

8. DISCUSSION AND CONCLUSIONS

The objectives of this project were three-fold. Firstly I aimed to constrain whether the Uitkomst Complex crystallized as a closed system or in a dynamic magma conduit setting. Secondly, I planned to determine whether the lithological units of the Complex crystallized from magma of different lineage, and whether any of the parental magmas can be compositionally related to the parental magmas of the Bushveld Complex. Thirdly I tried to clarify whether the sulphides segregated in response to crustal contamination *in situ* or at depth.

8.1. Emplacement History

Previous workers have suggested that the Uitkomst Complex may have crystallized in a dynamic conduit setting (Gauert *et al.*, 1995; Gauert, 1998; Maier *et al.*, 1998). This hypothesis was based largely on the reversed fractionation trends in the basal portion of the Complex, the compositional homogeneity of the MHZBG, and the relatively large proportion of sulphides and chromite to silicates.

The new data confirm the reversed fractionation trend in the basal portion of the Complex and the lack of fractionation in much of the MHZBG. The argument of there being excess sulphide in the Complex is more difficult to substantiate. Figure 4.6.(a) shows Cu/Zr ratios plotted versus MgO. It is seen that while the BGAB, LHZBG, PCR, lower portion of MHZBG and PXT clearly have cumulus Cu (and by implication, sulphide), the upper gabbroic Units and the upper portion of the MHZBG are Cu-depleted. Being that the gabbroic units, in particular, have a much wider lateral extension, the total Cu budget of the Complex is difficult to judge, but need not be in excess of the parental magma.

Distribution patterns of the PGE provide more insight. Pd/Ir ratios have been shown to behave in an opposite way to what would be expected in a closed system (Fig. 5.2.). They decrease with height up to the top of the MHZBG, whereas in the Bushveld Complex, Pd/Ir increases with height indicating that Ir is more compatible than Pd during crystallization of igneous rocks. This suggests that in the Uitkomst Complex, the upper portions of the MHZBG are not related to the underlying Units by means of *in*

situ fractionation. $[Cu/Pd]_n$ ratios (Fig. 5.6.) support this argument. Successive Units of the Complex up to the top of the MHZBG are undepleted in Pd relative to Cu. Were these mostly sulphide-rich Units related to each other by *in situ* fractionation; one would expect progressive Pd depletion of the rocks with height.

The olivine data of Li *et al.* (2002) also indicate that the individual Units are not related by *in situ* fractionation. They showed that there are two types of olivine present in the intrusion (Fig. 8.1.) (i) a primitive olivine that occurs in all the harzburgite units and the PXT and (ii) a highly evolved olivine that occurs in the GN. The primitive olivine is divided into 3 sub-types depending on the amount of Ni-depletion. These are (a) Ni-undepleted olivine (Ni >3000ppm), occurring in the sulphide-poor upper MHZBG (b) A moderately Ni-depleted (1300-2300ppm Ni) olivine occurring in the sulphide-rich LHZBG, PCR, and the lower portion of the MHZBG (c) A highly depleted olivine (<500ppm Ni) found in the upper portion of the PXT.

A final argument for the conduit model is the bimodality in the S and MgO contents of the rocks (Fig. 4.6.). This would be unexpected if the rocks represented a closed system and instead suggest the involvement of distinct magma pulses that were possibly contaminated by distinct country rocks, triggering sulphide segregation.

