Drilling directly from a magnetic airborne fixed wing survey: is it possible? A proposed criterion and a real example.

Renato Cordani, Reconsult Geofísica, rcordani@reconsult.com.br

Abstract

One of the main issues in modern mineral exploration is whether you can drill directly from an airborne survey or not, since ground surveys can be very high cost in both money and environmental points of view.

Modern helicopter systems with very tight line spacings are usually used for direct drilling (Witherly 2004), but in general airborne fixed wing surveys are not expressly recommended for direct drilling.

The aim of the present paper is to run forward models and to present a real example in order to discuss this issue, trying to supply an orientation guide that can be used to consider drilling directly from the airborne magnetic fixed wing surveys.

Introduction

In many situations the mineral explorer wants to directly find the magnetic rock source of the anomaly. The following geological models of economic deposits are, in most cases, highly magnetic: Iron Oxide Gold Copper (IOCG), Kimberlites (diamonds), alkaline complexes (phosphate, niobium), Nickel (both sulphide and laterite), Volcanogenic Massive Sulphide Deposits (VMS), Banded Iron Formations (Iron), etc.

A traditional geophysical airborne survey is line oriented and the mag is typically collected at 10Hz, therefore the sampling is about 8m along the line. Between the lines the sampling is obviously equal the line spacing, which is in general about 100m to 500m.

Considering the large sampling difference, the issue of drilling from the airborne survey or not is only related to the line spacing, since sampling in the line direction is far better.

By common sense, very large anomalies, detected in several parallel survey lines, are strong candidates for direct drilling, and on the other hand one-line anomalies are strong candidates for performing a ground survey before drilling.

Figures 1 and 2 show examples of those extreme cases.

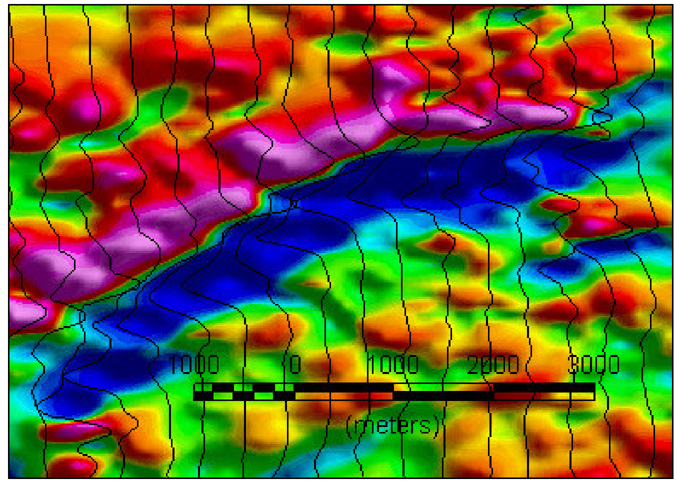

Figure 1: Total Magnetic Field (colors and profiles) for a magnetic survey in MG state, 400m line spacing.

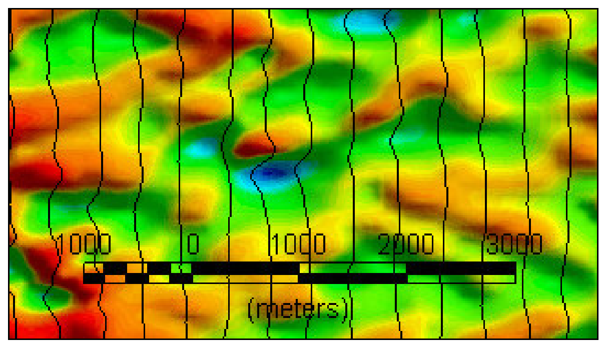

Figure 2: Total Magnetic Field (colors and profiles) for a magnetic survey in MG state, 400m line spacing.

In the profiles of the Figure 1, is easy to observe that the source rock produced an anomaly detected in about 14 survey lines, and therefore it is probably possible to intercept it in one of the central lines without any further ground survey. However, the anomaly at the center of the Figure 2 was mostly detected in only one survey line, and therefore it is very risky trying to drill it directly from the airborne survey.

In between these two extreme cases, the question worth discussing is **"how many survey lines must a rock be properly detected in before we consider drilling directly from the airborne survey"?**

Method

The method concept is to run forward models and compare the obtained amplitudes line by line, considering only the lines in the vicinity of the anomaly, and then chose a criterion conservative enough not to miss the source even in the worst-case scenario.

One proposed criterion is to subtract the standard deviation of all amplitudes from the maximum amplitude, calling this the “Limit number”, and then count the lines that the amplitude is above that number. If there are more than four lines above the “limit number”, the anomaly may be selected for drilling from airborne survey without additional ground mag survey.

