Chapter 46
Results of the Complex Airborne Geophysical Survey in the Central African Ridge Area

Yu. G. Podmogov, J. Moilanen and V. M. Kertsman

Abstract We review the results of different-scale airborne geophysical survey performed in the territory of the Republic of Rwanda. Such parameters as the modulus of the magnetic field vector, electromagnetic sounding data in time and frequency domain, as well as data from a gamma-ray spectrometer with a total scintillator volume of 32 L were continuously recorded during the flight. The software automatically performed the necessary navigation management on a real-time basis. Automated execution of flight tasks allowed to exclude an operator from the surveying process. It took only 6 months of field works to perform the survey at a scale of 1:50,000 over the area of 26,000 km^2, as well as detailing works. The total workscope amounted to 57,718 line km. Maps of anomaly magnetic field and its local part, apparent resistivity maps for the most informative frequency and time channels, Th, U, K concentration maps and Th-K ratio maps have been prepared for a short period of time. Based on the results of map interpretation we selected prospective sites for further study. Detailed airborne survey was performed for 5 sites, and ground geological and geophysical survey was performed for 3 sites. Based on the detailed survey results we selected new local objects associated with quartz-magnetite veined mineralization, dyke bodies, and mafic rock intrusions. Multiple pegmatite intrusions were identified. The information about magnetic, electrical and radiometric characteristics of rocks allowed to reliably classify the identified anomaly objects.

Keywords Electromagnetics · Magnetometry · Gamma-ray spectrometry EQUATOR

Yu. G. Podmogov
LLC«Geotechnologies», Moscow, Russia

J. Moilanen (✉)
ICS RAS, Moscow, Russia
e-mail: info@geotechnologies-rus.com

V. M. Kertsman
Geological Faculty of Lomonosov MSU, Moscow, Russia

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Introduction

Airborne geophysical survey began in Rwanda using EQUATOR (Fig. 46.1) technology (Felix et al. 2014, Karshakov et al. 2017) by 12th of October 2016. It was fully completed by 12th of April 2017. A survey at a scale 1:50,000 and infill works was completed on a square of 26,000 km^2. Total survey volume is 57,718 line km. About half of the survey time was in the rain season. And half of the survey area are situated in the rough terrain conditions. Average productivity of airborne geophysical survey is 9620 line km per month. Detailed characteristics of EQUATOR system are described by Karshakov et al. (2017).

Mapping of Granite Intrusions and Their Material Composition Definition

The local component of the magnetic field (Babayants and Tararuhina 2009) is weakly differentiated for granite massifs of different composition in Rwanda. Its intensity does not exceed the first units of nT (Fig. 46.2a). The outer contours of granite intrusions are determined reliably.

The apparent resistivity of granites, depending on their types, varies from 300 to 2500 Ω m (Fig. 46.2b). The most significant granites differ in their radiogeochemical specialization (Fig. 46.2d). The map of classes of radiogeochemical specialization (Babayants et al. 2015) was built on the basis of a two-dimensional correlation analysis. Originally maps of K and Th values were considered as

