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LUNDBERG EXPLORATIONS LIMITED
96 EGLINTON AVE EAST
TORONTO 12, ONT.

AIRBORNE GEOPHYSICAL SURVEY OVER IRON MOUNTAIN LAKE PROSPECT, PROVINCE OF QUEBEC FOR BELCHER MINING CORPORATION LIMITED

INTRODUCTION

In accordance with our agreement dated August 14, 1957, airborne geophysical surveys were carried out in the vicinity of the Great Whale River, Province of Quebec, for the Belcher Mining Corporation Limited. These surveys were undertaken to define an iron ore deposit found early in the summer of 1957. In a reconnaissance aeromagnetic survey made in July 1957 the area of general interest was outlined, but due to crude flight line control, and the limited time available, the results of this survey were not sufficient to permit mathematical analyses to be made. It was therefore suggested that a survey combining airborne magnetic and gravity methods might provide the most efficient method of ascertaining the ore potential of the area.

LOCATION AND ACCESS

The main ore zone is located in the vicinity of 55°03'N latitude, 76°50'W longitude, on what is now known as Iron Mountain, which lies about two miles south of a prominent lake which is now called Iron Mountain Lake. Iron Mountain Lake, upon which Belcher Mining Corporation Limited have erected a base camp, is located thirty-seven air mailes southeast by east from the settlement of Great Whale, located at Great Whale River's outlet into Hudson Bay.

Transportation in this region is by air. Special Charter flights direct from Moosonee or Timmins to Iron Mountain Lake may be arranged through Austin Airways. An all-weather landing strip for all types of aircraft has recently been completed at Great Whale River Settlement. Several airlines occasionally include Great Whale River in their itinerary.

A fine natural harbour for Hudson Bay freight vessels is available at the mouth of Great Whale River. The river itself is navigable by canoe only. There are several canoe routes from Great Whale River to Iron Mountain Lake, all of which involve long and difficult portages around falls and rapids. Remnants of an

Indian encampment a short distance from the Belcher Mining Camp, indicate that the lake is on a regular cross-country route. The inland canoe routes, however, must be considered for emergency only. At present, any heavy mining equipment must be flown into Iron Mountain Lake. In September 1957 some forty tons of iron ore were bagged and freighted by Canso Aircraft from Iron Mountain Lake to Great Whale Settlement, and from there the ore was transshipped by a coastal freight boat to Moosonee. Transportation by rail is available from Moosonee.

To judge by the topography, the building of a road or preferably a railroad, from Iron Mountain Lake to Great Whale Harbour would appear a relatively simple procedure.

Abundant hydro-electrical power can be obtained from waterfalls of 230, 160, and 150 feet on the Great Whale and Denys Rivers, within twenty-five miles of Iron Mountain Lake.

SURVEY PROCEDURE

The detailed survey was made along a 1/2 mile square grid over the area of interest. In order to ensure accuracy, and to facilitate interpretation of the airborne gravity data, the area was flown at two elevations, 1,000 feet and 2,000 feet above the ridge of Iron Mountain, which rises approximately 400 feet above Iron Mountain Lake. This lake was accepted as a datum level, the barometric altimeter in the aircraft being set to zero on the lake prior to take-off. The area was then flown at 1,400 feet and 2,400 feet barometric altitude above Iron Mountain Lake.

The area surveyed in detail is a block, twenty miles long and fifteen miles wide, the long axis of which trends about 30° south of east. The block itself is generally centered about Iron Mountain. All flight lines were extended beyond these rigid boundaries, with the result that on the eastern edge of the area, two magnetic anomalies were located, one of which may have considerable economic significance.

Three additional areas were covered using the airborne magnetometer only. These areas were flown at an elevation of 1,000 feet above the terrain. The western area was covered by five rather widely separated profiles to investigate rumours of a magnetic attraction here reported earlier to Lee Gauvreau. The second reconnaissance area, lying about thirty-two miles northeast of Iron Mountain Lake, was covered to investigate a variation of rock type as viewed from low flying aircraft. A black rock was observed in contact with a white granite. Regularly spaced flight lines, at one mile intervals, were flown in this area, which covered about ten miles in an easterly direction and seven miles in a northerly direction.

Finally, reconnaissance flights were made over a promising magnetic anomaly observed on the eastern extension of one of the detail lines. The reconnaissance flying here included lines 1/2 mile apart over a distance of about five miles.

The survey was conducted between August 27 and September 8, 1957. A total of 3,000 line miles was flown in the detail area and an additional 400 line miles (exclusive of ferry trips) were flown for reconnaissance purposes.

GEOLOGY

Until the last two years, very little has been known about the geology of the area. Prior to 1956 the only information was contained in a report by Dr. A. P. Low written in 1887 and published as Part J of the Geological Survey of Canada Report for 1887-88. Unfortunately, the names of the rivers and lakes used by Dr. Low have been altered on the modern maps, so that tracing his route is difficult. It would appear however that Dr. Low followed the Riviere Denys from Lac Silvy to the Great Whale River, and thence to Hudson Bay. Basically Dr. Low reported that a belt of chloritic and hornblendic rocks of Huronian Age appears to intrude the Laurentian gneisses near the west end of what is now known as Lac Denys. The strike of the hornblendic rocks was given as about N 10°W to N 20°W. Low also reported, "green chloritic or altered hornblendic rocks highly schistose in structure, with light quartoze veins generally running parallel to the bedding, but seen in places to cut from one plane to another". Dr. Low did not reach Iron Mountain Lake, however, thus the only indication of iron ore possibilities in this region is supplied by Low's report of volcanic rocks lying about ten miles south of Iron Mountain.

Lee Gauvreau reports that a Geological Survey of Canada party has been active in the area during the 1956 and 1957 field seasons. Apparently the reporting of the results of this work is to be restricted, however, according to an agreement between the Geological Survey of Canada and the Province of Quebec. Thus it may be some time before a report of this area is published.

In conjunction with the airborne geophysical survey described in this report, a programme of general geological mapping was initiated by the Belcher Mining Corporation Limited. A four mile picket line extending southward from the western part of Iron Mountain Lake provided mapping control. Traverses were run at 400 foot intervals on either side of this picket line across the iron formations. The results of this preliminary mapping were presented on a geological map prepared by Lee Gauvreau for Belcher Mining Corporation Limited, dated September, 1957.

Three major rock types are found in the area, granite, an intermediate to basic volcanic, and a banded iron formation. The field relationships of the various rock types were not studied by our personnel. Parts of the ore zone have been visited, however, and several representative samples taken. The granite rocks were not studied, therefore it is impossible to state their relationship with the iron formation-volcanic series, from first hand observation. A specimen of the iron formation, taken from a point near a granite contact, exhibited a number of well formed dark red garnets. Since garnet is a high temperature metamorphic mineral its presence here therefore suggests that the granite is later than the iron formation. Possible further evidence in this regard is the sharp cut-off of the iron formation-volcanic series at its southern end, and the apparent enrichment of the iron formation horizon in this vicinity.

The volcanic rock appears to be quite massive, and while highly metamorphosed, it appears to be relatively fresh, dark green to black in colour, and intermediate to basic in composition. Chlorite and hornblende are prominent minerals, and, as the iron formation is approached magnetite appears to become more abundant as if to suggest that the volcanics graded into the iron formation. One specimen, taken from near the volcanic-iron formation contact, exhibits a slight banded appearance, the bands being alternately chlorite-hornblende, and magnetite-hornblende. Naturally the specimen is quite magnetic. This gradational characteristic suggests the possibility of an igneous origin for the iron formation.

