# Chapter 5

# A Precise Zircon SHRIMP Age for the Post-Tectonic Entabeni Granite of the Limpopo Metamorphic Belt: Implications for the Age of the Soutpansberg Group.

## 5.1 Introduction

The Entabeni Granite is an unfoliated granite that intrudes the central zone of the Limpopo Belt (Fig 5.1)(Barton et al., 1995). This granite is unconformably overlain by red beds and basaltic volcanic rocks of the Soutpansberg Group (Fig 5.1). The relative age of the Soutpansberg and Waterberg Groups has long been a matter of debate (Cheney et al., 1990; Bumby, 2000). During this study, two precise U-Pb zircon ages of ca. 2053Ma were obtained for quartz porphyry lava flows within the Lower Waterberg Group (chapter 4). Whole rock Rb-Sr ages of 1749±104Ma and 1769±34Ma for hydrothermally altered lava flows and sills from the Sibasa Formation (Barton, 1979) and a Pb-Pb whole-rock age that define an imprecise secondary isochron of 1809 +263/-317Ma for the same samples (Cheney et al., 1990) are the only available geochronological data for the Soutpansberg Group. It would thus appear, as if the basal part of the Soutpansberg Group is younger than the lower part of the Waterberg Group. However, because of the poor quality of the geochronological data available for the Soutpansberg Group, it was decided to obtain a precise age on the Entabeni granite, to provide an accurate maximum age limit for the Soutpansberg Group that unconformably rests on the Entabeni Granite.

Earlier work on the Entabeni granite yielded a discordant (35%) $^{207}Pb/^{206}Pb$ zircon age of 1957±3Ma (Barton et al., 1995). During this study it was attempted to obtain a precise zircon SHRIMP age for the Entabeni granite, enabling differentiation between the relative ages of the Soutpansberg and Waterberg Groups.

