California Institute of Technology

Pasadena, California

MAGNETIC SURVEY OF THE SAN GABRIEL WASH

Los Angeles County, California

A Thesis

by

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In Partial Fulfillment of the Requirements

for the degree of Master of Science,

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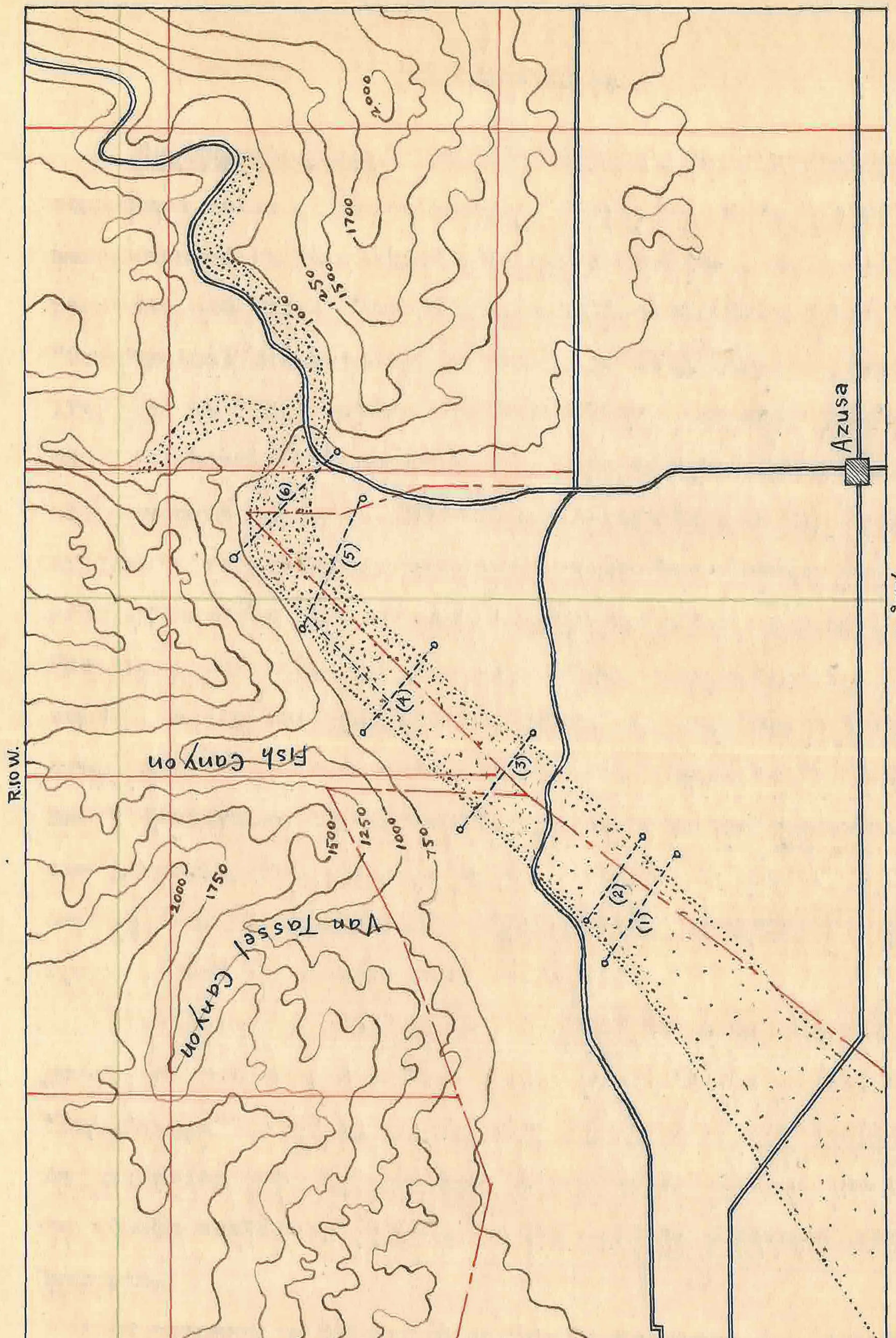
INTRODUCTION

As a partial fulfillment of the requirements in obtaining a degree of Master of Science in Geological Sciences at the California Institute of Technology, the writer was given the task of writing a thesis on the following subject: "Magnetic Survey and interpretation of the results over the San Gabriel wash."

The area is between Monrovia and Azusa, two miles west of Azusa. It is accessible by several roads branching from the Foothill Boulevard (U.S. Highway 66) running east and west, passing through Monrovia and Azusa. One of them is the Las Lomas Road going north along the west bank; the other one is an oiled road going to the Cyanide Company plant and continuing as a dirt road along the east bank. The upper part of the wash and the canyon itself can be reached by the State Highway 39 running northward from Azusa. From this road several dirt roads branch out.

The wash is too large to make a detailed survey in a short time. Thus, the work done is more or less a reconnaissance survey. It is surrounded by farms, the Cyanide Company plant, private properties and impenetrable jungle-like areas, so that it has not been possible to take readings anywhere. Another disadvantage is that the running water is controlled by the dam, and sometimes it cannot be crossed, due to abundance and speed of water. Big granite boulders covering the whole wash constitute still another disadvantage, making tripod settings very difficult.

The work was carried on under the directions of Dr. G.W. Potapenko, Associate Professor of Physics, whose assistance is gratefully acknowledged by the writer.



San Gabriel Wash
Scale: $\frac{1}{31250}$

THE INSTRUMENTS

The Magnetometer: It is a vertical field magnetometer, sometimes called "field balance," designed by A. Schmidt and manufactured by the Askania Werke in Berlin. It is an uncompensated old type. The full description of it is given in "Geophysical Prospecting for Oil" by Nettleton, on pages 178-179, and in "Exploration Geophysics" by Jakosky, on pages 92-98. In short, it consists of a balance made of two elliptical permanent magnets. The mass distribution of the balance system is so arranged that the gravity force holds the force exerted only by the vertical component of the magnetic field. For this, the axis of rotation of the balance must be horizontal and in the magnetic meridian, so that the horizontal component of the magnetic field has no torque on the balance. Small deviations of the moving system from the horizontal are directly proportional to the vertical intensity. This can be seen from the calibration curve. An optical arrangement is used to measure this deflection.

A special tripod is used to hold the magnetometer. The graduated rotating head has three levelling screws and a "bull's-eye" level to accomplish the first rough levelling. An extension tube is fastened to the under side of the head to attach auxiliary magnets at any desired distance from the balance.

A compass is fitted into the tripod head for determination of the magnetic meridian.

The magnetometer and the accessories, consisting of the compass, auxiliary magnets and adjusting tools, are carried in a wooden box, and the tripod in a canvas case.

As the balance is of the uncompensated type, a thermometer is attached in the insulating case.

