

# Sulphide Genesis in the Insizwa Intrusion, South Africa: Geochemical Constraints

R.G. Cawthorn and F.J. Kruger

School of Geoscience, University of the Witwatersrand, PO Wits, 2050, South Africa

e-mail: 065rgc@cosmos.wits.ac.za

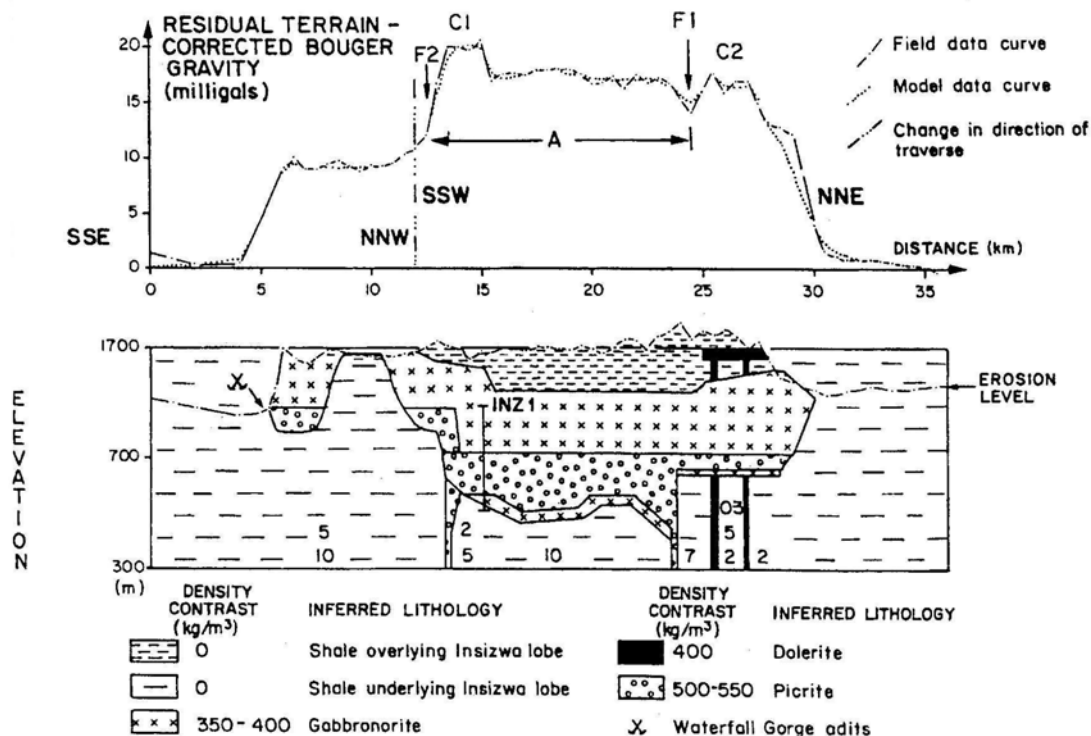
The minor showings of Cu-Ni-PGE mineralization at the Waterfall Gorge locality in the Insizwa Intrusion have been considered a classic example of magmatic sulphide liquid immiscibility. Here we present geochemical data that provide constraints on the processes producing that immiscibility.

## Introduction

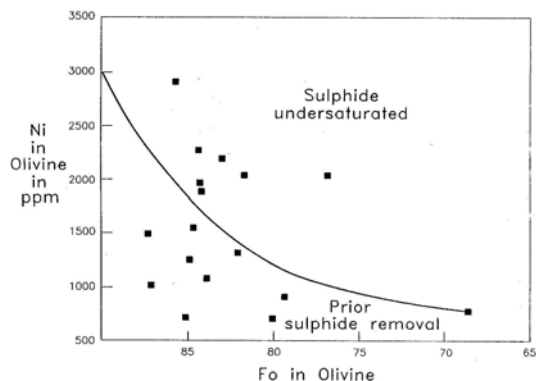
The mineralization at Waterfall Gorge was first exploited in 1865 for its copper. In 1908 nickel was reported in the ore, and in 1950s PGEs were reported (Maske and Cawthorn, 1986). Quantitative data on all these metals was presented by Lightfoot et al. (1984). Despite subsequent exploration no further economic resources have been defined, although geochemical modeling suggests the existence of a major hidden resource (Lightfoot et al. 1984).

