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Analysis of Representative Magnetic Profiles in the Passenger District

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ABSTRACT

This study presents an analysis of representative magnetic profiles obtained during a geophysical survey conducted in the Passenger district. The objective is to characterize spatial variations in the magnetic field in order to identify significant anomalies associated with the nature of the subsoil or the presence of buried objects. The results reveal high magnetic variability, characterized by a predominance of positive anomalies and significant contrasts between the various survey lines.

KEYWORDS: *Magnetic profiles, magnetic anomalies, interpretation, Passenger district, magnetic prospecting.*

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I. INTRODUCTION

The analysis of magnetic profiles is an essential step in the interpretation of geophysical prospecting data. It allows us to observe the variation of the magnetic field along measurement lines and to detect anomalies associated with geological or anthropogenic structures [1].

Developing a site for subdivision requires sufficient knowledge of the physical characteristics of the land. Indeed, before laying out the plots, roads, various networks and future buildings, it is necessary to identify any potential subsoil constraints. These constraints may be related to the geological nature of the land, lithological variations, disturbed areas, buried structures or even the presence of anthropogenic metal objects [2].

In the case of the Passager district, the site intended for the housing development may present heterogeneities whose surface expression is not always visible. Certain subsoil anomalies may remain masked by surface formations, fill, vegetation or existing human occupations. However, these elements can influence future works, particularly during earthworks, road opening, installation of networks or foundation placement [3].

Knowledge of the subsurface structure often remains limited, even though it is essential for land-use planning, geological risk management, and environmental studies. Geophysical methods, particularly magnetic prospecting, offer an indirect approach to detecting variations in the magnetic field related to lithological contrasts or the presence of buried structures.

However, the recorded magnetic data can be influenced by several factors, such as anthropogenic disturbances, variations in the Earth's magnetic field, and local geological complexity. Therefore, it becomes necessary to examine the ability of magnetic profiles to provide a reliable and interpretable picture of the subsurface in this area.

Thus, the main issue addressed in this study is as follows:

- To what extent does the analysis of magnetic profiles allow us to identify and characterize the geological structures underlying the Passager district despite the disturbances related to the urban environment?
- What is the likely origin of the observed variations: geological, anthropogenic, or instrumental?

Thus, we formulate our response as follows:
The anomalies observed in the magnetic profiles of the Passager district are mainly linked to lithological contrasts and the presence of buried geological structures.

Positive and negative variations in the magnetic field reflect respectively the presence of materials rich in ferromagnetic minerals and areas of low magnetic susceptibility.

Despite disturbances of anthropogenic origin (metal infrastructure, urban installations), it is possible to extract significant anomalies after data processing.

mapping can help identify areas requiring special attention before subdivision.

The objective of this research is to:
The overall objective of this study is to analyze the magnetic profiles recorded in the Passager district in order to characterize the anomalies of the magnetic field and to deduce the geological structure of the subsoil, as well as to:

- Perform magnetic measurements along representative profiles in the study area.
- Correct the collected data by taking into account diurnal variations and the regional magnetic field in order to obtain reliable anomalies.
- Identify and characterize the magnetic anomalies (positive and negative) present in the profiles.
- Interpret the anomalies in terms of geological structures, such as lithological variations, faults, fractures or intrusions.
- To assess the influence of anthropogenic disturbances on magnetic measurements and their impact on interpretation.
- Propose a simplified representation of the subsoil structure of the Passager district based on the results obtained.
- To provide a useful scientific basis for future geotechnical, environmental or mining studies in the area studied.

Data were collected using a portable magnetometer along carefully defined profiles within the study area. Measurements were corrected for diurnal variations and regional magnetic field to obtain reliable residual anomalies. The resulting profiles were then processed using graphical and numerical analysis techniques, including filtering and differentiation.

II. Theoretical concept on the analysis of magnetic profiles

The analysis of magnetic profiles falls within the field of applied geophysics, more specifically within potential methods. It is based on the study of variations in the Earth's magnetic field caused by the magnetic properties of rocks and subsurface structures. This approach is widely used for geological mapping, mineral exploration, environmental studies, and land-use planning [4].

