CHAPTER 1 INTRODUCTION, PURPOSE AND METHODOLOGY

1.1 Introduction

The Uitkomst Complex is considered to represent a satellite body of the Bushveld Complex (de Waal and Gauert, 1997; Marsch, 2003; de Waal, Graham and Armstrong, 2006). It is located between the towns of Machadodorp and Barberton in the Great Escarpment area in the Mpumalanga Province of South Africa. The Complex consists of a layered suite of ultramafic and mafic rock types that formed within a magma conduit (Gauert, 1998), intruded at 2044 ± 8 Ma. Preferential weathering of the mafic rocks has led to the formation of a valley, in which erosion has led to the exposure of the lowermost units of the complex on the farm Vaalkop 608JT, with successively higher parts of the stratigraphy being exposed westwards on the farms Uitkomst 541JT and Slaaihoek 540JT (Theart, 2000). Disseminated and massive sulphide and chromite ore bodies have been delineated within the lower units of the Complex.

The shallower economically mineralized parts of the Main Mineralized Zone of the Complex are targeted by the Nkomati Mine's expansion programme, and during the period July-December 2005 this zone was responsible for 23% of the general mine output and increasing steadily. This production was from the underground area overlying the Massive Sulphide Body. The Massive Sulphide Body (MSB) was exhausted in the first quarter of 2008. Mining is expected to continue utilizing the underground infrastructure, and production will be supplemented by three open cast pits, giving an expected life of mine of approximately 16 years. The first two pits were exhausted by 2010 and the focus is on the development of Pit 3 and is the focus of this investigation. The upper northwestern area contains high levels (>15 %) of altered mineralization that has a detrimental effect on the beneficiation of the ore by means of froth floatation to produce the concentrates. The location of Nkomati Mine is shown in Figure 1.1

1.2 Nkomati Mine

The sulphide ores of the Uitkomst Complex is being mined by the Nkomati Mine, owned by African Rainbow Minerals (ARM) and Norilsk Nickel in a 50:50 joint venture. This follows the take-over of LionOre by Norilsk Nickel.

ECT, an Anglovaal subsidiary, purchased the initial mineral rights to mine gold on the farms Mamre and Slaaihoek 540 - JT in 1939 (Company Report, 2007). During the early 1970's an INCO/AngloAmerican Prospecting Services joint venture began exploring the Uitkomst Intrusion for nickel (Anonymous, 2007). In 1992 Anglo American Corporation (AAC) conducted a feasibility study to exploit the disseminated sulphides on the farm Uitkomst as part of an open pit operation, but it was deemed not sufficiently economical (ARM Annual report, 2007).

During the early 1990's Slaaihoek was re-explored by Anglovaal and this was followed by a major drilling program commencing in 1993 (Theart, 2000). This and earlier programmes delineated three disseminated sulphide mineralized zones, namely the Basal Mineralized Zone (BMZ), Main Mineralized Zone (MMZ) and the Chromititic Pyroxenite Mineralized Zone (PCMZ). A Massive Sulphide Body (MSB) located at the base of the Uitkomst Complex was also identified (Theart, 2000). In the period 1993-94 a vertical shaft was sunk to a depth of 450 meters below surface to obtain a bulk sample for metallurgical test work (Theart, 2000). In 1995 the Anglovaal/AAC joint venture was formed to investigate the viability of the combined resources on Slaaihoek 540 – JT and Uitkomst 541 - JT. The pilot plant was constructed and commissioned towards the end of 1995 (Theart, 2000). The results of a feasibility study in 1996 showed that mining of the MSB of the Uitkomst Complex would be viable, and prompted the construction of the MSB concentrator plant and other infrastructure (Theart, 2000). In 1997, Nkomati Mine became South Africa's first primary nickel producer (Theart, 2000). In 2004, Anglovaal Minerals Ltd (later to be renamed African Rainbow Minerals Ltd) acquired AAC's share in the mine (Anonymous, 2007). The current joint venture was formed on 2 February 2005, African Rainbow Minerals Ltd announced the creation of a 50:50 non-incorporated business with LionOre Mining International Limited with regards to the Nkomati Mine.