The iron formation, in appearance at least, is typical of the Pre-Cambrian iron formations now referred to as taconites. The regular banded appearance, black magnetite bands alternating with white silica bands, strongly suggests a sedimentary origin. It is understood that grab samples of the iron formation returned assays of 40% iron (nearly 60% magnetite), while bulk sampling from a trench some 400 feet long across the strike of the formation gives a similar figure.

The grain size of the magnetite appears to be of the order of 100 mesh. The rock, while hard, appears to crush quite well and a clean concentrate can be obtained at 100 mesh, thus by a simple preliminary magnetic separation a grade of 60% iron could be made without difficulty.

The iron formation follows a somewhat arcuate trend, the strike in the southern section being about N 10°W swinging to north through the northern section. The dip is nearly vertical. The iron formation has been traced as a continuous unit for a distance of about 15,000 feet. Its maximum width including interbands of country rock is about 2,400 feet, of which 1,900 feet may be considered ore material.

The foregoing account of the geology should be taken as preliminary observation only but it may serve to indicate the vast ore potential of the area and provide background for the geophysical interpretation to follow.

INTERPRETATION OF AEROMAGNETIC DATA

This section of the report will summarize the results of the aeromagnetic survey. For a detailed analysis of the aeromagnetic data, the reader is referred to Appendix A of this report.

The results of the aeromagnetic survey of the detailed area show a major anomalous zone composed of an exceedingly strong magnetic anomaly coincident with the known magnetite deposit, and two satellite anomalies lying about five miles northwest of the ore body. In addition, two isolated magnetic anomalies, one lying about five miles southeast, and the other sixteen miles east, of the magnetite deposit, deserve consideration.

The major magnetic anomaly, described as Anomaly A is centered about Iron Mountain, and is coincident with the known magnetite deposit. This anomaly, which appears to be one of the strongest ever recorded, reaches a peak magnetic intensity of 25,000 gamma above the normal base level at a flight elevation of 1,000 feet. Even 2,000 feet above the causative body, the peak intensity is about 15,500 gamma. Mathematical analysis indicated that the field curve could be matched with reasonable precision by an outcropping body, 3,700 feet in width, extending to a more or less infinite depth, and having a magnetic susceptibility of 0.114 C. G. S. units, which may be considered to represent 38% magnetite. An examination of the magnetic intensity profiles indicated that the contact of the theoretical body lay under the 15,000 gamma contour (1,000 foot flight elevation). The area enclosed by the 15,000 gamma contour was then empirically selected as representative of the surface area of the ore zone. This area, amounting to 38,000,000 square feet, thus represented an ore body consisting of 3,800,000 tons per vertical foot of ore grading 38% magnetite, or 26.6% iron. It is known, however, from surface sampling that the ore grades about 40% iron. Due to resolution factors involved in magnetic calculations, it is possible to up-grade the iron percentage, while reducing the tonnage. By this means it would appear that magnetic Anomaly A could represent 2,500,000 tons per vertical foot of magnetite ore grading 40% iron.

As a check on these figures, the area of the magnetite-bearing horizons shown on Gauvreau's geological map was computed. If the grade of the magnetite ore remains constant, i.e. 40% iron as indicated by initial sampling, the geological map suggests that there is an ultimate ore tonnage of about 1,900,000 tons per vertical foot of magnetite ore grading 40% iron. This checks quite well with the magnetic calculations.

The shape of magnetic Anomaly A suggests that other magnetite-bearing horizons may exist both east and north of the now mapped zones which would narrow the discrepancy between the magnetic and geological estimates.

Theoretical curves were also calculated for Anomalies B_1, B_2, C, and D. Anomaly B_1 may represent about 483,000 tons per vertical foot of magnetite ore of 23.1% iron, or using the resolution factors, 280,000 tons per vertical foot of magnetite ore grading

40% iron. The top surface of this ore body possibly outcrops at bedrock, although it may be buried by up to 200 feet of overburden. This area definitely requires geological examination.

Anomaly B_2 is probably caused by an outcropping body which appears to have a surface area of about 4,000,000 square feet and a resulting susceptibility factor of 0.025C.G.S. units which would corresponds to some 6% iron. Resolved into ore containing 40%, this would only represent about 60,000 tons per vertical foot. It is doubtful whether this anomaly can be considered representative of ore grade material, but at least a cursory geological examination of the area should be made, to verify these assumptions.

Anomaly C, located five miles southeast of the major orebody, presents certain contradictory evidence. One method of interpretation suggests that it is buried by some 1,000 feet of overlying overburden or non-magnetic rock, while the other suggests that it may outcrop. An assumption which may be gathered from this, is that the major portion of the magnetic body, which appears to have a surface area of about 5,760,000 square feet may lie at greater depth, while off-shoots of the main mass may come to the surface. The main body appears as a mass lying 1,000 feet below the surface, of 576,000 tons per vertical foot with a grade of 16% or by resolution, 230,000 tons per vertical foot of magnetite ore of 40% grade. This anomaly area should be investigated on the ground.

All of the above ore bodies appear to have steep or vertical dips and extend to "infinite" depth. Anomaly D, located sixteen miles east of the major ore zone, however, appears to dip about 45 degrees to the west, and is probably limited in depth extent. It corresponds to an outcropping body about 2,700 feet wide, extending downward at an angle of 45^{o} to a depth of 4,200 feet. This causitive body probably contains only about 10% iron. It is therefore doubtful if this anomaly can be considered of economic value from an iron ore point-of-view. However, since it is reasonably accessible by virtue of a long narrow lake two miles away, geological examination of the anomalous area is doubtless warranted.

Within the detailed area, therefore, there are outlined three possible magnetite ore zones, which when resolved to an ore grade of 40% iron in keeping with the known assay results, aggregate over three million tons per vertical foot of magnetite ore. It must be emphasized that the figures given herein are "ultimate" ore reserves, and cannot be construed as "minable" ore reserves. The calculation of "minable" ore reserves is dependent upon the principles and practice of good mining methods, and much of the material which has been included in the calculations of "ultimate" ore reserves through the resolution powers of the magnetic data should be excluded due to mining problems.

The reconnaissance aeromagnetic surveys failed to reveal anything of particular interest. The five profiles flown in Area B west of the detailed area were remarkably flat and uninteresting, with the possible exception of their southern ends, where a weak magnetic linear, striking easterly is found on three lines, over a distance of two miles. This linear may possibly represent a contact or fault zone.

Seven profiles, spaced one mile apart, were flown to investigate a contact between the granite and a black rock in an area some thirty-five miles northeast of Iron Mountain Lake. These profiles shown on the map of Area C indicate that the contact between the two rocks, the granite and the black rock, follows an east-west topographic lineament. The black rock, while more magnetic than the granite, does not appear to contain any important amount of magnetite. It may represent a volcanic horizon, and as such could be interesting prospecting ground. There is no indication of an iron formation horizon in the area surveyed, but it is suggested that consideration be given to investigating this possible greenstone belt.

Area D may be considered as an eastern extension of the detailed area. Eleven profiles, each one of which was about fifteen miles long, were flown to investigate an anomaly picked up on an extended profile from the detailed area. A small anomaly, which appears to be quite limited in depth extent was defined. It does not appear to represent an iron ore occurrence however.

