

# Geo-Spatial Mapping of the Northern Bushveld Rustenburg Layered Suite (RLS) in South Africa

O. A. Bamisaiye<sup>1\*</sup>, P. G. Eriksson<sup>1</sup>, J. L. Van Rooy<sup>1</sup>, H. M. Brynard<sup>2</sup>, S. Foya<sup>2</sup>

<sup>1</sup>Department of Geology, University of Pretoria, Pretoria, South Africa

<sup>2</sup>Council for Geosciences, Pretoria, South Africa

Email: \*adunseyi@gmail.com

Received 5 November 2015; accepted 27 May 2016; published 30 May 2016

Copyright © 2016 by authors and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

---

## Abstract

The focus of this paper is on determination of the geometry and stratigraphic contact pattern of the Rustenburg Layered Suite (RLS) in the Northern Bushveld Complex area using available borehole data and trend surface analysis technique. This technique was used to analyse over one hundred borehole log data in the Northern Bushveld Complex in order to describe the geometric pattern and trends of the RLS rocks. The results demonstrate the usefulness of this technique in identifying structural features. Regional trends of each of the stratigraphic units reveal the presence of regional structures that were not obvious at the surface. This first part of the paper focused on the Northern Bushveld Complex, while the second and the third part focused on the eastern and western Bushveld limbs respectively.

## Keywords

Northern Bushveld Complex, Rustenburg Layered Suite (RLS), Regional Trends, Residual Structures, Igneous Layering, Trend Surface Analysis

---

## 1. Introduction

The Rustenburg Layered Suite (RLS) form laterally continues layers that can be correlated across the various limbs of the Bushveld Igneous Complex. Despite years of exploration and research in the Northern Bushveld Complex, some important subsurface features that could be relevant to mineral exploration in the area are still not well understood. Trend surface analysis was used to highlight positive and negative residual domains at the

\*Corresponding author.

**How to cite this paper:** Bamisaiye, O.A., Eriksson, P.G., Van Rooy, J.L., Brynard, H.M. and Foya, S. (2016) Geo-Spatial Mapping of the Northern Bushveld Rustenburg Layered Suite (RLS) in South Africa. *Open Journal of Geology*, 6, 302-313.

<http://dx.doi.org/10.4236/ojg.2016.65026>

subsurface using exploration borehole data obtained from the Council for Geosciences, Pretoria in South Africa. In addition, it also helps to delineate the geometry and structures that are essential for better mineral targeting from the surface down to about 3000 m (based on depth limit of available borehole data).

Trend surface analysis (TSA) is a method for estimating the overall distribution or trend from scattered observation by fitting a surface through a set of (x, y, z) points (*i.e.* the coordinate of each borehole (x, y) and the depth at each stratigraphic contact (z)) [1] [2]. The fitted surface may not pass exactly through the observed or sample points, Least Square regression is used to calculate and control the distance between the measured Z value. The difference is expressed as root mean square, the smaller the root mean square the closer the fit between the measured points and the fitted surface. The effectiveness of this technique in studying subsurface structures was first demonstrated by [3] but has since been employed in different aspects of geology for stratigraphic and structure controlled resource exploration [4]-[11]. This method is widely used in studying the geometry and structural pattern in areas where change in relief pattern between successive stratigraphic units can be related to structural movements [12]-[15]. It also finds application in geophysical data analysis [1].

Trend surface analysis method shows the best result in both regional and local (residual or small-scale) analysis of structural features [7] [9] [13]. [11] introduced an improved method of Trend Surface analysis that allowed for more geological control on local-fit procedure with the option of choosing the number of neighboring points. Recent improvement in computer programming and the availability of some advanced options has helped in exercising certain geologic control in data interpretation. These options include: high fidelity option (which utilizes a recursive algorithm to grid the residual repeatedly in order to ensure significant drop in cumulative error below the threshold), Declustering option (to normalize the presence of clusters which could introduce distortion [16], and logarithmic and power options

The major objective of this paper is to analyse and describe the relation and interaction between trend, residual structure and thickness of stratigraphic units with the aim of distinguishing between pre, syn and post emplacement structures. The study also attempts to find out the mechanisms responsible for localization and the geometry of structures as well as reconstruction of the developmental history of the Rustenburg Layered Suite (RLS). The relationship between the structure in which magma accumulates and thicknesses of the deposit is often inverse for any area that has not been structurally disturbed. Consequently, lowland areas such as trough and basins receive more magma (influx) than structurally positive area, except if the area has been structurally disturbed by later tectonic activities according to [2] [4]-[6].

## 2. Geology

The Northern Bushveld Complex is located in the northern parts of South Africa. Geological map of the Northern Bushveld shown in **Figure 1** illustrates the stratigraphy in the area. The stratigraphy has been grouped into four units *i.e.* Lower Zone, Critical Zone, Main Zone and Upper Zone in order to maintain the same stratigraphic order with the eastern and western Bushveld [17] [18]. The Critical Zone of the Northern Bushveld host the Platreef and it is made up of mainly pyroxenite with mineralization of platinum-group elements (PGE) and associated Ni and Cu [19].

