



Structural Controls on the Copper-Cobalt-(U)
Mineralisation of the Chimiwungo Deposit, Mwombezhi
Dome, Northwestern Zambia.

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Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in
Economic Geology.

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Signed on 10th November 2021 at Johannesburg

DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Science in Economic Geology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

_____ 10th _____ day of _____ November _____ 2021 _____ at _____ Johannesburg _____

ABSTRACT

The Lumwana Cu-(U) deposits located in northwestern Zambia make Lumwana Mine one of Africa's largest copper mines operating conventional multi-open pits. The Lumwana Project hosts two main deposits, namely, the Malundwe and the Chimiwungo deposits. The current mining operations are exploiting the Chimiwungo deposit, which forms the basis of this study. The deposit occurs within the Mwombezhi Dome, of the Central African Copperbelt's Domes region, where amphibolite facies metamorphism, thrusting, and recumbent folding have reworked the Paleoproterozoic basement rocks. The deformation events that yielded the Mwombezhi Dome have been associated with the formation of the Lufilian Arc during the Pan African events. The Chimiwungo deposit defines a tabular stratiform shear-zone-hosted mineralised body, which is characterised by two north-south trending 'ridges', called Ore Shoots. The deposit strikes E-W with a strike length of ~4 km and a dip of ~15° to the south. The orebody thickness averages around 80 m, with the Ore Shoots defining the thickest (~120 m) portions of the mineralised shear zone. The structurally controlled Cu-sulphide mineralisation dominantly occurs disseminated within the fabric elements of the main shear zone. The Chimiwungo tectonostratigraphy is truncated by north-directed, late, brittle steep normal faults that displace the orebody in the orders of tens to hundreds of metres. The mineralised shear zone is characterised by the presence of barren lithologies that are internal to the shear zone, which predominantly occur as boudins of varying lithological characteristics, sizes, and distribution patterns.

In this study, an extensive mapping exercise of the pit walls and creation of a 3D Leapfrog model using a dataset of 1,141 drillholes was combined to understand the nature and distribution of the internal units (amphibolites, basement gneisses, leucosomes, mylonites and pegmatites). The thickest boudins occurring internal to the orebody are amphibolitic in nature and are also responsible for the development and final geometry of the Ore Shoots. These competent lithologies appear to have undergone partial shear deformation, and also played a role during mineralisation and remobilisation of the Cu-sulphide mineralisation. Narrower shear zones that developed between these massive units during D3 deformation, acted as conduits for focusing mineralised fluid flow. High concentrations of Cu-sulphide mineralisation occur in a north-south linear trend, parallel to the shoots. Studies carried out on meso- and macro-structures associated with Cu-sulphide mineralisation show that the final configuration and distribution of the Cu-sulphides was largely driven by boudinage development and the shear fabric. Boudin development facilitated the accumulation of remobilised Cu-sulphides along the interboudin necks and pressure shadows. The presence of S-C and S-C' planes in the schistose fabric acted as depositional sites of the sulphides. The eastward-directed ductile flow associated with the main shear zone accounted for the presence of a highly developed schistose fabric which is localised along the eastern flanks of both shoots. The D3 deformational phase lasted much longer than the mineralising event and facilitated the remobilisation of Cu-sulphides. Evidence of syn-deformational mineralisation is presented in the form of L3 stretching lineation, meso-scale drag folds in the mineralised schist, late quartz-sulphide veins, and pressure-shadow-hosted mineralisation associated with porphyroblasts. A recrystallisation event facilitated the redistribution of quartz-sulphide assemblages into veins in random fractures within the ore package and partly within the barren internal units.

DEDICATION

*Dedicated to my beloved faithful ones. Jackie, Chaangu, Jemimah, Jahdiel and baby H. May this accomplishment be yours as an inspiration to go to higher heights and greater accomplishments. You guys push me to do more. Here's to many more degrees...
Cheers to greater success!*

QUOTE

“Iron is taken from the earth, and copper is smelted from ore. Man puts an end to darkness and searches every recess for ore in the darkness and the shadow of death.”

Job 28 vs 2 -3

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Chapter 1

INTRODUCTION

1.1 Background

The Lumwana Project, which consists of two major shear-zone hosted Cu-(U) deposits, Malundwe and Chimiwungo, is located within the Neoproterozoic Katangan Central African Copperbelt (CACB) of Zambia. The CACB is host to the world's largest stratiform copper-cobalt deposits and stretches from northern Zambia across the border, into the southern Democratic Republic of Congo (Cailteux *et al.*, 2005). The Malundwe deposit is approximately 4 km long, striking north-south and up to 1.5 km wide (east-west). The single Ore Schist horizon outcrops in the east, with an average thickness of 14 m, and a shallow dip of $\sim 15^\circ$ to the west. It is much smaller than the Chimiwungo deposit but is endowed with higher copper grades than Chimiwungo (Bernau, 2007). The Chimiwungo deposit which extends for approximately 4 km east-west and ~ 5 km north-south, has a shallow dip of $\sim 15^\circ$ to the south. The Chimiwungo deposit has higher overall cobalt mineralisation and some sporadic uranium mineralisation (Bernau, 2007).

The Chimiwungo deposit architecture is accentuated by the presence of two north-south trending antiformal-like structures known as shoots, which contain thicker zones of Cu-mineralisation. The higher Cu concentrations are aligned along the flanks of the shoots which, according to Poulsen (2013), define asymmetric boudin necks. The pinch-and-swell geometry of the boudinage structures at Chimiwungo appears to play a role in the distribution of copper mineralisation within the shear zone. The distribution of the Cu-Co mineralisation also appears to be largely controlled by preferential strain localisation along a Paleoproterozoic anisotropy in the form of intrusions, lithological contacts and mylonitic horizons in the pre-Katanga basement (Koegelenberg *et al.*, 2019). The well-developed extensional S–C' fabrics in the shear zone appear to demonstrate a relationship with the distribution of copper lode concentrations. In its lower portion, the ore package is characterised by the presence of sporadic quartz-sulphide veins. The mineralised quartz veins are discordant to the D3 foliation and suggest the possibility of a post-shearing mineralising event or remobilisation and recrystallisation of the pre-existing mineralisation. Also, present are narrow, steeply dipping, cross-cutting calcite-quartz-sulphide veinlets. The veinlets, which tend to host chalcopyrite mineralisation at shallower depths and bornite at greater depths, are associated with locally elevated copper grades (Dobrotin *et al.*, 2013).

While the Malundwe deposit shows a consistent stratigraphy and copper grade distribution, the Chimiwungo deposit, on the contrary, is characterised by a more complex structural architecture within the mineralised shear zone. The ore package at Chimiwungo plays host to barren lithological units that occur within the schistose matrix. Recent studies (Eglinger *et al.*, 2016; Turlin *et al.*, 2016; Koegelenberg *et al.*, 2019) have described the evolution of these mineralised shear zones in detail. However, the spatial pit-scale distribution and occurrence of unmineralised internal units within the ore package require further understanding. The barren internal units, which have been boudinaged, are predominantly composed of grey gneisses, amphibolites, amphibolitic gneisses, mylonites and

pegmatites. From the mining perspective at Lumwana's Chimiwungo pits, it has been observed that the reconciliation between the planned and achieved ore tonnes is widely lower (McCallum *et al.*, 2018). The presence of randomly distributed boudins of barren units within the Ore Schist is the major source of the observed discrepancy in ore tonnes reconciliation and subsequently, a negative reconciliation between the planned and achieved feed grade (McCallum *et al.*, 2018).

Preferential fluid flow within the low strain horizons of the shear zones also needs further study to understand the deposition and distribution of Cu sulphide lodes within the shear zones. The formation of north-south trending shoots containing thicker zones of Cu-mineralisation is also poorly understood. The shoots tend to display an antithetic relationship between the thickness of the ore and the quantitative copper content associated with the shoots.

1.2 Location and access

The Lumwana deposits are located in the Northwestern Province of Zambia, approximately 65 km west from the provincial capital of Solwezi, and 400 km northwest of the capital Lusaka (Fig. 1.1). The Lumwana tenements can be accessed from the T5 highway. Branching off the T5 highway is the 10 km long R1 road which leads to the Lumwana township site. The 3 km long R2 road which branches off from the R1 road leads to the active mining area.



Figure 1.1. Location of the Lumwana Cu-Co-(U) deposit in northwest Zambia, (from Dobrotin *et al.*, 2013)

1.3 Aim

- To describe the lithological nature, spatial distribution, and size of internal waste boudins within the Ore Schist. To understand the factors influencing the seemingly random distribution of boudins in the Ore Schist.
- To describe the nature of the internal structure in the shoots.
- To describe the distribution of copper mineralisation within the Ore Schist and associated structural controls relevant to overall shear zone evolution. To study the observed variation in the distribution of the Cu lodes and the associated factors.

1.4 Methodology

Field observations and data capturing included:

- Detailed pit mapping of structural trends and lithologies within the Chimiwungo ore deposit. The structural and lithological mapping was carried out using a phone mapping application known as Rocklogger™, linked to a Bluetooth-supported Garmin GLO GPS location device.
- Processing of mapping data was accomplished using Leapfrog™ modelling software and Vulcan™ mining software.
- Stereonets for structural data analysis were generated using Rocscience™ dips software.
- Photogrammetry using UAV data. Both fixed-wing and rotary drones were used in the capturing of images which were then processed using Pix4d™ drone image processing software. The flying of UAVs and processing of images was carried out in conjunction with Barrick Lumwana Mine Company (LMC) Survey section which oversees the UAVs at Lumwana mine. The processed drone data was analysed both in Leapfrog™ software and Vulcan™.

1.5 Expected Outcome

A model of the ore package and the intervening internal lithological units was created using Leapfrog™ modelling software. The model was built based on the available latest drill hole data, mapping data and photogrammetric data. Structural trends from the existing structure model were used to guide the trends of the lithological solids in the new model.

The structural data as modelled in Leapfrog™ was partly analysed in Vulcan™ for the purpose of understanding the Cu grade distribution as it relates to the structure. The Cu grade distribution studies were accomplished with the help of the Barrick Lumwana Mine Company (LMC) resource team through the reserve and grade control block models.

Chapter 2

REGIONAL GEOLOGY OF THE LUMWANA PROJECT

2.1 Tectonic setting

The Lumwana shear-zone-hosted deposits are located within the Domes Region of the Neoproterozoic Lufilian orogenic belt, also referred to as the Lufilian Arc. The ca. 900 km long arcuate belt has a characteristic north to north-northeast concave shape and stretches from east Angola, to the Democratic Republic of Congo's Katanga Province and into Zambia's Copperbelt and Northwestern Provinces (Cailteux *et al.*, 2005; Muchez *et al.*, 2015). On the regional scale, the belt is defined by five tectono-metamorphic regions from south to north namely: 1) the Katanga High, 2) the Synclinorial Belt, 3) the Domes Region, 4) the External Fold-thrust Belt, and 5) the Lufilian Foreland Basin (Porada, 1989; Cosi *et al.*, 1992; Salley *et al.*, 2005) (Fig. 2.1).