As soon as definite assays are available from different portions of the area now reported on, it will be possible to make more exact tonnage estimates.

INTERPRETATION OF GRAVITY GRADIOMETER DATA

The airborne gravity gradiometer data were observed over the main detail area only. Two maps showing gravity-contrast form lines at flight elevations of 1,000 and 2,000 feet are submitted. Each of these maps in turn is the combined product of flight lines flown in mutually perpendicular directions at the respective altitudes.

The basic interpretation of the airborne gravity data lies in the construction of the gravity "contours" or contrast form lines. While this is still a young art, it is interesting to note that similar patterns were obtained at the two flight elevations, from completely independent sets of data. The coloured "rings" represent positive zones of a gravity derivative, while the uncoloured "rings" represent negative portions.

When comparing the gravity-contrast contours with the aeromagnetic maps, it will be noted that the strongest gravity anomaly - the anomaly with the most red "rings" - coincides with aeromagnetic Anomaly A which in turn coincides with the Iron Mountain magnetite deposit. Two weaker gravity anomalies located a short distance northwest of the major anomaly coincide with aeromagnetic Anomalies B_1

and B_2. As in the aeromagnetic case, it is obvious that Anomaly B_1 is much stronger than Anomaly B_2.

Five miles southeast of Anomaly A, a fourth gravity anomaly is found to be coincident with aeromagnetic Anomaly C. Comparing the gravity anomaly over Anomaly C with that over Anomaly B_1, it will be noted that they have the same number of "rings" but that Anomaly C appears to cover a larger area. This suggests that Anomaly C represents a larger mass distribution at a greater depth. It will be noted that in all cases, the central ring of each anomaly decreases with height. However, the central ring of Anomaly C is reduced only slightly compared to that over Anomaly B_1. This suggests that a 1,000 foot increase in altitude has less effect on Anomaly C than on Anomaly B_1 and therefore that Anomaly C is deeper than Anomaly B_1. This interpretation is confirmed by the aeromagnetic results where the causative body for Anomaly B_1 lay at or near the surface, while that for Anomaly C lay nearly 1,000 feet below the surface. From the magnetic data the two masses seem to be of equivalent size, while from the gravity picture the body causing Anomaly C appears to be larger than that causing Anomaly B_1.

Two other minor gravity anomalies are shown. One of these lying three miles east of Anomaly C is coincident with a very weak aeromagnetic anomaly. While the magnetic result is uninteresting, the gravity anomaly may indicate a possible sulphide occurrence. It is realized that such a possibility is slim, but the country rock must be considered favourable for such an occurrence.

The second minor anomaly, located three miles northwest of Anomaly B_1, is somewhat difficult to explain. It is not associated with a magnetic anomaly and remains constant with regards to size and shape at the two elevations. This suggests that it may be associated with a deep-seated non-magnetic mass, rather than a topographic effect. It is quite possible that this anomaly in the gravity gradient may represent a gravity low however, and thus could indicate a granite pipe, or similar structure.

Anomaly A is by far the most interesting in the area. Consequently an attempt was made to derive some further information from it. The central blank areas of the two southern gravity anomalies appeared to be closely associated with the major ore body. The area of these blanks was therefore computed and total 24,650,000 square feet at 1,000 feet and 17,450,000 square feet at 2,000 feet. Assuming that this corresponds to the total surface area of the ore body, it becomes apparent that some 2,500,000 tons per vertical foot of ore are indicated by the 1,000 foot flights, and 1,700,000 tons per vertical foot by the 2,000 foot flights. It may be pointed out that geological mapping indicated some 1,960,000 tons per vertical foot of 40% iron ore, and the magnetic data suggested 2,500,000 tons per vertical foot of similar material. Thus, a high degree of coincidence appears to exist between the three methods of tonnage calculation. Again it should be emphasized that these tonnages represent ultimate ore reserves as opposed to minable ore reserves. However, the vast tonnage of material available for exploitation, almost certainly guarantees that even with a dilution factor of three to one, a magnetite deposit of very large dimensions has been indicated.

Respectfully submitted,

LUNDBERG EXPLORATIONS LIMITED,

John H. Ratcliffe,
Chief Geophysicist

Approved:

Hans Lundberg
President

Toronto, Ontario
November 21
1957

LUNDBERG EXPLORATIONS LIMITED
16 EGLINTON AVE EAST
TORONTO 12, ONT.

APPENDIX A

DETAILED INTERPRETATION OF AEROMAGNETIC DATA

The aeromagnetic survey was marked by the definition of a very intense magnetic anomaly lying about three miles south of Iron Mountain Lake. This anomaly, with a peak intensity of about 25,000 gamma recorded on the 1,000 foot elevation, and 15,500 gamma recorded on the 2,000 foot elevation, must be considered to rate among the strongest in the world.

In order to learn more about this anomaly, an attempt was made to calculate a theoretical curve which would match the anomaly observed along Profile A-A', at both flight elevations. The results are shown in Figure 1. Fortunately, the profile, taken at right angles to the local strike of the iron formation, trends almost magnetic East. Consequently it was possible to simplify the formula for deriving the theoretical magnetic field. According to Induction Theory, a vertical dyke, having infinite length and an infinite depth, and striking magnetic North, will produce an anomaly

$$\Delta V = 2 K I \sin i \left(\tan^{-1} \frac{x+m}{h} - \tan^{-1} \frac{x-m}{h}\right)$$

where ΔV = the anomalous vertical magnetic field in gamma

K = the average susceptibility difference between the anomalous body and its surroundings in C.G.S. units

I = the intensity of the earth's total magnetic field in the area, in gamma

i = the angle of inclination of the earth's total magnetic field to the horizontal

$I \sin i$ = the vertical component of the earth's total magnetic field (i.e. about 59,000 gamma)

x = the horizontal distance from the centre of the anomalous body to the point of observation

m = the half-width of the body

h = the depth of the top surface of the body from the plane of measurement, i.e. the aircraft

The curves shown in Figure 1(a) indicate that a fair match may be obtained between the observed profile and a theoretical profile based on a magnetic body having as constants: width = 3,700 feet, depth below aircraft = 1,320 feet, and susceptibility K = .114 C.G.S. units. Using the same width, and increasing the height by 1,000 feet to correspond to the 2,000 foot flight elevation, a theoretical curve was obtained for a similar profile at 2,000 feet. The observed field curve is compared with the calculated curve in Figure 1(b), the only adjustment made being in the susceptibility factor which had to be reduced by about 7% to K = .106 C.G.S. units for agreement in the peak intensity. The correspondence obtained in both cases appears to be highly satisfactory, suggesting that the theoretical estimates are reasonably accurate.

In general, the observed profiles are narrower at the peak and broader at the base than the calculated profiles. This suggests that the average magnetite content of the anomalous body is not uniformly distributed (Figure 2 (a)) as assumed in the induction theory formula but increases gradually from the flanks to the centre as shown in Figure 2(b). The actual situation as shown on the geological map of the area is shown in Figure 2(c). This may be averaged out over a wider body, as shown in Figure 2(d) to obtain a picture somewhat akin to that suggested in Figure 2(b). It may be seen that when the flanking magnetite-bearing horizons are averaged with the enclosing lavas, a wider but less magnetic mass may be obtained.

