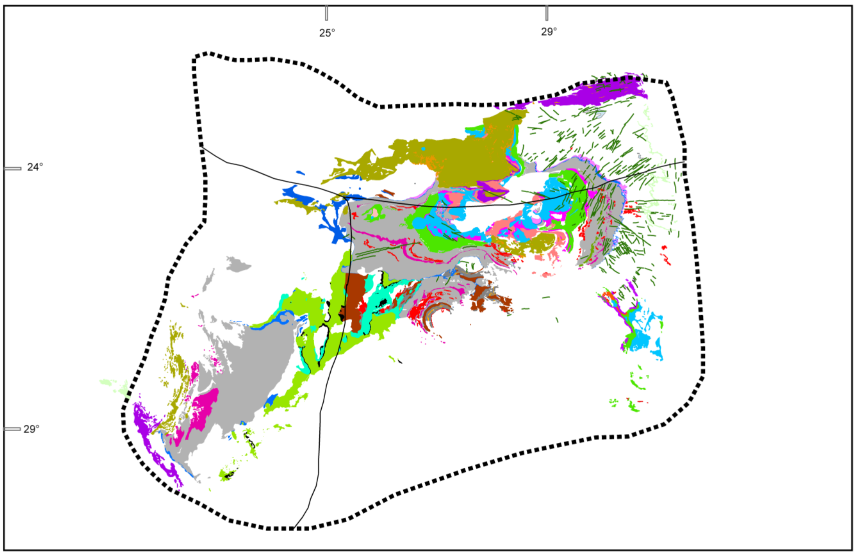
Visualizing the volcanic history of the Kaapvaal Craton using ArcGIS

Max Adolfsson

Dissertations in Geology at Lund University,
Bachelor's thesis, no 385
(15 hp/ECTS credits)



Department of Geology
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Abstract: The Kaapvaal Craton comprises a piece of well preserved Archaean crust making it a valuable subject in the pursuit of palaeocontinental reconstruction. The aim of this study was to visualize the volcanic events of the craton through time using arcGIS and available geochronological data. This was done by creating a number of so called 'time slice' maps that represent time periods from ca. 3 Ga to 1 Ga. These maps show the spatial and temporal distribution of the volcanic events occurring within the craton borders. Literary studies were made to recognize areas in need of additional geochronologic data in order to resolve uncertainties such as age constrains and correlations between formations. The onset of the Ventersdorp volcanism and the following transition to the predominantly sedimentary Transvaal Supergroup are examples of areas in need of additional studies in order to understand when these events occurred and how they relate to each other. The addition of new ages, such as the 2.4 Ga age for the Westerberg sill could yield new correlations that could contribute to further understanding the tectonic and magmatic events that occurred during the time period of the Transvaal Supergroup. A Kaapvaal Craton barcode map was produced using the existing geochronological data with addition of more recent data. This provides an up to date picture of the temporal distribution of volcanic events. This overview of the Kaapvaal Craton through time helps recognizing the areas in need of further studies in order to give way for a more complete understanding of the evolutionary trends of the craton.

Keywords: Kaapvaal Craton, ArcGIS, time slice maps, geochronology, correlations.

Supervisor(s): Ashley Gumsley, Ulf Söderlund

Subject: Bedrock geology

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Visualisering av den vulkaniska historian på Kaapvaal kratonen med hjälp av ArcGIS

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Sammanfattning: Kaapvaal kratonen består av ett välbevarat fragment av arkeisk jordskorpa som utgör ett värdefullt objekt vid palaeokontinentala rekonstruktioner. Syftet med den här studien var att visualisera vulkaniska händelserna i kratonen genom tiden med hjälp av ArcGIS och tillgängliga geokronologiska data. Detta gjordes genom att skapa ett antal så kallade 'time slice' kartor som representerar tidsperioder från ca . 3 Ga till 1 Ga. Dessa kartor visar den spatiala och temporala fördelning av vulkaniska händelser inom kratonens gränser. Litteraturstudier gjordes för att finna områden i behov av ytterligare geokronologisk data för att reda ut oklarheter, så som ålder förhållanden och korrelationer mellan formationer. Uppkomsten av Ventersdorp-vulkanismen och följande övergång till den sedimentärt dominerade Transvaal supergruppen är exempel på områden i behov av ytterligare studier för att förstå när dessa händelser inträffade och hur de relaterar till varandra . Tillskottet av nya åldrar, till exempel 2,4 Ga åldern för 'Westerberg sills' skulle kunna ge nya korrelationer som kan bidra till att ytterligare kunskap om de magmatiska och tektoniska händelser som inträffade under Transvaal-tidsperioden. Genom användning av befintliga och nyare geokronologiska data producerades en 'barcode map' för Kaapvaal Cratonenal som ger en uppdaterad bild av den tidsmässiga fördelningen av vulkaniska händelser. Denna översikt av den Kaapvaal kratonen genom tiden erkänner områden i behov av ytterligare studier för att få en mer fullständig förståelse för de evolutionära trender som präglat kratonens utveckling.

Nyckelord: Kaapvaal Craton, ArcGIS, time slice maps, geokronologi, korrelationer

Handledare: Ashley Gumsley, Ulf Söderlund

Ämnesinriktning: Berggrundsgeologi

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1 Introduction

The Kaapvaal Craton in southern Africa comprises a piece of early Earth history (see Fig. 1. for spatial distribution) . Together with the Pilbara Craton in Australia, the Kaapvaal Craton is one of the most well preserved pieces of Archaean crust. The cratons unique preservation of old crust enables this fragment to present a view into the events and processes that were active during early crustal development of the Earth (Lana et al. 2003). Eglington & Armstrong (2004) use a database system developed by Eglington (2000) called DateView to compile a geological and geochronological database for South Africa, Swaziland, Lesotho and Botswana which together with ArcGIS database was used to produce several "time slice" maps. The purpose of these so called "time slice" maps was to visualize the tectonic evolution and development of the Kaapvaal Craton through time and timing of the formation of major geological units.

Through time the lithospheric crust may break up or join together with different crustal fragments due to the tectonic events that controlled the dynamics on Earth. By matching crustal fragments spatially with the same age using geochronological methods, pieces of crust can be matched and supercontinents reconstructed. This approach is known as magmatic 'barcoding' and provides a deeper understanding of early Earth history, and also which continents were contiguous (Bleeker & Ernst 2006).

Large Igneouse Provinces (LIPs) are formed during extensive, but short- lived magmatic events associated with continental break-up (maximum of ~ 50 Ma, usually less than 10 Ma) and consists of varieties of mainly mafic to ultra mafic volcanic rocks such as sills, dykes, mafic intrusions and flood basalts (Coffin & Eldholm 1992). These large (> 100,000 km^3**)** igneous crustal provinices provides the necessary tools for barcoding and palaeocontinental reconstruction (Ernst et al. 2013). By providing a precise geochronologic age dating of these short-lived magmatic events associated with LIPs a magmatic 'barcode' is created. Combining this 'barcode' with additional information such as geological setting, geochemistry, palaeomagnetism and spatial distribution provides a powerful tool in understanding palaeocontinetal settings (find reference Bleeker and Ernst 2006).

The aim with this study is to update and revise the previous work of Eglington and Armstrong (2004) focusing on the volcanic units of the Kaapvaal Craton, especially in light of the new geochronological age dating achieved using baddeleyite as opposed to zircon; the latter which might be xenocrysts in some cases. During emplacement of lavas and tuff there is a possibility of contamination of xenocrystic zircons that originate from older rocks. If a sample of lava holds these inherent zircons the age obtained when tested will not represent the age of crystallization for the lava. In addition, during metamorphosis baddeleyite recrystallizes to zircon due to reaction with silica which in turn alters the age data when tested. Dating performed on baddelyiete is therefore more certain due to the fact that it is igneous and can not form during metamorphosis (Söderlund et al. 2013).

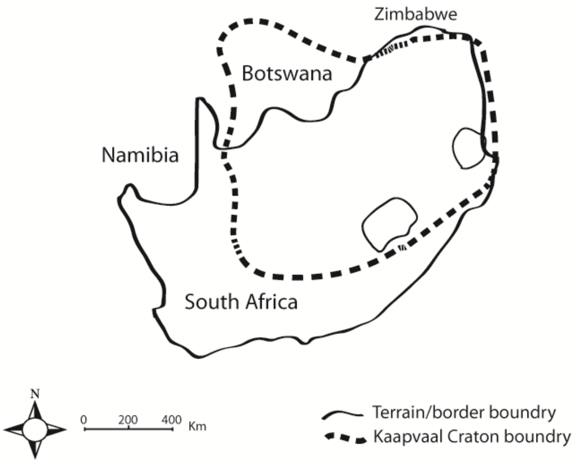

Fig. 1. Overview map showing the extent of the Kaapvaal Craton in relation to terrain and country borders. Modified from Mukasa et al. (2013).

By illustrating the spatial distribution of volcanic Groups and Supergroups of the Kaapvaal Craton, a new perspective on major tectonic events and the associated volcanics is provided, which in turn may help with the visualization of the Craton evolution through time. This is done by producing 'time slice' maps in ArcGis, similar to those of Eglington and Armstrong (2004) and a magmatic barcode for the Kaapvaal volcanic and intrusions.

This study will then attempt to recognize and emphasize where further studies are required to give a more complete and precise reconstruction and barcode of the Kaapvaal Craton evolution.

2 Material and Methods

ArcGIS has been used to construct overview maps of the Kaapvaal Craton containing information such as geological-, and temporal geochronological data from geological maps and literature. This allows the spatial extension of the different volcanic stratigraphic units to be interpreted. Five existing geological maps, produced by the Council of Geoscience in South Africa, where georeferenced using ArcMap to produce a single coherent map with using the WGS 1984 coordinate system. A geopfysical map of the Kaapvaal Craton area was used to highlight the craton boundry (see Fig.2.)

The volcanic units where marked and highlighted as separate polygons on the map. The polygons of different units where made as either single or grouped polygons depending on similarities /dissimilarities in age, lithology and distribution. Thereafter these groups of polygons where divided into time slice units representing time periods during certain tectonic events where active. The dolerite dykes which are marked as diabase on the maps are of varying ages and

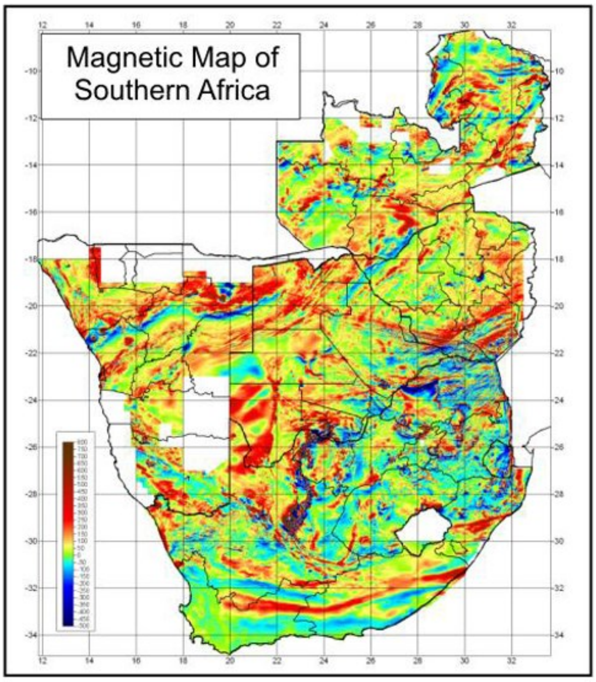

Fig. 2. Geophysical map of southern Africa showing magnetic anomalities which were used to constrain the Kaapvaal Craton border (Council of Geoscience in South Africa 2006)

do therefore not always represent the same age as the time slice itself. Although the general trends of these dykes are illustrated on the maps.