Fig. 46.1 Original construction of towed platform of EQUATOR technology

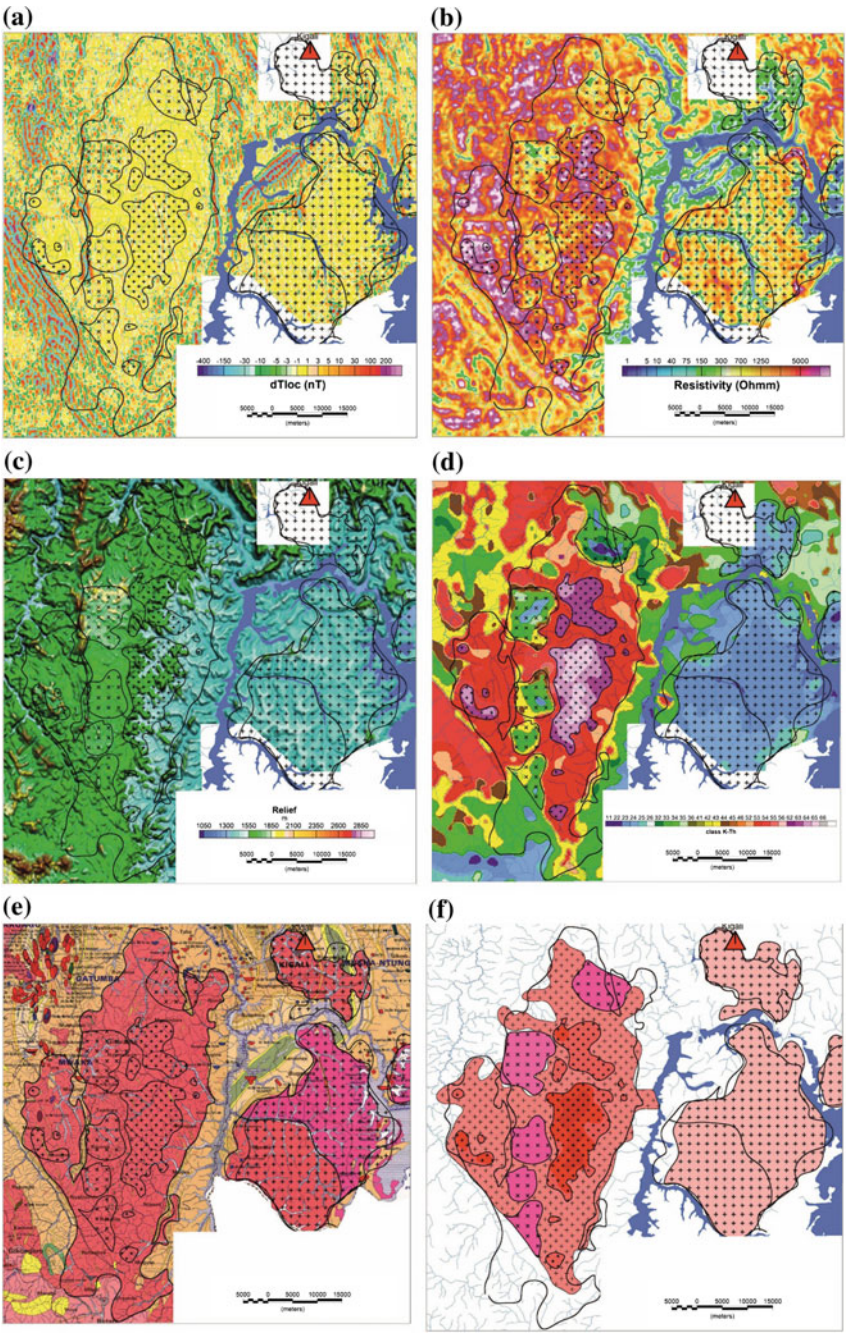

Fig. 46.2 Mapping of granite intrusions according to the technology of EQUATOR: **a** local component of the magnetic field; **b** apparent resistivity at a time gate 5 mcs; **c** digital elevation model; **d** map of radiogeochemical specialization classes for K-Th; **e** geological map; **f** varieties of granites from the interpretation of airborne geophysical data

Table 46.1 Physical properties of different types of granites

N	Pattern	K_Th class	dTloc (nT)	ρk (Ω m)	K (%)	Th (ppm)	Characteristic of granite massive
1		22–24	0–4	500–700	0.2–0.4	3.6–17.1	Low-radioactive granites, characterized by low potassium content, relatively low resistivity.
2		53–54	0–4	700–2500	2.0–2.15	11.2–16.4	Radioactive granites, high potassium content and medium thorium content, high resistivity.
3		33–35	0–4	300–600	0.86–0.91	10.9–24.2	Leucogranites, the content of potassium is below average, the content of thorium is medium, conductive.
4		63–65	0–4	1300–2500	3.6–3.9	10.4–24.3	Highly radioactive potassium granites, high content of potassium and thorium, high resistivity.

independent random variables. Each map was represented in the form of "stable-homogeneous" areas. The belonging of regions to different general populations was determined by the known rules of mathematical statistics. After this, algebraic intersections of maps of the domains K and Th were formed. As a result, stable areas of joint distribution of these elements were obtained. In general, the outer boundaries of granite massifs are in good agreement with the geological map. According to airborne geophysical data, it was possible to clarify their internal structure and distinguish four different types of granitoids (Table 46.1).

Results of Airborne Geophysical Survey at a Scale of 1:10,000

The work was carried out with the aim of detailing high-intensity linear magnetic anomalies and accompanying high-conductivity zones, revealed by the results of airborne geophysical survey at a scale of 1: 50,000. Detailed studies allowed to determine the shape, dimensions, and epicenters of magnetic anomalies (Fig. 46.3). A rapid assessment of the depths to the upper edge of the magnetic objects was performed. Objects with a minimum depth were selected for further study.