Thus, when estimating grades and tonnage by means of magnetic calculations, the general tendency is to reduce the grade but increase the tonnage due to the resolution factors involved. It now becomes apparent that the susceptibility factors calculated for the anomalous body may be low. These calculated values are:

$$K = .114 \text{ C.G.S. units at } 1{,}000 \text{ feet}$$
$$= .106 \text{ C.G.S. units at } 2{,}000 \text{ feet}$$

Assuming that the closer the plane of measurement to the causative body, the less the degree of resolution will be, the value of K = .114 C.G.S. units will be selected for further calculations. The width of the body is assumed to be 3,700 feet.

Many efforts have been made to measure the susceptibility of pure magnetite. The results vary widely. Experience suggests however that a value of K = .30 C.G.S. units is reasonably accurate for magnetic calculations. Thus, in this case, a susceptibility of K = .114 C.G.S. units suggests that the body contains

$$\frac{.114}{.30} \times 100\% = 38\% \text{ magnetite}$$

or 26.6% iron, over a calculated width of 3,700 feet. Reducing these figures to compare with the true width as observed in the field, we might expect $\frac{3,700}{1,900} \times 26.6 = 51.8\%$ iron over a width of 1,900 feet (two bands 350 feet and 1,550 feet wide). While the iron percentage is undoubtedly high (assay results have given values ranging from 40 to 45 percent iron), due to remanent magnetization possibly, it is obvious that we are dealing with the correct order of magnitude.

Since our calculations are based on the assumption that the body is (a) two-dimensional (i.e. has infinite strike extent) and (b) extends to infinity in the vertical direction, it is now apparent that the ore body itself must have considerable length and depth, since the calculated figures give widths and ore grades in excess of those observed in the field. There is also reason to believe that another iron formation horizon may lie parallel to, but east of, those horizons which have been mapped to date since the magnetic anomaly centre coincides with what is believed to be the location of the picket line used in geological mapping.

Examination of the 1,000 foot magnetic profile indicated that the 15,000 gamma contour lay over the calculated contact. Assuming that this empirical rule may hold for all profiles, it is possible to estimate a surface area for the ore body, and thus calculate an ore tonnage. The area enclosed by the 15,000 gamma contour includes about 1.36 square miles or 38,000,000 square feet.

This area would represent 3,800,000 tons per vertical foot averaging 26.6% iron. Since ore assays indicate that the formation runs about 40% iron, we must reduce this tonnage to

$$\frac{26.6}{40.0} \times 3,800,000 = 2,500,000 \text{ tons per vertical foot}$$

The surface area of the magnetite-bearing horizons, as determined from geological mapping is about 19,000,000 square feet. This represents 1,900,000 tons per vertical foot of ore which apparently grades about 40% iron as determined from the few assay results presently available. The tonnages calculated from the magnetic data are therefore about 25% higher than those estimated from geology. Again the discrepancy, which in reality is quite small, may be explained by remanent magnetization, or, perhaps, by an unmapped magnetite horizon.

It must be pointed out that all of the material shown on the geological map as magnetite cannot be considered ore. Open pit mining as generally practiced by iron ore companies tends to eliminate any zones less than 200 feet in width from primary consideration. Wider zones may be mined to a depth equivalent to their width. Thus, although it is obvious that the Iron Mountain magnetite bodies extend to considerable depth, the actual mining depth will be limited by the minable widths. Calculations of minable ore tonnages are however beyond the scope of this report. The tonnage figures given above may be considered ultimate ore reserves, as distinguished from minable ore reserves.

Four satellite anomalies deserve consideration. None of these magnetic anomalies have been visited on the ground, so that the data gained from the airborne surveys provide the only information concerning these bodies. Two of the satellite anomalies lie a short distance northwest of the main anomaly zone, a third is located five miles southeast of it, while the fourth anomaly may be seen sixteen miles east of the main anomaly. An interesting feature, common to all four of these anomalies, is their circular shape, suggesting that they are formed by vertical cylindrical structures. Since both length and width dimensions are relatively small, three dimensional bodies must be considered. Consequently the satellite anomalies will be discussed in terms of magnetic pole theory.

Assuming that the causative bodies extend to a depth greatly in excess of their distance from the plane of measurement, i.e. the height of the aircraft, we may calculate the anomaly due to a single pole of strength $K Z_o S$.

Thus $$\Delta Z = \frac{d}{r^3} K Z_o S$$

where ΔZ is the anomalous vertical component of the earth's magnetic field

d is the depth of the upper pole from the plane of measurement, i.e. the aircraft

r is the distance of the upper pole from the point of measurement, i.e. $r^2 = d^2 + x^2$ where x is the horizontal distance from the magnetic pole to the point of measurement

K is the magnetic susceptibility difference between the causative body and its surroundings in C.G.S. units

Z_o is the vertical component of the earth's magnetic field in gamma

and S is the area of the top surface of the causative body.

It may be noted that flights at two elevations permit easy calculations of the depth of the magnetic pole. Taking the maximum magnetic anomaly at the two elevations, we obtain

$$\Delta Z_1 \max = \frac{1}{d_1^2} K Z_o S$$

$$\Delta Z_2 \max = \frac{1}{(d_1 + 1000)^2} K Z_o S$$

$$\therefore \quad \frac{\Delta Z_1 \max}{\Delta Z_2 \max} = \frac{(d_1 + 1000)^2}{d_1^2}$$

$$\therefore \quad d_1 + 1000 = d_1 \sqrt{\frac{\Delta Z_1 \max}{\Delta Z_2 \max}}$$

$$\text{and} \quad d_1 = \frac{1000}{\sqrt{\frac{\Delta Z_1 \max}{\Delta Z_2 \max}} - 1}$$

Applying this to Anomaly B_1 as shown in Figure 3, we obtain

$$d_1 = \frac{1000}{\sqrt{\frac{11,500}{4,300}} - 1} = \frac{1000}{1.635 - 1}$$

$$= 1,574 \text{ feet subaircraft}$$

Then $KZ_oS = 11,500 \times 1574^2$

and $$KS = \frac{11,500 \times 2,477,476}{59,000}$$

$$= 482,898$$

In order to check the depth estimate and susceptibility factors, theoretical curves were calculated and compared to the field curves at the two flight elevations. In both cases a satisfactory match was obtained, as shown in Figure 3. Thus we may conclude that the upper pole of the causative body lies from zero to 200 feet below the ground surface, and that the body is characterized by a magnetization factor KS = 483,000.

Assuming that the anomaly is caused by material of similar grade to that found in the main ore zone, the susceptibility or K factor will be 0.1 C.G.S. units. The size factor S then becomes 4,830,000 square feet. Since the magnetic anomaly is circular, we may assume that it has a circular, or more likely, a square cross section, each side of which would be about 2,200 feet. Comparing this width with the distance between inflection points of the anomaly, a fair agreement is obtained. Thus the estimated surface area, 4,830,000 square feet, appears reasonably accurate, and consequently the assumption that the anomalous body has a susceptibility K = 0.10 C.G.S. units may be justified.

It would therefore appear that Anomaly B_1 could represent a body lying at a depth of from zero to 200 feet, containing about 483,000 tons per vertical foot of ore grading about 33% magnetite. This may be reduced, due to resolution, to a body containing 280,000 tons per vertical foot of ore grading 40% iron, in keeping with the known assays obtained at Iron Mountain. The anomaly clearly has merit and could represent an important addition to the magnetite ore reserves. Geological investigations in the area are strongly recommended.