The maps where described and conclusions on evolutionary trends where drawn with the help of literary studies and associated geochronological data. Existing age dating for the volcanics and intrusions of the Kaapvaal Craton was used to create an updated craton 'barcode'. This barcode toghether with the time slice maps will help recognizing areas in need of further dating and describing in the pursuit of a more complete craton evolutionary reconstruction.

3 Results – ’Time slice’ division and maps

The results of this study are presented as time slice maps as well as an overview literary study and geochronologic data of the volcanic events occuring on the Kaapvaal Craton.

3.1 Time slice 1: ca. 3.07– 2.60 Ga

As is shown in Fig 3., the sediments and volcanics during this period is distributed around the eastern and central part of the craton. All these sediments and volcanic are deposited directly on to the granite-greenstone basement. The northern parts of the craton have no preserved volcanic sequences from this time period, and neither do the western parts (compare Fig 1. with time slice maps for spatial distribution in relation to terrain- and country borders). This could be a result of the accretionary events occurring on the western and northern margins during this time period (Schmitz et al. 2004).

3.1.1. Dominion Group (ca. 3.074 Ga)

The sediments and volcanics of the Dominion group are preserved around the center of the craton within and east of the Vredefort Dome (see Fig. 4.).

The Dominion Group volcano- sedimentary sequence were deposited during a short period of rifting (3.09- 3.07 Ga). (Schmitz et al. 2004). The Dominion Group consists mainly of volcanic rocks, with some minor sediments at the base, deposited during the Mesoarchaean period. These successions where deposited unconformably on the granitiod basement rocks. Overlying the Dominion Group is the sedimentary sequences of the Witwatersrand Supergroup (Jackson 1992). The Dominion Group can be subdivided into three distinct formations (Grandstaff et al. 1986; Jackson 1992):

- The Rhenosterspruit Formation: mainly a clastic sedimentary unit, derived from weathered basement rocks and fluvial enviroment, with increasing abundance of interbedded volcanics in the upper parts (Jackson 1992)
- The Rhenosterhoek Formation: mainly lavas ranging from mafic to intermediate composition. The formation is discontinued by the overlying sequence making interpretations of different volcanological parameters difficult. The lava contains amygdales which indicates subaerial or subaqueous depostition (Grandstaff et al. 1986).
- The Syferfontein Formation: the uppermost formation of the Dominion Group and consists mainly of quartz-feldspar porphyries from felsic volcanic rocks with a sequence thickness up to 1500 m. Parts of the formation also include some basaltic to andesitic flows, breccias and tuffs (Grandstaff et al. 1986). Armstrong et al. (1991) dated this unit using the ion microprobe on zircon yielding an age of 3074 ± 6 Ma. However, this age result could have been due to contamination of xenocrystic zircons since the only other geochronological study done on this unit, by Niekerk & Burger (1969) yielded an age of 2725 ± 75 Ma.

3.1.2 Pongola Supergroup (ca. 2.98-2.60 Ga)

The geochronological data from this time period is presented in (Table 1).

The Pongola Supergroup consists of well preserved volcanic and clastic sequences of Mesoarchean age, which in turn overlies 3.1- 3.6 Ga crystalline granite-greenstone basement rocks. The preservation of the structure and geochemical features of these rocks makes the Pongola Supergroup an interesting target to better understand the crust-forming processes during Meso- Archaean times. The area of this supergroup

Table 1. Geochronologic data of Pongola Supergroup units including the Usushwana Complex and the dolerite swarms of the Badplaas Dyke Swarm. Ages and data collected from Dateview (Eglington 2000), Mukasa et al. (2013), Gumsley et al. (2013) and Olsson et al. (2010) *Inherent zircons

Group/Formation	Lithology	Age (Ma)	Method	Reference
Nzuse	Lavas	2978±2	U-Pb (radiogenic) Zircon	Walraven and Pape, J. Afr. Earth Sci.
Nzuse	Basalt	2883±69	Rb-Sr Whole rock	-
Nzuse	Rhyolite	2984±2.6	U-Pb (radiogenic) Zircon	-
Nzuse	Volcanics	2985±1	U-Pb (radiogenic) Zircon	-
Nzuse	Rhyolite	2940±22	U-Pb (radiogenic) Zircon	-
Nzuse	Rhyodacite	2985±1	U-Pb (radiogenic) Zircon	-
Hlagothi Complex	Layered sills	2866±2	U-Pb (radiogenic) Baddeleyite	Gumsley et al. (2013)
Hlagothi Complex	Layered sills	2874±2	U-Pb (radiogenic) Baddeleyite	Gumsley et al. (2013)
Mozaan	Quartz porphyry	2837±5	U-Pb (radiogenic) Zircon	Gutzmer et al. (1999)
Mozaan	Quartz porphyry*	2946±18	U-Pb (radiogenic) Zircon	Gutzmer et al. (1999)
Mozaan	Quartz porphyry*	3081±24	U-Pb (radiogenic) Zircon	-
Mozaan	Quartz porphyry*	3093±18	U-Pb (radiogenic) Zircon	Gutzmer et al. (1999)
Mozaan (lower sequence)	Andesite	2980±10	U-Pb (radiogenic) Zircon	Ludwig (1999)
Mozaan (middle sequence)	Rhyolite	2968±6	U-Pb (radiogenic) Zircon	Mukasa et al. (2013)
Mozaan (inter-bedded flow)	Andesite	2954±9	U-Pb (radiogenic) Zircon	Mukasa et al. (2013)
Usushwana Complex	-	2989.2±0.8	U-Pb (radiogenic) Baddeleyite	Olsson (2012)
Usushwana Complex	-	2989.8±1.7	U-Pb (radiogenic) Baddeleyite	Olsson (2012)
Badplaas Dyke Swarm	Dolerite	2967.0±1.1	U-Pb (radiogenic) Baddeleyite	Olsson et al. (2010)
Badplaas Dyke Swarm	Dolerite	2965.9±0.7	U-Pb (radiogenic) Baddeleyite	Olsson et al. (2010)

extends 120 km by 275 km, giving a minimum depositional area of 33,000km², and crosses over from South Africa into Swaziland (Strik et al. 2007). The volcano-sedimentary sequences of the Nsuze and Mozaan Groups are situated in the south eastern part of the Kaapvaal Craton, (see Fig. 5).

The Pongola Supergroup is subdivided into a lower unit: the Nsuze Group (dominated by volcanic rocks) and an upper sedimentary unit: the Mozaan Group (Armstrong et al. 1982). Together these groups comprise a 12 km sequence of volcanic and clastic material, although the thickness varies significantly in different areas (Armstrong et al. 1982). Both the Nzuse- and Mozaan Group of the Pongola Supergroup were intruded at 2871±30 Ma by the Usushwana Suite (Bumby et al. 2012). However, more recent baddeleyite dating of the Usushwana Complex suggest that the emplacement of took place earlier at ca 2989 Ma ago(Olsson 2012). This suggests a connection with eruption of early Nsuze lavas (Mukasa et al 2013).

The Nsuze Group (ca 2980-2960 Ma) is subdivided into three different units with varying lithology. The lower unit is comprised of the 800 m predominantly sedimentary- deposits of the Matonga Formation dated to 2980 ± 20 Ma on a inter-calated lava using U-Pb on zircons by Mukasa et al. (2013) . This is overlain by the middle unit, the Nhlebela/Pypklipberg lava: a ca. 7500 m volcanic sequence.

The upper most unit is a volcaniclastic- sedimentary sequence which varies in thickness from 500 to 600 m, comprising mostly the Agatha lava. This is separate from the middle unit by a sedimentary package – the White Mfolozi Formation. It has been the subject of several datings attempts, especially on the

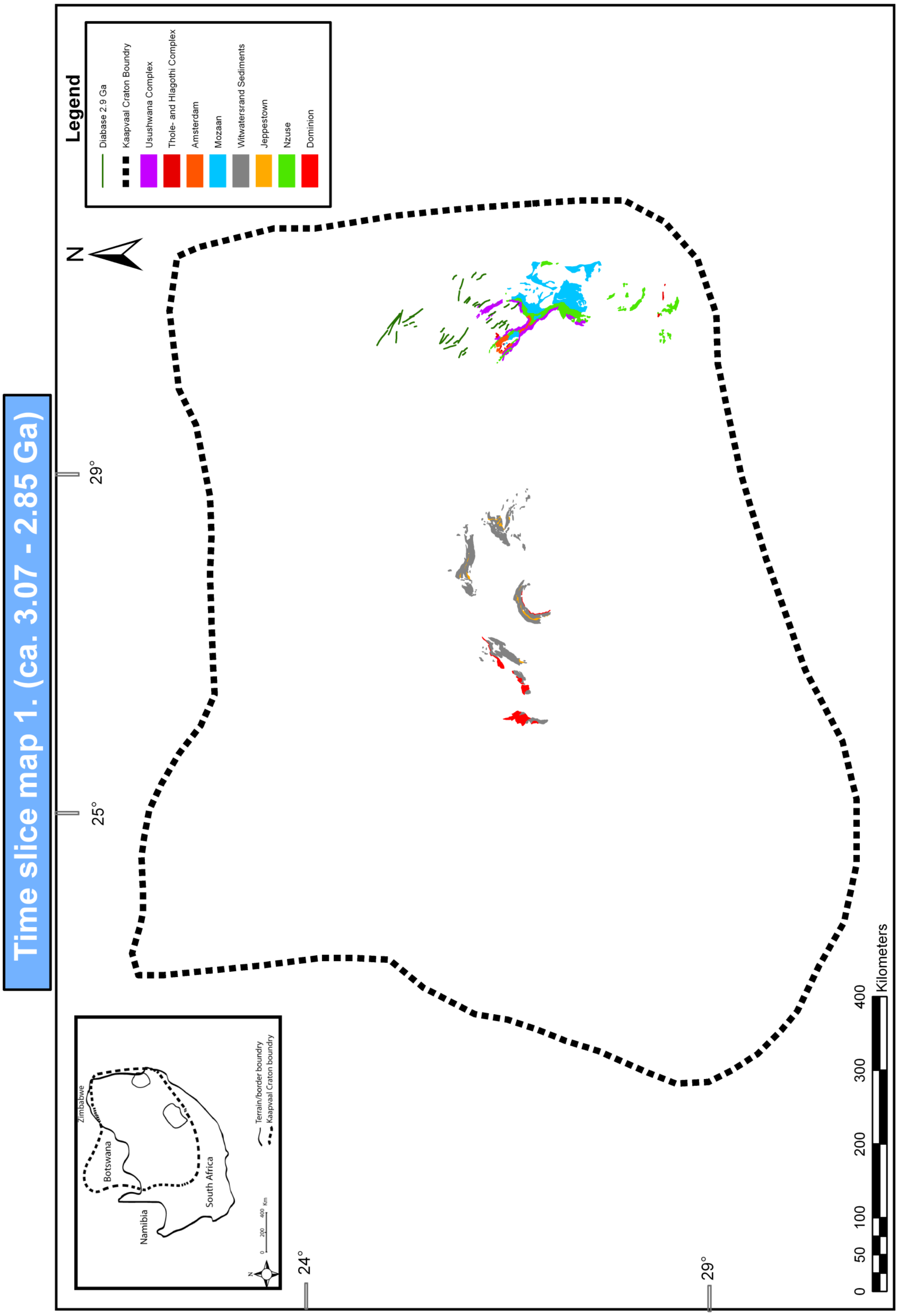

Fig. 3. Time slice map 1. showing the spatial distribution of the Pongola- and Witwatersrand Supergroups as well as the Dominion Group.

