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Palaeomagnetic results from a Neoarchaean dyke swarm in the Badplaas-Barberton area, South Africa

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ABSTRACT

A palaeomagnetic study is in progress on dyke swarms in the Badplaas-Barberton area and the preliminary results are presented here. The main aims of the study are to contribute towards the debate on Neoarchaean crustal evolution, and attempt to constrain the age, tectonic setting and genesis of these mainly tholeiitic dyke swarms.

The whole rock compositional data demonstrate that the magma is dominantly medium-potassium tholeiitic basalt. Anisotropy of magnetic susceptibility (AMS) data suggests a good correlation with magnetic flow direction.

Preliminary thermomagnetic results are very complex indicating several episodes of magma influx and/or re-magnetization. The calculated virtual geomagnetic poles for several individual dykes correlate with those of the Agatha Basalt from the Pongola Supergroup.

Key words: palaeomagnetism, anisotropy of magnetic susceptibility, dyke

INTRODUCTION

Two major dyke trends cut the ca. 3226±4 Ma Kaap Valley pluton (Layer *et al*., 1992; Tegtmeyer and Kröner, 1987) and ca. 3213±4 Ma Nelshoogte pluton (Layer *et al.*, 1998). The most prominent direction of strike is 317° ± 21° west of north. Another trend is approximately normal to the above at 46° ± 20° east of north (Figure 1).

The NW swarm appears to be emplaced along lineations that are orthogonal to the regional structural grain of the Barberton Greenstone terrain. Layer *et al*. (1998) obtained whole-rock $^{40}Ar/^{39}Ar$ ages for two cross-cutting dolerite dykes of ~1900 Ma. However, Havenga and Armstrong produced a $^{207}Pb/^{206}Pb$ age of 2972±11 Ma for two concordant points of another NW-trending dyke (Havenga, 1996). More recently Olssen *et al*. (2008) reported a U-Pb baddeleyite age of 2965±0.74 Ma from the regression of four analyses on a NW-trending dyke located close to the dykes dated by Layer *et al*. (1998). Another set of coarser grained microgabbro dykes with a similar trend to the dolerite dykes were also observed in the same vicinity by Layer *et al*. (1998) and a mean $^{40}Ar/^{39}Ar$ age of 3179±18 Ma was obtained from three biotite grains. From the above ages it is thus clear that several episodes of dyke intrusion occurred in the study area.

A paleomagnetic study is in progress on both the NW-SE trending dyke swarm, and the younger, crosscutting NE-SW dykes. The aim is to try to distinguish between the different intrusion episodes and thereby contributing towards the debate on Neoarchaean crustal evolution.

GEOLOGICAL SETTING

The Kaap Valley pluton is a circular intrusion 30 km in diameter that forms a valley surrounded by the more mountainous Barberton Greenstone Belt to the north, east and south. It is overlain to the west by the early Proterozoic Transvaal Supergroup. The main part of the Kaap Valley pluton is composed of hornblende tonalite with little or no biotite (Robb *et al*., 1986). Layer *et al*. (1996) report that the Kaap Valley pluton is cut pervasively by dolerite dykes, presumed to be early Proterozoic of age (on the basis of crosscutting relations) with a general northwest trend.

The Nelshoogte pluton is exposed as a semicircular body some 20 km in diameter with the western part of the pluton covered by the Transvaal Supergroup. The Nelshoogte pluton is bordered on the east by the Barberton Greenstone Belt, on the north by the Kaap Valley pluton and on the south by the Kees Zyn Doorns syenite and the Badplaas trondhjemitic pluton. The contact with the Kaap Valley pluton is not well exposed. The contact between the Nelshoogte pluton and the schists of the Barberton Greenstone Belt to the east is a sheared margin. The Nelshoogte pluton is generally a coarse-grained trondhjemite composed of plagioclase, quartz, microcline, biotite, epidote, muscovite and minor opaques.

GEOCHEMISTRY

Geochemical analyses were performed on all the dykes to determine any compositional variation between the different episodes of dyke intrusions.

