Botswana's Nationwide Tie Line Survey and New Magnetic Compilation

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ABSTRACT

In 2010-2011, the Department of Geological Survey (DGS) acquired a new airborne magnetic Tie Line Survey over Botswana. It was flown on a 10 km by 50 km grid and totalled 70,176 line-km of data. The control lines were flown in single segments over a short time period to provide the most accurate levelled data set. Strategic deployment of magnetic base stations facilitated diurnal correction using a distance-weighting scheme.

After compilation of the Tie Line Survey, some 70 higher resolution magnetic surveys were recompiled, most acquired by DGS supplemented by some from industry. They were then levelled to the magnetic datum provided by the Tie Line Survey, from which a new nationwide grid of total magnetic intensity at 50 m resolution was prepared. These data and enhanced nationwide magnetic grids were released by DGS in 2012.

Key words: tie line, magnetic, compilation, Botswana

INTRODUCTION

The Department of Geological Survey (DGS), over a period spanning the late eighties through to early 2000, acquired high-resolution aeromagnetic surveys over most of the country except for the southwest (Nossop - Ncojane Basin) area. These surveys were mostly conducted at survey specifications of 250 m line spacing and 80 m mean terrain clearance. The line direction for each survey block depended on the dominant strike of the geology. Additional coverage of aeromagnetic survey data was provided by private exploration companies, in places at higher resolution,

The compilation of the above individual, separate aeromagnetic surveys into one seamless magnetic grid and the long-term endeavour to produce a country-wide high resolution magnetic map prompted DGS to conduct a fixed-wing tie line magnetic survey over the entire country and then merge all existing high resolution aeromagnetic data. The country wide Tie Line Survey serves as a reference datum for past and for future surveys and preserves a full magnetic spectrum magnetic anomaly map of Botswana. Most institutions have opted for the use of satellite magnetic data and/or occasional/sparse low altitude magnetic traverses in an attempt to define a datum for merging multiple surveys to generate a single seamless compilation. However, near-earth satellite magnetic data regrettably do not have the spatial resolution and consequently, the long wavelength components of the magnetic anomaly map still suffer from artefacts.

The Tie Line Survey was conducted, with the following survey parameters:

- Traverse line spacing – 10 km
- Traverse line direction – grid east-west
- Control line spacing – 50 km
- Control line direction – grid north-south
- Ground clearance – 80 m
- Grid Projection – UTM 35S, WGS 84.

The historical high resolution survey data were subjected to a sequence of processes prior to matching to the tie line survey grid and then merging into a virtually seamless nationwide total magnetic intensity (TMI) grid at 50 m grid cell size.

As a result, DGS has realized its first objective of constructing a nationwide magnetic datum through the

acquisition of a state-of-the-art tie line survey, incorporating careful compilation of the data to account for variations in the geomagnetic field over the course of the survey. It has also realized its second objective of preparing a new nationwide grid of the total magnetic field and a series of filtered products, by levelling its high-resolution surveys to the tie line survey and merging them. The net result is a new total magnetic field grid for Botswana that is regionally consistent across the entire country and provides the best available representation of the magnetic field. It provides new insights to the DGS and industry for exploration and geological mapping in the following ways:

- Systematic mapping of groundwater related structures and potential freshwater aquifers,
- Production of high quality geological maps,
- Providing incentives for mineral exploration by the private sector and
- Generally assist in the long term development of the mineral resources of Botswana.

TIE LINE SURVEY

The Tie Line Survey was carried out between late September 2010 and mid-March 2011, employing two aircraft: an Air Tractor 402A crop duster (single engine turbine) and an Islander BN-2T (twin engine turbine) with stinger-mounted Geometrics G823-A cesium vapour magnetometers. A total of 70,176 line-km of data were acquired.