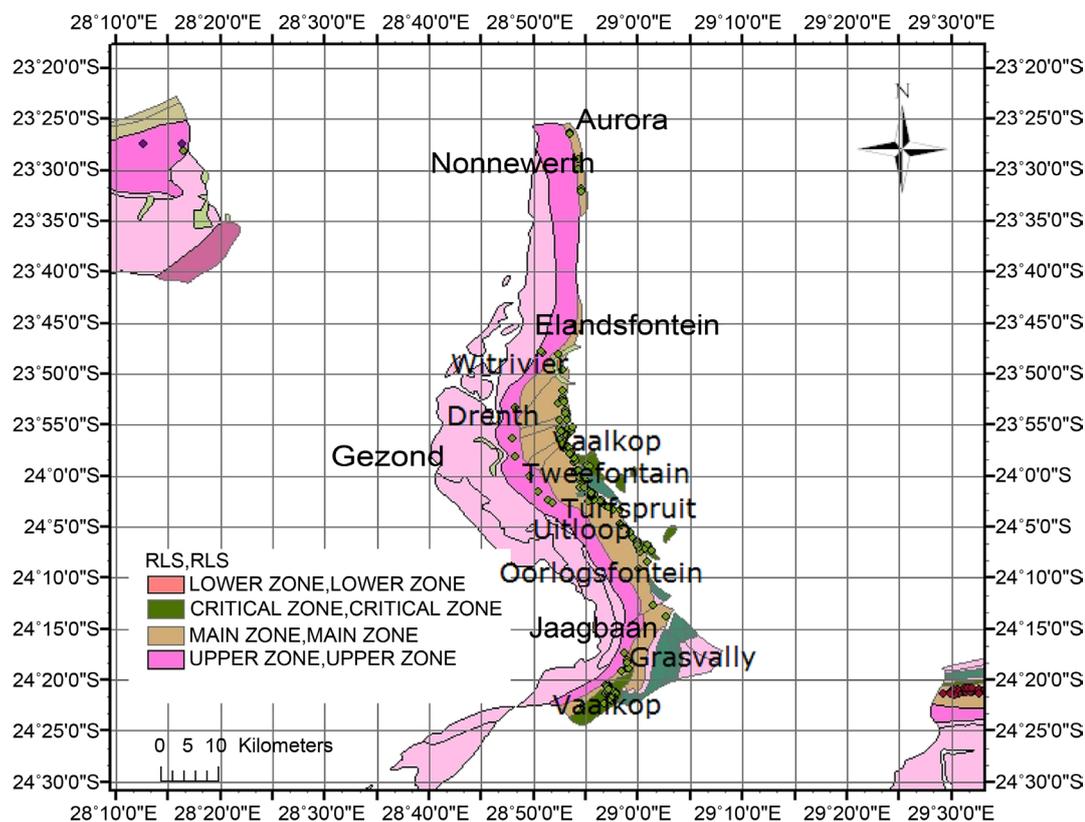
The footwall lithology to the Platreef varies from Archaean basement granites/gneiss in the northern parts to dolomitic rocks in the central section to shale, dolomite and quartzite in the southern sector [19] [20], while the Main Zone granodiorites form the roof to the Platreef. The Thabazimbi-Murchison Lineament (TML) separates the northern limb from the rest of the complex and must have played a major role during the intrusion of the Bushveld Complex as argued by [18].

## 3. Results of Trend Surface Analysis of Northern Bushveld

### 3.1. Northern Bushveld Residual Isopach and Structure

Upper Zone residual structure map in **Figure 2** reveals structural high domain among dominant low structural trend in the extreme northern parts of the Northern Bushveld Complex on farms Aurora, Harriet's wish and Nonnenwerth. The isolated structural high trends NNW-SSE and forms a closure on the Nonnenwerth farm.

The northern parts of Drenthe farm, is marked by strong isolated structural high domain around the Witrivier farm. This structure is elongated east-west and shortens along the N-S direction. The central section shows an irregular residual structural pattern with some residual structures almost forming a NNW trend (**Figure 2(c)**).



**Figure 1.** Geological map showing the northern Bushveld section with the farm names.

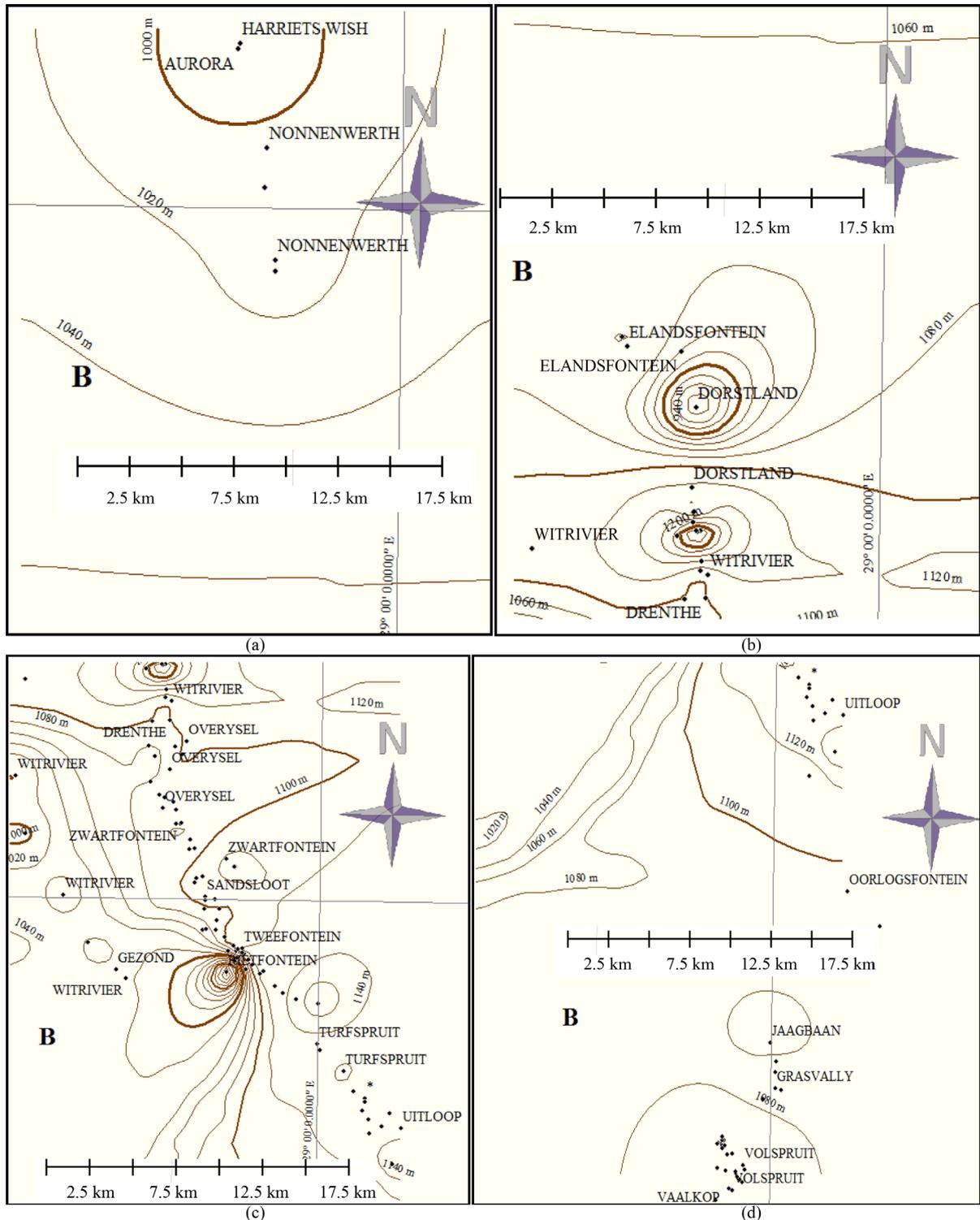
Between Drenthe and Overysel farms there is a significant change in the orientation of the structural trend, from the northeast-southwest trend in the western side to north-south in the centre and back to northeast-southwest trend on the eastern side (as indicated in [Figure 2\(b\)](#) and [Figure 2\(c\)](#)). [21] [22] reported similar change in strike and described the NE-SW trend as strike-slip shear zones. Platreef residual structures in [Figure 3\(c\)](#) indicate a structure high at the extreme north of the Northern Bushveld Complex. This structural high forms a closure that opens to the north. This section descends gradually to the south with some gaps between it and the central sector. The central section shows an irregular residual structural pattern with some residual structures forming a NNW trend.