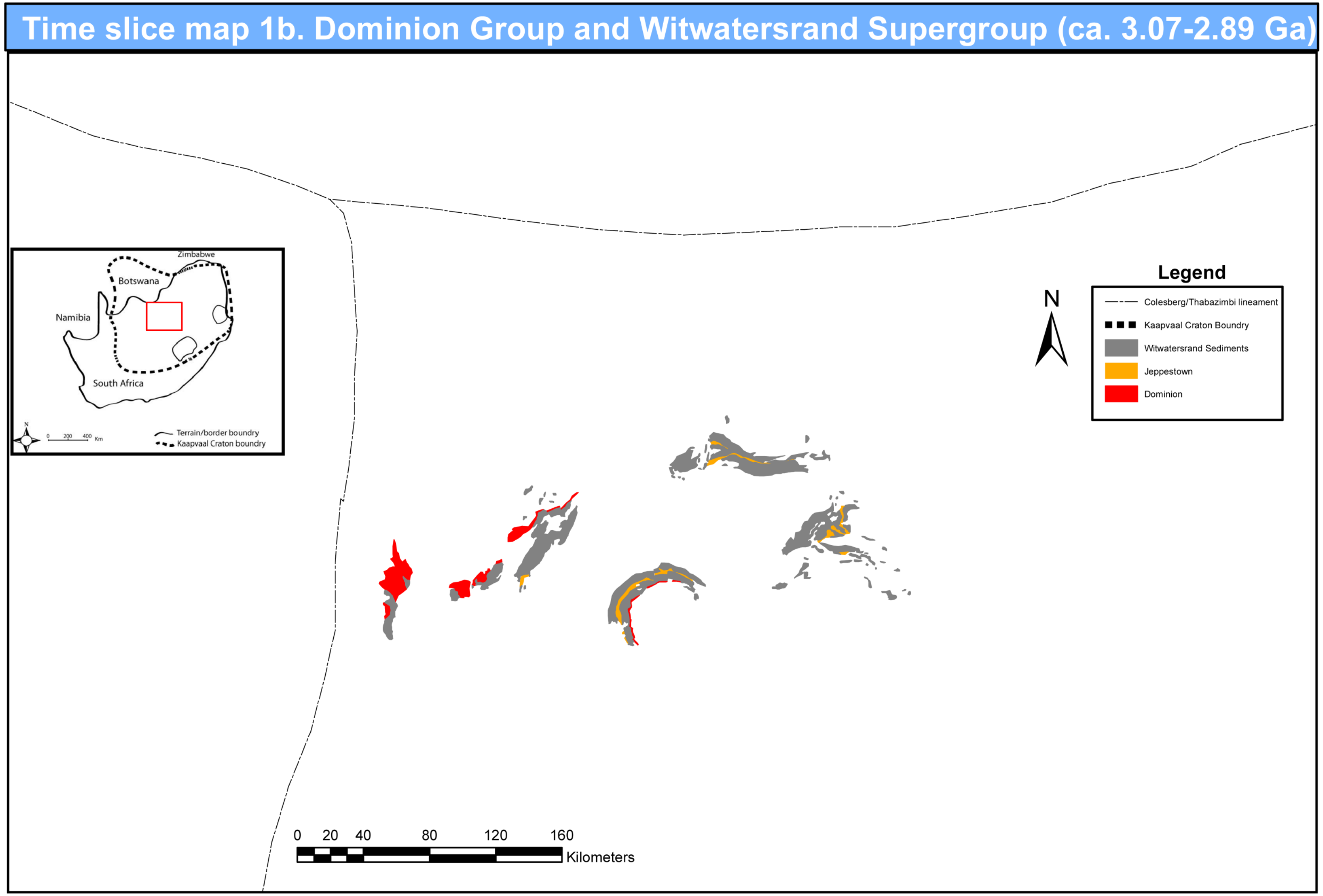

Fig. 4. Time slice map 1.c showing in detail the spatial distribution of the Witwatersrand Supergroup. Compare spatial relation to Colesberg lineament.

Agatha lava in the central parts of the basin. These ages range from 2985 to 2940 Ma using U-Pb zircon (Armstrong et al. 1982; Gumsley et al. 2013)

The sequences are located in the south eastern parts of the Kaapvaal Craton (see Fig. 5. for more detail) and the lithology of the volcanic unit gives the full range from basalt to rhyolite rocks in the Nzuse Group (Mukasa et al. 2013) . The sequence of the Nsuze Group was previously believed to be a product of extensive and rapid rifting (Strik et al. 2007). This, according to (Burke et al. 1985), explains the abrupt changes in lateral thickness of the sequences deposited in the Pongola Supergroup. Large volumes of volcanic rocks are then preserved in these structures suggesting a rift environment. The rifting period was then followed by a shallow marine shelf environment during which the sequence of the Mozaan Group was deposited (Strik et al. 2007). However, according to Mukasa et al. (2013) the rapid deposition of lavas and the structure of the volcanics of the Pongola Supergroup does not share similarities with modern analogs of rifting environments. The features of the volcanics can, however be linked to a continental arc basin as oppose to a rifting environment.

In the more eastern part of the craton an area of extensive NE-SW dolerite dyke swarms intrudes and cuts through eastern parts of the granitic basement (see Fig. 5.). This swarm is termed the Badplaas dyke swarm and was dated by (Olsson et al. 2010) at 2967.0±1.1 Ma using U-Pb on baddeleyite (TIMS), which correlates to the Nzuse Group lavas. This means that the basin possibly extended into this region too.

The layered sills of the Hlaghoti Complex intruded the Pongola Supergroup ca. 2.87 Ga ago during mantle plume activity in the southeastern part of the craton (Gumsley et al. 2013) . According to Gumsley et al.(2013) the intrusions and extensive magmatism occurring during this time period could be linked to a new 'Large Igneous Province'.

The Mozaan Group (ca 2860 Ma) is predominantly made up of sedimentary material ranging from mudstones to sandstones interlayer with conglomerates and BIF formations. These sedimentary units are interbedded by a minor volcanoclastic units in the upper sequence (Gold & Von Veh 1995). These units termed the Tobolska and Gabela lavas were dated by Mukasa et al. (2013) using U-Pb zircon (SIMS) method to 2954±9 Ma. This suggests a much older depositional time of this group than previous suggestions, although the presence of inherited zircons cannot be ruled out.

3.1.3 Witwatersrand Supergroup (ca 2.985- 2.894 Ga)

The Witwatersrand Supergroup is economically important, due to large gold deposits which are hosted in this predominantly sedimentary basin. It has thus been the subject to extensive exploration (Armstrong et al. 1991).

Overlying the older Dominion Group, the Witwatersrand Supergroup consists of mainly coarse clastic material with minor deposits of bimodal lava in the upper successions, the Crown and Bird formations (Jackson 1992; Guy et al. 2012).

This Supergroup was according to Schmitz et al. (2004) a product of the crustal collision of the Kimberly- and Witwatersrand block. This resulted in a subduction of the eastern Witwatersrand block and deposition of material in the forearc basin east of the subduction zone. This could explain the absence of sediments and volcanics on the western part of the craton since the forearc basin was formed within the eastern Witwatersrand block. The two blocks are separated by the NS trending Colesberg lineament (see Fig. 3 and 4.). (Schmitz et al. 2004)

The supergroup is divided into two groups: the West Rand Group and the Central Rand group. The sediments and volcanics of these groups are dirstributed around the central parts of the Kaapvaal Craton (see Fig. 5. for more detail)

The West Rand Group constitutes the lower sequences of the Witwatersrand Supergroup. It consists of mainly fluvial and marine sedimentary deposits ranging from variations of mudstone, banded iron formations to conglomerates. While this group mostly contains marine sedimentary sequences, the uppermost Jeppestown subgroup has a thin sequence of basaltic lava known as the Crown lava (Guy et al. 2012). This amygdaloidal flood basalt has a sequence thickness of ca 60m and was deposited 2914 ± 8 Ma ago (Armstrong et al. 1991), although as noted by the authors, the presence of xenocrysts are possible .

The West Rand Group is uncomformably overlain by the fluvial sediments of the Central Rand Group ranging from conglomerates, sandstones and shale (Manzi et al. 2013). The Central Rand Group contains a minor volcanic sequence called the Bird lava which is undated (Armstrong et al. 1991).

3.2 Time slice 2: ca 2.85- 2.60 Ga

3.2.1 Ventersdorp Supergroup (ca 2.78-2.70 Ga)

Geochronological data for the Ventersdorp Supergroup is presented in Table. 2.

The Ventersdorp Supergroup has a vast distribution stretching from the center to the south eastern and north western parts of the Kaapvaal Craton. The Rykoppies dyke swarm is situated in the north eastern parts of the craton separated from other Ventersdorp units (see Fig. 6.).

The Ventersdorp Supergroup overlies the Witwatersrand Supergroup with a angular unconformity marking the end of the deposition of the Witwatersrand Basin (Eglington & Armstrong 2004). The succession thickness is at average 4 km, but ranges to 8 km (Armstrong et al. 1991). With an area extent of ca 300,000 km^2 and relative short depositional time, this Supergroup represent the most extensive "Large Igneous Province" on the Kaapvaal Craton in the Neoarchean (Altermann & Lenhardt 2012).

Table. 2. Geochronologic data of the Ventersdorp Supergroup including the Rykoppies Dyke Swarm. Data collected from Dateview (Eglington 2000), Wingate (1998) and Olsson et al. (2010).