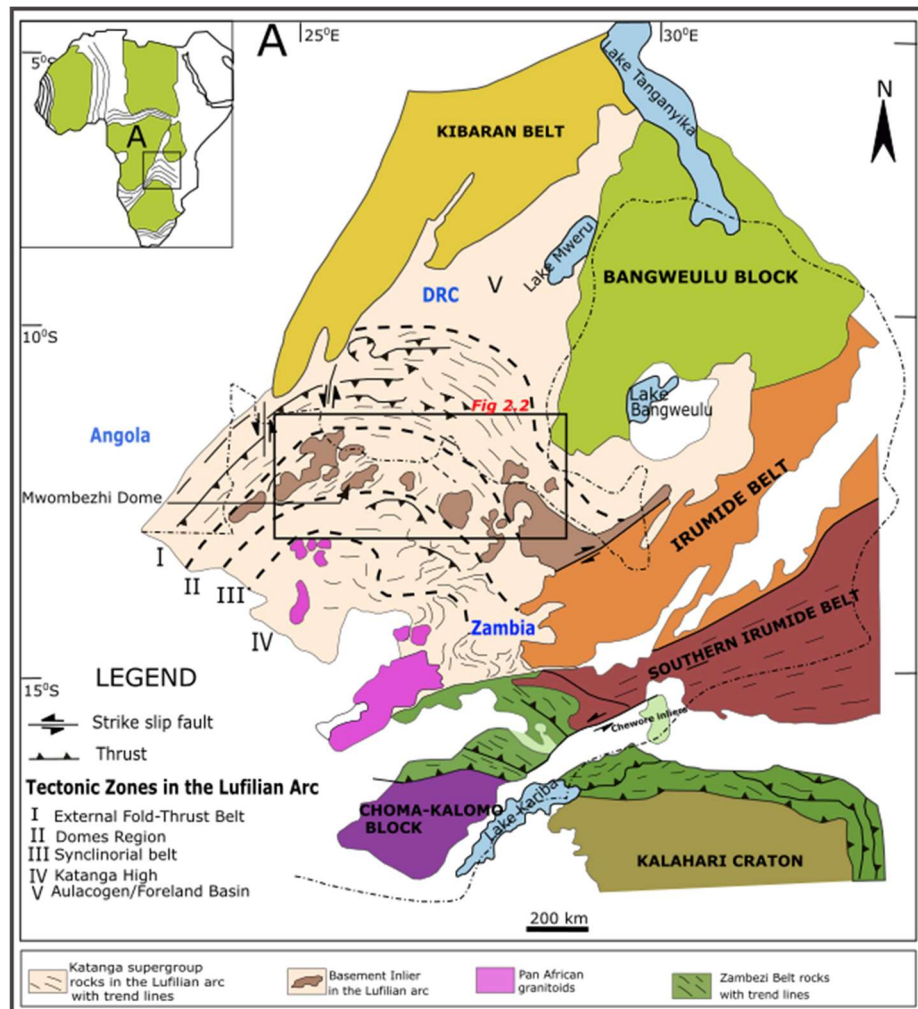


Figure 2.1. Geological map of the Lufilian Arc showing the location of the Mwombezhi Dome situated within the Domes region (De Waele *et al.*, 2008).

These regions display a broad, south-to-north decrease in metamorphic grade from upper amphibolite to lower greenschist facies (Selley *et al.*, 2005). This is a typical setting when transitioning from hinterland to foreland in a continental collision system (Selley *et al.*, 2005).

Located within this orogenic belt, are world-class sediment-hosted Cu-Co deposits within deformed Neoproterozoic Katangan Supergroup units of the external fold-thrust belt (Fig. 2.1). The Katanga Supergroup consists of a *ca.* 5 to 10 km thick sedimentary sequence which is commonly split into the Roan (lower), Nguba (intermediate), and Kundelungu (upper) groups (Table 2-1).

Table 2-1. Simplified stratigraphy of the Lufilian Belt modified after Cailteux *et al.* (2005), and Kipata *et al.* (2013).

Age (Ma)			Group	Sub-group	Formations and lithology	
~320	L. Palaeozoic		Karoo			
542	Early Palaeozoic		Katanga Supergroup	Kundelungu	Biano (ku3)	Red arkoses, conglomerate, sandstones, shales
530	Neoproterozoic	Ediacaran			Tectonic unconformity	
635					Ngule (Ku2)	Sandstones, calcareous siltstones, shales and limestones
					Gombela (Ku1)	Carbonated siltstones and shales
					Petit Conglomerate	Glacial diamictite
650				Cryogenian	Nguba	Bunyeka (Gg2)
710		Muombe (Gg1)				Carbonated siltstones and shales
						Dolomites and limestones
750		Grand Conglomerate			Glacial diamictite	
850		Roan			Mwashya (R4)	Calcareous shales
				Dipeta (R3)	Dolomitic siltstones, gabbros	
	Mines (R2)			Stromatolitic dolomitic siltstones		
	R.A.T. (R1)			Argillaceous dolomitic silts and sandstones		
1000	Tonian	883 ± 10 Ma Nchanga granite				
Paleo & Mesoproterozoic gneisses and schists						

The subdivisions are based on the existence of two regionally correlative diamictites, the Grand Conglomerate and the Petit Conglomerate (Cailteux *et al.*, 2005). The variably deformed and metamorphosed late Proterozoic sediments are believed to have been deposited in an extensional (rift) context (Cailteux, 1994). The Roan Group, which hosts most of the Cu-Co mineralisation, is composed of siliciclastic and carbonaceous sedimentary rocks of fluvial and lacustrine origin (Cailteux, 1994).

The Katanga High is typified by dominant *ca.* 883 ± 10 Ma Pan-African syn-tectonic granitic plutonism (Armstrong *et al.*, 2005). According to Hanson *et al.* (1993), this age constrains the lower limit for the deposition of the Katangan sediments. The Katanga High metasedimentary sequence is made up of alternating quartzites, quartz schists and sericite schists (Naydenov *et al.*, 2014). These are overlain by a sequence of marbles, calc-silicates and schists, all of which underwent greenschist facies metamorphism (Naydenov *et al.*, 2014). The sequence has been largely correlated with the Kundelungu Group, with the uppermost carbonaceous unit in the area (Upper Kundelungu) unconformably overlying weakly metamorphosed sedimentary rocks as shown in Table 2-1 (Porada & Berhorst, 2000). The weakly metamorphosed units include shales, slates, siltstones, mudstones, and local lenses of limestones. At the base of the sequence is a conglomerate layer that is composed of pebbles. This signifies a major unconformity and deposition that followed the exhumation of the older units (Wendorff, 2003). As with the Katanga High sequence, the Synclinorial Belt stratigraphy is not well constrained at depth. The units are dominated by low-grade carbonate and clastic units of the Kundelungu Group (upper Katanga Supergroup), with some Lower Roan Group outcrops (Naydenov *et al.*, 2014). Porada and Berhorst (2000) suggested that Katangan supracrustals belonging to the Katanga High and Synclinorial Belt are underlain by units of the Kalahari and Congo Cratons, respectively, thereby advancing an argument suggesting the presence of a major underlying basement suture.

The Synclinorial Belt transitions to the north into the Domes Region. This transition is accentuated by a sharp increase in deformation intensity, high grade metamorphism and a replication of the Katanga Supergroup sequence (Porada, 1989). This has been interpreted as a transition from a metamorphically complex foredeep terrain into a deep crustal terrain or basement high (Porada, 1989). The characteristic domal shapes of the Domes Region resulted from the emplacement of refolded thin nappes onto a flat topography (Cosi *et al.*, 1992). According to Cosi *et al.* (1992), this was a superposition of an allochthonous nappe complex composed of both basement and cover tectonostratigraphic units. The exposed part of the nappe piles represents the uppermost portions that were brought to the surface during exhumation from the deepest Lufilian orogeny.

The prominent domes in the region include the Kabompo, Mwombezhi, Solwezi, Luswishi and Kafue domes (Fig. 2.2). The internal fabric of these domes is characterised by Paleoproterozoic metatextitic ortho- and paragneisses, and schists. The Kafue Dome is cored by the volcanoclastic Lufubu Metamorphic Complex schist, which like other basement units, yields an age of *ca.* 1950 Ma. The overlying siliclastic cover has been correlated with the Mesoproterozoic Muva Supergroup (*ca.* 1941–1384 Ma; Key *et al.*, 2001; John *et al.*, 2004; Rainaud *et al.*, 2005; Selley *et al.*, 2005). This sequence of Mesoproterozoic siliclastics has been intruded by massive volumes of early Neoproterozoic granitoids

(i.e. Nchanga, 883 ± 10 Ma) and intermediate to mafic magmatic bodies at *ca.* 765–735 Ma (Armstrong *et al.*, 2005). Mantling and unconformably overlying the basement domes are several hundred metres of lower to upper amphibolite facies Lower Roan Group supracrustals. These are composed of muscovite-quartz-talc $\pm$ hematite schist and micaceous quartzite, which based on their inferred protoliths, are assigned to the base of the Katanga Supergroup (Cosi *et al.*, 1992; John *et al.*, 2011; Eglinger *et al.*, 2016). The base of the Katangan Roan Group defines a major Pan-African unconformity, which takes the form of a regional decollement that detached the Katanga Supergroup from the underlying basement (Porada and Berhorst, 2000; Selley *et al.*, 2005; Bernau, 2007). The Mesoproterozoic Muva Supergroup micaceous quartzite is overlain by carbonaceous metasediments and pelitic metasediments of the Upper Roan and Kundelungu Groups, respectively (Selley *et al.*, 2005). The lithological components of the Lower and Upper Roan sequences can largely be correlated throughout the Domes Region, although their protoliths probably differed based on their respective positions within the basins (Selley *et al.*, 2005).

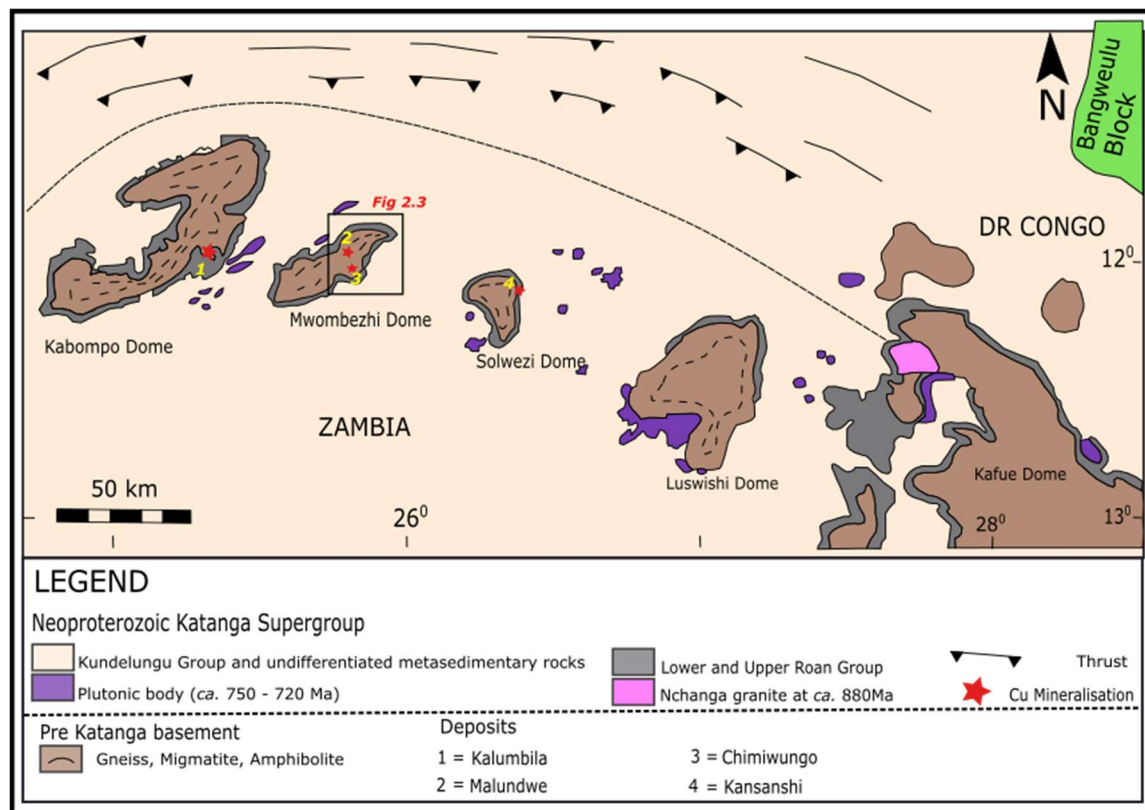


Figure 2.2. Simplified geological map of the Domes Region of the Lufilian Arc. (Modified after Baron, 2003)

To the north of the Lufilian Arc is the External Fold and Thrust Belt, albeit with the absence of basement domes (i.e., inliers). This belt denotes a transition from thick-skinned to thin-skinned tectonics and a decrease in the metamorphic grade, from amphibolite to greenschist grade (Koegelenberg *et al.*, 2019). The detachment of the Katanga Supergroup sequence from the basement rocks along the decollement is characterised by the occurrence of intense foreland-directed folding and thrusting. The presence of

upright axial planar fabrics in the External Fold and Thrust Belt is consistent with a general decrease in deformation intensity towards the Lufilian foreland into the Katanga Aulacogen Foreland (Selley *et al.*, 2005; Kipata *et al.*, 2013).

