Potential field analysis of the East African Rift in eastern Tanzania – guiding seismic survey planning

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SUMMARY

Recent oil discoveries in the Kenyan Lokichar Basin, along the eastern branch of the East African Rift system, have enhanced the oil and gas potential within the Tanzanian and Kenyan portions of the rift system. A combination of airborne gravity and magnetic surveying was completed over sections of the eastern branch of the East African Rift in eastern Tanzania to investigate the potential for thicker accumulations of Tertiary and Karoo sediments. The objective was to identify prospective basin areas warranting evaluation by seismic surveying. Interpretation and modelling of the regional aeromagnetic data identified major basement fault systems controlling basin formation and provided a qualitative assessment of depth to basement. Density contrasts typically expected for Precambrian basement and Karoo and Tertiary sedimentary sequences were used for forward modelling of the airborne gravity data. This showed the potential for up to 7 km thickness of basin sediments within the rift, and highlighted the possibility of Tertiary sediment within one of the identified sub-basins. Subsequent 2D seismic acquisition has refined the basin geometry, and identified an intra-basin structure of exploration interest.

Key words: East African Rift, magnetics, gravity

INTRODUCTION

The East African Rift (EAR) is an extensive (>1000km), complex onshore, craton-scale rift system within the eastern side of the African continent. It comprises two rift arms, known as the east and west branches. Recent oil discoveries in the Kenyan Lokichar Basin have demonstrated the potential for the EAR to become an important oil producing field (Africa Oil, 2015).

Previous studies by Le Gall et al. (2004) suggested that basin depths of 2 to 8 km are possible through the eastern arm of the EAR in northern Tanzania. They also postulated the potential for 2-3km of post-Karoo sediments within the Kidatu Basin.

This paper discusses the use of magnetic data to assist exploration in several rift segments within the eastern branch.

As a relatively unexplored oil province, there is limited information regarding the physical properties and sub-surface geometry of the rift basins. Coupled with the difficult terrain and land access, this presents a logistical and financial dilemma for early stage exploration focussed on seismic surveying. Potential field methods offer a cost effective alternative to identify favourable basement topography and basin development at a semi-regional scale, but lack the resolution needed to accurately map basin geometry and assess for potential trap sites at the prospect scale. Thus potential fields provide a means of focusing on prospective plays and designing suitable seismic programmes to evaluate these.

Our initial step – and the recommended approach where possible – was to use public domain magnetic data to identify the rifts and select deeper basin areas within that. Proprietary airborne magnetic and gravity surveys were then flown over three interpreted intra-rift basins (Figure 1, Table 1). Together with the regional legacy aeromagnetic data, these new surveys provided the basic datasets for the potential field analysis, which included the generation of a qualitative structural interpretation, quantitative depth-to-basement estimates, and geologically constrained 2.5D forward modelling. These tools were used to delineate rift margins and intra-rift faulting, assess and estimate sediment thickness within the basins and attempt to discriminate between Karoo and Tertiary rifting and sedimentation phases. The results were subsequently used to focus seismic survey planning.

The subsequently acquired 2D seismic data has confirmed and refined the basin geometry of the Kilombero Basin, and has identified an intra-basin structure of exploration interest.

For simplicity, this paper will focus on the Kilombero basin, however the same methodology was also applied to the Kilosa and Kidatu basins.

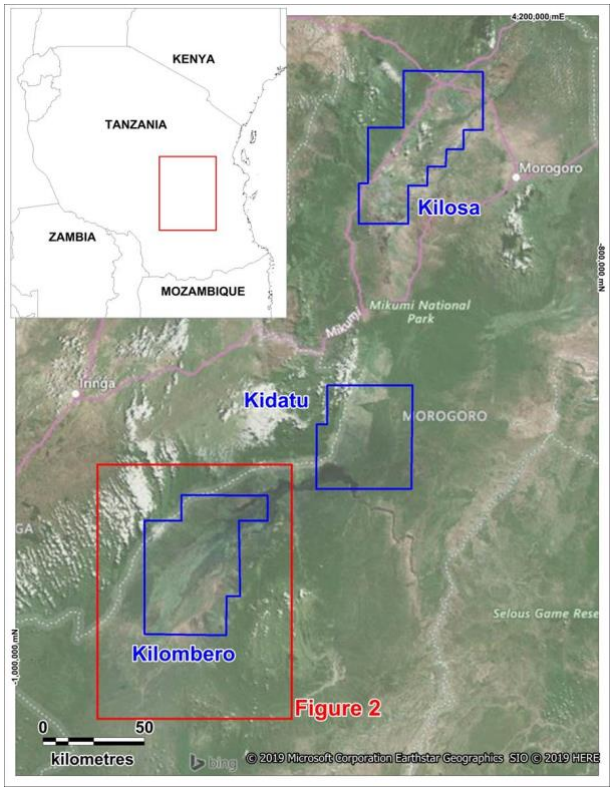

Figure 1. Location map of the newly acquired airborne surveys over the Kilosa, Kidatu and Kilombero basins.