Group/formation	**Lithology**	**Age (Ma)**	**Method**	**Reference**
Klipriviersberg	Lava	2714±8	U-Pb (radiogenic) Zircon	Armstrong et al. (1991)
Derdepoort	Basalt	2782±5	U-Pb (radiogenic) Zircon	Wingate (1998)
Platberg	Volcanics	2709±4	-	Armstrong et al. (1991)
Hartswater	Tuff	2732.9±3.2	U-Pb (radiogenic) Zircon	de Kock et al. (2012)
Hartswater	Porphyry	2724.3±5.8	U-Pb (radiogenic) Zircon	de Kock et al. (2012)
Allanridge	Basalt	-	-	-
Kanye	Volcanics	2784±4	U-Pb (radiogenic) Zircon	Grobler and Walraven (1993)
Kanye	Rhyolite	2784.7±1.7	U-Pb (radiogenic) Zircon	Moore et al. (1993)
Kanye	Rhyolite	2784.8±1.8	U-Pb (radiogenic) Zircon	Moore et al. (1993)
Makwassie	Quartz porphyry	2709±4	U-Pb (radiogenic) Zircon	Armstrong et al. (1991)
Makwassie	Quartz porphyry	3480±7	U-Pb (radiogenic) Zircon	Armstrong et al. (1991)
Makwassie	Quartz porphyry	2706±22	U-Pb (radiogenic) Zircon	Gericke (2001)
Rykoppies	Dykes	2683.1±1.6	U-Pb (radiogenic) Baddelyite	Olsson et al. (2010)
Rykoppies	Dykes	2685.5±5.5	U-Pb (radiogenic) Baddelyite	Olsson et al. (2010)
Rykoppies	Dykes	2662.3±2.5	U-Pb (radiogenic) Baddelyite	Olsson et al. (2010)
Rykoppies	Dykes	2661.9±3.3	U-Pb (radiogenic) Baddelyite	Olsson et al. (2010)
Rykoppies	Dykes	2658.9±3.2	U-Pb (radiogenic) Baddelyite	Olsson et al. (2010)
Rykoppies	Dykes	2672.9±1.8	U-Pb (radiogenic) Baddelyite	Olsson et al. (2010)

This Supergroup is subdivided into three broad groups consisting of various volcano- sedimentary sequences. The lower most Klipriviersberg Group composes a massive sequence of flood basalts reaching a thickness of up to 2000 m and is geochronologically dated to 2714±8 Ma using U-Pb on zircon (Armstrong et al. 1991). Although the Venterdorp Supergroup could, according to (Wingate 1998) be dated as far back as 2782±5 Ma if one regards the Derdepoort basalts as the most basal sequence, and possibly coeval with the Klipriviersberg. During this time the Kanye volcanics were also deposited in the northern part of the craton forming another sub-basin (Nelson et al. 1999).

During the period of deposition of these flood basalts the region experienced extensional tectonic activity which later resulted in NE-trending grabens (Armstrong et al. 1991). Previous theories suggest the collision of the Kaapvaal and Zimbabwe Craton as the cause of the deposition (Burke et al. 1985). However, the abcence of the vast Bushveld associated intrusion (~2057 Ma) on the Zimbabwe Craton and equal absence of 2575 Ma Great Dyke magmatism on the Kaapvaal Craton would suggest that this collision did not take place until after the Bushveld intrusion (Bleeker 2003).

The Klipriviersberg Group was then followed by the Platberg Group (2709±4 Ma, Armstrong et al. 1991) during which clastic material and bimodal volcanics made up the deposited material. However, de Kock et al. (2012) argue that the Platberg Group correlates to the Hartswater Group at ~ 2730 Ma which would mean that previous dating of the Platberg Group done by Armstrong et al. (1991) is erroneous.

The upper most Pniel Sequence, or Group, which is made up of a sedimentary- and a flood basalt formation. This sequence has not yet been dated (Armstrong et al. 1991).

The Pniel Succession is followed by the clastic dominated Bothaville formation which in turn is overlain by the flood basalts of the Allanridge formation (Van Der Westhuizen et al. 1991). The rift associated

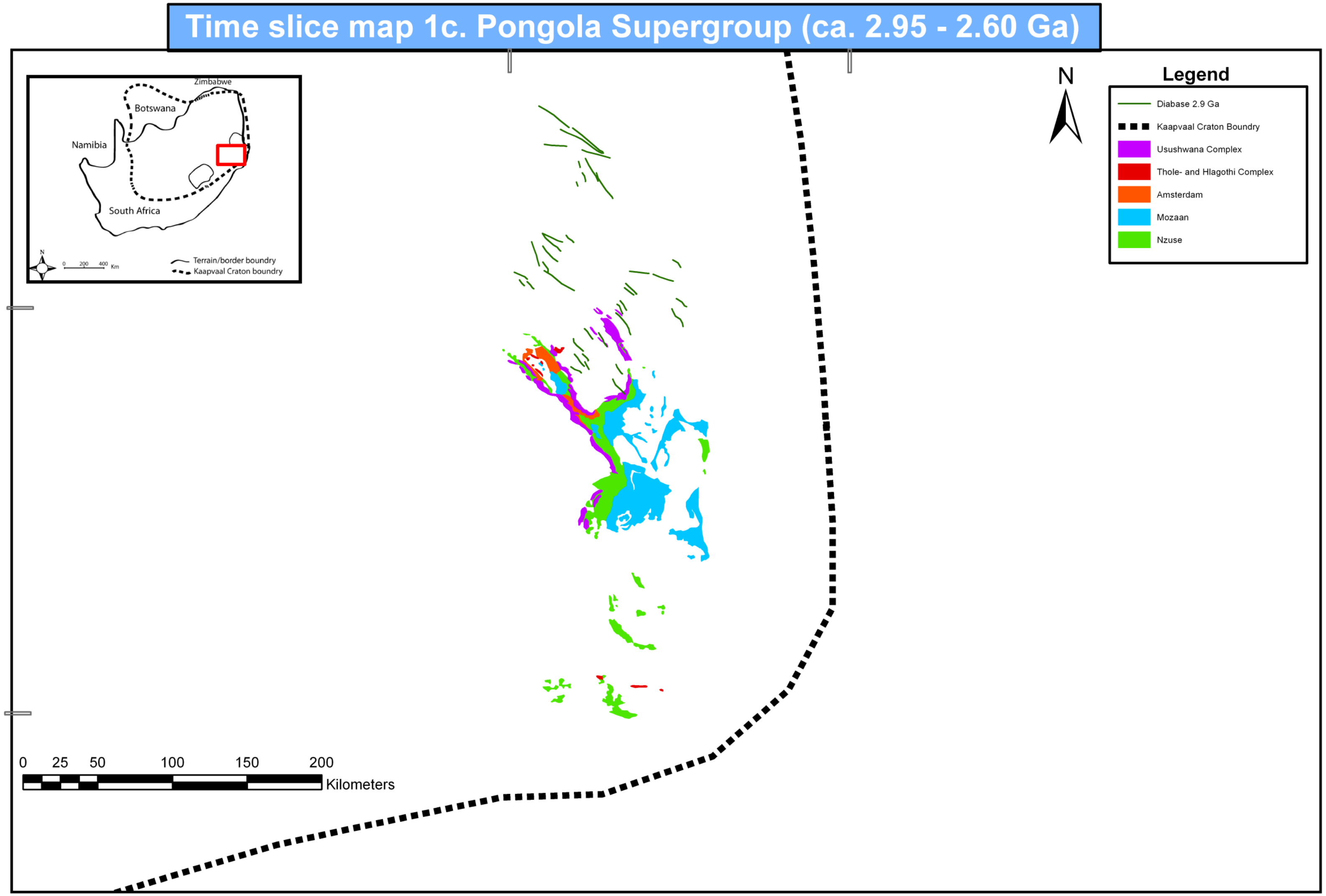

Fig. 5. Time slice map 1.b showing in detail the spatial distribution of the Pongola Supergroup with associated dykes and sills.

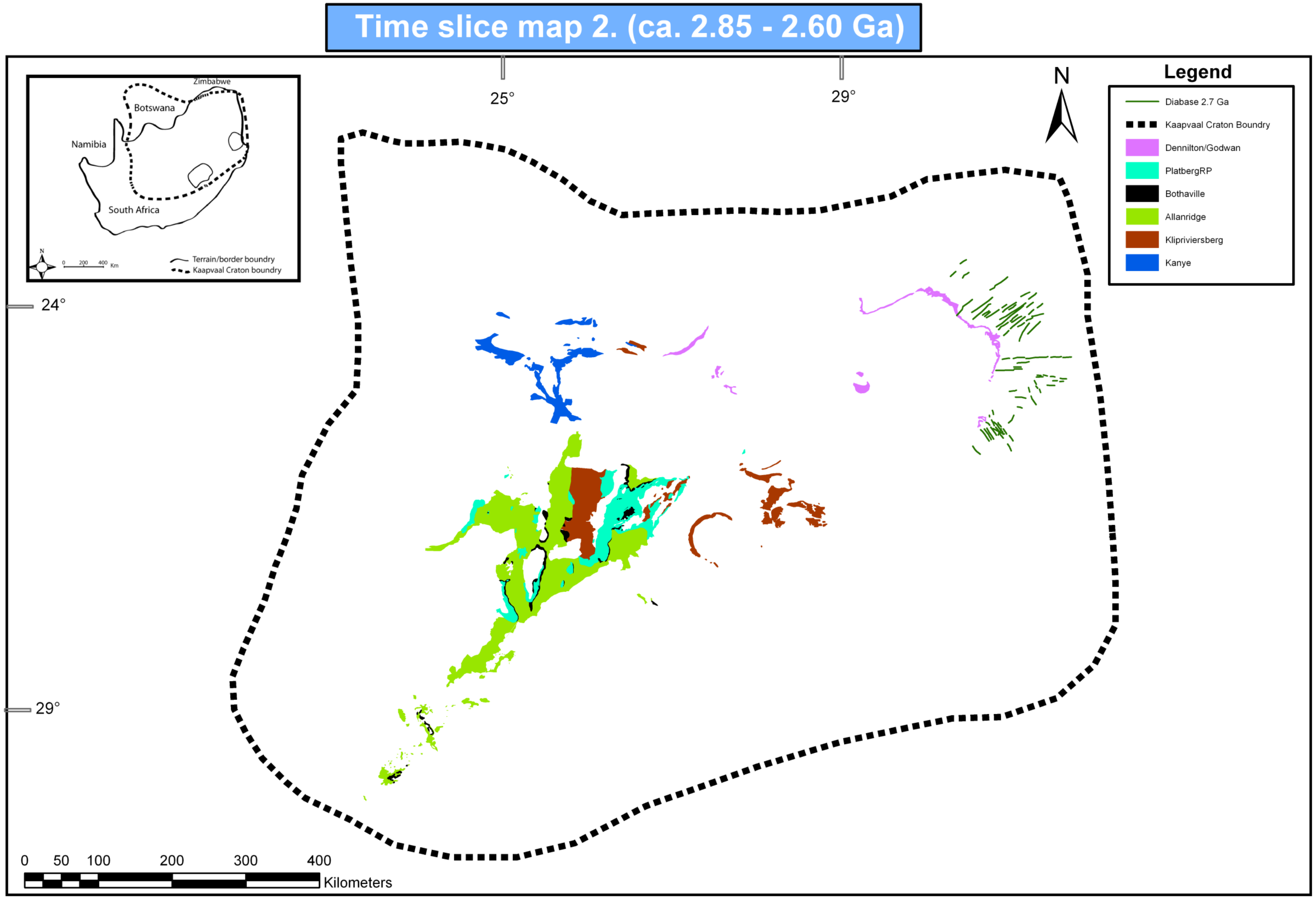

Fig. 6. Time slice map 2. showing the spatial distribution of the Ventersdorp Supergroup. Compare spatial distribution of the Dennilton/Godwan groups on time slice map 3.

