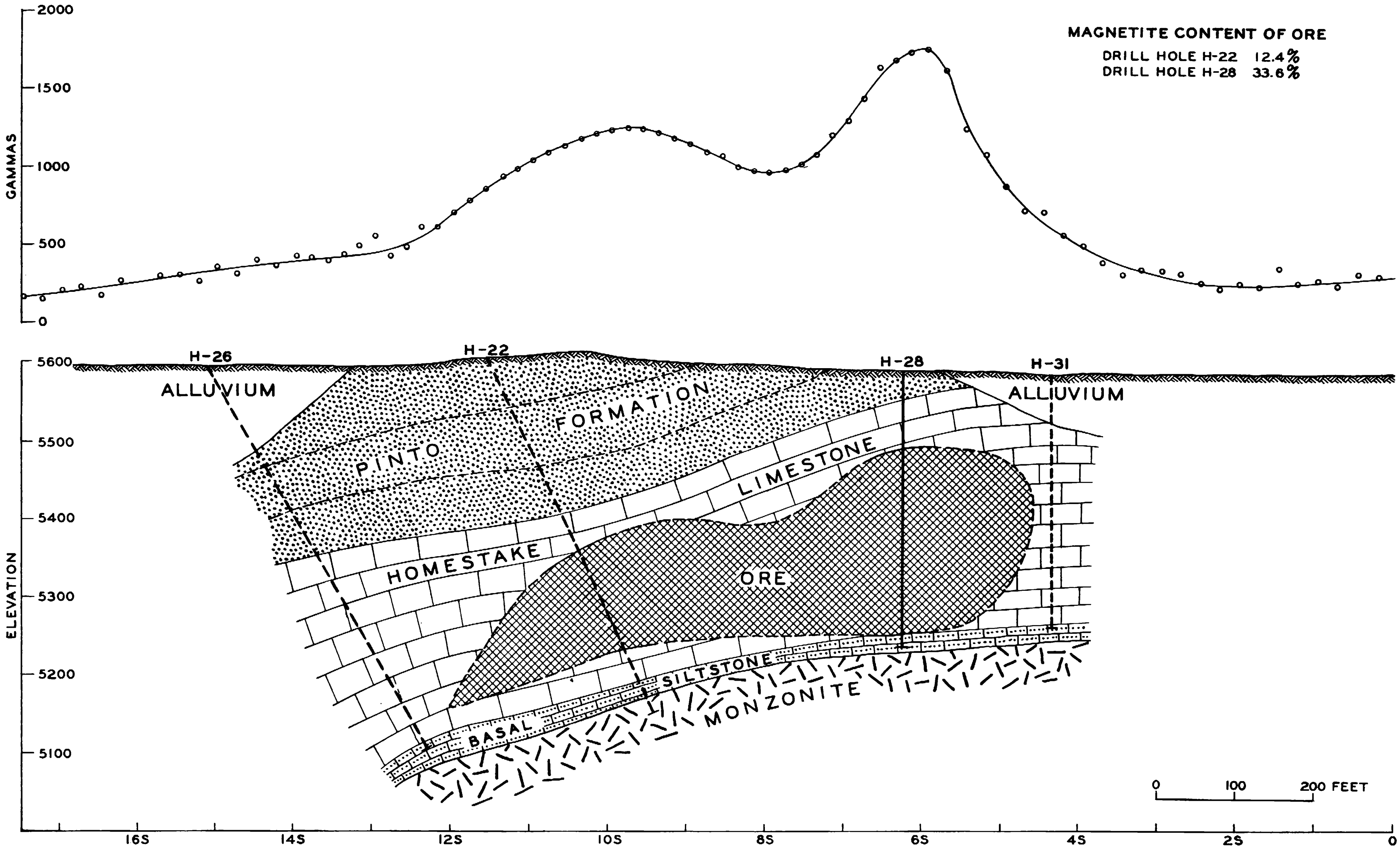

Figure 26. - Magnetic profile and geologic cross section along traverse 39.00 W, Thompson ore body, Desert Mound area, grid 19, showing discovery hole, H-22. (Topography and geology after W. E. Young.)

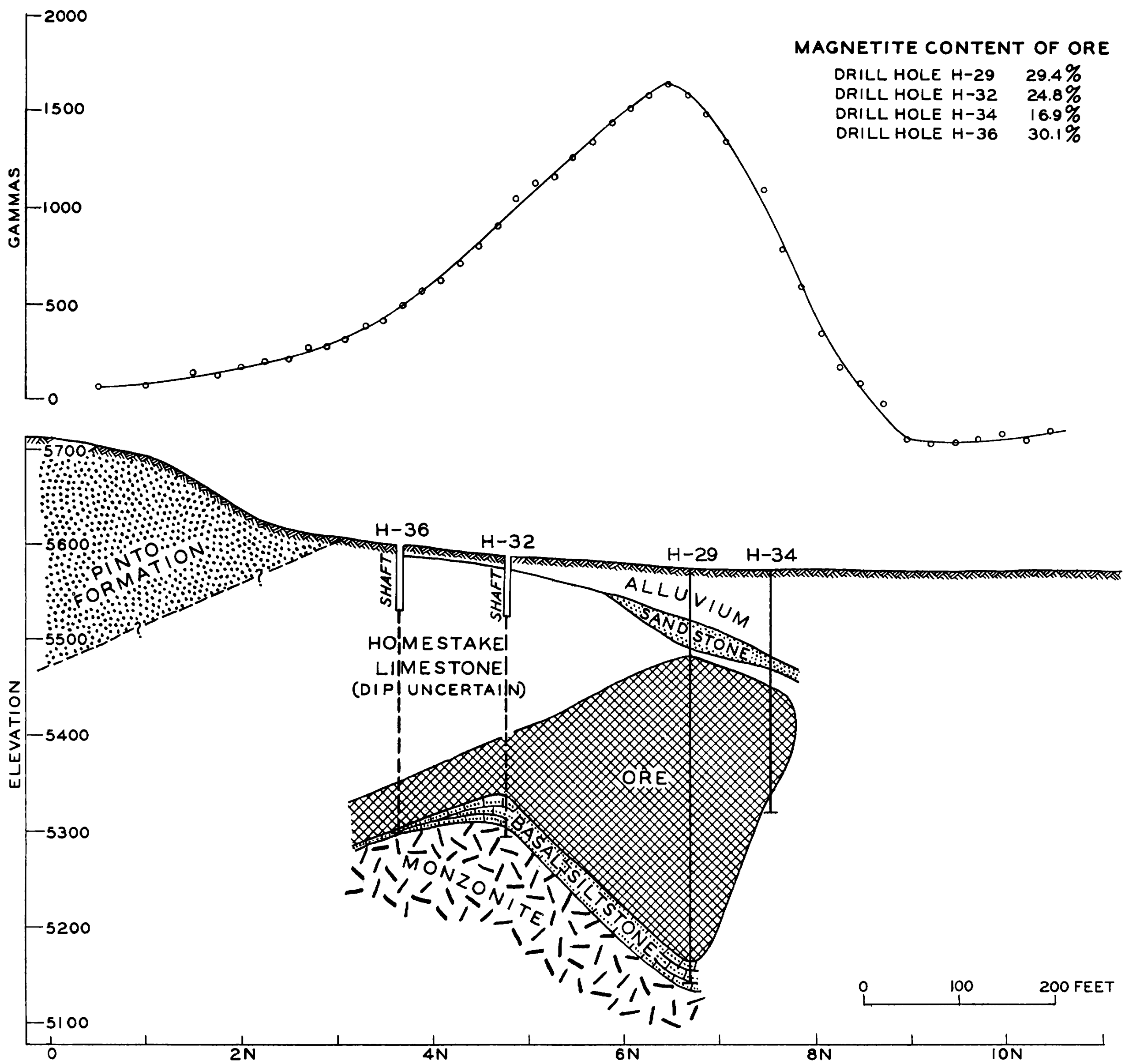

Figure 27. - Magnetic profile and geologic cross section along traverse 28.00 W, Short Line ore body, Desert Mound area, grid 19. (Topography and geology after W. E. Young.)

Anomaly GM. - Originally discovered by a magnetometer survey made by Sargis, anomaly GM (also known as the King ore body) was tested by Utah Iron Ore Corp. holes M-59 to M-65, inclusive. The grade of the ore penetrated in the holes was highly variable and averaged too low to be commercially important without beneficiation. It is not known whether the mineralization is confined to the monzonite alone or whether roof-pendant fragments of sedimentary rock may have been replaced with ore.

Anomaly GL. - Anomaly GL, representing a new discovery (also known as the Little Jim ore body), lies between the Short Line ore body and anomaly GM. The possibility that the anomaly might be due to magnetite that had replaced a block of sedimentary rock existing as a roof pendant appeared great enough to justify one test hole. Hole H-27 was therefore drilled and penetrated alternate layers of ore and monzonite, as well as of ore and two layers of altered sedimentary rock. No massive ore body was found, and the average grade of the ore probably is too low to be commercially important without beneficiation. The existence of altered sedimentary rock fragments suggests that some of the ore may have been formed by the replacement of the assumed roof-pendant fragments.

Thompson Deposit

Geology. - The Thompson ore body, which is not exposed at the surface, lies about 100 feet beneath the low hill of Pinto sandstone lying one-half mile west of the Milner pit. Here the exposed Pinto sandstone strikes east and dips about 20° S. A northward-trending fault may exist in the swale lying between this sandstone hill and the main West Extension ridge to the northeast. Geologic evidence of possible strong mineralization in the Homestake formation at depth is to be found in the existence of (1) nonmagnetic,51/ macroscopic martite crystals, which are found locally disseminated in the sandstone on the hill, and (2) joints and fractures, which are impregnated with magnetite and hematite.

Results of Magnetic Survey. - The Thompson anomaly is elongate in a north direction and shaped like a Cassinian oval with peaks on its north and south ends. To obtain the exact shape of the anomaly, both northward-and southward-trending magnetic traverses, spaced 100 feet apart, were surveyed.

The size of the anomaly is not pronounced. As any ore body here would be expected to lie at or near critical dip, however, the anomaly appeared strong enough to justify drilling.

Drilling Results. - Inclined hole H-22, the discovery hole which was located on the basis both of the magnetic anomaly and of the geologic evidence of mineralization, penetrated 147 feet of ore beginning at a hole-depth of 270 feet (see fig. 26).

The locations of the remaining test holes in the Thompson area were made largely on the basis of the geophysical results. Inclined hole H-26, which was drilled to test the down-dip extent of the ore body, encountered no ore. That this hole might lie at

51/ Several hand-sized specimens of sandstone that were heavily impregnated with martite crystals showed no observable deflection when brought close to the magnetometer.

or near the south limit of the ore body was anticipated prior to the drilling. Vertical hole H-28, which tested the north peak of the anomaly, penetrated 235 feet of ore beginning at a depth of 102 feet. Vertical hole H-31, which was drilled to delimit the north extent of the ore body, encountered no ore. It probably lies near the north edge of the ore body. The results of this hole substantiates the indication that the Short Line and Thompson ore bodies are not continuous.

Vertical hole H-33, which was drilled to delimit the west extent of the ore body, penetrated 86 feet of ore beginning at a depth of 314 feet. The hole probably lies within a few tens of feet of the west edge of the ore body.

Vertical hole H-35, which was drilled to delimit the east extent of the ore body, encountered no ore. The hole missed the east edge of the ore body probably by less than 50 feet and possibly by less than 25 feet. The results of this hole indicate that any thin blanket of ore possibly extending westward from the area of hole H-24 is not continuous with the Thompson ore body.

The existence of a magnetic saddle between the two magnetic peaks probably is caused by a decrease in breadth and width of the ore body in its central part, but the ore is thought to be continuous. The geophysical and drilling results show that the Thompson ore body is one of major size.

Area West of Thompson Deposit

In the alluvium-covered area west of the Thompson deposit magnetometer readings were taken along the following large-scale reconnaissance traverses: (1) Traverses 48.00W and 54.00W, and (2) 6.00S line as far west as 59.00W (see fig. 5). No large anomaly that suggests the existence of an ore body was found in the area. However, the general area deserves additional geophysical exploration of the large-scale reconnaissance type.

Short Line Deposit

History of Discovery. - Forty years ago Leith and Harder had found and mapped the fault, fault A, lying at the west end of the Milner ore body. In 1930 S. G. Sargis, working for the private geophysical firm of Mason, Slichter & Gauld, thinking that the fault may have caused a northward displacement of the favorable zone within which the Milner ore body was formed, made a detailed magnetometer survey in the area northwest of the Milner pit and found a large magnetic anomaly.

As confirmed in the present survey, the anomaly starts about 600 feet northwest of the Milner pit and extends westward about 2,100 feet. A distinct magnetic high exists at either end of the magnetic zone, with a saddle in the center. Sargis and Slichter considered the anomaly a favorable prospect for developing an ore body of major size, made quantitative estimates of the depth and possible size of the magnetic body, and recommended drilling within the anomaly.52/

In the 1930's the Utah Iron Ore Corp. did a large amount of development drilling within the anomaly, but presumably for reasons of claim ownership its drilling was

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52/ Letter from S. G. Sargis and Prof. L. B. Slichter.

confined to the area of the saddle and east thereof. Three northward-trending cross sections, with holes spaced 50 feet apart, were drilled on traverses 16.00W, 20.00W, and 24.00W, and five other prospect holes were drilled in the eastern part of the anomaly. The existence of a large ore body, called the Short Line ore body, was proved, and the quantitative estimates of depth and width of the magnetic body were in excellent agreement with the drilling results.53/ Wells' published estimate of 2,000,000 tons for this ore body54/ applies only to ore actually indicated by the drilling in the eastern half of the anomaly.

Geology. - The Short Line ore body lies at a depth of about 100 feet in an area completely covered with alluvium, the alluvium attaining a thickness of 50 to 100 feet in the area above the axis of the ore body. The drilling shows that the cross section of the ore body along traverse 20.00W probably is shaped approximately like an inverted isosceles triangle. As hole M-52 ended in ore at a depth of 330 feet, the vertical thickness of the ore exceeds 250 feet. The cross section along traverse 24.00W in the area of the magnetic saddle shows the ore body there also to be roughly triangular, though smaller than along section 20.00W.

Results of Magnetic Survey. - The predicted location of the apex of the magnetic body (see fig. 22), as indicated by the magnetic data, essentially coincides with the central axis of the ore body as revealed by the drilling in the east half of the anomaly. Throughout the east half of the Short Line anomaly the shape of the magnetic profiles along the northward-trending traverses is irreconcilable with a thick, tabular ore body dipping gently north or south but is in accord with a vertical or steeply dipping body, or a symmetrical body such as that indicated by the results of the drilling to date. The Utah Iron Ore Corp. test holes probably delimited the north and south extents of the east half of the main ore body. If the north edge of the ore body is cut by an eastward-trending fault that has displaced the Homestake formation downward on the north side of the fault so that any replacement ore might lie at a greater depth than the Short Line ore body, such an ore body lies too deep to produce a recognizable magnetic anomaly. Hole M-54 showed that a thin bed of probable replacement ore, about 15 feet thick, extends southward at depth in the area of traverse 20.00W. The outward bulge of the magnetic contours on the south side of the anomaly in the general area of traverse 20.00W justifies deepening hole M-50 until monzonite is encountered, to ascertain whether this bed of ore extends down-dip to the south. The result of this hole may help to clarify the problem of whether a thin bed of ore may extend between the areas of holes M-54 and H-24.

The magnetic high constituting the west half of the Short Line anomaly indicated a westward continuation of the ore already proved to the east. The trend of the west half of the magnetic anomaly suggests that the strike of the ore body in this part swings gently southward. Although the pronounced asymmetry of the magnetic profiles in the west half is irreconcilable with a thick, tabular ore body dipping gently to the north, it is reconcilable with a vertical or southward-dipping ore body. In this case, the indicated location of the apex predicted before Bureau of Mines drilling in the area lies necessarily north of the peak of the magnetic response curve, owing to the transverse magnetization effects of the earth's magnetic field.

53/ Letter from S. G. Sargis.
54/ Wells, Francis G., work cited in footnote 5, p. 494.

Insofar as the ore alone was concerned, the excellent geologic control provided by the earlier drilling permitted a reliable correlation of the magnetic and drilling results in the east half of the ore body. By carrying this correlation westward and applying it empirically to the west half of the anomaly, only a few key test holes were needed in the west half to give a large amount of information about the ore body.

Drilling Results. - In the Short Line area the holes drilled by the Bureau of Mines were located largely on the basis of the geophysical results. Vertical hole H-29, which lies on the predicted apex of the magnetic body, penetrated 316 feet of ore beginning at a depth of 95 feet (see fig. 27). Vertical hole H-30, lying on the indicated apex, penetrated 96 feet of ore, beginning at a depth of 195 feet. Vertical holes H-32 and H-36, which were drilled to test the southerly extent of the ore body, penetrated 57 and 49 feet of ore, respectively, beginning at depths of 191 and 247 feet, respectively. Vertical hole H-34 penetrated 107 feet of ore, beginning at a depth of 124 feet.

Problem of Position of Short Line Ore Body. - Any present attempt to explain the structural position of the Short Line ore body is limited largely by insufficient drilling information. Several features of the magnetic anomalies in the area may assist final solution of the problem, however.

The Short Line anomaly, if moved southward about 1,000 feet, would completely fill the area between the Thompson and Milner anomalies. Following Mackin's suggestion that separate blocks constitute the main Desert Mound ridge, the writer postulated that, in the area west of the Milner block, lies what may be called the Short Line block, which is offset northward relative to the Milner block and Thompson block. A northward-trending fault, which lies east of the Thompson ore body and west of the Short Line ore body, is also postulated. The horizontal displacement along the fault may be small, yet enough to control the mineralization. Thus the area embracing Desert Mound proper and the West Extension area comprises possibly a total of six blocks, which are separated by northward-trending faults or shear zones.

The drill holes in the Short Line area show that the monzonite lying beneath the southward-dipping, thin bed of ore that extends southward from the main Short Line ore body is much shallower than the monzonite lying directly beneath the deeper, triangular main mass of ore (see fig. 27). Two different geological possibilities can explain these facts. One possible explanation is that an eastward-trending, asymmetrical arch or fold, cored by monzonite, exists. In this case the thin, gently southward-dipping bed of ore would constitute the mineralization on the gentle limb of the anticlinal fold, and the main part of the ore body would represent the mineralization on the steeper limb. Another possible explanation is that the deeper, triangular main mass of ore may be a block of mineralized Homestake limestone that was faulted downward relative to the limestone exposed in the two shafts where holes H-32 and H-36 were drilled, the faulting having taken place along an eastward-trending, northward-dipping fault. It is possible, in addition, that a combination of arching and faulting, in the manner described here, may have occurred. The southerly dip of the beds indicates that arching, caused by intrusion of the monzonite, has occurred; but the pertinent question here is whether the crest of the arch lies at or near the ore body.

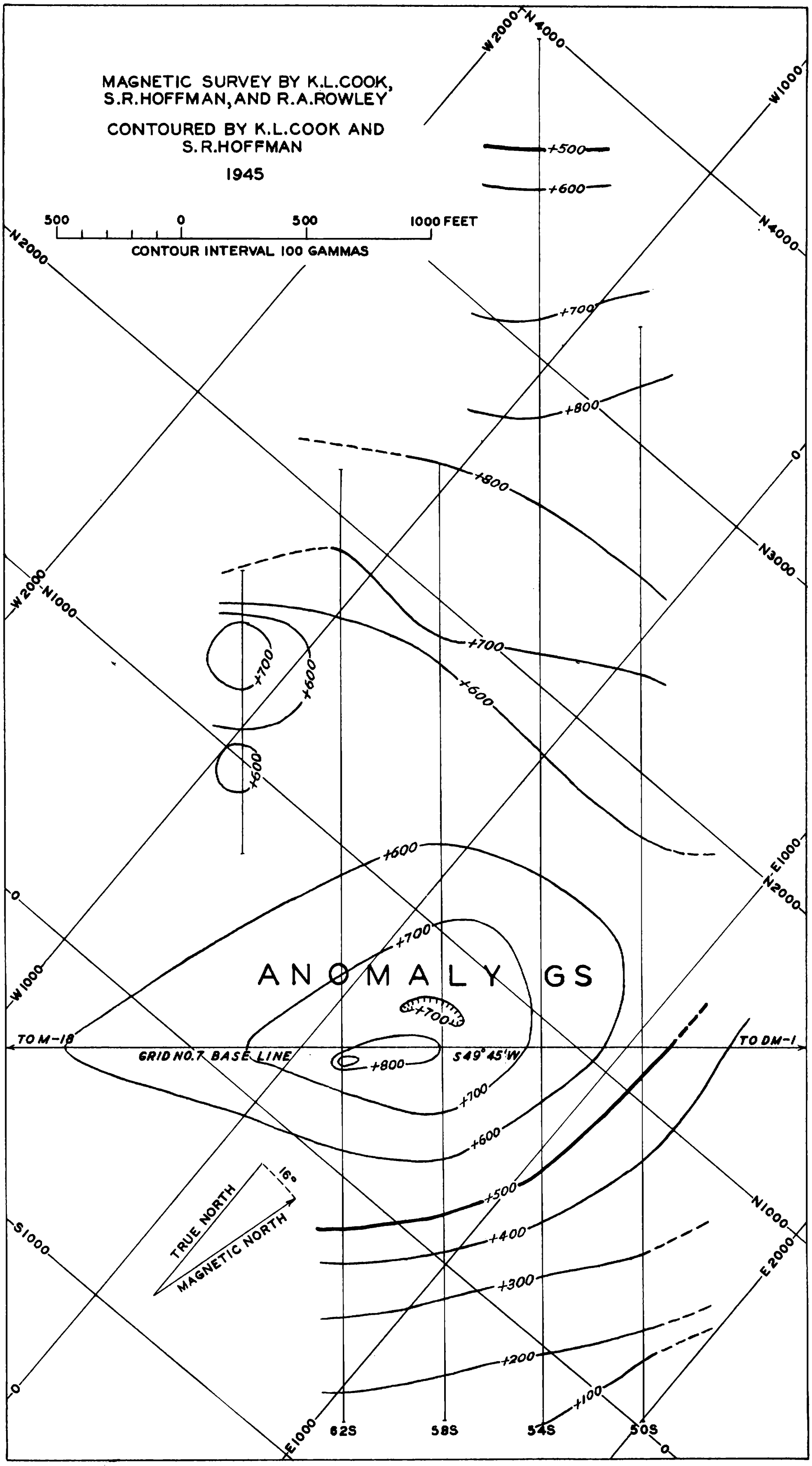

Figure 28. - Magnetic map of a reconnaissance survey of the northeastern part of grid 7, Desert Mound area, Granite Mountain.

Summary. - The geophysical and drilling results show that a continuous mass of ore exists beneath the west half of the Short Line anomaly. Thus the Short Line ore body, composed of a continuous mas of ore over 1,600 feet long, constitutes a deposit of major size.

Eastern Part of Grid 19

The eastern part of grid No. 19 comprises traverses 26.00E to 110.00E, inclusive. In this area the exact depth to the Homestake formation is not known, but judging from its depth in the Armstrong area to the northeast, it may lie as deep as 1,000 feet or more. Although the monzonite-sedimentary rock contact is mineralized locally, no large anomaly that would indicate a near-surface replacement ore body was found in the area surveyed (see fig. 23).

Magnetometer Grid 7

Magnetometer grid 7 comprises (1) a base line 5-1/2 miles long lying between triangulation stations DM-1 on Desert Mound and M-18 at the Homestake Mine (see fig. 3) and (2) five traverses spaced at 400-foot intervals between 50.00S and 66.00S (see fig. 28). Except for its extreme northeast end, the long base line lies over desert alluvium. The traverses likewise lie in an area covered with alluvium.