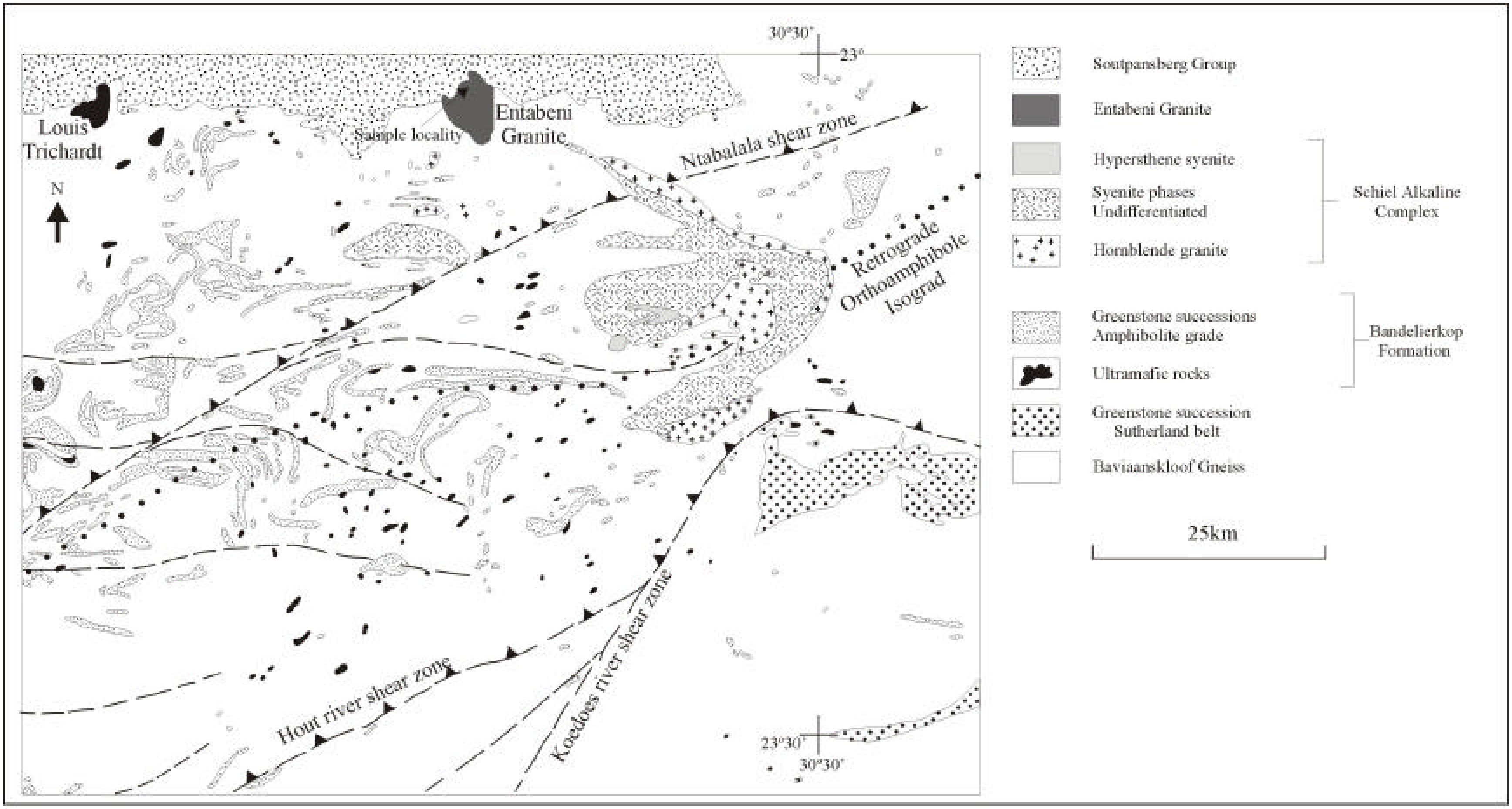

**Figure 5.1** Map indicating the outcrop area of the Entabeni Granite (modified after Barton et al., 1995).

## 5.2 Geological and Geochronological Constraints

The Limpopo mobile belt, with which the Entabeni granite is associated (Fig 5.1), is situated between the Archean Kaapvaal (De Wit et al., 1992) and Zimbabwe (Kusky, 1998) cratons. The belt is represented by an approximately 250 km wide ENE trending granulite facies terrane (Van Reenen et al., 1992) subdivided in a Northern Marginal Zone (NMZ), Central Zone (CZ) and Southern Marginal Zone (SMZ)(Fig 5.2). Peak granulite facies metamorphism reached 850°C at 9kbar in the SMZ of the Limpopo Belt (Van Reenen et al., 1987). The Hout River Shear zone forms the border between the SMZ and the Kaapvaal craton to the south. The Palala shear zone defines the boundary between the SMZ and the CZ to the north. Further to the north the Triangle shear zone forms the boundary between the CZ and NMZ (Fig 5.2). The Umlali shear zone is the border between the NMZ and Zimbabwe craton (McCourt and Vearncombe, 1992, Kamber et al., 1995). The structure and metamorphism of the Limpopo belt suggests that it may have formed in a similar tectonic setting to the modern day Himalaya Orogen (Treloar et al., 1992).

Aeromagnetic maps indicate the presence of a large arcuate structure along the northern and western margins of the Zimbabwe craton (Fig 5.2) that represents the ca. 2.0Ga Magondi Belt (Hilliard, 1999). Apparently, this structure continues around the southern boundary of the Zimbabwe craton into the Limpopo Belt (Fig 5.2). However, there is marked difference in the magnetic signature along the southern boundary of the Zimbawe craton, in the main outcrop area of the Limpopo belt, when compared to the structure along the northern and western boundaries of the Zimbawe craton, which include the westernmost extent of the CZ of the Limpopo Belt (Fig 5.2).

The Entabeni granite intrudes the CZ of the Limpopo metamorphic belt north of the Ntabalala shear zone, which in turn is thought to be the eastern continuation of the Palala shear zone (Fig 5.1). The Entabeni granite is a small, undeformed, peraluminous two mica, alkali granite. Previous studies have suggested an anorogenic origin for this granite (Du Toit, 1979; Barton et al., 1995). Previously, the Entabeni granite was reported to have a discordant (more than 35% discordant) zircon U-Pb age of 1957±3Ma (Barton et