The Lumwana copper deposits of Chimiwungo and Malundwe are hosted in the Paleoproterozoic lithologies of the Mwombezhi Dome, a northeast-trending bi-lobed basement dome in the Domes Region (Fig. 2.2). The Dome comprises granitic gneisses, migmatites, amphibolites and schists, unconformably overlain at their margins by rocks of the Neoproterozoic Katangan Supergroup (Cosi *et al.*, 1992). Also, occurring within the Domes Region are two other major deposits, Kalumbila Co-Ni-Cu Mine located in the Kabompo Dome and the vein-hosted Kansanshi Cu-Au Mine to the east of the Solwezi Dome. The deposits in these domes occur at different stratigraphic levels, but are predominantly hosted in the reworked pre-Katanga basement gneisses and schists near the margins of domes at a regional scale (Koegelenberg *et al.*, 2019). Besides the basement mineralisation, the deposits also occur within clastic and chemical metasedimentary units which belong to the basal part of the Katangan Supergroup (Koegelenberg *et al.*, 2019).

The copper mineralisation at the Lumwana deposit is hosted almost entirely within the high grade metamorphosed, intensely sheared, recrystallised, muscovite-phlogopite-quartz $\pm$ kyanite schist (Richards and Nisbet, 2003). The intensely sheared zone locally referred to as the Ore Schist, is dominated by chalcopyrite and bornite which occur as disseminated sulphides (typically <5%) (Dobrotin *et al.*, 2013). The distribution of copper mineralisation within the shear zone appears to be controlled by the internal geology of the shear zone.

2.2 Evolution of the Lufilian Belt

The Neoproterozoic Lufilian Arc represents a collision of Archean to Mesoproterozoic basement blocks of both the Democratic Republic of the Congo (DRC) and Zambia. The main blocks responsible for this orogenic belt on the DRC side include the Kasai Block and Kibaran Belt bounding the Lufilian Arc to the north and northwest, respectively. On the Zambian side, the Lufilian Arc is bounded by the Bangwuelu Block and Irumide Belt to the northeast and southeast, respectively (De Waele and Fitzsimons, 2007; Kipata, 2013) (Fig. 2.1). The Lufilian Arc, of which the Domes Region is an integral part, formed during the collision of the Angola-Kalahari and Congo-Tanzania Plates between 650 and 530 Ma, with the peak of metamorphism at *ca.* 550 Ma (Hanson *et al.*, 1993; Unrug, 1997; Porada and Berhorst, 2000; John *et al.*, 2004). This peak of metamorphism has been associated with the formation of the talc-kyanite assemblages located in both the Domes Region and Zambezi Belt (John *et al.*, 2004). According to Eglinger *et al.* (2016), peak metamorphism was followed by syn-to late-orogenic exhumation, subsequent crustal collapse, and the closure of the Lufilian Orogenic events. These activities were associated with retrogression and occurred between *ca.* 510 Ma and 470 Ma using (Rb-Sr and K-Ar geochronometer, Turlin *et al.* 2016). The cooling period has been supported by the muscovite U-Th-Pb ages using late metamorphic monazite grains (Cosi *et al.*, 1992; John *et al.*, 2004; Eglinger *et al.*, 2014, 2016; Turlin *et al.*, 2016).

The collision was associated with the assembly of the supercontinent Gondwana between 750 and 500 Ma (Porada and Berhorst, 2000; Frimmel *et al.*, 2011) and was accompanied by NE-directed folding and thrusting at 560–550 Ma. The assembly of the Gondwana supercontinent led to the closure of the Mozambique Ocean basin, by subducting oceanic lithosphere and forming eclogites at 600 Ma (John *et al.*, 2003; Kipata, 2013). This ocean basin formed due to the rifting between the Congo and Kalahari after 880 Ma and the separation of the Congo-Tanzania plate from the Angola-Kalahari plate during the breaking of Rodinia. This produced a passive continental margin on the southern side of the Congo Craton (Porada and Berhorst, 2000; John *et al.*, 2003). The felsic magmatism events that produced the Nchanga Granite occurred just before or during the early rifting stages of ocean basin development (Armstrong *et al.*, 2005). Furthermore, the age of the Nchanga Granite (883 ± 10 Ma) has been used to constrain the new maximum age for the deposition of the Katanga Supergroup at 880 Ma (Armstrong *et al.*, 2005). The final stage during the collision was followed by tectonic uplift, erosion and subsequent cooling (John *et al.*, 2004).

The Lufilian Arc is predominantly composed of supracrustal clastic and chemical metasedimentary rocks of the Katangan Supergroup (Cailteux, 1994; Cailteux *et al.*, 2005; Batumike *et al.*, 2009). Deposition spanned from rifting and eventual separation of the Rodina supercontinent to the convergence and final amalgamation of the Kalahari and Congo Cratons during the Pan-African Orogenic cycle (Unrug, 1989; Hanson *et al.*, 1993; Porada and Berhorst, 2000). The 7 to 10 km thick Katangan Supergroup metasedimentary rocks were deposited in the rift basin which formed *ca.* 800 Ma. The Supergroup is made up of the Roan, Nguba and Kundelungu Groups (Table. 2.1), which are demarcated by two regional diamictites of geological significance (Cailteux *et al.*, 2005). The Grand Conglomerate at the base of the Nguba Group marks the separation of the Roan and the Nguba groups, while the Petit-Conglomerate at the base of the Kundelungu Group separates the Kundelungu and Nguba groups. The Petit-Conglomerate, which is composed of clasts of the underlying Nguba Group denotes the reversal from extensional to compressional tectonics and the commencement of the north-verging Lufilian folding and thrusting (Batumike *et al.*, 2007).

On the southwestern (DRC) side, the Lufilian belt is characterised by the presence of a complex cover of allochthonous Roan and Kundelungu groups (Selley *et al.*, 2018). The base of the allochthonous strata is defined by deformed megabreccias of the Roan group. The megabreccias which range between 1 m to 10 km in thickness are generally derivatives of different stratigraphic units (Jackson *et al.*, 2003). The megabreccias, are supported in a fine dolomitic, chloritic, talc-like, siltstone matrix which displays sporadic occurrences of sulphides. Megabreccias have been known to occur in association with salt tectonics, particularly in diapirs whose halite has been partly or wholly exhausted (Jackson *et al.*, 2003). The Roan megabreccias appear to have developed along weaker strata believed to have been caused by the depletion of the evaporites at ~765 to 740 Ma (Nowecki, 2014). In the southwestern DRC the megabreccias are associated with the Kolwezi Klippe, a feature which is suggestive of a large-scale end moraine in glacial salt tectonics (Jackson *et al.*, 2003). Therefore, the emplacement of the allochthon may have been facilitated by the extruded and overpressured Roan salt sheet, which lubricated the Lufilian Roan carbonate-dominated mixed sediments.

The withdrawal of halite from diapirs ultimately induced a localised break-through across what was initially a hydrological seal (Selley *et al.*, 2018). This created entry points for the deeper-level residual mineral-rich brines which migrated up-stratigraphy where they were reduced, thereby forming ore deposits. The transfer of the minerals in the Katangan Roan group sediments was necessitated by the general highly soluble nature of the evaporites that were present during salt tectonics. Furthermore, when the conditions allowed for the evaporites to crystallise, the crystalline rocks promoted deposition of the dissolved minerals (Jackson *et al.*, 2003). The low permeability of the crystalline rocks impeded fluid flow, therefore promoting mineral deposition (Jackson *et al.*, 2003).

2.2.1 Roan Group

On the DRC side of the Fold-Thrust Belt, the Roan Group has been subdivided into four subgroups from bottom to top: RAT ('Roches Argilo-Talqueuses' or R 1), Mines (R 2), Dipeta (R 3) and Mwashya (R4) (Table. 2-1). The Roan Group sequence is characterised by several transgressive and regressive lithotypes whose deposition was driven by two main cycles (Cailteux, 1994). The first cycle was dominated by an intracontinental to sub-continental basin deposition and was followed by the deposition of the carbonate platform sediments during the second cycle (Cailteux, 1994). The R1 subgroups being the lowest in the series, is believed to have been deposited transgressively over the pre-Katangan basement, with a coarse-grained sandstone base overlain by a dolomitic siltstone sequence (Cailteux *et al.*, 2005). This subgroup is believed to be the first carbonate platform of the Roan deposition cycle and to have been deposited under an oxidised, hot, arid to semi-arid environment (Cailteux *et al.*, 2005).

The Mines Subgroup, which is host to the major Cu-Co stratiform deposits of the Central African Copper belt, is mostly a carbonate/dolomitic succession (Cailteux and De Putter, 2019). The units were deposited under reducing conditions, in a shallow-water/hypersaline tidal flat, reef and lagoonal setting, during a major transgressive–regressive event (Cailteux, 1994). The subgroup is characterised from bottom to top by a transgressive sequence that starts with shallow water, bedded, silty dolomite, followed by tidal laminar carbonates, and an overlying reef Stromatolitic Formation. The algal environment is responsible for the occurrence of organic matter within these rocks, and for reducing conditions, which favoured metal trapping (Batumike *et al.*, 2007). The topmost formation of the Mines Subgroup defines a unit that corresponds to a regressive sequence of carbonate shallow-water reef, tidal, and locally evaporitic sediment deposition (Cailteux and De Putter, 2019). This formation, which is also known as the Kambove Carbonates (Cailteux, 1994), is interlayered with clastic beds and progressively thickens up to 2–3 m. The unit signifies a progressive change in the sedimentary environment, from carbonate (Mines) to siliciclastic (Dipeta) deposition (Cailteux, 1994).

Following the deposition of the Mines Subgroup, a regression took place during Dipeta (R3) sedimentation. The Dipeta Subgroup is mainly composed of dolomite beds alternating with a combination of shales and siltstones (Cailteux and De Putter, 2019). The regression process yielded the deposition of siliciclastic rocks comprising oxidised hematitic, dolomitic siltstone and sandstone similar to the RAT facies (Cailteux, 1994; Hitzman *et al.*, 2012).

The Mwashya (R4) Carbonate Formation is characterised by massive reef stromatolite, interlayered with peritidal, microbial, talc-bearing and arenitic dolomites. It also contains mafic volcanic beds of regional extension which are locally accompanied by magnetite-hematite banded iron formation (BIF), both of which are considered markers for the lower Mwashya subgroup (Batumike *et al.*, 2007; Cailteux, 1994). The Mwashya Subgroup units are overlain by a regional diamictite, marking the base of the Nguba Group (Batumike *et al.*, 2007). According to Wendorff (2003) and Master *et al.* (2005), the Mwashya Subgroup is the lowermost part of the Nguba Group.

2.2.2 Nguba Group

The Nguba Group overlies the Roan Group. It is subdivided into two major subgroups, namely the Muombe and Bunkeya Subgroups (Table 2-1). The base of the Nguba Group is represented by a regional diamictite marker, the 'Grand Conglomerate', also called the Mwale Formation (Batumike *et al.*, 2007). This unit is described by them as the most consistent Formation within the entire Katangan basin. It is a diamictite that was deposited between 765-735 Ma during the worldwide Sturtian glaciation (Master and Wendorff, 2011). The Grand Conglomerate is a fine- to medium-grained, matrix-supported conglomerate with pebbles and cobbles of different origins. There is evidence of a glacial origin for this diamictite based on its polymictic texture, striated clasts, and poorly sorted fine-grained matrix (Batumike *et al.*, 2007; Master and Wendorff, 2011; Wendorff, 2011).