The central part of the northern limb in [Figures 3-5](#) hosts most of the residual positive and negative isopach domains for Upper Zone unit. These isolated thickness domains coincide with those on the Main Zone residual maps.

The extreme northern part of the northern limb in [Figure 6](#) reveals northward thickening of Upper Zone stratigraphic unit. The immediate south of this area is marked by an E-W trending fault with a downthrow to the south around Nonnenwerth farm and parallel to Zebediela Fault in the southern sector. [22] described the age of the E-W trending faults as post-Karoo. Around the southwestern part of Nonnenwerth farm, the Upper Zone thickens southwards and terminates abruptly around Dorstland farm. Widespread SE thinning follows this, while NNW-SSE alternating thickening and thinning dominate the central part of the sector.

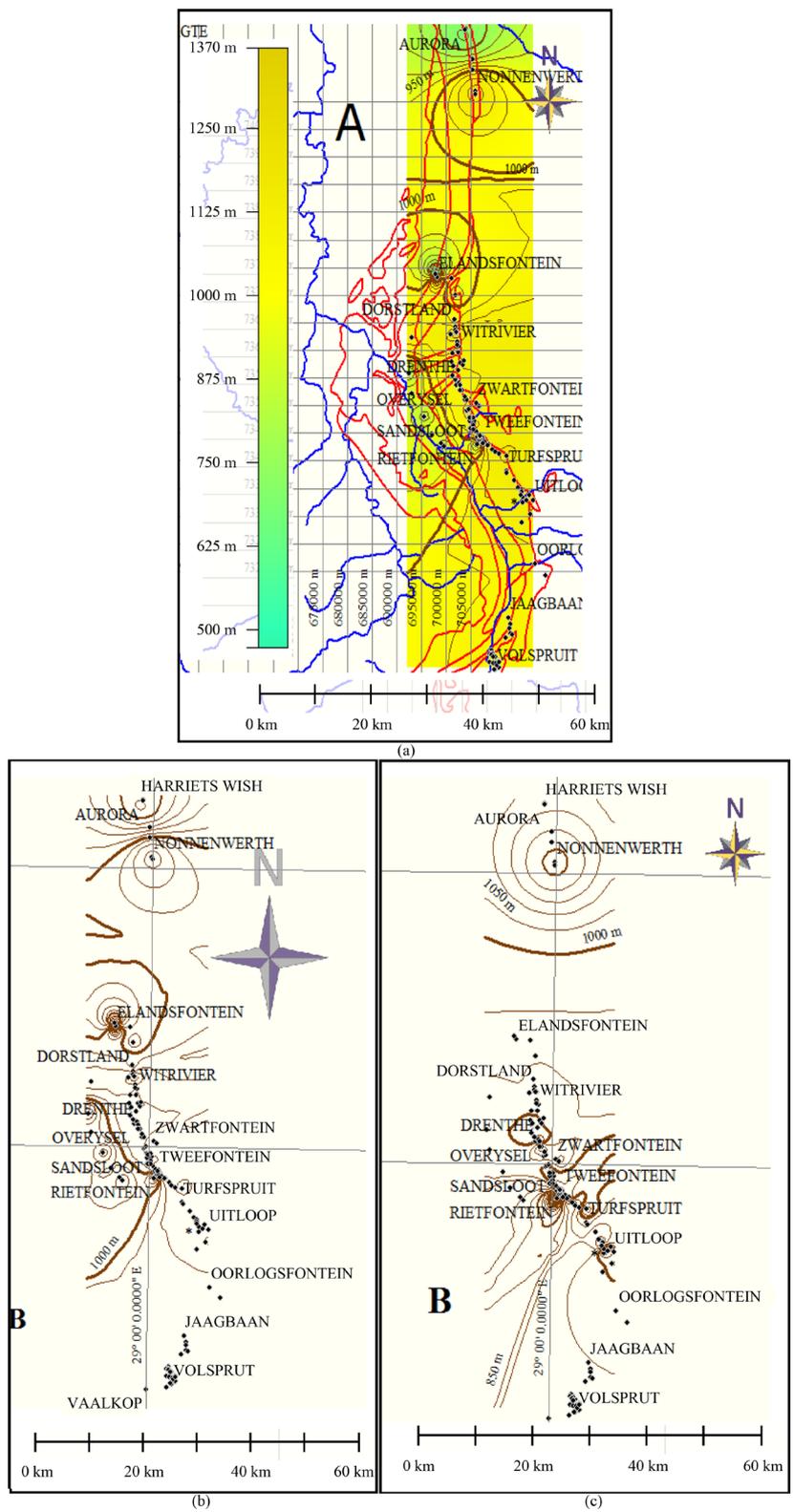
Main Zone residual isopach maps in [Figure 5\(b\)](#) indicate central thickening with thinning to the north and south. Platreef residual isopach map in [Figure 5\(c\)](#) show gradual thinning northward towards the extreme north. While southwards, it formed an anticlinal closure around Dorstland farm. However, the Grasvally area did not indicate any structure on the Platreef and Main Zone residual isopach map as indicated in [Figure 5\(b\)](#) and [Figure 5\(c\)](#).