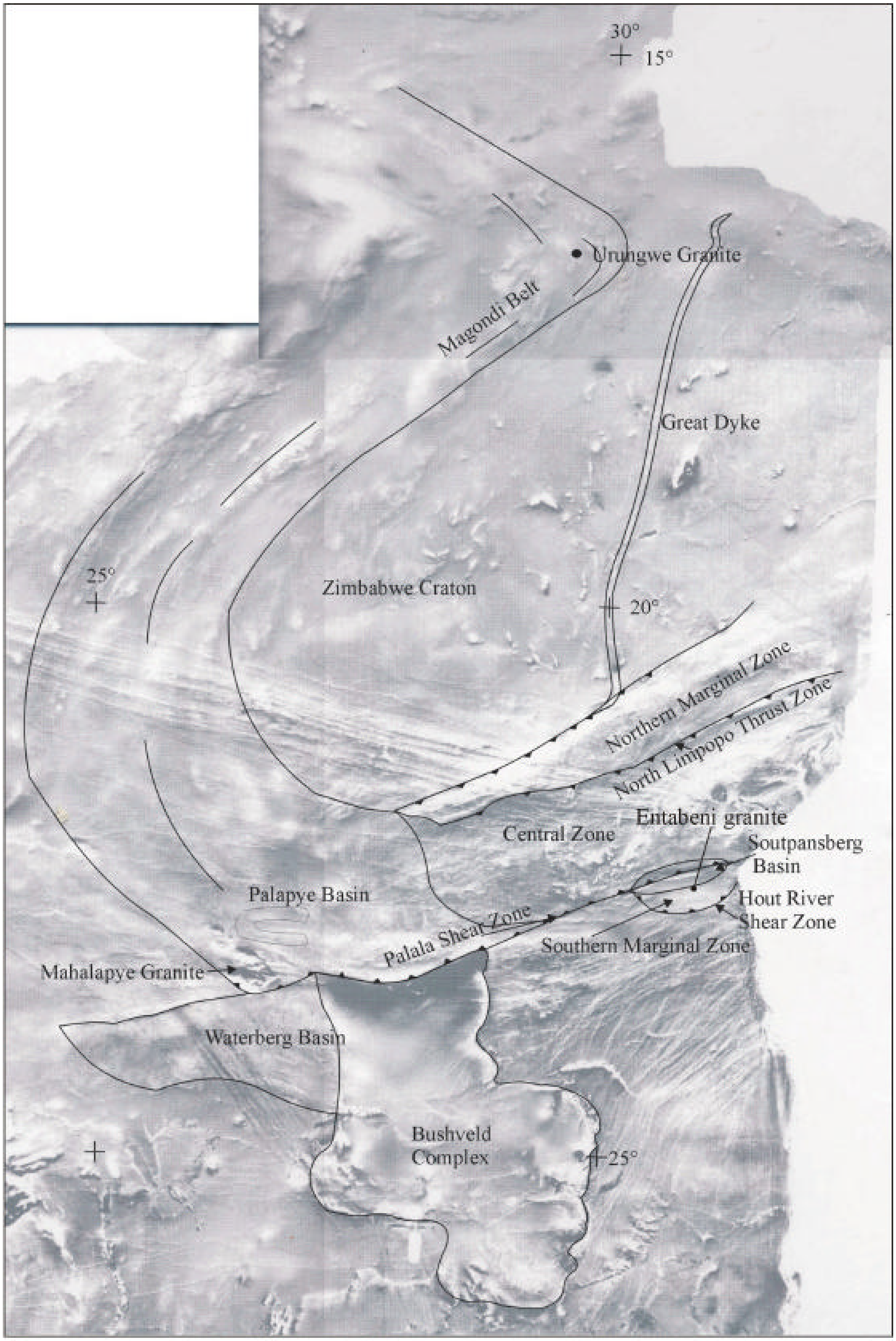

**Figure5.2.** Aeromagnetic map indicating the Zimbawe craton, Limpopo Belt and northern part of the Kaapvaal craton. Note the position of the Entabeni granite. Modified from De Beers (1998).

al., 1995). For this study, the Entabeni granite was sampled in a fresh road cut at 23°02'11.9"S; 30°13'02.4"E near the Timbadola saw mill (Fig 5.1).

## 5.3 Zircon geochronology

The zircon grains of the Entabeni granite are mostly elongated, euhedral and display homogenous as well as oscillatory zoned internal structures (Fig 5.3). One of the grains was more than 500micron in length (Fig 5.3). Eighteen analyses were performed on 16 different grains (Table 5.1). Core and rim ages for the two grains that were analysed in two spots are within error of one another (Table 5.1). Most of the grains have an U content of 200-400ppm, unlike the grains that were analysed by Barton et al. (1995) that were reported to contain more than 800ppm of U. Of the 18 analyses, 16 yielded nearly concordant (within 6% discordancy) ages. In combination they give a precise $^{207}$Pb/$^{206}$Pb age of 2021±5Ma (Table 5.1, Fig 5.4). This is regarded as the best estimate for the crystallization age of the Entabeni Granite.