Throughout the Katanga basin, the Grand Conglomerate varies in facies from continental, to shallow and then to deep marine facies (Master and Wendorff, 2011). This variation of facies was governed by the sedimentation environment, ongoing tectonic activities and variation of climate and ice dynamics (Master and Wendorff, 2011). The overlying units are composed of dolomitic shales and dolomites belonging to the Kaponda, Kakontwe and Kipushi formations of the Muombe Subgroup (Table 2-1). The upper part of the Nguba Group, the Bunkeya Subgroup, consists of siliciclastic units of sandstone and pelite (Batumike *et al.*, 2007).

2.2.3 Kundelungu group

Overlying the Nguba Group is the Kundelungu Group, which was deposited during the latest Neoproterozoic to the early Paleozoic. It is commonly subdivided into the Gombela (Ku1), Ngule (Ku2) and Bianco (Ku3) subgroups (Batumike *et al.*, 2007) (Table 2-1). The base of the Kundelungu Group is defined by a diamictite also known as the 'Petit Conglomerate', with a probable erosional unconformity (Wendorff, 2003). This Petit Conglomerate layer, classified under the Gombela Subgroup, could have been deposited during the Marinoan-Varanger ice age (Zientek *et al.*, 2010). It is overlain by cap carbonate rocks of the Lusele Formation, known as the "Calcaire rose" (Dewaele *et al.*, 2008). The Gombela Subgroup is predominantly characterised by siltstone-shale-carbonate units that overlie the Petit Conglomerate (Table 2-1). Overlying the Gombela Subgroup is the Ngule Subgroup, which consists of a series of interlayered pelitic to sandy, carbonate-bearing, siltstone and sandstone beds (Batumike *et al.*, 2007). The uppermost Katangan sediments of the Bianco Subgroup comprise a continental clastic molasse-type sequence dominated by coarse- to fine-grained, ripple-marked, red siltstones and

intraclastic conglomerates (Cailteux and De Putter, 2019). This unit was deposited unconformably over the folded Katangan rocks (Master and Wendorff, 2011). The ripples show internal cross laminations and are flat-topped, an indication of partial erosion during falling water levels. No metamorphism has been observed in the red siltstones, and they contain an abundance of detrital muscovite that yielded a depositional maximum (^{30}Ar - ^{40}Ar) age of 573 ± 5 Ma, defining the capping of the Katanga Supergroup (Master *et al.*, 2005). The minimum depositional age for the Bianco Subgroup is approximated to be younger than 540 Ma (Kampunzu and Cailteux, 1999). This, therefore, leads to the fact that the Bianco sequences may have been deposited during the Cambrian rather than during the Neoproterozoic (Cailteux and De Putter, 2019), defining the Katangan Supergroup deposition period of < 883 Ma to *ca.* >500 Ma (Cailteux *et al.*, 2005).

2.3 Mwombezhi Dome Geology

2.3.1 General

The Mwombezhi Dome which, hosts the Lumwana deposits, extends up to *ca.* 67 km along its two lobes and is up to 20 km wide in the NW–SE direction (Fig. 2.3) (Tripp, 2013). According to Bernau, (2007), the tectonostratigraphy of the northeastern lobe of the Mwombezhi Dome has been described as consisting of upper and lower structural levels. The lower structural level is dominated by less deformed Paleoproterozoic basement gneisses and schists, and a stable crystalline base, whose composition is characterised by the granites that are generally correlated with the *ca.* 883 ± 10 Ma Nchanga granite intrusion (Armstrong *et al.*, 2005; Tripp, 2013). Several layer-parallel shear zones are recognised cross-cutting a tectonostratigraphic package of gneissic layers derived from both igneous and sedimentary protoliths (Tripp, 2013). The upper structural level underlies the mantling Lower Roan clastic sequence, the “Rimming quartzite” and is interpreted as the footwall to the Katanga Décollement (Fig. 2.3) (Dobrotin *et al.*, 2013). The Katanga Décollement separates the Paleoproterozoic basement units from the overlying Katangan Supergroup sediments and is composed of a magnesium-rich quartzite which grades into the muscovite-quartz-talc-kyanite-hematite schist in places (Cosi *et al.*, 1992; John *et al.*, 2004). The décollement is also marked by an L-S tectonite that exhibits an intense north-south mineral lineation.

The upper structural level is characterised by high-intensity strain and imbrication related to thick-skinned thrusting (Bernau, 2007). Embedded in this structural level are “allochthonous” blocks believed to belong to the Roan Group that are arguably the result of overthrusting. These apparently ‘foreign’ Roan Group slivers also locally known as “internal quartzites” are characterised by low-angle, recumbent folds that form kilometre-scale nappes (Koegelenberg *et al.*, 2019). These bodies range from altered Lower Roan micaceous quartzite and muscovite-quartz-talc-kyanite-hematite schist, to the Mwashya- or Nguba-age marbles, calcareous pelites/calc-silicates, carbonate amphibolite breccias, basalts and gabbros (Richards, 2012).

Cosi *et al.* (1992) describe the crustal evolution model of the Mwombezhi Dome as a north-verging, rootless nappe, that developed above mid-to-lower crustal ramps whose core is composed of “allochthonous” pre-Katanga Paleoproterozoic gneisses and schists. However, the model falls short of an explanation addressing the observed absence of Katanga Supergroup units at lower structural levels. The lower crustal levels are instead characterised by less deformed basement gneisses and schists which

are a tectonostratigraphic equivalent of the nearby Solwezi and Kabompo Domes (Eglinger *et al.*, 2016; Williams and Nisbet, 2017).

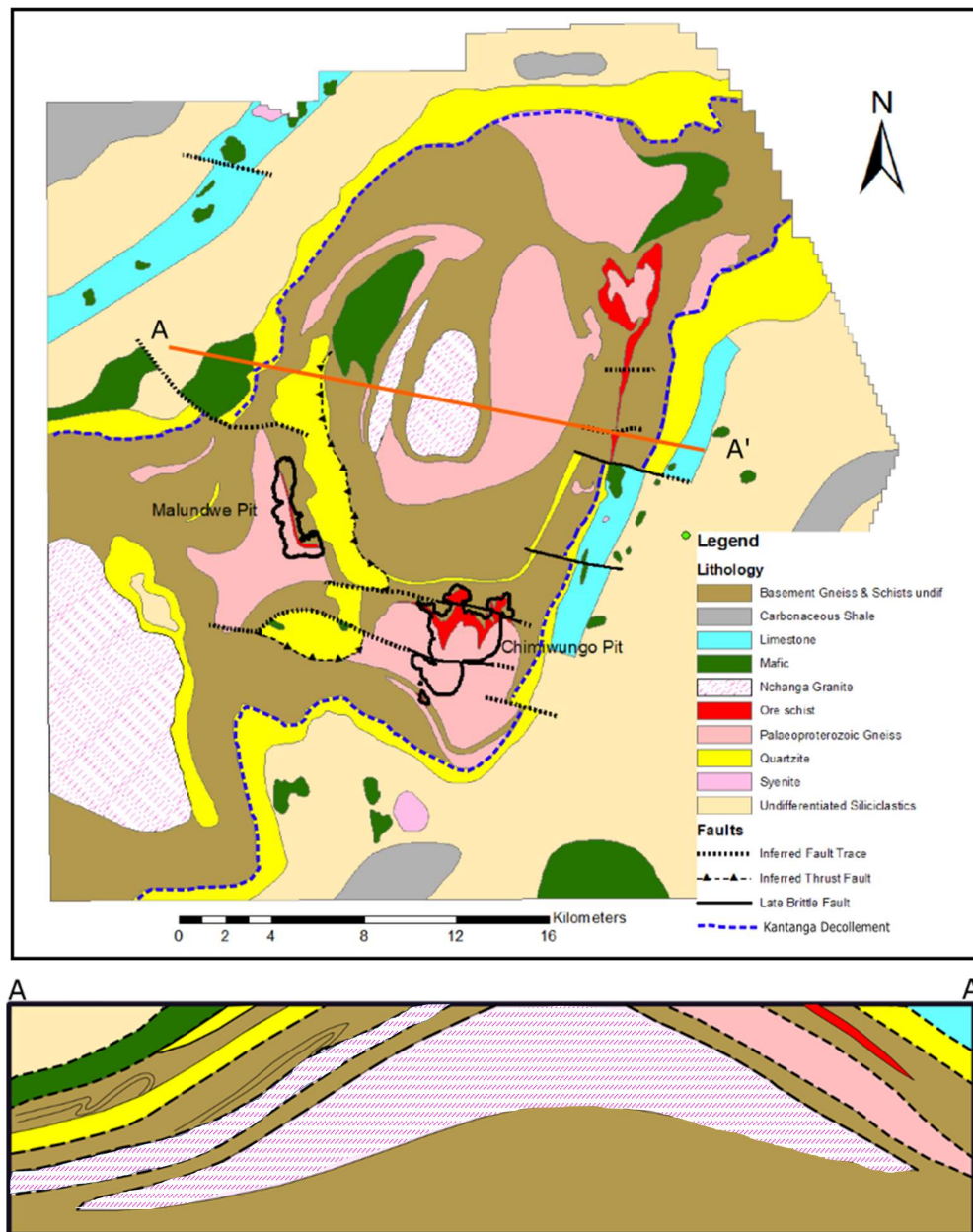


Figure 2.3. Geological map of the Mwombezi Dome, showing the location of the two largest deposits (Malundwe and Chimiwungo) (Dobrotin *et al.*, 2013).

The “Rimming Quartzite” has been correlated with the Lower Roan lithologies but its protolith is not very well understood as its chemical composition is extremely rare in nature and indicates a metasomatic origin (Johnson, 2002). The fluids responsible for the metasomatism of the “Rimming Quartzite” were possibly derived from the pore fluids of shallow-water sediments, driven off the Congo plate by the over-riding Kalahari plate during a continent-continent collision at 530 Ma (John *et al.*, 2004). In the centre of the Dome is a granite locally called “Central Granite”, which intruded the

basement units. This younger granite, which represents a major final intrusive event at *ca.* 870-900 Ma has been correlated with the Nchanga suite (Tripp, 2013). This age is well within the error margin of the 879 ± 16 Ma age assigned to the Kafue Rhyolite, which underlies the supposedly Katangan-equivalent Zambezi Belt supracrustals (Hanson *et al.*, 1993). The occurrence of this intrusive event implies that felsic magmatism happened just before or during the early stages of the opening of the Katangan basin (Armstrong *et al.*, 2005). Evidence from diamond drill core has revealed that the granites at the core of the northeastern lobe of the Mwombezhi Dome show minimal deformation as compared to the highly deformed granite gneiss units which host the Chimiwungo and Malundwe deposits.

According to Bernau (2007), this observation supports the concept that the granites at the core of the northeastern lobe of the Mwombezhi Dome postdate the Lufilian deformation events. However, it seems unlikely that these granites postdate the Lufilian orogeny, because the Pan-African events responsible for this deformation record peak metamorphism at between 550 Ma and 530 Ma (Eglinger *et al.*, 2016), implying that the granites intruded the basement units much earlier than the deformation events, even though they may have undergone minimal deformation. Dobrotin *et al.* (2013) described this unit as predominantly composed of moderately to weakly foliated coarsely crystalline quartz-feldspar-biotite meta-syenogranite to meta-monzogranite. The preservation of the massive texture associated with igneous rocks has also been observed in the amphibolites and in the granitoid gneisses during pit mapping.

The Mwombezhi Dome metabasic units occur across stratigraphy and show some variations in form, degree of deformation and age. The rock units that occur in the younger lower Roan metasediments are characterised by pillow-shaped structures which points to the fact that they were extruded as flows underwater. The metabasalts yield an LA-ICPMS age of 756 ± 27 Ma (Tripp, 2013), and according to Tembo *et al.* (1999), the rocks were derived from the tholeiitic basaltic magmas that resulted from upwelling of asthenospheric mantle. The geochemical data available in the rocks are consistent with an extensional regime during the initial rifting stage of the Lufilian Belt (Tembo *et al.*, 1999). The fine-grained extrusive mafics are also part of the conformable Katangan sequence found outside the Dome generating soils locally enriched in Cu (Dobrotin *et al.*, 2013). The second suite of mafics is related to the older basement rocks of the Mwombezhi Dome. These have been observed to have intruded the granitoid gneisses of the hangingwall and the gneisses/migmatites of the footwall to the orebody. These metabasic units which have been identified in the mineralised shear zone (orebody), appear to have played a crucial role in the development of the shear zone. Predominantly composed of amphibole with lesser plagioclase and more rarely olivine, this lithology is present as outcrops and has also been intersected in drilling at the two main deposits (Malundwe and Chimiwungo) (Dobrotin *et al.*, 2013).