Field Operation: The field operation was carried on in a similar manner as described by Nettleton on page 184, except the orientation, as the turntable has a stop-ring so adjusted that the turntable may be turned exactly 180 degrees without reading the scale. The following is a short description of the field operation:

1 - The tripod is set firmly and the turntable is levelled roughly by means of the "bull's-eye" level.

2 - The compass is set on the tripod head, the head oriented until the west of the compass scale is magnetic north. As the direction of the north of the compass scale will coincide with the north of the magnetic axis of the magnetic balance, this position puts the axis of rotation of the balance into the magnetic meridian, the north pole toward the east.

3 - The compass is removed, and the instrument is set upon the tripod and carefully levelled.

4- The clamp hanging the balance is released, let down on the knife-edge bearing, and a reading is taken in this east direction. A number of readings must be taken until a consistent value is evident. It is better to clamp and release the balance for each reading rather than record a few values while the scale is drifting. Usually it was clamped three or four times, and five readings were taken for each direction.

5 - The balance is clamped. The instrument is rotated 180 degrees, by means of the stop-ring, and the readings repeated.

6 - Time and temperature are recorded.

7 - The balance is clamped; the instrument is returned to its case.

The reason why so many readings were taken at each station is that the knife-edge bearings were suspected to be chipped. It is explained later, in connection with the conduct of the survey.

Taking readings in the east and west direction eliminates the effect of the deviation between the true and the determined magnetic meridians.

Temperature Effects: It is known that temperature changes produce probably the largest error in magnetometer readings, among the physical factors. The temperature effect is due to (1) changes in magnetic moment, decreasing moment with increasing temperature, (2) differential expansion of the component parts of the moving system, and (3) elastic lag of the component parts. In the later instruments these effects are compensated by suitable mass adjustments. As this arrangement is affected by the gravitational force, the compensation would be for a locality, and should be rearranged for another locality.

The instrument used in this survey is an old type, and is not compensated. Therefore, a calibration curve should have been plotted to compensate the temperature effects, showing the correction for various temperature changes.

This curve is obtained by plotting the temperature correction in gammas against the temperature changes in centigrades. The writer was provided with a ply-wood chamber, large enough to enclose the magnetometer set up on the tripod, when the legs are at the shortest position. Heating coils, a rheostat and a thermometer constitute the necessary equipment. The magnetometer scale is read through a glass-covered hole on the top of the chamber. Although the insulation could be taken off to attain the constant temperature, this experiment would take at least a day's work. The experiment was not done due to the following reasons:

1 - The diurnal variations would be much larger than the thermal variations, so that a second magnetometer was needed to record the diurnal variations at a constant temperature, while the other one is undergoing the temperature changes. As only one magnetometer was available, this could not be done. However, this task could be accomplished by a single magnetometer if a cooling fan is used, but the results would not be accurate as this kind of cooling would be superficial, and the moving system could not keep up with sudden temperature changes.

2 - Due to the climatic conditions of California, the temperature varied between 23 and 28 centigrade during the course of the survey. If 25 centigrade is taken as the base temperature, the temperature correction is insignificantly small, and the calibration trouble is not justified, since this correction is smaller than the accuracy obtained by similar instruments. If an auxiliary magnet is used, this

might not be true. Change in magnetic moment of the magnet and change in length of the magnet support would be large enough for even a few centigrades to affect the accuracy. The scale of the instrument happened to be in view, and the anomalies were small enough, so that no auxiliary magnet was used. In the example of the calculations, the most common temperature coefficient was taken. It is -0.8 gammas per degree centigrade. It is seen, from the example, that this correction is between -2.4 and -2.4 gammas, whereas the diurnal correction is between -26.0 and -12.8 gammas.

Calibration of the Magnetometer: This can be accomplished either by using auxiliary magnets of known magnetic moment or by producing a known electromagnetic field in a pair of Helmholtz coils. The latter method gives more precise and satisfactory results, as auxiliary magnets lose their strength with time and must be recalibrated once in a while.

A Helmholtz coil, whose name plate is as follows, was used.

Heiland Research Corporation
Type M 101   Serial No. 122
Drwn C B chkd L V C
Date 11-29-43
Made for Calif. Tech.
Drwg No. 4 - 1442

It consists of two identical coaxial coils of equal radius placed at a distance apart approximately equal to the radius, their axis being vertical for a vertical magnetometer. The coils are so mounted that they can be set over the instrument in such a way that the center of the moving system coincides with the center of the space between the coils, so that the produced vertical electromagnetic field is substantially constant and uniform around the moving system. An auxiliary box contains all the equipment necessary, a battery, milliammeter, rheostat, and reversing switch.

The procedure is as follows: A certain amount of current is given, and east and west readings are taken, as explained under "Field Operation." The switch is reversed, and again east and west readings are taken. The difference between the averages of both current directions is the deflection for double field. The scale value is calculated from the formula

$$\gamma = \frac{2KI}{D}$$

where γ = Scale value (intensity in gammas per scale division)

D = Deflection for double field (current reversed)

I = Current in milliamperes

K = Coil constant = 26.2 (given by the manufacturer)

The data, calculations, results, and the deflection curve are shown on the following pages. From the curve for I = 10 ma. the double deflection is found to be 11.9 divisions. This value gives = 44.0 gammas per division.

The axis of the coil base does not coincide with that of the tripod, so that the magnetometer could not function reversibly. Levelling was necessary for both east and west positions. The coil itself moves on the support, causing variations in reading. The apparatus is somewhat rough.

Calibration of the Magnetometer (May 23, 1944; 11 AM–1 PM; Temp. 20°–21°C)

Milliamps	East	West	Aver.	Reversed East	Reversed West	Reversed Aver.	D	γ
0	9 8.2 8	9 6.3 7	8				0	
2	9.3 8.8 9.3	8.7 8.7 9	8.9	8 8.3 6.9	6.7 5.8 6.4	7.1	1.8	58.1
4	12.3 13 12	10.8 11.4 10	11.6	6 6.4 6.7	6.4 5.5 5.6	6.1	5.5	38.1
6	13.6 12.8 13.8	11 11.2 11.7	12.4	6.3 6 6.4	4.5 5.2 5	5.6	6.8	46.3
8	14.5 13.5 14.8	12.5 12.6 13	13.5	4.5 3.5 4	2.5 4 2.7	3.5	10.0	41.9
10	14.8 15.2 14.7	14.5 14.3 14	14.6	2.8 3.4 2.4	1.8 2.2 2.7	2.5	12.1	43.3

$\gamma = \frac{2KI}{D}$ = Intensity in gammas per scale division (scale value)

D = Deflection for double field (current reversed)