## 5.4 Discussion

A precise crystallization age of 2021±5Ma for the Entabeni granite provides a maximum age for the unconformably overlying Soutpansberg Group. This is an important finding because it illustrates that the basal Tshifhefhe Formation of the Soutpansberg Group (Fig 5.5)(SACS, 1980) is at least 35Ma younger than the lower part of the Waterberg Group (Fig 5.5). Quartz porphyritic lavas in the lower Swaershoek Formation of the Waterberg Group yielded ages of 2054±4Ma and 2051±8Ma (see Chapter 4, this thesis). Earlier whole rock Rb-Sr ages of 1749±104Ma and 1769±34Ma for hydrothermally altered lava flows and sills from the Sibasa Formation (Fig 5.5)(Barton, 1979) and Pb-Pb whole-rock data age 1809 +263/-317Ma for the same lava samples (Cheney et al., 1990) thus most probably correctly estimate post-depositional alteration of the rocks. Ages similar to those of the Sibasa Formation have been reported for dykes intruding the Southern Mariginal Zone of the Limpopo belt and NW trending dykes in the Barberton region. Barton (1979) reported Rb/Sr ages of 1899±107Ma and 1876±68Ma for the Sand River dykes that intrude the Southern Marginal Zones of the Limpopo belt. Layer et al. (1998) reported $^{40}$Ar/$^{39}$Ar ages of 1902±6Ma and 1876±6Ma for NW trending dykes in the