Table. 3. Geochronologic data of the Transvaal Supergroup including the Westermberg Sill and the proto-basinal fill of the Delliton, Wolberg and Godwan Groups. Data collected from Dateview (Eglington 2000), Kampmann (2012), Cornell et al. (1996) and Olsson et al. (2010).

Group/Formation	Lithology	Age (Ma)	Method	Reference
Ongeluk	Andesite	2238±87	U-Pb (radiogenic) , Zircon	-
Ongeluk	Andesite	2239±71	U-Pb (radiogenic) , Zircon	-
Ongeluk	Andesite	2222±13	Pb-Pb, Whole rock	Cornell et al. (1996)
Hekpoort	Andesite	2181±21	Rb-Sr, Whole rock	(not much info)
Hekpoort	Andesite	2184±76	Rb-Sr, Whole rock	MacFarlane nad Holland (1991) referenced in Cornell (1996)
Vryburg	Lavas	2642±2	U-Pb (radiogenic) , Zircon	Walraven et al (in press), referenced by Nelson et al. (1999)
Vryburg	-	-	U-Pb (radiogenic) , Zircon	-
Machadodorp	Lavas	-	-	-
Westerberg	Sill	2442±5	U-Pb (radiogenic) Baddelyite	Kampmann (2012)
Dennilton, Wolberg, Godwan Groups (proto - basinal fill)		~2657-2659	-	unpublished report SACS, 1993
Buffelsfontein	Lavas	~2664	-	Barton et al., (1995)

flood basalts of the Allanridge formation makes up the uppermost part of the Ventersdorp Supergroup. This formation could be correlated to the Rykoppies dykes (~2683-2686 Ma) which were formed during the transition from the volcanic dominated Ventersdorp Supergroup to the sedimentary dominated Transvaal Supergroup. These Rykoppies Dykes may also be related to the Transvaal Supergroup and its basal proto-basinal fills. However, due to the insufficiency of geochronological data from this time period these correlations are not certain (Olsson et al. 2010).

3.3 Time slice 3: ca 2.65-2.05 Ga

3.3.1 Transvaal Supergroup (ca 2.65- 2.05 Ga)

Geochronological data for the Transvaal Supergroup is presented in Table. 3.

The sediments of the Transvaal Supergroup extend throughout large areas from the western to north eastern parts of the craton. The older Vryburg and Black Reef formations are preserved on the margin of the younger Transvaal sediments, forming the base of the succession, with some associated volcanism. The volcanic units of the Ongeluk- Hekpoort formations have a large distribution area in the south western part of the supergroup while smaller outcrops can be observed in the more central and north eastern parts of the craton (see Fig. 7.).

The flood basalts of the Allanridge formation, representing the upper most part of the Ventersdorp Supergroup, was deposited during a renewed rifting period on the Kaapvaal Craton (Burke 1985b). This is suggested to be the onset of the Transvaal sedimentary deposition in proto-basinal fills which occurred at ca. 2657- 2659 Ma according to an unpublished report (Olsson et al. 2010)

The Transvaal Supergroup can be divided into three separate basins: the Griqualand West basin (Botswana), the Kanye Basin (Botswana) and the Transvaalbasin (South Africa), the Kanye basin being seen as an extension of the Griqualand West basin. The basement high referred to as the Vryburg Arc separates the basins (see Fig. 7. for basin distribution), although the basal sequences (eastern Chuniespoort Group and western Ghaap group) can be correlated in both the Transvaal and Griqualand West basin (Moore et al. 2001)

The basal unit of the Transvaal and Kanye Basin, the Black Reef Formation, is comprised of sedimentary rocks ranging from mudstones to conglomerates. This formation is correlated to the sedimentary/volcanic Vryburg Formation of the Griqualand West basin (Eriksson et al. 1993) with some reports of limited volcanism.

The lowermost groups of the Transvaal Supergroup are separated from the middle Pretoria (Transvaal basin) and Postmasburg Group (Griqualand West basin) by an unconformity creating a substantial hiatus in the Transvaal Supergroup stratigraphy. This has made it

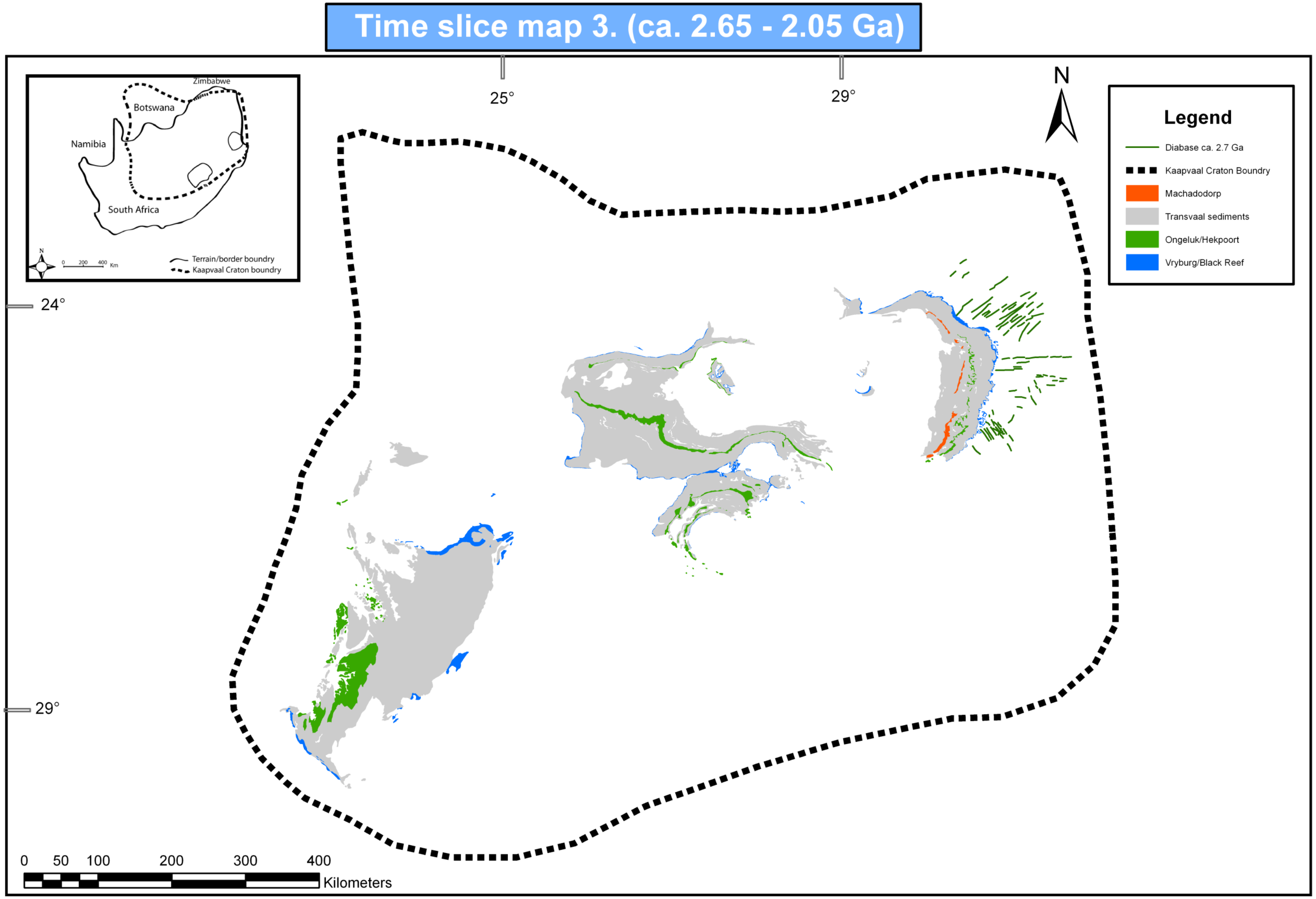

Fig. 7. Time slice map 3. showing the spatial distribution of the Transvaal Supergroup. Compare spatial distribution of the Dennilton/Godwan groups on time slice map 2.

Table. 4. Geochronologic data of the Bushveld Complex including the Rooiberg Group. Data collected from Dateview (Eglington 2000) and Olsson et al. (2010).

Group/Formation	Lithology	Age (Ma)	Method	Reference
Rooiberg (Dullstroom)	Lavas	2101±28	Pb-Pb, Whole rock	-
Rooiberg	Lavas	2061±2	-	Walraven (1997)
Rustenburg Layered Suite		2057.7±1.6	U-Pb, Baddelyiete	Olsson et al. (2010)
Rashoop Granophyre Suites	Granophyre	2053±12	-	Coertze et al. (1978)

difficult to correlate the sequences in the middle groups with only the Ongeluk- Hekport volcanics matching in terms of lithology and age (Eriksson et al. 1993; Cornell et al. 1996).

The Machadodorp volcanics which may be stratigraphically related to the Hekpoort lava (Moore et al. 2012), have not yet been dated.

The Timeball Hill formation (2324±17 Ma) of the lower Pretoria Group hosts a minor lava termed the Bushy Bend Lava member. This member is followed by black shales which in turn are overlain by the Hekpoort formation (Eriksson 1994).

The Ongeluk- and Hekpoort formations of the Transvaal- and Griqualand West basin represent a volcanic event of major scale that took place between 2223± 13 Ma (Ongeluk) and 2184±76 Ma (Heekport) ago. These two formations are preserved in the two larger basins (Transvaal and Griqualand West basin) and match stratigraphically, although situated in separate basins, and are made up of basaltic lavas (Cornell et al. 1996). The Hekpoort- Ongeluk volcanics are interpreted as a product of mantle plume activity resulting in the associated continental flood basalts (Oberholzer & Eriksson 2000).

Moore et al. (2001) suggests however that the correlation between the Hekpoort and Ongeluk Formations was done with uncertain age data as the different methods used by Armstrong et al. (1991) yielded a wide spread in age difference between the formations. This would suggest that the correlations between the Pretoria and Postmasburg Groups may be invalid.

The volcanics of the Ongeluk- and Hekpoort formations are overlain by sediments with a thickness of a few thousand meters which later was intruded by the Bushveld Complex (Olsson et al. 2010)

3.4 Time slice 4: 2.05–1.95 Ga

3.4.1 Bushveld Complex and Rooiberg Group (ca. 2.05- 1.95 Ga)

Geochronological data for the Bushveld Complex is presented in Table. 4.

The Bushveld Complex is situated in the north eastern part of the craton and can be divided into three separate limbs: the western-, eastern- and northern limb (see Bushveld mafic and acid on Fig. 8.).

The upper part of the Transvaal Supergroup is unconformably overlain and intruded at 2057.7±1.6 Ma ago by the Bushveld Complex with older associated Rooiberg lava at 2061±2 Ma, and the Rashoop Granophyre Suites at 2053±12 Ma (Olsson et al 2010).

According to Twist & French (1983) the original estimated volume of the Rooiberg Group exceeded 300.000 km3. Hatton & Schweitzer (1995) suggest that this group is more related to the Bushveld Complex than the previous link to the Transvaal Supergroup.

