9 TECTONO-METAMORPHIC HISTORY OF THE CENTRAL ZONE, BASED ON NEW AGE, STRUCTURAL, AND METAMORPHIC DATA.

9.1 Introduction

Previous studies in the CZ of the LB (section 7.1) have been interpreted to show that this zone suffered a *single major* tectono-metamorphic event, either in the late-Archaean or in the Paleoproterozoic. However, new age, structural and metamorphic data of the present study suggest the CZ was in fact affected by *two major* tectono-metamorphic events, in the late-Archaean and in the Paleoproterozoic, allowing, for the first time, a direct link between the evolution of specific major fold types and the two different tectono-metamorphic events.

9.2 The late-Archaean event

Structural mapping, petrologic studies and U-Pb SHRIMP zircon dating of the different structural varieties of the Singelele-type quartzo-feldspathic gneisses show that the Avoca sheath fold, located in the CZ west of Alldays (Figure 18), was emplaced as the result of a shear deformational event that documents top-to-the-NE movement of high-grade material during the late-Archaean. The different structural varieties include: (i) a penetratively foliated gneiss with a granite composition that defines the rim of the structure; (ii) a poorly foliated variety with a strongly developed lineation (L-tectonite) and trondhjemitic composition that outcrops in the central part of the fold, and (iii) a virtually undeformed variety that outcrops in the centre of the fold. Based on field relationships and petrographic characteristics, the foliated gneiss is interpreted as pre- to syn-tectonic, the L-tectonite as syn- to late-tectonic, and the undeformed variety as post-tectonic. U-Pb (SHRIMP) data for zircons from the foliated gneiss and the L-tectonite yielded ages of 2651 ± 8 Ma and 2626.8 ± 5.4 Ma respectively, not only supporting their different tectonic status, but also accurately constraining the formation of this major sheath fold to the late-Archaean. This interpretation is in agreement with Kröner et al. (1998, 1999) and Hofmann et al. (1998) who showed that the Singelele-type gneiss precursor near Musina was emplaced syntectonically during the major fabric-forming event (D_2) in the late-Archaean. The alternative interpretation, namely that all structural varieties of the quartzo-feldspathic gneisses are pre-tectonic with reference to the Paleoproterozoic event, is also not supported by the fact that the less deformed (and younger) varieties are not restricted to the core areas of major sheath folds. Relatively homogenous quartzo-feldspathic rocks in fact have been described from different areas in the

Central Zone (e.g. Pretorius, 1986, 1993). A good example includes the homogenous garnet-bearing leucocratic variety with disoriented rafts of metapelitic gneiss that outcrop next to the road, and close to the hunting camp on the farm Macuville, WNW of the well-known Three Sisters locality on the farm Boston.

A study of U and Th anomalies in the LC by Andreoli et al. (2003) showed that the high radiogenic signature of the CZ is directly related to the Grey Gneiss Unit and the Singelele-type gneisses, while the Bulai Pluton show no evidence for U and Th enrichment. The late-Archaean Limpopo Orogeny is thus characterized by a distinct geochemical signature of regional enrichment in U and Th that is restricted to the CZ and the NMZ (Kramers et al., 2001) while the SMZ shows no such signature. The suggestion (this study) that peak metamorphism in the CZ in fact occurred in the late-Archaean is further supported by evidence for wide-spread anatexis that accompanied the emplacement of precursors to Singelele-type gneisses throughout the CZ (Bahnemann, 1973; Hofmann et al., 1998; Holzer et al., 1998). The Paleoproterozoic event, in contrast, was not accompanied by significant anatexis.

It can thus be concluded that the CZ experienced a major high-grade fabric-forming event accompanied by peak metamorphism and by granitic magmatism that is reflected by an abnormally high radiogenic signature. The development of large-scale sheath fold formation during this event is related to top-to-the-north exhumation of the high-grade rocks in the late-Archaean.

9.3 The Paleoproterozoic event

A detailed metamorphic study of metapelitic gneisses from the Baklykraal cross fold located west of Alldays in the CZ, identified a single generation of garnets in samples T73, T20 and T18 that reflects a single DC *P-T* path during the evolution of the fold. PbSL data points of garnets from sample T73, define an isochron of 2023 ± 11 Ma, which constrain this high-grade event to the Paleoproterozoic. Important to note, is that metapelite sample, RB1, characterized by the presence of *two* generations of garnet, has a slightly older Pb-Pb age of 2173 ± 79 Ma, interpreted as a mixing age that possibly reflects the late-Archaean event. U-Pb zircon data of metapelite samples T73 and RB1, yield ages between 3100 and 3367 ± 10 Ma, similar to that for metapelitic gneisses near Musina (e.g. Kröner et al., 1999). Since the

rock types exposed in the Baklykraal structure can be correlated with similar rocks comprising the BBC near Musina, this data possibly constrain the age of the protolith to the Baklykraal rocks to the Mid-Archaean.

