



# Structural analysis and implicit 3D modelling of high-grade host rocks to the Venetia kimberlite diatremes, Central Zone, Limpopo Belt, South Africa



I.J. Basson<sup>a, c, \*</sup>, P.K. Creus<sup>a</sup>, C.J. Anthonissen<sup>a</sup>, B. Stoch<sup>a</sup>, J. Ekkerd<sup>b</sup>

<sup>a</sup> Tect Geological Consulting, Unit 8, AMDEC House, Steenberg Office Park, Tokai, South Africa

<sup>b</sup> De Beers Consolidated Mines, Private Bag X01, Southdale 2193, Johannesburg, South Africa

<sup>c</sup> Department of Earth Sciences, Stellenbosch University, Private Bag X1, Matieland, 7602, South Africa

## ARTICLE INFO

### Article history:

Received 28 September 2015

Received in revised form

26 February 2016

Accepted 5 March 2016

Available online 11 March 2016

### Keywords:

Venetia Mine

Limpopo Belt

Central Zone

High grade

Implicit

3D modelling

## ABSTRACT

The Beit Bridge Complex of the Central Zone (CZ) of the Limpopo Belt hosts the  $519 \pm 6$  Ma Venetia kimberlite diatremes. Deformed shelf- or platform-type supracrustal sequences include the Mount Dowe, Malala Drift and Gumbu Groups, comprising quartzofeldspathic units, biotite-bearing gneiss, quartzite, metapelite, metacalcsilicate and ortho- and para-amphibolite. Previous studies define tectonometamorphic events at 3.3–3.1 Ga, 2.7–2.5 Ga and 2.04 Ga. Detailed structural mapping over 10 years highlights four deformation events at Venetia. Rules-based implicit 3D modelling in Leapfrog Geo™ provides an unprecedented insight into CZ ductile deformation and sheath folding.  $D_1$  juxtaposed gneisses against metasediments.  $D_2$  produced a pervasive axial planar foliation ( $S_2$ ) to isoclinal  $F_2$  folds. Sheared lithological contacts and  $S_2$  were refolded into regional, open, predominantly southward-verging, E–W trending  $F_3$  folds. Intrusion of a hornblendite protolith occurred at high angles to incipient  $S_2$ . Constrictional-prolate  $D_4$  shows moderately NE-plunging azimuths defined by elongated hornblendite lenses, andalusite crystals in metapelite, crenulations in fuchsitic quartzite and sheath folding.  $D_4$  overlaps with a: 1) 2.03–2.01 Ga regional  $M_3$  metamorphic overprint; b) transpressional deformation at 2.2–1.9 Ga and c) 2.03 Ga transpressional, dextral shearing and thrusting around the CZ and d) formation of the Avoca, Bellavue and Baklykraal sheath folds and parallel lineations.

© 2016 Elsevier Ltd. All rights reserved.

## 1. Introduction

Venetia Mine, in production since 1992, is situated 75 km west of Messina in the Limpopo Belt of South Africa and is currently in open pit operation with pit base expected at approximately 500 m, after which the mine will commence with underground mining. The ca. 520 Ma Venetia kimberlite diatremes of the Limpopo Province of South Africa have been the focus of intense research, particularly since the commencement of full-scale mining in the early 1990's (e.g. Allsopp et al., 1995; Phillips et al., 1999; Smith and Barton, 1995; Seggie et al., 1999; Kurszlaukis and Barnett, 2003; Brown et al., 2009; Richardson et al., 2009). Regional geological mapping has established the framework of metamorphic and structural events of the Central Zone of the Limpopo Belt (Brandl,

2000, 2002; Klemd et al., 2003; van Reenen et al., 2004; Rigby et al., 2011) which form the context for mine-based studies (e.g. Barnett, 2003; Doorgapershad et al., 2003; Barton et al., 2003).

This study, which is based on a total of 1 year of in-pit mapping and structural analysis over a 10-year duration and numerous mining phases, resolves the local, relative deformation history of this portion of the Central Zone of the Limpopo Belt. This structural analysis is incorporated into the construction of a fully-constrained 3D implicit model with dimensions of 2.7 km along-strike, 2.5 km across-strike and a depth below surface of 1.5 km, constructed using Leapfrog Geo™, which provides unprecedented insight into the geometry of a large-scale sheath fold that is superimposed on a complexly-deformed terrain.

## 2. The Limpopo Belt

The ca. 3.3–2.0 Ga, ENE–WSW trending Limpopo Belt forms the high-grade gneissic terrane between two lower-grade, granite-greenstone-dominated cratons: the Zimbabwe Craton to the north

\* Corresponding author. Tect Geological Consulting, Unit 8, AMDEC House, Steenberg Office Park, Tokai, South Africa.

E-mail address: [ianbasson@tect.co.za](mailto:ianbasson@tect.co.za) (I.J. Basson).