Figure 3 and Figure 4 show a synthetic survey in both map and profile, line spacing = 100m and synthetic rock source in red 50m below surface. In all models, black profiles are magnetic field, flight clearance is constant = 100m and DTM is constant = 0m.

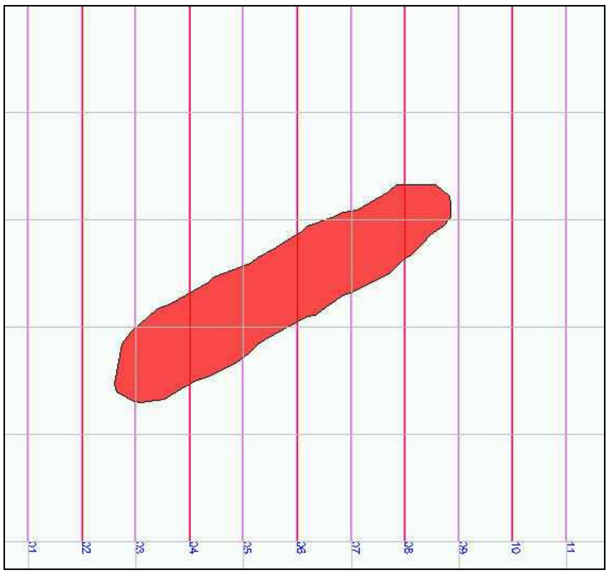

Figure 3: Configuration of the synthetic survey and synthetic rock, in map.

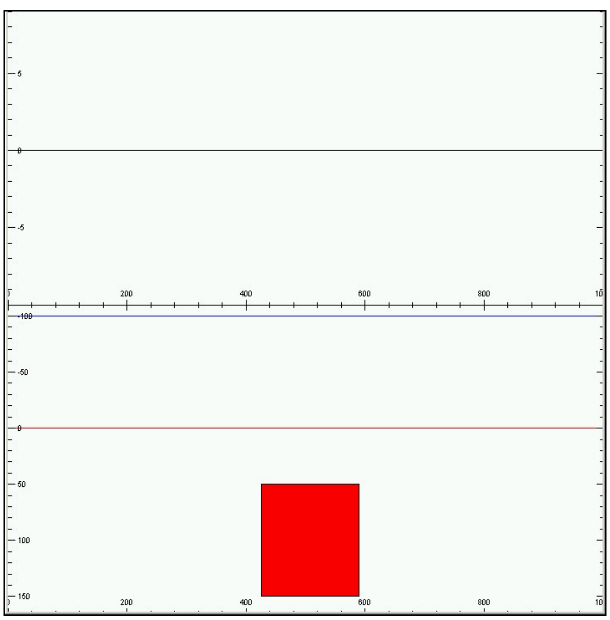

Figure 4: Configuration of the synthetic survey and synthetic rock, profile of the central Line (Line 6).

Now we will compute the magnetic anomaly field for a susceptibility of $80x10^{-3}$ SI, as per Figure 5, table 1 and Figure 6.

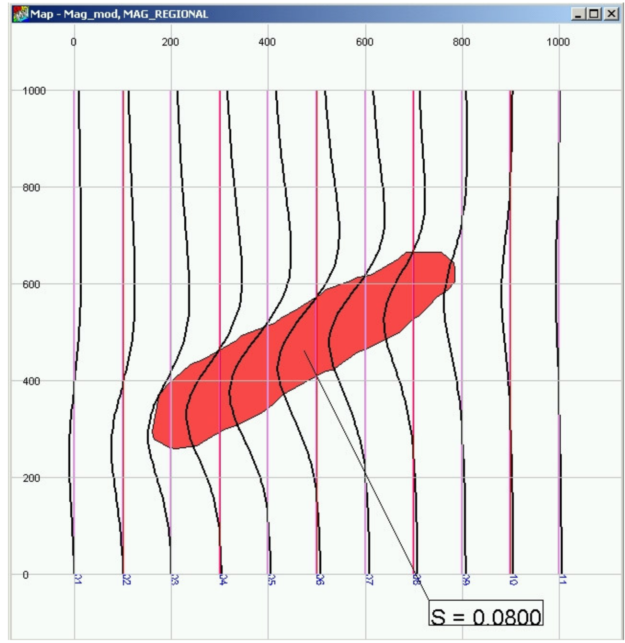

Figure 5: synthetic magnetic anomalies due to a magnetic rock at 50m depth.

Line	Min	Max	Amplitude
1	-10.5	14.5	25.0
2	-24.0	24.0	48.0
3	-45.9	36.7	82.5
4	-65.6	44.0	109.6
5	-74.8	46.0	120.8
6	-76.3	44.8	121.0
7	-71.1	37.9	109.0
8	-57.7	23.6	81.3
9	-36.5	10.1	46.6
10	-17.5	6.7	24.2
11	-7.3	6.0	13.2
Standard Deviation			41.1
Limit Number			79.9

Table 1: magnetic amplitudes per line due to the synthetic rock of the Figure 3. In yellow the lines in which the amplitudes are above “Limit Number”.