2.3.2 Mwombezhi Dome Structural Geology

The Mwombezhi Dome architecture is characterised by several thrust sheets which define the tectonostratigraphy of the Domes Region. These thrust sheets are bound by shear zones of the Lufilian Orogeny which define the contacts between the basement and the Katangan Supergroup rocks (Richards, 2012). The Mwombezhi Dome structure has been interpreted by previous workers as either

complex recumbent folding of Katangan sediments overlying older basement (Mulela and Seifert, 1998) or as an allochthonous nappe-pile complex composed of both basement and sedimentary cover (Cosi *et al.*, 1992). However, due to poorly exposed and heavily weathered outcrops, compounded by inadequate structural and geophysical information across the Dome, the structural evolution of the Mwombezhi Dome remains enigmatic (Porada, 1989; Cosi *et al.*, 1992; Eglinger *et al.*, 2016; Turlin *et al.*, 2016). The majority of the outcrops comprise lithologically competent mafic rocks and micaceous quartzite units of the “Rimming Quartzite” that are resistive to weathering and consequently form topographic highs.

The deformation events of the Mwombezhi Dome have been defined by three main stages: D1–D3 (Eglinger *et al.*, 2016). Peak metamorphism, which has been assigned to the first deformation stage, is interpreted to represent a High Pressure – Medium Temperature (HP–MT) event which is attributed to burial down to 40–50 km under a geothermal gradient of 15–20 °C /km (Eglinger *et al.*, 2016). This event is closely linked to subduction of the continental margin of the Congo craton followed by collision with the Kalahari craton at *ca.* 550–530 Ma using the U-Th-Pb dating of the syn-metamorphic monazite grains (John *et al.*, 2011; Eglinger *et al.*, 2016). Structural data at Chimiwungo suggests D1 as a top-to-the-NNE fore-thrusting event typified by flat-lying proto-mylonites and mylonites associated with NNE-verging isoclinal flexural/drag folds and nappes (Cosi *et al.*, 1992; Eglinger *et al.*, 2016). These drag folds, which vary in magnitude, are also observed to be closely associated with a pervasive layer-parallel gneissic S1 foliation (Yeo, 2007).

Eglinger *et al.* (2016) described the D2 event as a syn-orogenic exhumation of highly deformed basement rocks, which was characterised by an isothermal decompression due to tectonic accretion of the subducted Congo cratonic units that became decoupled from the down-going slab. This syn-orogenic exhumation of the Paleoproterozoic metamorphic rocks was characterised by an increase of the geothermal gradient to 25–30 °C/km⁻¹. This was then followed by retrogression from upper amphibolite to lower amphibolite facies conditions (Eglinger *et al.*, 2016). In the Mwombezhi Dome, the second deformation stage, D2, produced a south-dipping S2 schistosity, which may be attributed to local under-thrusting of the Katanga Supergroup in the Domes region. This stage is accentuated by the preferred orientation of phlogopite and muscovite basal cleavage planes, coupled with the transposition and mylonitisation of the metatexitic gneissosity (Turlin *et al.*, 2016). D2 kinematics are defined by the generation of a top-to-the-south and -southeast axial planar foliation and associated folding and re-folding (F2) of the gneissic foliation in the immediate overlying sequences (Cosi *et al.*, 1992; Eglinger *et al.*, 2016). The D2 retrograde phyllonitic schist is generally characterised by dark, intensely schistose, quartz + phlogopite/biotite ± epidote ± chlorite ± muscovite ± kyanite ± hematite assemblages in the cover and quartz - phlogopite/biotite ± plagioclase ± kyanite ± scapolite ± epidote ± muscovite in the basement (Turlin *et al.*, 2016).

The final deformation stage, D3, is marked by the transposition of the steep-dipping S2 schistosity to a shallow-dipping S3 schistosity and the development of a top-to-the-NNE, late-tectonic, extensional detachment (Turlin *et al.*, 2016). This stage is responsible for the development of the Cu-mineralised shear zones. The late to post-orogenic gravitational crustal collapse of the Lufilian orogenesis is

associated with the formation of D3 (Eglinger *et al.*, 2016; Turlin *et al.*, 2016). The development of top-to-the-north low-angle extensional detachments, described as C3 shear bands in the kyanite-muscovite-biotite schists, occurred during this post-orogenic stage (Eglinger *et al.*, 2016).

The domal tectonic events were terminated by a series of late steep NNE-dipping D4 brittle dip-slip and oblique-slip faults (Fig. 2.3). The oblique-slip faults predominantly show a dextral sense of displacement and transect the boundary between the Paleoproterozoic basement units and the Neoproterozoic Katangan units (Fig. 2.3). The faults cut across the entire tectonostratigraphic sequence of the Mwombezhi Dome (Dobrotin *et al.*, 2013). This has positively impacted the economics of the deposit by way of exposing some faulted segments of the supposedly continuous orebody (Fig. 3.2). The faults stretch from hundreds of metres to tens of kilometres along strike, displaying variations in both the down-dip orientation and throw (from tens of metres to hundreds of metres throw). On the surface, they occur as zones of iron oxide rich clays and broken ground up to 50 m thick. The bigger brittle faults, such as the Chimi South Fault, comprise multiple anastomosing planes.

The faulting event does not appear to be related to earlier ductile D1 to D3 events (Barron, 2003; Williams and Nisbet, 2017). Also, there has been no evidence of any relationship between the late faulting event and the sulphide mineralisation hosted in the phyllonites. The exact timing of this faulting event is not well understood, but the displacement of D1-3 features and the accompanying structures point to either a late upper-crust extension during the final stages of post-orogenic collapse or post-Lufilian (far-field) tectonics (Eglinger *et al.*, 2016).

2.3.3 Metamorphism of the Mwombezhi Dome region

The observed current mineral assemblage associated with the Mwombezhi Dome, suggests an evolving prograde and retrograde metamorphic history (Poulsen, 2013). In the Mwombezhi Dome, the peak of metamorphism was reached during the Kalahari and Congo continental collision. The peak P-T metamorphic conditions of 13 ± 1 kbar and 750 ± 25 °C were recorded in the talc-kyanite-muscovite-biotite schists, one of the Lower Roan Group units of the Mwombezhi Dome (John *et al.*, 2004). These conditions correlate to burial depths of approximately 50 km (Cosi *et al.*, 1992; John *et al.*, 2004). They are further confirmed by the occurrence of migmatitic gneisses and strongly foliated metatexite that envelop the less deformed amphibolite boudins.

Following peak metamorphism, the upper structural level was progressively transposed and retrogressed by wide, highly strained phyllonitic shear zones. These zones record a Medium Pressure – Medium Temperature (MP-MT) D2 fabric at 8–6 kbars, 600–640 °C and *ca.* 530-500 Ma (Eglinger *et al.*, 2016). The development of this fabric was followed by an even lower-grade D3 generation of less than 6 kbar, 600–540 °C and *ca.* < 500 Ma shear zones (Eglinger *et al.*, 2016). In the overlying Katangan cover, D1 structures are represented by a ductile, low angle to sub-horizontal, high strain schistosity mainly registered in the “Rimming Quartzite/whiteschist”. In the basement, the migmatitic and almost metatextic gneissic structures are largely concordant with the Katanga-basement interface (also referred to as the Katanga Decollement) (Koegelenberg *et al.*, 2019).

The D3 (S3) structures are well-preserved at the base of the Lower Roan, at the Katangan Decollement and in the upper structural level of the Mwombezhi Dome. In the upper structural level of the Mwombezhi Dome, the D3 structures are characterised by high-intensity schistose fabric and an assemblage of quartz-muscovite-biotite/phlogopite $\pm$ kyanite $\pm$ sulphide schist (Bernau *et al.*, 2013; Turlin *et al.*, 2016). The late kinematic phyllonitic zones whose scale of thickness ranges from centimetres to hundreds of metres is characterised by several kilometres in both length and width. These D3 (S3) phyllonitic shears zones are also locally referred to as 'Ore Schist' as they host elevated and economical Cu sulphides mineralisation. At the Chimiwungo deposit of Lumwana, the D3 shears dip gently towards the south and display a penetrative extensional S–C' fabric with a top-to-the-north kinematic sense of movement (Koegelenberg *et al.*, 2019). The D3 event appears to be predominantly associated with the formation of an extensional decoupling, which was as a result of late exhumation and subsequent gravitational crustal collapse of the Lufilian Belt (Eglinger *et al.*, 2016; Turlin *et al.*, 2016). The post-orogenic gravitational collapse occurred simultaneously with the cooling of the high-grade metamorphic nappes of the entire Lufilian orogenic belt (Turlin *et al.*, 2016). According to John *et al.* 2004, the Rb-Sr isotopic system of muscovite, recorded a closure temperature of below *ca.* 500 °C.

Chapter 3

GEOLOGY OF THE CHIMIWUNGO DEPOSIT

3.1 Introduction

The Chimiwungo deposit occurs as a large tabular stratiform low-grade orebody, dipping shallowly to the south. The deposit has a strike length of *ca* 5 km east-west and averages between 40 m and 80 m in thickness. It is located ~8 km southeast of Malundwe and is characterised by two shallowly SSE- to S-plunging 'ridges', referred to as the Roan and the Equinox shoots (Fig. 3.1 and 3.2).

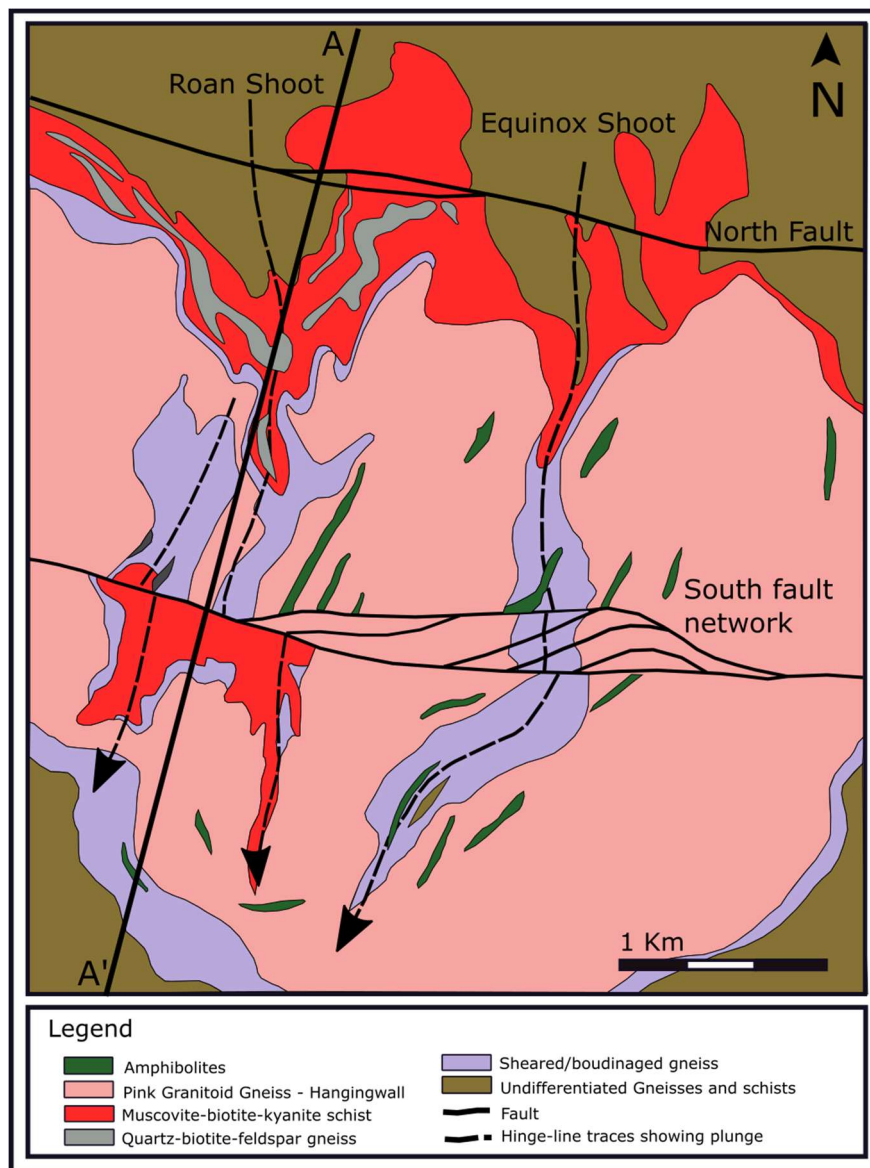


Figure 3.1. Simplified Chimiwungo geology map (modified after (Koegelenberg *et al.*, 2019))