Results of Magnetic Survey. - A low, broad anomaly (anomaly GS) exists in the area between traverses 50.00S and 70.00S. It may be due either to (1) variation in the magnetic susceptibility of the underlying rocks, (2) a near-surface mass of igneous rock, or (3) a deep-lying ore body. At present either of the first two possibilities seems more probable.

Though readings taken at 100-foot intervals along the base line of grid No. 7 show no pronounced anomaly south of traverse 66.00S that suggests the existence of an ore body, additional large-scale magnetic reconnaissance measurements in the desert alluvium between Granite Mountain and Iron Mountain may be justified.

MAGNETIC SURVEYS OF IRON MOUNTAIN AREA

Magnetometer Grids in Iron Mountain Area

Iron Mountain was more than half encircled by a system of overlapping magnetometer grids, which lie chiefly along the monzonite-sedimentary rock contact at the west, north, and northeast margins of the mountain (see fig. 6). Starting with grid 20, which lies in the Milner Hill area, and going clockwise around Iron Mountain, the successive grids are to be found in the order listed below:

Grid 20
Grid 18
Grid 16
Grid 17
Grid 5
Grid 3

All are overlapping grids, except grid 3, which lies apart from the others on the south side of Iron Mountain.

General Geology of Iron Mountain Area

Along the south and east margins of the Iron Mountain intrusion the Homestake limestone is exposed essentially all the way from the Burke deposit to the Homestake mine (see fig. 3, A and B). On the west and northwest margins the Pinto sandstone lies in direct contact with the monzonite for 3-1/2 miles. The extreme north margin is bordered by alluvium. Blocks of the Homestake and Pinto formations form roof pendants, particularly in the north central part of the intrusion. Most of the blocks are less than 1,000 feet in their longest horizontal dimension, but the roof pendant on which the Comstock and Mountain Lion group of claims are located is 1 mile long and 2,000 feet wide.

The main replacement ore bodies that crop out along the margin of Iron Mountain are the Milner Hill deposit on the west; the Homestake and Pot Metal deposits on the east; and the Blowout, Black Hawk, Pinto, Burke No. 2, Burke No. 3, and Duncan deposits on the south and southwest. Wells55/ reports that a large ore body, now called body A and B, lies at depth south of the Black Hawk, the body having been discovered by a magnetometer survey made by private parties. The main replacement ore bodies existing as roof pendants are the Mountain Lion, Comstock, and Dear. Several ore bodies of the vein type exist within the monzonite. These include the Tip Top, Chesapeake, Excelsior, and Black Magnetic deposits.

Only four of these deposits have been mined on a large scale. In 1936 the mining of the southwest end of the Black Hawk ore body was begun by the Columbia Iron Mining Co. The mining operations of this company were later shifted to the Burke No. 2 and Burke No. 3 ore bodies, from which a large amount of ore was taken during World War II. The Duncan ore body was mined during World War II by the Colorado Fuel & Iron Co.

Magnetometer Grid 20

Magnetometer grid 20 covers a large part of the southwest border of Iron Mountain. Starting at a point lying northwest of the Duncan ore body, the grid (see fig. 29) extends 6,800 feet northward along the monzonite-sedimentary rock contact and thus embraces the area of the Burke ore bodies and the Milner Hill area.

During the early 1930's S. G. Sargis made a magnetometer survey of the central and northern, but not the southern, parts of the grid. The detailed results of this survey were not made available to the Bureau of Mines.

The grid in the present work was laid out so that it coordinates essentially coincide with those of the Columbia Iron Mining Co.56/ Magnetometer readings were taken along both eastward-trending traverses and northward-trending lines.57/

55/ Wells, F. G., work cited in footnote 5, p. 496.

56/ The two coordinate systems were made to coincide originally by arbitrarily choosing 40.00N as a reference point on the already brushed 42.00W line, which was used as an auxiliary base line to the north, and as far south as 17.00N. South of 17.00N, the 49.58W line was used as an auxiliary base line. The discrepancy between the Columbia and Bureau base lines is only a few minutes of arc.

57/ For reasons of claim ownership some areas in the grid were not surveyed. However, in places readings were taken along brushed lines that form the outer boundaries of claims.

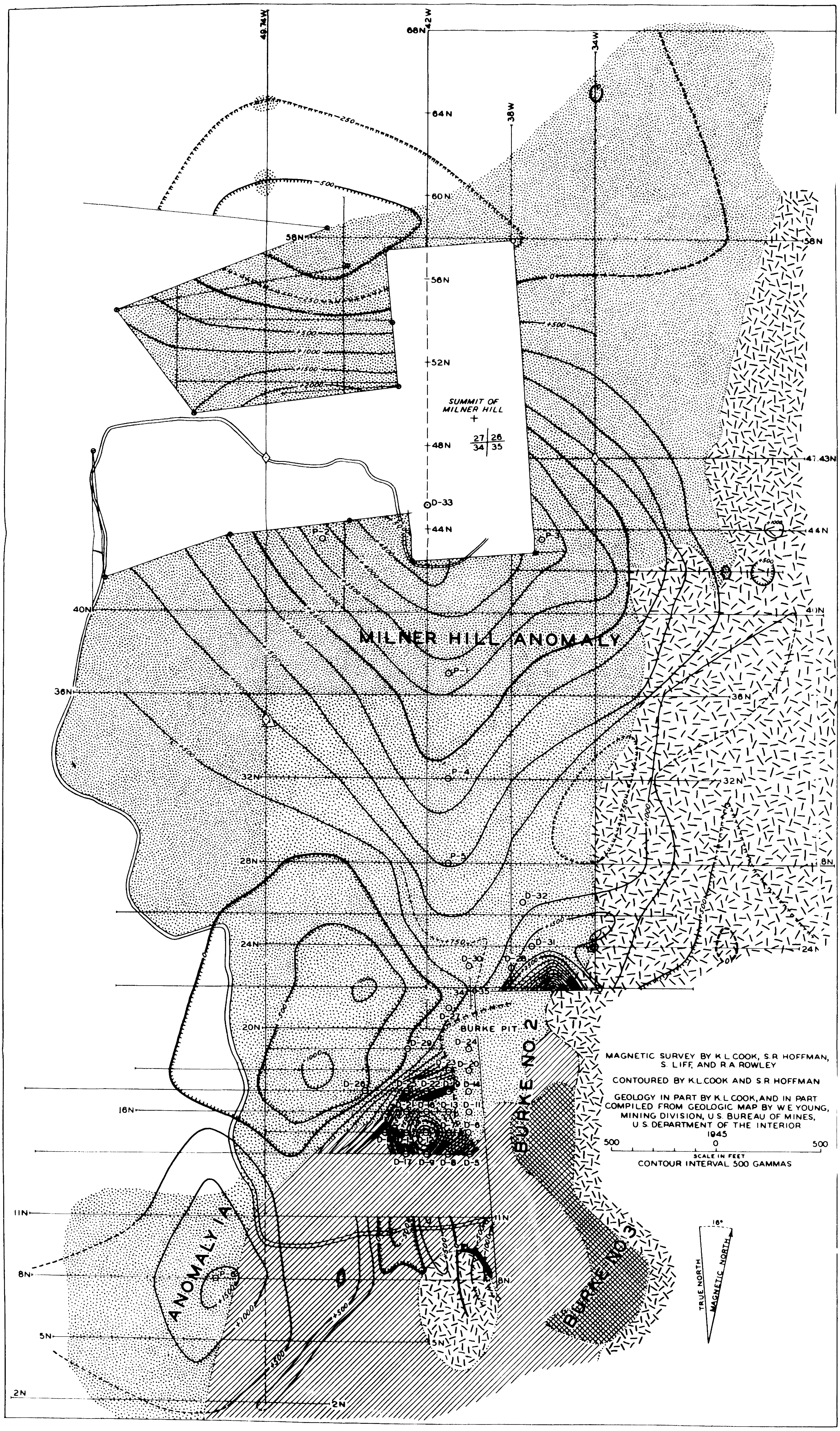

Figure 29. - Magnetic and geologic map of grid 20, Milner Hill area, Iron Mountain.

Geology 58/

The southwest margin of the Iron Mountain intrusion is characterized by roof pendants and by irregular fingers and plugs of monzonite that have intruded the Homestake limestone. The area was subject to intense mineralization, and some of the largest known ore bodies of the district were formed here.

The southern part of grid 20 lies within the area of irregular plugs. Here, in the vicinity of the Burke ore bodies, the limestone lying in contact with the monzonite strikes generally north and dips 20°-40° W. One of the monzonite plugs, which is about 500 feet long and 300 feet wide, is exposed about 200 feet west of the Burke No. 3 ore body and is completely surrounded by Homestake limestone. At the northeast border of the plug, the limestone at the contact is heavily mineralized locally with ore. The monzonite-limestone contact on the west side of the plug is obscured by float, but several exposures of limestone farther to the west indicate that the limestone probably extends for a horizontal distance of about 600 to 800 feet west of the plug.

As shown on Leith and Harder's map, the Burke No. 2 and No. 3 ore bodies, before they were mined, were exposed continuously over a strike distance of about 1,600 feet. During 1941-43 development drilling with 100-foot centers was done on these deposits by the Columbia Iron Mining Co. and the Federal Bureau of Mines, the Bureau having drilled 32 holes. The drilling showed that the ore bodies dip about 45° W. and that they are separate ore bodies at depth, the Burke No. 3 body lying at a lower elevation than the Burke No. 2.

From the geology alone it appears that the above-mentioned monzonite plug would probably delimit the westward, down-dip extent of the Burke No. 3 ore body and that a similar plug lying immediately south of the exposed ore would delimit its south extent along the strike. 59/ The Burke No. 2 ore body, not being bounded by monzonite in this manner, extends farther along the strike and farther down-dip than the Burke No. 3. At the north end of the Burke No. 2 ore body the Homestake limestone wedges out northward, and the Pinto quartzite comes in direct contact with the monzonite. The quartzite strikes north and dips 30°-60° W. Concerning this area lying north of the Burke No. 2 ore body, Leith and Harder 60/ state:

> It will be noted that on the western side of Iron Mountain the Cretaceous quartzite comes directly in contact with the andesite 61/ at an elevation considerably higher than the limestone-andesite contact on the southern and eastern sides of the laccolith where the ore is exposed. Ores are found cementing brecciated quartzite, but do not constitute important

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58/ The geology discussed in this section, particularly for those claim areas on which rights of trespass were not granted by the private companies, is based largely on Leith and Harder's map of the south and west slopes of Iron Mountain. (Leith, C. K., and Harder, E. C., work cited in footnote 3, plate VI.)

59/ As the ore is known to dip under the monzonite in places in the district, the criterion that a monzonite outcrop terminates an ore body, though true for the Burke No. 3 ore body, is not always reliable.

60/ Leith, C. K., and Harder, E. C., work cited in footnote 3, p. 88.

61/ Now classified as monzonite.

deposits......There is nothing in the supposed origin of the ores to preclude the possibility that ore deposits may be found beneath the quartzite along the limestone-andesite contacts, especially farther down on the steeper slopes of the andesite. If the deposits are there, it may be pointed out that their size has not been diminished by erosion.

As Leith and Harder[62] showed no fault on their map, they probably assumed that topography alone accounts for the pronounced wedging-out of the Homestake limestone at the north end of the Burke No. 2 ore body.

Results of Magnetic Survey

Burke No. 3 Ore Body. - The fact that the negative magnetic center associated with the Burke No. 3 ore body lies east of the monzonite plug indicates that (1) the Burke No. 3 ore body terminates east of the east edge of the plug and (2) probably no large ore body underlies the plug at shallow depth.

Burke No. 2 Anomaly. - Lying over the Burke No. 2 ore body, the Burke No. 2 anomaly consists of a highly positive magnetic ridge, which extends northeastward for about 1,800 feet. Its negative counterpart, lying on the down-dip side of the ore body, consists of a lesser, oval anomaly which, though comparable in extent, trends much more toward the north than does the positive ridge.

The drilling done by the Bureau of Mines delimited the down-dip extent of the ore body in its central part. Here, as seen in figures 29 and 30, the down-dip edge of the ore body lies approximately vertically beneath the zero-gamma contour, or where the magnetometer readings change from positive to negative. Owing to the relative uniformity of the physical factors involved, this excellent correlation is maintained for a distance of about 600 feet along the strike in the central part of the ore body. Owing to end effects, this correlation would not be expected to hold at the ends of the ore body.

According to the drilling results, the ore found in hole D-12 showed both a greater thickness and a higher magnetite content than the ore found in the adjacent holes D-7 and D-15 (see fig. 31). These facts may or may not explain the local positive center found over hole D-12 on the main magnetic ridge. Some additional ore may lie at a depth greater than that already penetrated by the drills. The inferred ore probably would not lie at the same stratigraphic horizon as the Burke No. 2 ore body but below it, for hole D-18 penetrated to the depth of this horizon and was barren. Furthermore, the drill logs of holes D-7, D-12, and D-13, on traverse 15.00N, indicate that the Lower Blue member of the Homestake limestone failed by about 50 feet or more to be completely penetrated by these drill holes. Therefore, it is possible that if vertical holes D-12 and D-18 were extended until monzonite is encountered, additional ore might be found.

The north end of the Burke No. 2 ore body was not definitely delimited by the drilling. Hole D-31 shows that the ore body extends northward as far as traverse 24.00N. It is doubtful whether the bulk of the Burke No. 2 ore body itself extends north of traverse 25.55N. Reasons for believing that a cross fault may exist at the

62/ Leith, C. K., and Harder, E. C., work cited in footnote 3, plate VI.

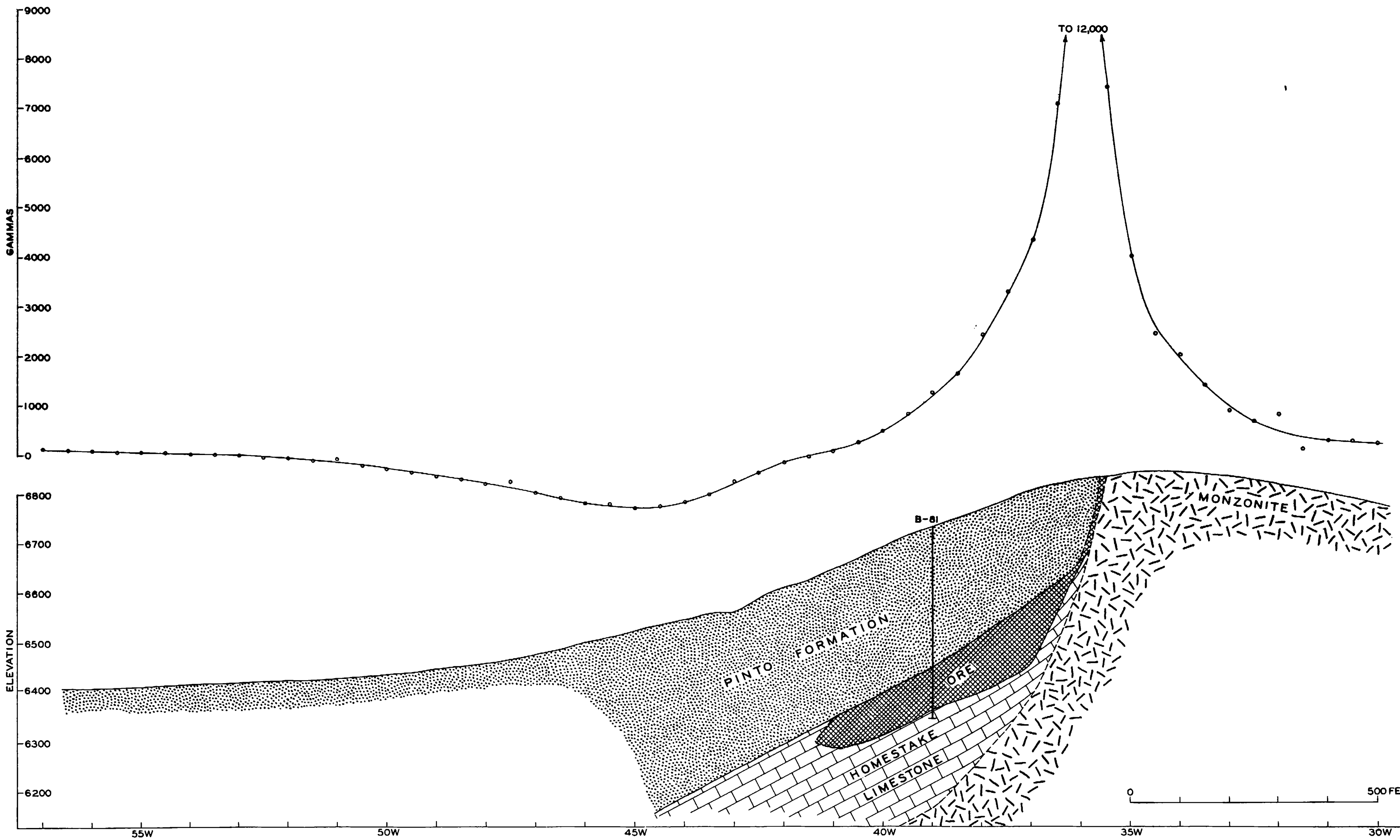

Figure 30. - Magnetic profile and geologic cross section along traverse 22.00 N, Burke No. 2 ore body, grid 20. (Topography and geology after W. E. Young.)

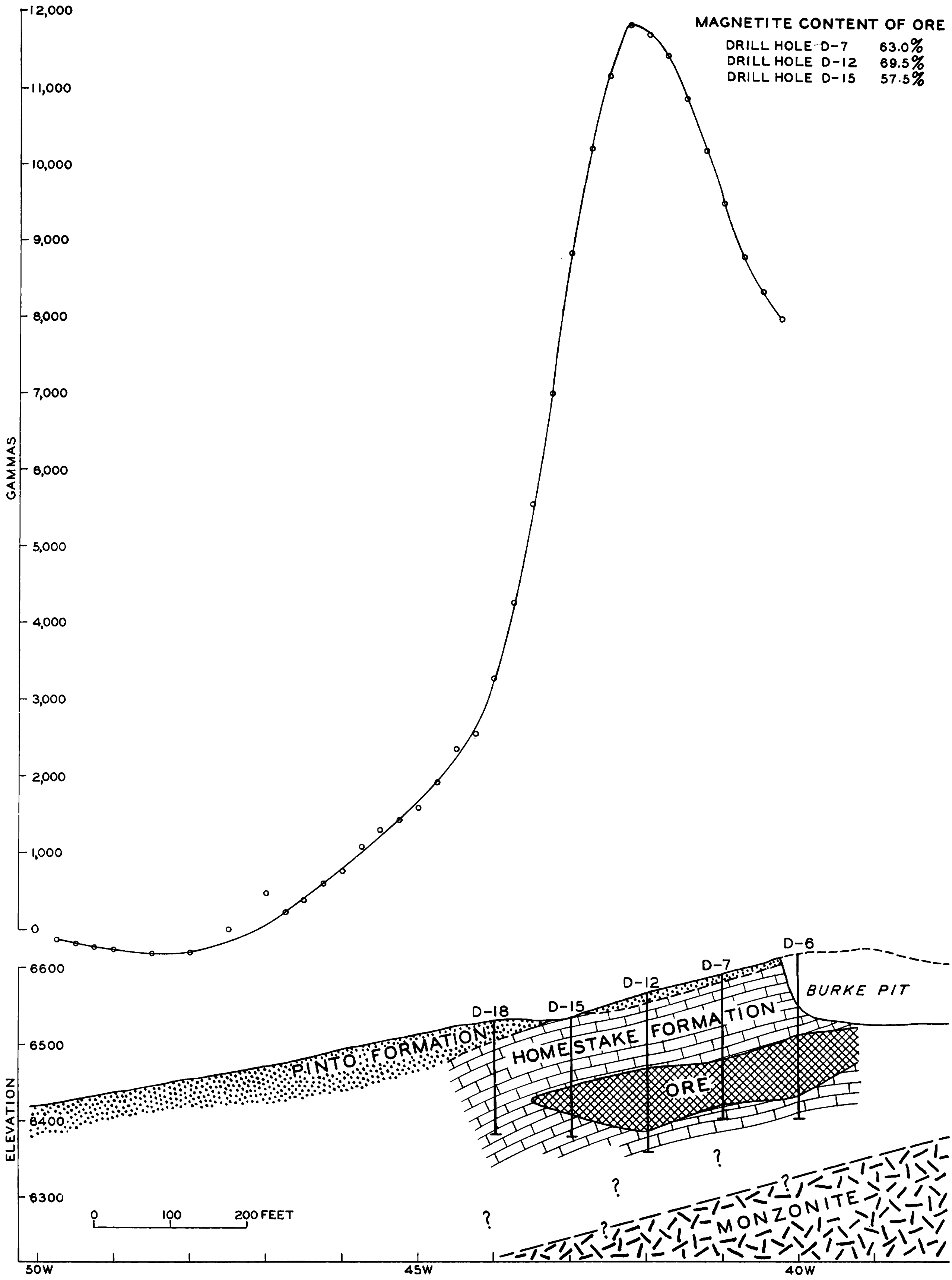

Figure 31. - Magnetic profile and geologic cross section along traverse 15.00 N, Burke No. 2 ore body, grid 20. (Topography and geology after W. E. Young.)

the north end of the ore body and that the northwest edge of the ore body may be continuous with the south end of the Milner Hill ore body are discussed later in connection with the Milner Hill anomaly.

Milner Hill Anomaly. - The pear-shaped Milner Hill anomaly, originally discovered by Sargis, is the largest and most extensive anomaly observed during the surveys of the Iron Springs district. It extends northward for about 3,000 feet and eastward for more than 3,000 feet. Lying about 800 to 1,000 feet west of the monzonite-quartzite contact, the northward-trending axis of the anomaly parallels both the contact and the strike of the quartzite. Complete closure of all contour lines, except possibly the +500-gamma contour line, probably would be obtained in the unsurveyed areas. A small, oval negative anomaly lies immediately north of the positive anomaly and is related to it.

Throughout the area covered by the positive anomaly, many exposures of quartzite and sandstone members of the westward-dipping Pinto formation are to be found. The only large outcrop of ore within the confines of the anomaly lies on top of Milner Hill and extends over an area of about 7,500 square feet. A large amount of ore float covers the slopes of Milner Hill, and in particular the west slope, where large ore boulders commonly 3 and often 6 to 10 feet in diameter constitute a mantle that extends far west of the hill itself. Although the thickness of the ore float is generally less than a few tens of feet, the large ore boulders produce a very jagged response curve. However, this erratic effect caused by the near-surface ore float is superimposed on an otherwise broad, smooth response curve of high intensity, which indicates a large amount of magnetite at depth.63/ The fact that the magnetic anomaly is not noticeably distorted by large changes in topographic relief in the area affords additional evidence that the magnetite causing the anomaly lies at great depth.

The south end of the Milner Hill anomaly is offset about 500 feet west of the north end of the Burke No. 2 anomaly. That the offset lies in the general area where the Homestake limestone wedges out suggests that a major cross fault or shear may exist - a structural change that may mark the north limit of the mineralization of the Burke No. 2 ore body and the south limit of the Milner Hill mineralization. The actual offset of the fault may be only a small fraction of the 500-foot offset in the anomalies and yet be sufficient to control the mineralization on either side of the fault.

