Nigeria's Nationwide High-resolution Airborne Geophysical Surveys

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Summary

Nigeria is nearing completion of an ambitious program for nationwide airborne geophysical coverage and interpretation, providing significant positive contributions to both the minerals and oil exploration sectors. It forms part of a broader strategy to stimulate investment through the Sustainable Management for Mineral Resources Project (SMMRP).

Introduction

Airborne geophysics, particularly aeromagnetic and gamma-ray spectrometer (radiometric) surveys, form a critical component of geological mapping and mineral resource inventory programs in many African countries (Reford et al, 2009). In the 60's and 70's, regional aeromagnetic surveys were fairly widespread over much of the continent, in both sedimentary and hard rock terrains (Barritt, 1993). In the 80's and 90's, higher resolution surveys, incorporating radiometrics, were carried out in certain countries, particularly in southern Africa. In the last decade, a number of national initiatives (e.g. Madagascar, Mozambique, Namibia, Morocco, Mauritania, Uganda, Ghana) have seen the high-resolution geophysical coverage greatly improve. The surveys form part of larger initiatives to improve the geological knowledge of a country or region, with the ultimate objectives to increase mineral investment and develop a sustainable mining industry. These geoscience programs are typically accompanied by reforms in the mining law to promote such investment. They contribute to tectonic reconstruction, groundwater and environmental applications, and petroleum exploration, all of which ultimately assist societal development (Reeves, 2005). International funding agencies such as the World Bank, European Community and African Development Bank have seen the value in such programs, and ensure that airborne geophysics receive a large share of project budgets. In jurisdictions throughout the world, it has been demonstrated that high-quality geophysical coverage leads directly to increased and more focused exploration. A trend in the last few years has been the inclusion of an airborne electromagnetic follow-up component to the airborne geophysical program.

Nigeria has gained near nationwide airborne geophysical coverage, through high resolution horizontal gradiometer magnetic and radiometric surveys, flown at 500 m line spacing and 80 m mean terrain clearance and totaling almost 2 million line-km.

The surveys were flown (Figure 1) as follows:

2003	Pilot Project	Ogun State
2005-07	Phase 1	Blocks A+C and B
2007-09	Phase 2	Blocks D1, D2, D3 and D4

All surveys were carried out by Fugro Airborne Surveys on behalf of the Nigerian Geological Survey Agency. Phase 2 forms part of the World Bank-supported SMMRP. As part of Phase 1, time-domain electromagnetic surveys were flown at 200 m line spacing in 2008-09 with the Tempest system over three blocks, totaling 24,000 line-km. Additional TDEM surveys are planned for Phase 2. To complete the airborne coverage, the Niger Delta block will be flown in 2010 with magnetics at 1 km line spacing. In addition, a quarter of the block will incorporate airborne gravity.

The data acquisition required as many as seven aircraft at once. This, coupled with the multi-year and multi-season campaigns, required innovative approaches for survey planning, instrument calibration, data compilation and grid merging.

Processing and Modelling

The resolution of the magnetic data, incorporating the measured horizontal gradients, affords a range of processes that highlight the high-frequency responses. These are useful for accurately locating contacts, tracing horizons and delineating structure. Vertical derivatives, horizontal gradients, the analytic signal amplitude and tilt derivative have all played a role in the interpretation, and contributed to semi-automated techniques for tracing contacts and anomaly peaks. The magnetic inclination for the country varies from 7°N to 13°S, which is problematic for computation of a clean grid of the pole-reduced magnetic field. Consequently, a nationwide grid of the reduced-to-equator magnetic field was prepared, incorporating the variations in the magnetic inclination and declination.

Figure 2 shows the first iteration of the depth-to-magnetic sources from northeast Nigeria, prepared using Source Parameter Imaging™ (Thurston and Smith, 1997). For the most part, this image represents the depth-to-magnetic basement. However, in some parts of the basins, intra-sedimentary sources including shallow volcanics interfere with the basement signal and are not easily separated by filtering. The image shown here incorporates a 15 km low-pass filter, to readily recognize the major geological elements. The final iteration of the depth-to-magnetic-sources will incorporate the interpreted structure in a "grid with barriers" technique, so that vertical and lateral offsets