II.1. Principle of the Earth's magnetic field

The Earth's magnetic field is generated primarily by the movements of the Earth's liquid outer core. It can be considered a global dipolar field, to which are added local variations due to the nature of the materials present in the Earth's crust. These variations are called magnetic anomalies [4].

- Magnetic properties of rocks. Rocks possess various magnetic properties, the main ones being:
- Magnetic susceptibility: the ability of a material to become magnetized under the effect of an external magnetic field.
- Induced magnetization: magnetization acquired under the influence of the Earth's magnetic field.
- Remanent magnetization: magnetization retained by certain rocks after the disappearance of the external field.

Rocks rich in ferromagnetic minerals (such as magnetite) exhibit a strong magnetic response, unlike sedimentary rocks which are generally weakly magnetic.

II.2. Principle of magnetic prospecting

Magnetic prospecting involves measuring variations in the total magnetic field at the Earth's surface using an instrument called a magnetometer. These measurements are taken along profiles (measurement lines) or on grids covering a study area.

The data collected reflects the overlap of several components:

- The main magnetic field (global Earth field)

- Temporal variations (diurnal variations)
- Local anomalies related to the subsoil

II.3. Concept of magnetic profile

A magnetic profile is a graphical representation of the variations in the magnetic field as a function of distance along a measurement line. It allows for the visualization of magnetic anomalies and the identification of buried geological structures.

The anomalies can be:

- Positive: associated with highly magnetic materials
- Negative: associated with weakly magnetic materials or certain geometric configurations

II.4. Processing of magnetic data

To obtain reliable results, the data must undergo several processing steps:

- Correction for diurnal variations
- Subtraction of the regional magnetic field
- Filtering (low-pass, high-pass)

Calculating derivatives to accentuate anomalies

These treatments make it possible to isolate significant local abnormalities.

II.5. Interpretation of magnetic profiles

Interpretation involves linking observed anomalies to geological structures. It can be:

- Qualitative: visual identification of anomalies
- Quantitative: mathematical modeling to estimate the depth, shape, and nature of the sources

The structures typically detected include:

- Faults and fractures
- Lithological contacts
- Magmatic intrusions
- The cavities or altered areas

II.6. Limitations of the method

Despite its effectiveness, magnetic profile analysis has certain limitations:

- Sensitivity to anthropogenic disturbances (metallic objects, infrastructure)
- Ambiguity in interpretation (multiple sources can produce the same anomaly)
- It is necessary to combine this with other geophysical methods for better accuracy.

III. Result

III.1. Selection and location of profiles

Three representative magnetic profiles were selected from all the measurement lines acquired at the Quartier Passager site. Their selection was based on their ability to traverse the main anomalies identified on the residual anomaly map and to cover the different magnetic domains of the site. The selected profiles are as follows:

- **Profile 1:** an east-west trending profile, 160 m long, crossing the central positive domain of the site. It intersects the major positive anomaly and allows for the analysis of its morphology and spatial extent.
- **Profile 2:** an east-west trending profile, 120 m long, located in the western part of the site. It illustrates the gradual transition between the western negative magnetic domain and the central positive domain.
- **Profile 3:** North-south trending profile, 70 m long, located in the eastern part of the site. It crosses the secondary positive anomaly and allows for the analysis of its symmetry and amplitude.