Because hole D-30 penetrated 69 feet of low-grade ore that constitutes the northwestern part of the Burke No. 2 ore body, the ore may persist north of this hole to the vicinity of traverses 24.00N and 25.55N, where it may become an integral part of the mineralization associated with the Milner Hill anomaly. If this is so, it is doubtful whether the thickness of the ore in the general area of traverse 24.00N will greatly exceed 70 feet, for this area is a transition area between the Burke No. 2 and Milner Hill anomalies. In going north from traverse 24.00N, the thickness of any replacement ore in the Homestake limestone beneath the Milner Hill anomaly may exceed 70 feet and may increase northward.

63/ The smooth magnetic contour lines shown on the magnetic map were obtained by a "smoothing-out" process that discounts the effects of the near-surface ore boulders - effects that usually were recognized when 20-foot intervals were taken between magnetometer stations.

Bureau of Mines hole D-33, though lying probably several hundred feet southeast of the positive center of the Milner Hill anomaly, provides an excellent test of the anomaly. The hole was located on the basis of Sargis' magnetometer survey. In the hole unmineralized sandstone was encountered down to a depth of 591 feet. From depths of 591 to 705 feet the core showed veinlets of magnetite in fractures and breccia zones and zones of disseminated magnetite within the sandstone and siltstone. In the next 600 feet, from depths of 705 to 1,305 feet, most of the rock is partly mineralized with disseminated magnetite in sandstone and siltstone; and a dozen separate magnetic zones, averaging 25 feet in thickness and ranging from 30 to 60 percent in magnetite content, can be delineated and classified as low-grade ore. One zone, from depths of 970 to 1,035 feet, is 65 feet thick. Beginning at a depth of 1,305 feet, the drill penetrated 70 feet of medium- to high-grade ore, which is probably replacement ore in the Homestake limestone. The drilling was stopped in ore at a depth of 1,374 feet to permit replacing the small drill rig with a large rig. The project was terminated before the hole could be deepened.

The iron and magnetite contents of the core and sludge of this hole, taken from the drill log compiled by W. E. Young, are as follows:

(1) Including core and sludge, the calculated "weighted adjusted average" iron content from depths of 705 to 1,374 feet is 30.9 percent.

(2) The assay results of the core composite from depths of 590 to 1,374 feet show an average iron content of 25.0 percent and a magnetite content (by weight) of 45.2 percent.

(3) Including core and sludge, the calculated average iron content of the core composite from depths of 1,019 to 1,374 feet is 29.4 percent; and the average magnetite content of the same core composite is 48.8 percent.

Thus the hole shows that the central part of the Milner Hill anomaly is underlain by (1) about 600 feet of sandstone containing little or no disseminated magnetite; (2) below this, about 700 feet of heavily mineralized sandstone and siltstone which has an average magnetite content of about 45 percent and which may be regarded as low-grade ore; (3) and finally, at least 70 feet, and possibly much more, of replacement, medium- to high-grade, magnetite-hematite ore with a magnetite content of 50 percent or more, probably in Homestake limestone. Thus the observed magnetic response is caused by the combined effects of the magnetite in the sandstone and the magnetite in the replacement ore.

The problem of predicting the economic potentiality of the Milner Hill anomaly involves the basic principles and limitations of the magnetic method. The magnetic method gives no discrimination between a widespread magnetic body with a uniformly low magnetite content lying at shallow depth and a body with a higher magnetite content lying at greater depth. This lack of uniqueness and the lack of enough auxiliary geologic control at depth in the Milner Hill area seriously limit the predictions that can be made at present.

The anomaly indicates that the intense mineralization extends horizontally over a large area. In the district it has been demonstrated that intense magnetite mineralization in the Pinto formation increases the chance that ore will be found in the underlying Homestake limestone. The results of hole D-33 suggest that the entire

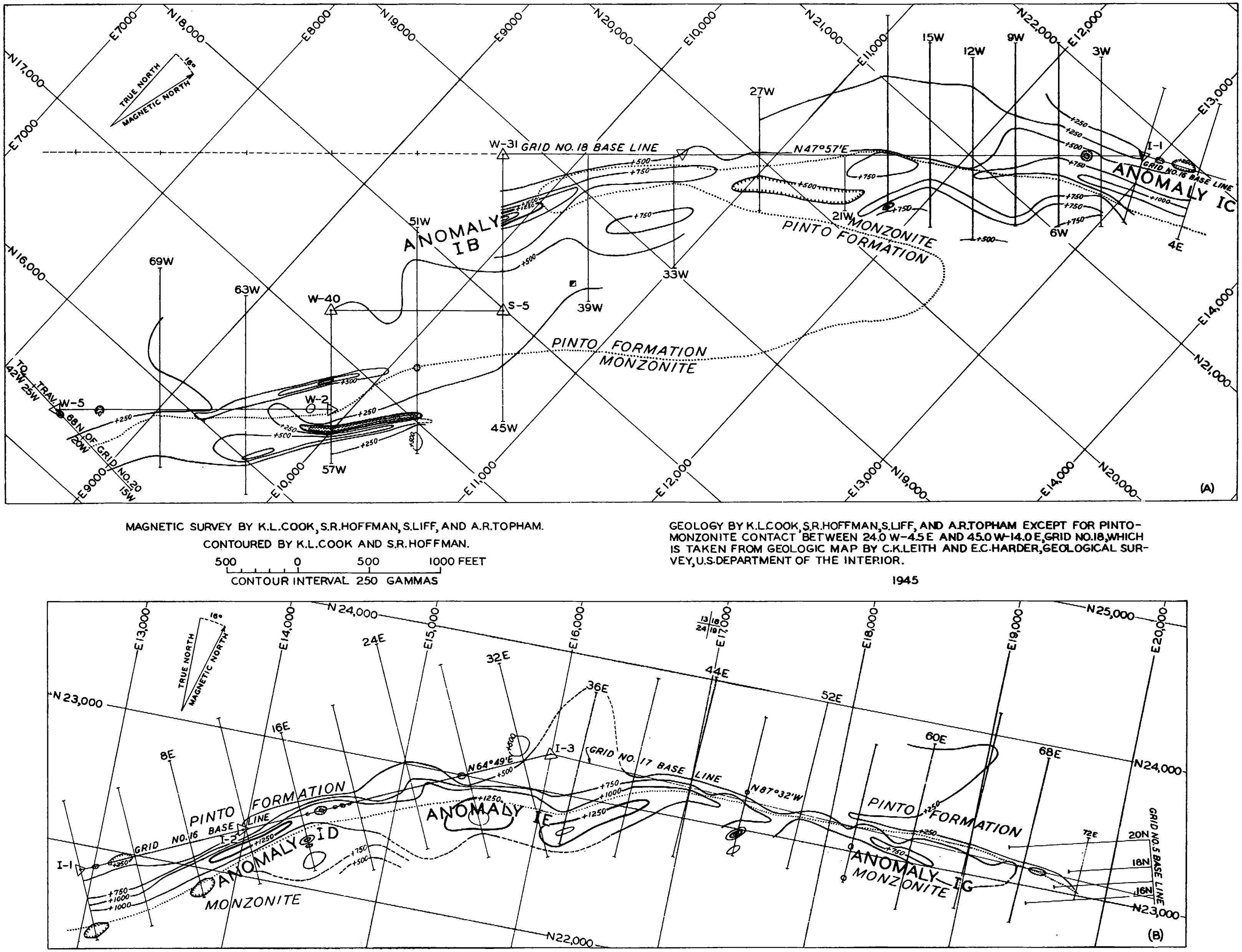

Figure 32. - Magnetic and geologic maps of reconnaissance surveys of (A) grid 18 and (B) grids 16 and 17, Iron Mountain.

thickness of Homestake limestone may be mineralized beneath the central part of the Milner Hill anomaly. It is probable that this ore, called the Milner Hill ore body, is not continuous with the pod of ore exposed on top of Milner Hill itself and is therefore probably an unexposed ore body. The anomaly is so well-defined that only a relatively few test holes will be necessary to ascertain the order of magnitude of its potential tonnage. If the ore in the Homestake limestone horizon is found to extend throughout the main part of the anomaly, the Milner Hill ore body may prove to be the largest in the Iron Springs district.

Anomaly IA. - Anomaly IA, lying at the southwest end of grid 20, represents a separate magnetic body that is not connected with either the Burke ore bodies to the east or the Duncan ore body to the southeast. This anomaly constitutes a new geophysical discovery.

The present reconnaissance survey shows that the eastern part of the anomaly is elongate in a north direction. Thus the strike of the magnetic body is about the same as the strike of the sedimentary rocks in the area. The anomaly is about 1,400 feet long along the strike, in its northern part is about 600 feet in width, and in its southern part widens down-dip to about 1,200 feet in width.

Although good exposures of Homestake limestone and Pinto sandstone are to be found in the area of the anomaly, no ore is exposed. The peak of the anomaly coincides approximately with the Homestake-Pinto contact and lies about 1,000 feet west of the above-mentioned monzonite plug. It is not known whether the magnetite mineralization causing the anomaly lies at depth on the west flank of the outcropping plug and is therefore genetically related to it or whether the mineralization may lie above a second, separate plug lying at depth.

Although the anomaly may be due to vein magnetite, the general geologic setting favors its interpretation as a replacement ore body whose apex lies 200 to 300 feet below the surface.

Magnetometer Grids 16, 17, and 18

Grids 16, 17, and 18, which cover the northwestern and northern margins of Iron Mountain, extend along the monzonite-Pinto contact for nearly 3 miles. Both grid 18, the south end of which joins grid 20, and grid 16 trend northeastward. Grid 17, the east end of which joins grid 5, trends eastward.64/ The grids consist of reconnaissance traverses taken from 300 to 600 feet apart (see fig. 32).

Geology

The Pinto sandstone is well-exposed throughout most of the area covered by the three grids. Ordinarily the exposures are numerous enough to determine the exact location of the monzonite-sandstone contact within a few tens or scores of feet. In some places, however, the location of the contact is not known within several hundred feet. In many places along the contact the sandstone is mineralized locally with specularite. No Homestake limestone is exposed in the area. Throughout grids 16 and 18, the strike of the sandstone is northeast, and the dip varies from 15° NW.

64/ Contrary to the usual convention, the traverse numbers of grid No. 17 (for example, traverse 36.00E) are made to follow consecutively the traverse numbers of grid 16).

to 45° NW. The monzonite-sandstone contact is regular throughout the area, except in the central part of grid 18, where a long, narrow, northeastward-trending finger of monzonite protrudes out into the sandstone for eight-tenths of a mile.

The results of hole D-33 indicate that the base of the Pinto sandstone probably lies at an altitude of about 5,200 feet in the Milner Hill area. On the assumption that no major stratigraphic breaks exist along the northwestern part of Iron Mountain, this altitude provides an index of the approximate location of the base of the Pinto formation within the area northeast of hole D-33. However, for continental deposits such as the Pinto sandstone great irregularities in thickness may be found over short distances along the strike, and therefore correlations are not altogether reliable.

In the area about three-fourths of a miles north of Milner Hill the Claron limestone, according to Leith and Harder,65/ lies normally on the Pinto sandstone. Accordingly, the sandstones exposed along the northwestern part of Iron Mountain probably constitute the upper or middle stratigraphic members of the Pinto formation.

The widespread distribution of the Homestake limestone throughout the district makes reasonable the assumption that the limestone underlies the sandstone in this area at a depth probably exceeding 500 feet and possibly exceeding 1,000 feet. Its location at depth depends on (1) the thickness of the overlying Pinto sandstone and (2) the dip of the monzonite-sedimentary rock contact on the flanks of the intrusion. On the one hand, a great thickness of overlying sandstone and a gentle, westerly contact dip would conspire to make the up-dip side of the limestone at depth lie many hundreds, and possibly thousands, of feet horizontally northwest of the exposed monzonite-sandstone contact. On the other hand, a thin sandstone and a steeply dipping contact might combine to make the limestone at depth lie nearly vertically beneath the contact.

Plan of Magnetic Survey

In view of the uncertainty of the location of the Homestake limestone at depth, the following plan for exploration of the area was adopted:

(1) Because the monzonite-sandstone contact would have to be surveyed to investigate the possibility of a steep contact and of a large body of ore lying almost vertically beneath the contact, it seemed desirable first to lay out a grid system with base lines near the contact and with short reconnaissance traverses crossing the contact.

(2) After the grids were laid out and magnetometer readings were taken across the contact, the extension of traverses and detailed surveys could be made wherever favorable results warranted. In any event, the extension southeast of traverses 15.00E to 39.00E, inclusive, was planned in order that the large reentrant of sandstone could be surveyed completely.66/

65/ Leith, C. K., and Harder, E. C., work cited in footnote 3, plate II.
66/ The sandstone constituting this reentrant may not be underlain by Homestake limestone at depth, however.

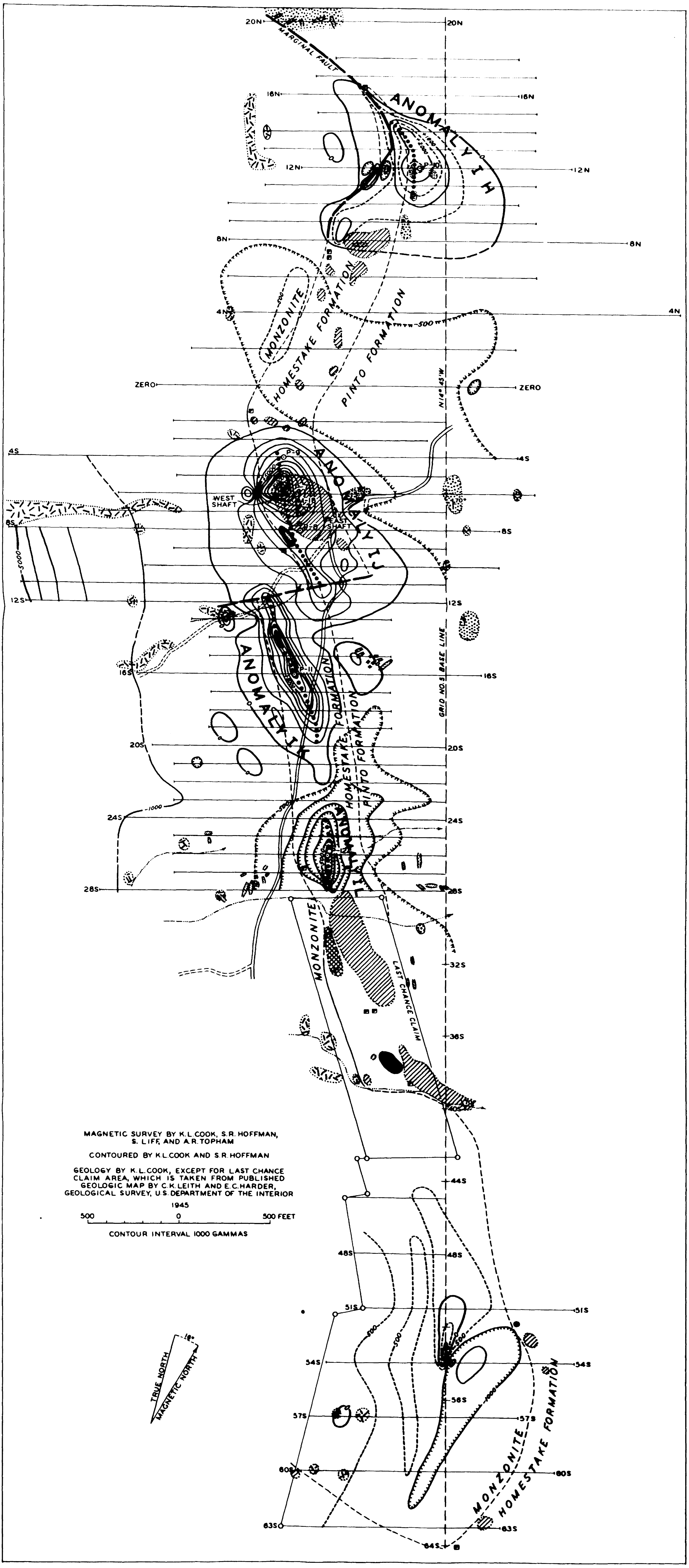

Figure 33. - Magnetic and geologic map of grid 5, Homestake mine area, Iron Mountain.

Results of Magnetic Survey

Time permitted execution of only the first part of this plan. The short reconnaissance traverses indicate that throughout the three grids the contact area is mineralized. On all but a few traverses, a recognizable anomaly is observed in the area of the contact.

In places where the peak of the anomaly lies over exposed sandstone or sandstone float, the anomaly is doubtless due to mineralization in the sandstone. Evidence of the mineralization is found locally in the macroscopic specularite crystals in the sandstone; and, judging from the magnetic results, some magnetite probably accompanies the specularite. Anomalies IC and ID fall in this category.

In places where the peak of the anomaly lies over monzonite float covering the steep slopes and where the location of the contact is not known within a few hundreds of feet, the anomaly may be due to mineralization in possible underlying sandstone or in the monzonite. Anomalies IE and IG fall in this class. Exposures of mineralized sandstone at 42.00E on the base line of grid 17 suggest that at least part of the magnetic response of anomaly IF is due to mineralization in the sandstone.

None of these anomalies observed in the immediate vicinity of the contact indicate that a large body of commercial ore lies within a few hundred feet of the surface. However, they show that mineralizing solutions penetrated the sandstone lying at or near the contact throughout most of the contact area of the three grids. This fact tends to increase the possibility that the Homestake limestone may also be mineralized at depth.

Anomaly IB lies in the vicinity of the tip of the monzonite finger and about 1,000 feet west of the main monzonite-sandstone contact. The readings on traverses 51.00W and 57.00W suggest that a low, broad anomaly, which perhaps constitutes the west flank of anomaly IB, may be found southwest of these two traverses. Too little work was done in the area to appraise its economic possibilities.

Summary. - The magnetic results suggest no point along the contact of the three grids where the risk of drilling would not be very great. Nonetheless, an ore body may lie at a depth of 1,000 feet, say, in the Homestake limestone - an ore body that may give an anomaly of only 500 gammas or less if the overlying Pinto sandstone is not heavily mineralized. Such an anomaly in this area probably would be masked largely or entirely by the magnetic effects of known near-surface mineralization found in the contact area.

In spite of these serious limitations additional magnetic work in grids 16, 17, and 18 appears justifiable.

Magnetometer Grid 5

Magnetometer grid 5, lying in the Homestake Mine area, covers the northeast margin of Iron Mountain and extends 1-1/2 miles along the monzonite-Homestake contact (see fig. 33). Detail work was done in the northern part of the grid, and reconnaissance work in the southern part.

In places within the grid the Homestake limestone and Pinto sandstone are well-exposed, but in other places they are covered over long distances along the contact with float or alluvium. On the geologic map (see fig. 33) the location of the monzonite-Homestake contact is inferred partly from the outcrops and partly from the geophysical data. The location of the Homestake-Pinto contact is inferred from the sparse outcrops alone. The beds strike N. 20°-50° W. and dip steeply east in the northern part of the grid and, according to Leith and Harder,67/ steeply west in the southern part.

Anomaly IH

Geology. - On the north end of the grid between traverses 9.00N and 20.00N, the few exposures to be found indicate a transition area. Here, immediately north of traverse 9.00N, faulting or shearing has caused the Homestake limestone to wedge out northward so that in the general area of traverse 17.00N the Pinto sandstone probably lies in direct contact with the monzonite directly beneath the alluvium covering this area. Here also the strike of the sedimentary rocks changes from northwest to west, thus conforming to the curvature of the contact in this area.

Results of Magnetic Survey. - Anomaly IH, lying in the transition area and extending about 1,200 feet northwest, consists of a main central part, which overlies exposed Pinto sandstone, and northwest and southwest extensions, both of which overlie alluvium. The northwest extension is elongate in a west direction, which suggests that a westward-trending marginal fault exists. The southwest extension trends southward in the same direction as the fault or shear zone. Thus the main central part of the anomaly lies at the intersection of these two major structural trends. No ore is exposed in the main central part. However, at the tip of the northwest extension some replacement ore was found in a 40-foot shaft; and immediately south of the southwest extension replacement ore in limestone was found in a 30-foot shaft. As the ore encountered in these shafts lies far out on the flanks of the anomaly, the area of the main, central part of the anomaly is a favorable location for possible discovery of an ore body of economic importance. The asymmetry of the response curve suggests that the magnetic body is dipping east.

Anomaly IJ

Geology. - Anomaly IJ covers the area of the Homestake mine proper. The development work at this mine was done in the early 1900's. The 200-foot, vertical "east shaft" encountered iron ore at depth. The 100-foot, steeply inclined "west shaft" penetrated more than 50 feet of ore; the crosscut at the 50-foot level of this shaft shows that the ore body is at least 60 feet in thickness, and workings on the 100-foot level prove that the main ore body extends downward at least to that level.

In the area of the mine the Homestake limestone and Pinto sandstone strike about N.40° W. and dip 70°-80° E. The consistently steep dip of the Pinto beds lying about 800 feet east of the Homestake-Pinto contact suggests that the limestone maintains its steep dip for a considerable depth before it is flexed out to a more gentle dip. Therefore the ore body in this area probably is dipping steeply east. The exposures of ore in several trenches lying at or near the monzonite-Homestake contact indicate

67/ Leith, C. K., and Harder, E. C., work cited in footnote 3, plate IV.

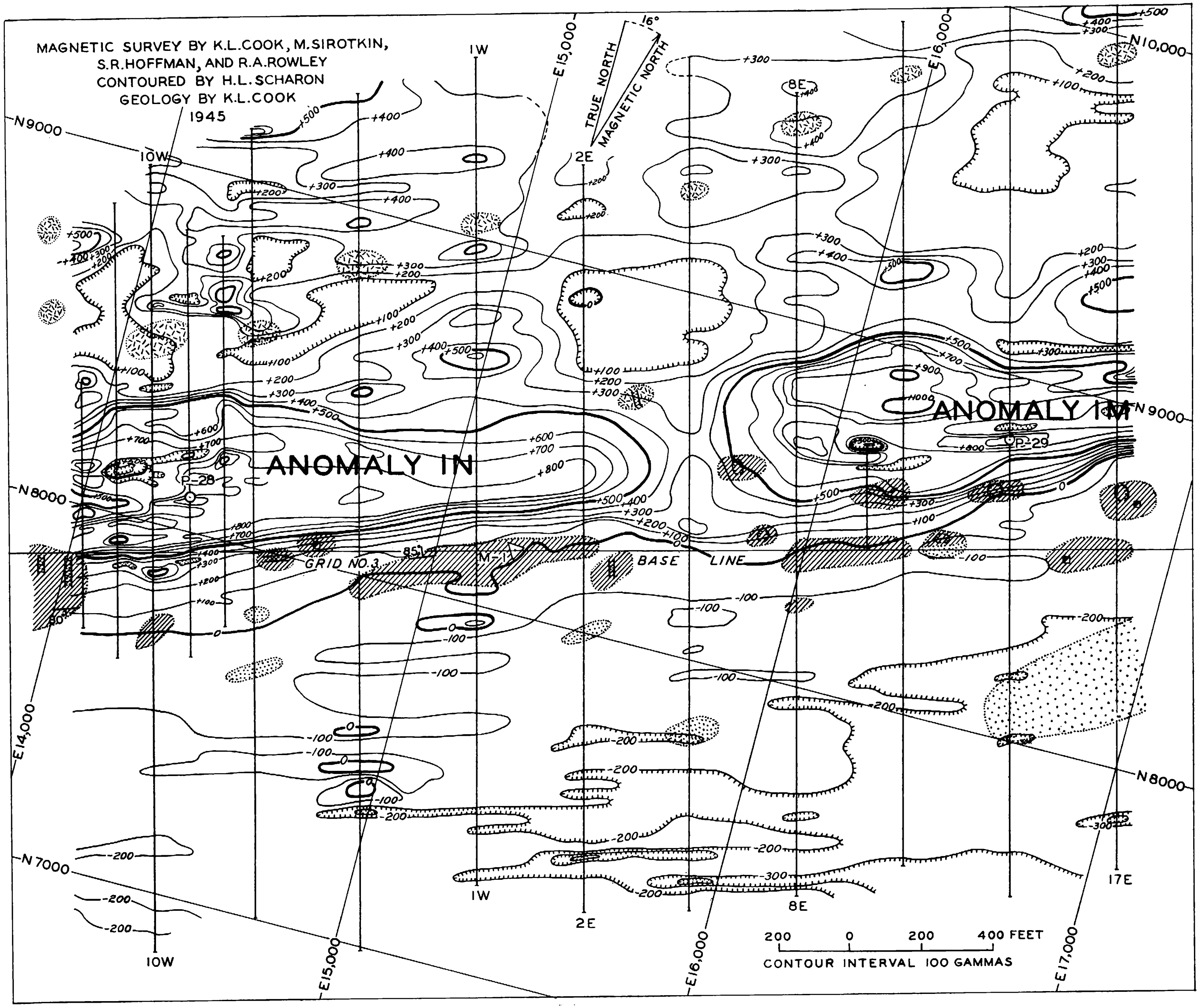

Figure 34. - Magnetic and geologic map of grid 3, Iron Mountain.

that the width of the ore body at the surface is probably less than 25 feet. The areas lying at the extreme ends of the anomaly - that is, between 9.00S and 12.00S, and between 2.00S to 6.00S - are covered largely with monzonite and ore float, and no exposures of ore are to be found.