Central thickening in the Northern Bushveld is rather irregular, probably due to the presence of faults in the area. For example on Overysel farm (see [Figure 6](#)), there is a prominent “side by side” or adjacent thickening (coincides with negative structure domain on the structure contour map) and thinning (coincides with positive structure domain on the structure contour map) with southeast plunging. Another similar structure occurs around

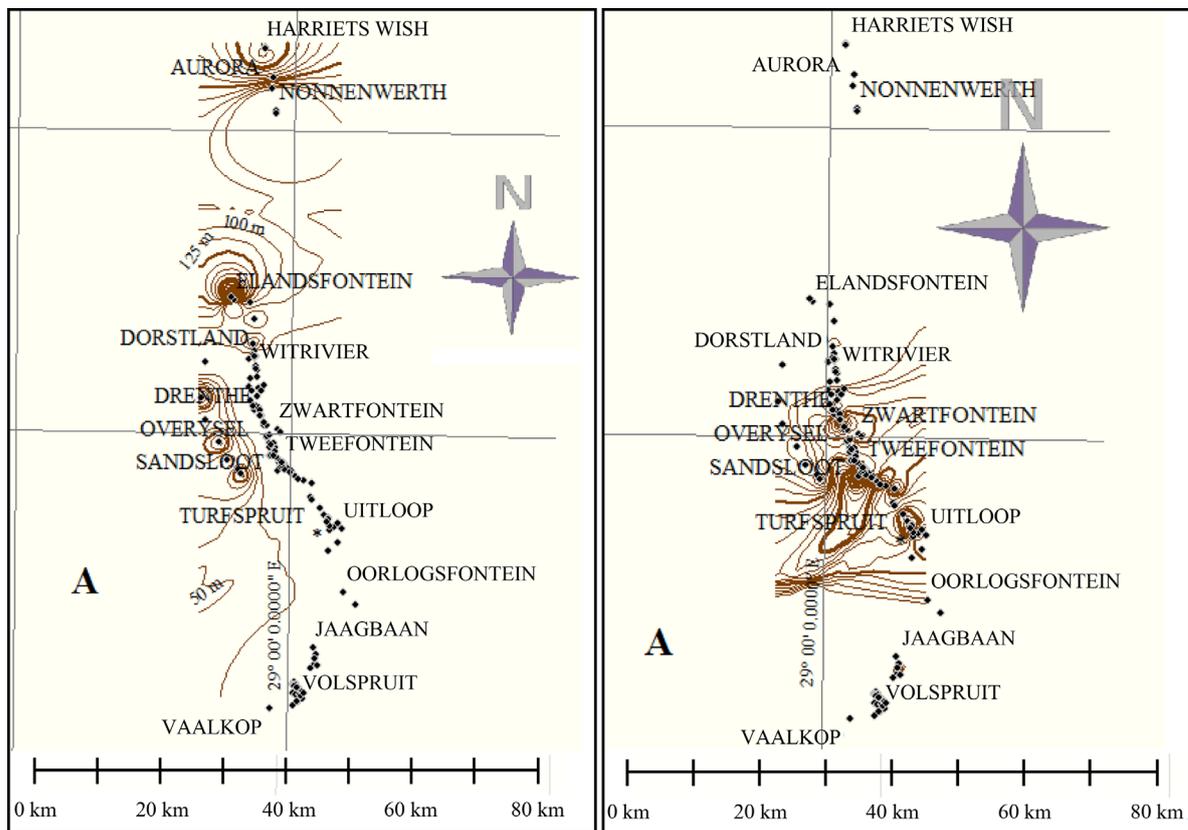


**Figure 2.** Close-up view of the Upper Zone top interval structure contour map of the northern Bushveld divided into, the extreme northern edge, lower northern part, central part and extreme southern part respectively.

the Tweefontein farm with thinning on the Tweefontein Hill and thickening on adjacent southwest plunging Syncline (see **Figure 6(a)**). At Uitloop farm south of the Turfspruit (**Figure 6(b)**) a similar type of structure is repeated with thickening on the downward side that is oriented to the NW and adjacent thinning occurring



**Figure 3.** Interval residual structure maps for Upper Zone, Main Zone, and Platreef (from left to right with a contour interval of 25). A show the geological contact (red lines) and drainage (blue lines) maps draped on the structure contours. It also illustrate the correlation between the structural grain and the shape of the river channels in the area (slightly curved along geologic contacts in the south). Most of the rivers trend N-S to NNW-SSE, E-W and ENE.



**Figure 4.** Upper Zone and Main Zone residual isopach maps showing first order surfaces of the Northern Bushveld Complex (with a contour interval of 25).

across an isolated structural high. This central thickening trend terminates southwards with east-west oriented steep sloping downthrow to the south. However, an isolated positive thickening is present in the synclinal structure on the Grasvally farm as shown in [Figure 6\(c\)](#).