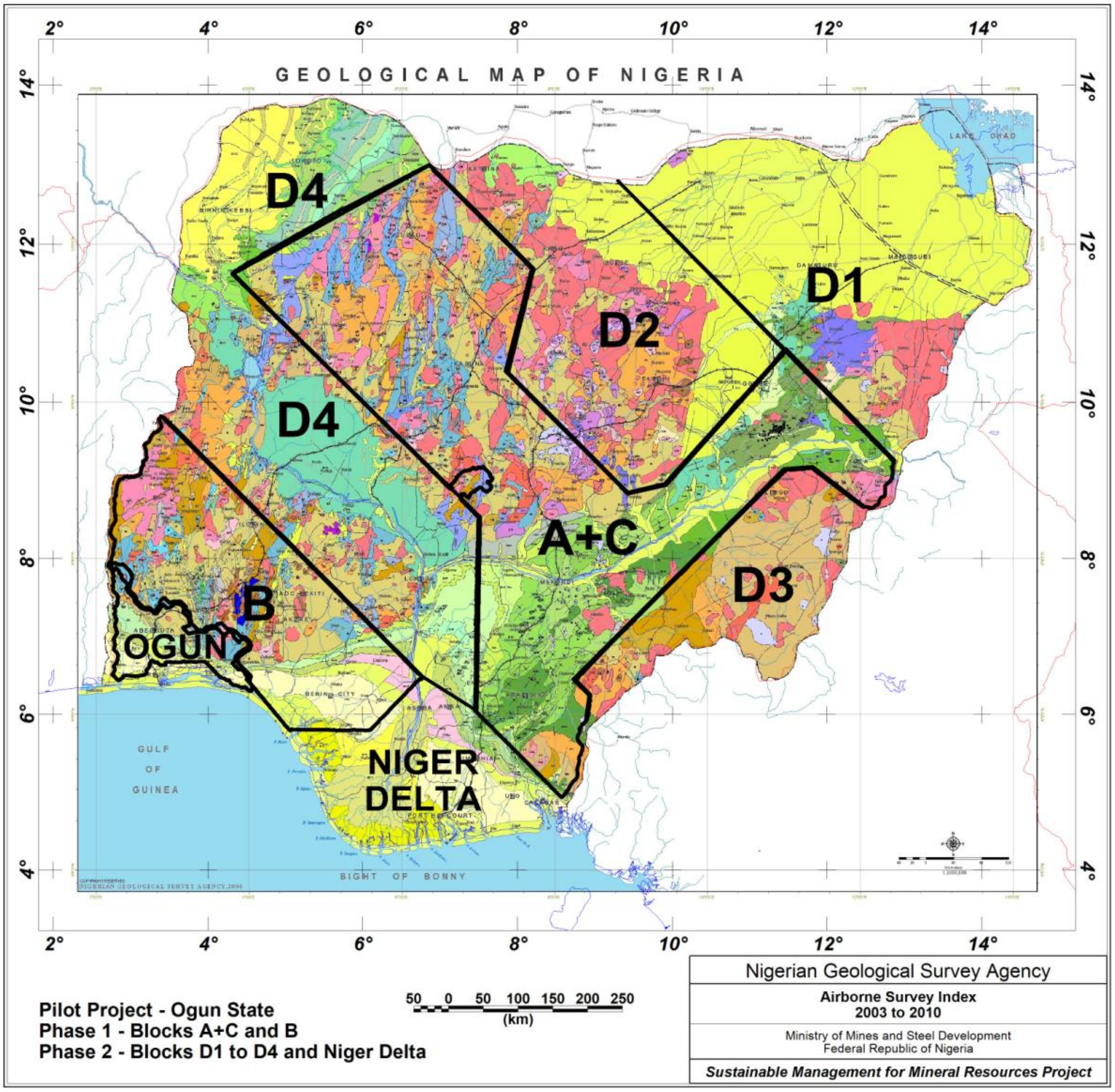

Figure 1: Index map of the airborne survey blocks flown between 2003 and 2010 for the Nigerian Geological Survey Agency (electromagnetic surveys not shown). In the background is the Geological Map of Nigeria (NGSA, 2006).

are sharply defined in the depth map. In this part of Nigeria, the map highlights the deepest parts of the basins, localized sub-basins and large areas of shallow basement (e.g. western part of the Bornu Basin). It provides confirmation that the Cretaceous rifting that formed the Benue Trough extended well to the northeast and contributed to the formation of the Chad Basin as well. The depth information derived from the magnetic data has important implications in determining areas of prospectivity for both minerals and oil & gas deposits.

Interpretation

The survey data are currently being interpreted by Fugro Airborne Surveys (Phase 1) and by Paterson, Grant & Watson Limited (Phase 2). PGW has prepared nationwide merged grids, and will integrate the two interpretations. The data have proven extremely valuable for:

- Depth-to-source mapping of the inland sedimentary basins, delineating areas of interest for oil & gas exploration, as well as mapping shallow basement with extensions of known mineral belts

- Determining signatures of known occurrences such as gold deposits, lead-zinc deposits and kimberlite pipes
- Mineral potential mapping
- Characterization of the "Older" and "Younger" granites
- Mapping intrasedimentary igneous sources, sedimentary horizons and structure
- The complementary mapping capabilities of radiometric and electromagnetic data in both hard rock terrains and exposed sediments (e.g. Benue Trough).