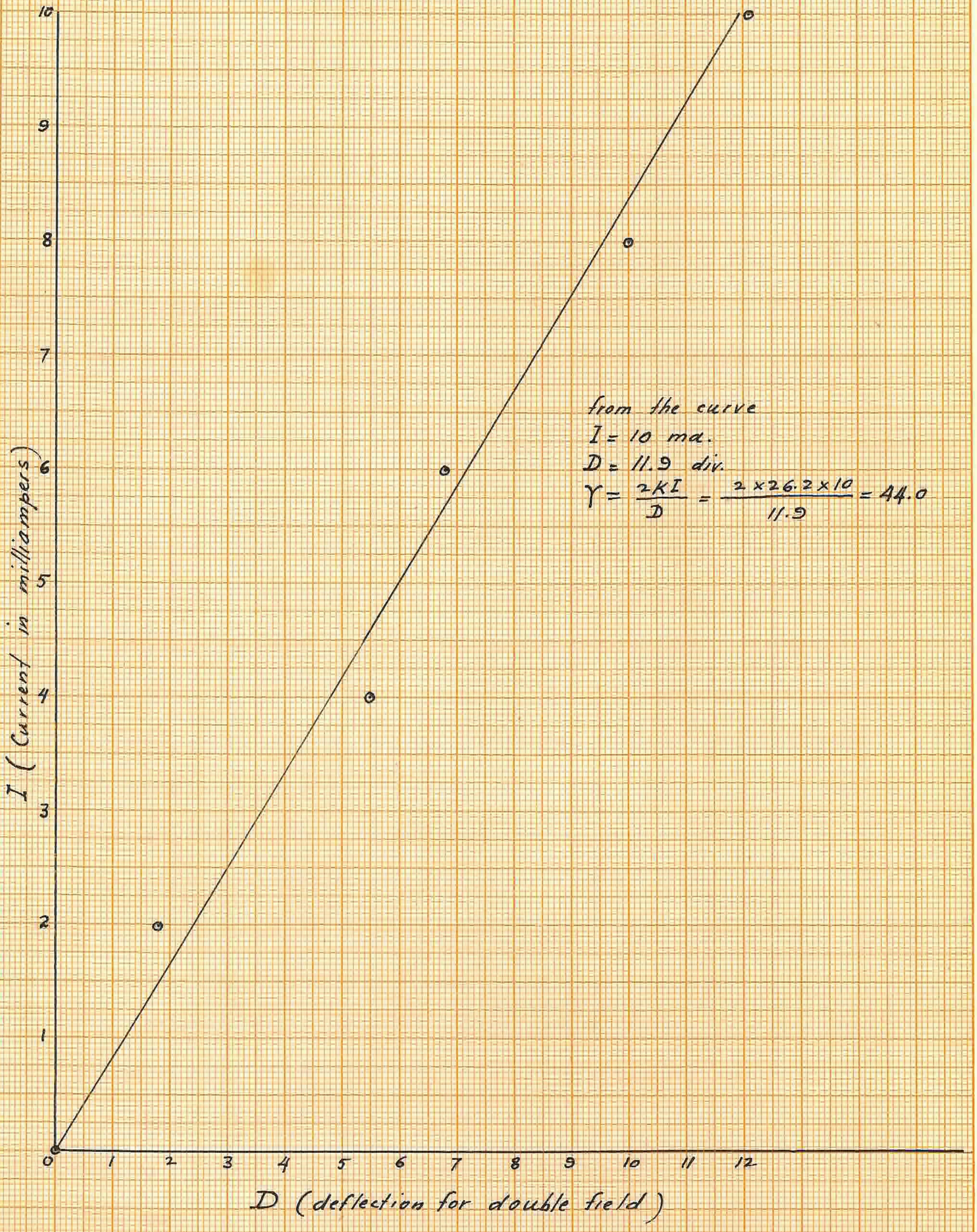
I = Current in milliamperes

K = Coil constant = 26.2

The average of the last three values = 43.8 γ's per division

From the curve: $\gamma = 44.0$

Calibration of the Magnetometer



CONDUCT OF THE SURVEY

First, a preliminary survey was run in order to have a rough idea about the anomalies. It was found that no auxiliary magnet would be needed, and large drifts were observed. Considering these facts, it was thought that very accurate readings taken at large intervals, such as 100 feet, would show the anomalies more accurately than fairly accurate readings taken at short intervals. Thus, it was decided to take eight readings on each station, four east and four west readings; the station intervals being 80 to 150 feet, usually 100 feet.

As no detailed topographical map was available, the station locations had to be accomplished by pacing. Thus, it was necessary to confine the survey to profiles across the wash, as the stations could not be tied up to draw the isogams. Each profile has a base station, and is independent. Establishment of a primary base, and tying up the local bases to this one, was not necessary or convenient.

One diurnal variation curve was obtained for each profile, as each profile took a day's full work. For this, the magnetometer was returned to the local base at one to two-hour intervals, the reference time being 1 PM. The diurnal variation curve of the profile 6 is given as an example.

As the surveyed area was small enough, normal corrections related to latitude and longitude were not necessary.

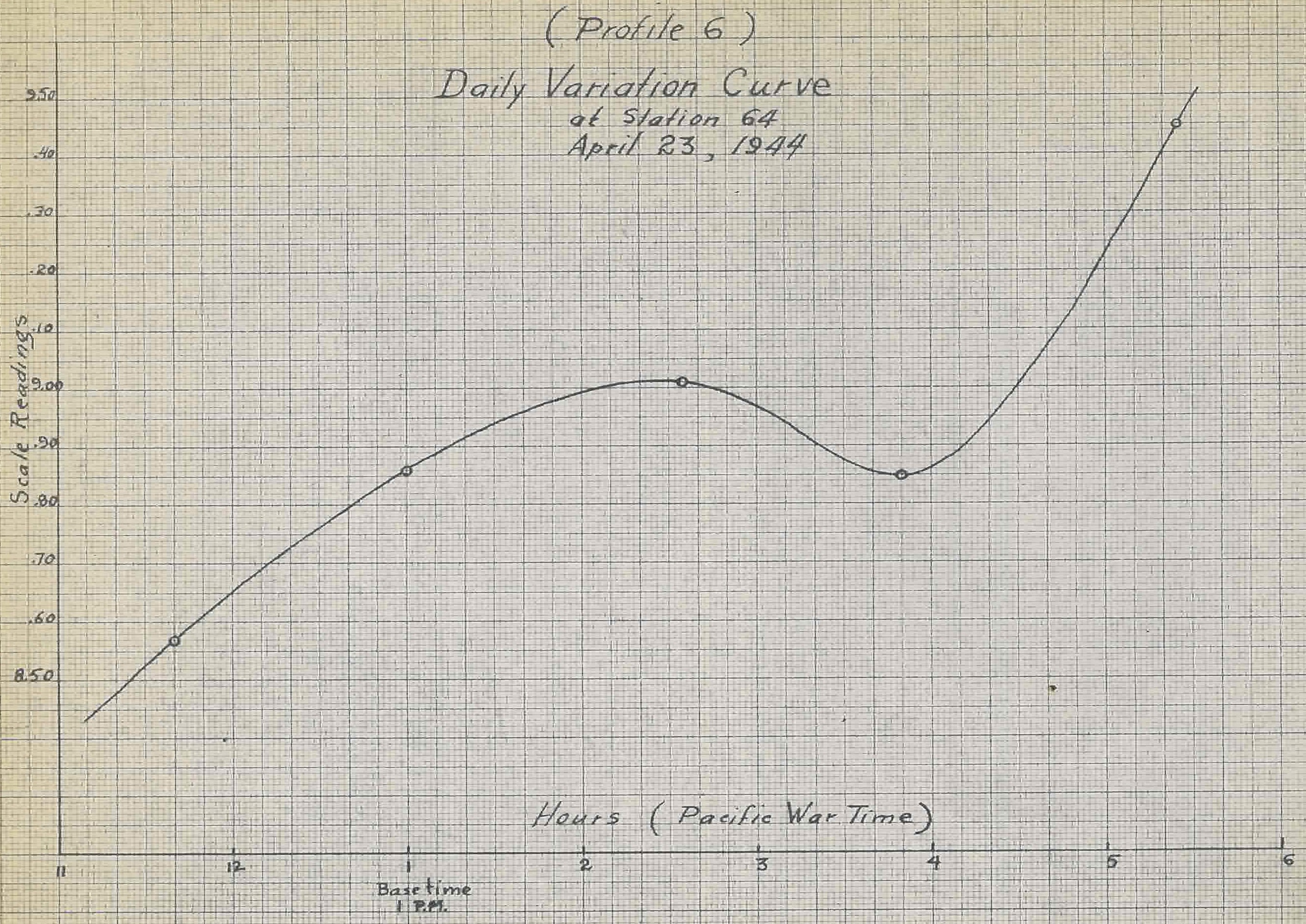
The map shows the profiles and the topography.

