Discussion

Geometrical relations between the Transvaal Supergroup, the Rooiberg Group, and the mafic rocks of the Bushveld Complex: a discussion (S.Afr. J. Geol., 101, 275–279)

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In his paper on the geometrical relations between the Transvaal Supergroup and the Bushveld Complex, Cawthorn (1998) argues that there is no need to infer a considerable period of pre-Rooiberg Group erosion prior to emplacement of the Bushveld Complex–Rooiberg volcanic rocks. He further suggests that a significant time interval between the Pretoria and Rooiberg Groups is now common knowledge, but that the extent of Pretoria Group erosion before Rooiberg volcanism is unknown. We note that these two proposals of Cawthorn (1998) are not readily compatible: a considerable time gap should in fact promote a reasonable amount of weathering and erosion between the deposition of the two groups. We wish to contribute positively to the debate on the relationship of the Transvaal and Bushveld rocks by qualifying the proposals of Cawthorn (1998) on the basis of the evidence presented below.

In passing we also wish to point out that Cawthorn's (1998) otherwise logical explanation of the apparent absence of certain upper Transvaal units due to Bushveld intrusion, makes use of 'layer cake stratigraphy', whereby each formation has a constant thickness down-dip. This is highly unlikely in any preserved sedimentary basin and adequate geometrical data is in fact available for the Pretoria Group: for example, isopach maps provided by Schreiber (1990) for the eastern part of the basin, and by Eriksson *et al.* (1991) for the whole basin. In addition, Eriksson and Reczko (1995) provide three-dimensional fence diagrams for the Rooihoogte–Magaliesberg Formations across the basin.

Time interval between Pretoria and Rooiberg Groups

The age data alone do not help to quantify any possible time interval between these two groups. As Cawthorn (1998) points out, the only relevant ages are 2061 ± 2 Ma (Walraven, 1997) for the Rooiberg lavas and 2240 – 2230 Ma (Walraven *et al.*, 1990) for the Hekpoort lavas of the Pretoria Group. This leaves a time period of *c.* 167 – 181 Ma for the deposition of the 10 post-Hekpoort Pretoria Group formations, with a combined thickness, in the eastern part of the basin, of approximately 5000 m (Eriksson *et al.*, 1993). Assuming no significant hiatuses between these ten formations, an approximate sedimentation rate for the post-Hekpoort Pretoria formations of 28 mm/1000 yr. is obtained. The tectonic framework for the Pretoria Group is thought to resemble a passive continental margin (Eriksson and Reczko, 1995); in such settings, maximum tectonic subidence rates, averaged over millions of years, are commonly in the range 10 – 40 mm/1000 yr. (*e.g.* Blatt *et al.*, 1980). Tectonic subsidence rates will necessarily increase due to sedimentation loading and sediment compaction (Allen and Allen, 1990). This suggests that there was significantly more time available between the Pretoria and Rooiberg Groups than that required by an average inferred sedimentation rate. In the absence of major inferred hiatusus in post-Hekpoort sedimentation (*e.g.* Button, 1973; Eriksson and Reczko, 1995), there is thus a distinct possibility that there was enough time between Pretoria and Rooiberg Group deposition for significant erosion of the Pretoria strata to have taken place. As the five post-Magaliesberg formations are preserved only in the east of the Transvaal basin (Button, 1973) with a single, correlated Rayton Formation in the south–central basin (*e.g.* Van der Neut, 1990) and a probably equivalent Woodlands Formation in the west of the basin (Eriksson *et al.*, 1998), quantification of their pre-Bushveld erosion is problematic. As an alternative, the upper Transvaal Supergroup rock record may be examined for evidence of significant pre-Bushveld deformation.

Evidence for pre-Bushveld deformation of Transvaal strata

Hartzer (1994; 1995) has documented in relative detail the structural geology of the Transvaal floor rocks to the Bushveld Complex in all the main inliers of such rocks within the complex. He finds a consistent pattern of pre-Bushveld deformation, comprising three folding events which resulted in interference patterns. More recently, field work in the far western part of the Transvaal basin, on either side of the South African–Botswana border, has confirmed a wider application of Hartzer's deformation episodes, to the entire Pretoria Group succession in that region (Eriksson *et al.*, 1998). In addition, the pre-Bushveld Marico Hypabyssal Suite of Engelbrecht (1986), comprising mafic sills intrusive into the Pretoria Group, has undergone a similar style of deformation; in contrast, the Nietverdiend Bushveld intrusives are not similarly strained (Eriksson *et al.*, 1998). The latter authors distinguish an upper portion of the Woodlands Formation which suggests chaotic slump deposition and postulate that this may belong to a new stratigraphic unit, interspersed between the Transvaal and Bushveld rocks and possibly also including the Otse Basin succession in eastern Botswana.