At present mining of disseminated sulphides takes place via underground and open pit mining. The oxidized chromite reserve is being mined as part of the pre-strip operations to expose the LHZBG for open pit operations (Anonymous, 2010). The MSB (Massive

Sulphide Body) that was the initial target of mining was exhausted by February 2008 (Anonymous, 2010). The expansion projects, Phase 2a and b, aim to mine the MMZ ores from two areas, namely the current underground infrastructure and from surface mining which would also incorporate mining of the PCMZ and near surface chromite ores (Anonymous, 2010). The ore obtained from the PCMZ (Peridotic Chromitite Mineralised Zone, after mine nomenclature) is being processed separately by the PCMZ concentrator plant.

The MMZ was mined out in Pit 1 during 2009 and Pit 2 during 2010 (Smith and Kotze, 2010). Pit 3 was being developed at the time this thesis was written and has a life expectancy of 16 years. As part of the Phase 2a expansion project, the MMZ plant capacity was increased to 375 000 tpm during 2010. The Phase 2b expansion aims to develop the current MMZ plant into a 250 000 tpm PCMZ plant (Anonymous, 2010).

During 2006 Nkomati mined and produced approximately 300 000 tonnes of lumpy chromite ore from open pit 3 after successful testing of the product (Anonymous, 2007). The chromite resource overlies the disseminated sulphide resource of the MMZ in the open pit 3 area and is mined as part of the pre-strip for this open pit (Anonymous, 2007). The PCMZ material is being stockpiled for later extraction of the chromite (Anonymous, 2010).

An aerial view of the infrastructure and surroundings at Nkomati Mine is provided in Figure 1.1 and 1.2.

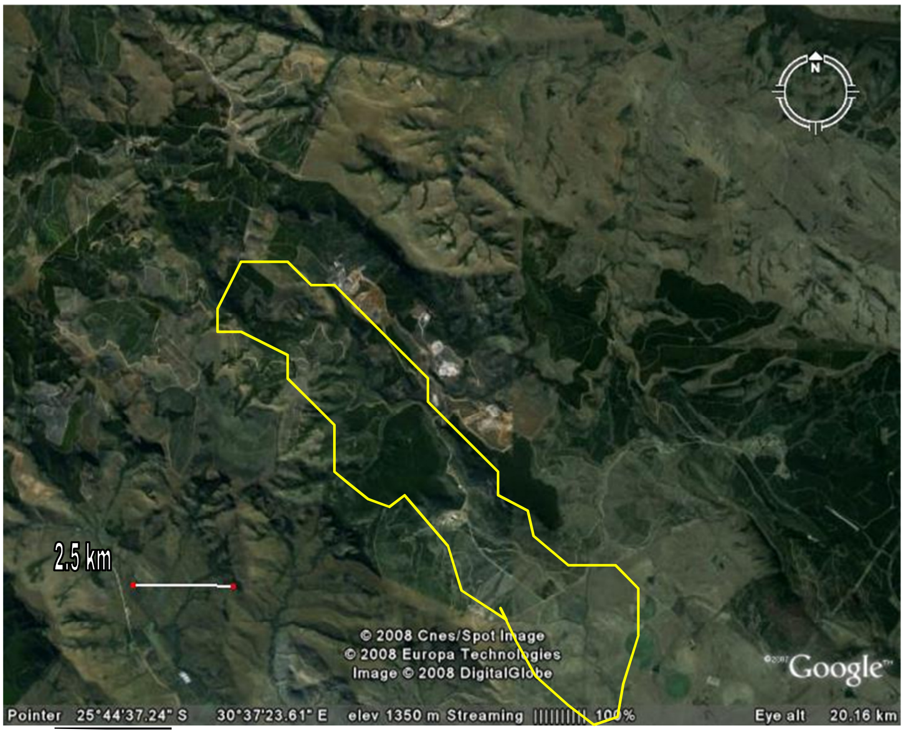


Figure 1.1. Aerial view of Nkomati Mine and surroundings. The surface exposure of the Uikomst is indicated by the yellow line. The white bar represents 2.5 kilometers (image from Google Earth, 2008).