The field procedure of the magnometer has been discussed in connection with the instruments.

Calculations of the Profile 6

Calculations of [t]he Profile 6

Station	Location	Time	Temper.	Readings		East Aver.	West Aver.	Average	Value in gammas γ = 44.0	Temperature Correction α = −0.8 T_0 = 25°	Daily Variation Correction	Reduced Value	
				~~East~~	West								
64	Base	11:40	25°C	8.4 9.5 8.3 8.5	8.0 9.4 7.8 8.3	8.73	8.40	8.57	376.8	0	+12.8	389.6	
65	100 ft. S45°E of 64	11:50	25	9.8 7.9 8.9 8.8	7.8 7.0 7.3 7.5	8.9	7.4	8.15	358.5	0	+11.0	347.5	
66	100 ft. S45°E of 65	12:00	26	8.1 8.8 8.5	7.2 7.3 7.8	8.5	7.4	7.95	345.5	−0.8	+9.2	353.9	
67	100 ft.	12:15	26	7.3 8.8 8.8	9.1 8.4 8.8	8.7	8.8	8.85	389.5	−0.8	+6.6	395.3	
68	100 ft	12:20	26	7.0 6.8 9.0	8.8 7.8 7.7	7.5	8.0	7.75	341.0	−0.8	+5.7	345.9	
69	100 ft.	12:30	26	8.8 9.2 9.3	7.9 7.3 8.5	9.2	7.9	8.55	376.0	−0.8	+4.4	379.6	
70	150 ft. on the Hill.	12:45	27	9.3 9.6 9.4	8.6 8.8	9.4	8.7	9.05	398.0	−1.6	+2.2	398.6	Two-foot water pipe between 69 & 70
64		1:00	27	9.3 9.0 9.2 9.0	8.6 8.6 8.6 8.6	9.10	8.60	8.86	390.0	−1.6	0	388.4	
64		2:35	28	9.8 9.8 7.8 8.7	9.1 8.3 9.1	9.25	8.80	9.01	396.0	−2.4	−6.6	387.0	
71	100 ft. N45°W of 64	2:50	28	9.6 10.6 10.3	10.2 10.0 7.7	10.3	10.0	10.15	446.5	−2.4	−5.7	438.4	
72	100	3:00	28	9.3 7.6 8.3 8.7	8.7 8.7 8.7	8.5	8.7	8.60	378.0	−2.4	−4.8	370.8	
73	100	3:05	28	8.2 8.5 7.8	7.2 7.3 8.2 8.0	8.2	7.8	8.00	352.0	−2.4	−3.9	345.7	
74	100	3:15	28	8.2 8.5 7.8	7.3 6.9 7.5	8.2	7.3	7.75	341.0	−2.4	−2.6	336.0	
75	100	3:30	29	7.8 7.3 7.8	6.7 6.7	7.7	6.7	7.20	316.8	−3.2	−0.8	312.8	
76	100	3:35	29	6.3 6.0 5.0	5.7 4.2 5.5	6.0	5.5	5.75	253.0	−3.2	0	249.8	76 to 81 are on the gravel wash.
64		3:50	28	9.9 9.8 9.8	8.0 7.3 8.0 8.7	9.80	7.90	8.85	389.5	−2.4	+0.4	387.5	
77	100	4:05	28	4.2 5.0 4.7 5.0	3.7 3.8 3.3	4.8	3.7	4.25	187.0	−2.4	0	184.6	
78	100	4:10	27	5.5 5.0 5.2	4.4 5.0 4.8	5.2	4.8	5.00	220.0	−1.6	−1.3	217.1	
79	100	4:30	26	6.7 6.9 7.1	6.5 6.4 6.0	6.9	6.4	6.65	292.4	−0.8	−6.1	285.5	
80	100	4:40	26	8.4 9.1 9.3	9.0 8.3 9.3	9.0	9.0	9.00	396.0	−0.8	−9.2	386.0	
81	100	4:50	26	12.5 13.6 13.1 12.3	12.1 11.2 12.3	12.5	12.1	12.30	541.0	−0.8	−12.3	527.9	
82	100	5:00	26	16.2 15.0 16.7	15.3 16.0	16.2	15.7	15.95	702.0	−0.8	−16.3	684.9	River between 81 & 82. 82 is on the slope of the hill.
83	24 ft. S70°W of 82.	5:05	26	9.3 16.0 13.9 15.8	15.0 15.3	15.0	15.0	15.00	660.0	−0.8	−17.6	641.6	
64		5:25	26	10.4 8.7 9.9 9.2	9.7 8.9 8.9 9.6	9.65	9.27	9.45	416.0	−0.8	−26.0	389.2	


(Profile 6)
Daily Variation Curve
at Station 64
April 23, 1944
Scale Readings
8.50
.60
.70
.80
.90
9.00
.10
.20
.30
.40
9.50
Hours (Pacific War Time)
11
12
1
2
3
4
5
6
Base time
1 P.M.