### 3.2. Relationship between Residual Isopach and Structure of the Northern Bushveld

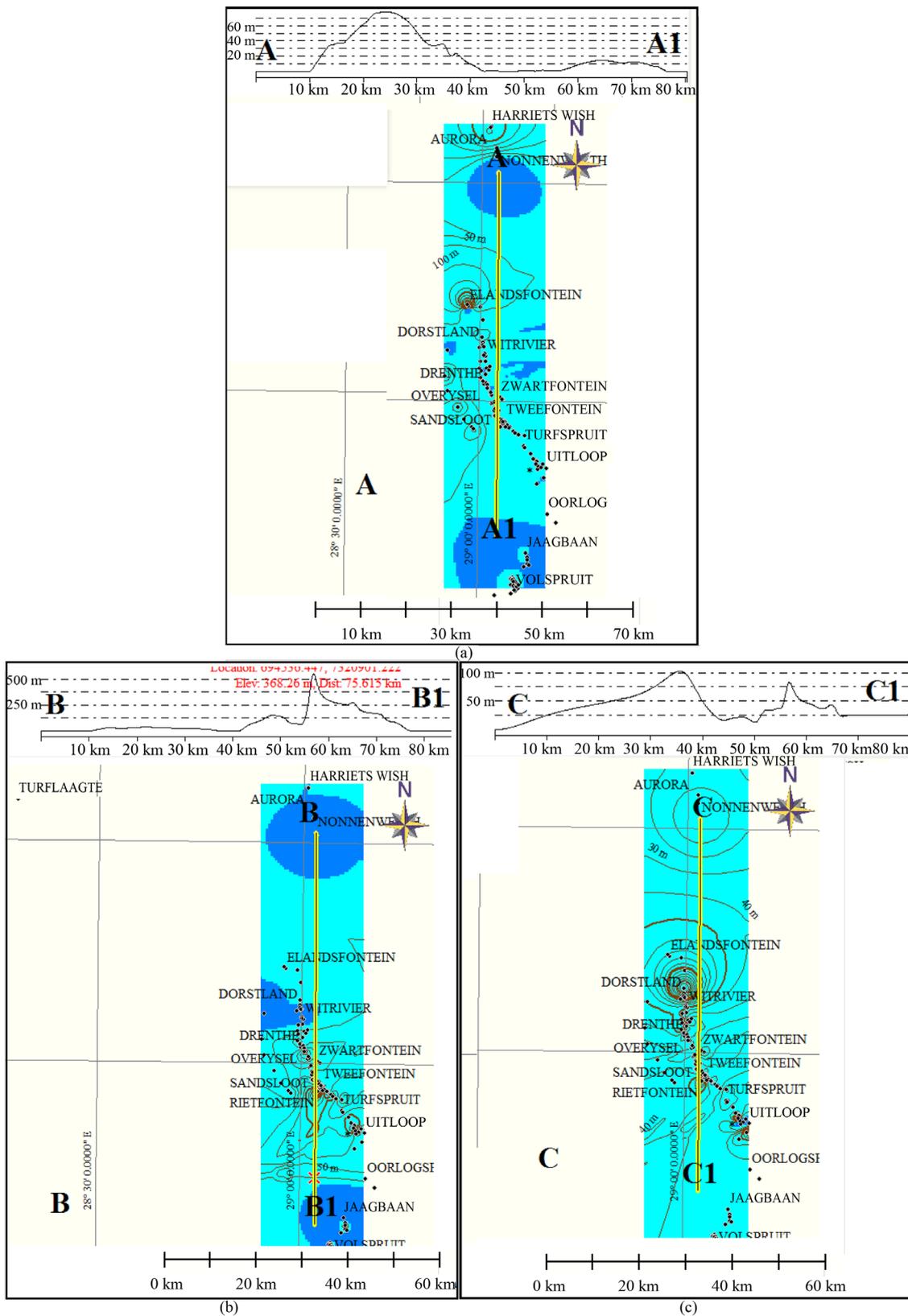
Most parts of the Northern Bushveld Complex show inverse correlation between structure and thickness right from the Upper Zone to the Achaean floor as indicated in [Figures 5-7](#).

### 3.3. Northern Bushveld Structure Trend

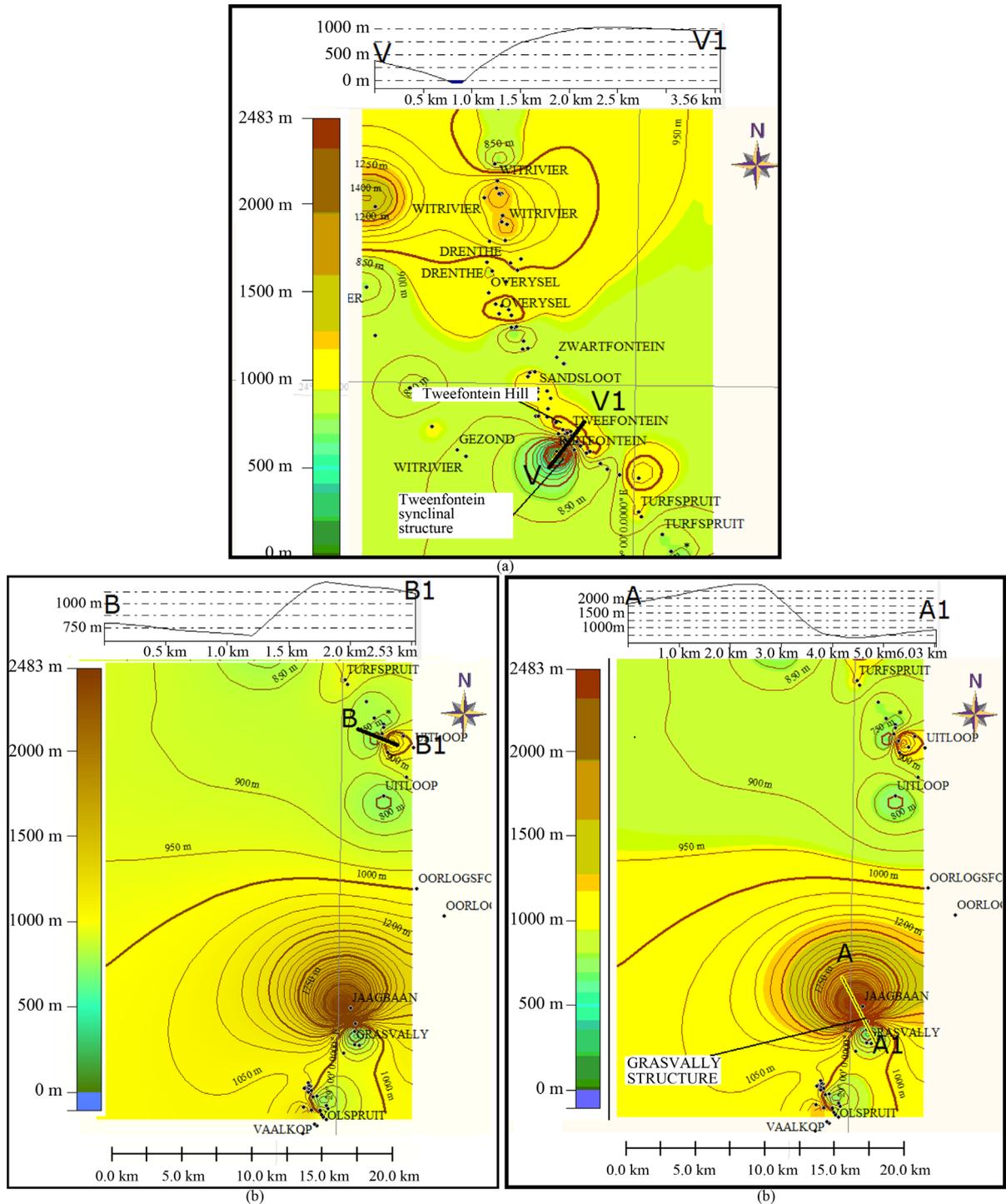
The trend surface on the Upper Zone, Main Zone and Platreef units in the extreme northern part shows structural negative domain with a regional dip to the north. The southern and southwestern parts are structurally negative. However, the central part forms a structural positive area with NW-SE trend. Regionally, the western part of the central sector is dominated by structural high while the southwestern side descends sharply. Northwest of Sandsloot farm, the unit trends NNW and dip to the southwest. However, on Sandsloot farm and south of Zwartfontein farm, the trend changes to approximately ESE and dips southwards. The western part of Tweefontein slopes steeply south-eastwards consequently, demarcating the structural low trend in the west from the NW trending structure high (Tweefontein hill) similar to what was reported by [23]. Further southward between Jaagbaan and Volspruit, there is a structural high domain.