The location of these profiles is shown in **Figure 1.**

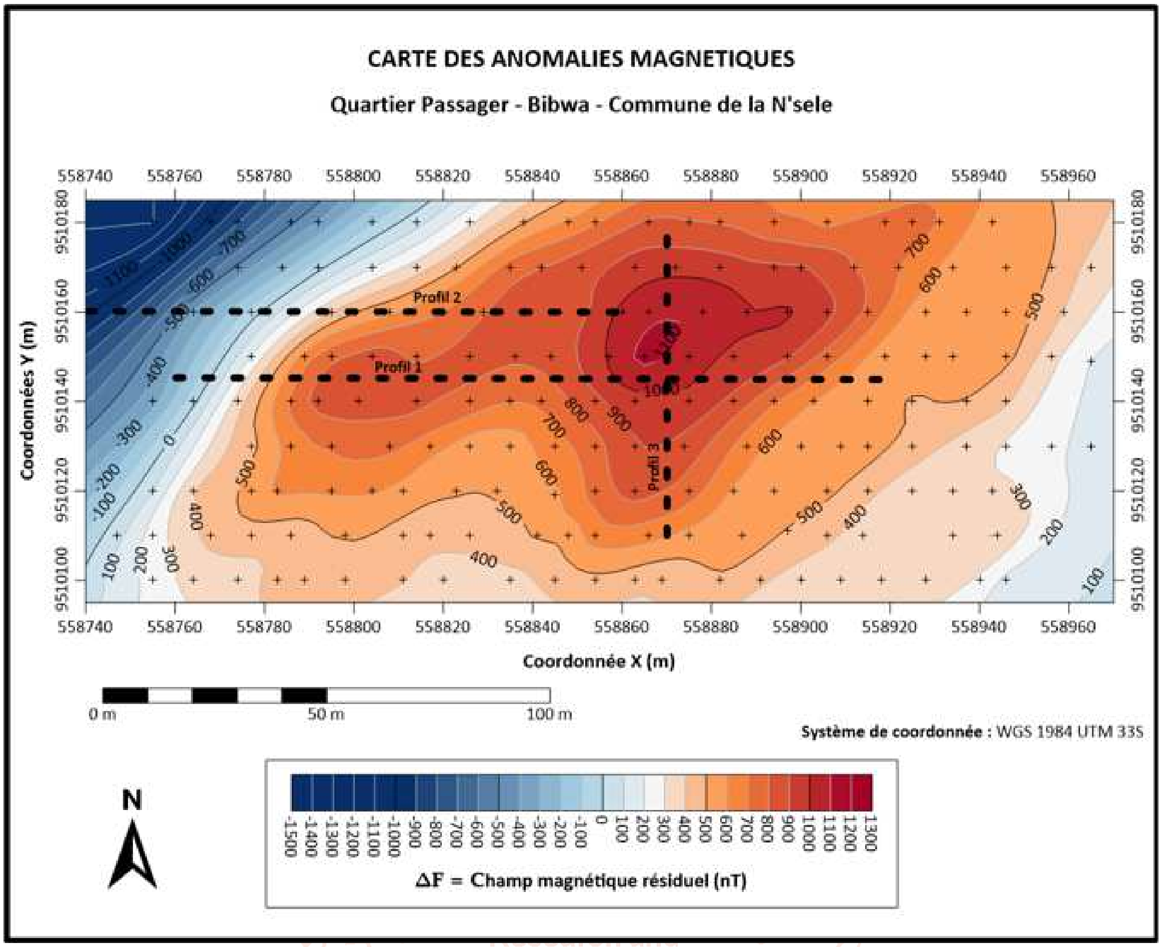