Results of Magnetic Survey. - Anomaly IJ, lying between traverses 2.00S and 13.00S, extends northwestward about 1,100 feet, parallel to the strike of the Homestake limestone. The main positive magnetic center lies in the vicinity of the "west shaft". The predicted location of the apex of the magnetic body is shown in figure 34.68/

In the general area where the anomaly terminates abruptly on its north end, the trend of the exposed limestone abruptly changes through about 45° from northwestward to northward. As a large amount of cross-shearing probably effected this change in trend, the north end of the anomaly apparently coincides with a cross-shear zone. In the vicinity of traverse 12.00S, the anomaly apparently is abruptly displaced southwest horizontally about 300 feet and then continues southeastward with essentially the same trend. This feature suggests the existence of a crossfault or shear zone69/ in the vicinity of traverse 11.00S; and, as this area is completely covered largely with monzonite and ore float, this major structural change is inferred on the basis of geophysical evidence alone. As the anomaly that is offset to the southwest shows features in contrast with those of anomaly IJ, it is considered a separate anomaly.

The information afforded by the shafts proves that anomaly IJ is due to an ore body. The consistently high magnetic intensity suggests that the ore is continuous over a strike distance of at least 900 feet, the main mass of the ore being confined between traverses 3.00S and 12.00S. The block of ore probably is confined between a cross shear zone on the north and a fault or shear zone on the south. In accord with the known geology, the shape of the magnetic response curves, particularly in the central part of the anomaly, indicates that the ore body probably dips steeply east. A larger tonnage of ore probably will be found in the northern part of the ore body, especially between traverses 4.00S and 9.00S, than in the southern part.

In the area between traverses 2.00S and 6.00N, no anomaly was found that suggests the existence of an ore body of economic importance.

Anomaly IK

Geology. - Anomaly IK is the separate anomaly offset west of anomaly IJ. It extends about 1,100 feet along the strike between traverses 11.00S and 20.00S. No outcrop of sedimentary rock or ore was observed either within the area covered by the anomaly or in that 400 feet east of the anomaly. In fact, for 1,800 feet, between traverses 10.00S and 26.00S, no outcrop of Homestake limestone was found, although it presumably lies at depth in that area. A large amount of thick float, consisting predominantly of cobbles and boulders of monzonite, ore, and sedimentary rock, which

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68/ In this case the apex shown indicates the probable top of the main body of replacement ore at depth rather than the true apex of the ore body, which, in accordance with the strict meaning of the term, lies at the surface as a thin bed of ore. The thin ore is probably continuous at depth with the thicker main ore body.

69/ An inferred fault is shown on the geologic map (see fig. 33).

predominate in the order named, covers the surface. Most of the float came from the higher slopes of Iron Mountain lying to the west. The existence of boulders of ore float up to 10 feet in diameter necessitated small intervals between magnetometer stations in this area.

Results of Magnetic Survey. - Anomaly IK indicates that a near-surface magnetic body extends for at least 700 feet along the strike and that the body is vertical or steeply dipping. The anomaly may be caused by a magnetite vein lying within the monzonite or at the monzonite-Homestake contact. However, it is more probably caused by replacement ore in Homestake limestone. The bulk of the ore probably does not extend south of traverse 20.00S or north of traverse 11.00S. In the vicinity of traverses 21.00S and 22.00S, small, irregular stringers or pods of ore probably exist, and in this sense the mineralization may be regarded as continuous between anomalies IK and IL. However, the stringers or pods probably are too small to be commercially important.

Area West of Anomalies IJ and IK

In the area lying several hundred feet west of anomalies IJ and IK, a very large negative anomaly was discovered over the monzonite. Starting in the area of 16.00W and going west, the magnetic values continue to increase negatively as far as the traverses were run. These negative values probably are a manifestation of the east end of the Mountain Lion ore body. As the complete magnetic response curve over the ore body could not be obtained, because of claim ownership, the possibility of ore underlying the area surveyed cannot be correctly evaluated. If the eastward-dipping Mountain Lion ore body extends eastward under the monzonite or is faulted downward on its east side, it is not impossible that ore may lie under the surveyed area.

Anomaly IL

Geology. - Anomaly IL lies between traverses 22.00S and 28.00S in an area covered with float consisting mainly of cobbles and boulders of ore and monzonite. No outcrop was found in this area. Leith and Harder's map70/ shows that many exposures of limestone are to be found in the area immediately south of traverse 28.00S. This fact suggests that the limestone continues northward to underlie anomaly IL. The limestone which contains lean ore exposed in a 20-foot shaft near traverse 27.00S within anomaly IL gives strong support to this possibility.

Results of the magnetic survey. - Anomaly IL consists of a strong, magnetically negative center. Leith and Harder's map71/ shows that beginning at a point about 100 feet south of traverse 28.00S, a 75-foot-wide ore body is exposed southward for a distance of 400 feet. The negative anomaly is probably due not to anomalous polarization, but rather to the magnetic response of the north pole of a northward-striking ore body which at depth is continuous with the ore exposed south of traverse 28.00S. As the ore body acts like a strongly polarized bar magnet, a pronounced positive magnetic center would be expected over the exposed ore constituting the south end of the ore body, owing to the magnetic effect of the south pole of the bar magnet. The

70/ Leith, C. K., and Harder, E. C., work cited in footnote 3, plate IV.
71/ See footnote 70.

anomaly is probably caused by a near-surface, vertical or steeply dipping ore body, which extends continuously between traverses 23.00S and 28.00S.

South End of Grid 5

Geology. - The surveyed area between traverses 43.00S and 64.00S is covered largely with monzonite float, and the location of the monzonite-Homestake contact can only be inferred from a few exposures of Homestake limestone. The exposures show definitely, however, that in this area the monzonite bulges out into the sedimentary rocks. Low-grade replacement ore in limestone was encountered in the area in a 25-foot shaft and in a 10-foot-deep pit lying at or near the contact.

Results of Magnetic Survey. - The magnetic response curves in the area show only a minor amount of mineralization in the Homestake limestone. In the area surveyed between traverses 43.00S and 64.00S no anomaly was found that suggests a near-surface ore body of commercial importance.

Summary

Four separate magnetic anomalies were discovered in the Homestake mine area. From previous underground workings at the Homestake mine, one of these anomalies is known to be due to replacement ore in the Homestake limestone. The geologic control strongly suggests that the three other anomalies are probably caused also by replacement ore in the Homestake limestone.

The ends of the anomalies apparently coincide with definite structural features which include a marginal fault, a cross fault, and shear zones.72/ It is suggested that the crossfaults and shears have formed separate, differentially mineralized blocks of ore and may tend to control the mineralization in the same manner as they apparently do in the Desert Mound area.

Magnetometer Grid 3

Magnetometer grid 3 lies in the Blowout-Crystal Springs area on the south side of Iron Mountain, the west end of the grid lying about 1,500 feet east of the Blowout ore body. Except in the area between traverses 7.00W and 12.00W, only reconnaissance traverses, spaced 300 feet apart, were run throughout the area (see fig. 34).

Geology. - In the grid 3 area the monzonite-Homestake contact trends eastward, the monzonite lying to the north. The well-exposed Homestake limestone strikes N. 80° E. and dips from 70° S. to 70° N. Thus the limestone beds are essentially vertical and in places overturned so that they dip toward the monzonite. Because the steep dip of the overlying Pinto sandstone beds persists many hundreds of feet south of the limestone, the vertical dip of the Homestake beds can conceivably persist to a depth of as much as 1,000 feet before they finally begin to dip at a more gentle angle southward.73/ As the ore ordinarily replaces the lower part of the Homestake limestone, any near-surface replacement ore body probably would have a vertical or steep dip.

72/ No definite structural feature was observed between anomalies IK and IL, however.
73/ Letter from J. N. Mackin.

The monzonite-Homestake contact itself is covered largely with alluvium and monzonite float, and generally its exact location in this area is not known within 50 to 100 feet. From the sparse evidence provided by a few outcrops, the nature of the float, and a few adits and shafts, a brecciated zone at least 100 feet wide, containing fragments of limestone, siliceous limestone, and chalcedony, is known to exist along the contact. In places east of the grid the brecciated zone is locally mineralized with small pods of exposed ore.74/ A shaft at 15.50E-0.20S exposes slightly mineralized limestone.

Results of Magnetic Survey. - Two separate magnetic anomalies were found. Anomaly IN extends about 1,500 feet along the west half of the grid, and anomaly IM extends about 1,000 feet along the east half (see fig. 34). The axis of each anomaly probably lies over the brecciated zone. The anomalies suggest that the magnetic bodies are vertical or steeply dipping. The bodies may consist of magnetite disseminated in the breccia (in which case they will have little or no commercial value), or they may consist of magnetite in replacement ore. The small magnitude and erratic nature of the magnetic response tend to decrease the possibility of finding large, massive, near-surface replacement ore bodies in the area. Nevertheless, the possibility of finding ore of some commercial value justifies drilling.

MAGNETIC SURVEYS OF THREE PEAKS AREA75/

Magnetometer Grids in Three Peaks Area

That part of the margin of the Three Peaks intrusion where outcrops of sedimentary rocks are found was covered by a system of overlapping magnetometer grids, which extend half the distance around the monzonite intrusion. Starting with grid 9, which lies at the southeast border of the intrusion, and going clockwise around The Three Peaks (see fig. 7), the successive grids are to be found in the order listed below:

Grid 9
Grid 8
Grid 14
Grid 13
Grid 12
Grid 10
Grid 11

The remaining half of the margin of the Three Peaks intrusion, where no outcrops of sedimentary rock were found, was surveyed only in part, within grid 21 and along several large-scale reconnaissance traverses.

74/ Leith, C. K., and Harder, E. C., work cited in plate V.
75/ Many prominent peaks of monzonite are to be seen when viewing the monzonite interior of the Three Peaks intrusion from the north, east, or south. In viewing the intrusion from the west, however, three rugged peaks, all of about the same size and height, stand out in prominent profile. These peaks, called "The Three Peaks" by Leith and Harder, give the area its name.

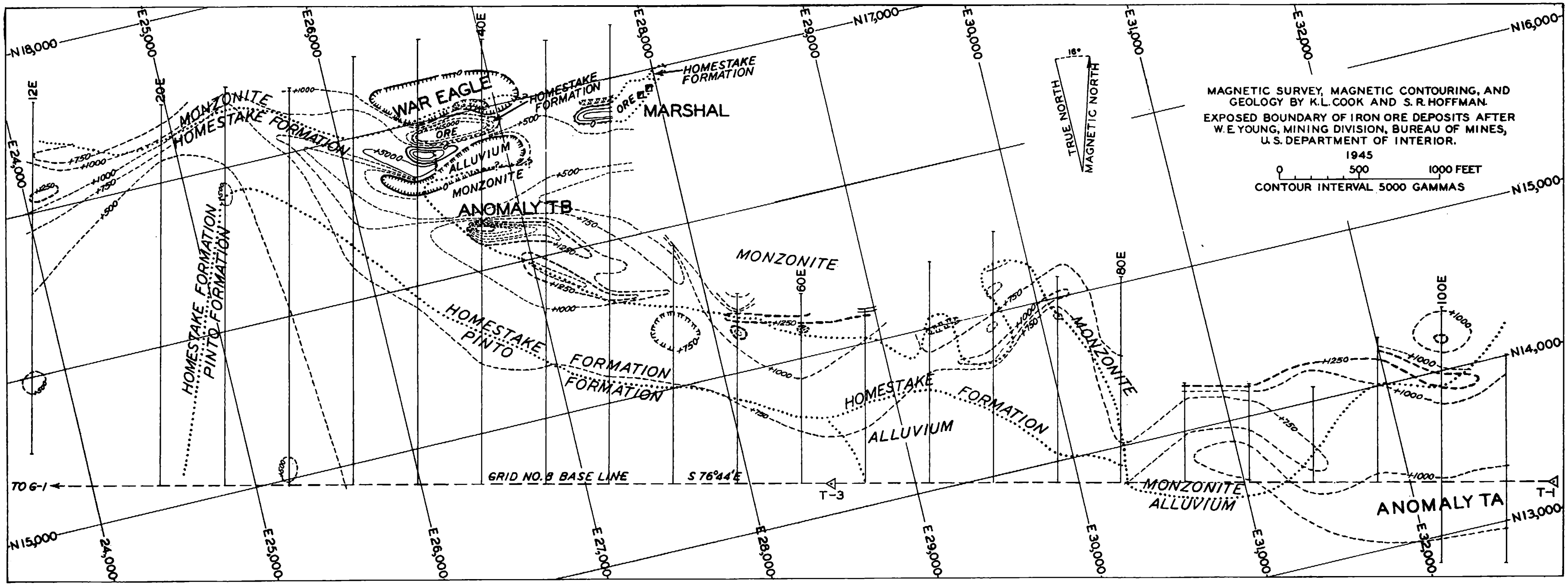

Figure 35. - Magnetic and geologic map of reconnaissance survey of grid 8, Three Peaks.

General Geology of Three Peaks Area

Throughout the south and west margins of the Three Peaks intrusion, the Homestake and Pinto formations are well-exposed, and the exact location of the monzonite-sedimentary rock contact is generally known within a few scores of feet (see fig. 3, A and B). The remaining north, east, and southeast margins, which constitute about half of the border of the intrusion, are covered with alluvium. Here, in going outward from the center of the intrusion, the exposed monzonite gives way to alluvium, and the location of the monzonite-sedimentary rock contact beneath the alluvium is not definitely known. The periphery of the monzonite intrusion, not including the bulges and reentrants of monzonite, is at least 15 miles long.

The previously known replacement ore bodies exposed along the border of the Three Peaks area are the Marshal, War Eagle, and McGarry deposits. The replacement ore exposed on the Irene claim is probably a roof pendant. Many fissure veins of magnetite are to be found within the monzonite, the largest exposures of vein ore being the Blackbird and Great Western deposits. Except for the Great Western ore body, which was mined on a small scale from 1937 to 1946, none of these ore bodies has been exploited.

Magnetometer Grid 9

Grid 9 covers the area lying at the southeast tip of the Three Peaks intrusion. The grid extends northeastward 1 mile. Magnetometer readings were taken along reconnaissance traverses only (see fig. 7).

Geology. - Except in its western part, where a few exposures of monzonite are to be found, the grid lies in an area covered with alluvium. The area was originally believed to be the most likely place of finding the monzonite-sedimentary rock contact.

Results of Magnetic Survey. - Throughout the area surveyed, no magnetic anomaly was observed that suggests the existence of a near-surface ore body of commercial importance. Of all the areas surveyed in the district, grid 9 gave the most uniform magnetic field, the magnetometer readings being remarkably constant throughout the alluvium area. The response curves show no break that can be confidently interpreted as the monzonite-sedimentary rock contact. Therefore, it is believed that either the contact is too deep to give a recognizable change in magnetic response or it lies south of the area covered in the survey.

Magnetometer Grid 8

Lying along the south margin of the Three Peaks intrusion, grid 8 extends eastward for a distance of two miles (see fig. 35). Its east end is continuous with grid 9. Reconnaissance work only was done on the grid.

Geology

Throughout most of the grid the monzonite and Homestake limestone are well-exposed, and the exact location of the monzonite-Homestake contact is known within a few tens or scores of feet. The beds generally strike southeast and dip gently southwest. Leith and Harder indicate several cross faults in the sedimentary rocks on the west end of the grid, but the writer did not attempt to map these faults during the present work. On the east end of the grid, in the general area of traverse 80.00E, the Homestake limestone disappears beneath the alluvium and is not to be found exposed in the remaining east and northeast segments of the Three Peaks intrusion.

The only replacement ore bodies exposed within the grid are the War Eagle and Marshal deposits, which lie in the central part of the grid. The War Eagle deposit is formed in a reentrant of the Homestake limestone. Lying about 800 feet east of the War Eagle ore body, the Marshal deposit is formed in a narrow finger of limestone that may constitute the inner tip of the same reentrant, provided that the limestone is continuous beneath the alluvium lying between the ore bodies. Being almost completely surrounded by monzonite, the ore bodies, like the limestone blocks in which they are formed, are probably roof pendants.

Results of Magnetic Survey

War Eagle and Marshal Deposits. - As no pronounced anomaly was observed on traverse 44.00E, the War Eagle and Marshal ore bodies appear to be separated by essentially barren bedrock in the area of the alluvium. The bulk of the ore in these two deposits probably is confined largely to the areas where they are exposed. It is unlikely that they extend far down-dip.

Anomaly TB. - Anomaly TB, which lies over monzonite, is probably caused by a magnetite vein which may be of some small commercial importance.

Anomaly TA. - In the alluvium-covered area lying east and southeast of traverse 80.00E, the monzonite-sedimentary rock contact doubtless lies south of the base line. Traverses 100.00E and 104.00E were extended south of the base line for a distance of 1,500 feet, which originally seemed adequate to cover the assumed contact area. Neither of these traverses shows a break that can be reliably interpreted as the contact. Nevertheless, each shows a small positive anomaly, designated anomaly TA, in the general area of the assumed contact. The area warrants further investigation to ascertain the trend of the contact beneath the alluvium, thus providing information that will prove helpful in the future exploration of the southeast and east margins of the Three Peaks intrusion.

Magnetometer Grids 12, 13, and 14

Grids 12, 13, and 14 are overlapping grids that extend along the southwest margin of the Three Peaks intrusion for 1-1/2 miles (see fig. 36). The three grids make a zigzag pattern that conforms with the irregular monzonite-sedimentary rock contact in the area. Of the three grids, grid 13 lies in the center, and grids 12 and 14 overlap the north and south ends of grid 13, respectively. The south end of grid 14 intersects the west end of grid 8, and the north end of grid 12 intersects the south end of grid 10.

Geology

Throughout most of the area covered by the three grids the rocks are well-exposed, and the exact location of the monzonite-sedimentary rock contact is known within a few tens or scores of feet. Within the grids the Homestake limestone lies in direct

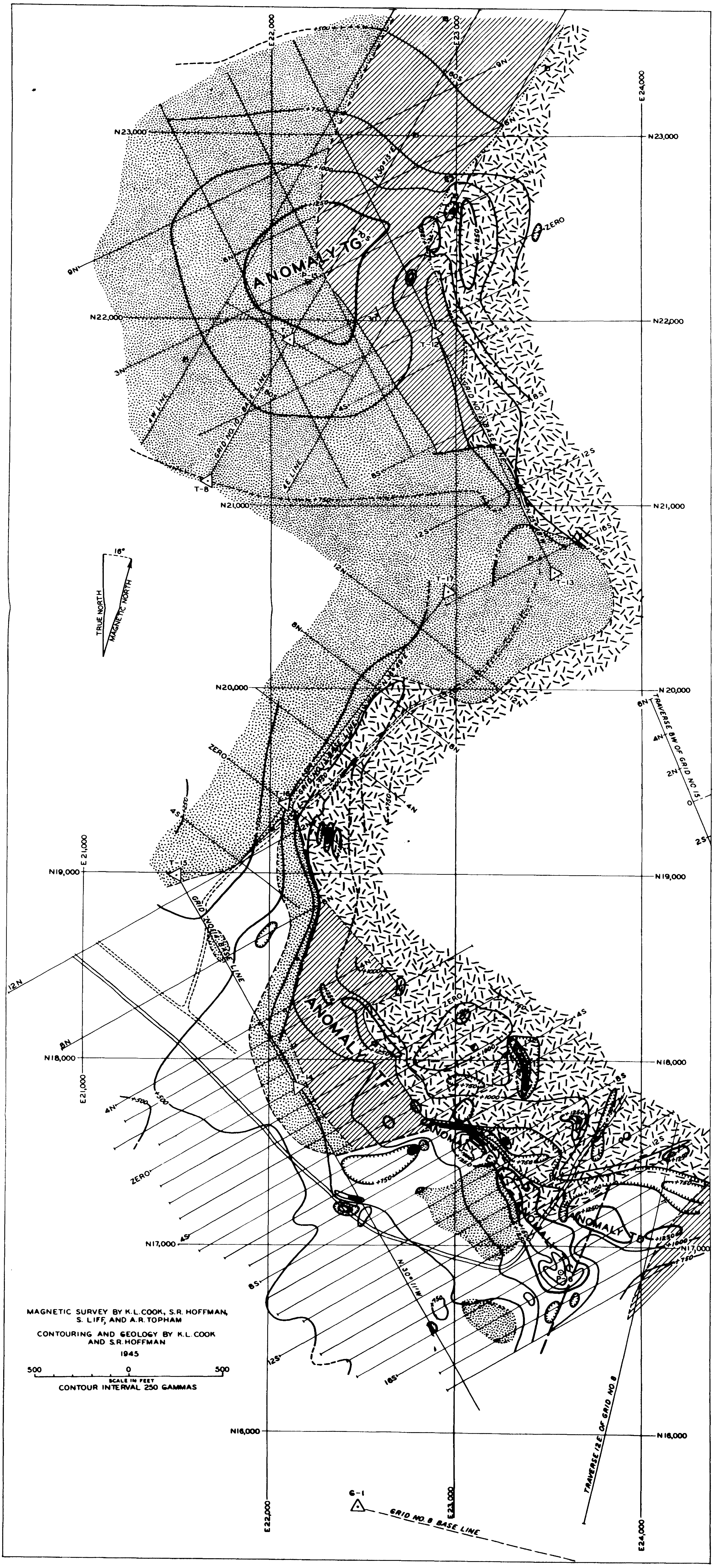

Figure 36. - Magnetic and geologic map of grids 12, 13, and 14, Three Peaks.

contact with the monzonite only in the central and northern parts of grid 12 and in the central and extreme southern parts of grid 14. In the remaining areas of the grids, beds of the Pinto formation lie in contact with the monzonite. The contact is irregular, and abrupt changes in its direction are to be found. These features are explained by Leith and Harder,76/ on their geologic map, by several crossfaults, and by several marginal faults, which extend continuously along the contact throughout the area of the grids, except in the northern part of grid 12. No attempt was made by the writer to map all the faults in this area. The approximate location of the monzonite-sedimentary rock contact was mapped with a degree of accuracy that varied in accordance with the amount of detailed magnetometer work done on each grid.