### 3.4. Northern Bushveld Isopach Trend

The Upper Zone isopach trend has a prominent NNW thickening trend in the extreme north and southwards between Nonnenwerth and Elandsfontein the trend changes to N-S thickening in the west and thins out towards the



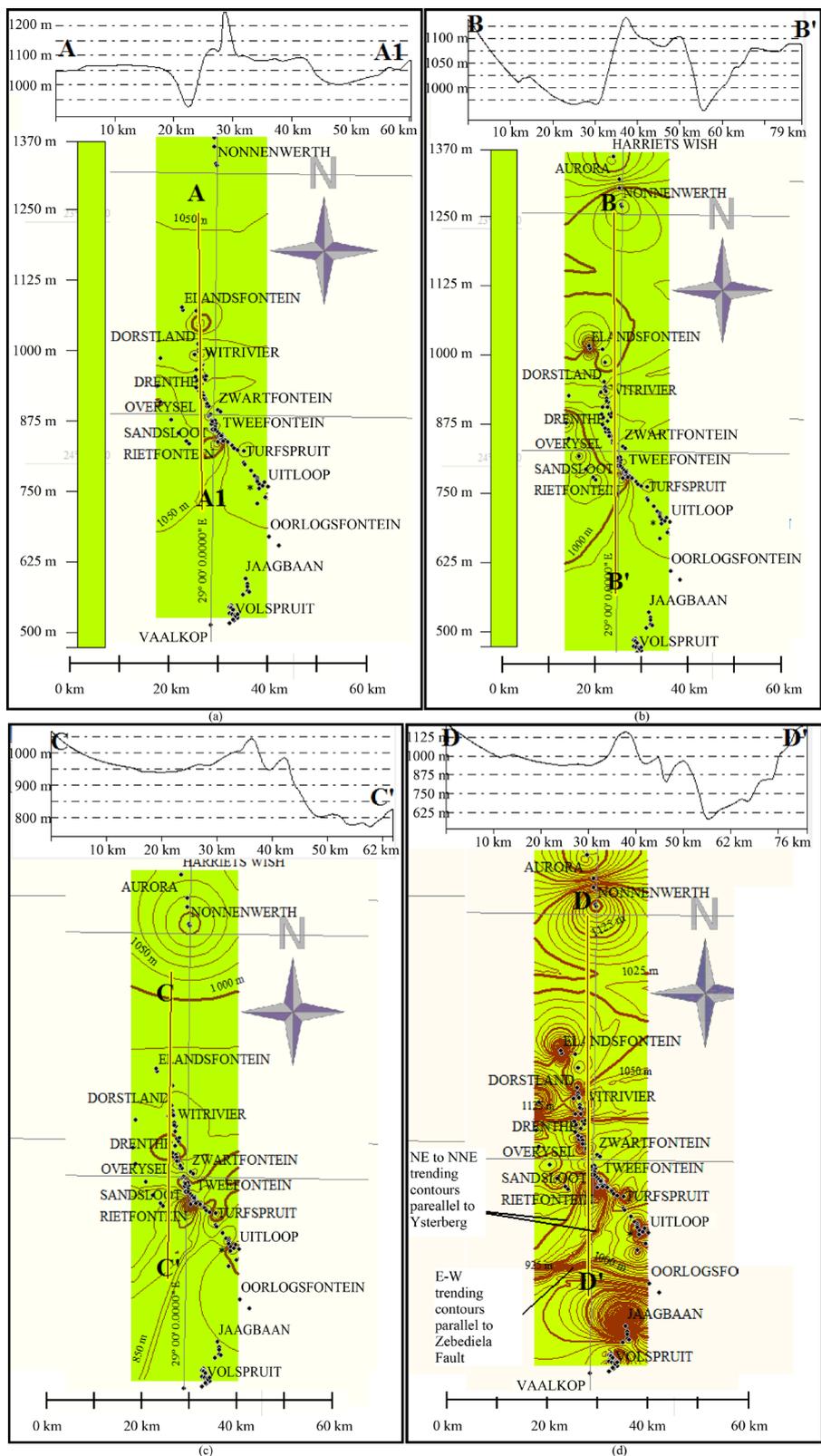
**Figure 5.** Profile A-A1 on Upper Zone residual isopach A, B-B1 on Main Zone B and C-C1 on Platreef C residual isopach of Northern Bushveld Complex showing a graben structure in the central part.



**Figure 6.** Close-up view of profile V-V1 across the Tweefontein synclinal structure dipping to the southwest and adjacent Tweefontein Hill in the Northern Bushveld. Profile B-B1 on Uitloop farm showing downthrow to the west in the central sector of the Northern Bushveld Complex. Structure contours at the base of the Marginal Zone of the Northern Bushveld southern sector with profile across the Grasvally structure.

east. This trend extends to the centre except for the presence of isolated thickening and thinning domains in the western part. The extreme southern part trend almost N-S with thickening to the west.

The Main Zone unit exhibits an eastward thickening trend as indicated in the figures. This trend is, however



**Figure 7.** Profile A-A1 on Upper Zone interval A and B-B' on the Main Zone residual structure (B) of Northern Bushveld Complex showing a horst structure in the central part (Contour interval 50 for A 25 for B). Profile C-C' on Platreef A and D-D' on Archaean floor rock B residual structure of Northern Bushveld Complex showing a horst structure in the central part (Contour interval 25).

irregular and wider at the centre due to the presence of isolated thickening and thinning domains which are oriented almost NNW-SSE except for the Tweefontein area where the trend changes to NE-SW. Around Overysel farm the thickening trend extends eastwards and thins out in the west. While in the Rietfontein area (adjacent to Tweefontein) the thickening trend is southwest.

First order Platreef isopach trend reveals strong N-S trend while the second order indicates a NW-SE trend in the northern part and NNW-SSE trend in the southern part with the central part showing some irregular pattern. The interpreted trends coincide with the reported strike orientations from field observation.