A similar analysis was made for Anomaly B_2, which is also shown on Figure 3.

Here $$\frac{(d_1 + 1000)^2}{d_1^2} = \frac{3900}{1200} = 3.25$$

$$\therefore \quad d_1 = 1245 \text{ feet subaircraft}$$

and $$KS = \frac{3900 \times 1245^2}{59000}$$

$$= 102,459$$

Actually when the calculated curve was compared with the field curve, it was found that a slightly deeper body $d = 1320$ feet produced a more desirable match. Recalculating KS, we obtain

$$KS = \frac{3469 \times 1320^2}{59000}$$

$$= 102,447$$ which agrees with the previous value admirably.

The anomaly is again circular, thus the assumption of a square top is justified once more. The distance between inflection points appears to be about 2,000 feet, thus the area of the top surface would be about 4,000,000 square feet. The susceptibility K therefore is $\frac{102,447}{4,000,000} = 0.025$ C.G.S. units. But this susceptibility factor is about one-quarter of that assumed for the ore bodies, and probably represents material grading about 6% iron. If the estimate of surface area was grossly in error, it would be possible to resolve the grade-size factor to consideration of an ore body containing 60,000 tons per vertical foot of ore grading 40% iron. While this is a distinct possibility, it is much more likely that the anomaly represents a much larger tonnage of lower grade material. The anomaly is probably sufficiently interesting to justify surface geological investigation.

The field curve for Anomaly C, shown in Figure 4, was matched adequately by a theoretical curve having constants $d_1 = 2,300$ feet and KS = 412,441. The distance between inflection points appears to be about 2,400 feet. Thus for a body having a square cross section, the surface area S will be 5,760,000 square feet, and consequently the susceptibility $K = \frac{412,441}{5,760,000} = 0.07$ C.G.S. units.

It is therefore suggested that Anomaly C represents a magnetite body lying beneath 900 to 1,000 feet of overburden or barren rock. This body which probably has a square cross section contains about 576,000 tons per vertical foot of magnetite ore grading about 16% iron. This may be resolved to 230,000 tons per vertical foot of magnetite ore grading 40% iron.

As a check on the depth estimate, a graphical method involving the horizontal distance between the two points of half maximum slope was tried. The depth to the body is given by this distance divided by 1.6. Depths calculated by this method, on both flanks of the anomaly at both altitudes indicate that the top of the anomalous body is quite close to the surface, and in fact, probably outcrops. This appears to contradict the original calculation which suggests that the body lies at a depth of 1,000 feet. The sharp portions of the magnetic anomaly occur near the peak, however. Therefore, it is highly probable that minor offshoots of the main mass do reach the surface, but that the major mass is buried.

This body, however, could represent a substantial addition to the magnetite ore reserves of the area, and, therefore should receive further attention.

It was found desirable to calculate Anomaly D, as shown in Figure 5, by means of induction theory. The shape of the field curve suggested a dipping body, limited in depth extent. The curve match obtained for an outcropping dyke-like body, dipping 45° to the west, with a true width of 1,900 feet, and a depth extent of 4,200 feet is quite good. The susceptibility of the body need only be 0.04 C.G.S. units, representative of material carrying 13.3% magnetite or 10% iron. These calculations were roughly checked by pole theory and the depth and susceptibility found to be quite comparable.

Thus it would appear that Anomaly D does not represent an economic concentration of magnetite. Before it is written off, however, it is suggested that a geological examination of the area would be highly desirable.

Toronto, Canada
November 22
1 9 5 7

LUNDBERG EXPLORATIONS LIMITED
96 EGLINTON AVE EAST
TORONTO 12 ONT

APPENDIX B

AIRBORNE GRAVITY GRADIOMETER SURVEY

When the results of a new method are introduced, it is necessary to touch briefly upon the principles involved. The attached reprint of "Airborne Gravity Surveys" published in C.I.M.M. Transactions, may serve this purpose.

When studying the airborne gravity gradiometer maps submitted with this report, it is necessary to keep in mind that it is not an intensity that is mapped, but the positive portions of a function that combines a timing phase of the instrument and a derivative of the vertical gravity gradient along the flight lines.

Positive portions of the recorded curve between two points of inflection are first as dashes along the flight lines, then the positive areas are mapped by contouring and colouring. In order to identify the zones different colours have been used grading from green through blue to red as the centres of the gravity anomalies are approached.

When a derivative function of the vertical gradient is mapped, gravity contrasts at shallower depths become pronounced anomalies which stand out from the regional gravity picture.

The advantage of using a derivative for detail interpretation has been amply proven and even a minute anomaly in the gravity field may become a well defined feature by contouring the pattern.

As the direction of flight warps the pattern, it is necessary to fly an area in two directions, preferably at right angles to each other. By combining the flight pattern from both directions, it is then possible to eliminate the effects of the flight direction and compute the true anomaly.

Information as to the relative magnitude of the anomalies may be gained by recording at two or more levels. Such a programme also insures that the anomalies will be properly located, as two completely independant sets of data must be processed to form a pattern concentric around the centre.

Processing of the Results

The different steps of outlining the pattern on Maps

Nos. 25-443-13 and 14 may be followed by first studying the contours and the airborne recordings (heavy dashes along the flight lines) shown on Maps Nos. 7, 8, 9, 10, 11, and 12. The patterns on Maps Nos. 7 and 8 are combined to show the results on Map No. 11 and the combination of patterns on Maps Nos. 9 and 10 is shown on Map No. 12.

The unadjusted pattern shown on Maps Nos. 11 and 12 appear quite angular and unrealistic but by inscribing smooth curves into the angular features, the patterns on final Maps Nos. 13 and 14 are obtained.

Certain spurious (kicks) caused by imperfections in the instrument have been eliminated before the interpretation was made. These corrections are very few however and should it be desired to check back on the flown recordings, these would be willingly submitted for inspection.