STRUCTURAL INTERPRETATION

A regional structural interpretation of an area covering the Kilosa, Kidatu and Kilombero basins was performed using legacy aeromagnetic data (Figure 2). This generated a robust, working structural framework of the Palaeoproterozoic basement geology across the wider Kilosa-Kilombero area. This highlighted much more structural complexity and history within and around the rift system than could be gleaned from assessing the present landscape using satellite spectral and topographic data, which mainly reflect Tertiary-Recent activity.

AUTOMATED DEPTH-TO-BASEMENT

Naudy (Naudy, 1971) and Euler-based (Thompson, 1971; FitzGerald, 2004) depth estimation methods were used as first pass tools to examine the underlying basement topography of the survey areas. The Euler method did not produce coherent results for either the magnetic or gravity datasets. In contrast, the Naudy analysis produced coherent results (Figure 3) which are generally consistent with the positions of the rift faults, particularly those with significant vertical throw, as previously defined by the qualitative structural interpretation of the magnetics. Additionally, the depths resolved showed overall agreement with the sediment thicknesses estimated by Le Gall et al. (2004).

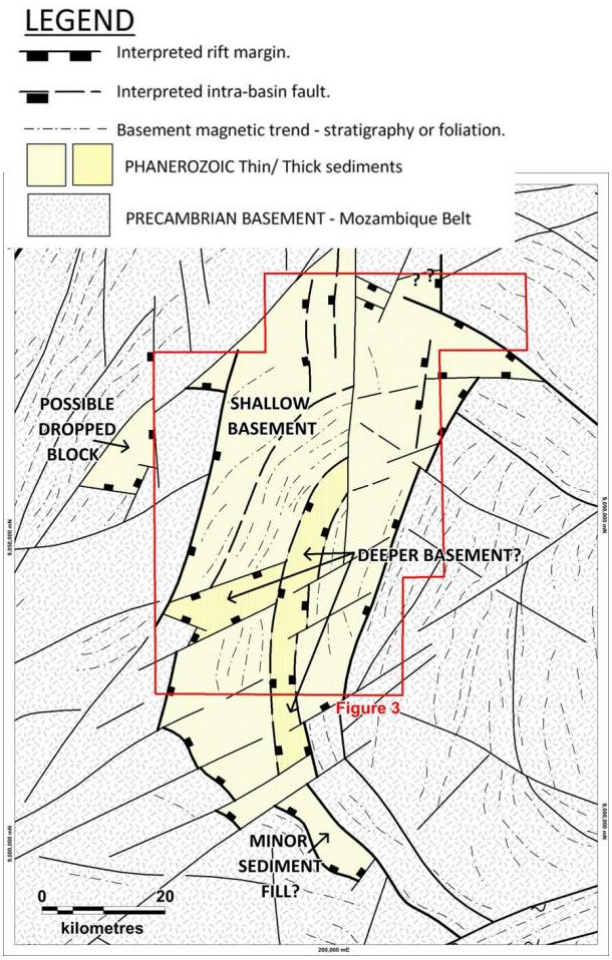

Figure 2. Structural interpretation of the Kilombero Basin.