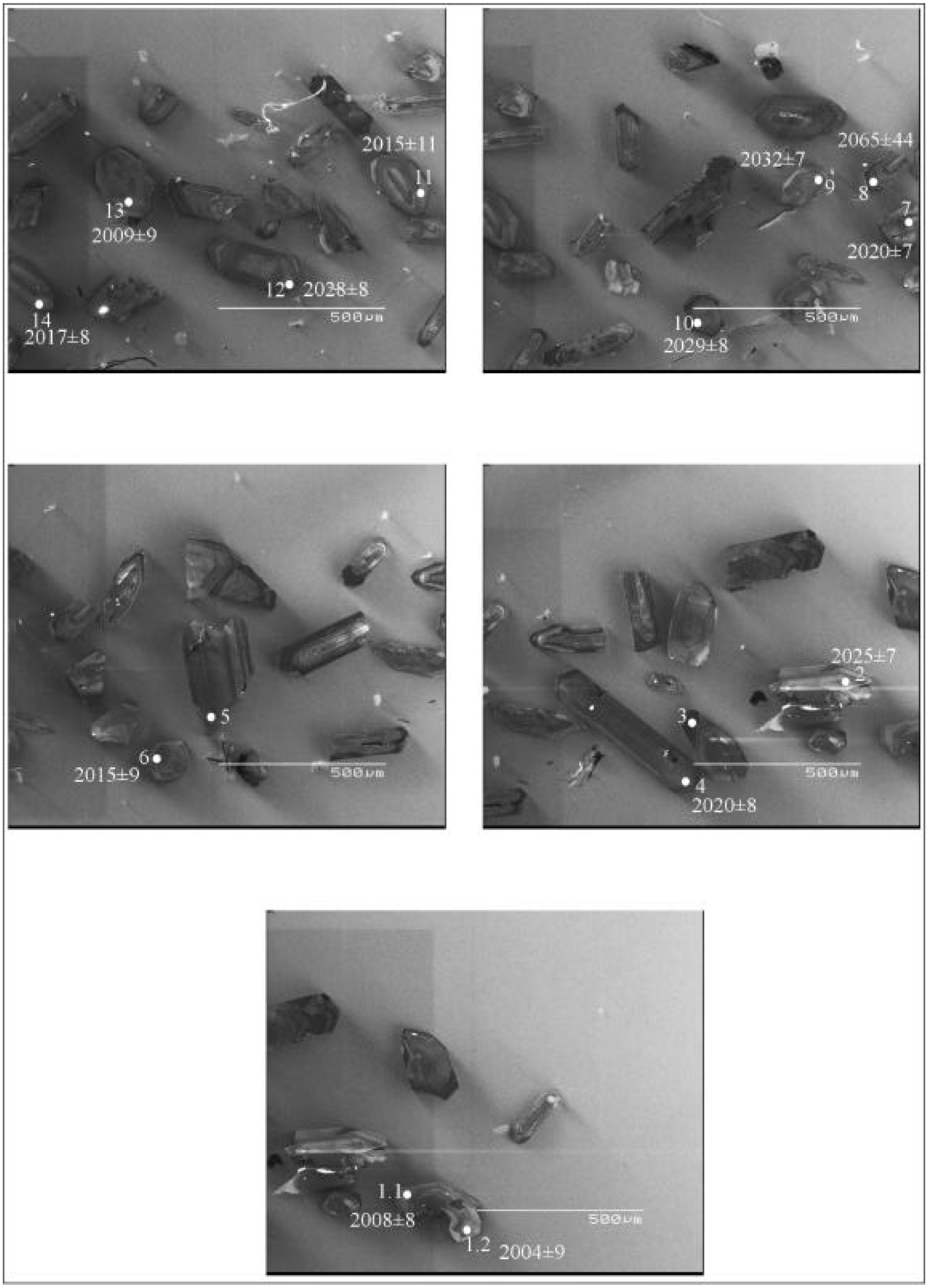

**Figure 5.3** Cathodoluminescence images of zircons from the Entabeni granite. Analysed spots and ages obtained are indicated.

**Table 5.1** Summary of SHRIMP U-Pb data for zircons from the Entabeni granite.

| Spot | (1) % $^{206}Pb_c$ | Ppm U | ppm Th | $^{232}Th/^{238}U$ | ppm $^{206}Pb*$ | (1) $^{206}Pb/^{238}U$ Age | | (1) $^{207}Pb/^{206}Pb$ Age | | % Discordant | (1) $^{207}Pb^*/^{206}Pb^*$ | ±% | (1) $^{207}Pb^*/^{235}U$ | ±% | (1) $^{206}Pb^*/^{238}U$ | ±% | errcorr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | 0.09 | 214 | 105 | 0.51 | 66.6 | 1,992 | ±20 | 2,008.3 | ± 8.2 | 1 | 0.12356 | 0.46 | 6.170 | 1.3 | 0.3621 | 1.2 | .931 |
| 1.2 | 0.09 | 244 | 125 | 0.53 | 77.7 | 2,030 | ±23 | 2,004.3 | ± 9.0 | -1 | 0.12328 | 0.51 | 6.290 | 1.4 | 0.3700 | 1.3 | .935 |
| 2.1 | 0.06 | 237 | 113 | 0.49 | 75.3 | 2,030 | ±23 | 2,024.6 | ± 7.2 | 0 | 0.12470 | 0.41 | 6.363 | 1.4 | 0.3700 | 1.3 | .956 |
| 3.1 | 10.01 | 3091 | 1029 | 0.34 | 271 | 565.7 | ± 3.2 | 1,605 | ±50 | 65 | 0.0990 | 2.7 | 1.252 | 2.7 | 0.09172 | 0.59 | .215 |
| 4.1 | 0.05 | 226 | 125 | 0.57 | 70.8 | 2,001 | ±13 | 2,020.0 | ± 7.5 | 1 | 0.12438 | 0.42 | 6.241 | 0.87 | 0.3639 | 0.76 | .873 |
| 5.1 | 8.38 | 809 | 580 | 0.74 | 241 | 1,776 | ±11 | 2,070 | ±86 | 14 | 0.1280 | 4.9 | 5.60 | 4.9 | 0.3171 | 0.74 | .150 |
| 6.1 | 0.61 | 441 | 342 | 0.80 | 130 | 1,888 | ±12 | 2,015.4 | ± 9.3 | 6 | 0.12406 | 0.53 | 5.822 | 0.92 | 0.3404 | 0.75 | .820 |