The interpretation is being prepared at the 1:250,000 scale on Nigeria's standard map layout, with a nationwide synoptic interpretation at the 1:1 million scale. Each map sheet incorporates three interpretation products:

- Litho-structural interpretation – basement, intrasedimentary and sedimentary units evident in the geophysical data together with structure
- Geophysical interpretation – geophysical elements and character
- Regolith interpretation – surficial material and geomorphology.

Each map sheet will be accompanied by a report, cross-section and series of images incorporating magnetic, radiometric, terrain and Landsat data. The interpretation and geophysical imagery will be delivered in a GIS for digital archiving and interrogation.

Figure 3 provides a snapshot of the geophysical responses over the central part of the Benue Trough, and the adjacent exposed basement rocks to the northwest (Jos Plateau) and southeast (Adamawa Sardauna Massif). A variety of sources are evident, including granites, shallow volcanics, sedimentary horizons and deep basement.

Conclusions

The new high-resolution airborne survey coverage in Nigeria provides a wealth of information that will illuminate geological thinking for decades to come. It constitutes a vast improvement over the previous generation of aeromagnetic data from the 1970's, and will contribute to the mapping and unraveling of Nigeria's geologic history. It forms a key component of the country's strategy to encourage investment in the minerals sector and broaden oil & gas exploration beyond the Niger Delta. The high resolution and quality of the data, coupled with the comprehensive interpretations now underway, are being described as a "national treasure"

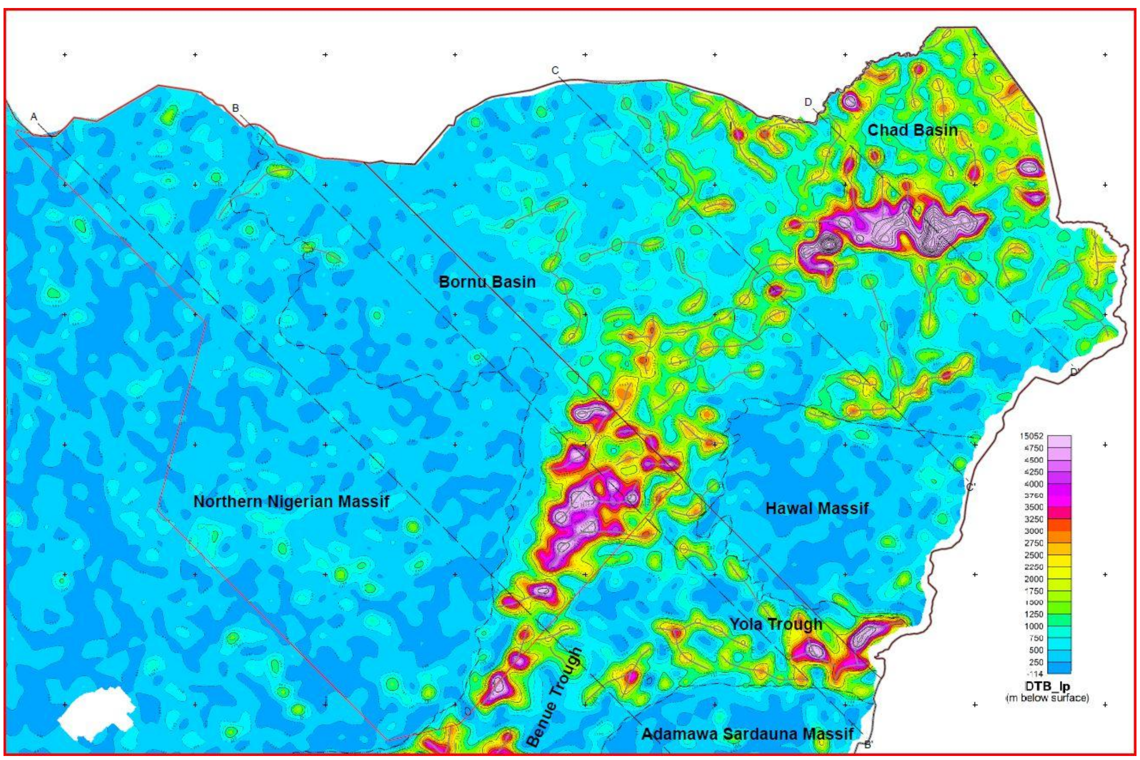

Figure 2: Depth-to-magnetic source map for northeast Nigeria.