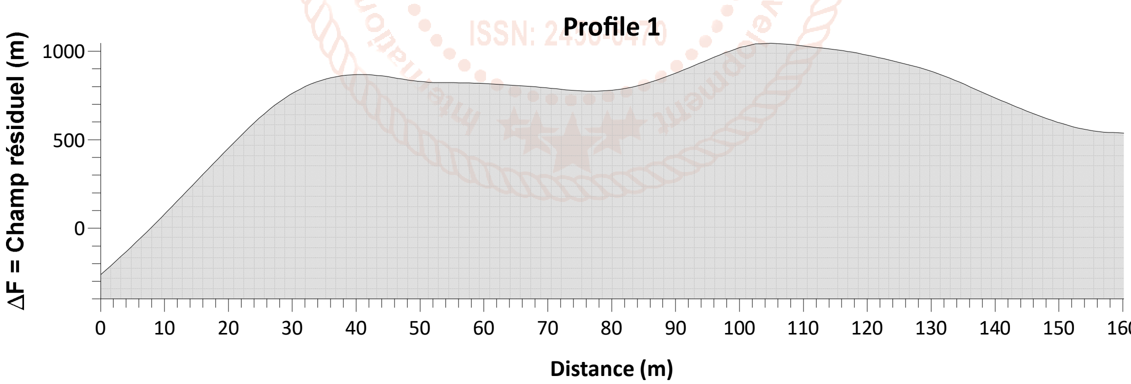
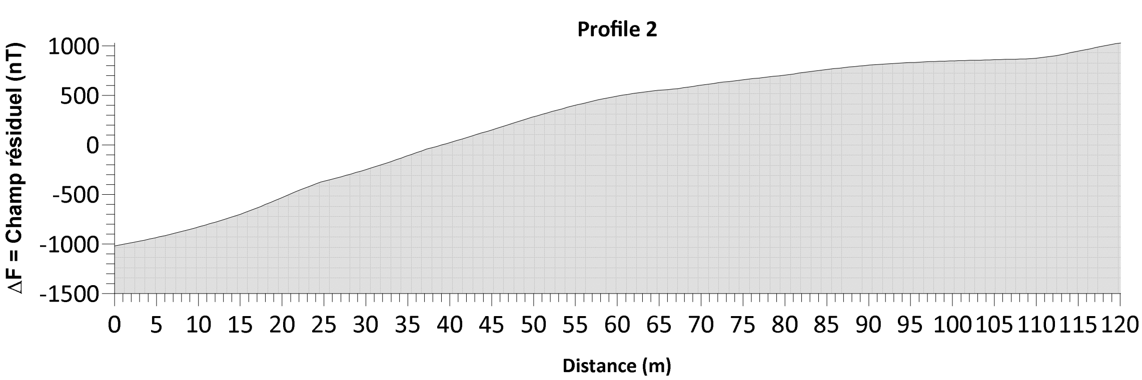
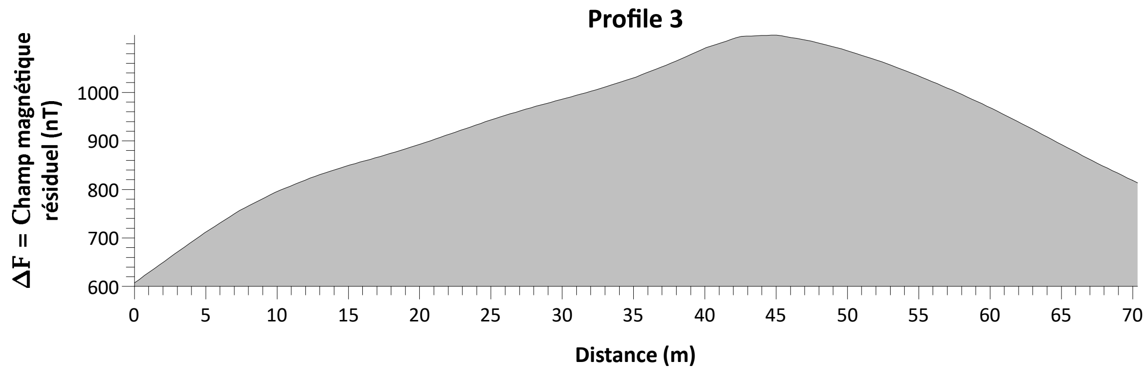