The major and trace element data (Maré, 2008; Maré, 2009) show that the samples have basic to intermediate chemistry with 49%-57% SiO_2 content for the NW-trending dykes in the Kaap Valley pluton and 43%-65% SiO_2 for the NW-trending dykes in the Nelshoogte pluton. The SiO_2 content of the NE-trending dykes in the Kaap Valley pluton varies between 49% and 55%. Hunter and Halls (1992) reported an average SiO_2 content of 54% from a separate study on mafic dykes towards the south-west of the present study area. Havenga (1996) reported SiO_2 contents varying between 46% and 56% for the Kaap Valley dykes and between 48% and 62% for the Nelshoogte dykes.

The alkaline content (Na_2O+K_2O) of both the NW- and NE- trending dykes vary between 1% and 6% (mean 3.58%), typical of basaltic and basaltic andesitic volcanic rocks.

The whole rock compositional data (Maré, 2008; Maré, 2009) demonstrate that the dykes are dominantly medium-potassium tholeiitic basalts. The major and trace element analysis indicate a normal fractionation trend of basaltic magma.

There was no clear distinction in the geochemical signatures of the NW-trending dykes that could be used to separate them into the proposed different age groups. The NE-trending swarms however show some distinction in terms of MgO content.

PALAEOMAGNETIC RESULTS

During the study, a total of 49 NW-trending and 14 NE-trending (including five closely spaced NW-trending granodioritic dykes (site DNW5) in the Nelshoogte pluton) were sampled. Sites were located in riverbeds, road cuts and surface outcrops. Samples were collected near the centre of the dykes, and where dyke margins outcrop, complete traverses across them were undertaken...

The magnetic susceptibility values of the sampled NW-trending dykes range between 0.108 x 10^{-3} and 40.940 x 10^{-3} (mean 2.486 x 10^{-3}) SI units. The magnetic susceptibility values of the NE-trending dykes range between -0.186 x 10^{-3} and 63.220 x 10^{-3} (mean 14.640 x 10^{-3}) SI units. The magnetic intensity of the NW-trending dykes range between 4.19 x 10^{-5} A/m and 3.21 x 10^{+2} A/m (mean 12.16 A/m). The intensities of the NE-trending dykes range between 3.12 x 10^{-4} A/m and 2.65 x 10^{+2} A/m (mean 70.12 A/m).

Temperature variation of magnetic susceptibility was used to identify magnetite as the main magnetization component with a Curie temperature of 575-600°C. This was confirmed with progressive thermal demagnetization that showed no remanence remained after heating at 600°C.

Anisotropy of magnetic susceptibility (AMS) indicate a good correlation between the maximum susceptibility axis (K1) and magma flow direction as demonstrated by data from site DNW22 (Figure 2). A traverse across the same dyke was sampled (site 2NW21) a few kilometers to the north of site DNW22.

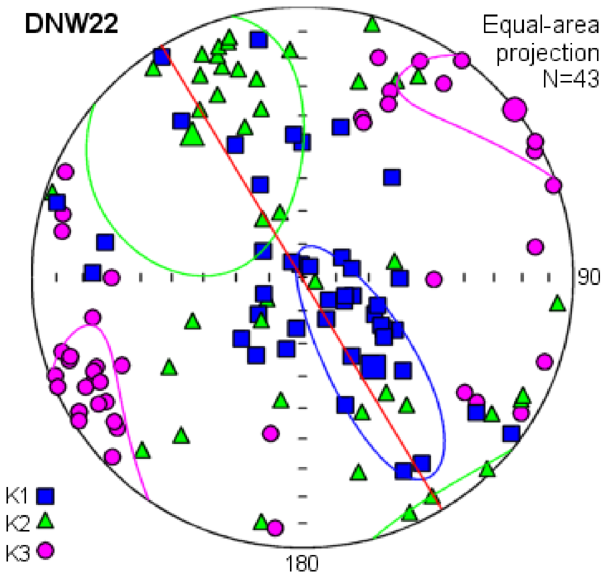

Figure 2: Equal-area projection of the principal axes of the AMS ellipsoids of specimens from site DNW22. The dyke strike is indicated by the red line. Squares (K1) correspond to the maximum susceptibility; triangles (K2) to the intermediate susceptibility; and circles (K3) to the minimum susceptibility. The mean tensors with associated confidence ellipses are indicate by larger icons. In this case the maximum susceptibility vector (K1) correlates with the south-easterly flow direction.