### 3.5. Relationship between Northern Bushveld Isopach and Structure Trend

The residual structure and isopach indicate inverse correlation for most parts of the northern limb from the Upper Zone unit to the Archaean floor rock unit (see [Figure 6](#) and [Figure 7](#)). This implies that most of the present day structures are either reactivated pre-Bushveld structures or structures initiated by the emplacement of the RLS due to structural adjustment of the host rock.

The residual structure map in [Figure 7\(a\)](#) revealed a horst structure at the centre of the northern limb. This is particularly obvious on Upper Zone and Main Zone residual structure maps, however it is less pronounced on Platreef residual structure map. The horst structure is very irregular and multi-peaked on the Archaean floor residual structure map (see profile in [Figure 7](#)). On corresponding Upper and Main Zone isopach maps in [Figure 6](#) the horst structure geographically coincides with a depression or graben structure at the centre of the northern limb implying an inversion of the previous uplifted area. This also implies that the central region that was initially an uplifted section must have experienced subsidence or downwarping in order to accommodate the present thick accumulation of mafic deposit. However, since the same signature was observed on all the intervals structure and isopach maps, down to the Archaean floor, the centrally located horst and graben structure may probably signify a post Bushveld structure or a reactivated Archaean structure.

Change in regional dip direction from eastward in the northern parts of the Elandsfontein farm to westward at the southern parts of Witrivier farm is noteworthy and was earlier reported by [24] based on field observation. An isolated residual positive domain exists on Grasvally farm, the structure slopes down northwards toward Jaagbaan and southwards toward Volspruit farm forming a horst structure. A similar structure exists on the floor rock residual structure (see [Figure 5](#) and [Figure 7\(d\)](#)) between Uitloop and Turspruit farms, this structure shows a structure high that slopes steeply to the northwest and gently to the southwest. Similar structures appear on the Main Zone structural map as a fault with downslope to the northwest. Southward on Volspruit farm is a negative structure bounded by positive structures on both east and west. However, most of the faults in the southern sector of the Northern Bushveld area strike NE to ENE parallel to Ysterberg fault, identified as dextral strike slip faults associated with layer parallel thrust by [21]. The structural pattern from the Upper Zone unit down to the Archaean floor rock did not indicate any major difference.

## 4. Discussion

Patterns formed by structural contours on the floor rocks reveal the influence of the floor rocks on the morphology of the layered rocks. Most parts of the RLS show inverse correlation between the structures and the thickness of the magma infill. This may imply that most of the structures were already in place before the RLS rocks deposited. Consequently, most of these structures can be interpreted as syn-Bushveld structures that were later modified. The Western and Northern Bushveld show widespread inverse structure and thickness relationship imply basement control. However, the central sector of the Northern Bushveld indicates a structural inversion in which areas that showed up as positive domain on structure contour maps also coincides with areas with positive thickness domain on the isopach map. This feature is usually related to thrusting [25]-[27], affecting all the layers of the RLS and the floor rocks, and thus, suggest a post-Bushveld event. The residual structures in the central sector show prominent NNW-SSE trend. Major trends, identified in this study correlate with the findings from structural investigation of [21] [22] on the Northern Bushveld Complex, who described most of the structures as strike-slip and thrust faults. The centre of the Northern Bushveld sector (between Witrivier and Oversel farms) consists of NE-SW structural trends and slightly dips to the NW.

Presence of side-by-side residual positive and negative structures similar to horst and graben structures dominates the central and the southern sector of the Northern Bushveld. [28] described similar structures in the field as domes and adjacent basin-like structures of varying sizes. [29] recognised similar structures in the western

limb and described them as structures that were initiated by magmatic processes and not directly caused by faulting, and hence can be described as a secondary effect. [30] described similar structures as basin-fold structures. The most prominent among these structures occur around Overysel farm and dips to the SE. Others occur around Tweefontein farm and form a synclinal structure (that dips to the SW) adjacent to the Tweefontein Hill (field observation by [24] confirmed the presence of this synclinal structure). Around Uitloop (NE of Grasvally farm) there is another synclinal structure (Grasvally structure). [31] earlier described the Grasvally structure as a horst structure that brought most of the RLS and underlying metasediments to the surface. [32] identified similar structure using an aeromagnetic survey.

A regional scale horst and graben structure occur in the central sector and shows a fast changing structural pattern of floor rocks than on the upper horizons. This structural pattern can be interpreted as large scale salient and recess structure commonly associated with thrust belts as described by [24] [26]. [22] observed and described similar horst structures in the Northern Bushveld as basement highs, with undulating floor.

The method clearly demonstrates its usefulness in constraining subsurface features that are very important to exploration.

## Acknowledgements

This study forms part of O. A. Bamisaiye's Ph. D research supported by the University of Pretoria and Council for Geosciences, Pretoria.