Figure 1: Map showing the spatial arrangement of the profiles







III.2. Field variations, significant peaks, disturbed areas and stable areas

Profile 1

Profile 1 exhibits significant magnetic dynamics over its entire 160-meter length. Three successive phases can be distinguished in the evolution of the residual field:

- **Phase 1 (0 to 30 m):** the profile begins with slightly negative values, close to -100 to -150 nT, then rises rapidly towards positive values. This rapid rise over about twenty meters indicates a marked positive gradient, consistent with the approach of a magnetic source.
- **Phase 2 (30 to 110 m):** The field reaches an initial plateau around +850 nT between 30 and 45 m, followed by a slight inflection towards +750 nT, then a gradual rise to the maximum peak of approximately +1000 nT, reached between 100 and 110 m away. This zone constitutes the core of the major positive anomaly.
- **Phase 3 (110 to 160 m):** the field gradually decreases from the peak, reaching values close to +500 to +550 nT at the end of the profile. The descent slope is gentler than the initial ascent, giving the profile a characteristic asymmetry, often indicative of an inclination or lateral decentering of the source.

Profile 2

Profile 2 exhibits a monotonous and regular evolution of the magnetic field over its entire 120 meters:

- At the beginning of the profile (0 to 5 m): the values are strongly negative, with a minimum recorded around -1,000 to -1,100 nT, corresponding to the western magnetic depression clearly identified on the map.
- From 5 to 120 m: the field rises continuously and progressively, going from -1000 nT to nearly +1000 nT at the end of the profile. The rise is regular, without any notable peaks or inflections, which indicates a constant positive gradient along the entire length of the profile.
- At the end of the profile (110 to 120 m): the values approach +900 to +1000 nT, confirming entry into the central positive domain.

This regular morphology, without isolated peaks, suggests that this profile does not directly cross the core of a localized source but rather a zone of gradual transition between two magnetic domains of contrasting susceptibility.

Profile 3

Profile 3, the shortest of the three (70 m), has a well-defined bell-shaped morphology:

- At the beginning of the profile (0 to 5 m): the values start around +620 to +650 nT, which confirms that this profile is entirely within the positive domain of the site.
- From 5 to 45 m: a gradual but sustained rise to a maximum peak of approximately +1140 nT, reached at a distance of about 40 to 45 m. This steady rise indicates a source whose susceptibility gradually increases towards the center.
- From 45 to 70 m: symmetrical and regular descent, with values returning to +700 to +750 nT at the end of the profile.

The nearly symmetrical bell shape of this profile is highly characteristic of a well-localized magnetic source with an approximately equidimensional geometry (isometric or spherical body to a first approximation). The full width at half maximum (FWHM) of the anomaly is approximately 40 to 45 m, which, according to the rule of thumb commonly used in magnetic prospecting, suggests a source roof depth of approximately 15 to 20 m (Telford et al., 1990; Blakely, 1995).

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III.3. Identification of significant peaks and anomalies

The following table summarizes the main characteristics of the peaks identified on the three profiles:

Profile	Length (m)	ΔF minimum (nT)	ΔF maximum (nT)	Peak position (m)	observed gradient
P1	160	≈ -150	≈ +1000	100–110 m	Strong (initial phase)
P2	120	≈ -1 100	≈ +1000	No isolated peak	Regular and continuous
P3	70	≈ +620	≈ +1140	40–45 m	Moderate, symmetrical

These results confirm that the most intense anomaly is located in the area crossed by Profiles 1 and 3, with values exceeding +1000 nT. Profile 2, meanwhile, mainly illustrates the lateral transition between the two dominant magnetic domains of the site.

III.4. Disturbed and stable zones

Cross-analysis of the three profiles clearly distinguishes two types of magnetic domains on the site:

Disturbed areas

They correspond to areas of high magnetic variability, identified on Profiles 1 and 3:

- the gradients are strong to very strong (especially on the initial phase of Profile 1);
- the amplitudes are high, exceeding +1000 nT;
- The peaks are clearly distinct.

These areas are interpreted as the site of localized magnetic sources, probably linked to subsurface concentrations of ferruginous or lateritic materials. They constitute areas of potential geotechnical risk, requiring further investigation before any development.

Stable areas

Profile 2 clearly illustrates the nature of the transition zones. Despite a strong overall contrast (from -1100 to +1000 nT), the variation is regular and continuous, without any abrupt breaks. This regularity reflects a gradual heterogeneity rather than a contrasting point source.

Furthermore, the ends of Profiles 1 and 3 (values between +500 and +700 nT, low gradients) correspond to calmer areas, exhibiting better magnetic homogeneity and therefore greater predictability of the subsoil.