Figure 3 indicates the difference in the alignment of the magnetic minerals from the western and eastern margins of the dyke. The principles by which flow directions can be determined in volcanic dykes were laid out by Knight and Walker (1988). While the magma is flowing in the dyke, elongate particles become imbricated against the chilled margins. In the ideal case, such as site 2NW21, the K1 directions from the two margins are distinct and fall on either side of the dyke trace.

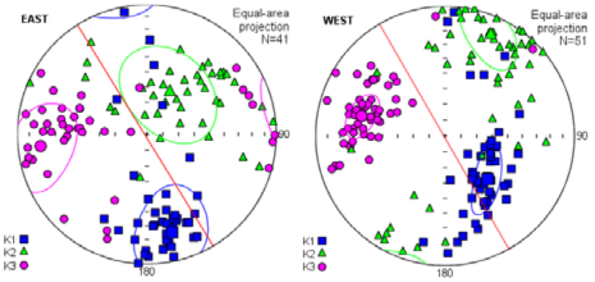

Figure 3: Equal-area projection of the principal axes of the AMS ellipsoids of specimens from the eastern and western margins of dyke 2NW21. The dyke strike is indicated by the red line. Squares (K1) correspond to the maximum susceptibility. The K1 data from the eastern margin plots on the western side of the strike line and the western data plot on the eastern side of the strike line. This correlates with a south-easterly flow direction.

Because the convention is to plot AMS data in lower hemisphere projections, the fact that the western margin data plot on the eastern side and the eastern margin data plot on the western side suggests that the magma flow within this dyke was towards the south-east (after work by Knight and Walker, 1988; Baer, 1995; Tauxe et al., 1998; Canon-Tapia, 2004).

Progressive thermal demagnetization has so far been performed on 26 of 49 northwest-trending dykes and the preliminary results were discussed in Maré (2008). Several dykes produced completely random results and were probably affected by lighting-induced remament magnetization (IRM) as suggested by Strik *et al*. (2007). These dykes will not be discussed further. More than one high temperature (HT) component as well as a medium temperature (MT) component has been isolated in nearly all the remaining dykes.

Preliminary data from the NW-SE trend indicate a convergence of the virtual geomagnetic poles (VGPs) of several dykes (Figure 4) in the vicinity of both the published poles of the ca. 2984±2.6 Ma Agatha Basalt, Pongola Supergroup (Hegner *et al.*, 1993; Strik *et al.* 2007) as well as the ca. 2875±40 Ma Usushwana complex (Layer *et al*., 1988). The calculated pole for the negative magnetization direction of dyke DNW16 correlates best with the pole for the Post-Pongola dolerites of Strik *et al*. (2007) which is of unknown age.

DISCUSSION AND CONCLUSIONS

This study agrees with Layer *et al*. (1996, 1998) and Strik *et al.* (2007) that the magnetic directions of the Neoarchaean dyke swarms studied are not well defined. Preliminary results from the NW-SE dykes correlate with results from the Pongola Supergroup, but can also be correlated with other, younger, thermotectonic events such as the emplacement of the Ushushwana Complex or the intrusion of post-Pongola dolerites (Figure 4). The challenge is to refine the results further, for example, by using the magma flow directions obtained with AMS to link the different magnetization components to the different intrusion episodes.