Bumby (1997) studied the tectonic history of the Rustenburg Fault in the western Bushveld. He provides evidence to support post-Pretoria and pre-Bushveld deformation, encompassing two compressive deformational events. The latter are analogous to those previously discussed by Hartzer (1995) for the western Bushveld fragments and Bumby was able to identify pre-Bushveld strike-slip movement along the Rustenburg Fault of up to 10.6 km in the Silverton–Magaliesberg Formations (Bumby *et al.*, 1998). Fault rocks along the Rustenburg Fault zone were extensively recrystallized and locally assimilated by intrusion of the Rustenburg Suite (Bumby, 1997).

Conclusions

The strong evidence for a consistent pre-Bushveld deformation history in the Transvaal floor rocks to the Bushveld Complex, in various parts of the preserved Transvaal basin, suggests that there was indeed a time interval with the potential for erosion between the end of Pretoria Group sedimentation and the onset of Bushveld–Rooiberg magmatism. Such a period, which on the available chronologic evidence and inferred sedimentation rates discussed above, would possibly have led to significant erosion of upper Transvaal strata; indeed, the Silverton Formation is the uppermost unit preserved in the Crocodile River Fragment (interpreted as a floor-attached dome; Hartzer, 1995) in the western Bushveld. As the Bushveld Complex intruded into upper Transvaal formations, and thus also into any post-Transvaal erosional products overlying the inferred Transvaal erosion surface, preservation of these post-Transvaal sediments would be unusual. Perhaps this is why such inferred eroded Transvaal-sourced deposits are found only in the far west of the basin, where Bushveld intrusives were less prominent. During Rustenburg emplacement, concomitant tectonic uplift and exposure of these magmatic rocks also resulted in essentially syn-intrusive sedimentation, now preserved as the Loskop Formation (Martini, 1998). Weathering, erosion, and resultant sedimentation are thus continuous processes on most geological time scales and their apparent scarcity in the time interval (of whatever length inferred) separating Transvaal and Bushveld events is probably rather a matter of poor preservation than non-formation.

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Author's reply to discussion

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I apologize to readers and to Eriksson *et al.* for my scientific myopia, but I see little of relevance in the above discussion to the debate on the geometrical relationships of emplacement of the Bushveld Complex. Eriksson *et al.* focus on two aspects of my paper, namely the time interval and tectonic activity between the Pretoria and Rooiberg Groups, and the 'layer-cake stratigraphy' (uniform thickness) used in my model. Neither is crucial to the geometrical relations I presented in my Figure 2 and Table 1. I stated very specifically (p. 277, column 2, lines 17 to 21) that 'there had been major pre-Rooiberg erosion' and that 'there is certainly enough time for such a process [erosion]'. Hence, I concur with the principle re-expressed by Eriksson *et al.* regarding pre-Bushveld erosion and tectonism. I used layer-cake stratigraphy purely for simplicity. I showed (in my Figure 3) that the thickness of sedimentary rocks that was present in sub-outcrop below the mafic rocks of the Bushveld Complex, and not exposed on surface, could be related to the angular discordance between the sedimentary rocks and the intrusive body. The relative lateral thicknesses of individual formations is of no consequence in this geometrical reconstruction.

The purpose of my paper was to re-examine the misrepresentation of relationships in the paper by Cheney and Twist (1991). They stated (p. 119) that the model of the Bushveld Complex cutting across the Pretoria Group suffered a 'serious problem' in that 'the footwall rocks that must be presumed to have been lifted by intrusion do not actually occur in the hanging wall'. They therefore proposed that there had been major erosion of the Pretoria Group, and suggested that the Bushveld Complex was emplaced along this unconformity. I showed that their geometrical interpretation was too simplistic, and was invalid provided that there was an angular discordance between the sedimentary rocks and the mafic intrusion. Nowhere in their discussion do Eriksson *et al.* comment on this revised interpretation for the non-exposure of units of the Pretoria Group. I still conclude that there is no