Lying in the monzonite intrusion and about 2,000 feet east of grid 13, several large magnetite veins, including the Great Western ore body, are to be found. As these veins lie relatively near the monzonite-limestone contact, it is evident that ore-bearing solutions capable of intense mineralization migrated through the general area of the three grids and that the Homestake limestone in the vicinity may also have been favored with intense mineralization.

Results of Magnetic Survey

Grid 14. - Four small magnetic anomalies were found in grid 14. Anomaly TC extends for about 700 feet along the contact. In the northern part of the anomaly good exposures of conglomerate and sandstone indicate that the Homestake limestone is largely, and possibly wholly, faulted out. To account for the abrupt reappearance of the large mass of Homestake limestone constituting the hill lying east of anomaly TC, Leith and Harder77/ show a northward-trending fault whose location coincides with the southeast end of anomaly TC. It is not known whether or not the anomaly is underlain at depth by Homestake limestone.

Anomaly TD lies a few hundred feet east of anomaly TC in an area covered with alluvium and some limestone float. As it is not known whether the monzonite-sedimentary rock contact lies north or south of anomaly TC, the economic importance of the anomaly is uncertain.

Anomaly TE lies in the general area of the monzonite-sedimentary rock contact between traverses 6.00S and 9.00S. The area beneath the anomaly is of little or no economic importance. The north end of the anomaly may coincide with a crossfault.

Anomaly TF is a broad, low anomaly lying between traverses 5.00S and 4.00N. Throughout its length, the anomaly overlies exposed Homestake limestone. The ends of the anomaly coincide approximately with the locations of two crossfaults, which abruptly terminate the Homestake limestone. The limestone beds strike northwest and dip gently southwest. Under these conditions any replacement ore body formed in the limestone probably would lie nearly at the critical dip and tend to give a relatively small response. Nevertheless, it seems unlikely that a thick body of ore underlies the anomaly.

76/ Leith, C. K., and Harder, E. C., work cited in footnote 3, plate II.
77/ See footnote 76.

Grid 13. - On grid 13 magnetometer readings were taken along base-line and reconnaissance traverses only. Throughout the area covered by the grid, beds of the Pinto formation are in contact with the monzonite. No magnetic anomaly that would indicate a near-surface ore body of commercial importance was observed in the area surveyed.

Grid 12. - In the southern part of grid 12, where reconnaissance work only was done, no magnetic anomaly was observed that would indicate a near-surface ore body of commercial importance.

In the general area of traverse 9.00S, where a cross fault probably exists, and in the area to the north, the Homestake limestone is well-exposed. In the central part of the grid the limestone strikes north and dips about 30° W.; in the northern part the strike gradually changes from north to about N. 30° E., the dip remaining gentle. In the area of this change in strike magnetic anomaly TG was discovered over the sedimentary rocks. Defined approximately by the +1,000-gamma contour line, the low, broad anomaly is oval, its central part being elongate in a direction parallel to the strike of the beds. The positive center of the anomaly lies about 100 feet west of the Homestake-Pinto contact.

Although the magnetic relief is only about 500 gammas, the anomaly could be caused by an ore body of commercial importance. The geology of the area indicates that any possible replacement ore body beneath the zone would lie 250 to 350 feet deep. Because of this probable depth limitation, it seems more likely that the anomaly, if it is caused by an ore body, is due not to a thick, but rather to a thin blanket of ore.

The negative results of hole H-8, which partly tested anomaly GC, an anomaly that in many respects is similar to anomaly TG, increase greatly the drilling risk of testing anomaly TG. However, the possibility of finding an economic-size ore body appears great enough to justify a test.

Magnetometer Grid 15

Grid 15 consists of several traverses taken across the Great Western vein deposit (see fig. 7). The vein, which strikes east and dips steeply north, is about 700 feet in length and 40 feet in maximum width at its center.

Results of Magnetic Survey. - No broad response curve suggestive of great depth extent of the deposit was observed. However, the severe reverse polarization effects caused by magnetite veins adjacent to and parallel with the main deposit would tend to obscure any low geophysical anomaly.

Magnetometer Grid 10

Magnetometer grid 10 extends along the northwest border of the Three Peaks intrusion for 3-1/2 miles. Most of the grid consists of three long, parallel reconnaissance lines which extend northeastward parallel to the monzonite-Homestake contact and were placed 400 feet apart (see fig. 7). Detailed cross traverses were run only in the April Fool claim area, which lies about 2,000 feet northeast of triangulation station T-5.

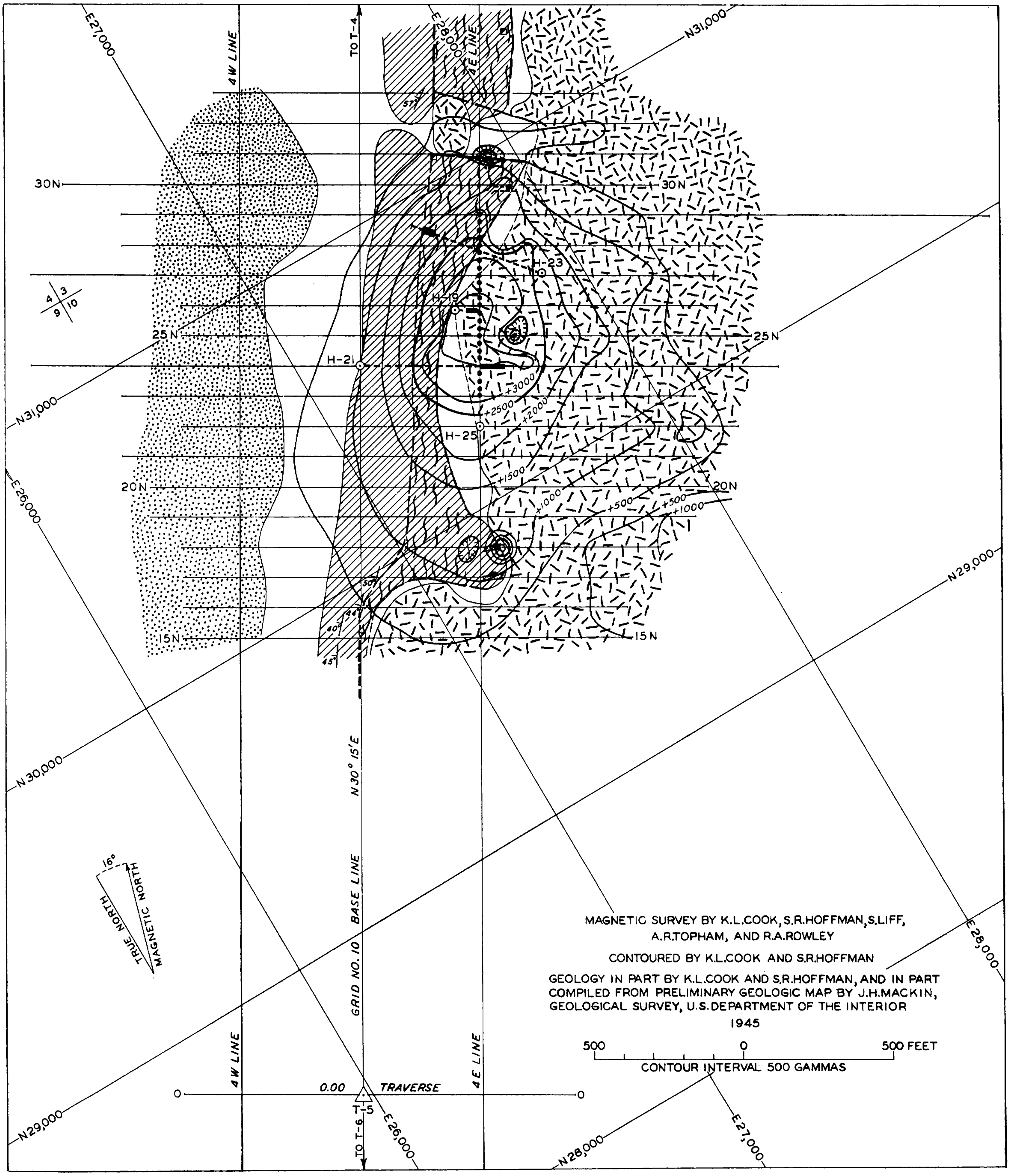

Figure 37. - Magnetic and geologic map of April Fool claim area, grid 10, Three Peaks.

Geology

The Homestake and Pinto formations, which are well-exposed throughout the area covered by grid 10, strike about N. 30° E. and dip 30°-60° NW. The unusual uniformity of strike over 3 1/2 miles along the margin of the intrusion permitted the reconnaissance work to be done along three long, parallel lines. Throughout most of the area of the grid, the basal siltstone member of the Homestake formation is either exposed or inferred to exist from the abundant float. The monzonite-Homestake contact extends in a direction parallel to the strike of the beds except in a few places where, because of faulting or shearing, the monzonite juts out abnormally into the limestone, or the limestone forms a reentrant in the monzonite.

The only large exposures of replacement ore in the grid 10 area are the McGarry and Irene deposits. The McGarry deposit forms an exposure which is about 400 feet long and 100 feet wide and lies just southeast of traverse 5.00N on grid 10. Here the ore has replaced a limestone block that has been faulted into the monzonite, thus forming a reentrant. The Irene ore deposit lies in the northeastern part of grid 10 and is probably a roof pendant. The area of the Irene deposit was not surveyed.

Small exposures of replacement ore are to be found (1) in an adit and pit which lie at or near the monzonite-Homestake contact in the vicinity of traverse 30.00N and (2) in several trenches which lie at or near the contact in the vicinity of traverse 17.00N.

Results of Magnetic Survey

Magnetometer readings were first taken along the three long reconnaissance lines. With the exception of the area overlapping grid 12 in the southern part of grid 10, no anomaly suggestive of a near-surface ore body of commercial size was found in the surveyed area south of triangulation station T-5 or north of traverse 33.00N. In the general area of 5.00N on the 4.00E line an anomaly was observed, representing an effect of the McGarry deposit, which is exposed about 100 feet southeast of this point.

The most important result of the reconnaissance work was the discovery of a large magnetic anomaly in the April Fool claim area, lying about 2,500 feet north of triangulation station T-5. Following the discovery, a detailed magnetic survey along traverses spaced 100 feet apart was made in this area between traverses 15.00N and 33.00N, and the extent of the newly discovered April Fool anomaly was delineated. The anomaly extends about 1,700 feet in the direction of the strike of the beds and about 1,000 feet, on an average, in a direction perpendicular to the strike.

As the April Fool claim area affords a good example of some of the problems encountered in geophysical interpretation in mining geophysics, a rather detailed discussion of this area is given here.

Detailed Geology of April Fool Claim Area

Throughout the April Fool claim area the lower members of the Homestake formation are intensely sheared along the shear zone shown in figure 37. At the southern terminus of the anomaly, in the general area between traverses 15.00N and 17.00N, the limestone and basal siltstone are folded and sheared, their strike bending to conform roughly with the direction of the monzonite-Homestake contact in the immediate vicinity. The abrupt thinning of the Homestake limestone between the exposed monzonite and Pinto sandstone in the area of traverses 15.00N and 16.00N and the breccia float at 16.80N-2.10E are evidence of crossfaulting and shearing.

At the northern terminus of the anomaly, in the general area between traverses 30.00N and 33.00N, is to be found a mass of monzonite which protrudes out into the limestone about 300 feet from the normal monzonite-Homestake contact in the area and which is almost completely surrounded by exposed limestone in contact with it. As the basal sediments are not to be found between traverses 31.00N and 33.00N in the area north of this mass, the mass is probably either an intrusive tongue that has overridden the basal siltstone and part of the limestone or a monzonite block that has been faulted into the limestone. On the north side of the monzonite mass the highly contorted shear planes in the limestone conform roughly to the border of the mass.

The ore exposed in trenches lying at or near the monzonite-Homestake contact in the vicinity of traverse 17.00N and the ore exposed in a pit and an adit, which penetrated 10 feet of good ore, at or near the monzonite-Homestake contact in the vicinity of traverse 30.00N, were probably formed by mineralizing solutions which ascended along openings caused by cross faulting or shearing in these respective areas. In view of the fact that crossfaults and shears often tend to control the mineralization in the district, it was considered a significant fact, from the time of the discovery of the anomaly, that these two restricted areas of pronounced crossfaulting and shearing coincide essentially with the north and south termini of the anomaly.

In the central part of the anomaly, which lies in the area between the two cross-faulted and cross-sheared areas just described, the dip of the limestone is 60° NW, or greater, as contrasted with a dip of 40°-45° NW. in the general area of traverse 15.00N. Thus, in going northward from traverse 15.00N, the dip increases. The maximum value that the dip may attain in the area adjacent to the monzonite-Homestake contact between traverses 25.00N and 29.00N is uncertain because of the intense shearing. Near the monzonite-Homestake contact in the vicinity of traverse 29.00N the limestone is locally metamorphosed to marble. Between traverses 21.00N and 29.00N the location of the monzonite-Homestake contact is uncertain because of large talus boulders of monzonite. Basal siltstone float, which is to be found on traverse 29.00N, indicates that the basal siltstone probably underlies the talus at that point; yet it is not known whether the basal siltstone underlies the talus in the area between traverses 20.00N and 28.00N. If the basal siltstone were absent beneath the talus, a marginal fault could be postulated.

Statement of Geological Problem. - It will be noted on the magnetic map (see fig. 37) that the predicted location of the apex of the magnetic body projected vertically to the surface[78] extends along the 4.00E line largely over monzonite. Before the test drilling in the area, one of the vital problems of interpretation was to reconcile the possibility that the anomaly might be due to replacement ore with the fact that essentially the eastern half of the anomaly probably overlaid near-surface monzonite and that the predicted location of the apex possibly overlaid near-surface monzonite. At that time the writer submitted the following geologic possibilities:

78/ The predicted center of apex in figure 37 is shown as it was drawn before test drilling in the area.

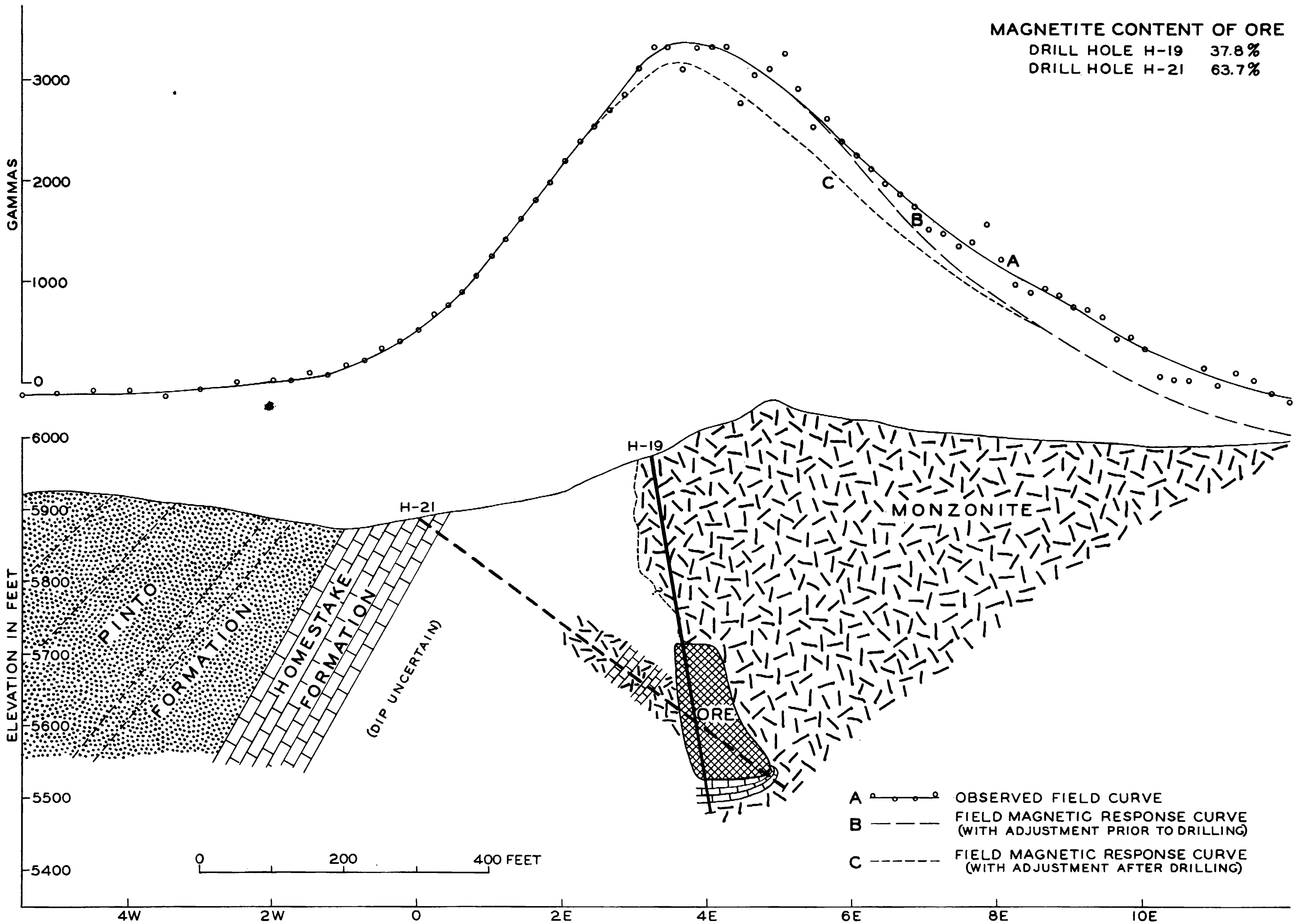

Figure 38. - Magnetic profile and geologic cross section along traverse 26.00 N, April Fool ore body, grid 10. (Topography after W. E. Young and J. H. Mackin. Geology in part after W. E. Young.)

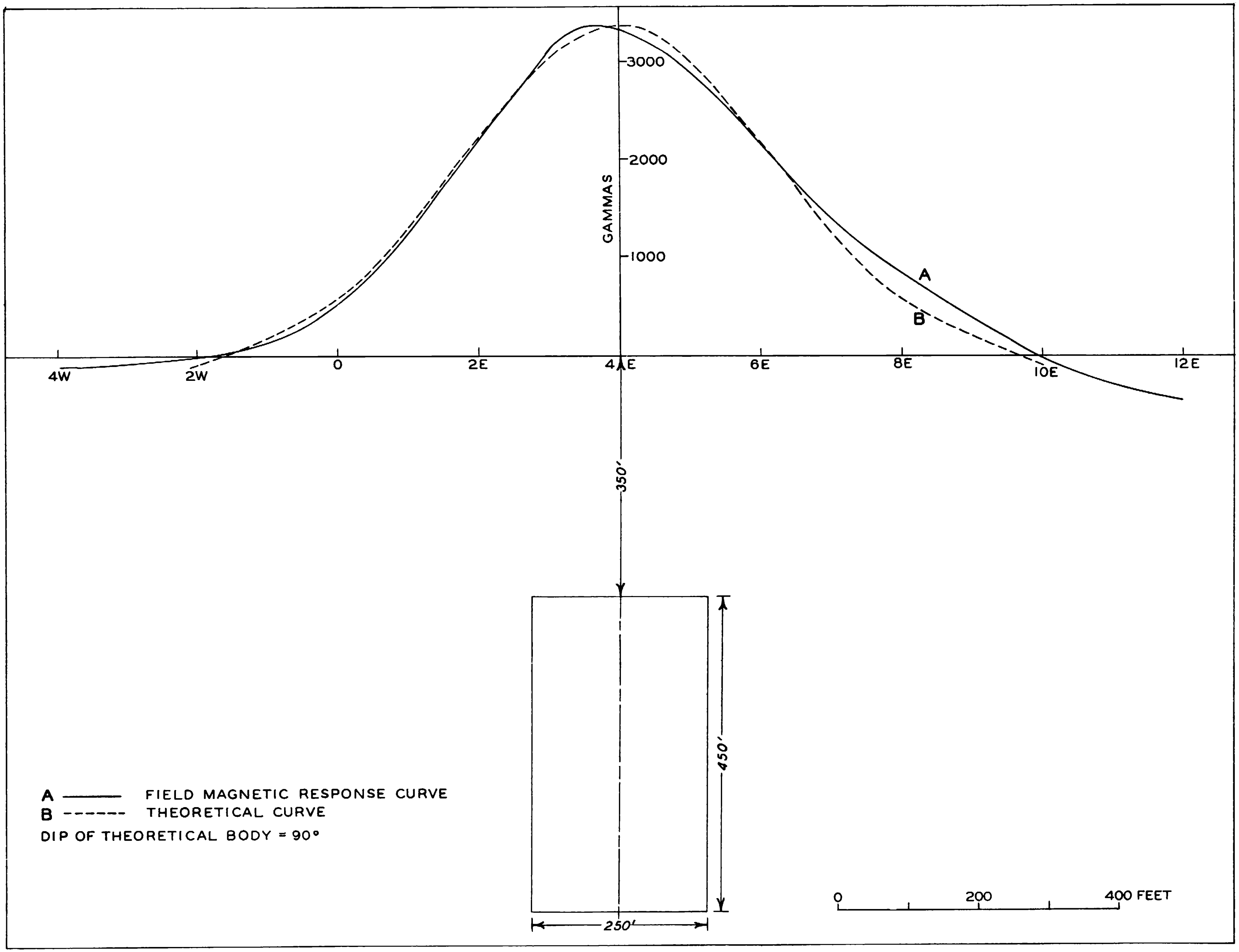

Figure 39. - Comparison of field magnetic response curve obtained on traverse 26.00 N, April Fool ore body, grid 10, and theoretical curve for a vertical body with an assumed magnetite content of 40 percent.

(1) That, in view of the crossfaults and crossshears on its two ends, the whole limestone block lying between traverses 17.00N and 31.00N may at depth be faulted under the monzonite.

(2) That the monzonite lying between traverses 17.00N and 33.00N may have overridden the limestone during the intrusion. This process would be greatly aided if, before the intrusion of the monzonite, the limestone beds at depth had been either vertical or overturned.

A third and currently favored interpretation, which was not advanced until after the second test hole on the April Fool ore body had been completed, is that during the process of intrusion a block of limestone became foundered at depth in the molten magma and was subsequently replaced with ore.

Geophysical Interpretation of April Fool Claim Area

Necessity for Quantitative Determinations. - Quantitative determinations for the April Fool anomaly were necessary for the following reasons:

(1) It was necessary to ascertain whether the magnetic body causing the anomaly could be expected to be of economic size and thus justify test drilling.

(2) In the contingency that the first test hole started in monzonite, it was imperative that a minimum depth of drilling be assigned to the hole before it should be abandoned.

Method of Analysis. - In making the theoretical calculations for the northward-striking April Fool ore body, theoretical magnetic bodies with rectangular cross sections and vertical dip were assumed. As the magnetic body strikes 14° east of magnetic north, the transverse horizontal magnetization effect on the vertical intensity was neglected in the calculations.

Magnetic Profile Chosen. - Only the magnetic field response curve for traverse 26.00N was used in the present quantitative study. This particular magnetic profile was chosen because (1) it lies in the central part of the anomaly and (2) it is similar to the profiles of traverses 24.00N, 25.00N, and 27.00N. Consequently, the results obtained from a study of this single profile may be applied to the general area between traverses 24.00N and 27.00N.