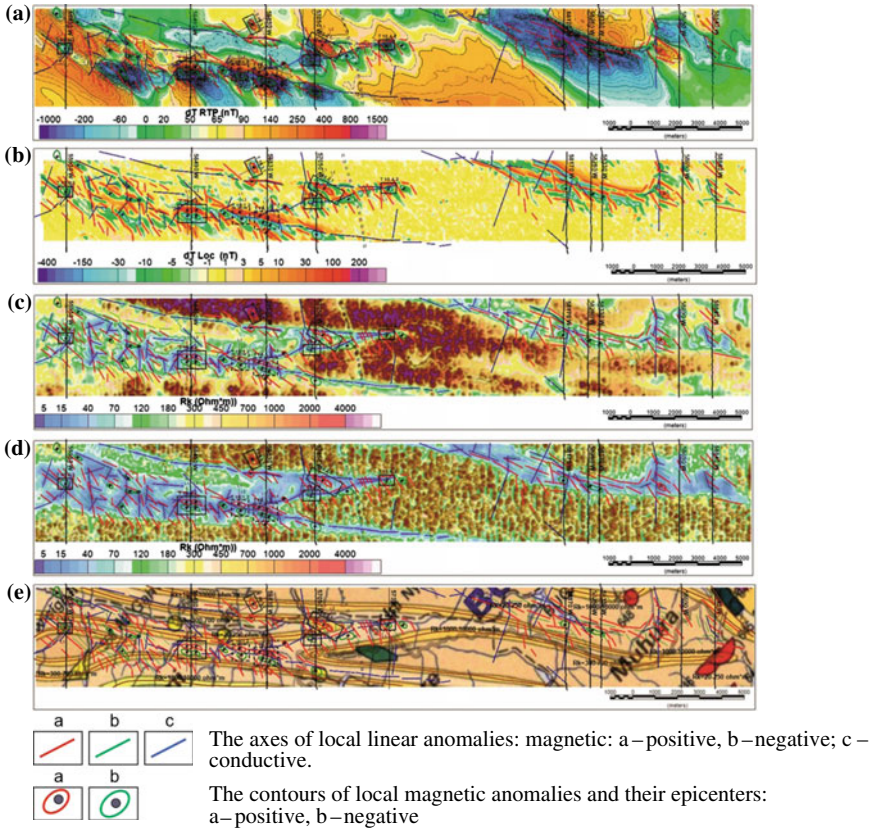

Fig. 46.3 Example of infill survey at a scale of 1: 10,000: **a** magnetic field reduced to the pole; **b** local component of the anomaly magnetic field; **c** apparent resistivity map at a gate of 5 μs; **d** map of apparent resistances for a window of 1000 μs; **e** fragment of the geological map

All picked up magnetic anomalies are situated in linear zones. They are accompanied by an increased density of lineaments which were picked up along the axes of linear magnetic and electrical anomalies, as well as relief forms.

Apparent resistivity maps show rocks with anomalously high resistivity (1000–10,000 Ω m). They correspond to quartzites. Rocks with medium resistivity are typical for metamorphic shales. Anomalously conductive zone (20–250 Ω m) with substantial vertical thickness (more than 100 m) is very interesting. Its conductivity sharply increases with depth. There is a magnetic anomaly in that zone. Such low-resistivity zones do not always coincide with depressive forms of relief and are most likely associated with the intrusion of igneous rocks of a younger age. Within the infill area, low-resistivity anomalies with limited vertical thickness (up to 30 m) are also fixed. We associate them with the weathering crust.