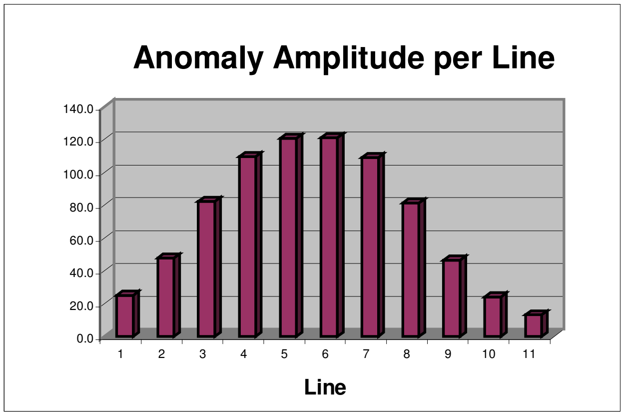

Figure 6: histogram of the anomaly amplitude per line.

Considering the whole survey: the magnetic anomaly is detected in all survey lines, our synthetic rock intercepts six survey lines (Lines 3, 4, 5, 6, 7 and 8), and the same six lines honor the “Limit number” criterion.

Once the criterion is acceptable, the next step is to pick the highest amplitude line (in this case Line 6) and drill it along this line in the middle of the modeled body, and the source won’t probably be missed.

Now let’s consider a smaller synthetic body, intercepting only one survey line, as per Figure 7 and Table 2. The body is also 50m depth and 80×10^{-3} SI susceptibility.

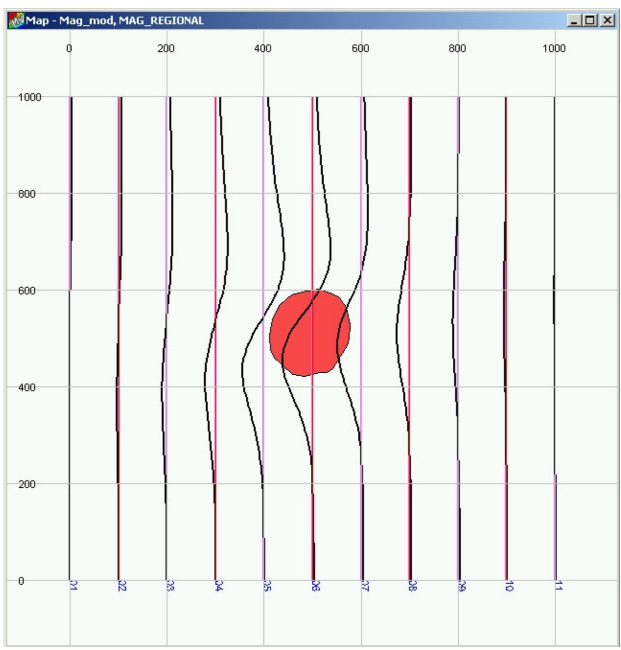

Figure 7: synthetic magnetic anomalies due to a magnetic rock at 50m depth.

Line	Min	Max	Amplitude
1	-0.9	2.7	3.6
2	-2.4	4.1	6.5
3	-5.4	7.2	12.6
4	-12.0	13.9	25.9
5	-24.0	23.3	47.4
6	-33.7	20.5	54.2
7	-27.2	8.0	35.2
8	-14.1	2.9	17.0
9	-6.4	2.3	8.6
10	-2.8	1.9	4.7
11	-1.1	1.6	2.8
Standard Deviation			18.3
Limit Number			35.9

Table 2: magnetic amplitudes per line due to the synthetic rock of the Figure 6. In yellow the lines in which the amplitudes are above “Limit Number”.

In this case, only two lines are above the limit number. If we pick the highest amplitude line to drill (Line 6), we would probably intercept the source.

However, this is the best scenario, for the rock source is located about the center of the survey line. Next picture and table show a worst-case scenario, when the source is between the lines.