THE RESULTS

and

THE CONCLUSIONS

Readings taken at a station vary a great deal; such as 5.4, 8, 7.8, 8.9 divisions for east and 4.2, 7, 7.2 divisions for west. However, there are readings which do not show large variations, and the east readings do not deviate so much from the west readings; such as 9.3, 8.3, 8.7 east and 8.7, 8.7, 8.7 west.

If the instrument alone was responsible for these irregularities, there would always be a great dispersion of readings, like the first example. It seems that the quartz knife-edge is slightly chipped, or the quartz cylindrical surfaces are scratched, but the main cause of the drift is probably the amplification of frequent magnetic storms, by tin can dumps, steel fences which hold the gravel ridges on both sides of the wash, and power lines.

The cross section profiles show that the vertical component of the magnetic intensity decreases as one goes up stream. The average (regional) values of the profiles are as follows:

Profile No.	Regional Value
1	700 gammas
2	800 "
3	550 "
4	400 "
5	250 "
6	300 "

An up-stream profile was made between the sections 4 and

5, and a decrease of 180 gammas was observed within 1,000 feet, the gradient being 0.18 gammas per foot (see the up-stream profile curve).

As we go up stream, the thickness of the alluvium and gravel becomes less and less, and the bedrock comes closer to the surface. If it was not for the accumulated heavy magnetite sand, we should expect higher magnetic intensity values as we go up stream. The section 2 seems to be the highest one. This is where the Cyanide Company plant is located.

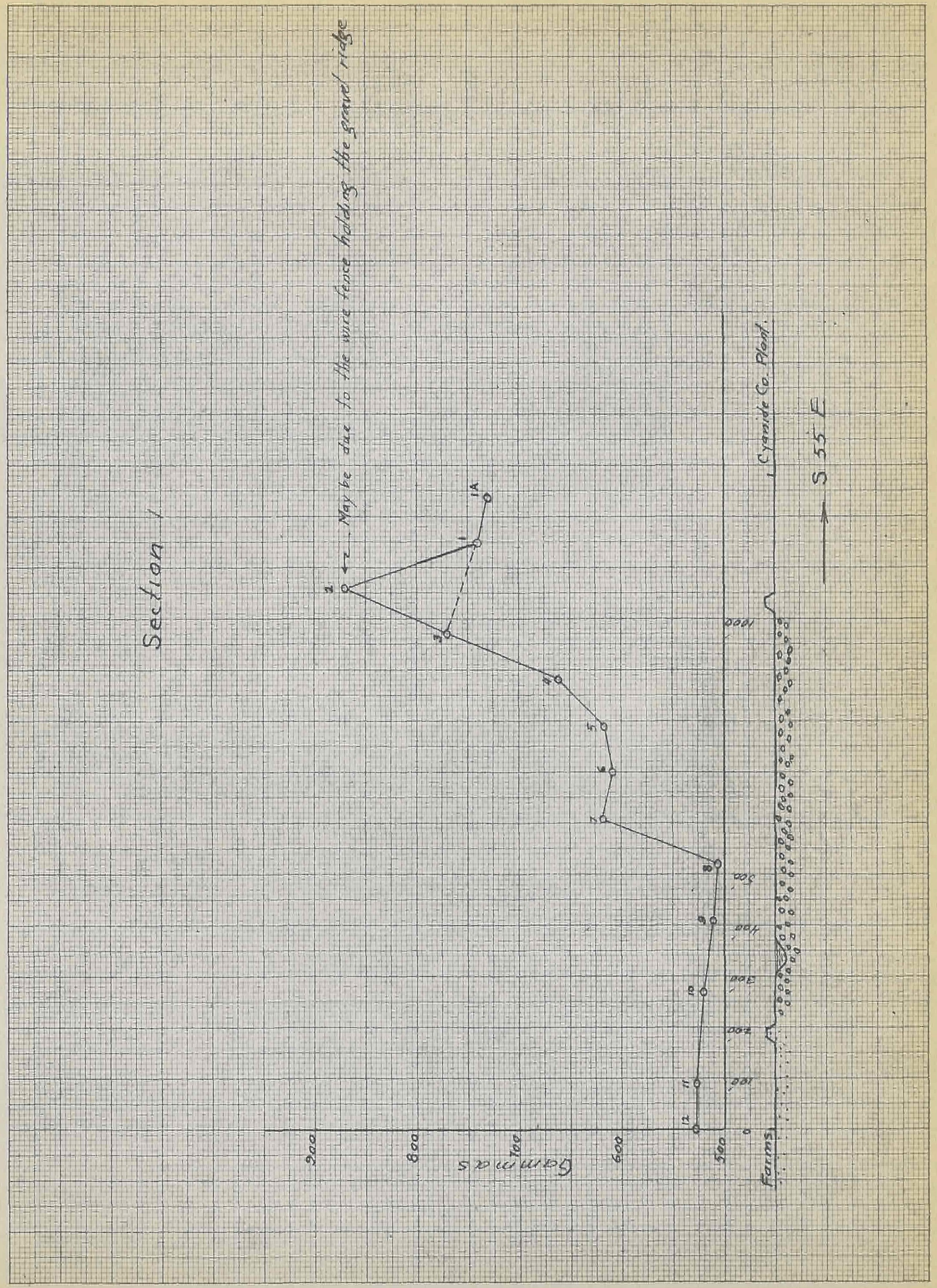
A maximum magnetite sand concentration zone is to be expected along any wash. In the further up-stream part water speed is too much to allow fine particles to settle, and the time during which concentration has been going on is shorter.