Figure 1.2. Aerial view of the infrastructure at Nkomati Mine. The white bar represents 250 meters (image from Google Earth, 2007).

1.3 Comparison with other intrusions

To understand the processes involved in the interaction between carbonate country rock and intruding magma in the Uitkomst Complex, as well as the possible assimilation of the carbonate rocks by the intrusion, the available literature on several other intrusions has been considered. Of these, the Platreef is considered the most significant as both deposits were probably formed in response to the interaction between the Bushveld Complex magma and interaction with the Malmani dolomite of the Transvaal Supergroup. The Platreef and the interaction between the Bushveld magma and the Transvaal Supergroup sediments have been investigated by various authers, e.g. Kinnard et al., (2005), MacDonald et al., (2005), Armitage et al., (2002), Harris and Chaumba, (2001) and Gain and Mostert, (1982). Similarities and differences between the Platreef and Uitkomst Complex will be discussed in subsequent sections. Other examples where pervasive assimilation examples were described include intrusions in the Kola Belt in Siberia (Li, et al., 2003; Barnes et al., 2001; Dokuchaeva and Yakovlev, 1994), Ioko-Dovyren (Wenzel, et al., 2001; Wenzel, et al., 2002) in Russia and the Horavaer intrusion (Barnes et al., 2005) in Norway.

The effect of partial assimilation e.g. along the contact of other intrusions into carbonate country rock was also considered. These examples include the contact reactions at Gebel Yelleq in Egypt (Abu El-Enen et al., 2004), at Werfen in Italy (Povoden et al., 2002), Adamello in Italy (Bucher-Nurminen, 1982), Tokatoka in New Zealand (Baker and Black, 1980) and Scawt Hill in Northern Ireland (Tilley and Harwood, 1931).

The Uitkomst Complex is also compared to other conduit systems such as the Kabanga intrusion,Tanzania (Deblonde and Tack, 1999; Evans et al., 1999; Evans et al., 2000), and the Pants Lake and Voisey's Bay in North America (Li, Ripley and Naldrett, 2001) intrusions. Reference is also made to xenoliths from the Eastern Bushveld (Wallmach, Hatton and Droop, 1989) and from the Kiglapait Intrusion, Labrador (Owen, 2000).

1.4 Aims of the study

The purpose of the research project is to investigate the cause and effects of the extensive talc-chlorite alteration found in the Lower Harzburgite and Chromiferous Harzburgite Units of the Uitkomst Complex, localized in the upper north-western portion of the intrusion. This phenomenon has bearing on the nature and distribution of the sulphide minerals in the Chromatiferous Harzburgite Mineralized Zone (PCMZ) and to a lesser extent the Main Mineralized Zone (MMZ) ore bodies. These affected orebodies are currently being exploited in the underground operation and in the area delineated for a large scale open cast mine, referred to as Pit 3.

The possible effects of the interaction between the intruding magma source of the mineralized lower units and the dolomite country rocks are currently unknown. In order to quantify these effects the nature and abundance of the xenoliths in the lower units will be considered. The origin and nature of the alteration fluids responsible for the composition and distribution of the alterations zones will be determined. The formation of the hybrid rocks and the other effects of the assimilation processes on the composition and physical properties of the magma will be considered. The interaction between the magma and the country rocks will further be used to determine its influence on the shape of the intrusion and the effects of carbonate-rich and other late-stage fluids on primary magmatic and hybrid minerals must be investigated.