The Bushveld Complex with its associated basalt-rhyolite volcanics, mafic dykes/sills and intrusions, comprises the center of the Bushveld Large Igneous province (Cawthorn & Walraven 1998). Von Gruenewaldt et al. (1980) subdivided the Bushveld Complex into three suites based on lithology:

- The Rustenburg Layered Suite
- The Rashoop Granophyre Suite
- The Lebowa Granite Suite

The Rustenburg Layered Suite of the Complex covers an estimated area of 65,000 km2 with a varying thickness of 7-9 km making it the world's largest intrusion of layered mafic rocks (Eales & Cawthorn 1996; Schweitzer et al. 1997)

Schweitzer et al. (1997) suggest that the Rashoop Granophyre Suite and the Rooiberg Group have matching geochemical properties which could point to a common source rock. This melting of the source rocks are interpreted to be related to a mantle plume which resulted in a short-lived deposition of volcanic rocks. This was then followed by the granite intrusion of the Lebowa Granite Suite

3.5 Time slice 5: 1.95- 1.87 Ga (1.45-1.20 Ga for Pilanesberg)

3.5.1 Waterberg Group, Soutpansberg Group, Olifantshoek Supergroup and the Pilanesberg Alkaline Province (ca. 1.95-1.20 Ga)

Geochronological data for this time period is presented in Table. 5.

The sediments and volcanics of Watersberg and Soutpansberg groups is widely spread throughout the northern part of the Kaapvaal Craton occurring in northern South Africa and extends into parts of Botswana. The Olifantshoek sediments and volcanic are

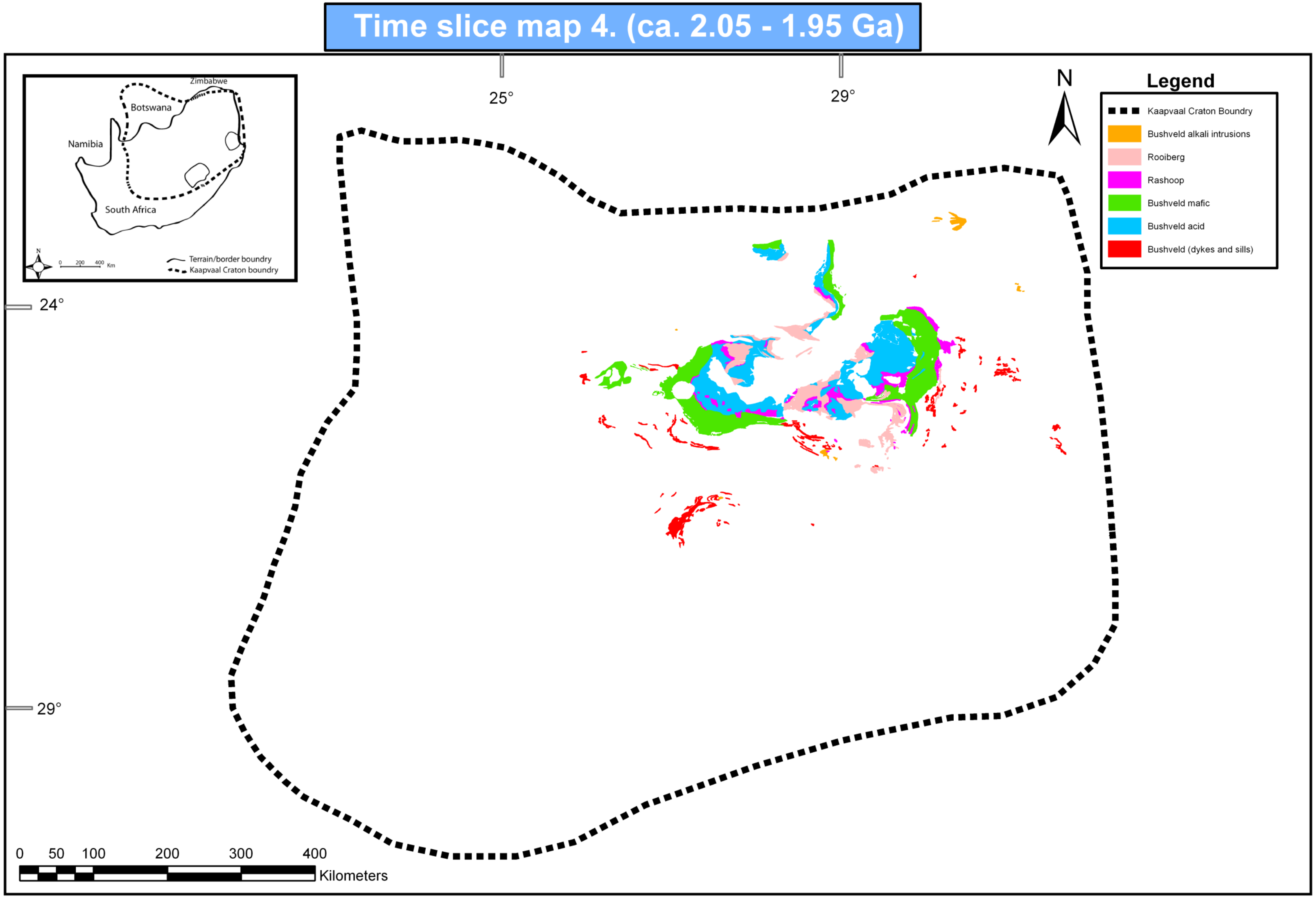

Fig. 8. Time slice map 4. showing the spatial distribution of the Bushveld Complex.

Table. 5. Geochronologic data of the Watersburg- Soutpansberg Group and the Olifantshoek Supergroup and the Pilanesberg Alkaline Province. Data collected from Johnson et al. (2006) and Cornell et al. (1998)

Group/Formation	Lithology	Age (Ma)	Method	Reference
Soutpansberg (Sibasa Formation)	Basalt	1769±34	Rb-Sr, Whole rock	Barton (1979)
Soutpansberg	-	2025±25	-	Unpublished palaeomagnetic work (D. Jones and A. Reid, University of Zibabwe)
-	Dolerite sill	Ca. 1880	U-Pb (radiogenic) Baddelyite	Hanson et al. (2004)
Olifantshoek (Hartley)	Basalt	1893±48	Rb-Sr, Pb-Pb, Whole rock	Armstrong (1987)
Olifantshoek (Hartley)	Basalt	1928±4	U-Pb (radiogenic) Zircon (evaporate)	Cornell et al. (1998)

found along the south western margin, and are thought to be coeval. The younger Pilanesberg Alkaline Province also occurs as scattered circular forms in the northern and towards the center of the craton, but formed much later (see Fig. 9.)

The predominantly sedimentary Waterberg Group is found in the northern parts of the Kaapvaal Craton where it is deposited unconformably on parts of the Bushveld Complex, the Transvaal Supergroup and the older Archean granites and gneisses. The sediments and minor volcanics are preserved in two separate basins called the Warmbaths Basin, (which is further divided into the Nylstroom Protobasin and the Main Basin) and the Middelburg Basin (Callaghan et al. 1991; Eriksson et al. 2006).

The volcano- sedimentary Soutpansberg Group situated in the northeastern part of the craton where it is partially overlain by younger sediments and volcanics of the Karoo Supergroup. These groups together with the Blouberg Formation was deposited during a time in Earth history when an increase in oxygen in the atmosphere resulted in the formation of "red beds", which are common in these sediments (Johnson et al. 2006)

The tectonic environment in which this group was emplaced has been debated with theories circling around whether a rift- associated depositional environment is correct or not (Barker 1979; Cheney et al. 1990))

The volcanics of the lower Soutpansberg Group have been altered due to hydrothermal activity making age constrains for these formations difficult to obtain as geochronological studies reflect the timing of these fluids e.g. (Barton 1979). Cheney et al. (1990) constrained the lower part of the Soutspanberg Group to an emplacement age between ca. 1974 Ma and 1800 Ma. These rocks are correlated to the basal units of the Waterberg Group (Barker 1979)

However, baddeleyite crystallization ages for dolerite sills (ca 1880 Ma) intruding the Waterberg Sequence obtained by Hansson et al. (2004) suggests that the Waterberg Group predates the Soutpansberg Group. This together with the stratigraphic relationship between the two groups occurring in the Blouberg Mountain area could suggest that the Soutpanberg Group is younger than the intrusion of the dolerite sills thus retracting the previous correlation between the groups (Johnson et al. 2006). Dolerite dykes intruding along NE-trends were emplaced on the NE Kaapvaal Craton in the area, and reflect ages of ca. 1.87 Ga (Olsson, 2012).

The Olifantshoek Supergroup, occurring in the south western parts of the Kaapvaal Craton (see Fig. 9.) comprises a succession of sandstone, interbedded shale and lava which unconformably overlie sediments of the Transvaal Supergroup. The sediments were deposited in a fluvial environment with fault controlled subsidence as a result of rifting (Cornell et al.1998; Johnson et al. 2006).

The volcanic rocks of the Olifantshoek Supergroup are confined to the basalt of the Harley Formation occurring in the lower parts of the stratigraphy (Cornell et al. 1998). Geochronological studies performed by Armstrong (1987) and Cornell et al. (1998) yielded the ages 1893±48 Ma, respectively 1928±4 Ma for the Hartley basalt.

Finally, the Pilanesberg Alkaline Intrusion occurred during a relatively tectonically stable period of the Kaapvaal Craton between 1450 Ma and 1200 Ma and consists of a wide variety of alkaline rocks (Johnsson et al. 2006). The most prominent of these intrusions is the circular Pilanesberg Complex which is situated in within the eastern limb of the Bushveld Complex (compare Fig. 8 and 9.). The rocks of this intrusion were probably emplaced during several volcanic events, although the presence of plutonic rocks suggests a series of different events. The formation of alkaline intrusions such as the Pilanesberg Complex have long since been debated and disputed because of their complex lithologies (Johnson et al. 2006).