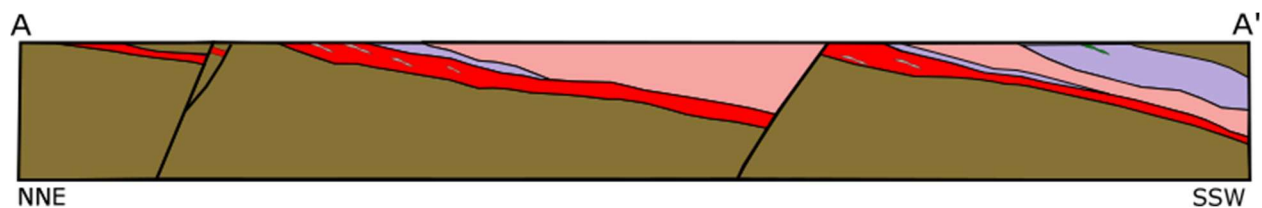


Figure 3.2 Schematic N-S cross-section with no vertical exaggeration through the Chimiwungo deposit highlighting the different strata. Two major normal faults partition the strata into three segments. Lithologies are shown in the same colours as in Fig. 3.1.

The ore package is thickest along the hinges of these structures, averaging around 110 m thick along the Roan Shoot and 130 m thick along the Equinox Shoot. The Chimiwungo orebody involves shear zone hosted mineralisation, with the main shear zone defining the ore package.

Mineralogically, the shear zone is characterised by muscovite-phlogopite/biotite-quartz-kyanite $\pm$ sulphide $\pm$ garnet hosted in the schistose fabric (Bernau, 2007). Locally, it is referred to as the Ore Schist due to its enrichment in economical copper ore minerals, namely, chalcopryite $\pm$ bornite $\pm$ chalcocite. These copper-sulphide minerals are hosted as disseminations along the S3 foliation and shear planes of the Ore Schist. The Chimiwungo deposit is characterised by the presence of intervening internal gneissic units which are generally barren, although sporadically occurring weak mineralisation has been observed in the gneisses in places.

Generally, the Chimiwungo mining volume can be divided into three main domains based on the positioning of the economic horizon within the stratigraphic sequence (Koegelenberg *et al.*, 2019). The three main domains are: 1) the footwall, 2) the ore package and 3) the hangingwall domains. The mineralogical assemblages of the major lithological units in each of the domains are documented in Table 3-1.

Table 3-1. Lithostratigraphy of the Chimiwungo deposit

Domain	Unit Name	Composition Minerals
Hanging wall	Pink Hangingwall Gneiss	Quartz-feldspar-phlogopite $\pm$ muscovite $\pm$ magnetite
	Grey Hangingwall Gneiss	Quartz-phlogopite/biotite $\pm$ muscovite $\pm$ feldspar
	Hangingwall Schist	Quartz-biotite-muscovite-feldspar
	Hangingwall Amphibolites	Amphibole-quartz-phlogopite-feldspar
Ore package	Ore Schist	Muscovite-phlogopite/biotite-quartz-kyanite $\pm$ sulphides
	Internal Grey Gneiss	Quartz-biotite-muscovite-feldspar
	Amphibolitic gneiss	Quartz-biotite-feldspar-amphibole $\pm$ garnet
	Internal Amphibolite	Amphibole-quartz-phlogopite-feldspar $\pm$ sulphides
	Leucosome	Quartz-feldspar $\pm$ amphiboles $\pm$ biotite
	Pegmatites	Plagioclase-quartz $\pm$ muscovite
Footwall	Footwall Schist	Biotite-epidote-chlorite $\pm$ feldspar $\pm$ talc $\pm$ amphibole
	Mottled schist	Phlogopite-chlorite-kyanite $\pm$ quartz $\pm$ scapolite $\pm$ muscovite
	Footwall Quartzite “Internal Quartzite”	Quartz-muscovite-talc
	Amphibolites	Amphibole-quartz-feldspar
	Undifferentiated gneisses	

3.2 Footwall

The Chimiwungo footwall is defined by several lithotypes which occur basal to the ore package. Because of the economical insignificance of the footwall, it is the least exploited domain in the entire Mwombezhi Dome. In most cases, drilling has been stopped 15 – 30 m below the base of the mineralised zone. Consequently, the understanding of the geology of the footwall both laterally and at depth is limited.

The footwall package is generally composed of schists, amphibolites and gneisses, some of which show similarity to the units of the hangingwall domain. Immediately underlying the ore package, the footwall package is marked by a distinct dark-coloured biotite-epidote-chlorite-quartz $\pm$ amphibole $\pm$ talc $\pm$ sulphide schist. This S2 schist locally referred to as the Footwall Schist, is quite distinct and easily distinguishable from the Ore Schist, thereby acting as a reliable marker unit when carrying out pit mapping or logging of a borehole across the Ore Schist-Footwall Schist contact. The Footwall Schist is sometimes known to host copper-sulphide mineralisation, albeit sub-economical in most cases. The footwall mineralisation takes a similar form to the mineralisation in the Ore Schist. The sulphides are disseminated and mainly concentrated along the S2 foliation planes of the Footwall Schist. Both chalcopyrite and bornite mineralisation have been reported in the footwall, however, bornite mineralisation tends to be enhanced where the biotite/phlogopite content is relatively higher.

Footwall amphibolites have been observed to be associated with the shoots. In places, the amphibolites appear to be sheared and retrogressed to biotite-phlogopite schists which are partly responsible for the dark-coloured appearance of the Footwall Schist. Further alteration and retrogression of the biotite-phlogopite assemblage to chlorite has been observed. These metamorphic events can be associated with the retrograde clockwise P-T path and are understood to be associated with D2 synorogenic exhumation events (Eglinger *et al.*, 2016).

A unique feature of the Footwall Schist is discrete zones characterised by phlogopite-chlorite-kyanite (commonly retrogressed to scapolite)-quartz poikiloblasts (Dobrotin *et al.*, 2013). The schist unit which is characterised by the poikiloblasts is referred to as “The Mottled Schist” (Fig. 3.3a). The poikiloblasts are predominantly composed of a combination of kyanite and scapolite, which are randomly orientated (Dobrotin *et al.*, 2013) (Fig. 3.3b). The kyanite, which makes *ca* 30% of the poikiloblasts, tends to occur in two texturally distinct morphologies (Bernau, 2007). The first form defines an early population of euhedral kyanite that occurs as clusters separated by aligned biotite, chlorite and anhedral quartz grains. The later kyanite population occurs as poikilitic porphyroblasts with quartz and biotite inclusions that form augen within the fabric (Bernau, 2007). The schistosity fabric which hosts the kyanite-scapolite poikiloblasts is dominated by biotite and chlorite, along with minor quartz and muscovite. Locally, this unit has been observed to occur between the Ore Package and the deep-seated Footwall Quartzite and gneisses.

The proportion of Mottled Schist seems to increase along the eastern and western margins of the deposit and decrease with increasing depth below the base of mineralisation. This Mottled Schist is

locally also mineralised, but the grades are not continuous or thick enough to be of economic significance (Dobrotin *et al.*, 2013).

The Footwall Quartzite also locally referred to as “Internal Quartzite” is another prominent unit of the footwall package which underlies the footwall contact and the Mottled Schist. Though commonly referred to as a quartzite, lithologically, the unit tends to exhibit dark bands of platy minerals. Consequently, the unit has at times been called the ‘White Schist’ unit; however, this usage has been discontinued because of its genetic connotations (Cosi *et al.*, 1992). The protoliths of this unit are believed to have been a higher energy conglomeratic arenite and lower energy muscovite-talc schist (Tripp, 2013). The presence of heavy minerals and dark grey hematite bands suggests the presence of bedding associated with the protolith. Further petrological studies interpreted this unit as being a clastic metasedimentary unit of varying mud, dolomite and conglomerate constituents (Tripp, 2013).

Conspicuously, these rock types occur sandwiched between packages of older footwall basement rocks, hence the other name, ‘Internal Quartzite’. The occurrence of this unit in the Chimiwungo footwall is not too well understood, but it is thought to be an allochthonous slice of quartzite emplaced within basement rocks during a fore-thrusting event (Richards, 2012). Several outcrops of this internal lithology are also known in the southern half of the Dome (Richards, 2012). Detrital zircons from within this unit have been dated by U-Pb Zircon geochronology at $<1126 \pm 23$ Ma (Tripp, 2013). This date reflects the maximum age of deposition of the sediments, which also happens to be the age of crystallisation of zircons in the igneous rocks from which the sediments are derived.



Figure 3.3. The footwall Mottled Schist. (a) In-situ image capturing the scapolite-kyanite porphyroblasts embedded in a slightly tarnished biotite-phlogopite $\pm$ quartz matrix. The image was taken from the footwall of Chimiwungo main pit, stage 1 (CM_1). (b) A section along freshly drilled core detailing the occurrence of the mineral assemblage. The coin used for scale is 24 mm in diameter. scp = scapolite; phl = phlogopite; bio = biotite.

3.3 Ore Package

The Chimiwungo ore package is an approximately 80 m thick tabular shear zone that hosts sulphide mineralisation in a predominantly muscovite-phlogopite-quartz $\pm$ kyanite schist. The mica-rich schist, which strikes E-W and dips shallowly with gentle undulations to the south, is characterised by the presence of intervening barren units in the form of boudins with an E-W trending pinch-and-swell geometry (Fig. 3.4). The randomly distributed barren units, locally referred to as “Middle Gneisses”, are dominantly composed of grey gneisses, Amphibolitic Gneisses, amphibolites, leucosomes, mylonites and pegmatites. Field mapping has revealed that the bulk of these units tend to occur more continuous in the north-south direction, confined to the two shoots.

The disseminated copper-sulphides occur within the S3 foliation fabric of the Ore Schist and are predominantly in the form of chalcopyrite and bornite (Fig. 3.5a and d). Bornite is mostly associated with the lowermost parts of the Ore Schist which are dominated by the presence of phlogopite-biotite. Also randomly present within the ore package are relatively thin garnet-rich zones. The centimetre-to a metre-scale thick layers host red garnets which display an antithetic relationship with the sulphide mineralisation. According to Turlin *et al.* (2016), these garnet-rich layers display the same textures and similar mineralogy as the Ore Schist, except for the absence of kyanite and sulphide mineralisation (Fig. 3.5c). The garnet poikiloblasts which are characterised by the presence of oriented phlogopite, chlorite, plagioclase, quartz and rutile inclusions, lack the presence of pressure shadows. The poikiloblasts are mostly distributed parallel to the orientation of the Ore Schist fabric. Based on these observed textural features, Turlin *et al.* (2016), suggested that the garnet poikiloblasts grew coeval with the development of the Ore Schist, i.e. at the syn-D3 deformation stage. However, it was also observed that in some of the garnet poikiloblasts, the orientation of the inclusions displayed a slight deviation when compared to the orientation of the hosting S3 schistosity. Therefore, Turlin *et al.* (2016), proposed that these poikiloblasts partially grew during the D2 event, before being transposed/recrystallised in the S3 schistosity.