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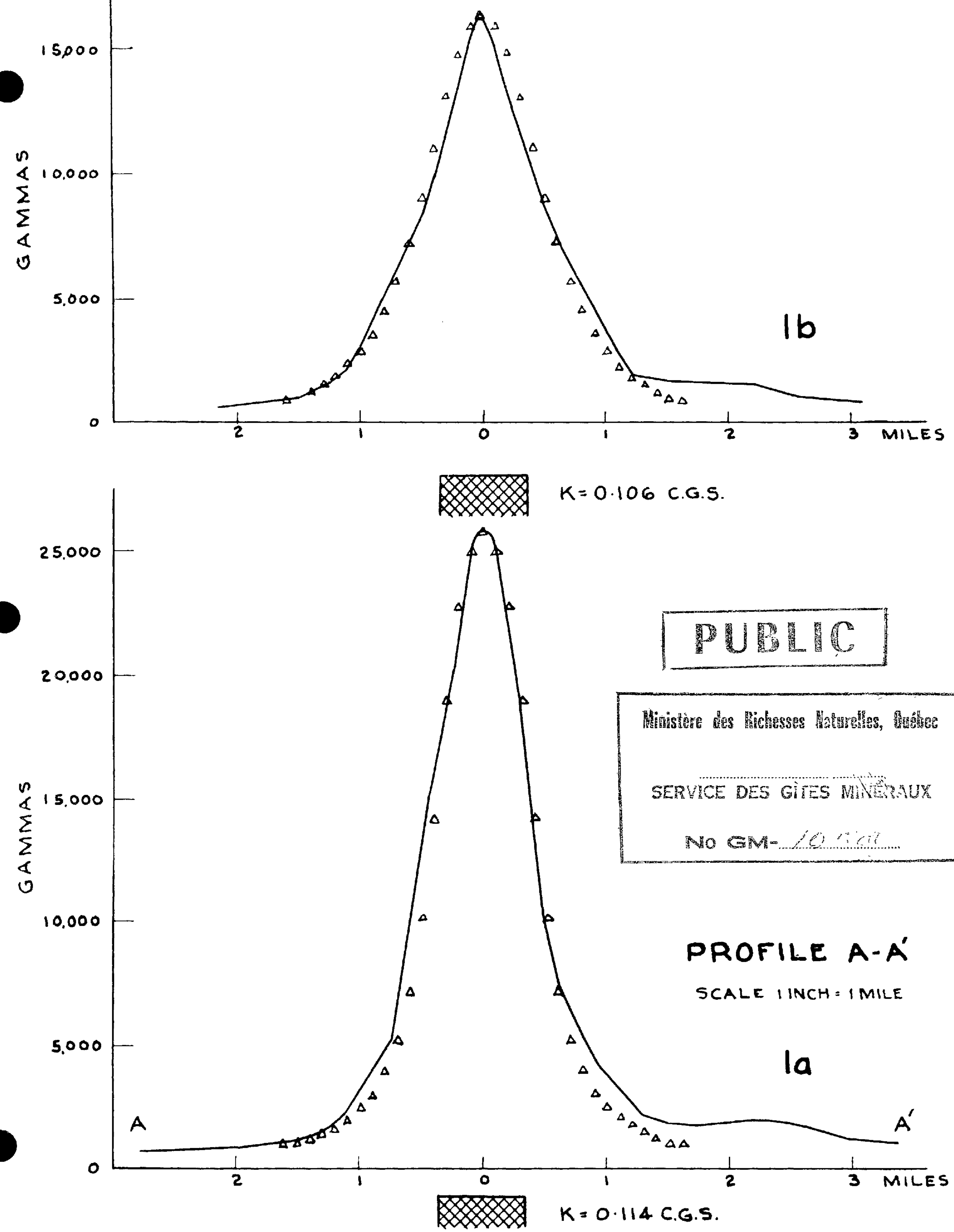
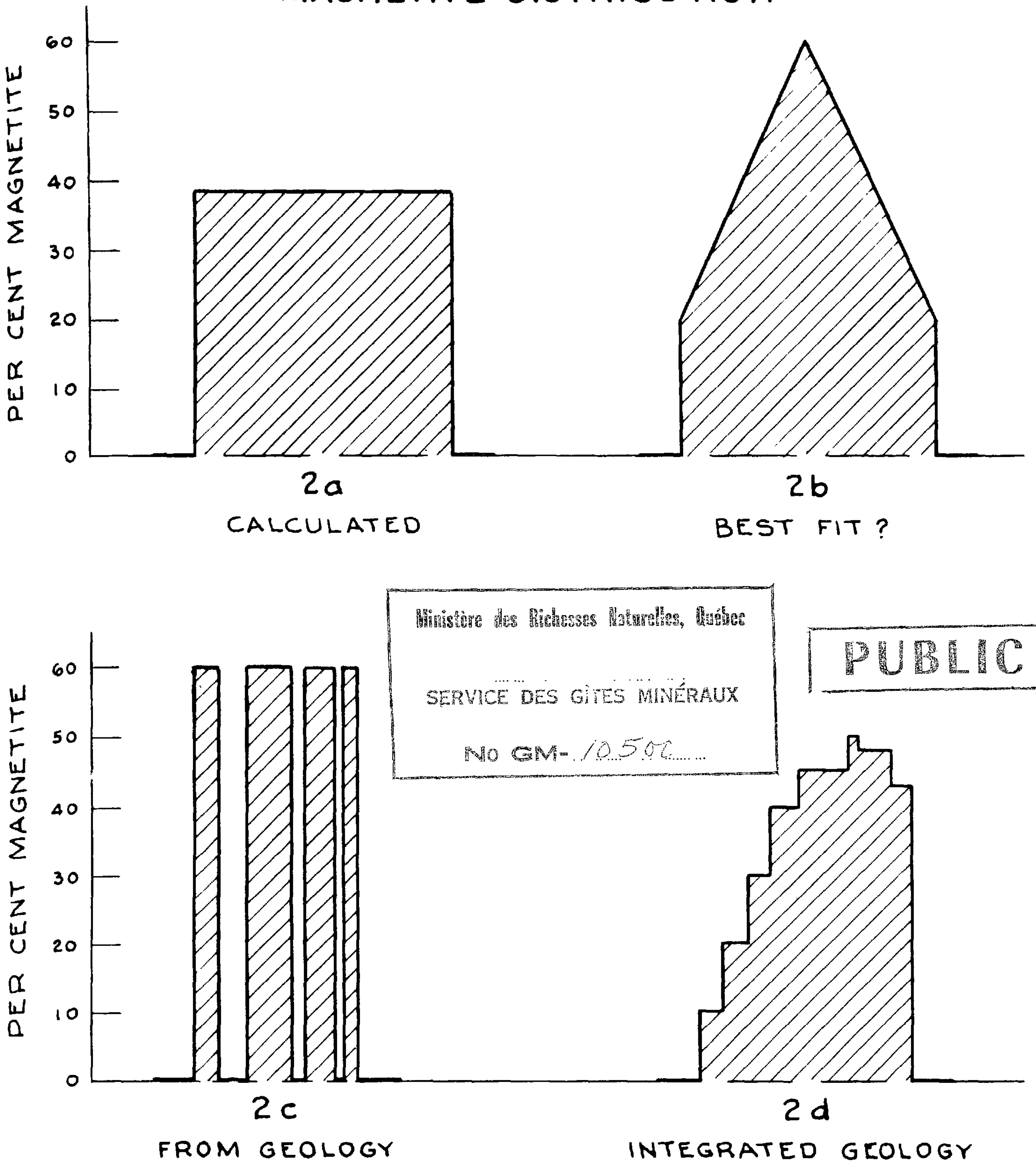
FIG. 1