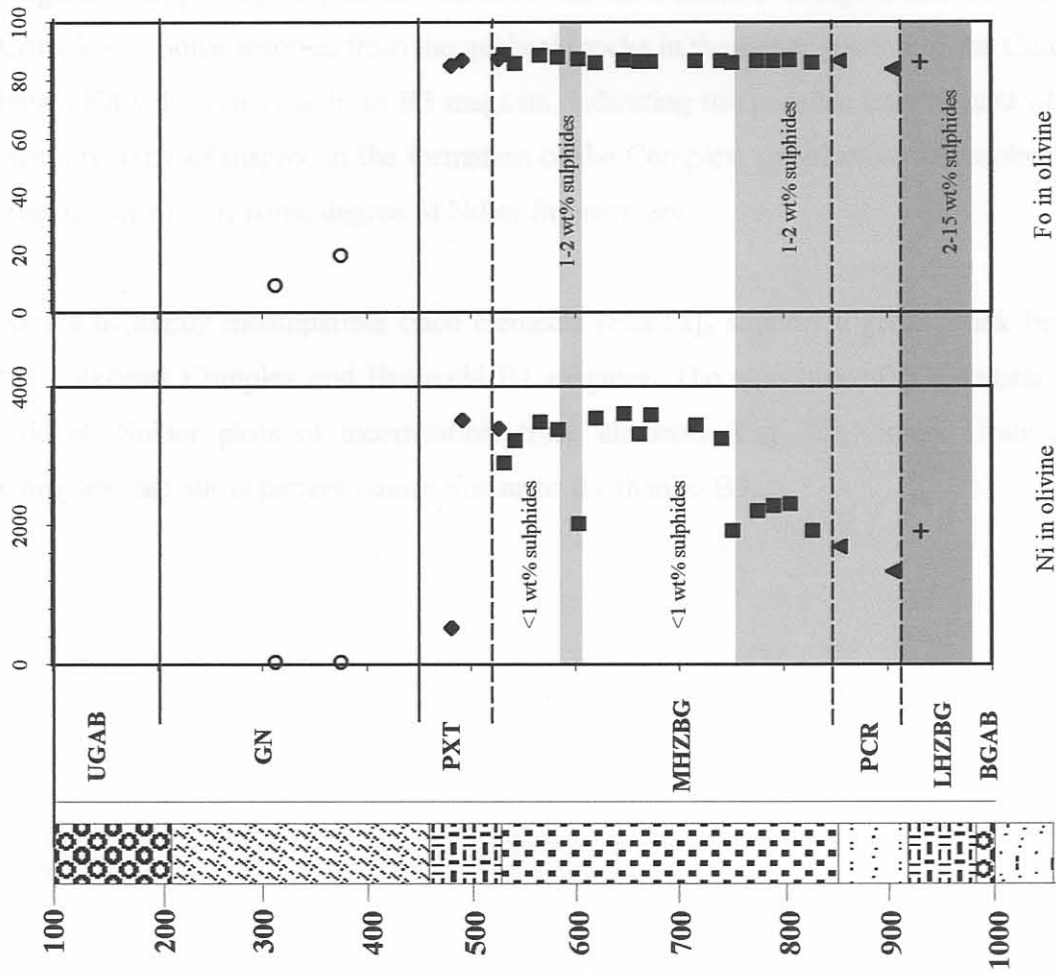


Fig.8.1. Olivine Ni (ppm) and Fo content (mol%) against stratigraphic height (m).

8.2. The Nature of the Parental Magmas

Previous authors suggested that the Uitkomst Complex crystallized from several distinct parental magmas (De Waal and Gauert, 1997) and that these magmas are related to Bushveld B1 and B2 magmas. (Gauert *et al.*, 1995; De Waal *et al.*, 2000). This proposal may be assessed by comparing Nd isotopes and ratios of highly incompatible trace elements from the Uitkomst Complex and the Bushveld Complex. Figure 7.3. shows the $\epsilon_{Nd}(T)$, values of the Uitkomst Complex are similar to B1 magmas, supporting a genetic link between the Bushveld Complex and the Uitkomst Complex. Some samples from the gabbroic rocks in the upper portion of the Complex have ϵ_{Nd} values more akin to B3 magmas, indicating the possible involvement of more than one type of magma in the formation of the Complex, or selective contamination of magmas *in situ*, or some degree of Nd or Sm mobility.

Ratios of highly incompatible trace elements $[Sm/Ta]_n$ support a genetic link between the Uitkomst Complex and Bushveld B1 magmas. The signature of B3 magma is less evident. Spider plots of incompatible trace elements (Fig. 4.8.) in all Units of the Complex also show patterns more similar to B1 than to B3.

8.3. The origin of the sulphide mineralization

The metal concentrations of the rocks of the Uitkomst Complex may be used to clarify two questions (a) did the sulphides segregate *in situ* due to contamination or mixing of contrasting magmas (b) did the magmas segregate at depth and then become entrained by successive surges of ascending magma.

Gauert *et al.* (1995) suggest that degassing of dolomite in the LHZBG caused an increase in oxygen fugacity of the magma and acted as a “trigger mechanism” for the precipitation of sulphide and chromite. The sulphur isotopic data of Li *et al.* (2002) and some of my trace element data support this model. The sulphides of the mineralized Units have $\delta^{34}\text{S}$ between -8 and 2, in accord with the S isotopic signature of pyrite-bearing shaly intervals in Malmani dolomites in the Fochville area. In contrast, the sulphides of the S-poor Units have a mantle signature. Li *et al.*, discard the possibility of the S of the sulphide-rich Units being derived from the Timeball Hill Shale, as the latter have S-isotopic signatures (-12 to -18) that are too divergent from the Uitkomst sulphides. At the same time, the fact that the sulphide-bearing and the sulphide-poor ultramafic rocks have similar incompatible trace element values (Fig. 4.10. and Fig. 7.3.) suggests that assimilation of external S was not accompanied by significant silicate assimilation. This may indicate that the S was added to the magma by means of devolatilization analogous to the situation in parts of the Duluth Complex (Ripley and Alawi, 1988). If the sulphides segregated in response to contamination of the magma with dolomite, then a model of entrainment of the sulphides from depth is precluded. However, some relatively localised entrainment of sulphides remains a possibility. The relatively low Cu/Ni ratios of the sulphides in the LHZBG, PCR and MHZBG can be modelled by sulphide segregation from B1 magma.