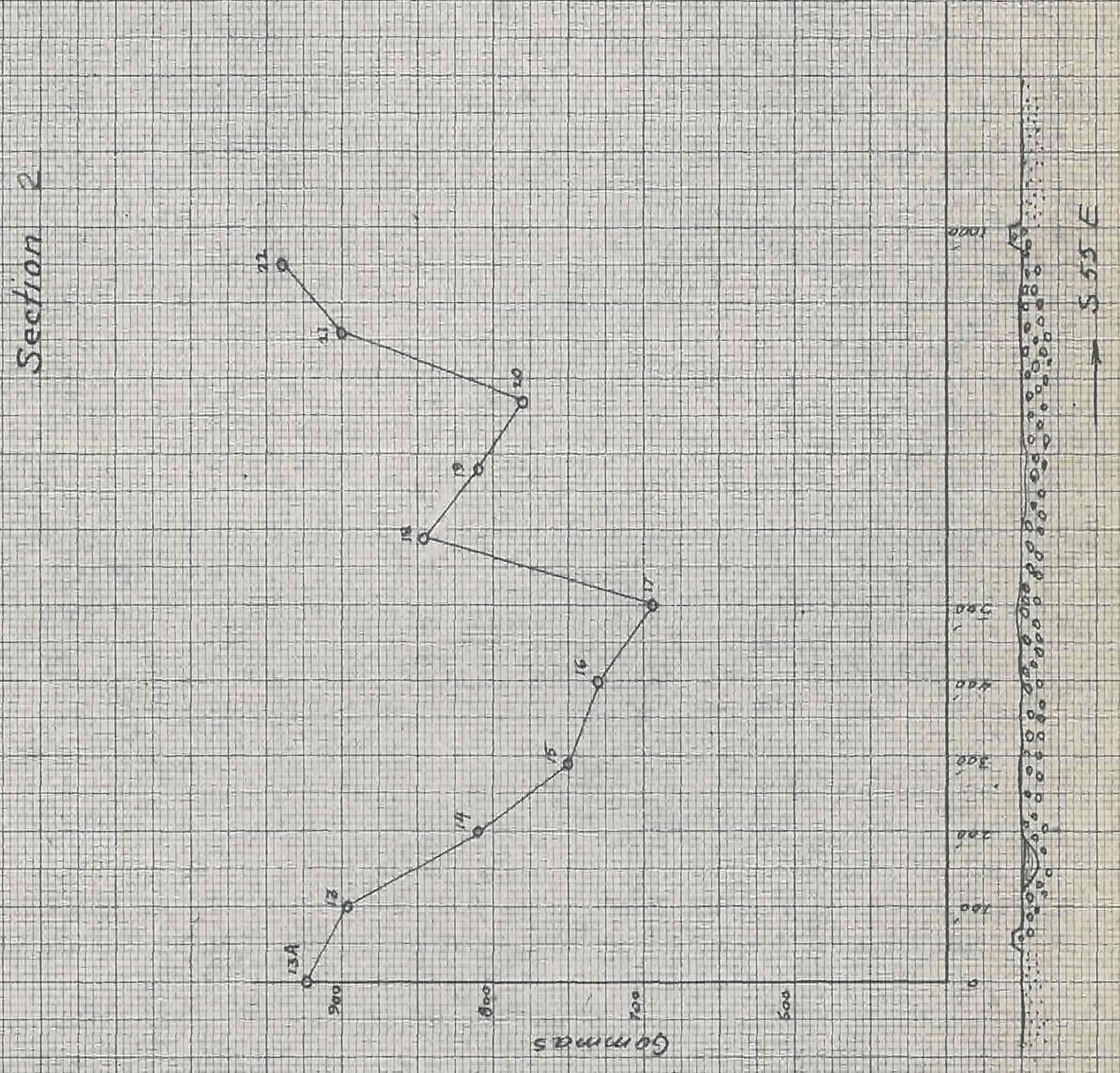
The curves themselves have little significance. They show too much variation.Probably this is due mostly to artificial factors. The area contains a large number of dumping places, fences, near by rail and power lines, etc.

It was impossible to draw isogams, since a detailed topographical map was not available, and it would not be accurate to correlate stations fixed by pacing. A detailed transit survey of the area would require too much time.

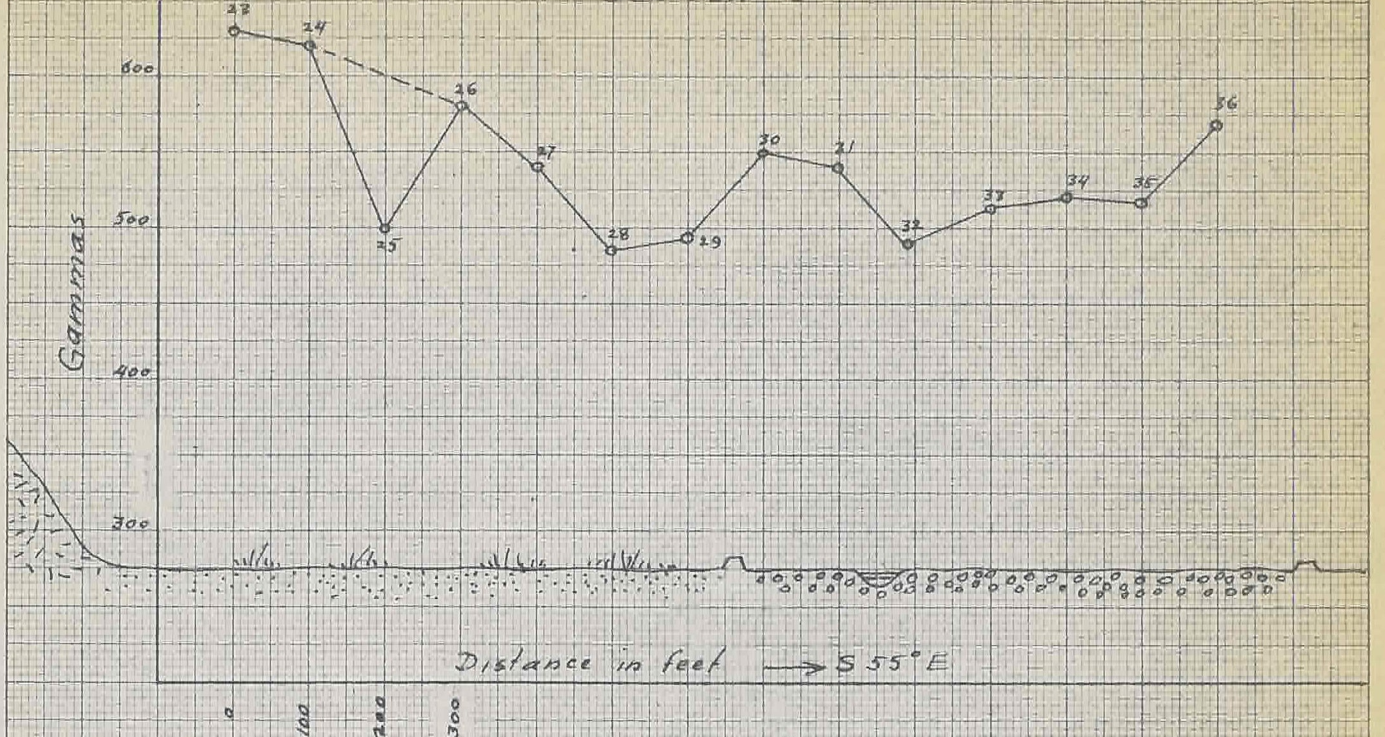
The profile 6, whose calculations are given as an example, must be paid more attention.