Adjustments. - Curve A of figure 38 is the field magnetic response curve for traverse 26.00N and represents the combined effects of the response due to the magnetic body at depth and that due to the different susceptibilities of the monzonite and sedimentary rock. To obtain the true magnetic response curve that is representative solely of the magnetic body at depth, the observed curve must be adjusted in the area of the monzonite and in the area of the monzonite-sedimentary rock contact by subtracting the response due to the monzonite alone. The effect of this adjustment is to make the regional value over the monzonite correspond with the regional value over the barren sedimentary rocks; in this way, the magnetic values are reduced to a common base. In the present case, where the difference in regional value between the monzonite and Pinto formation is 400 gammas, this value being based on the results of many response curves taken across the monzonite-sedimentary rock contact in the April Fool claim area, the adjustment is safely made far out on the flanks of the observed curve in the area overlying definite monzonite outcrop by subtracting 400 gammas from the observed anomaly. The results of this operation on the eastern flank of curve A, figure 38, give the eastern flank of curve B in the figure.

In the general area of the monzonite-Homestake contact the adjustments are less reliable because (1) even if the exact location of the geologic contact is known, the gradient of the response curve, which depends on factors that ordinarily cannot be correctly evaluated in advance, can be only approximately estimated on the basis of experience in the district; and (2) if the exact location of the geologic contact is not known within several scores of feet, the uncertainty of the adjustment is correspondingly greater. If the peak of the curve lies in the general area of the geologic contact, which is usually the case, an incorrect adjustment may shift the peak of the curve enough to cause erroneous estimates of depth, width, and dip, as well as of the predicted location of the center of apex of the magnetic body.

These limitations do not vitiate quantitative estimates of the depth and size of magnetic bodies, provided that the anomalies are large enough to absorb these inherent errors to a large degree. But these limitations do place on the estimates a certain probable error that must be recognized in the final analysis of the results.

The April Fool anomaly presents a limitation of this kind. Before the test drilling the exact location of the monzonite-Homestake contact along traverses 24.00N to 28.00N was very uncertain. In making the adjustment the contact was conservatively assumed to lie at about 5.00E, and the possibility of an eastward-dipping contact was taken into account. Thus the adjustment in the general area of the monzonite-Homestake contact was made by subtracting values intermediate between zero and 400 gammas, the subtracted values decreasing in a direction toward the sedimentary rocks, from the observed anomaly. The results of this adjustment on the central part of curve A, (fig. 38), gave the central part of curve B in the figure.

Curve B of figure 38 was thus used as the most probable magnetic response curve due to the magnetic body indicated at depth below traverse 26.00N. It was recognized that an error of as much as 400 gammas might exist in the curve between 2.00E and 6.00E because of the uncertainty of the arbitrary choice of the monzonite-Homestake contact.79/ As the flanks of curve B, particularly the west flank, appeared reliable, and as a maximum error of 400 gammas was not prohibitive in view of the large anomaly of 3,500 gammas, it seemed that rather reliable quantitative estimates could be made.

Quantitative Estimates. - In the present study magnetic response curve B of figure 38 was compared with the theoretically calculated curves of assumed ore bodies of different sizes and magnetite contents. An example of how the magnetic response curve fits the theoretical curve for an assumed vertical body with 40 percent magnetite content is given in figure 39. Curve A of figure 39 is identical with curve B of figure 38. Such good agreement indicates that the observed magnetic response curve may be explained in terms of an ore body with an approximately vertical dip.

79/ Subsequent drilling showed that the monzonite-Homestake contact lies at about 3.10E and therefore that the adjustment at the contact should have been carried farther west, giving curve C (fig. 38) rather than curve B of the same figure. The resulting shift of the peak of the anomaly would have led the writer to shift slightly westward the predicted location of the center of apex of the magnetic body on traverse 26.00N.

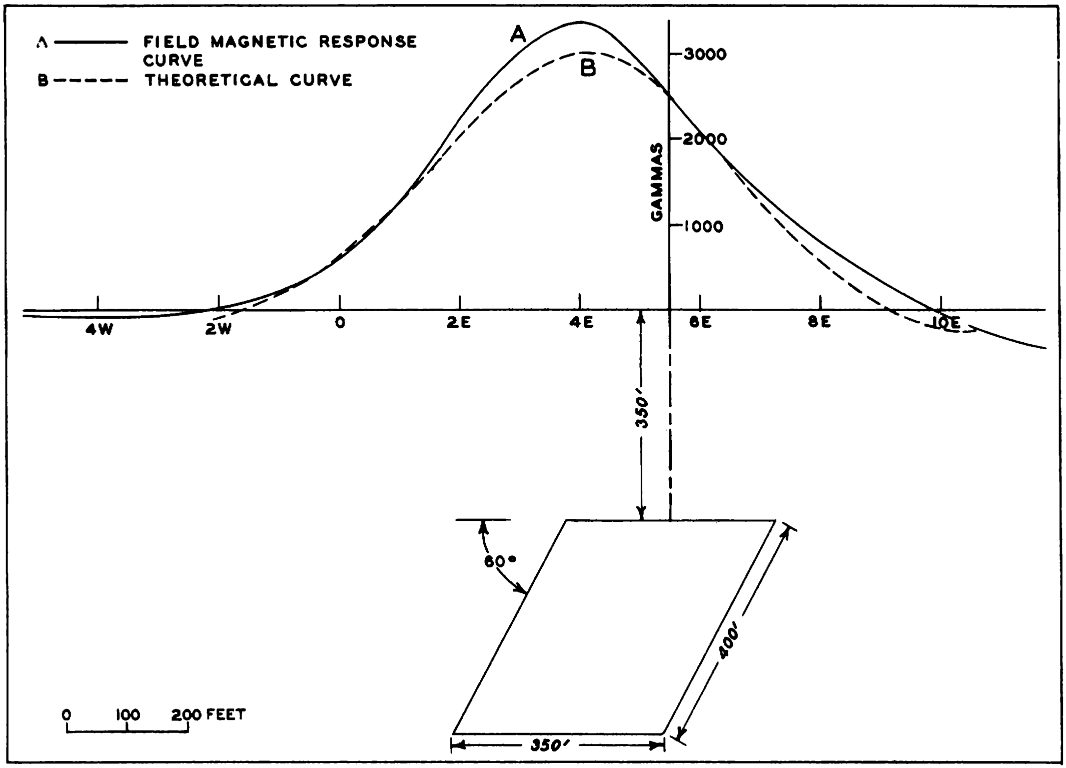

Figure 40. - Comparison of field magnetic response curve obtained on traverse 26.00 N, April Fool ore body, grid 10, and theoretical curve for a body with an assumed dip of 60° W. and 30 percent magnetite content.

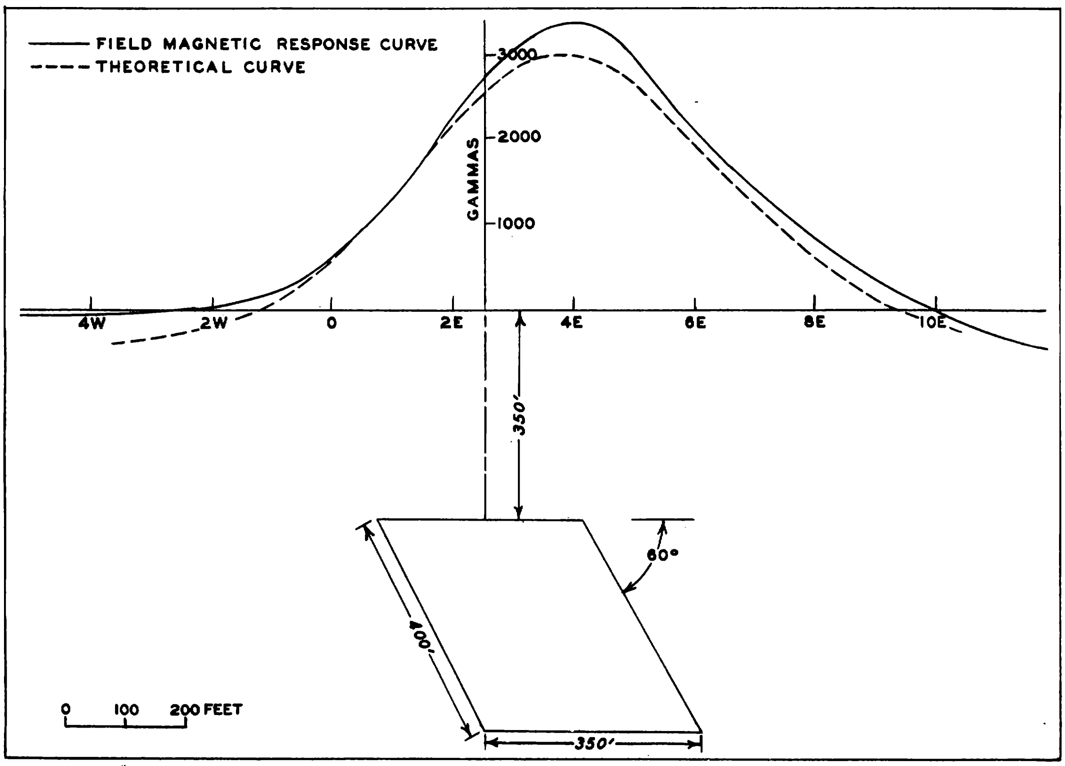

Figure 41. - Comparison of field magnetic response curve obtained on traverse 26.00 N, April Fool ore body, grid 10, and theoretical curve for a body with an assumed dip of 60° E. and 30 percent magnetite content.

Figures 40 and 41 show comparisons of the same field magnetic response curve and the theoretical curves for bodies of 30 percent magnetite content dipping 60°W. and 60°E., respectively. The uncertainty in the shape of the response curve, due to causes already discussed, is as great as the difference between the two theoretical curves for the differently dipping bodies. Therefore, it was not possible to tell from theoretical considerations alone which way the body is dipping or to assign a value to the dip, other than to say that it is probably 60° or greater. If the body is dipping eastward the apex of a tabular body will be slightly west of the position shown on the magnetic map; if the body is dipping westward, the apex of the body will lie slightly east of that shown on the magnetic map (see fig. 37).

To give a notion of the size of the possible ore body, various depths, widths, and depth extents were estimated for assumed vertical bodies with different magnetite contents (for example, 10, 15, 20, 30, 50, and 100 percent) and with the above-discussed assumption of magnetic susceptibility. Table 6, which in its present form was made available to the project engineer before the first test hole was drilled, summarizes the preliminary results of these calculations. The calculations indicate, for example, that for a vertical magnetic body with 40 percent magnetite content the depth to the apex would be 225 to 400 feet, the width 125 feet or more, and the depth extent 100 feet or more. In general, the estimated depths increase slightly and widths vary inversely with increasing magnetite contents. This means roughly that a small, deep magnetic body of high magnetite content will produce essentially the same anomaly as a large, shallow magnetic body of low magnetite content.

There are severe limitations and qualifications that must be placed on the estimates in table 6:

(1) The depths listed might exceed somewhat the actual depths to the highest part of the ore. They represent rather the depth at which the magnetite itself has become rich and extensive in width. Some magnetite stringers and considerable hematite might possibly lie above this level.

(2) Estimates of the possible maximum widths and depth extents of the magnetic body were very uncertain and were omitted from the table. Estimates of only the possible minimum widths and down-dip extents were listed.

Uncertainties in the estimates arise from the following causes:

(a) Although the topographic relief along traverse 26.00N amounts to about 150 feet, no exact elevation corrections were made in the calculations. The effects due to relief were estimated approximately, however, and the resulting uncertainties imposed on the estimates given in table 6 were roughly evaluated.

(b) The degree of uncertainty of the magnetic response curve at its peak and the resulting limitations on the estimates given in table 6 have already been emphasized.

TABLE 6. - Preliminary estimates for April Fool magnetic body, grid 10, based on an assumed vertical body1/ in feet

Assumed magnetite content by volume, percent	Depth to apex of body2/	Width of body3/	Depth extent of body3/	Best fit			
				Depth2/	Width	Depth extent	Remarks
10	100-275	300 or more	200 or more	200	550	700	Fair fit
15	150-325	250 or more	175 or more	275	500	600	Good fit
20	175-350	200 or more	150 or more	300	400	600	Do.
					500	400	
30	200-375	150 or more	100 or more	350	350	400	Excellent fit
40	225-400	125 or more	100 or more	350	250	450	Do.
50	250-400	75 or more	100 or more	350	200	450	Do.
100	250-400	Much smaller than for 50%					

1/ Calculations based on the assumption that the magnetic susceptibility of pure magnetite is 0.25.

2/ Distances refer to the vertical depth below the elevation at point 26.00N-4.00E, which is the chosen datum point.

3/ The estimates represent what is believed to be conservative minima of width and depth extent.

(c) Susceptibility tests, which will be discussed presently, indicate that the magnetic susceptibility of the border porphyritic phase (about 200 feet in width) of the monzonite in the area of the observed magnetic response curve under study may be somewhat higher than that of the normal monzonite in the district. The possible effect of this border phase was considered approximately in the estimates in table 6 principally by reducing the estimated widths and depth extents of the magnetic bodies.

(d) All theoretical calculations assume a vertical magnetic body. The magnetic body may actually be somewhat inclined from verticality, however.

(e) The transverse horizontal magnetization effect on the vertical intensity was neglected.

(f) The theory itself assumes a magnetic body of uniform magnetization, which is certainly not the case in the April Fool ore body. It involves approximations, and neglects the influence of edges and corners.80/

(g) The uncertainty in the assumed value of the magnetic susceptibility constituted the most serious limitatión. In particular, if the assumed value is lower than the true value, the size of the calculated ore body will be greater than the true size.

80/ Heiland, C. A., work cited in footnote 20, p. 393.

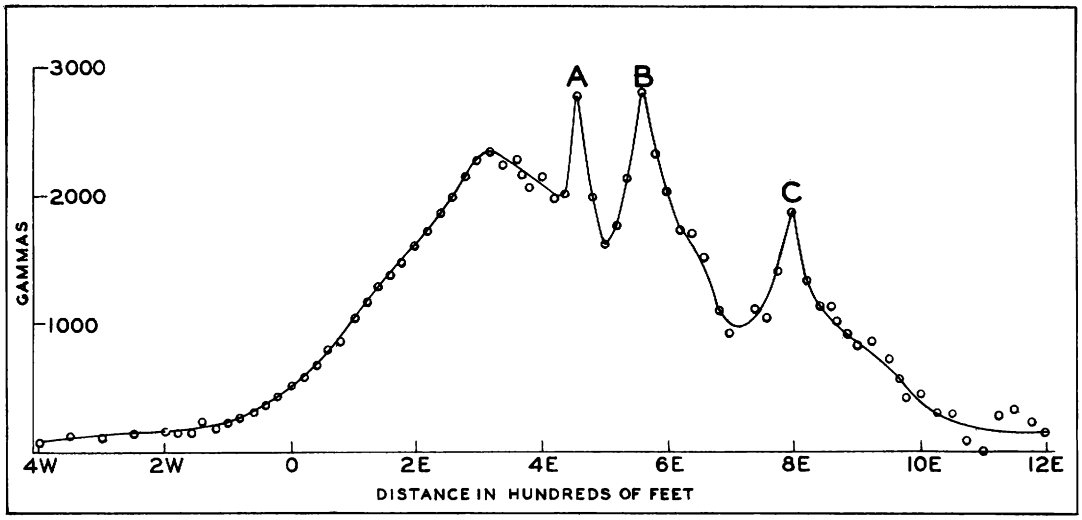

Figure 42. - Magnetic profile along traverse 28.00 N, April Fool ore body, grid 10. Peaks A, B, and C indicate near-surface magnetite.

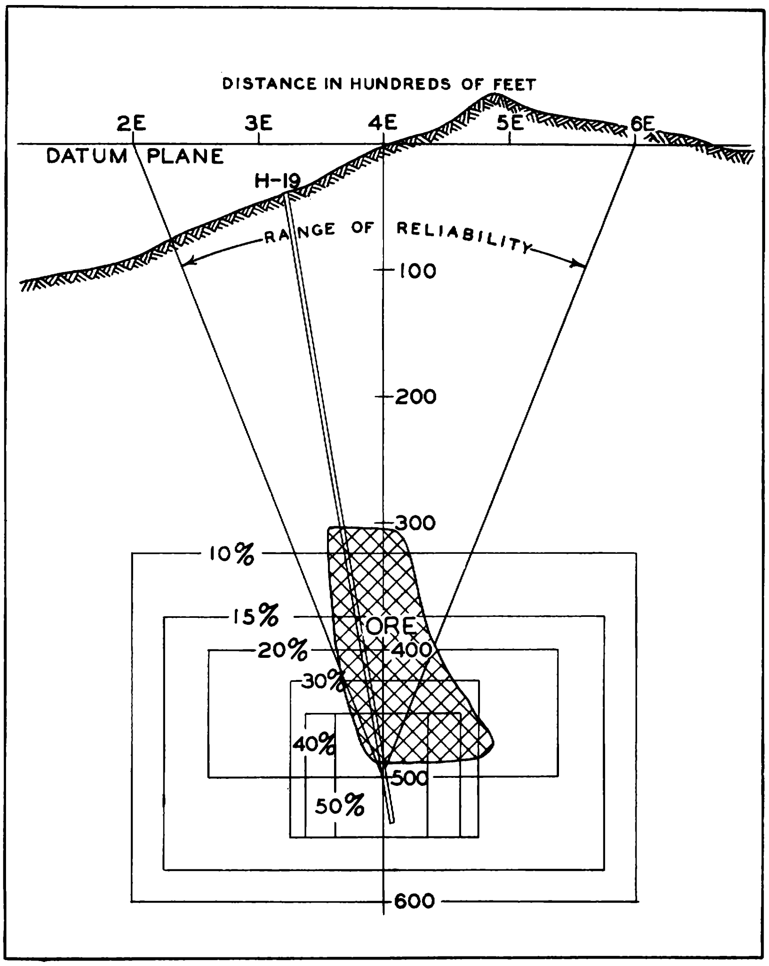

Figure 43. - Geologic cross section along traverse 26.00 N, April Fool ore body, grid 10, showing boundaries of desirable drilling targets for assumed vertical magnetic bodies with different magnetite contents, and showing the discovery hole, H-19. (Topography after W. E. Young and J. H. Mackin. Geology in part after W. E. Young.)

In compiling table 6 these serious limitations and the resulting uncertainties that they cause in the quantitative estimates were considered. For example, for a theoretically calculated vertical magnetic body with 40 percent magnetite content, a depth to apex of 350 feet, a width of 250 feet, and a depth extent of 450 feet (see table 6) provided an excellent fit with the observed response curve (see fig. 39). Nevertheless, after considering the uncertainties involved, the following estimates for such a magnetic body were given in table 6: A depth of 225 to 400 feet, a width of 125 feet or more, a depth extent of 100 feet or more. The other estimates are similarly conservative and represent the most reasonable estimates that could be made before the drilling.

Geologic Considerations Incident to Geophysical Interpretation. - The main problem of the April Fool anomaly was to explain the magnetite at depth which gives rise to the large, broad anomaly. The types of magnetic bodies that might have been responsible for the observed anomaly were:

(1) Magnetite lying at depth within replacement ore. The purely geologic phases of this problem have already been considered.

(2) Magnetite vein, of possible commerical size, lying at depth at the monzonite-Homestake contact.

(3) Magnetite vein, of possible commercial size, lying at depth completely within monzonite.

(4) Disseminated magnetite, too low in iron to be of commercial value, lying at depth within either sedimentary rocks or monzonite.

As the surface geology did not suggest which of these geologic possibilities was most probable, no one of them could be singled out as the correct interpretation of the anomaly.

Problem of Susceptibility of Monzonite in April Fool Claim Area. - As a large part of the magnetic anomaly centered over monzonite, it became desirable before the drilling to ascertain whether the magnetic susceptibility of the monzonite underlying the magnetic anomaly differed markedly from that of the monzonite lying outside the anomaly. In running the traverses, the magnetometer readings over the monzonite indicated that the magnetic susceptibility of the monzonite is variable. Nearly every one of the magnetic profiles in the April Fool claim area shows manifestations of small veinlets of magnetite at depth in the monzonite or places where the monzonite has been slightly enriched with magnetite, probably during the magnetic differentiation. In figure 42, showing the magnetic profile along traverse 28.00N, peaks A, B, and C afford outstanding examples of this phenomenon. These peaks are local, near-surface effects superimposed on top of a large, broad anomaly. Effects of this type are commonly observed on the monzonite throughout the Iron Springs district.

A brief examination of the magnetic susceptibility[81/] of 116 specimens taken from monzonite outcrops in the general area of the April Fool anomaly gave the following results:

81/ The order of magnitude of the relative susceptibility of various specimens was obtained by holding hand-sized specimens, all of essentially the same dimensions, at the same distance from the magnetometer.

(1) In the porphyritic border zone of the monzonite, between traverses 24.00N, and 28.00N, 47 samples were taken in the area between 4.00E and 6.00E. Although the majority of these specimens show susceptibility values higher than average for the monzonite, they were not universally high, but spotty. More than one fourth of the specimens were within the susceptibility range of normal monzonite.82/ In the area between 5.00E and 6.00E, most of the specimens were within the range of normal monzonite. In particular, of seven specimens taken at regular intervals over a distance of 100 feet in a north direction between traverses 25.00N and 26.00N, at 6.00E, five gave normal values, and two represented spots enriched with magnetite.

From these observations it appears that the porphyritic areas of rather high magnetic susceptibility between traverses 24.00N and 28.00N are (1) local and not persistent and (2) restricted to a width of less than 200 feet in a direction perpendicular to the strike of the monzonite-Homestake contact. It was not known whether the high susceptibility of the monzonite persists at depth between traverses 24.00N and 28.00N.

(2) Within grid 10 in the general area between 6.00S-2.50E and 6.00S-3.00E, which lies about 2,600 feet south of the April Fool area and thus outside of the magnetic anomaly, is to be found a bold ledge of monzonite which constitutes the border zone of the intrusive rock. Specimens taken from this ledge show magnetic characteristics similar to those found in the porphyritic border zone of the intrusive rock in the April Fool claim area. Yet no pronounced anomaly was observed in this area on the 4.00E reconnaissance line, which passes within about 50 feet of the ledge.

(3) Within grid 10, in the area between 13.80N-5.00E and 14.60N-5.00E, which lies just outside and south of the April Fool anomaly, is also to be found a bold ledge of monzonite which constitutes the border zone of the intrusive rock. Of 10 samples taken from this ledge at regular intervals between 13.80N and 14.60N along the 5.00E coordinate line, the susceptibility values of five specimens were as high as those observed in the porphyritic border zone of the intrusive rock in the April Fool claim area. Yet no large, broad anomaly was observed on traverse 15.00N, which passes over the northern part of this monzonite ledge.

(4) Five specimens taken in the vicinity of 15.40N-1.50E and 10 83/ in the area between 15.20N-5.10E and 15.90N-5.10E suggest that the monzonite in these areas is essentially normal. Yet on traverse 16.00N is seen a manifestation of the magnetic body at depth. Furthermore, the local, sharp magnetic peak at about 1.00E on traverse 16.00N indicates probably a shallow magnetite vein lying at the monzonite-Homestake contact. Thus in going northward from the area lying south of the anomaly, the magnetic evidence of this shallow mineralization along the monzonite-Homestake contact is first observed in the general area where the magnetic body at depth begins first to manifest itself in the magnetic anomaly.

82/ By "normal" monzonite is meant monzonite that contains a normal amount of magnetite and that has not been exceedingly enriched with magnetite during the magmatic differentiation.