The country was divided into thirteen sectors to acquire the traverse line data, for logistical reason. Some sectors broke the traverse lines into two or three overlapping segments. Each sector employed strategically located magnetic base stations for accurate monitoring and correction of geomagnetic diurnal variations. The 19 control lines were acquired during a single period (March 2 to 18, 2011) and were not broken into segments. Four base stations at three locations were deployed for most of these flights. Seven locations in all were utilized as the control line acquisition progressed across the country.

Industry-standard quality control, calibration and correction of the data were applied in the field. Additional post-processing was implemented, particularly to determine the diurnal corrections. The data from the multiple base station locations were interpolated to each sample location using a distance-weighted averaging scheme. The overlapping traverse lines required slight base level shifts to construct continuous lines (Figure 1). After IGRF correction, the traverse and control lines were iteratively levelled to produce the final channel of TMI data, which was then gridded (Figure 2).

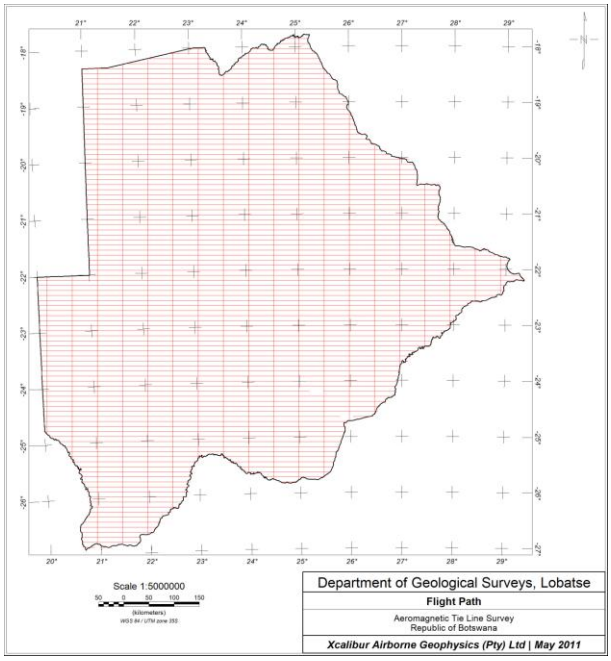

Figure 1. Flight path for Botswana Tie Line Survey.

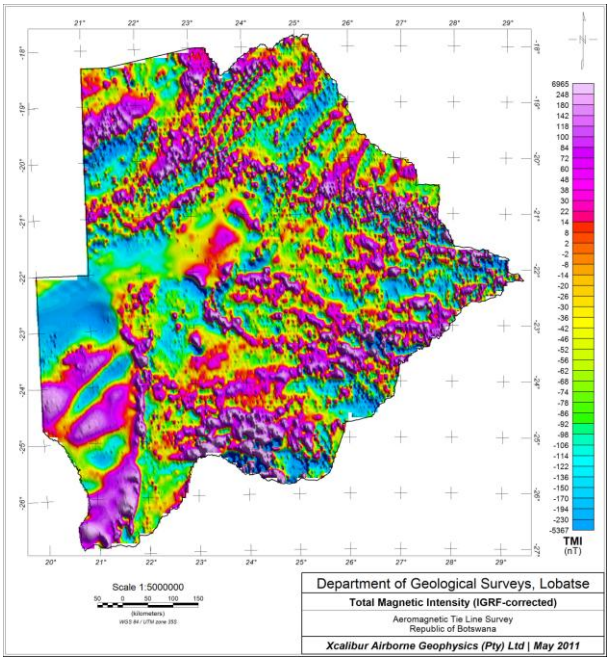

Figure 2. Total magnetic intensity after IGRF correction for the Botswana Tie Line Survey.

MAGNETIC COMPILATION

The new compilation of the nationwide magnetic grid incorporated 70 individual data sets. Figure 3 shows 52 separate surveys incorporated in the compilation. In addition, 18 smaller surveys were compiled in the Orapa area. Prior to merging, each data set was inspected for level noise and other types of errors (e.g. positioning, IGRF correction). Most required some kind of clean-up to meet current standards. Profile data were available for the majority of surveys and were used to prepare new grids at survey resolution.