A calculated DC *P-T* path for the Baklykraal cross fold records lower metamorphic conditions than a similar DC *P-T* path calculated for the Ha-Tshansi sheath fold near Musina (Van Kal, 2004) (Figure 38). This data, to be confirmed as part of a subsequent Ph.D study, support the suggestion that peak metamorphic conditions were reached at lower crustal levels during the late-Archaean event, and that the Paleoproterozoic event documents a process that occurred at higher crustal levels. The absence of widespread anatexis during the Paleoproterozoic event, and evidence for widespread anatexis during the late-Archaean event (e.g. Holzer et al., 1998), can thus be explained by the lower *P-T* conditions documented for the Paleoproterozoic event in this study.

It can thus be concluded that the CZ experienced a high-grade metamorphic event not accompanied by wide spread anatexis during the Paleoproterozoic. The Paleoproterozoic event was accompanied by a major deformational event that transposed the pre-existing regional gneissic fabric without the development of a regional penetrative gneissic fabric. This resulted in the development of major nappe-like cross folds of which the Campbell- and Baklykraal folds are the best examples.

9.4 Conclusion

The late-Archaean event in the CZ is probably documented by the presence of large sheath folds that developed intrafolial with respect to the regional fabric (D_2). A single population of linear elements defines the central fold axis of sheath folds, suggesting top-to-the-NE movement during exhumation of the CZ. The timing of this event is constrained to the late-Archaean by the emplacement of precursors to Singelele-type gneisses. Published data (e.g. Bahnemann, 1973; Hofmann et al., 1998; Kröner et al., 1998) for the anatectic origin of the precursors to the Singelele-type gneisses supports the suggestion that peak metamorphic conditions in the CZ was probably reached in the late-Archaean. This is further supported by the abnormally high radiogenic signature of the Grey Gneiss Unit and of the Singelele-type gneisses (Andreoli et al., 2003), and by preliminary metamorphic data (Van Kal, 2004) that show that DC *P-T* paths associated with the formation of sheath folds document substantially

high *P-T* conditions than *P-T* conditions associated with the development of cross folds (Figure 38).

The Paleoproterozoic event in the CZ is documented by the presence of major N-S oriented cross folds that transpose the regional D_2 gneissic fabric. This event, however, did not result in the development of a regional gneissic fabric. Cross folds are characterized by the presence of two populations of linear elements. The one population define the N-S oriented fold axis, while the second population is associated with top-to-the-NNE movement of material during exhumation, resulting in folds with a nappe-like geometry. The timing of this event is accurately constrained to the Paleoproterozoic by PbSL dating of garnet from metapelitic gneisses that were used to calculate a DC *P-T* path. These gneisses are characterized by the presence of a single generation of garnet. A slightly older age, that possibly reflects an earlier event (late-Archaean), was obtained from a sample with two generations of garnet. The DC *P-T* path records lower *P-T* conditions than the conditions reached during the late-Archaean event, thus explaining the lack of widespread anatexis at ~ 2000 Ma. The Paleoproterozoic event is interpreted to reflect a transpressive orogeny that resulted in the juxtaposition of the CZ and the SMZ along the Palala Shear Zone (Schaller et al., 1999).

9.5 Future work as part of a Ph.D project

The conclusion that the CZ of the LC suffered high-grade metamorphism and deformation as the result of two major orogenies will be pursued in more detail during a subsequent Ph.D study. This study will focus on outstanding issues that need to be addressed to accurately model the geologic evolution of this geologically very complex zone.

A more detailed characterization of the nature of the late-Archaean and Paleoproterozoic events. This will involve detailed structural, metamorphic, fluid-inclusion and geochronologic studies of sheath- and cross folds from other areas in the CZ. Of special importance is PbSL dating of garnet, supported by dating of monazite inclusions in the core and rim of the garnet. This will form the basis for the accurate construction of *P-T-Fluid-t* paths. Specific areas to be studied in detail include the outcrops in the vicinity of the Three Sisters locality on the Farm Boston, the Ha-Tshansi- and Bellevue sheath folds, and the Campbell cross fold. Previously studied localities in the core of the Campbell cross fold on

the farm Verbaard, SE of Musina (e.g. Kröner et al., 1998), is of special importance for the construction of *P-T-Fluid-t* paths for successive fabric-forming events preserved in metapelitic gneisses with associated leucocratic anatectic veins.

Additional detailed work (structural, metamorphic and geochronologic) will be done to establish without reasonable doubt, the role played by the Tshipise-Mahalapye Straightening Zone in the evolution of the CZ of the LC.

Evidence that the SMZ may not be part of the LC will also be addressed, including: (1) the presence of a gravitational anomaly that is restricted to the SMZ, (2) the absence of a radiogenic signature associated with granitic magmatism, (3) the fact that the Matok pluton was emplaced ~ 100 Ma earlier than the Bulai Pluton in the CZ, and geophysical evidence for a regional-scale geologic structure, including the ZC, NMZ and CZ, that is terminated in the south by the Palala Shear Zone.