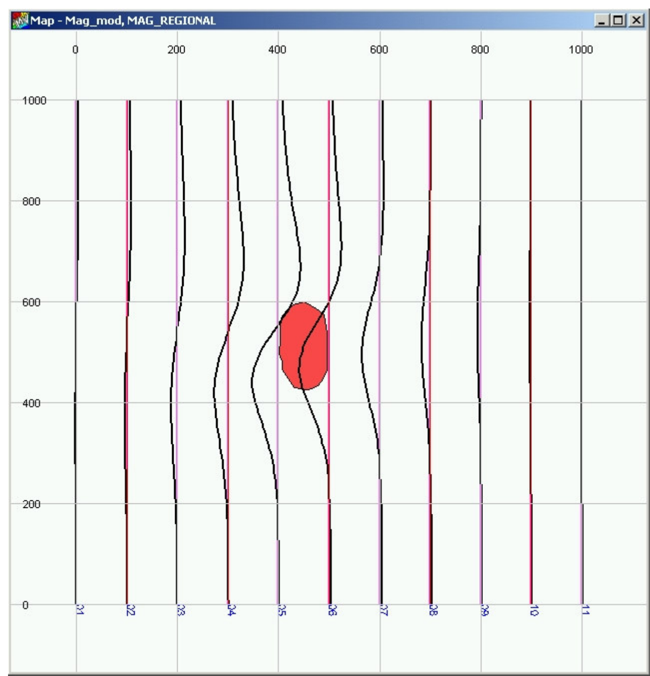

Figure 8: synthetic magnetic anomalies due to a magnetic rock located in between the lines at 50m depth.

Line	Min	Max	Amplitude
1	-0.8	1.8	2.6
2	-1.9	2.9	4.8
3	-4.3	5.4	9.7
4	-9.4	10.7	20.0
5	-17.6	15.2	32.8
6	-20.0	8.6	28.6
7	-12.2	2.8	15.0
8	-5.7	1.5	7.2
9	-2.5	1.2	3.8
10	-1.1	1.0	2.1
11	-0.4	0.9	1.3
Standard Deviation			11.1
Limit Number			21.7

Table 3: magnetic amplitudes per line due to the synthetic rock of the Figure 7. In yellow the lines in which the amplitudes are above “Limit Number”.

In this case even if we pick the highest amplitude line (Line 5), and drill the anomaly along that line, we would miss the source.

Therefore, we suggest a minimum of four lines above the “limit number” as a reasonable safe target to drill directly from the airborne survey.

Real Example

Considering the example of real anomalies of the Figure 1 and Figure 2, and analysing the amplitudes line per line in the original database, it is possible to build Table 4 (Figure 1) and Table 5 (Figure 2).

Line	Min	Max	Amplitude
1	23246.3	23684.2	437.9
2	22781.1	23801.9	1020.8
3	22761.2	23874.1	1112.9
4	22667.8	24027.0	1359.3
5	22593.2	24136.3	1543.2
6	22775.1	24160.0	1384.9
7	22484.1	23999.6	1515.5
8	22443.9	24156.8	1712.9
9	22667.9	23758.2	1090.3
10	22801.0	24030.1	1229.1
11	22862.8	23941.5	1078.7
12	22823.9	23989.2	1165.2
13	22852.3	24049.7	1197.4
14	22858.7	23769.0	910.3
15	23215.5	23407.5	192.0
Standard Deviation			397.8
Limit Number			1315.0

Table 4: magnetic amplitudes per line due to the anomaly of the Figure 1. In yellow the lines in which the amplitudes are above “Limit Number”.

Line	Min	Max	Amplitude
1	23430.3	23430.3	0
2	23442.5	23469.5	27.1
3	23334.0	23508.2	174.2
4	23251.4	23563.9	312.5
5	23290.6	23492.1	201.5
6	23400.1	23460.9	60.8
7	23430.3	23430.3	0.0
Standard Deviation			120.4
Limit Number			192.1

Table 5: magnetic amplitudes per line due to the anomaly of the Figure 2. In yellow the lines in which the amplitudes are above “Limit Number”.

The anomaly of the Figure 1 matches the “Limit number” criterion in five survey lines (Table 4), while the anomaly of the Figure 2 matches the “Limit number” criterion in only two survey lines (Table 5).

Therefore, in this real example we propose to drill directly from the airborne survey the anomaly of Figure 1, but not drill without further ground magnetics the anomaly of Figure 2.

Discussion

Considering the results, the author proposes in this paper that it is possible to drill an anomaly directly from the airborne fixed wing survey **if** at least four lines matches the “Limit number” criterion, i.e., the amplitudes of four lines are above the difference between the maximum amplitude and the standard deviation of the amplitudes of all lines around the anomaly.

Several warnings must be observed before using the results on your next drilling programme, such as:

1) The drilling objective must be intercepting a magnetic rock directly.
2) The assumption that all the anomaly (or at least the majority of it) is caused by an unique source.
3) The amplitude of the target anomaly must be much higher than the noise level.
4) Ambiguities on interpretation regarding magnetic remanence and source dip remain, but if there is enough sampling on the airborne mag, the ground mag would not solve the ambiguity problem anyway.

Acknowledgments

This research was supported by Reconsult Geofísica.

References

Witherly Ken, Irvine Richard, Morrison Edward (2004) The Geotech VTEM time domain helicopter EM system. *ASEG Extended Abstracts* **2004**.