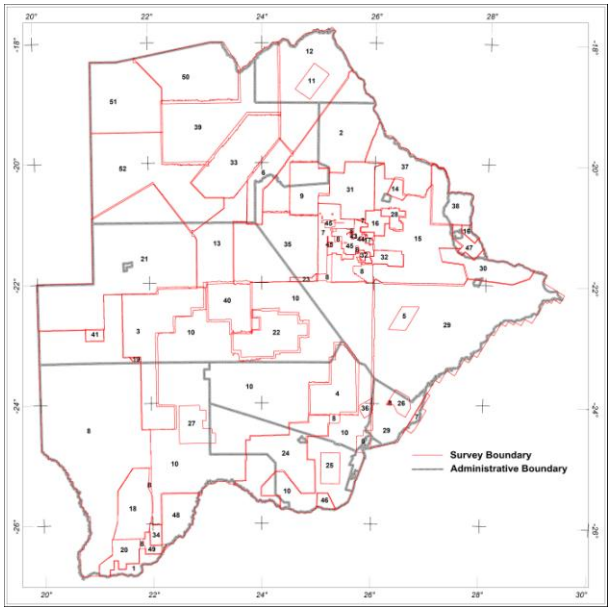

Figure 3. Index of merged high-resolution surveys.

The levelling of the magnetic survey grids to the Tie Line Survey followed methodology modified after Reford et al. (1990). The difference between the survey grid and tie line grid (i.e. the magnetic datum) was computed and the iteratively filtered twice in both the north-south and east-west directions to determine a long wavelength correction. The filter wavelengths chosen are mainly dependent on survey dimensions. Where line data were available, the correction was sampled back to the profile database and a new corrected grid prepared.

For the final merge, overlapping grids were trimmed to preserve the data from higher resolution surveys. The magnetic datum levelling process described above inherently minimizes differences between surveys so that boundary corrections are minimal. The Geosoft "suture" option was used to prepare the nationwide merge at 50 m cell size. Figure 4 shows a comparison between the previous merge, the Tie Line Survey datum and the new merge. The longer wavelengths in the new merge match the Tie Line Survey very well. The new merge also incorporates data sets that were not incorporated in the previous merge. From the TMI grid, various enhanced grids were prepared, including the first and second vertical derivatives, the horizontal derivatives in X and Y, the tilt angle and the analytic signal amplitude.

All corrections applied to the individual surveys, and the filter parameters utilized in the datum levelling process, are fully documented in Xcalibur (2012). A complete review of the methodologies employed from data acquisition through to merging is also provided.

Maus et al. (2012) conducted a comparison of different vintages of the nationwide magnetic compilations of the United States and of Australia, as well as the CHAMP satellite magnetic field model MF7. The newest compilation for the United States incorporated levelling to the older NURE tie line data whereas the most recent Australian compilation incorporated a recent tie line survey (Milligan et al., 2009). One comparison was done by plotting the radially averaged power spectrum of each data set to determine the data content at various wavelengths. A similar comparison is made here in Figure 5 for the following magnetic grids:

- MF7 over Botswana and surrounding region
- MF7 over Botswana only
- Tie Line Survey TMI
- Previous merged TMI
- New merged TMI.

The satellite grids were sampled at a cell size of 11,200 m, the Tie Line Survey at a cell size of 1,000 m and the merged grids at a cell size of 50 m. The power spectra show the following:

- The longest wavelengths in the satellite model are degraded when the grid is windowed to cover Botswana only.
- Both the satellite models and the Tie Line Survey are noisy at shorter wavelengths.
- The merged grids show little noise across all wavelengths.
- The new merge shows an improvement in the 300 m to 1000 m wavelength, where a notch appears in the old merge.