According to Tripp (2013), the Ore Schist is either a hydrothermally metasomatised version of the feldspathic Grey Gneiss and schist, or a clay-rich protolith intercalated with metasedimentary rocks that became the Grey Gneiss. Field observations suggest that the contact between the gneissic units and the Ore Schist is transitional (Fig. 3.5b). The U-Pb age of the Ore Schist is 1900 Ma (maximum age), which conforms to the age of the basement Grey Gneiss (Tripp, 2013). The age similarity and transitional contacts between the Grey Gneiss units and the Ore Schist reflect a basement gneiss protolith that was deformed and metasomatically altered to the Ore Schist. Also, the strain gradient between the wall rocks of the deposit and the main shear zone shows the progressive development of the shear zone and the associated metasomatism. Metasomatism of basement protoliths may have occurred during the mineralisation phase. The development of the shear zone is thought to have provided a conduit for the flow of oxidised weakly acidic brines (McGowan *et al.*, 2003) which were responsible for destroying feldspar by removing Ca and Na and residually enriching Al.

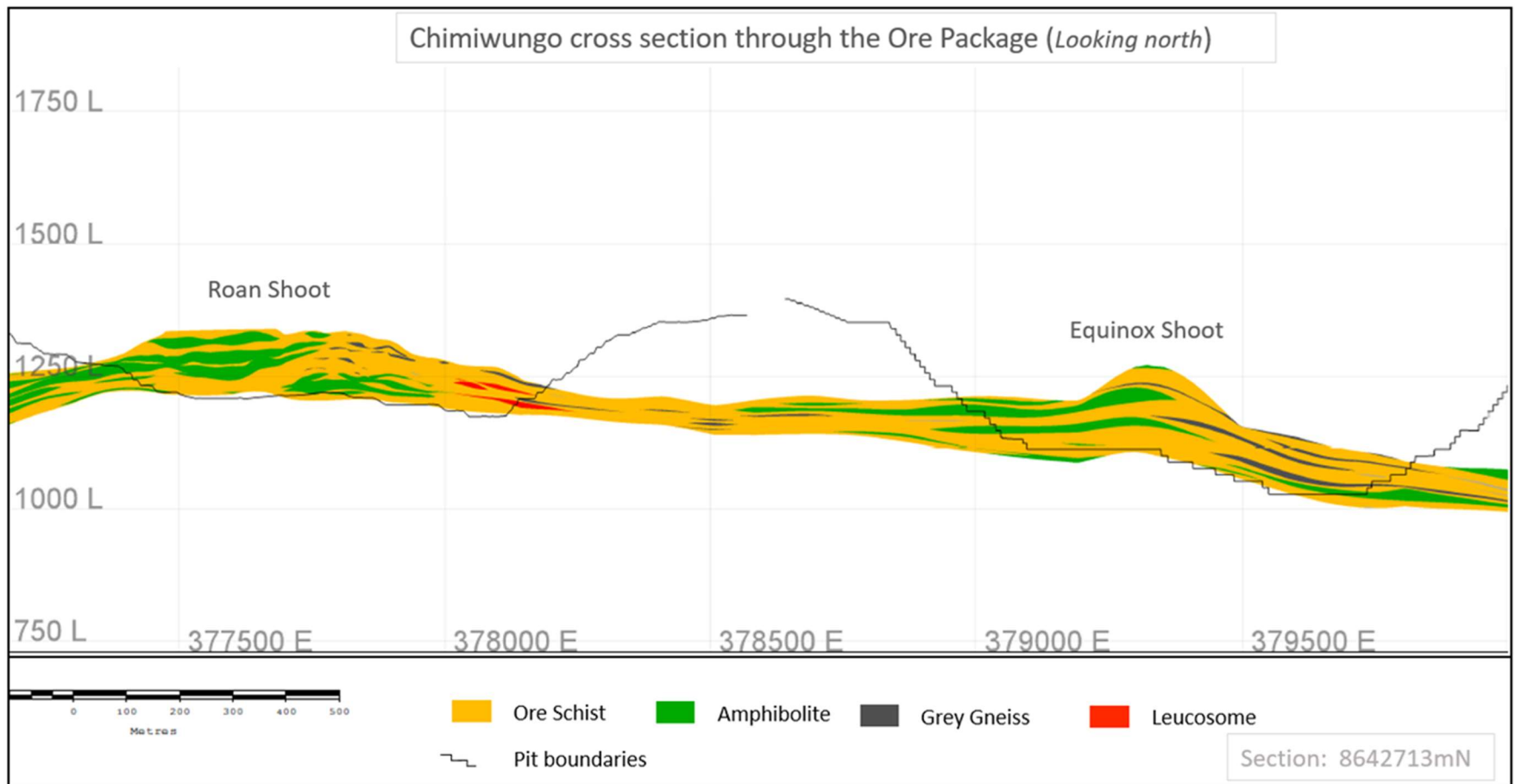


Figure 3.4. Cross-section across the Chimiwungo ore package (looking north), based on a depth-slice through a 3D model built from lithological mapping, structural mapping and drillhole data. The section provides an overview of the occurrence and distribution of the unmineralised units within the main shear zone (ore package).

This process may also have been responsible for the introduction of Mg-metasomatism into the system possibly in the form of dolomite. The resulting metamorphosed mineral assemblage shows a muscovite-phlogopite-chlorite zonation from top to bottom respectively.

According to Bernau (2007), the alteration in the Ore Schist has been observed in both thin sections and in the XRF geochemistry. This has been characterised by the loss of sodic plagioclase and scapolite with increased levels of alteration. Even though the potassium feldspar (microcline) has equally been removed through alteration, the presence of potassium in the Ore Schist has been preserved in the form of muscovite and phlogopite/biotite (Bernau, 2007).

In order to understand the origin of these basement gneisses, Turlin *et al.* (2016), undertook some geochemical investigations on the basement gneiss. The authors investigated the rutile from garnet-rich layers of the Ore Schist (Fig. 3.5c) for the Cr/Nb ratio, which they compared with those from the kyanite-muscovite schist. The difference in the two ratios led to a suggestion that the chemical environment of rutile crystallisation differed in these two chemically distinct layers.

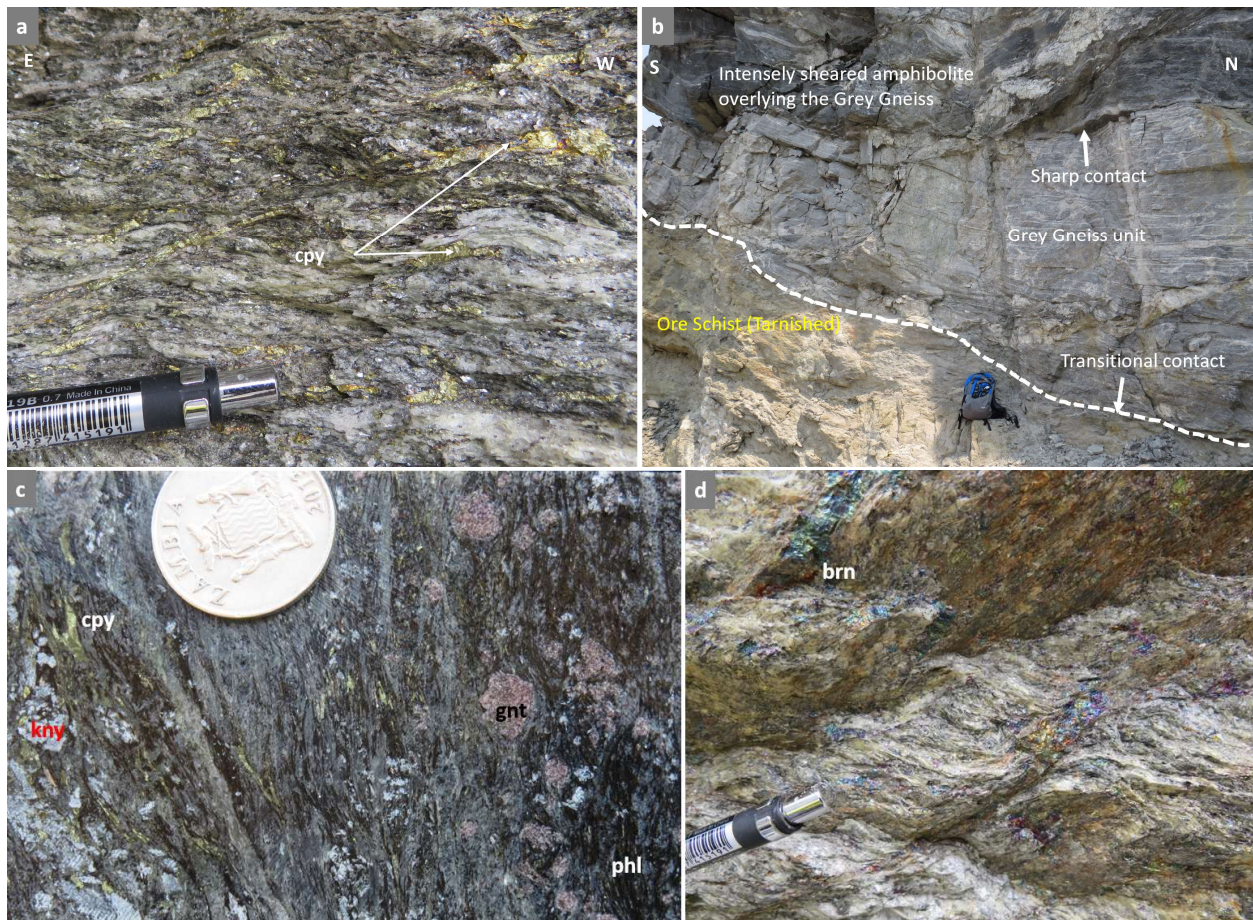


Figure 3.5. The occurrence of the chalcopyrite ± bornite mineralisation in the Ore Schist. (a) Chalcopyrite mineralisation is observed hosted along the S3 foliation planes in the Ore Schist. (b) The Grey Gneiss unit is sandwiched between the Ore Schist below it and the amphibolitic gneiss above it. The vivid sharp contact between the amphibolitic gneiss and the grey gneiss signifies a difference in the origin of the two units. (c) Ore Schist transitions into a garnet-rich layer. The garnet-rich layer shows no muscovite or sulphide mineralisation, and minimal kyanite. Also, an increase in phlogopite is observed in the garnet poikiloblasts layer. The coin used for scale is 24 mm in diameter. (d) Bornite and chalcopyrite in a muscovite-biotite-quartz schist. The bornite shows close association with the chalcopyrite. gnt=garnet, phl=phlogopite, cpy=chalcopyrite, kny=kyanite, brn=bornite.

The observation was said to be consistent with a pre-metamorphic lithological compositional layering whose origin was from a sedimentary sequence.

Turlin *et al.* (2016) suggested that the rounded nature of the zircon grains enclosed in the quartz-plagioclase matrix and in the micaceous minerals of the S3 schistose foliation indicate a detrital origin inherited from a sedimentary protolith. These and many other arguments led the authors to conclude that the protolith of the mineralised host rock at Lumwana is sedimentary. This conclusion is supported by the proposition of Benham *et al.* (1976), and which complements the conclusions of Bernau (2007) and Bernau *et al.* (2013).

3.3.1 Mineralisation

The primary copper-sulphide mineralisation at the Chimiwungo deposit generally occurs as pairs of two different copper-bearing sulphides, which shows a down-section zonation in diamond drill core (Bernau, 2007). The mineralisation occurs as fine to medium grains disseminated within the S3 foliation planes of the schistose fabric (Fig. 3.5a). Generally, copper-sulphide mineralisation is observed to occur as chalcopyrite (CuFeS_2) at shallower depths, to chalcopyrite (CuFeS_2) - carrollite (CuCo_2S_4) and, finally, to chalcopyrite (CuFeS_2) - bornite (Cu_5FeS_4) at increased depths with accessory pyrite (FeS_2). Other sulphide phases only observed at Chimiwungo include cubanite (CuFe_2S_3) with pyrrhotite (FeS) (Bernau *et al.*, 2013). Chrysocolla ($\text{Cu}_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4$), malachite ($\text{Cu}_2(\text{CO}_3)(\text{OH})_2$) and azurite ($\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$) occur within the ore schist at very shallow depths. Close to surface, the moderate to weakly weathered ore schist tends to have fluid flow along its foliation planes. It has been observed that the presence of oxygenated surface water has over time enhanced the breakdown of the sulphides to oxides, with minimal destruction of the micas and quartz of the schist.