## Structure and Stratigraphy

Waterfall Gorge occurs at the southern limit of the Insizwa intrusion, which is one of four limbs of the Mount Ayliff Intrusion, where an undulating sheet up to 1000m thick consists of lower olivine-rich cumulates overlain by gabbros. A gravity survey identified major deep fault-bounded structures (Fig. 1), with ultramafic rocks up to 600 m thick (Sander and Cawthorn, 1996). Note that the Waterfall Gorge mineralization may lie in a separate sub-basin from that drilled and described here. Subsequent drilling proved the existence of these structures. A geochemical study of the core (INZ1) is presented here. The bore core revealed a basal olivine-phyric microgabbro that rapidly graded up into olivine-rich cumulates, with very minor homogeneously distributed chromite that contain interstitial orthopyroxene, clinopyroxene and plagioclase, and traces of ilmenite, biotite and quartz. The overlying succession consists of a thin olivine gabbro and thick gabbro.



**Figure 1.** Gravity cross-section (north-south, with a slight dog-leg) across Insizwa intrusion (Sander and Cawthorn, 1996), showing location of Waterfall Gorge adits and borehole INZ1 studied here.



**Figure 2.** Plot of Fo versus Ni content in olivine relative to trend considered to distinguish olivine formed from a magma that has undergone prior sulphide removal.

### Olivine Compositions

The search for sulphide mineralization associated with ultramafic bodies can be aided by studies on the Ni and Fo content of olivine, and Ni-depleted olivine exists in this section (Fig. 2). The most magnesian olivine is Fo<sub>87</sub>, found in the lherzolite zone, and also as phenocrysts in a thin sill immediately in the floor of the intrusion. Such a magnesian composition has implications for the composition of the parental magma. The total range of composition is shown in Fig. 3a. In the basal olivine microgabbro the composition is Fo<sub>77</sub> but increases rapidly upward into the lherzolite, where values vary irregularly, are typically in the range Fo<sub>84-86</sub> and do not fall below Fo<sub>82</sub>. In the overlying olivine gabbro values decrease, and reach Fo<sub>68</sub>, 300m into the gabbro zone.

The stratigraphic layers that show this Ni-depletion profile are shown in Fig. 3b. In order to indicate these zones of Ni depletion, the ratio of Ni/Fo is plotted. On Fig. 2, it is shown how the Ni/Fo value of olivine varies at the boundary between sulphide-saturation and sulphide-undersaturation. The actual Fo content of the olivine in the vertical succession is then used to predict the Ni/Fo value at any given level, such that a sulphide saturated-undersaturated boundary can be defined as a function of height and Fo content of olivine. The Ni/Fo data are then plotted on this vertical profile (Fig. 3b), showing the zones of Ni-depletion, presumably due to prior sulphide separation. At approximately 200 m above the base is a zone of pronounced Ni depletion.