| 7.1 | 0.10 | 382 | 247 | 0.67 | 116 | 1,953 | ±13 | 2,019.8 | ± 7.0 | 3 | 0.12436 | 0.39 | 6.068 | 0.89 | 0.3539 | 0.79 | .897 |
| 8.1 | 3.45 | 325 | 176 | 0.56 | 109 | 2,063 | ±25 | 2,065 | ±44 | 0 | 0.1276 | 2.5 | 6.63 | 2.9 | 0.3771 | 1.4 | .492 |
| 9.1 | 0.01 | 335 | 205 | 0.63 | 104 | 1,987 | ±12 | 2,031.8 | ± 6.7 | 2 | 0.12521 | 0.38 | 6.234 | 0.78 | 0.3611 | 0.69 | .874 |
| 10.1 | 0.03 | 256 | 170 | 0.69 | 79.6 | 1,991 | ±12 | 2,029.2 | ± 8.1 | 2 | 0.12503 | 0.46 | 6.239 | 0.83 | 0.3619 | 0.70 | .835 |
| 11.1 | 0.71 | 341 | 300 | 0.91 | 101 | 1,902 | ±11 | 2,015 | ±11 | 6 | 0.12401 | 0.61 | 5.868 | 0.91 | 0.3432 | 0.68 | .740 |
| 12.1 | 0.16 | 394 | 254 | 0.67 | 125 | 2,021 | ±13 | 2,028.3 | ± 7.9 | 0 | 0.12496 | 0.44 | 6.345 | 0.85 | 0.3682 | 0.72 | .853 |
| 13.1 | 0.06 | 225 | 121 | 0.56 | 69.0 | 1,965 | ±15 | 2,008.6 | ± 9.0 | 2 | 0.12358 | 0.51 | 6.072 | 1.0 | 0.3564 | 0.90 | .869 |
| 14.1 | 0.04 | 243 | 138 | 0.59 | 75.5 | 1,986 | ±19 | 2,017.3 | ± 8.4 | 2 | 0.12419 | 0.47 | 6.177 | 1.2 | 0.3607 | 1.1 | .919 |
| 15.1 | 0.20 | 378 | 223 | 0.61 | 120 | 2,021 | ±16 | 2,008.1 | ± 9.5 | -1 | 0.12355 | 0.54 | 6.273 | 1.1 | 0.3683 | 0.91 | .861 |
| 15.2 | 0.17 | 290 | 163 | 0.58 | 92.0 | 2,021 | ±21 | 2,005.5 | ± 8.4 | -1 | 0.12336 | 0.47 | 6.264 | 1.3 | 0.3682 | 1.2 | .932 |
| 16.1 | 5.25 | 932 | 607 | 0.67 | 300 | 1,959 | ±11 | 1,989 | ±40 | 2 | 0.1222 | 2.2 | 5.98 | 2.3 | 0.3551 | 0.67 | .290 |