83/ 3 of these 10 specimens showed susceptibility values somewhat higher than normal.

(5) Of 13 specimens taken at rather regular intervals on traverse 21.00N between 3.80E and 5.00E, 8 had normal values, and the remainder were high.

(6) Of 13 specimens taken along traverse 31.00N,84/ all but 1 had normal values. Yet this traverse lies in the area where ore is exposed in the pit85/ at the monzonite-Homestake contact and where the magnetic body at depth manifests itself somewhat.

The results of the susceptibility determinations may be summarized as follows:

(1) At least two areas lying within half a mile of the April Fool anomaly can be found where the border phase of the monzonite shows susceptibility values that are as high and that vary locally in the same manner as the values within the porphyritic border zone in the central part of the April Fool anomaly (see (2) and (3) above). Yet these areas show no pronounced magnetic anomaly and probably are barren of ore. Therefore no surface indications suggest that the magnetic character of the monzonite at depth within the April Fool anomaly and between traverses 24.00N and 28.00N, where high susceptibility values are locally observed at the surface and where a large, broad anomaly exists, is any different from the character of the monzonite at depth in these two areas, where similar high susceptibility values are locally observed at the surface but where no broad anomaly exists.

(2) Along traverses 21.00N and 31.00N, which lie within the April Fool anomaly, the magnetic properties of the monzonite are apparently essentially normal at the surface (see (5) and (6) above).

Summary of Geophysical Interpretation and Reasons for Test Drilling. - (1) In spite of the possibility that the observed anomaly could have been caused by magnetite at depth disseminated within the monzonite, the surface observations and susceptibility determinations did not give this interpretation strong enough support to discourage test drilling in the area.

(2) In view of the relation which the intense faulting and shearing in the area bear to the observed anomaly, geological relations were considered favorable enough by the writer to justify test drilling in the area.

(3) The estimates given in table 6 indicated that the observed anomaly could be due to an ore body of economic size.

(4) The April Fool anomaly is similar in size and extent to the anomalies observed over known ore bodies of the district; and, to the writer's knowledge, no magnetic anomaly with a size, extent, and geologic setting similar to those of the April Fool anomaly has failed to indicate commercial ore in the Iron Springs district.

For these reasons the April Fool anomaly was considered an attractive prospect for developing an ore body of major size, and testing drilling was therefore recommended.

84/ 5 were taken from the monzonite west of the pit in ore, and the remainder were taken from the area east of the pit.

85/ See footnote 84.

Drilling Targets. - To help clarify some of the risks and problems incident to the choice of a first test hole along traverse 26.00N, figure 43 was drawn and presented in its present form 86/ to the project engineer before the drilling. Not to be confused with the calculated possible boundaries of an assumed vertical magnetic body as such, the diagram shows the boundaries of the desirable drilling targets for assumed vertical magnetic bodies of different magnetite contents. 87/ Moreover, the fact that the depth to the top of the targets is 300 to 450 feet is not to be construed as implying that this is the most probable depth to the top of the magnetic body. To drill for a body of a specified magnetite content, the drill should be aimed at the center of the indicated target. For example, a vertical hole at 3.00E on traverse 26.00N would run considerable risk of missing completely a vertical magnetic body whose magnetite content is 30 percent or more. Similarly, a vertical hole at 3.50E on traverse 26.00N would run considerable risk of missing completely a vertical magnetic body whose magnetite content is 50 percent or more.

Owing to the uncertainties of the estimates in table 6 and to the fact that the April Fool magnetic body could be steeply dipping, rather than vertical, the diagram is reliable only for vertical or steeply inclined holes less than about 20° from verticality.

The possibility that the body might be dipping either east or west made very risky any first test hole that was greatly inclined away from verticality and made more feasible a vertical or nearly vertical test hole. The best hole was apparently a vertical hole at 4.00E on traverse 26.00N. As this location was inaccessible for the drill because of the large talus blocks of monzonite, the drilling of an inclined hole was imperative; and it was recommended that the drilling target should be a point lying 500 feet vertically below the point 26.00N-4.00E (see fig. 43). Inclined hole H-19, which dipped 81° E., was pointed at this target. On the basis of the estimates in table 6, it was recommended that if this first test hole started in monzonite, it should be drilled to a depth of at least 300 feet. 88/

Drilling Results in April Fool Claim Area

Inclined hole H-19 penetrated a total thickness of 190 feet of ore, the ore beginning at a hole depth of 267 feet (see fig. 38). Thus the apex of the ore body lies 297 feet below the elevation of the datum point to which the depth estimates in table 6 were referred. The hole started in monzonite and penetrated solid monzonite until, at a depth of 210 feet, an altered calcareous contact material was encountered.

To test further the size of the April Fool ore body, inclined holes H-21 and H-23 and vertical hole H-25 were drilled, largely on the basis of the geophysical

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86/ With the exception of the cross section of the ore body, which was added after the drilling.

87/ The diagram is based on estimates given in table 6 and applies only to drilling targets along traverse 26.00N.

88/ Calculations made independently by Hugo E. Kuehn, of the Baltimore office of the Division of Geophysical Exploration, using a method different from that of the writer, indicated that the probable depth of the magnetic body was 150 to 300 feet.

results. Of these, the first two holes penetrated 95 and 104 feet of ore, respectively, and hole H-25 encountered no ore.

Not enough drilling was done to ascertain the exact cross-sectional size of the ore body, but in the general area of traverse 26.00N the average width is apparently between 75 feet and 100 feet, and the depth extent is at least 190 feet. The average magnetite content of the ore, based on the analyses of the ore obtained in holes H-19, H-21, and H-23, is 43.2 percent by weight.89/

The results of the four holes clarify many, but not all, of the geological problems of the April Fool ore body. As the ore that was penetrated in the three holes was predominantly of the replacement type, the ore body is probably of that type. The drilling showed further that (1) in the area of traverse 26.00N the ore body is vertical or steeply dipping, possibly east, (2) along traverse 24.00N it may be dipping steeply east, and (3) along traverse 28.00N it may be dipping west. Figure 38 shows the most probable cross section along traverse 26.00N that can be drawn at present, hole H-21 being projected into the section.

As hole H-21 penetrated about 215 feet of monzonite before encountering ore, the April Fool ore body apparently constitutes a large block of ore that may be completely surrounded by monzonite. Being replacement ore, the ore body was apparently once a block of Homestake limestone that was mineralized after the block became foundered in the molten magma. It is the only known ore body of this type in the district.

Confirmation of Geophysical Predictions in April Fool Claim Area

It was correctly predicted that along traverse 26.00N the magnetic body is vertical or steeply dipping.

In the areas tested by holes H-19 and H-21 the location of the apex of the magnetic body was correctly predicted. As hole H-23 encountered the ore body at a point probably lying a distance of a few scores of feet down-dip below the apex, the predicted location of the apex in the area of this hole is also apparently correct. Although drilled to a depth of about 500 feet, vertical hole H-25, which was on traverse 22.00N at a point where the apex was incorrectly predicted, encountered no ore; but it did pass through a total thickness of about 50 feet of altered limestone at depths of 345 to 366 feet and 427 to 452 feet. As the ore body probably extends southward at least as far as traverse 22.00N, hole H-25 probably barely missed the ore body; further drilling along this traverse is desirable.

89/ In an ore consisting of a mixture of magnetite and hematite only, the percentage of magnetite by volume will equal the percentage of magnetite by weight only if the density and texture of the magnetite is the same as that of the hematite which, in general, is not true. In view of the possible errors in the value of the percentage of magnetite by weight in the ore samples, errors which are inherent in the chemical method of the analysis, it can be assumed, for all practical purposes for which these values are being used in the present case, that the percentages by volume and by weight are essentially equal.

By interpolating between the estimates given in table 6 for magnetite contents of 40 and 50 percent, the estimates of depth, width, and depth extent of a body with 43.2 percent magnetite content are found to be, respectively, 235 to 400 feet, 75 to 110 feet, and 100 feet or more.90/ As shown in table 7, these estimates are in unexpectedly close agreement with the observed depth and dimensions of the known ore body.

TABLE 7. - Comparison of theoretically determined estimates and observed depth and dimensions of April Fool ore body in feet

	Estimates interpolated from table 6	Observed value, based on drilling
Depth to apex	235 to 400	297
Width	75 to 110	75 to 100
Depth extent	100 or more	190

Summary of Geophysical Results in April Fool Claim Area

The April Fool ore body was found solely as the result of the discovery and correct geophysical interpretation of the magnetic anomaly. At the time of the discovery, the possible existence of a replacement ore body within the intrusive was contrary to all observed geologic conditions in the district. The ore body is of major size and economic importance.

Magnetometer Grid 11

Lying along the northwest margin of the Three Peaks intrusion, grid 11 extends northward for 1-1/2 miles (see fig. 44). The base line lies along or near the monzonite-sedimentary rock contact throughout the length of the grid. Detailed traverses cover the southern part of the grid and reconnaissance traverses cover the northern part.

Geology

In the southern part of grid 11 are found good exposures that define the location of the monzonite-sedimentary rock contact within a few tens of feet. Here the Homestake limestone lies on the west side of the contact and the monzonite on the east side. Lying west of the Homestake limestone, the Pinto sandstone strikes N. 15^{o}-25^{o} E. and dips 50^{o}-60^{o}W.

In the general area of traverse 6.00N the Homestake limestone begins to wedge out northward, and at or near traverse 20.00N, where well-recognized lower quartzite members of the Pinto formation lie in contact with the monzonite, it disappears completely. Because of the close resemblance of the Homestake limestone and the Proctor limestone, (one of the lower members of the Pinto formation also exposed in the area), it is difficult to choose the exact location of the north tip of the wedge of Homestake limestone. The tip doubtless lies between traverses 14.00N and 20.00N. The wedging-out of the Homestake and Proctor limestones indicates a marginal fault whose throw is probably at least several hundred feet.

90/ It should be recognized that the value of 43.2 percent for the magnetite content represents the result of the sampling of only 3 holes and may not be representative of the whole ore body.

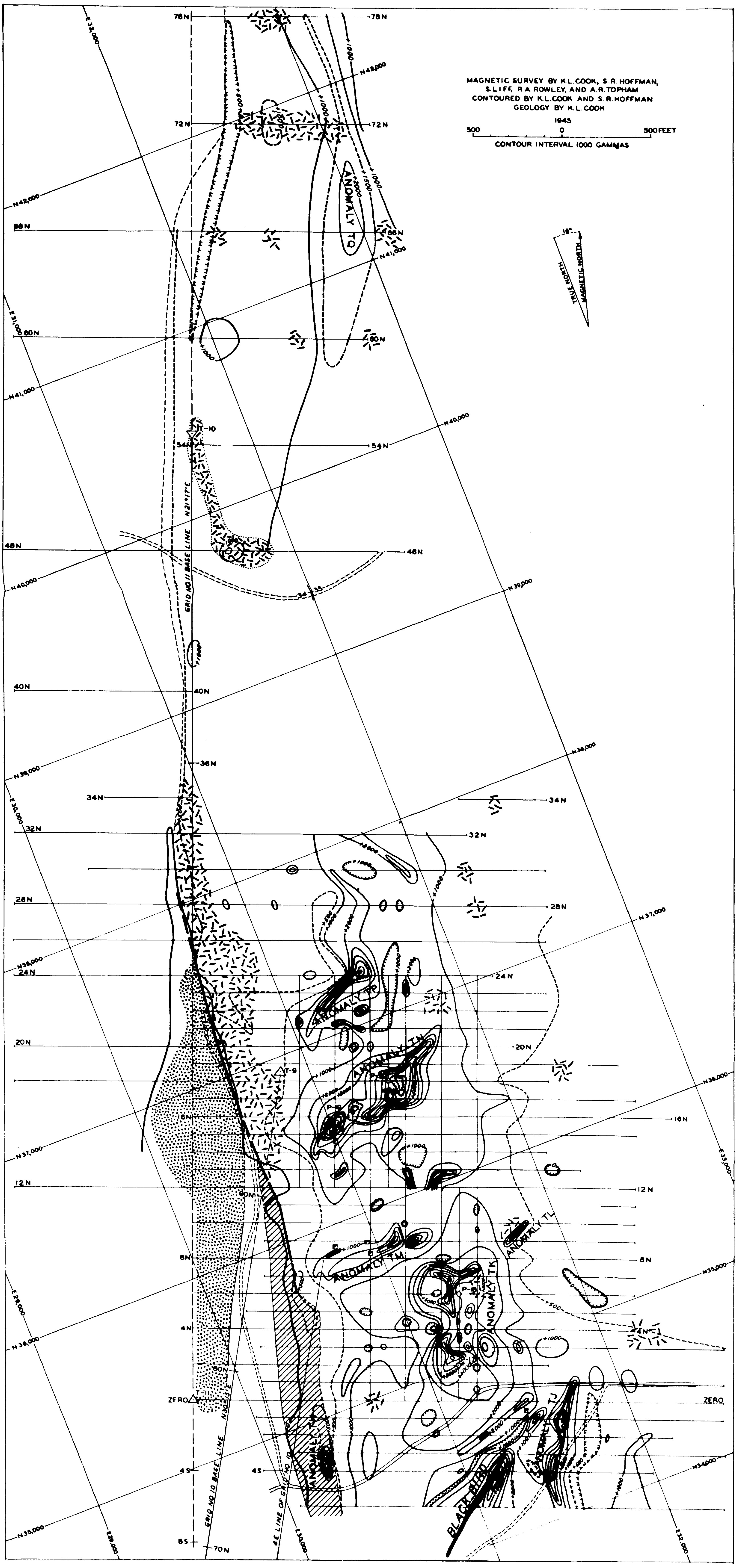

Figure 44. - Magnetic and geologic map of grid 11, Three Peaks.

In the area between traverses 20.00N and 24.00N the strike of the exposed quartzite is essentially the same as that to the south, and the dip is probably about 80° W., which is much greater than that to the south. Measurements of dip in this area are not entirely reliable, however, because of the flat-lying exposures.

In the northern part of the grid no exposures of sedimentary rock were found north of traverse 26.00N, and the base line lies approximately on the line of demarcation between the exposures of monzonite on the east side of the line and a mantle of alluvium on the west. Several outcrops of monzonite indicate that the margin of the intrusion extends at least to the extreme north end of the grid before it trends markedly northeast. The type of sedimentary rock underlying the alluvium is not known. If the throw of the fault is less than 1,000 or 2,000 feet, the alluvium probably is underlain by members of the Pinto formation. If it is more than 2,000 feet, the Pinto formation at the contact may give way to the Claron formation, especially in the northern part of the grid, and Claron limestone may lie beneath the alluvium.

Thus the possibility of finding near-surface replacement ore throughout the northern part of the grid and perhaps also throughout the north, northeast, and east margins of the Three Peaks intrusion depends largely on the throw of the fault. If the throw is large, the Homestake limestone and any possible replacement ore lie at great depth.

Replacement Ore. - Throughout the grid the only replacement ore to be found at or near the monzonite-sedimentary rock contact is exposed in a shaft and a pit, both of which were dug in the lower part of the Homestake limestone in the vicinity of traverse 4.00S.

A block of sedimentary rock that has been replaced with ore is exposed in the Irene claim area, which lies a few hundred feet southeast of the south end of the grid. As the block is surrounded by monzonite and lies about 1,500 feet east of the main monzonite-limestone contact, it is probably a roof pendant that has been heavily mineralized. The ore is apparently of good grade locally.

Magnetite Vein Ore. - As the mantle of alluvium in the southern part of the grid is generally less than 5 feet, several outcrops of monzonite and fissure veins of magnetite are to be found in this area. As most of the exposures are small and flat-lying, only a few reliable strike and dip measurements of the veins can be made. The measurements indicate that the strike of the veins is northeast in the Blackbird area, about S. 80° E. in the area of anomaly TM, and intermediate between these directions in the intervening area. Local exceptions to this generalization of the strikes can be found, and more than one system of veins possibly exist, just as two or more predominant joint systems exist in the monzonite in the southern part of the grid.

Lying at the south end of the grid, the lens-shaped Blackbird fissure vein is the largest exposed vein in the area. It is about 700 feet in length and 35 feet in maximum width at its center. At the surface its dip is apparently 80° E.

Results of Magnetic Survey

Much detailed magnetometer work was done in the southern part of the grid for the following reasons:

(1) Since it is one of the most heavily mineralized areas lying within the Three Peaks intrusion, the area provides a good opportunity to study the magnetic response of the heavily mineralized monzonite and of the vein deposits in the monzonite.

(2) The frequent crossing of the monzonite-sedimentary rock contact during the measurements in the area of grid 11 gave a sound correlation of the geology and geophysics of the contact area. This correlation could then be used in the large-scale reconnaissance on the north and east margins of the Three Peaks intrusion to determine the approximate location of the monzonite-sedimentary rock contact beneath the alluvium.

(3) The area makes a good testing ground because it is level and only thinly wooded.

(4) The results of the drilling on the April Fool ore body, which lies 1-1/2 miles south of the grid, suggest that blocks of sedimentary rock may have toppled into the molten magma near the present contact at the northwest edge of the Three Peaks intrusion. This fact, plus the existence of the roof-pendant-type ore body on the nearby Irene claim, makes the area favorable for possible discovery of a replacement ore body of the roof-pendant type which may lie beneath exposures of monzonite in the area.

Monzonite-Sedimentary Rock Contact. - The exposures in the southern part of the grid provide excellent opportunity to correlate the location of the monzonite-limestone contact with the break in the magnetic response curve observed at the contact. As the break is similarly observed in the northern part of the grid, the correlation can be extended to this area, where the location of the contact beneath the alluvium can be inferred with a probable error of less than 100 to 200 feet. The inferred location of the contact is shown on the geologic map (see fig. 44).

Replacement Ore. - No magnetic anomaly that would indicate a large, near-surface body of commercial ore was found anywhere in the grid in the surveyed area lying west of the contact. It is remarkable that the Homestake limestone lying west of the contact is apparently so barren in an area where the monzonite has been so intensely mineralized.

Anomaly TH. - Anomaly TH overlies the replacement ore encountered in a shaft and pit in the Homestake limestone. The trend of the anomaly, and therefore the strike of the ore body, parallels the monzonite-Homestake contact. The ore body at depth is probably 100 to 300 feet in length and less than 60 feet in width. It may have some small commercial importance.

Blackbird Anomaly. - Time permitted surveying only the northern part of the exposed Blackbird vein. The trend of the anomaly parallels the strike of the vein. The relative symmetry of a magnetic profile taken perpendicular to the strike indicates that the vein is vertical or steeply dipping.

As the anomaly terminates south of traverse 2.00S, the main Blackbird vein extends northeastward little farther than traverse 3.00S. The flanks of the magnetic response curve suggest that the central part of the vein extends probably at least a few tens or scores of feet in depth. Although the southern part of the deposit was not surveyed, the ore body is apparently of commercial size and warrants test drilling.

The ore exposed about 300 feet northeast of the exposed north tip of the main vein is not continuous with the main vein and forms part of a small vein less than 200 feet long, which is too small to be of much commercial importance.

Anomaly TJ. - Anomaly TJ lies in an area completely covered with alluvium. As the trend of the anomaly is essentially parallel to that of the fissure veins in the area, the anomaly is caused probably by a vein which, though it may be of much smaller tonnage than the Blackbird vein, may have some small economic importance. It lies at a shallow depth, possibly directly beneath the alluvium.

Anomaly TK. - Anomaly TK, which extends northward 1,400 feet, is defined approximately by the +1,500-gamma contour line. Two separate, positive highs lie within the anomaly, one in the northern and one in the central part.

Few exposures are to be found within the anomaly, most of the area being covered with a mantle of alluvium. Some ore float is to be found between lines 14.00E and 15.00E, especially in the area of the two magnetic highs. An eastward-trending magnetite vein, which is about 75 feet long and 3 feet wide, is exposed east of the 15.00E line and between traverses 7.00N and 8.00N. The northeastern part of the positive high in this area is caused by this vein. Similarly, the remainder of the northern positive high, as well as the southern positive high, is probably due to near-surface magnetite veins possibly lying immediately below the alluvium.

To investigate the possibility that numerous eastward-trending veins underlie the anomaly, magnetometer readings were taken along several northward-trending lines in addition to those along the regular traverses. Each response curve along these lines shows about six exceedingly strong, narrow peaks superimposed on a large, broad anomaly,91/ the distance between successive peaks commonly being 100 to 200 feet. The peaks probably are caused by veins of ore which are 5 feet or more in width and lie at shallow depth, possibly directly beneath the alluvium. That the peaks cannot be definitely correlated between lines 14.00E, 15.00E, and 16.00E means that the veins are short. On the regular eastward-trending traverses each response curve ordinarily shows only one or two peaks of this kind. The far greater frequency of occurrence of the peaks along the northward-trending lines indicates that the strike of the small veins within the anomaly is nearer east than north.

91/ The readings on both the lines and regular traverses were much more erratic than is indicated by the contour lines on the magnetic map, which were obtained by "smoothing out" the observed response curve. In fact, the jagged nature of the response curves obtained throughout the grid 11 area necessitated much "smoothing".

A system of joints, which strike east and dip north, has been formed in this area. The veins within the anomaly probably tend to follow the joints.

The broad flanks of the anomaly appear to be caused by magnetite lying at depth. The broad anomaly trends in a direction parallel to the monzonite-limestone contact. No exposures of ore veins seen by the writer in the southern part of the grid suggest that any large vein has been formed striking in this direction. If several of these eastward-striking magnetite veins continue down-dip a few scores of feet or more, it is possible, of course, that in the aggregate they could cause a response curve similar to the one actually observed.

The anomaly is large enough to justify testing to ascertain whether the magnetite at depth is formed within monzonite, or possibly within sedimentary rock.

Anomalies TL and TM. - Anomaly TL trends slightly north of east, thus conforming to the general trend of the vein system in the area. It is probably caused by a vein of ore, too small to be commercially important.

Anomaly TM extends eastward about 500 feet. Immediately north of and outside of the anomaly an eastward-trending magnetite vein is exposed which parallels the trend of the anomaly. Anomaly TM also parallels the strike of the 75-foot-long vein exposed in the northern part of anomaly TK. Anomaly TM probably is caused by a fissure vein of ore which strikes east and dips steeply north. The vein lies at a shallow depth, possibly directly beneath the alluvium, and may have some small commercial importance.

Anomaly TN. - Anomaly TN, extending northeastward about 1,000 feet, is defined approximately by the +2,000-gamma contour line. A local positive high lies at either end of the anomaly. Several fissure veins of magnetite are exposed within the area of the anomaly. In the western part of the anomaly, the exposed veins strike east and dip steeply north, as indicated by a 1-foot-wide vein and a 2-foot-wide vein, which are well-exposed in two shafts in the area. In the eastern part of the anomaly three well-exposed veins strike S. 70°-80° E. Their dip is indeterminate. The local highs are manifestations of near-surface magnetite, but the broad magnetic response indicates magnetite at depth. The widely spaced contour lines comprising the northern part of the anomaly, which are in striking contrast with the closely spaced contour lines on the southern part, indicate that the main mass of magnetite causing the anomaly dips north.

On the north and south flanks of the anomaly, the contour lines are not continuously concave toward the center of the magnetic zone; rather they are undulatory. Along the south side of the magnetic zone the changes in curvature are so abrupt that at least two offsets in the anomaly are recognized. Two similar, though far less pronounced, offsets are seen also on the north side. This offset feature may be due to a number of eastward-striking magnetite veins, which lie en echelon. As the en echelon pattern may be formed by stresses that cause little or no faulting, the offset feature of the anomaly does not necessarily mean that the rocks have been displaced. At depth the veins may coalesce to form a single massive northeastward-trending body of ore or continue as individual eastward- or southeastward-trending veins that form fingers and lenses of ore rarely over 10 to 20 feet wide.