III.5. Summary

Profile	Domain type	Main characteristic	Implications for the housing development
P1	Disturbed	Large, asymmetrical positive anomaly, peak at +1000 nT	Further investigations needed
P2	Transition	Continuous gradient from -1100 to +1000 nT	Geological contact to be specified
P3	Localized disturbance	Bell-shaped anomaly, peak at +1140 nT, source estimated at 15–20 m	Area of moderate to high risk

The profile analysis confirms and refines the geophysical zoning established from the maps. The well-defined positive anomalies in Profiles 1 and 3 indicate significant magnetic sources, while Profile 2 illustrates the gradual nature of the contact between the two major magnetic domains of the site. These results will directly inform the development recommendations presented in the following section.

IV. Summary of results and recommendations

This section aims to gather and prioritize all the results obtained from the magnetic survey carried out on the Quartier Passager site (Bibwa, Commune de la N'sele). It seeks to identify the main trends in the magnetic behavior of the subsoil, to identify the major constraints, to delimit the areas favorable to urbanization and to formulate concrete recommendations for the development of the future housing estate.

IV.1. Main trends observed

The combined analysis of the total magnetic field intensity map, the residual anomaly map, and the representative profiles highlights several major trends:

A. Strong magnetic heterogeneity of the site

The site does not exhibit uniform magnetic behavior. The total amplitude of anomalies, ranging from -4,199 nT to +4,241 nT on the point data (and from -1,321 nT to +1,143 nT on the interpolated grid), reflects a significant variability in the materials constituting the subsoil.

B. A predominance of positive anomalies

Approximately 65.75% of the stations show positive values, and the average of the interpolated residual field is clearly positive (+412 nT). This polarization indicates a widespread presence of ferromagnetic materials, likely ferruginized lateritic formations characteristic of the region's tropical context.

C. A clear spatial zoning

The site is structured into two large opposing magnetic domains:
- a dominant positive area, located in the center and to the east;
- a negative area, located on the western border.

D. Mostly superficial sources

The high gradients and the presence of dipolar signatures on the profiles indicate that most of the magnetic sources are located at shallow depths (estimated between a few meters and about twenty meters depending on the anomalies).

IV.2. Major anomalies and their implications

Three major anomalies structure the magnetic behavior of the site and have direct implications for development.

Anomaly	Location	Amplitude	Probable origin	Implications for the housing development
Major positive anomaly (A)	Central-East	+1100 to +1140 nT (grid)	Ferruginized laterites / hardened cuirass	Potentially hard ground, difficult earthworks
Secondary positive anomaly (B)	Central-West	+500 to +800 nT	Localized iron concentration	Moderate vigilance
Major negative anomaly (C)	West / Northwest	-1100 to -1321 nT (grid)	Sandy or clayey materials with low magnetic content	Loose soil, to be checked by a geotechnical engineer

Main implications:
- The major positive anomaly (A) indicates the probable presence of hardened materials (lateritic crusts) likely to complicate excavation work and the laying of underground networks (sanitation, water supply, electricity).
- The major negative anomaly (C), on the other hand, could correspond to loose soils whose bearing capacity will need to be checked before any heavy construction.
- The intense, localized peaks identified at specific points indicate the presence of ferrous waste or buried metallic objects, which must be located and removed during the site development phase.

Conclusion

Magnetic surveys conducted at the Quartier Passager site revealed significant heterogeneity in the subsoil, structured around major anomalies of both natural origin (ferruginized laterites, sandy materials) and anthropogenic (buried ferrous objects). This study demonstrates the crucial role of geophysics in the preliminary site assessment for development, by revealing constraints invisible at the surface.

The results obtained provide a solid basis for reasoned and safe development of the neighborhood, provided they are supplemented by targeted geotechnical investigations of the areas identified as critical. Thus, magnetic mapping constitutes not only a diagnostic tool, but also a valuable instrument for supporting sustainable urban planning.

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