3.6 Time slice 6: ca. 1.1 Ga

3.6.1 Umkondo Igneous Province (ca 1106-1112

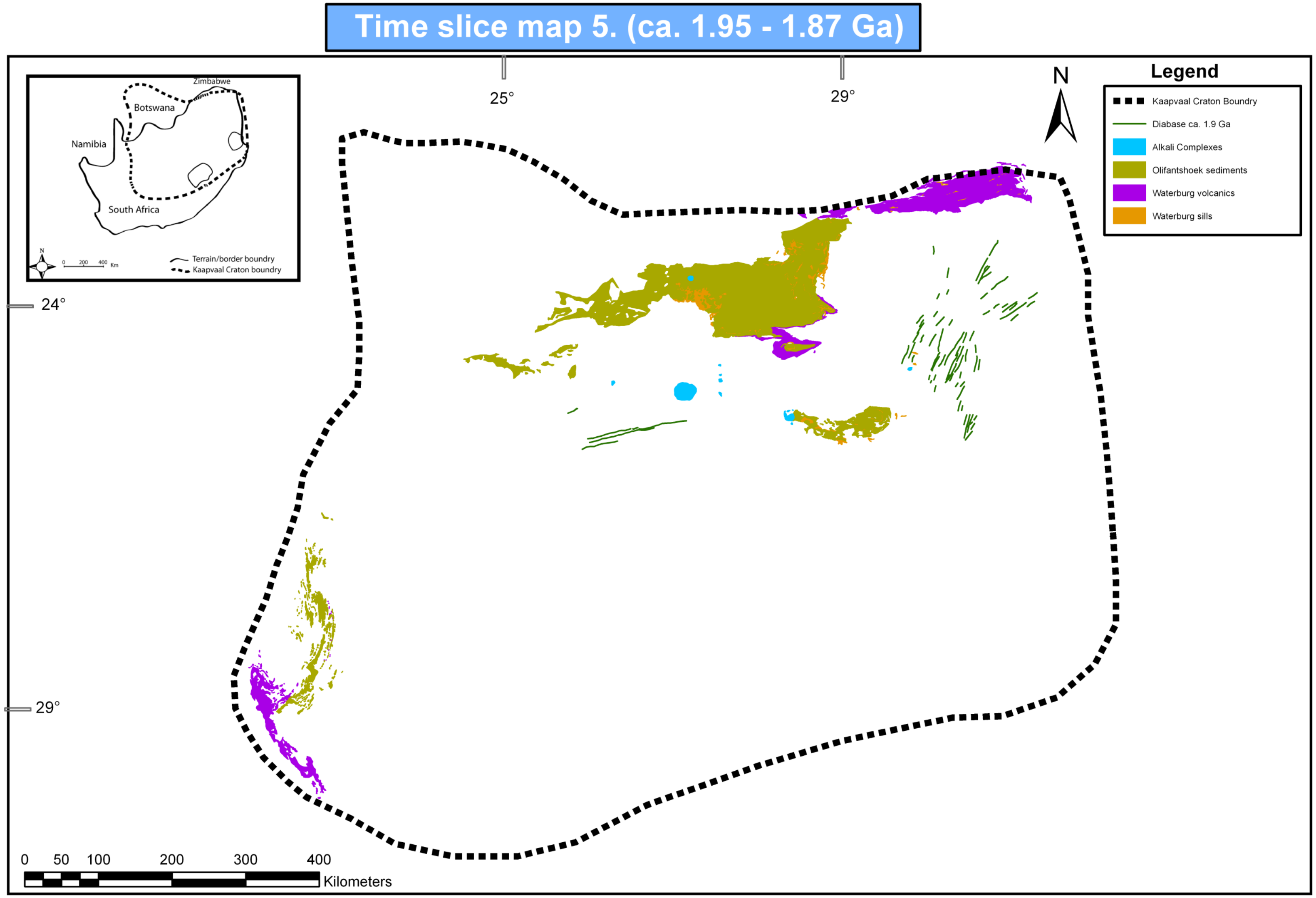

Fig. 9. Time slice map 5. showing the spatial distribution of the Watersberg Group, the Olifanshoek Supergroup and the Pilanesberg Alkaline intrusions. Note that the Alkaline intrusions do not occur until ca. 1200 to 1450 Ma.

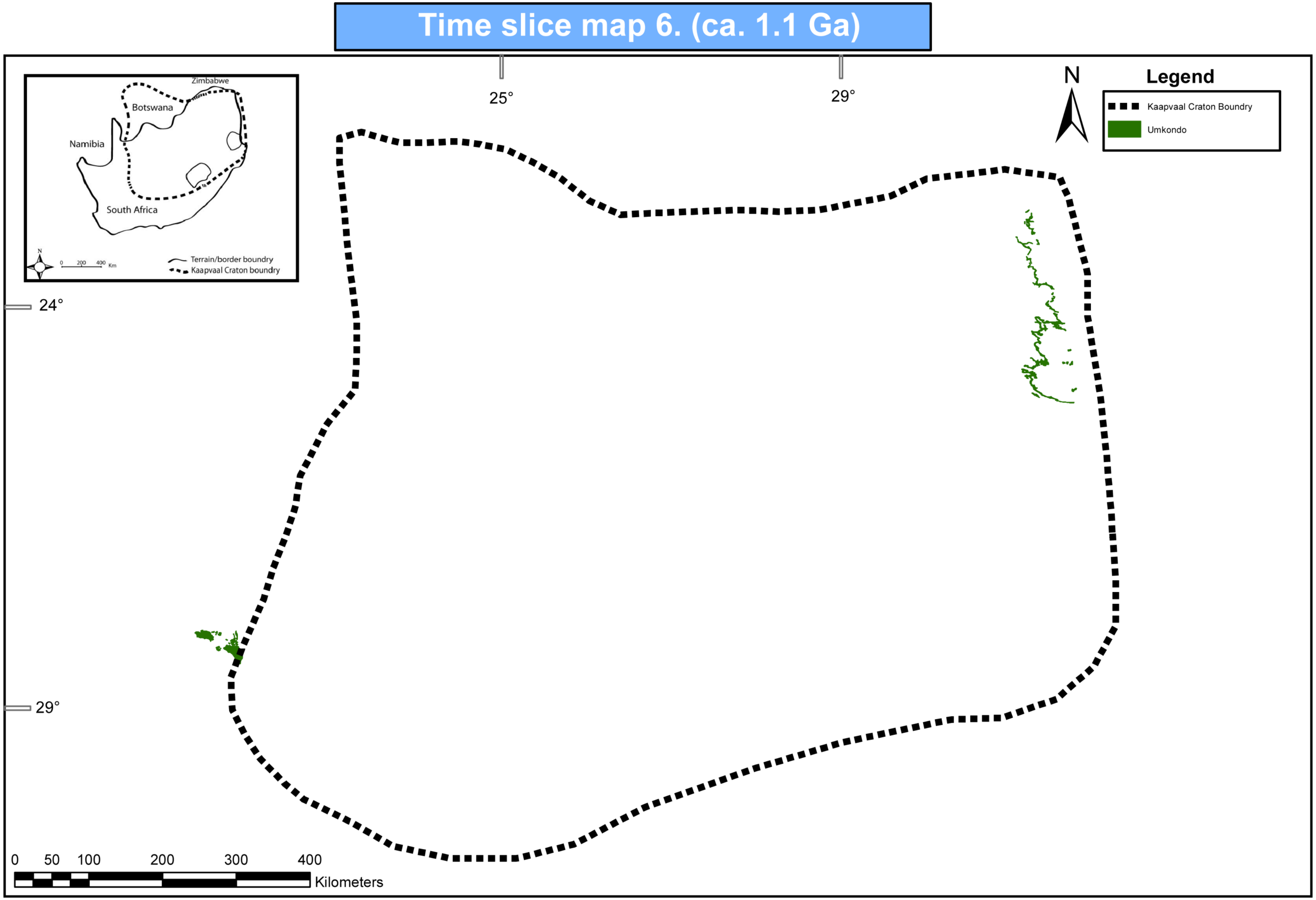

Fig. 10. Time slice map 6. showing the spatial distribution of the Timbavati Gabbro of the Umkondo Igneous Province.

Ma)

The extensive dolerite sills of the Umkondo Igneouse province where emplaced during a large scale magmatism event that occurred between 1106 Ma and 1112 Ma ago (Johnsson et al. 2006).

These dolerite sills of the Umkondo Group extends through eastern Zimbabwe, south to the eastern margins of the Kaapvaal Craton where it is known as the Timbavati Gabbro (see Fig. 10.).

The geocronological data published by Burger and Walraven (1979, 1980) yielded and age from 1072±4 Ma to 1123±5 Ma, which together with palaeomagenetic studies performed by Hargraves et al. (1994) suggested the connection and coeval relationship between the Umkondo igneous Province in Zimbabwe and the Timbavati Gabbro in South Africa.

Other intrusions of dykes and sills believed to be related to the Umkondo Igneous event are the Anna's Rust Gabbro, the Vredefort Mafic Complex and the Greenland Formation. These are all occurring within the vicinity of the Vredefort dome. Although the Greenland Formation and its associated dykes and sills is yet to be dated, similarities to the Anna Rust Gabbros, in geochemical and petrological attributes suggests a close link to the Umkondo Igneous event (Reimold et al. 2000; Johnsson et al. 2006)

5 Discussion

4.1 Time slice 1

Summarizing the spatial and temporal links through arcGIS and geochronology, it becomes apparent that further age dating is required on both the Dominion, Witwatersrand and Pongola supergroups.

The Dominion Group hosts just one age, and needs further verification to rule out the possibility that this age is biased due to the presence of xenocrystic zircon in the sample dated. Additional ages in the greater Pongola basin could confirm if there is any link or not between these two groups, particulary in the Dominion-Nsuze era (see Fig. 5.).

Ages within the Pongola basin are constrained only to the Hartland area of the central Pongola sub-basin. Ages in the other sub-basins will enable us to establish their continuity across the greater basin for stratigraphic comparison. Complimented by studies of the lavas at different height intervals will also allow for a greater spread in ages, and also to further validate stratigraphic connections based on this.

Beukes & Cairncross (1991) suggest a possible correlation between the Mozaan Group and the Crown lava of the West Rand Group of the Witwatersrand Supergroup. The Crown and Bird lava of the Witwatersrand supergroup, and the Tobolsk and Gabela lavas of the Mozaan group could with further dating validate this correlation.

In addition, the presence of mafic dykes and sills, (see Fig. 5.) into the basement or these successions can provide additional correlations, and can further validate the lava ages. Such studies were highlighted on the Badplaas dyke swarm and the Usushwana Complex (Olsson et al. 2010; Olsson, 2012)

4.2 Time Slice 2

The geochronological dating of the Ventersdorp Supergroup is associated with several uncertainties which make correlations of several units problematic.

The correlation between the Platberg Group and the Hartswater Group done by Armstrong et al. (1991), was based on lithological comparisions, although the 2709±4 age for the Platberg at and the 2744.4±3.4 Ma on the Hartswater (de Kock et al. 2012) do not match.

The Klipriviersberg Group was previously considered as the lower most unit of the Ventersdorp Supergroup. This group was dated at 2714±8 using U-Pb on zircon by Armstrong et. al (1991). This age still makes this group considerably younger than the lithologically correlateable Hartwater Group.

Wingate (1998) also argued that the Klipriviersberg age produced by Armstrong et al. (1991) might be incorrect due to the significant age difference on the otherwise stratigraphically associated Derdepoort basalt. This is further acknowledged by (de Kock et al. 2012) with their recent dating of the Hartswater Group. The basal unit of the Ventersdorp Supergroup might consist of the much older Dredepoort basalts at 2782±5 Ma rather than the Klipriviersberg Group (Wingate 1998)

Further dating of the Klipriviersberg Group is required to rule out these uncertainties concerning correlations. The Pniel Sequence and the Allanridge formations are also need to be dated to confirm or discard the correlation between the Allanridge lavas and the Rykoppies dyke swarm.

The period between upper Ventersdorp and lower Transvaal still uncertain due to insufficient geochronological data. This is evident with the presently unkown stratigraphic relationship between the proto-basinal fills of the Dennilton, Wolberg and Godwan group.

According to Olsson et al. (2010) and references therein state that the Rykoppies dykes and Allanridge lavas might coincide with the transition from the volcanic period of the Ventersdorp Supergroup to the sedimentary depositions in the Transvaal Supergroup.

4.3 Time slice 3

The proto-basinal fills of the Dennilton, Wolberg and Godwan group occur in the transitional phase of Ventersdorp volcanism to the onset of sedimentary deposition of the Transvaal Supergroup. Whether these groups falls in the Ventersdorp- or Transvaal Supergroup is uncertain. The distribution of these groups would suggest a closer link to the Transvaal Supergroup than the Ventersdorp Supergroup (compare the spatial relationship between the Dennilton/Godwan and the Ventersdorp –Transvaal Supergroups on time slice maps 2 and 3).