Profile 6: It seems that the river shifted its channel toward the northwest bank, and the area which is covered by gravels is younger tham the soil-covered part, so that the river channel and the gravel wash have less magnetite sand concentration, therefore show a magnetic low. The average value over

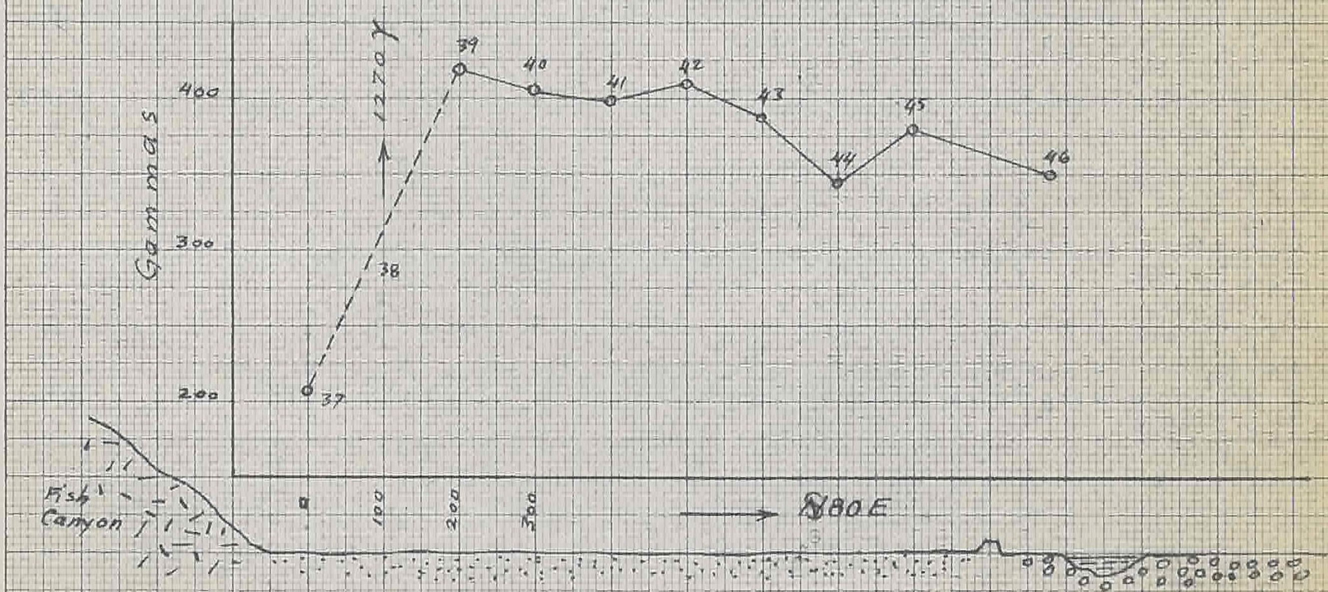

Section 1
← May be due to the wire fence holding the gravel ridge
Gammas
900
800
700
600
500
0
100
200
300
400
500
1000
1
1A
2
3
4
5
6
7
8
9
10
11
12
Farms
Cyanide Co. Plant
S 55 E

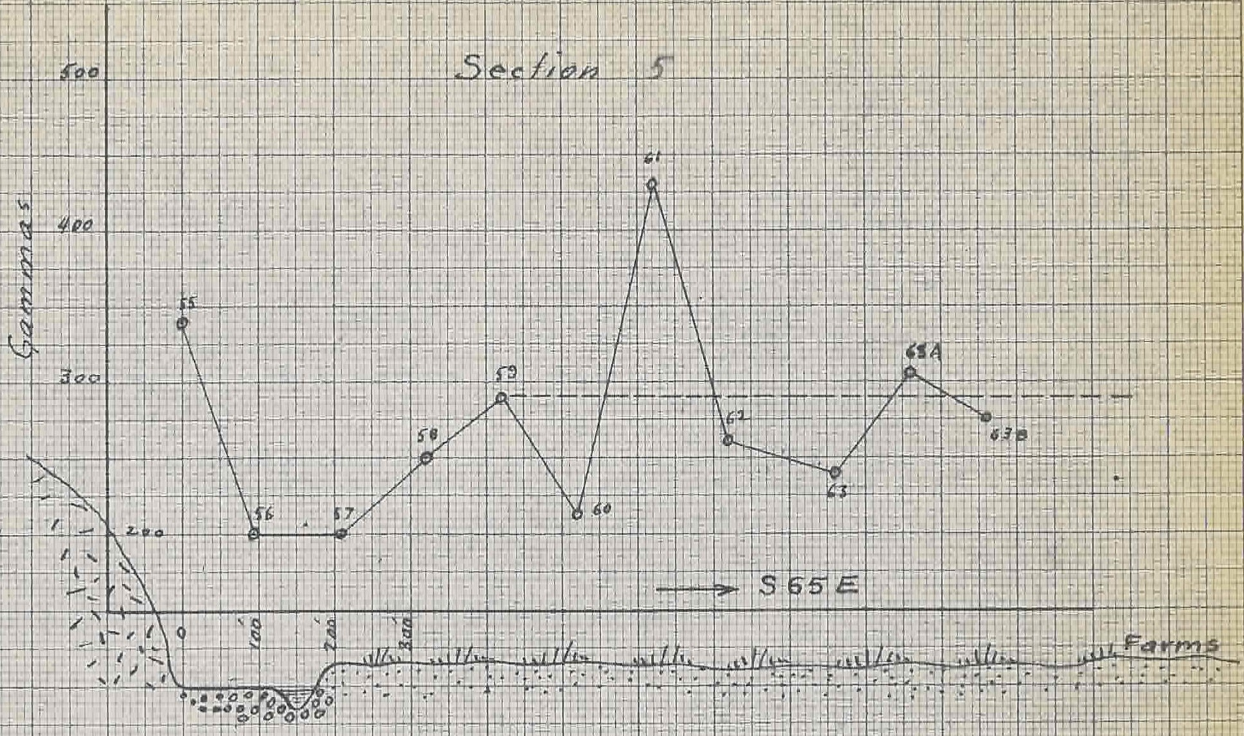

Section 2
Gammas
900
800
700
0
100
200
300
400
500
1000
13A
13
14
15
16
17
18
19
20
21
22
S 55 E