## References

- [1] Agterberg, F.P. (1984) Trend Surface Analysis. Spatial Statistics and Models. Springer, Berlin.
- [2] Unwin, D. (2009) Trend Surface Models. In: Kitchin, R. and Thrift, N., Eds., *International Encyclopedia of Human Geography*, Elsevier, Oxford, Vol. 11, 484-488. <http://dx.doi.org/10.1016/b978-008044910-4.00551-4>
- [3] Krumbain, W. (1959) Trend Surface Analysis of Contour-Type Maps with Irregular Control-Point Spacing. *Journal of Geophysical Research*, **64**, 823-834. <http://dx.doi.org/10.1029/JZ064i007p00823>
- [4] Cook, A. (1969) Trend-Surface Analysis of Structure and Thickness of Bulli Seam, Sydney Basin, New South Wales. *Journal of the International Association for Mathematical Geology*, **1**, 53-78. <http://dx.doi.org/10.1007/BF02047071>
- [5] Baird, A., Baird, K. and Morton, D. (1971) On Deciding Whether Trend Surfaces of Progressively Higher Order Are Meaningful: Discussion. *Geological Society of America Bulletin*, **82**, 1219-1234. [http://dx.doi.org/10.1130/0016-7606\(1971\)82\[1219:ODWTSO\]2.0.CO;2](http://dx.doi.org/10.1130/0016-7606(1971)82[1219:ODWTSO]2.0.CO;2)
- [6] Wren, A. (1973) Trend Surface Analysis—A Review. *Canadian Journal of Exploration Geophysics*, **9**, 39-44.
- [7] Davis, R.W. (1973) Quality of Near-Surface Waters in Southern Illinois. *Groundwater*, **11**, 11-18. <http://dx.doi.org/10.1111/j.1745-6584.1973.tb02952.x>
- [8] Wharton, S. (1993) Exploraton within a Complex Thrust-Fold System—Moruga East Field, Trinidad. AAPG Bulletin (American Association of Petroleum Geologists), Tulsa, 77.
- [9] Davis, J.C. and Sampson, R.J. (2002) Statistics and Data Analysis in Geology. Wiley, New York.
- [10] Evenick, J. (2008) Introduction to Well Logs and Subsurface Maps. PennWell Books, Tulsa.
- [11] Mei, S. and Energy, A. (2006) Structure Mapping for the Clear Hills-Smoky River Region Using Well-Log Data and Geostatistical Analysis [Electronic Resource], Alberta Energy and Utilities Board, Alberta Geological Survey.
- [12] Salvador, E. D. and Riccomini, C. (1995) Neotectônica da região do Alto Estrutural de Queluz, SP-RJ, Brasil. In: Grohmann, C.H., Ed., *Trend-Surface Analysis of Morphometric Parameters: A Case Study in Southeastern Brazil*. *Revista Brasileira de Geociencias*, **25**, 151-164.
- [13] Davis, J.C. (1986) Statistical and Data Analysis in Geology. John Wiley & Sons, Hoboken.
- [14] Grohmann, C.H. (2005) Trend-Surface Analysis of Morphometric Parameters: A Case Study in Southeastern Brazil. *Computers and Geosciences*, **31**, 1007-1014. <http://dx.doi.org/10.1016/j.cageo.2005.02.011>
- [15] Mei, S. (2009) Geologist-Controlled Trends versus Computer-Controlled Trends: Introducing a High-Resolution Approach to Subsurface Structural Mapping Using Well-Log Data, Trend Surface Analysis, and Geospatial Analysis. *Canadian Journal of Earth Sciences*, **46**, 309-329.
- [16] Shaw, B.R. (1977) Evaluation of Distortion of Residuals in Trend Surface Analysis by Clustered Data. *Journal of the International Association for Mathematical Geology*, **9**, 507-517. <http://dx.doi.org/10.1007/BF02100962>
- [17] Kinnaird, J.A. and McDonald, I. (2005) An Introduction to Mineralisation in the Northern Limb of the Bushveld Complex. *Applied Earth Science: Transactions of the Institutions of Mining and Metallurgy: Section B*, **114**, 194-198.

- <http://dx.doi.org/10.1179/037174505x62893>
- [18] Kinnaird, J.A. (2005) The Bushveld Large Igneous Province. Review Paper, the University of the Witwatersrand, Johannesburg, 39 p.
- [19] Kinnaird, J.A., Hutchinson, D., Schurmann, L., Nex, P. and De Lange, R. (2005) Petrology and Mineralisation of the Southern Platreef: Northern Limb of the Bushveld Complex, South Africa. *Mineralium Deposita*, **40**, 576-597. <http://dx.doi.org/10.1007/s00126-005-0023-9>
- [20] Cawthorn, R. and Molyneux, T. (1986) Vanadiferous Magnetite Deposits of the Bushveld Complex. *Mineral Deposits of Southern Africa*, **2**, 1251-1266.
- [21] Friese, A.E.W. (2004) Geology and Tectono-Magmatic Evolution of the PPL Concession Area, Villa Nora-Potgietersrus Limb, Bushveld Complex. Geological Visitor Guide, Potgietersrus Platinums Limited, 57 p.
- [22] Friese, A. and Chunnett, G. (2004) Tectono-Magmatic Development of the Northern Limb of the Bushveld Igneous Complex, with Special Reference to the Mining Area of Potgietersrus Platinums Limited. *Geoscience Africa 2004, Abstract Volume*, University of the Witwatersrand, Johannesburg, 209-210.
- [23] Armitage, P.E.B. (2011) Development of the Platreef in the Northern Limb of the Bushveld Complex at Sandsloot, Mokopane District, South Africa. University of Greenwich, London.
- [24] Nex, P. (2004) Formation of Bifurcating Chromitite Layers of the UG1 in the Bushveld Igneous Complex, an Analogy with Sand Volcanoes. *Journal of the Geological Society*, **161**, 903-909. <http://dx.doi.org/10.1144/0016-764903-154>
- [25] Marshak, S. (1988) Kinematics of Orocline and Arc Formation in Thin-Skinned Orogens. *Tectonics*, **7**, 73-86. <http://dx.doi.org/10.1029/TC007i001p00073>
- [26] Van Der Pluijm, B.A. and Marshak, S. (2004) Earth Structure: An Introduction to Structural Geology and Tectonics. 2nd Edition, WW Norton, New York.
- [27] Strine, M. and Wojtal, S.F. (2004) Evidence for Non-Plane Strain Flattening along the Moine Thrust, Loch Srath nan Aisinnin, North-West Scotland. *Journal of Structural Geology*, **26**, 1755-1772. <http://dx.doi.org/10.1016/j.jsg.2004.02.011>
- [28] Van Der Merwe, M. (1976) The Layered Sequence of the Potgietersrus Limb of the Bushveld Complex. *Economic Geology*, **71**, 1337-1351. <http://dx.doi.org/10.2113/gsecongeo.71.7.1337>
- [29] Scoon, R.N. and Teigler, B. (1994) Platinum-Group Element Mineralization in the Critical Zone of the Western Bushveld Complex; I, Sulfide Poor-Chromitites below the UG-2. *Economic Geology*, **89**, 1094-1121. <http://dx.doi.org/10.2113/gsecongeo.89.5.1094>
- [30] Perritt, S. and Roberts, M. (2007) Flexural-Slip Structures in the Bushveld Complex, South Africa? *Journal of Structural Geology*, **29**, 1422-1429. <http://dx.doi.org/10.1016/j.jsg.2007.06.008>
- [31] Barrett, D.M., Jacobson, J.B.E., McCarthy, T.S. and Cawthorn, R.C. (1978) The Structure of the Bushveld Complex South of Potgietersrus, as Revealed by a Gravity Survey. *Geological Survey of South Africa Transactions*, **81**, 271-276.
- [32] Campbell, G. (2011) Exploration Geophysics of the Bushveld Complex in South Africa. *The Leading Edge*, **30**, 622-638. <http://dx.doi.org/10.1190/1.3599148>