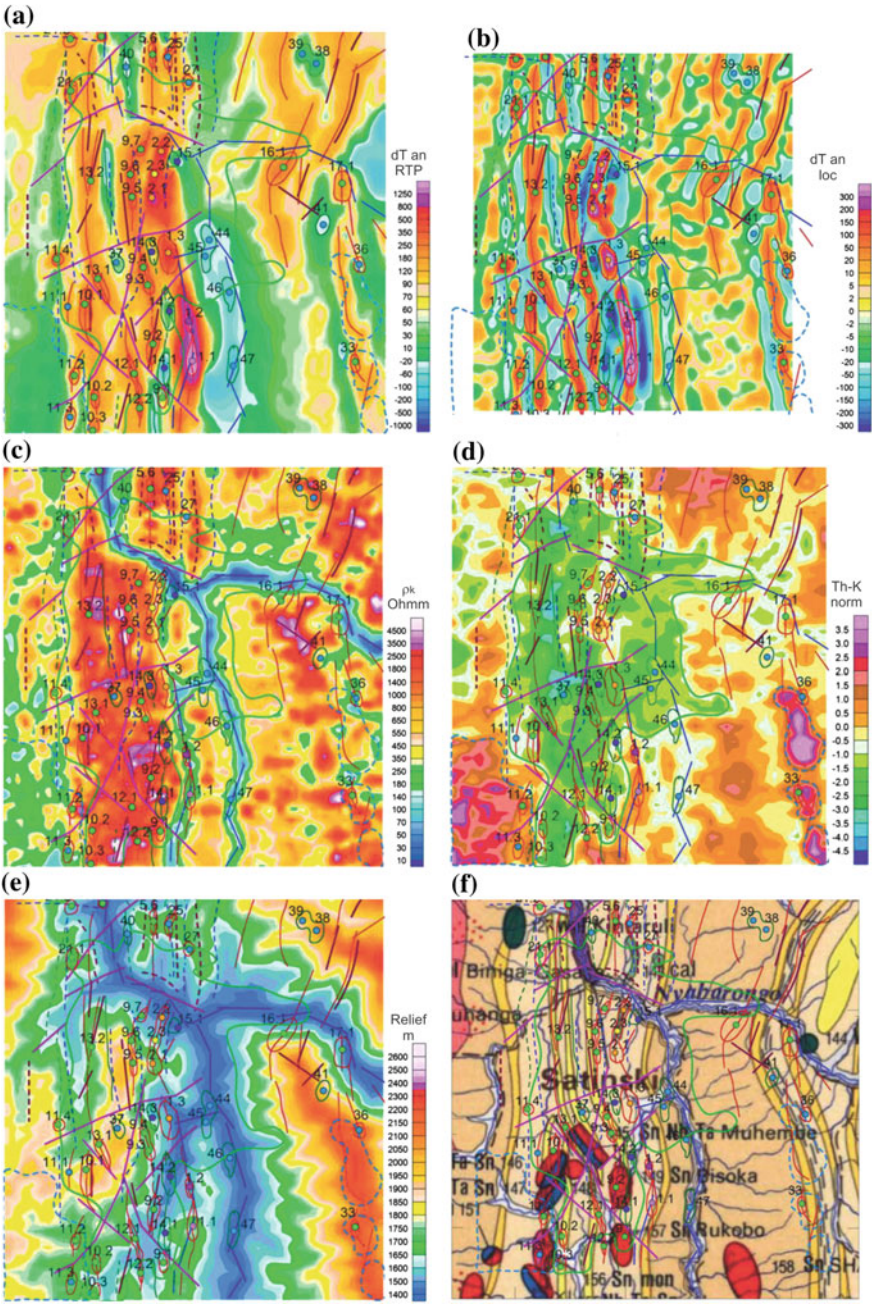

Fig. 46.4 Results of airborne geophysical survey at a scale of 1: 25,000. **a** an anomaly magnetic field map reduced to the pole; **b** local part of anomaly magnetic field map; **c** apparent resistivity map for depth interval 0–30 m; **d** a map of the difference of the normalized concentrations of Th-K; **e** a map of the digital elevation model; **f** a fragment of the geological map

Results of Airborne Geophysical Survey at a Scale of 1:25,000

The area (Fig. 46.4) is situated in the field of shale development and granite-gneiss rock formation. The basic tectonic faults have a meridional strike, and orthogonal to them—sublatitudinal. This is also emphasized by modern hydro-network and relief. A large number of ore occurrences of cassiterite, wolframite and coltan are concentrated to the south of the infill block.

We have identified a number of intense anomalous objects in various geophysical fields. They are not reflected in the modern geological map. They represent a significant search interest.

Intrusions of ore pegmatites are distinguished by weakly-medium intensive (20–100 nT) isometric magnetic anomalies with dimensions of 300–500 m. It has been established on known objects. Pegmatite bodies are usually characterized by high resistivity of 900–2000 Ω m. Unfortunately, they do not create contrast anomalies with host rocks.

It is interesting that the revealed magnetic anomalies have different radiogeochemical specialization. There are individual objects with a dominant potassium or thorium, as well as a general increase in radioactivity.

A number of intense linear magnetic anomalies of the meridional orientation are revealed. They are accompanied by linear conduction zones. Probably, magnetic anomalies are associated with dikes of amphibolites, and conduction zones with sulphide mineralization. These bodies are absent on the geological map and represent a certain search interest.

Conclusions

Survey at a scale of 1:50,000 allowed:

- to significantly clarify information about the geological structure of the territory;
- to classify granite massifs;
- to pick up linear and isometric intrusions of the basic and ultrabasic composition;
- to pick up laterite weathering crusts of bauxite and (or) rare-earth types.

Different geochemical specialization of young volcanogenic formations in the north-west of the territory was revealed. 35 perspective targets perspective for various minerals have been identified.

Infill survey at a scale of 1:10,000–1:25,000 allowed to identify contours, shape, size and position of the epicenters of local geophysical anomalies and their radiogeochemical specialization. Local anomalies are also highlighted which associated with intrusions of mafic rocks, promising for sulfide, copper-nickel mineralization.

Infill survey results allow to reduce volume of ground geophysical and drilling operations.

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