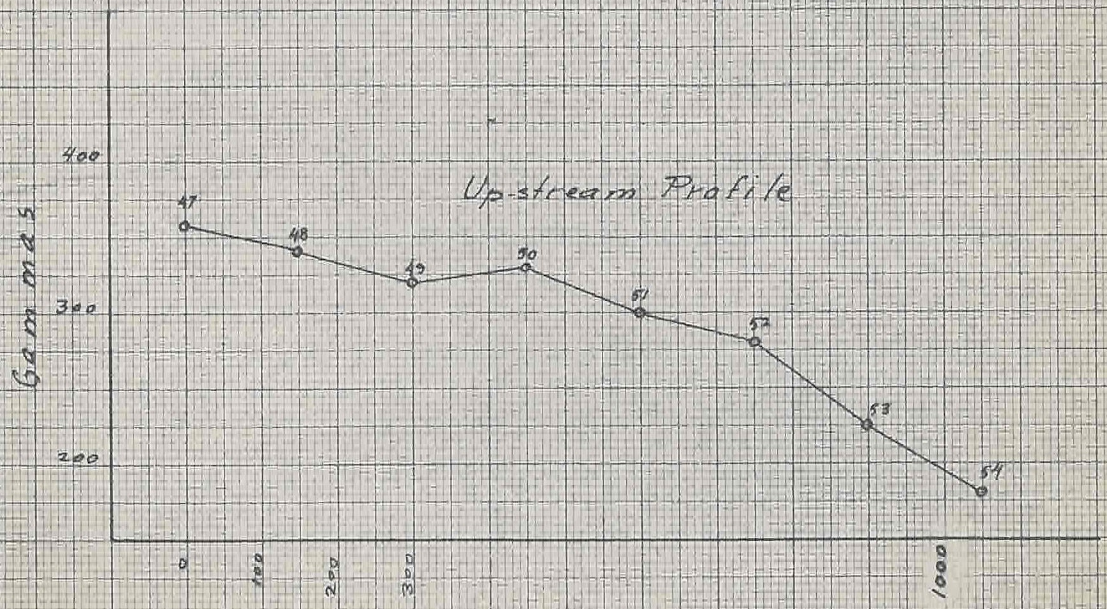
Section 3

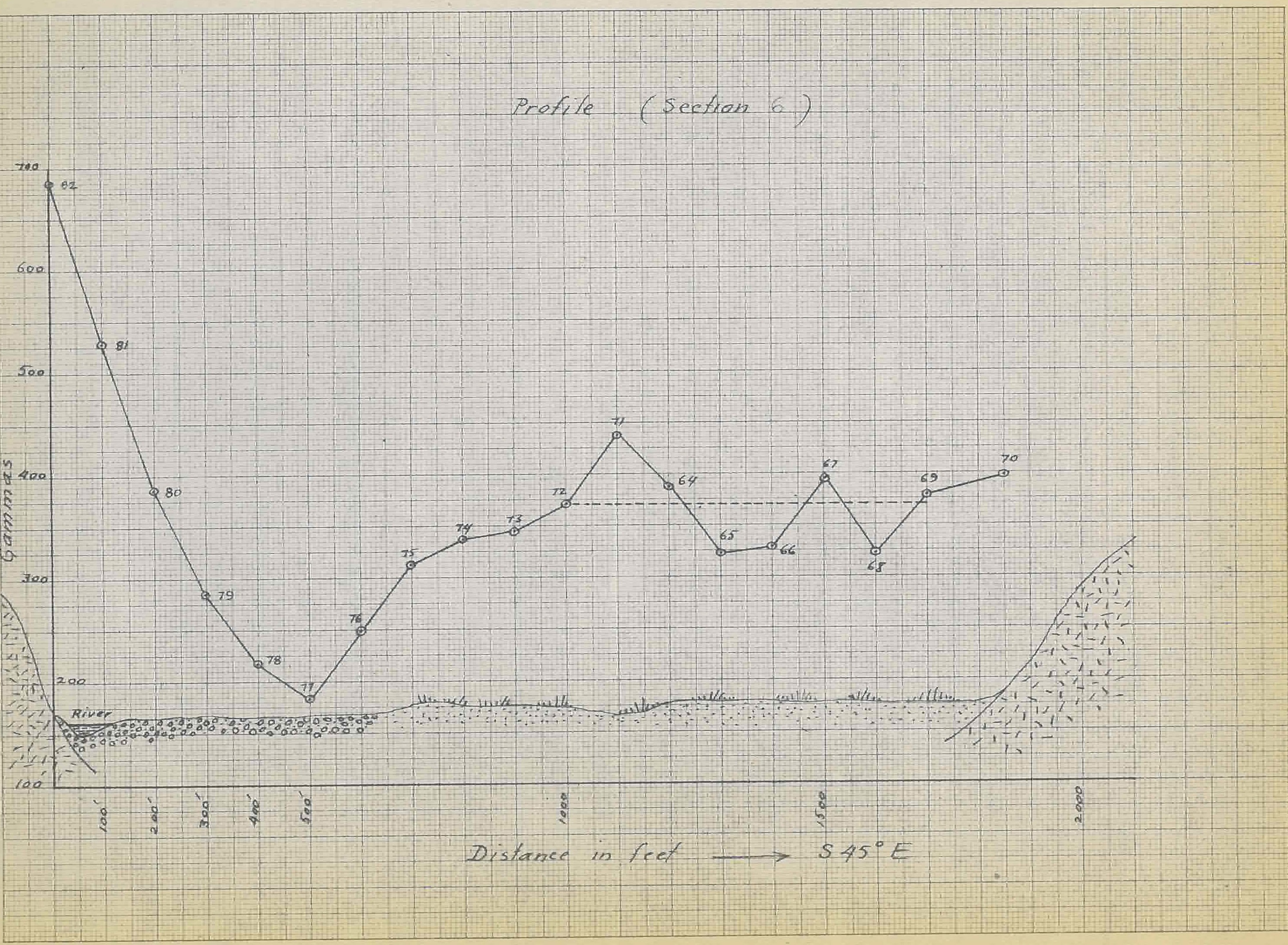


Section 4




Section 5
Gammas
500
400
300
200
55
56
57
58
59
60
61
62
63
63A
63B
S 65 E
0
100
200
300
Farms


Up-stream Profile
Gammas
400
300
200
47
48
49
50
51
52
53
54
0
100
200
300
1000


Profile (Section 6)
Gammas
700
600
500
400
300
200
100
82
81
80
79
78
77
76
75
74
73
72
71
64
65
66
67
68
69
70
River
100'
200'
300'
400'
500'
1000
1500
2000
Distance in feet → S 45° E

the soil-covered part, that is between 76 and 70, is about 370 gammas, whereas over the gravel wash it is 184 gammas. The sudden increase, starting over the gravel wash at Station 77, is due to the adjacent granite hill; otherwise it would be low over the channel (see Section 6).

The anamoly over the soil-covered part is quite large (about 200 gammas), indicating that the placer deposit is very shallow.

Since the placer channel is filled with granite boulders, gravels and sand, the relation between magnetite sand and gold concentrates is masked, and the following procedure must be carried on before reaching a conclusion.

1 - Determination of the maximum magnetic anomaly zone along the channel (Section 2 in this case).

2 - A close magnetic survey of this zone, aided by a detailed topographical map. Magnetic contours are constructed, and concentration "patches" are located. The results of this survey show that these concentration zones are located on the alluvium from which the channel receded, and not on the gravel wash.

3 - The next question is whether the magnetic sand is associated with placer gold deposits or not. To find this, samples from mountains where the streams come from, or the gravels and boulders in the stream channel, must be crushed and concentrated, then a fire-assay made.

4 - If the magnetic sand is found to contain sufficient gold, then the question arises whether or not the anomalies show enough concentration to warrant an exploitation. For

this, panning, trenching, test-pitting, or boring can be used. If the zone does not contain large boulders, drive-pipe or rotary fish-tail drillings are advisable; otherwise, churn drilling is necessary. Depth of the deposits is another factor and is determined by boring, test-pitting, or by using another geophysical method, such as electrical or seismic prospecting.