Olsson et al. (2010) highlighted the similarity in ages for the Rykoppies Dyke Swarm (2660-2685 Ma) and these protobasinal fills (2657-2659 Ma including the 2664 Ma Buffelsfontein group). However, this correlation is uncertain until further validated.

While the lower sequences are comparable in both basins of the Transvaal Supergroup by lithologies and ages, the middle and upper parts of the Transvaal Supergroup yields no correlations between the separate basins other than the Ongeluk/Hekpoort volcanic event. As even this correlation might be invalid (eg Moore et al. 2001), these volcanics need additional geochronological dating. Moore et al. (2001) propose new correlations in the Transvaal Supergroup where the Ongeluk Formation is considered to correlate to the middle Chuniespoort Group while the Hekpoort Formation belongs to the younger Pretoria Group.

Cornell et al. (1996) also recognizes that these ages are uncertain as the volcanics could have been subject to alteration resulting in a disturbed isotope system.

More recent baddeleyite U-Pb dating of the Westerberg sill performed by (Kampmann 2012) gives an age of 2442±5 Ma which might prove to be a correlative age to the suggested older age of the Ongeluk Formation. This age could fill a gap in the Kaapvaal Geochronological stratigraphy and could suggest a correlation with the onset of worldwide great oxygenation event and related tectonic activity.

The Machadodorp Volcanic Member is one of only three volcanic units present in the Transvaal Supergroup and has not yet been dated (Lenhardt et al. 2012). Studies of this member might shed additional light on the dynamics of the Transvaal volcanics.

4.4 Time slice 4

The time duration of which the Bushveld Complex crystallized is debated (eg, (Cawthorn & Walraven 1998). A consensus is that the magmatism was short-lived although age constraints of the Bushveld event are still uncertain. Olsson et al. (2010) have provided an age of 2057 Ma for the onset of the Bushveld magmatic emplacement although further geochronologic data is needed to constrain the actual period of emplacement, especially between the different limbs.

The eastern and western limb show similarities in their mafic sequences and can therefore be correlated. (Cawthorn & Webb 2001) suggests that the mafic rocks of the Bushveld Complex continues at depth in the central parts connecting the both limbs (see time slice map 4. for limb distribution). However, a lithological difference in the northern limb makes the connection and correlation to the eastern and western limbs more difficult. Age constraints on the dolerite dykes from the Bushveld Complex also need to be validated in order to test the greater extent of Bushveld- related magmatism.

4.5 Time slice 5

As Cornell et al. (1998) states, the scarcity of representative geochronological data of the Watersberg-Soutpansberg and Olifantshoek basins makes correlations within this period difficult. New data, such as the baddelyiete ages of the intrusive dolerite sills and dykes in the Waterberg area obtained by Hanson et al. (2004) and Olsson (2012), can help resolve these problems with the stratigraphical records of the groups.

The economic importance of copper and iron ore deposits within these groups may further fuel the interests in a more complete understanding of the nature of the tectonic environment during this time period.

The origin of the different rocks included in the later occurring alkaline intrusions such as the Pilanesberg Complex has not yet been established. More studies are needed to understand the origin of the different rocks associated with these intrusions, and further, a precise age.

4.6 Time slice 6

The association of the intrusive units of the Anna's Rust Gabbro, the Vredefort Mafic Complex and the Greenland Formation to the Umkondo Igneous Province is considered to be correct. However, the connection with the Greenland Formation should be further strengthened by providing an age for the formation. Further age dating in areas where the Umkondo does not occur could also assist in resolving the complete, extent of the Umkondo Igneous Province.

4.7 Kaapvaal Craton barcode

The barcode map (Fig. 11.) shows that the Kaapvaal Craton has undergone periods of more extensive volcanism as well as less active periods. Söderlund et al. (2010) created barcode maps for the Zimbabwe and Kaapvaal cratons, as well as other Archean cratons. The correlative ages on the Kaapvaal Craton are relatively sparse, however. As new data emerges a more detailed barcode can be made.

Most of the intrusions and volcanic events on the Kaapvaal Craton occurred during the time up until ca. 2.6 Ga, which this older barcode does not illustrate. Additional correlations might be possible with these older formations such as a correlation between the Hlagothi Complex and the Millindinna Complex and the Zebra Hill dykes on the Pilbara craton in Australia which is discussed in Gumsley et al. (2013). In addition, there is now also a correlation to be made at 2.4 Ga. with the Westerberg sill, and also possinly 2.2 Ga, if the ages of the Ongeluk-Hekpoort are indeed correct (Gumsley. 2014 pers. comm.)

The Kaapvaal Craton barcode show a period of extensive magmatic events between ~ 2980 Ma and 2642 Ma after which the activity decreases and the craton experience greater sedimentation. There are, however a few events during this period which are uncertain. The period of the middle to upper Transvaal has very few dated events with the Ongeluk/Hekpoort age being uncertain. The new addition of the ca. 2.4

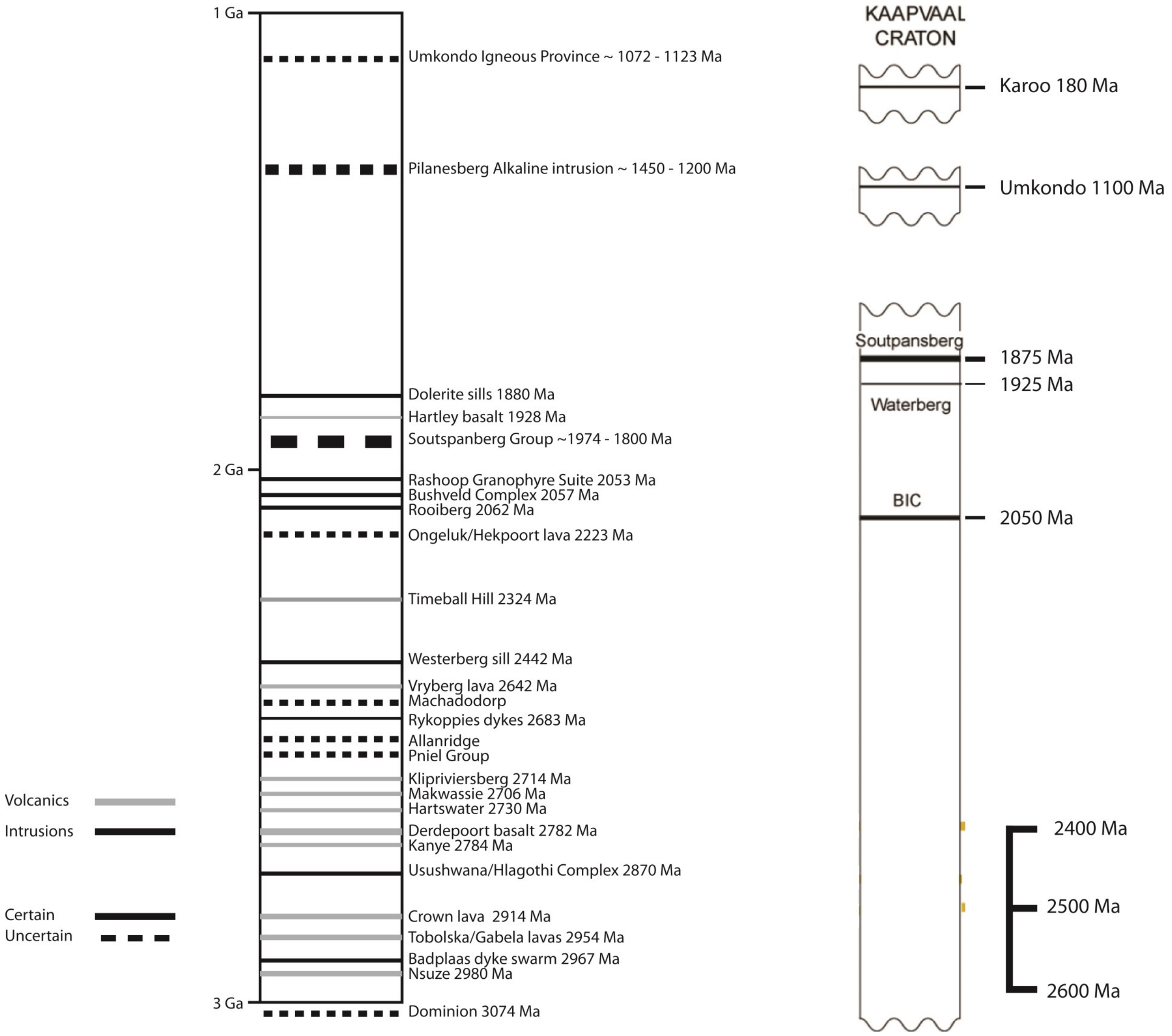

Fig. 11. The magmatic barcode for the Kaapvaal Craton showing the ages of volcanics and intrusions (to the left). The barcode to the right made by Söderlund et al. (2010) represent volcanic and intrusive rock ages for the Kaapvaal Craton that correlates to other Archean cratons. The barcode on the right side is modified from (Söderlund et al. 2010).

Ga Westerberg sill provides an age in an otherwise less eventful time period. There is also a need to resolve the transition between the Venterdorp and Transvaal regimes.

An increase in magmatic activity occurred ca. 2 Ga associated with the intrusion of the Bushveld Complex. These intrusions are considered to have been emplaced at very short durations leaving a gap between the Bushveld Complex and the following Soutpansberg Group. However, this group must be considered uncertain due to the scarcity of reliable data, particulary on the satellite intrusions, as well as on the Soutpansberg.

After the emplacement of the Waterberg/ Olifanshoek volcanics, no volcanic or intrusive events took place until the onset of the Pilanesberg Alkaline intrusions creating the great gap in age data shown in the upper part of the barcode (see Fig. 11.). The ages for the Pilanesberg event ranges from ~ 1450 to 1200 Ma which creates an uncertainty for the time of emplacement of these formations. The next record of magmatic activity did not occur until 1.1 Ga with the onset of the extensive Umkondo Igneous Province. The decrease of magmatic activity in the in the upper part of the barcode is considered to be a result of the tectonic stable phase that the craton experienced during this time period.

5 Summary

Today, the Kaapvaal Craton is considered a stable craton illustrating an almost complete Mesoarchean to Palaeoproterozoic stratigraphy. During the history of the craton, a series of tectonic and igneous events have formed the crustal architecture that is visible today.

The time slice maps created in this work, together with the barcode and literary description of the Kaapvaal Craton provides an overview of these events. This study also highlights the need of additional datings to resolve the timing of evolution. Geochronologic data is essential to understand the relationship between units at all levels (supergroups, groups and formations).

The time slice maps give a valuable perspective on the spatial relationship between different units. Combined with additional geochronologic data this becomes a useful tool for further studies and could yield a more complete understanding of the Kaapvaal Craton history. A more complete barcode for the Kaapvaal Craton could yield additional correlations to other cratons such, as the Pilbara Craton in Australia. Such data can then be used for palaeocontinental reconstruction and prove the existence of Valbaara.

6 Acknowledgements

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