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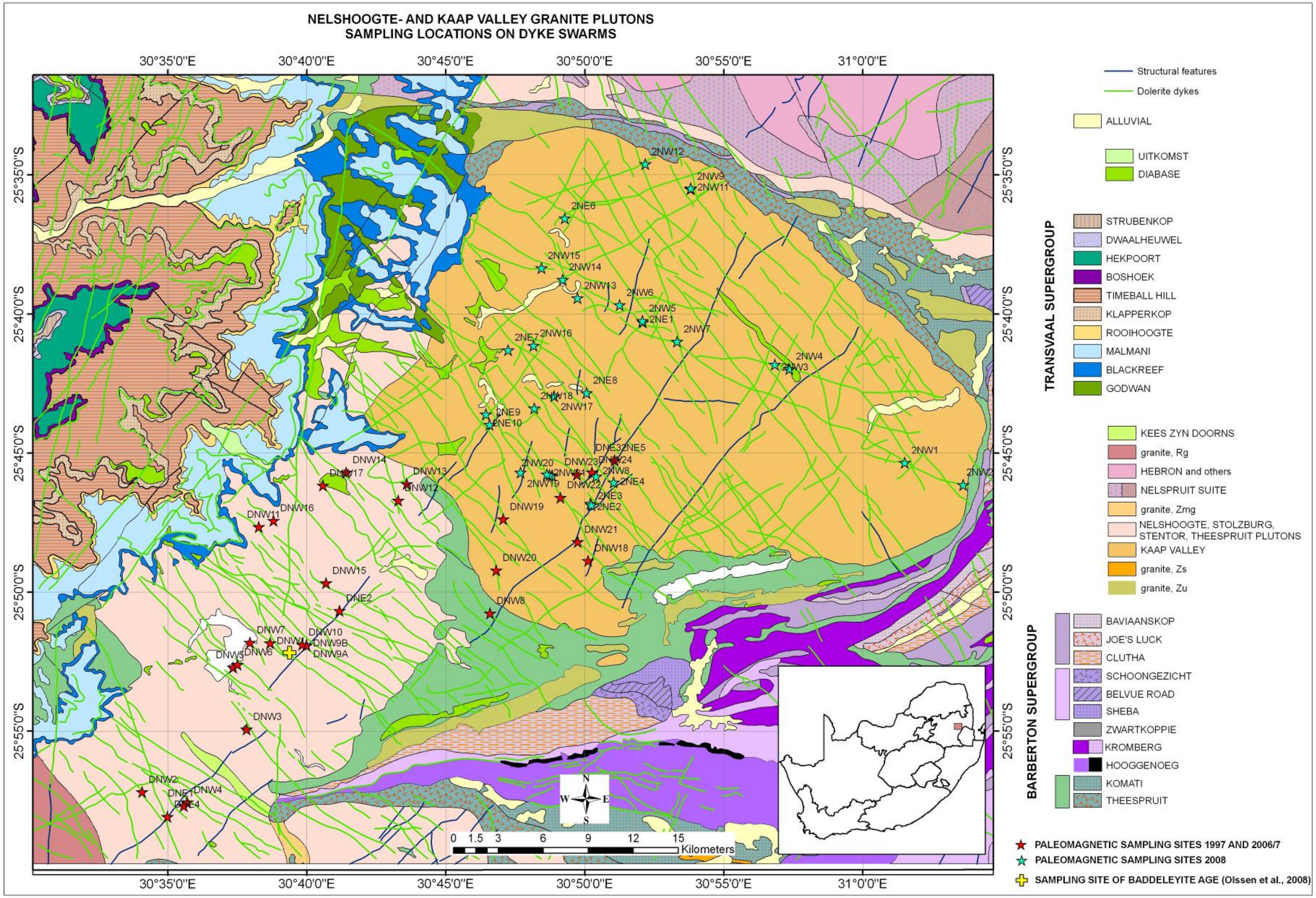

Figure 1: Location map of palaeomagnetic sampling on dykes in the Nelshoogte- and Kaap Valley plutons.