Because anomaly TM lies only a few hundred feet east of the area where the Homestake limestone wedges out, it is conceivable that some sedimentary rock may underlie at least the western part of the anomaly and that the anomaly may be due in part to replacement ore at depth. It may or may not be significant that the trend of the anomaly is essentially the same as that of the replacement ore body on the Irene claim.

Drilling in the zone appears justified. Even though the anomaly may be caused by vein magnetite alone, the deposit could be of commercial size, although beneficiation may be necessary.

Anomaly TP. - Lying in an area completely covered with alluvium, anomaly TP probably is caused by a magnetite vein lying at shallow depth, possibly directly under the alluvium. The vein may have some small commercial importance.

Anomaly TQ. - Lying about 1,000 feet east of the monzonite-limestone contact in an area where monzonite is well-exposed, anomaly TQ extends about 1,000 feet parallel to the contact. No exposures of ore were observed along the reconnaissance lines. Not enough work was done in the area to estimate the economic importance of the anomaly.

Reconnaissance of Northeast Three Peaks Area

Geology

A reconnaissance of the geology in the area lying north and east of grid 11 showed that, although most of the area is covered with a thin mantle of alluvium, several exposures of monzonite, but none of sedimentary rock, are to be found as far north as the center of section 26, T. 34 S., R. 12 W. (see fig. 3).

Plan of Magnetic Survey

The contrast in the regional magnetic values of the monzonite and the sedimentary rock in the grid 11 area makes it appear possible to find the monzonite-sedimentary rock contact throughout the north and east margins of the Three Peaks area, provided that the mantle of alluvium is not too thick.

In exploring this area, the proper attack is first to try to find the possible monzonite-sedimentary rock contact by large-scale reconnaissance work over the alluvium, and then to explore the probable contact in greater detail for any magnetic response that may indicate ore at depth. Time did not permit the completion of this plan for the entire alluvium-covered area, although part of the plan was realized for the area lying north and east of grid 11 (see fig. 7). In this area magnetometer readings were taken along 14 reconnaissance traverses, which generally trend northeastward. Most of the traverses cross the inferred contact. Except along traverse 1, no exposures are to be found within the general area covered by the traverses.

Traverses 4 to 10, inclusive, comprise a reconnaissance grid to which no designating number was assigned and whose traverses are spaced 1,000 feet apart. Traverses 1 and 2, which are not included in this grid, lie about three-fourths of a mile north of traverse 5 and trend northeastward. Traverses 11, 13, and 14, which are spaced about 1,000 feet apart, lie immediately south of this grid. The directions of all of the traverses were determined by Brunton compass, and all distances were paced.

Results of Magnetic Survey

Readings taken along traverse 1, which starts in the area of the exposed monzonite and extends southwestward toward the interior of the monzonite intrusion, gave the regional value of the monzonite in the area. Readings taken along northeastward-trending traverse 2, which lies in an area completely covered with alluvium, gave, on its northern half, the probable regional value of the sedimentary rock under the alluvium. The difference of the regional values in this area is about 750 gammas.

On traverse 2 the break in the response curve over the assumed contact is not sharp, as it was in the grid 11 area where the bedrock lies at shallow depth. Instead, the break has a gentle slope, which suggests a far greater depth of overburden than in the grid 11 area. Similar breaks were observed on traverses 4 to 7, inclusive, and the approximate location of the inferred contact is indicated in figure 3.

Although each of the remaining reconnaissance traverses lying south of traverse 7 shows a gradually diminishing magnetic response in a northeast or east direction, no break was observed that could be reliably interpreted as the contact. The absence of a break may be due to any one of the following reasons:

(1) The contact may not underlie the area covered by these traverses.

(2) The contact may be too deep to show a recognizable change in the response.

(3) The contact may be covered with a lava flow which underlies the alluvium and which, because of its similar magnetic susceptibility to that of monzonite, cannot be distinguished magnetically from the monzonite.

Traverses 4 to 7, inclusive, and traverse 12 showed a recognizable magnetic anomaly which warranted the establishment of a detailed magnetometer grid (grid 21) in the area.

Magnetometer Grid 21

The purpose of grid 21 was to investigate further the anomaly discovered on the reconnaissance traverses. The grid, which was laid out by a transit survey, extends 4,000 feet northwest in a direction parallel to the inferred contact (see fig. 45). As the reconnaissance work indicated that the anomaly would be smooth and regular, the traverses were spaced 250 feet apart. To provide additional detail in the central part of the anomaly, magnetometer readings were taken also along lines 0.00, 2.50E, and 5.00E.

Geology. - No outcrops were found in grid 21, as the area was covered with alluvium. Although ore pebbles are to be found locally in the alluvium, no surface indications of ore, such as concentrations of ore cobbles or boulders, were found.

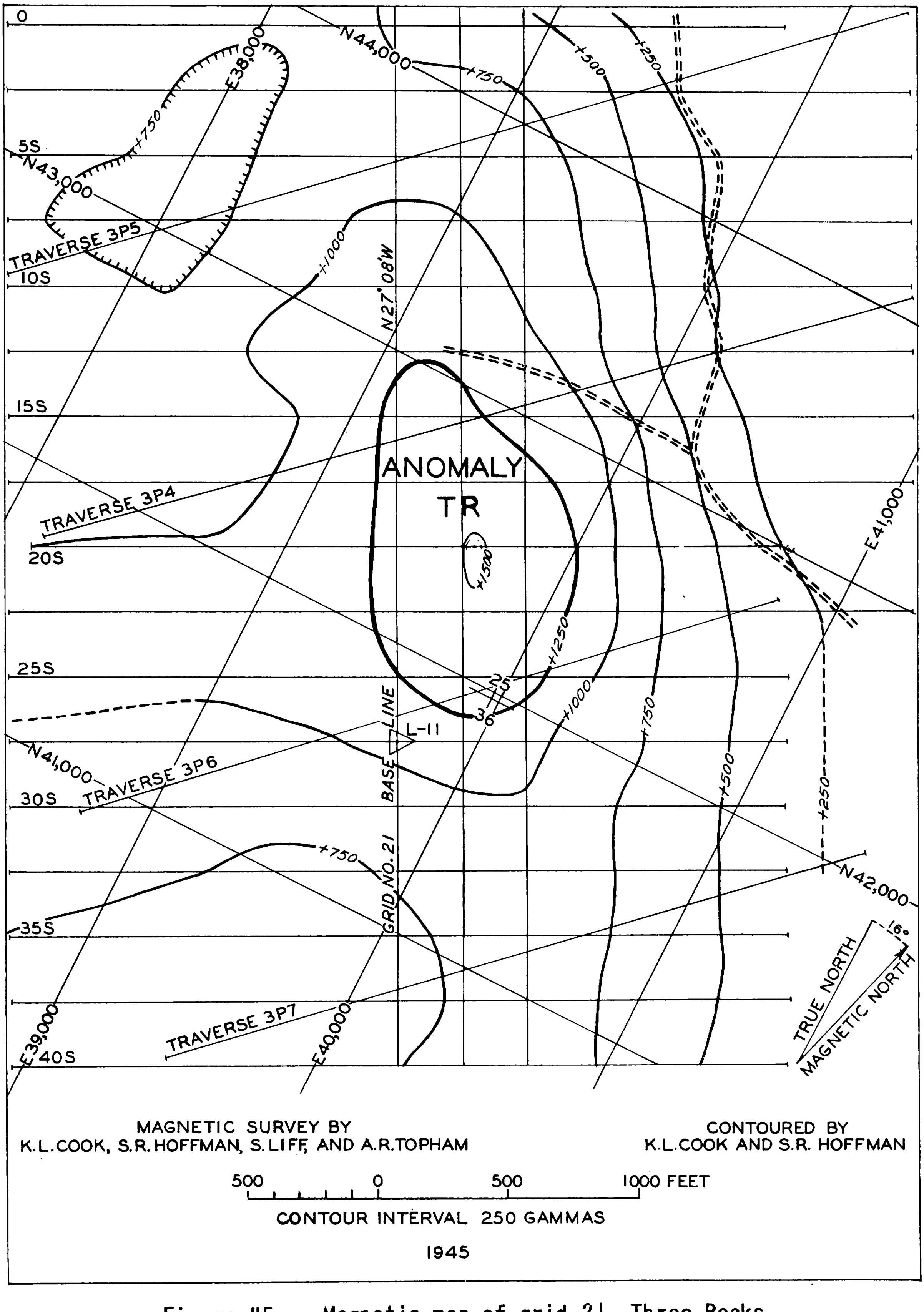

Figure 45. - Magnetic map of grid 21, Three Peaks.

Results of Magnetic Survey. - A northwestward-trending anomaly, extending parallel to the inferred contact, was discovered. Designated as anomaly TR, it consists of an oval positive high, which, on the basis of the near closure of the +1,000-gamma line, is about 2,400 feet long and 1,200 feet wide. The maximum intensity of the anomaly, taken from the 1,000-gamma contour line, is about 500 gammas. An eastward-dipping magnetic slope lies east of the positive high. Calculations show that the observed magnetic anomaly can be reconciled with an economic-size replacement ore body with a magnetite content of 10 percent and an apex approximately 500 feet below the surface. If the anomaly is caused by a commercially important ore body whose magnetite content is comparable to that of other replacement ore bodies in the district (somewhat greater than 10 percent), such an ore body necessarily lies at a depth of 500 feet or more.

Although it may be caused by an ore body, other equally plausible interpretations of the observed anomaly can be given:

(1) If in the area of the positive high the monzonite came much nearer the surface as a dome beneath the alluvium, some increase in magnetic field might be observed in the area. However, the effect would not be as pronounced as the observed response, provided that the magnetic susceptibility of the monzonite remains constant. The value of the maximum response in anomaly TR exceeds the average regional value of the monzonite by 500 gammas.

(2) An increase in the magnetic susceptibility of the underlying monzonite or sedimentary rock could cause the anomaly. In particular, the anomaly could be caused by a more heavily mineralized border phase of the monzonite, such as that found in the grid 11 area. In this case the anomaly may be caused by small veins or stringers of magnetite, or disseminated magnetite, in the underlying monzonite.

(3) It is possible, though unlikely, that the anomaly is due to a basic lava flow lying beneath the alluvium.

SUMMARY OF RESULTS OF MAGNETIC SURVEYS

Outcropping ore bodies were surveyed to determine, insofar as was possible from the magnetic data, their probable length, width, depth extent, strike, dip, and tonnage. Geologically favorable areas where no ore is exposed were explored in an endeavor to find new ore bodies. Favorable locations were determined for exploratory diamond drilling, both in areas of exposed ore bodies and in areas of newly discovered magnetic anomalies.

Forty-five separate magnetic anomalies that indicate the possible existence of ore bodies were observed. Of these, 13 anomalies are caused by outcropping ore bodies of proved commercial size. Five are caused by outcropping ore bodies of proved commercial size which were discovered in whole or part as a result of the geophysical surveys. Of the remaining anomalies, which lie in practically untested areas where few or no ore bodies are exposed, six probably are caused by large, unexposed replacement ore bodies and nine may be caused by large, unexposed magnetite veins of some small commercial importance.

Ten different ore bodies were tested by 36 drill holes put down by the Federal Bureau of Mines (see table 8). These holes gave helpful correlation of the geology and geophysics and served to check the qualitative interpretation and quantitative prior estimates of depths and sizes of the ore bodies.

In the district the strikes of both outcropping and nonoutcropping ore bodies were well-indicated by the trends of the anomalies. The directions of dip and rough estimates of the angles of dip can be obtained from the shapes of the magnetic response curves for outcropping ore bodies but are less reliable for non-outcropping ore bodies. For near-surface, nonoutcropping ore bodies with steep dips, reliable estimates of the possible depths of cover and widths of the bodies for different assumed magnetite contents can be made in special cases. Estimates of only the relative thicknesses of the ore within individual near-surface ore bodies were generally possible in the district. The depth extends of the near-surface, probable ore bodies that have not been drilled can generally be predicted only qualitatively. If one drill hole has tested the down-dip extent of an ore body, however, rather accurate predictions of down-dip extent can be made for other parts of the ore body along the strike. The lengths of the near-surface ore bodies and the location of their apices can usually be predicted accurately.

It should be emphasized that some anomalies may not be due to ore of commercial grade but to magnetite along breccia zones. It is possible that there may exist at depth ore bodies which do not produce recognizable anomalies either because they are essentially nonmagnetic or lie too deep.

The magnetic anomalies thus gave an idea of the possible sizes of the magnetic bodies and, depending on the amount of geologic control, the likelihood of finding ore. Drill holes on the basis of the magnetic surveys were kept away from obviously barren zones and confined to those areas which gave some prospect of finding ore. When the drilling of one test hole proved that the ore body was of commercial grade and size, only a few additional, carefully planned, key test holes were generally needed to give a large amount of information about the ore body.

TABLE 8. - Summary of drilling results of holes drilled by the Bureau of Mines in the Iron Springs District in 1944-45

Hole No.	Location of hole: Area	Grid No.	Magnetic grid coordinates	B. M. coordinates	Collar elevation	T., R., and sec.: T. 35 S.	T., R., and sec.: T. 36 S.	Bearing of hole	Dip of hole	Stratigraphic units and depth intervals: Alluvium	Pinto	Homestake limestone	Basal siltstone	Miscellaneous	Monzonite	Ore: Depth intervals	Character	Total thickness	Magnetite content %	Total depth of hole (feet)	Bottomed in—	Assays of ore, weighted adjusted averages: Fe	SiO_2	Al_2O_3	MgO	CaO	P	S
1	Lindsay Hill	1	1.01S- 5.20E	N 9,518 E 17,461	6011	R. 12 W. Sec. 32			90°	0-5		5-224	317-396			224-317		93	19.5	396	Basal siltstone	48.4	8.32	4.63	1.88	2.27	0.07	0.06
2	Do.	1	5.85S- 5.80E	N 9,033 E 17,527	5985	R. 12 W. Sec. 32		N. 90° W.	45° W.	0-17		17-75				75-177		102	13.3	177	Ore	57.11	5.51	2.06	1.08	2.21	.27	.01
3	Do.	1	9.80S- 6.55E	N 8,636 E 17,598	5904	R. 12 W. Sec. 32		N. 90° W.	45° W.	0-3		3-218	221-230		230-235	21[illegible]-221	Low grade	2		235	Monzonite	20.6	25.6	9.6	3.05	10.0	.05	.01
4	Lindsay South	1	16.00S- 3.80E	N 8,020 E 17,315	5928	R. 12 W. Sec. 32		N. 90° W.	45° W.	0-42		61-105		42-61 Breccia	147-152	105-147		42	29.5	152	Do.	52.6	12.2	2.03	1.45	1.72	.24	.02
5	Lindsay Hill	1	4.00S- 7.80E	N 9,218 E 17,724	5956	R. 12 W. Sec. 32		N. 90° W.	45° W.	0-25		25-220	381-429		429-437	[illegible]20-381		161	17.4	437	Do.	49.5	9.7	3.34	2.95	3.76	.33	.04
6	Pioche	2	4.30E- 3.40S	N 14,136 E 16,475	5673	R. 12 W. Sec. 29		S. 30° W.	57° SW.	0-16		16-145 192-207 237-303				145-192 207-237		77	18.2	303	Altered limestone	52.3	10.1	3.91	2.95	2.28	.17	.0[illegible]
7	Do.	2	7.03S- 6.84E	N 13,845 E 16,840	5725	R. 12 W. Sec. 29			90°	0-6	6-97	97-271 320-321	318-323		323-332	271-318		47	44.4	332	Monzonite	56.9	5.8	2.26	2.66	2.05	.23	.09
8	Do.	2	9.56S-11.90E	N 13,730 E 17,340	5663	R. 12 W. Sec. 29		S. 85° W.	60° SW.	0-20	20-139	139-370	370-404		404-407			0		407	Do.							
9	Constitution	2	46.80W- 3.40S	N 12,830 E 11,520	5786	R. 12 W. Sec. 30			90°	0-12	12-284			317-322 Limestone (16.4% Fe)	327-355	284-317 322-327		38	44.6	355	Do.	32.4	21.0	6.99	5.58	8.72	.57	.35
10	Lindsay Hill	1	0.99N- 6.85E	N 9,682 E 17,784	5965	R. 12 W. Sec. 29		N. 90° W.	50° W.	0-41		41-185	356-360 365-375			185-356 360-365		176	12.8	375	Basal siltstone	54.5	7.13	5.36	2.72	2.45	.14	.03
11	Do.	1	1.50S- 8.45E	N 9,470 E 17,789	5936	R. 12 W. Sec. 29		N. 90° W.	48° W.	0-24		24-367	390-405	376-390 Ore and limestone		367-376		15	17.0	405	Do.	35.0	22.8	8.0	5.24	4.69	.24	.02
12	Constitution	2	0.00N-48.45W	N 13,115 E 11,280	5757	R. 12 W. Sec. 30		S. 13° E.	57° S.		0-463			482-489 Mica schist and ss.	489-521	463-482		19	54.3	521	Monzonite	46.3	13.9	8.9	5.53	5.98	.12	.01
13	Armstrong	1	25.90S- 2.50W	N 7,026 E 16,704	6063	R. 12 W. Sec. 32			90°		173-1306					0-145 145-173	High grade Low grade	145	32.0	1306	Pinto shale	53.0	9.92	2.65	1.32	4.93	.43	.05
14	Lindsay Hill	1	2.78N- 5.02E	N 9,888 E 17,443	5963	R. 12 W. Sec. 30			90°			0-102	176-206			102-176		74	9.9	206	Basal siltstone	53.0	7.54	3.35	2.98	3.93	.29	.05
15	Do.	1	0.99N- 8.40E	N 9,718 E 17,784	5927	R. 12 W. Sec. 32		N. 90° W.	43° W.	0-15	15-49	49-226	427-435			226-427		201	15.4	435	Do.	49.0	11.3	4.6	3.85	2.47	.21	.03
16	Do.	1	6.00S- 9.00E	N 9,037 E 17,866	5915	R. 12 W. Sec. 32		N. 90° W.	45° W.	0-33	33-100	100-310	386-404			310-385		75	13.2	404	Do.	53.3	8.51	3.33	2.16	4.07	.25	.03
17	Constitution	2	0.00N-48.45W	N 13,115 E 11,280	5757	R. 12 W. Sec. 30			90°	0-10	10-604	604-738	793-813		813-853	738-793		53	68.1	853	Monzonite	51.7	9.16	3.35	3.38	3.94	.23	.73
18	Armstrong	1	26.93S- 4.05W	N 6,917 E 16,571	6062	R. 12 W. Sec. 30		N. 90° W.	70° W.					No core 135-149	150-175	0-149		149	29.4	175	Do.	59.2	6.14	1.96	.90	2.91	.45	.03
19	April Fool	10	25.85N- 3.20E	N 30,610 E 27,550	5919	R. 12 W. Sec. 10		S. 60° E.	81° E.			252-262 453-468 472-490		210-252 Ls. contact material	0-210 252-262 490-500	267-453 468-472		190	37.8	500	Do.	49.6	7.38	2.98	3.71	5.58	.15	.04
20	Iron Springs Arch	2	18.58N- 5.44E	N 16,293 E 16,010	5538	R. 12 W. Sec. 20			90°		0-470	470-741		741-772 Sh. and ss.	772-804			0		804	Do.							
21	April Fool	10	24.00N- 0.00E	N 30,608 E 27,188	5860	R. 12 W. Sec. 12		S. 60° E.	36° E.			0-250 340-360 586-607			250-340 360-491 607-628	491-586		95	63.7	628	Do.	48.1	9.6	2.99	3.6	6.61	1.11	.02
22	Thompson	19	38.22W-11.57S	N 3,402 E 1,503	5602		R. 13 W. Sec. 2	N. 0° E.	65° N.		0-220	220-270 417-452	452-500			270-417		147	12.4	500	Do.	51.9	7.14	3.02	3.48	4.7[illegible]	.08	.07
23	April Fool	10	27.05N- 6.10E	N 30,565 E 27,874	5982	R. 12 W. Sec. 10		N. 40° W.	50° W.			309-372 457-589	661-708		0-277 372-457 708-716	277-309 589-661		104	32.3	716	Do.	46.9	10.04	3.84	3.5	4.86	.17	.27
24	Desert Mound	19	20.32W- 1.87S	N 4,372 E 3,288	5653		R. 13 W. Sec. 2	N. 0° E.	60° N.		0-237	237-457	472-477			457-472		15	54.7	477	Basal siltstone	41.7	16.4	5.96	4.9	4.1	.28	.10
25	April Fool	10	22.00N- 4.00E	N 30,206 E 27,416	5948	R. 12 W. Sec. 10			90°			345-366 427-452			0-345 366-427 452-497			0		497	Monzonite							
26	Thompson	19	38.00W-15.13S	N 3,045 E 1,530	5595		R. 13 W. Sec. 2	N. 0° E.	60° N.	0-125	125-262	262-558	558-565					0		565	Basal siltstone							
27	Anomaly GL	19	12.09N- 1.31E	N 5,783 E 5,445	5673	R. 13 W. Sec. 35			90°										20.4	192	Monzonite	15.2	45.1	14.4	5.1	3.2	.01	.26
28	Thompson	19	38.98W- 6.27S	N 3,930 E 1,425	5588		R. 13 W. Sec. 2		90°	0-30	30-35	35-102	337-355			102-337		235	33.6	355	Basal siltstone	45.7	11.8	4.04	3.65	5.91	.26	.03
29	Short Line	19	27.92W- 6.72N	N 5,235 E 2,530	5577	R. 13 W. Sec. 35			90°	0-55	55-86	86-95	411-433			95-115 115-411	Low grade High grade	316	29.4	433	Do.	49.3	9.5	3.1	3.3	4.9	.18	.04
30	Do.	19	30.40W- 5.81N	N 5,140 E 2,290	5578	R. 13 W. Sec. 35			90°	0-58		58-194	286-295			194-286		92	22.5	295	Do.	52.0	9.4	3.4	2.2	4.5	.13	.04
31	Thompson	19	38.30W- 4.40S	N 4,124 E 1,495	5581		R. 13 W. Sec. 2		90°	0-70		70-322	322-328					0		328	Do.							
32	Short Line	19	27.74W- 4.88N	N 5,040 E 2,555	5588	R. 13 W. Sec. 35			90°			51-191	248-263	0-51 Shaft	263-293	191-248		57	24.8	293	Monzonite	47.6	9.4	3.0	3.5	6.7	.06	.05
33	Thompson	19	40.40W-10.51S	N 3,510 E 1,255	5605		R. 13 W. Sec. 2		90°		0-157	157-314	400-415			314-400		86	24.4	415	Basal siltstone	54.0	8.8	3.4	2.6	1.6	.06	.06
34	Short Line	19	28.00W- 7.60N	N 5,310 E 2,525	5574	R. 13 W. Sec. 35			90°	0-102		102-124	231-251			124-231		107	16.9	251	Do.	43.7	14.0	4.8	4.5	5.8	.13	.03
35	Thompson	19	36.29W-10.26S	N 3,530 E 1,685	5602		R. 13 W. Sec. 2		90°		0-187	187-446	446-457 458-464		457-458 464-465			0		465	Monzonite							
36	Short Line	19	27.32W- 3.82N	N 4,939 E 2,594	5598	R. 13 W. Sec. 35			90°			71-247	29[illegible]-296	0-71 Shaft	296-301	247-296		49	30.1	301	Do.	51.0	8.3	3.4	2.3	4.9	.14	.08