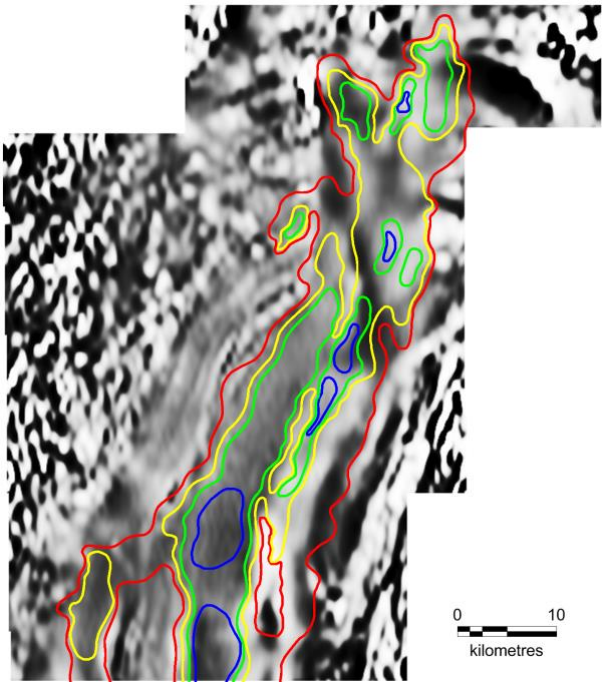

Figure 3. Depth contours derived from the Naudy analysis of the Kilombero aeromagnetic data, over RTP1VD image. Red = 1km, Yellow = 2km, Green = 3km, Blue = 4km.

2.5D FORWARD MODELLING

2.5D forward modelling of the gravity data was used to evaluate the density contrasts and geometries required to match the observed gravity data. A basement-sediment density contrast of 0.15 ±0.05 g/cm^3 was used for Karoo sediments, while the younger, less consolidated Tertiary sediments were assumed to have a contrast of 0.3 ±0.05 g/cm^3. Using these density values, the modelling generally produced a good fit to the observed data, and modelled depths were also comparable in most places to the depths obtained from the Naudy analysis. Modelling of the Kilosa and Kidatu data tended to require relatively low basement-sediment density contrasts, which is considered more likely to reflect dominantly Karoo sediments within these basins. At Kilombero, a higher density contrast of 0.3 g/cm3 was required to best fit the observed data, consistent with the presence of predominantly Tertiary sediment within the basin.

It should be noted that due to the lack of physical property data, the density contrasts used are not well constrained, but are considered the best estimate based on the information available at the time.

2D SEISMIC RESULTS

2D seismic has been shot over a section of the Kilombero Basin. The higher resolution of seismic data maps the rift-basin geometries far better than was possible using the potential field methods, but, broadly speaking the location of the rift shoulders and basin geometry outlined by the integrated magnetic and gravity analysis are consistent with the seismic data. Additionally, the seismic surveys have highlighted an intra-basin feature of exploration interest.

CONCLUSIONS

The analysis and modelling of aeromagnetic and airborne gravity surveys flown over the Kilombero Rift has successfully identified intra-rift basins of sufficient depth for generation of oil from suitable source rocks. The depths generated by the Naudy automated method applied to the magnetic data are broadly consistent with the seismic interpretation. Forward modelling of the gravity data over the Kilombero Basin required a density contrast of 0.3 g/cm^3, which strongly suggests the presence of lighter, less consolidated and more prospective Tertiary sediments in this section of the rift. Subsequent 2D seismic data acquired in the Kilombero basin has identified a prospective intra-basin structure that is the current focus of exploration in the Kilombero region.

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REFERENCES

Africa Oil, 2015. Corporate presentation accessed 21 March 2019. https://www.africaoilcorp.com/i/pdf/Presentation-November2015.pdf

FitzGerald, D., Reid, A., McInerney, P., 2004, New discrimination techniques for Euler deconvolution: Computers & Geosciences, 30, 461-469.

Le Gall, B., Gernigon, L., Rolet, J., Ebinger, C., Gloaguen, R., Nilsen, O., Dypvik, H., Deffontaines, B., Mruma, A., 2004, Neogene-Holocene rift propagation in central Tanzania: Morphostructural and aeromagnetic evidence from the Kilombero area: Geological Society of America Bulletin, 116, 490-510.

Naudy, H., 1971, Automatic determination of depth on aeromagnetic profiles: Geophysics, 36, 717-722.

Thompson, D.T., 1982, EULDPH: a new technique for making computer-assisted depth estimates from magnetic data: Geophysics, 47, 31-37.

Table 1. Summary of airborne magnetic and gravity survey specifications

Survey Block	Line Spacing (m) (gravity / magnetics)	Line Direction	Sensor Height (m AGL) (gravity / magnetics)	Instrumentation (gravity / magnetics)
Kilosa	2,000 / 1,000	090-270	515 / 94	GT-1A / Scintrex CS3
Kidatu	2,000 / 1,000	090-270	668 / 48	GT-1A / Scintrex CS3
Kilombero	2,000 / 1,000	090-270	714 / 46	GT-1A / Scintrex CS3