The methodology employed in this investigation consists of a systematic review of the available data, using the borehole logs made available for this study by ARM and a comparative literature study. The analytical component is comprised of petrographical descriptions of thin sections made from selected pieces of quartered core, obtained from the Moody's estate core-yard, and geochemical data obtained from whole rock analyses of these pieces of core, using x-ray diffraction (XRD), x-ray fluorescence (XRF) will be used. The geochemistry of the minerals present has been established by means of electron microprobe (EMP) analyses.

1.5 Study area

The study area is located in the shallow part of the Uitkomst Complex, where the basal units of the Complex outcrop on the farm Uitkomst 541JT. The area has been indicated in Figure 1.3 as the "study area" and largely coincides with that of the deeper part of Pit 3 in this figure. The area falls slightly outside the north-western border of the designated open pit area. The "narrower" part of the intrusion, referred to later in the dissertation, falls in the upper left part of the study area block. The "wider" part of the intrusion referred to in the dissertation falls in the central and lower right part of the study area.

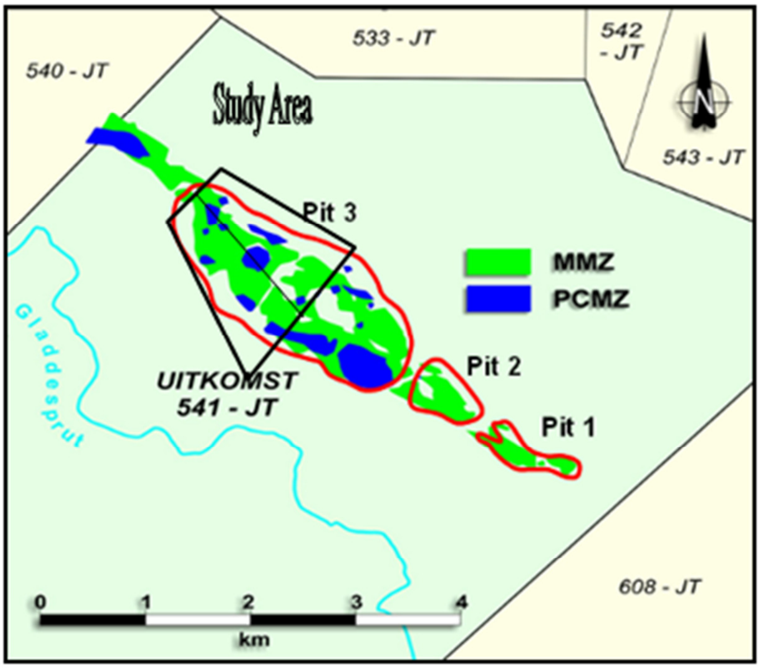


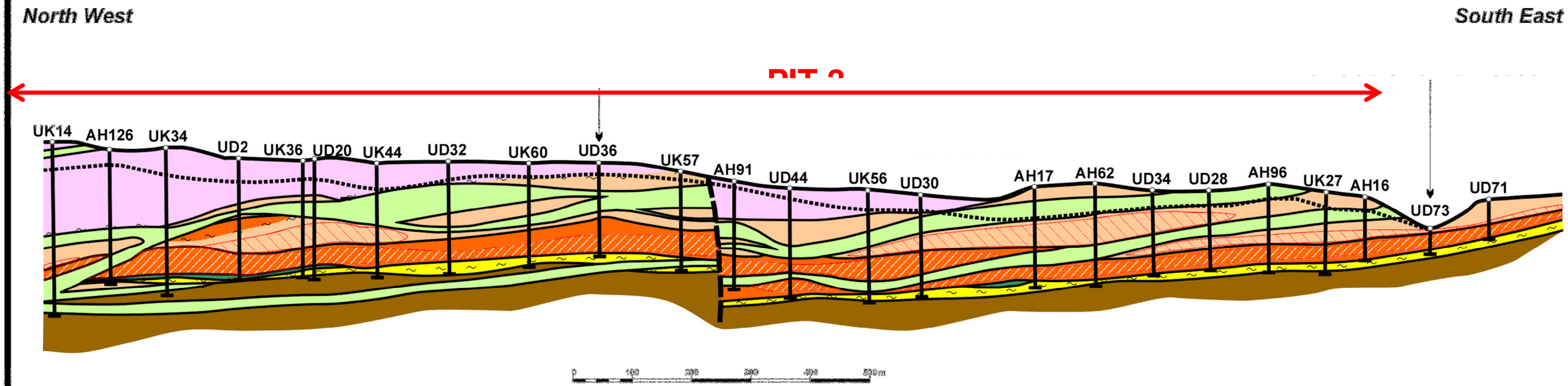
Figure 1.3. A Surface projection of the distribution of the mineralized zones in the area indicated for the large scale open pit operation. The study area falls in "Pit 3" (red line) where indicated by the box (black line). The cross-section is along the thin black solid line in the study area box. (Adapted after: Nkomati Mine Geological Staff, pers. Comm. 2005).