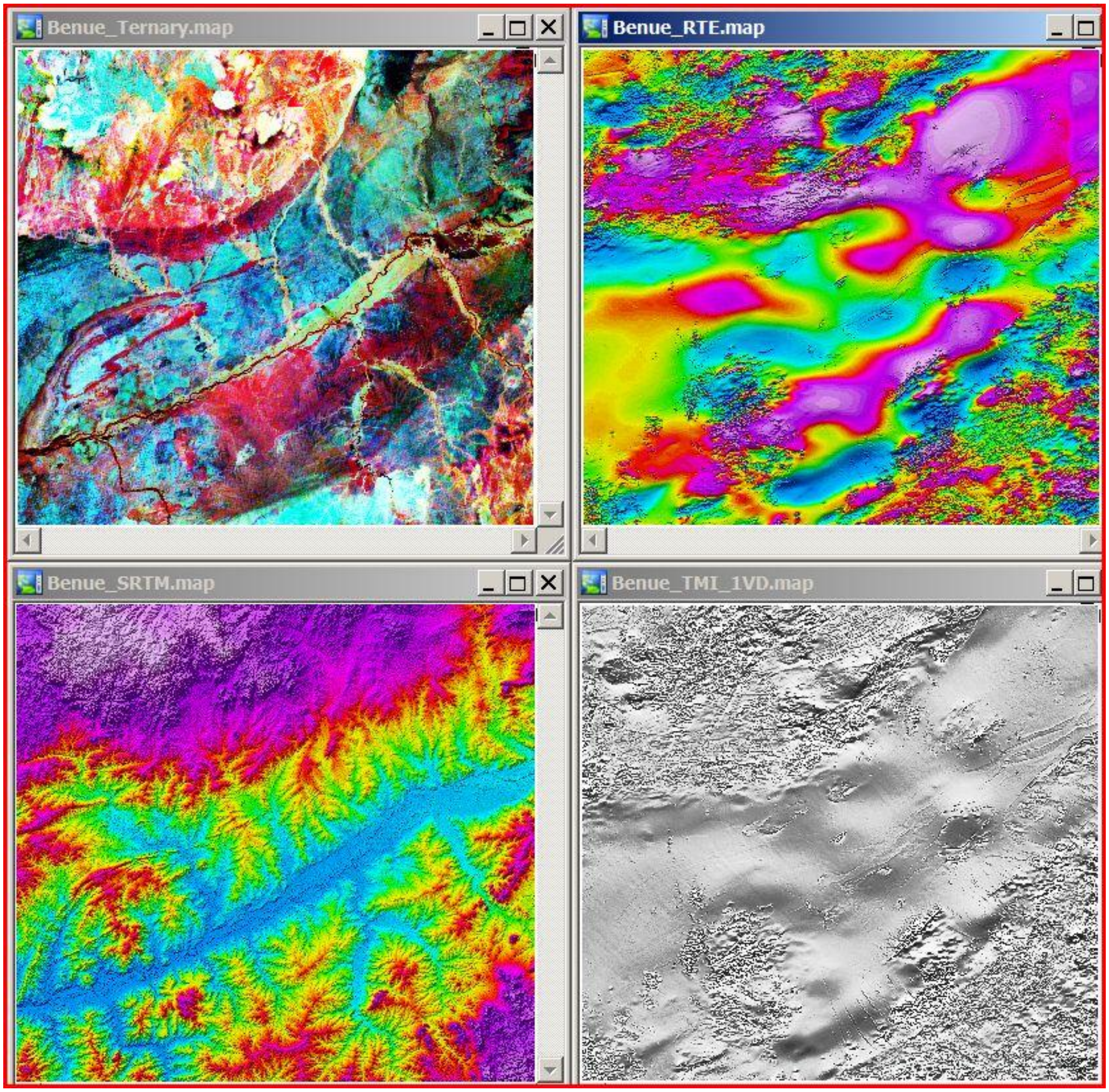

Figure 3: Geophysical responses over the central Benue Trough (250 km x 230 km):
Top left – Ternary image of radiometric data (RGB = K-Th-U)
Top right – Reduced-to-equator magnetic field
Bottom left – SRTM digital elevation model
Bottom right – First vertical derivative of the total magnetic field.

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EDITED REFERENCES

Note: This reference list is a copy-edited version of the reference list submitted by the author. Reference lists for the 2010 SEG Technical Program Expanded Abstracts have been copy edited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

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