Errors are 1-sigma; $Pb_c$ and $Pb^*$ indicate the common and radiogenic portions, respectively. Error in Standard calibration was 0.61% (not included in above errors but required when comparing data from different mounts). (1) Common Pb corrected using measured $^{204}Pb$.

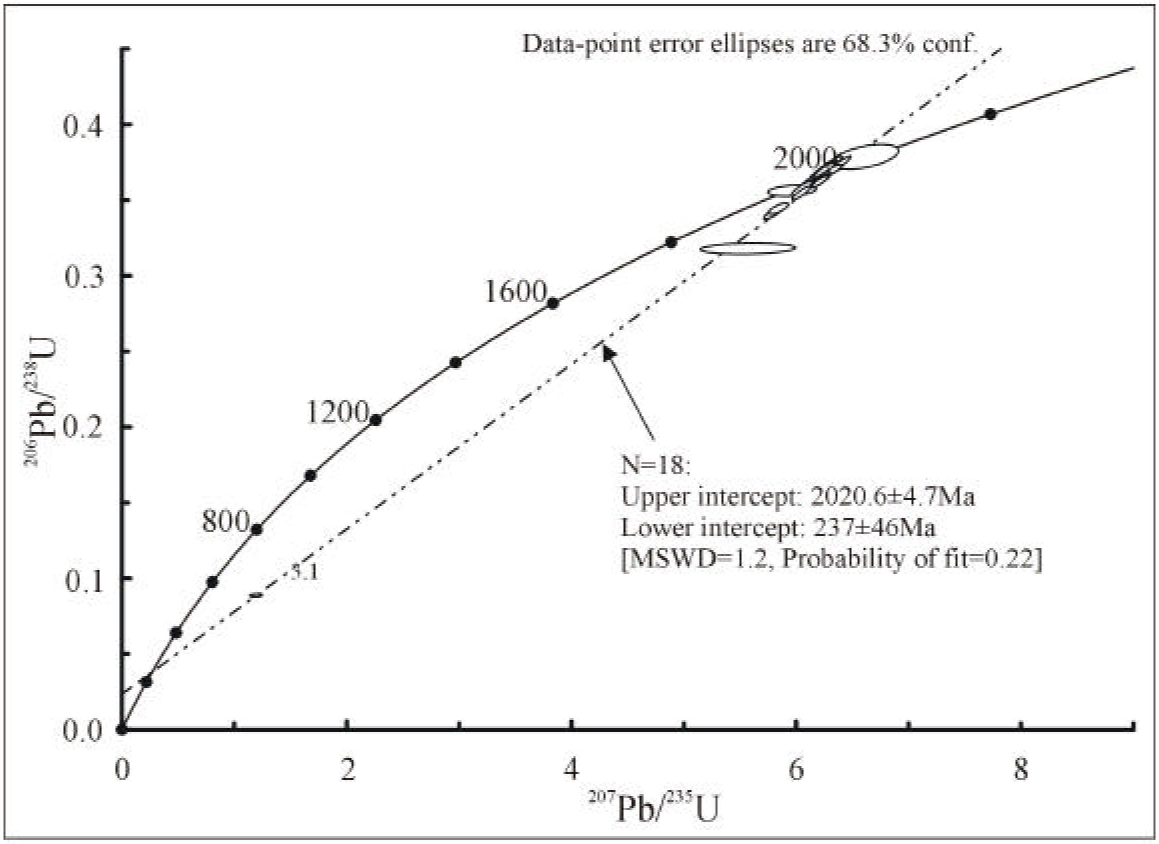

**Figure 5.4** Concordia plot for zircons from the Entabeni granite, Limpopo belt.

Barberton region. It may therefore be suggested that extrusion of the Sibasa lava may have been a widespread event on the Kaapvaal craton.

The true depositional age of the Sibasa lavas remains uncertain, but it must have taken place between 2021±5Ma and ~1749±104Ma, the timing of alteration of the Sibasa lava. The only other volcanic event known in this time period on the Kaapvaal craton is the extrusion of the Hartley lava near the base of the Olifantshoek Group (Fig 5.5)(SACS, 1980) in Griqualand West. The latter has an age of 1928±4Ma (Cornell et al., 1998). It is thus quite possible that the Sibasa lavas document the same volcanic event as the Hartley lavas (Fig 5.5).

Time-correlation of Sibasa lavas with the Hartley lavas, leaves a large time gap between the volcanic event and deposition of the unconformably overlying Wylliespoort

Formation which contains detrital zircons with ages as young as 1850Ma (see Chapter 8, this thesis)(Fig 5.5).