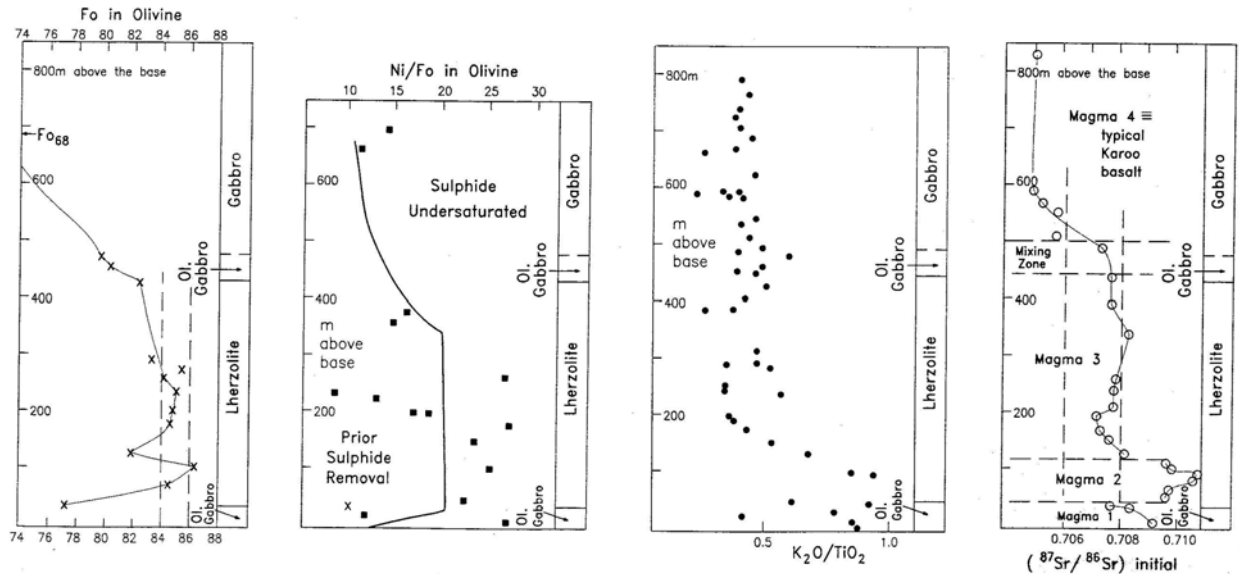
### Whole-rock Geochemistry

Certain trace element ratios can be used to identify processes, such as crustal contamination that may be important in generating immiscible sulphides. Specifically, the K<sub>2</sub>O/TiO<sub>2</sub> value (Fig. 3c) will not be affected by olivine fractionation or accumulation, and may identify assimilation processes or addition of magmas with different ratios. At the base of the olivine gabbro there is a high ratio that decreases upward, but is followed by a sharp increase at the base of the lherzolite. There follows a slow, but steady, decline up to 200 m. Thereafter there is a rather heterogeneous zone, but there is a distinct high value at 230 m.

Initial Sr ratios can perform a similar function to trace elements ratios. Whole-rock data are presented in Fig. 3d. High and steady decreasing values occur through the lower olivine microgabbro. A distinct and very high ratio is seen at the base of the lherzolite, followed a distinct decrease, rather than the slow decrease seen in the K<sub>2</sub>O/TiO<sub>2</sub> value from 100 - 200 m. In unison with the K<sub>2</sub>O/TiO<sub>2</sub> value, there is a break to higher values at 230 m. At the top of the lherzolite there is a change to lower values throughout the gabbro. All values up to the top of the olivine gabbro are exceptionally high (>0.7075), whereas the values in the gabbro are typical of ratios reported for the Karoo basalt lava, with which the Insizwa is temporarily associated.

### Addition of magma

These data suggest that there may have been multiple periods of magma injection or of variable contamination within the intrusion. A model for the different magmas is given in Fig. 3d. The first magma produced the basal olivine microgabbro. The sharp isotopic break at the base of the lherzolite suggests that a different magma was added. The reverse at 120 m suggest that either a third magma was added, or that mixing between the first and second occurred. The subdued break at 200 m may suggest addition of another magma, but differences between what are called 3A and 3B in Fig. 3d could be related to inherited inhomogeneity within the previous episodes of magmatism. The isotopic shift indicating a fourth magma at the level of the gabbro shows that the evolution from lherzolite to gabbro is not due to fractionation processes.



**Figure 3.** Vertical section through ultramafic portion of the bore core showing: a. Fo content in olivine, b. Ni/Fo content in olivine relative to trends defining prior sulphide removal (Fig. 2), c. whole-rock  $K_2O/TiO_2$  values, d. initial  $^{87}Sr/^{86}Sr$  values. Ratios in 3c and 3d indicate zones of crustal assimilation and/or addition of chemically distinct magmas.

### Mineralization Potential

In the absence of any observable sulphides in the core, the most obvious evidence of the potential for mineralization is the distinct decrease in Ni/Fo in olivine at about 200 m height in the lherzolite. The fact that close to this level there is an increase in Sr isotope ratio and  $K_2O/TiO_2$  value could be attributed to magma addition or crustal contamination. The fact that there is no mineralization in the core suggests that any sulphides formed at this level lies nearer to the conduit through which this magma entered the system.

A comparison with the mineralization at Waterfall Gorge is instructive. Lightfoot et al. (1984) reported a maximum Fo content of the olivine of 82.5, much lower than reported here in the lherzolite. Their initial Sr isotope ratios were in the range 0.7075-0.7084. These data are reminiscent of the basal olivine microgabbro from this study, and not

from the bulk of the lherzolite. It would appear that the magmatism that produced the bulk of the lherzolite was not represented in the rocks produced at Waterfall Gorge. Thus the structural basins shown in Fig. 1 may represent distinct and isolated magmatic chambers at least at the levels of the ultramafic rocks. Each basin may have had its own feeders, and mineralization may be limited to proximity to these structures.

### References

- Lightfoot, P.C., Naldrett, A.J. and Hawkesworth, C.J. 1984. *Econ. Geol.*, 79, 1857-1879.
- Maske, S. and Cawthorn, R.G. 1986. In: *Mineral Deposits of Southern Africa*, Geological Society of South Africa, Johannesburg, 2, 2149-2158.
- Sander, B.K. and Cawthorn, R.G. 1996. *Journal Applied Geophysics*, 35, 27-43.