APPENDIX 'A' - IRON MOUNTAIN LAKE

FIG. 2

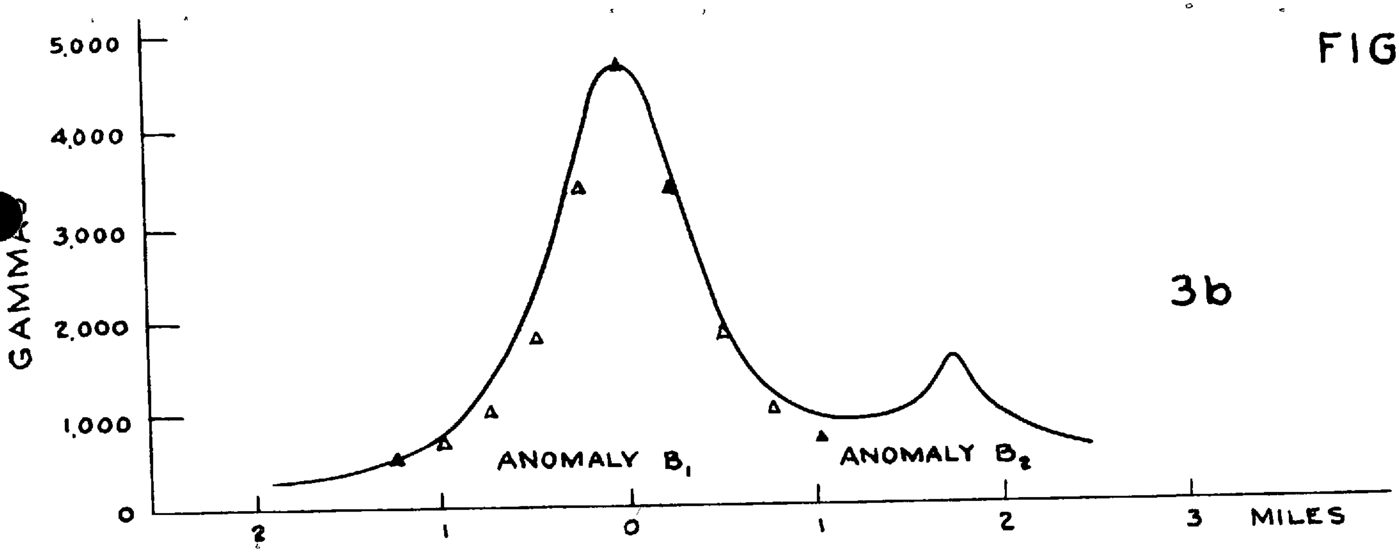
GRAPHICAL REPRESENTATION OF MAGNETITE DISTRIBUTION

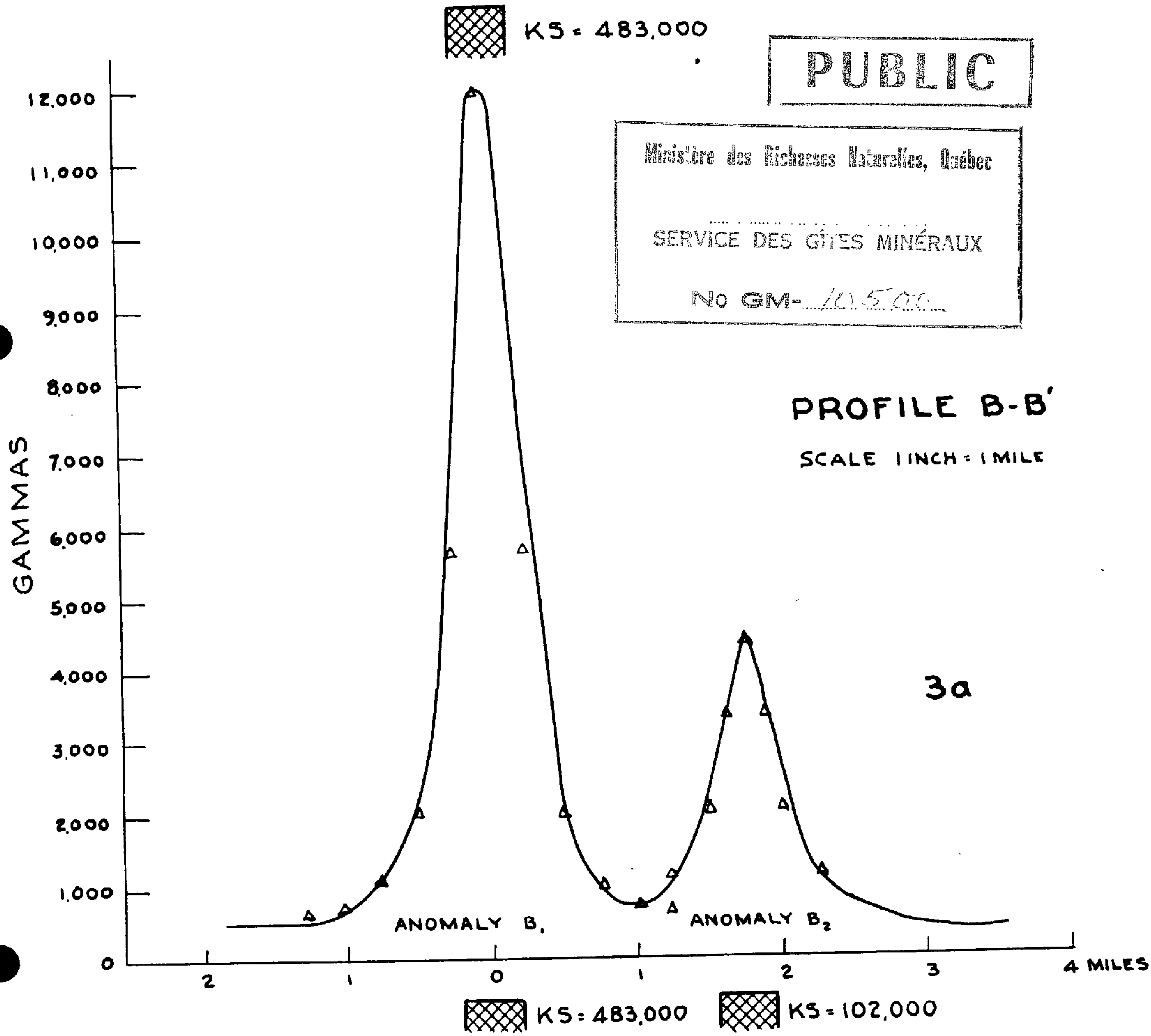


SCALE 1 INCH = 2000 FEET

APPENDIX A - IRON MOUNTAIN LAKE

FIG. 3



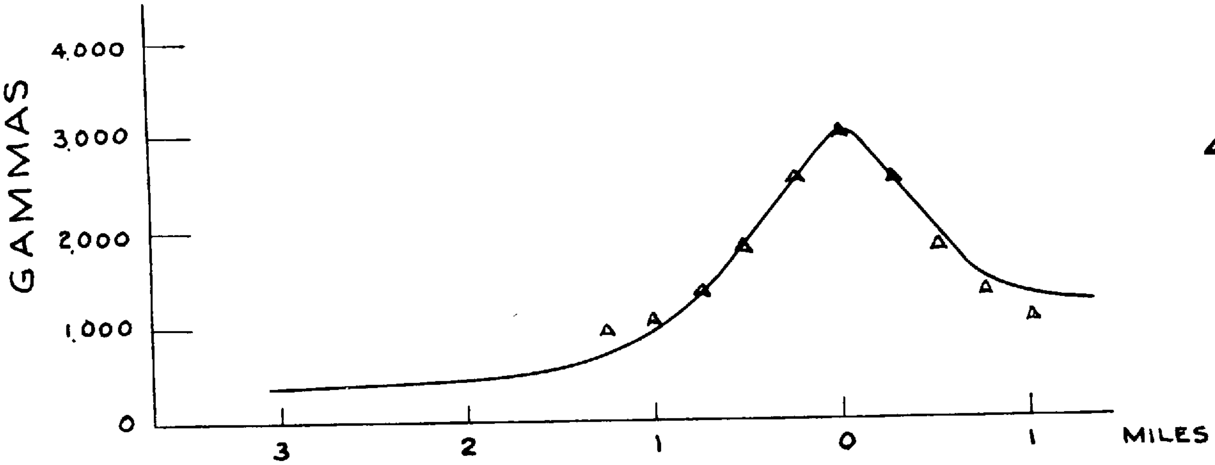


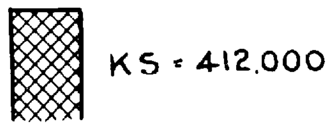
PROFILE B-B'