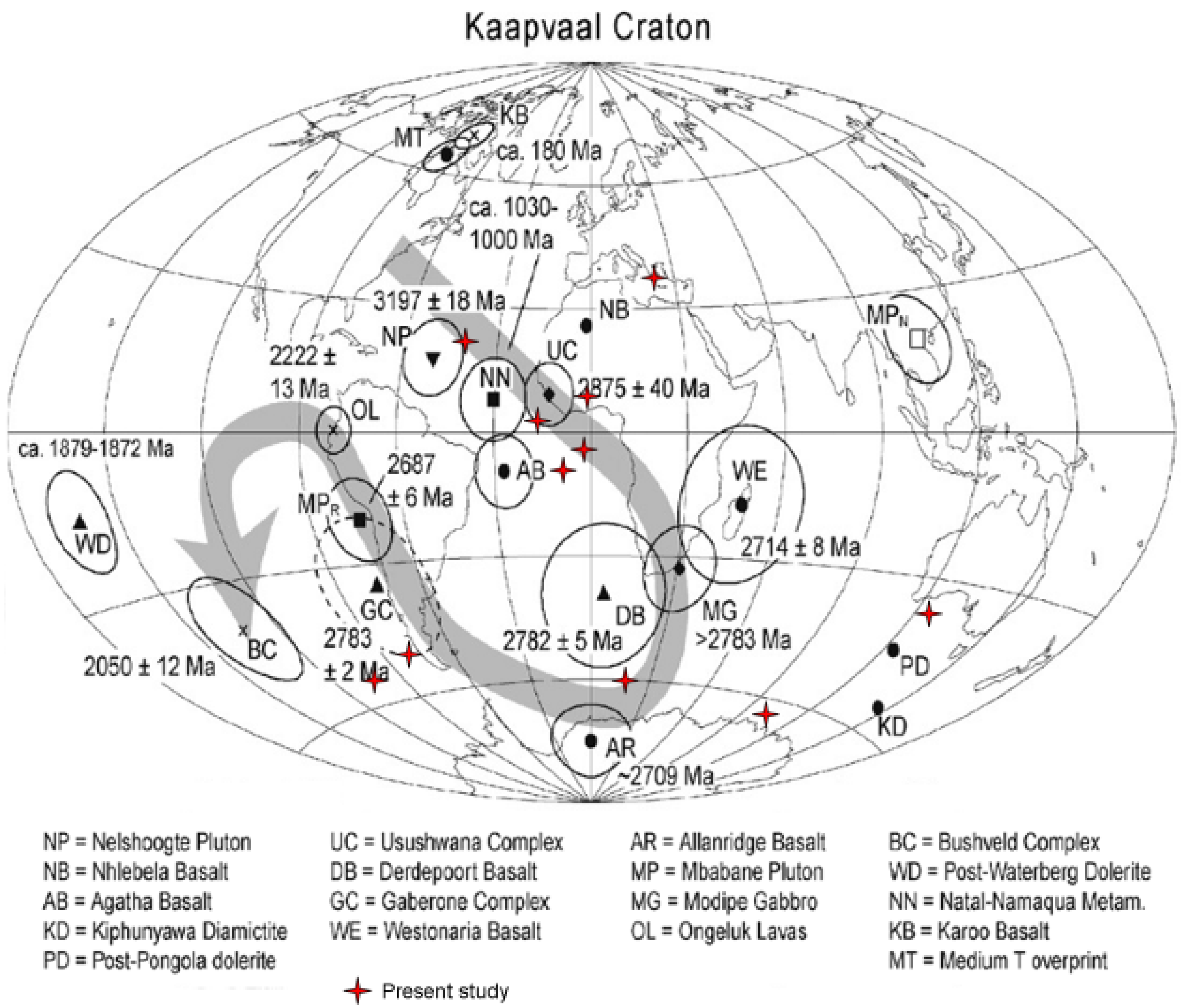

Figure 4: APWP of the Kaapvaal Craton modified after Strik *et al*. (2007) with preliminary VGPs for individual dykes indicated as red crosses. A cluster of poles occurs in the vicinity of the Agatha Basalt (AB) and the Ushuswana Complex (UC).