A section through the orebody in the study area is given in Figure 1.5 and is indicated by the arrow lines. The locality of the boreholes selected for sampling and analyses are shown in a plan view, which also indicates the approximate margins of the complex in this area in Figure 1.6. The thick black line represents the inferred boundary of the Uitkomst Complex and the dashed line represents the inferred area that may contain relative proportions talc in excess of 15 %. This area has been deemed a "talc rich zone" from composite metallurgical test samples taken in the area identified for the large scale open pit operation (Bradford, Internal company report, 1996).

Figure 1.4. Section of the area indicated for the development of a large scale open pit operation. The study area is located in the upper northwestern to central part of Pit 3. The study area extents further to the North West than indicated on the diagram. Adapted after Theart (1996). Next page.

Figure 1.5. Positions of the boreholes sampled during this investigation. The dashed line indicate the inferred "talc rich zone" as determined from composite samples (After L. Bradford, pers. Comm. ,2005). Subsequent page.

Figure 1.4



LEGEND

- Diabase sills and dykes
- Peridotite Unit
- Chromititic Peridotite Unit
- Lower Pyroxenite Unit
- Basal Gabbro Unit

(Peridotite Unit to Basal Gabbro Unit: **UITKOMST COMPLEX**)

- Oaktree Formation, quartzite, Blackreef Quartzite Formation — **TRANSVAAL SEQUENCE**
- Nelshoogte Granite

- Fault zone
- Basal Shear Zone
- Depth of weathering
- Sulphide mineralized zones within the Chromititic Peridotite Unit (PCMZ)
- Sulphide mineralized zones within the Lower Pyroxenite Unit (MMZ)