SCALE 1 INCH = 1 MILE

APPENDIX 'A' - IRON MOUNTAIN LAKE

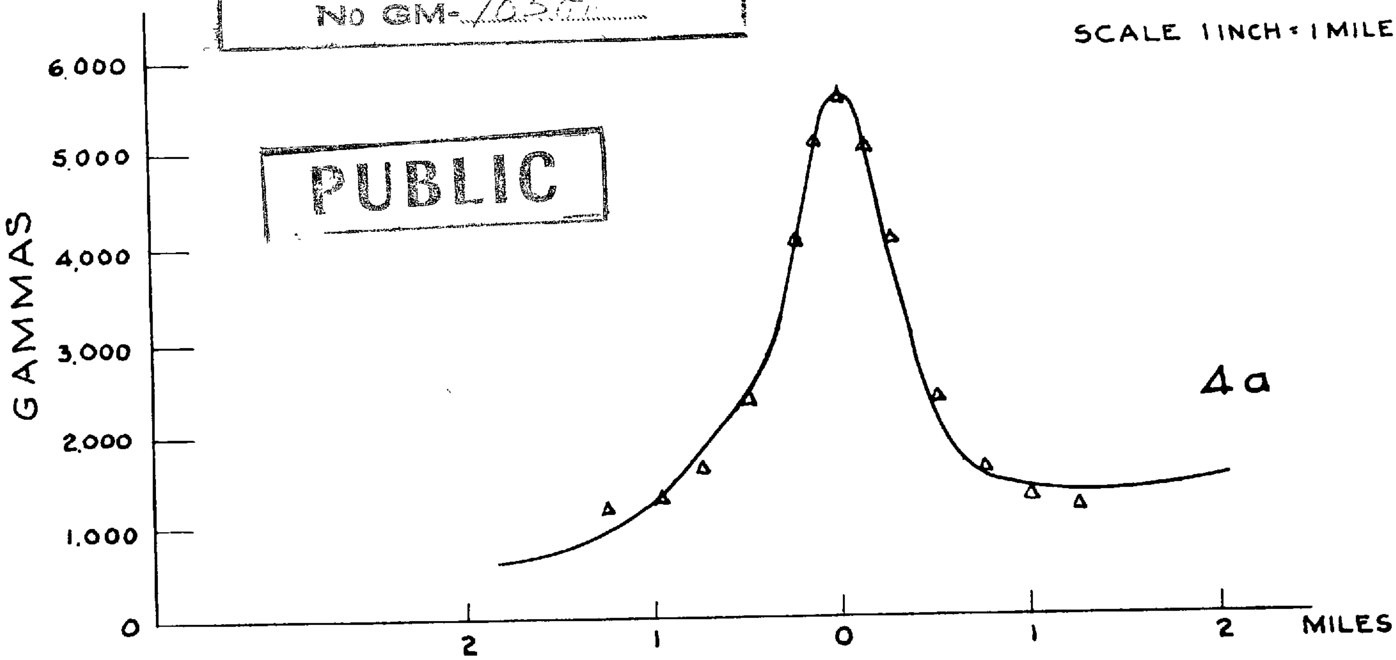
FIG. 4

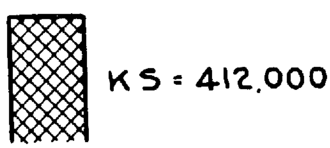




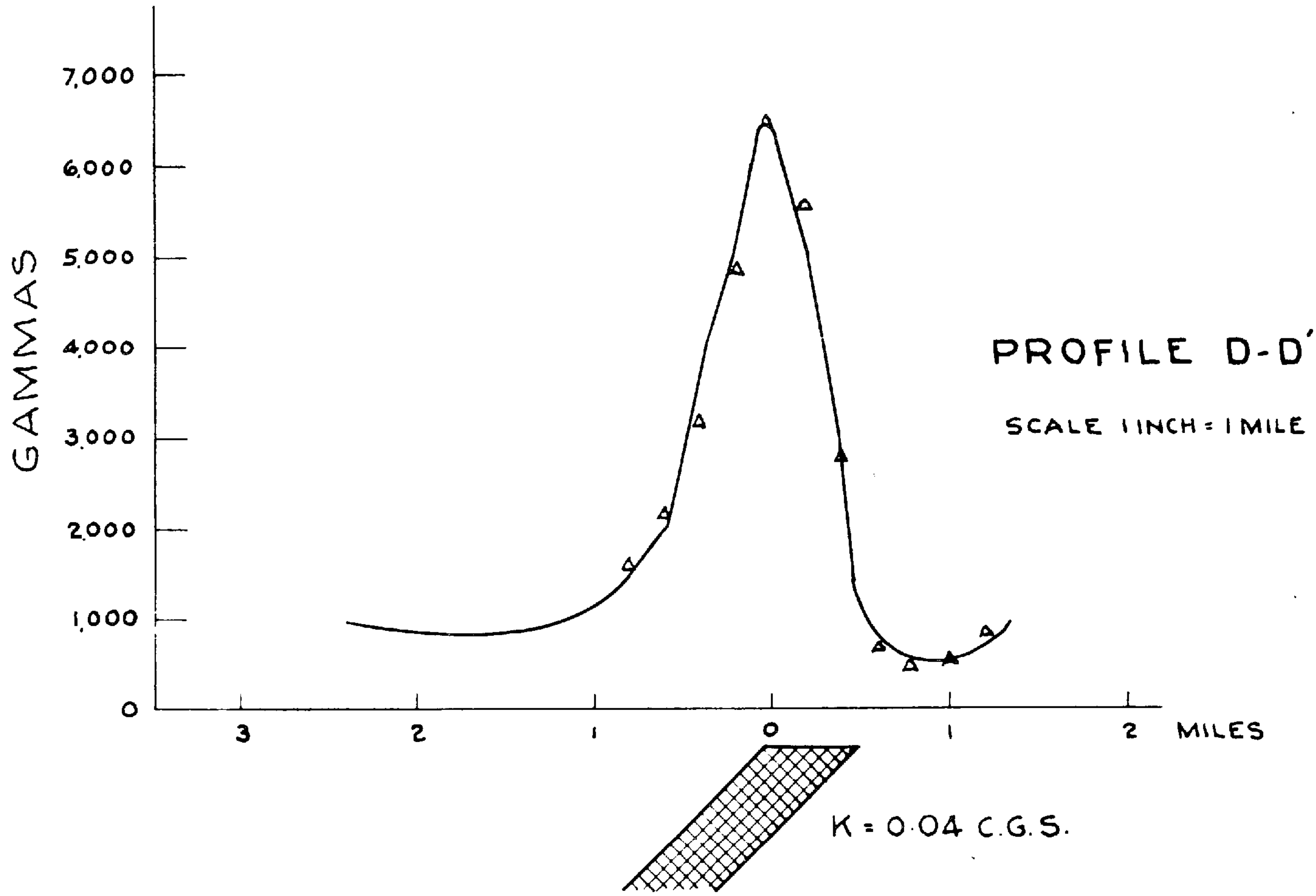
PROFILE C-C'

SCALE 1 INCH = 1 MILE





APPENDIX 'A' - IRON MOUNTAIN LAKE



APPENDIX 'A' - IRON MOUNTAIN LAKE