The satellite model was not used to apply a long wavelength correction to the Tie Line Survey or new merge since the wavelengths out to 500 km (i.e. roughly half the north-south and east-west dimensions of Botswana) were fully sampled by the Tie Line Survey. This was confirmed by inspection of filtered grids (400 km low-pass Gaussian), where the tie line survey TMI upward continued 5 km showed greater spatial resolution and somewhat higher anomaly amplitudes than model MF7 (Xcalibur, 2012).

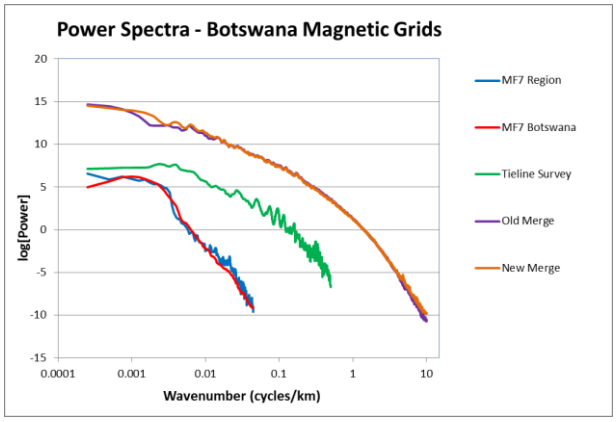

Figure 5. Comparison of power spectra for TMI grids of satellite magnetic data (CHAMP model MF7), the Tie Line Survey, and previous and new merges.

CONCLUSIONS

The nationwide Tie Line Survey of Botswana was acquired in 2011 and published in 2012. It facilitated the seamless levelling of 70 individual datasets into a coherent nationwide grid of total magnetic intensity at 50 m resolution. Careful logistical planning, magnetic base station deployment and data compilation procedures ensured that the Tie Line Survey provided an accurate national magnetic datum for the current and future generations of national magnetic compilations in Botswana.

ACKNOWLEDGMENTS

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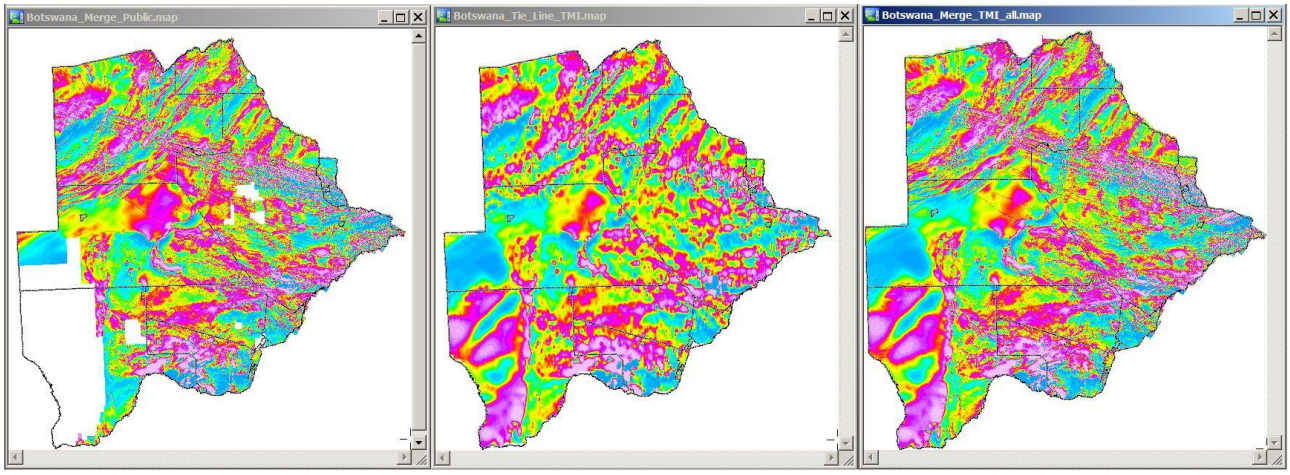

Figure 4. Comparison of previous and new nationwide total magnetic intensity (TMI) merge: Left – Previous merged TMI, Centre – Tie line survey TMI, Right – New merged TMI.