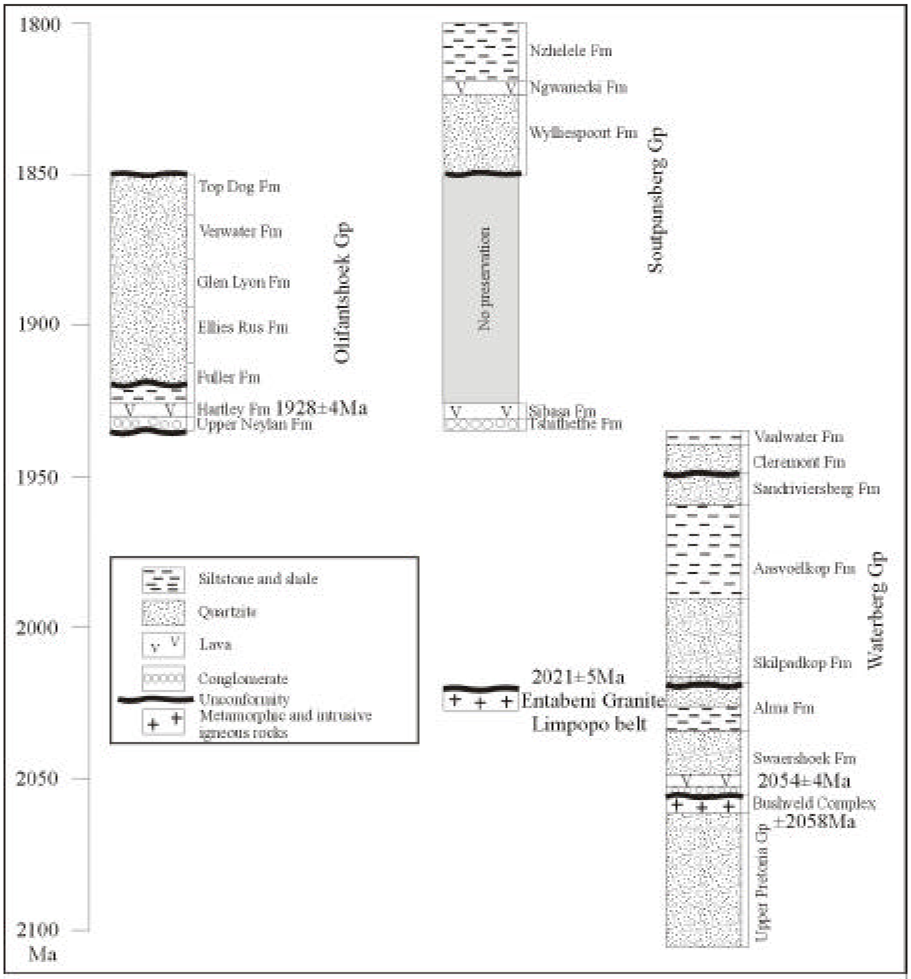

**Figure 5.5** Stratigraphic relationship of the Waterberg and Olifantshoek Groups.

With regards to its position in the Limpopo Metamorphic Belt, the $^{207}$Pb/$^{206}$Pb age of 2021±5Ma obtained for the Entabeni Granite corresponds very well to radiometric ages obtained for metamorphic minerals from the Beit Bridge complex (Holzer et al., 1998), Triangle (Kamber et al., 1995) and Palala shear zones (Holzer et al., 1999; Jaeckel et al., 1997; Holzer et al., 1998). The age of the Entabeni granite is also very similar to that of the Mahalapye granite from the CZ of the Limpopo Belt at 2024±7Ma (Fig 5.2)(Gutzmer and Beukes, 1998; McCourt and Armstrong, 1998). In combination, these ages confirm the presence of a major tectonomagmatic event took place in the Limpopo belt around 2020Ma ago.

The precise age of the Entabeni granite also has important implications for the understanding of the origin of the Limpopo metamorphic belt. Firstly, the age corresponds to ages of different major shear zones, like the Palala and Triangle shear zones, indicating that granite emplacement took place during or immediately after tectonic movement along the shear zones. Secondly, the age is not much different from ages obtained in the Magondi metamorphic belt to the west and north of the Zimbabwe craton. A SHRIMP U-Pb zircon age of 1997±3Ma was recently obtained for the syn-tectonic Urungwe granite (Fig 5.2)(Hilliard, 1999, McCourt et al., 2001) that intrudes amphibolite to granulite facies rocks of the Magondi Supergroup (Kirkpatrick, 1976; Treloar, 1988, Master, 1991; Hilliard, 1999). The latter has a poorly constrained Rb-Sr whole rock age of 2170±100Ma obtained from mafic lava in the basal Deweras Group (Treloar, 1988). Conventional U-Pb zircon ages of 1932±27 and 1960±39 for two charno-enderbites that intrude the early Proterozoic basement gneisses in the internal part of the Magondi belt (Munyanyiwa et al., 1995), are thought to represent the minimum age of the Magondi orogeny (Hilliard, 1999).

This possible synchronous tectonism and magmatism in the Magondi and Limpopo belts makes for a very interesting scenario. As mentioned in the introduction, aeromagnetic data clearly indicate continuity of structural lines from the Magondi belt into the western area of the Limpopo belt (Fig 5.2). These lines define a large arc, which could be interpreted to have formed during indentation (collision) of the Zimbabwe craton in a southwesterly direction into the northwestern part of the Kaapvaal craton at around 2000Ma (Fig 5.2). Large shear zones such as the Palala and Triangle may have formed during left lateral movement of the Zimbabwe craton relative to the northern margin of the Kaapvaal craton. In such a scenario, the northern and southern marginal zones of the Limpopo belt may represent north and south-directed thrust escape structures (Fig 5.2). Most importantly, this implies that the older (2700Ma) high grade metamorphic rocks of the Limpopo belt may only have been juxtaposed with the Kaapvaal craton during the collisional event at 2000Ma. That this block came in as part of the Zimbabwe cratonic block is also illustrated by the fact that the arcuate structural trends developed during the southwestward collision cut across the west-east grain of the CZ of the Limpopo belt and terminate against the Palala shear zone which could have been a major transcurrent fault formed during the collision (Fig 5.2).

## 5.5 Conclusions

Two very important conclusion can be drawn from the age of 2021±5Ma obtained for the Entabeni granite, namely

a)lavas of the lower part of the Soutpansberg Group are distinctly younger than the lower units of the Waterberg Group, and

b)the Entabeni granite intruded during a major tectonic event in the Limpopo belt at around 2021Ma. This corresponds in age to development of the Magondi mobile belt. Based on structural trends on the regional aeromagnetic map of southern Africa this may imply that the Zimbabwe craton collided in southwesterly directed motion with the northwestern part of the Kaapvaal craton at around 2021Ma (Fig 5.2). A consequence of this interpretation is that the Central Zone of the Limpopo Mobile Belt may only have become attached to the Kaapvaal craton at around 2.0Ga and not, as previously thought, at 2.65-2.7Ga (Fig 5.2).

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