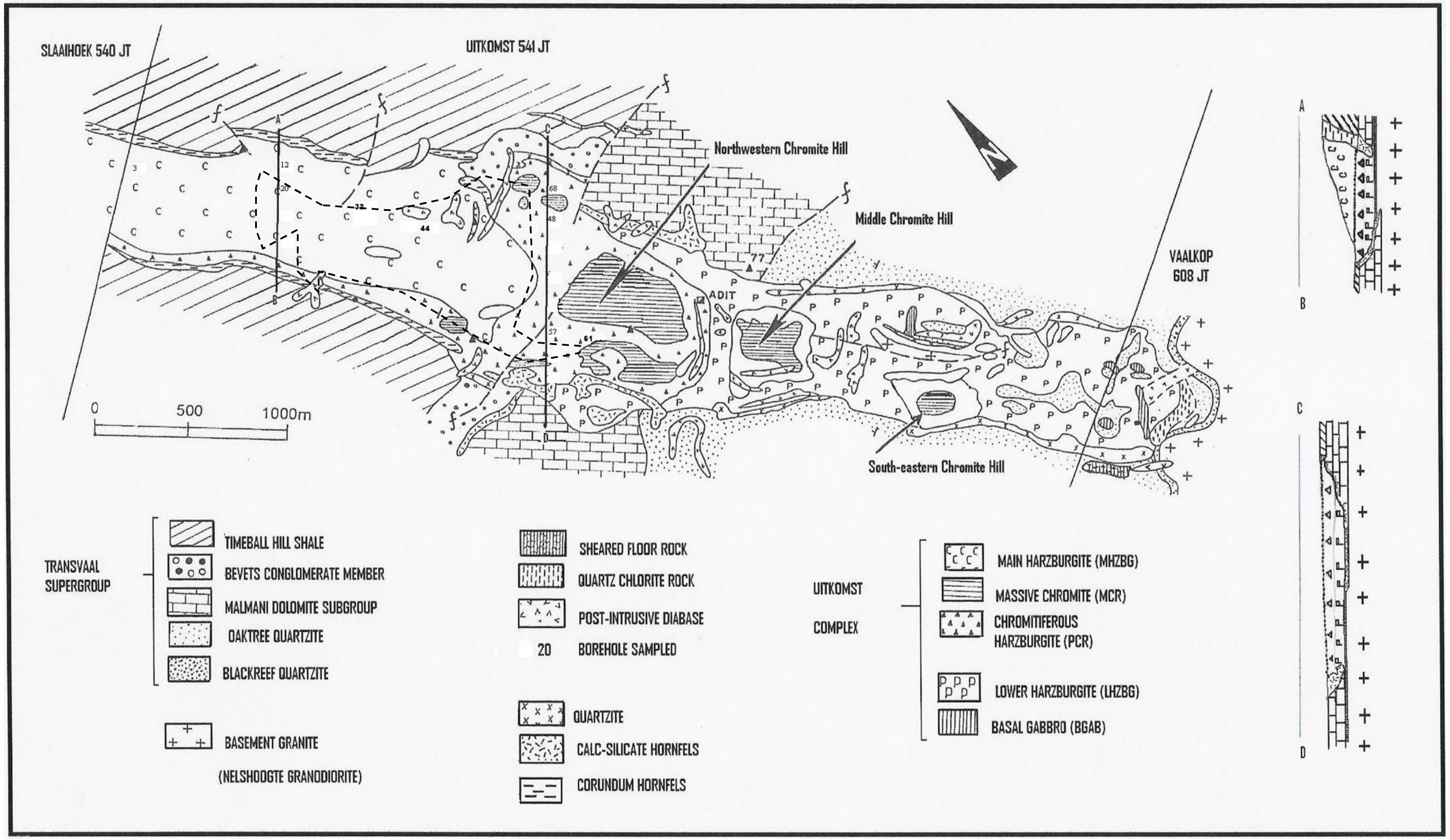

SLAAIHOEK 540 JT
UITKOMST 541 JT
VAALKOP 608 JT
Northwestern Chromite Hill
Middle Chromite Hill
South-eastern Chromite Hill
ADIT
0 500 1000m
A
B
C
D
TRANSVAAL SUPERGROUP
TIMEBALL HILL SHALE
BEVETS CONGLOMERATE MEMBER
MALMANI DOLOMITE SUBGROUP
OAKTREE QUARTZITE
BLACKREEF QUARTZITE
BASEMENT GRANITE
(NELSHOOGTE GRANODIORITE)
SHEARED FLOOR ROCK
QUARTZ CHLORITE ROCK
POST-INTRUSIVE DIABASE
20 BOREHOLE SAMPLED
QUARTZITE
CALC-SILICATE HORNFELS
CORUNDUM HORNFELS
UITKOMST COMPLEX
MAIN HARZBURGITE (MHZBG)
MASSIVE CHROMITE (MCR)
CHROMITIFEROUS HARZBURGITE (PCR)
LOWER HARZBURGITE (LHZBG)
BASAL GABBRO (BGAB)

Figure 1.5