The copper grade in the Ore Schist generally ranges between 0 up to ~5%, and its distribution is largely driven by structure. The high Cu grades are predominantly hosted in the muscovite-phlogopite-quartz $\pm$ kyanite schist ore horizons and typically comprise bornite and chalcopyrite (Fig. 3.6b). The close association between chalcopyrite and bornite at depth appears to be backed by a chemical transitioning between the two copper-sulphide minerals. Naturally, bornite is known to occur in primary copper ores formed at low temperatures in the near-surface environment, as well as in ore deposits that have been subjected to alteration (Holényi and Amcoff, 1996). Bornite is commonly known to occur together with secondary Cu-sulphides (Cu_2S , CuS etc) (Holényi and Amcoff, 1996). Chalcopyrite and digenite ($(\text{Cu}, \text{Fe})_9\text{S}_5$) are also known to usually occur as two-phase exsolution lamellae in most bornite crystals (Holényi and Amcoff, 1996). At the Chimiwungo deposit, secondary minerals include digenite after bornite and chalcopyrite, which later underwent alteration to covellite (CuS) (Bernau, 2007). The observed formation of chalcopyrite through exsolution appears to have typically occurred only along certain favourable interstices of lamellae in the parent bornite crystals (Fig. 3.6). The process produces an exsolution lamellae texture, which has been observed to naturally point to near-room-temperature conditions (Holényi and Amcoff, 1996). The observed intergrowth of the bornite-chalcopyrite-digenite crystal assemblage implies that chemical replacement also known as replacement-exsolution occurred.

Dissolved copper ions precipitated as CuS along grain boundaries, while chalcopyrite and digenite form lamellae in the host bornite crystal (Fig. 3.6a) (Holényi and Amcoff, 1996).

Kyanite and quartz porphyroblasts form as augen within the muscovite-phlogopite-quartz $\pm$ kyanite schist fabric and are characterised by sulphide inclusions and the presence of pressure shadows. Generally, the sulphides occur parallel to the S3 schistose foliation cleavage planes and within concordant quartz veins (Fig. 3.5a).

Sporadic uranium mineralisation occurring as discrete pockets has been known to be associated with zones of high Cu grade. The uranium, which is sub-economic, consists of vein-hosted uraninite (UO₂) and disseminated brannerite ((U, Ca, Ce)(Ti, Fe)₂O₆) (Bernau, 2007). Also, present in the Ore Schist is cobalt mineralisation which is associated with the copper mineralisation at Chimiwungo. Cobalt mineralisation occurs at sub-economic levels as carrollite (CuCo₂S₄) and is known to be associated with the lower portions of the orebody (Bernau, 2007). One of the prominent features of the Chimiwungo mineralisation is the presence of steep ($\sim 80^\circ$), north-dipping, quartz-calcite stringer veins that are discordant to the S3 foliation (Fig. 3.6d).

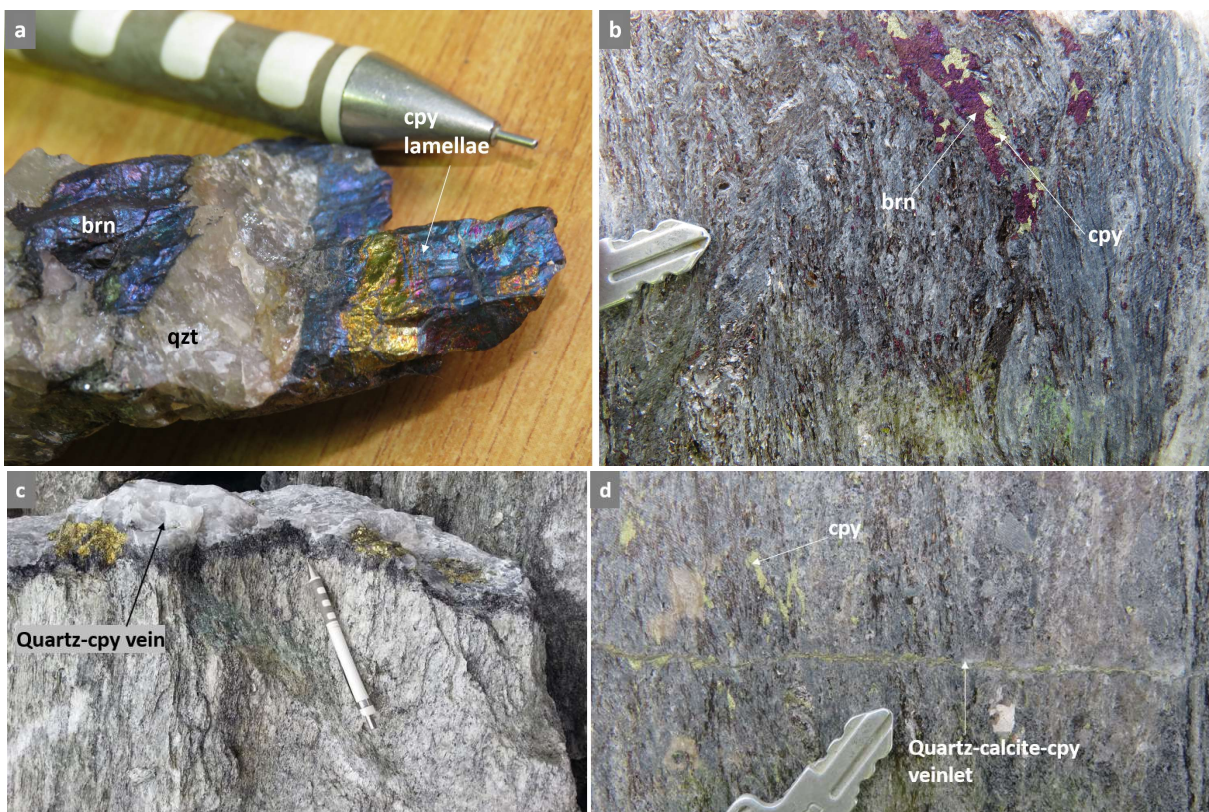


Figure 3.6. Chimiwungo copper-sulphide mineralisation. (a) A sample from a quartz vein showing the exsolution lamellae texture in the primary bornite. (b) Chalcopyrite replacing bornite in the muscovite-phlogopite-quartz schist. The sample is characteristic of the high copper grade portions of the shear zone. (c) A late chalcopyrite-bearing quartz vein that is discordant to the S3 foliation. (d) A quartz-calcite veinlet discordant to S3 foliation hosting chalcopyrite. qzt=quartz, cpy=chalcopyrite, brn=bornite.

These narrow veinlets, which occur at various depths within the ore package, host chalcopyrite and bornite mineralisation. The veins have not been adequately picked up during pit wall mapping due to limited visibility associated with capturing such narrow structures. However, their presence in the drill core is strongly registered because drilling at the Chimiwungo deposit is also directed to the north at 80°, hence drilling is parallel to the veins. The distribution and timing of these stringer veins is not well understood; however, they may have been formed during the later phase of the D3 considering that these events lasted ~40 Ma (Eglinger *et al.*, 2016). Additional late quartz veins that crosscut both the mineralisation and the barren intervening gneiss units have been encountered. These metre-scale wide veins equally occur randomly and are commonly barren, although they may locally host pyrite, chalcopyrite and/or bornite mineralisation (Fig. 3.6c).

The sampled units from the Chimiwungo Ore Schist yielded molybdenite Re-Os dates at 525.9 ± 2.2 Ma (glassy quartz vein) and 534.2 ± 2.2 Ma (pegmatite vein) (Nowecki, 2014).

3.4 Hangingwall

The Chimiwungo hangingwall suite is defined by all the lithological units overlying the Ore Schist top contact and is dominated by the presence of four readily identifiable lithotypes (Table 3-1). The predominant units of the hangingwall are: 1) Hangingwall Schist, 2) Grey Hangingwall Gneisses, 3) Amphibolites and 4) the Pink Hangingwall Gneisses. These units will be described in detail below: -

3.4.1 Hangingwall Schist

The Hangingwall Schist is a fine to weakly-banded, dark grey to black biotite-muscovite-quartz $\pm$ feldspar $\pm$ kyanite $\pm$ epidote schist which overlies the ore horizon in certain regions of the hangingwall domain. Typically, the schist unit lacks feldspars, however, potassic alteration has been observed at the contacts with the Pink Hangingwall Gneiss (Fig. 3.7a and b). K-feldspars have been observed along the S2 foliation planes of the dark schist, changing its colour from dark grey to pinkish-grey. The unit locally exhibits asymmetrical extensional shear bands and mylonite fabrics which have been observed wrapping around more competent gneissic and amphibolitic units. Generally, it has been thought that the development of this unit was through shearing of pre-existing gneissic units (Tripp, 2013). This is supported by the presence of texturally late centimetre-scale phlogopite shear bands (C2) observed to locally crosscut the granite gneiss fabric (Fig. 3.7a). These C2 mylonites are composed of predominantly intensely strained, fissile, dark quartz-biotite-dominated assemblages and display a well-developed, biotite/muscovite stretching lineation. Furthermore, the contact between the Hangingwall Schist and the relict gneissic boudins appears to be transitional (Fig. 3.7c). This further enhances the understanding that this schist has a complex gneissic protolith and was developed during south-southeast-directed shearing.

The Hangingwall Schist is uncommon and pit mapping has shown that the unit occurs aligned locally more to the eastern flank of the Roan Shoot, ~30 m from the Ore Schist (Fig. 3.7). The unit is more commonly associated with increased fabric development and usually transitions into the Ore Schist. Although texturally and mineralogically different from the Ore Schist, the Hangingwall Schist has on numerous occasions been mistaken for the Ore Schist. Thicker and wider zones of the Hangingwall Schist

have been observed to host minimal to no boudins (Fig. 3.7c). The Hangingwall Schist was petrographically determined as meta-tonalite with a single igneous population of zircons at *ca* 1919 Ma, suggesting that the younger (1700 Ma) Pink Hangingwall meta-granitoid intruded a complex package of orthogneiss and paragneiss (Tripp, 2013).



Figure 3.7. Various occurrences of the Hangingwall Schist and the associated gneissic fabrics within the hangingwall package. (a) Developing of the S2 foliation fabric around more competent granitoid Pink Hangingwall Gneiss (S1) unit of CM_4 pit on the southern wall. The C2 mylonitic fabric can be seen truncating the gneissic foliation planes. (b) The less strained thick S2 phyllonitic unit proximal to a granitoid Pink Hangingwall Gneiss in CM_4 pit. Potassic alteration can be seen in the upper half of the image. (c) A fully developed S2 phyllonitic schist wrapping around a more competent gneissic pink granitoid boudin in the hangingwall of CM_4 pit. The contact between the two units is gradual, implying that the S2 phyllonite is a shear product of the gneiss. (d) Subhorizontal and fully developed S2 fabric showing a rich biotite content, with minimal feldspars. This mineral assemblage occurs distal to the Pink Hangingwall Gneiss. The image was captured in CM_5, on the southeastern wall. CM_number = Chimiungo Main_Pit Stage.

Locally at Lumwana, the Hangingwall Schist has been assigned the S2 (D2) deformation fabric (Eglinger *et al.*, 2016). S2 is a transgressive phyllonitic fabric linked to the development of a relatively low (<35°) to moderate angle C2 mylonitic fabric that crosscuts and wraps around gneissic structures (Fig. 3.7a and c). Overall, the development of the D2 fabric has shown some variation in strain partitioning. It is exhibited as narrow (focused), centimetre-scale wide, intensely strained mylonitic horizons (Fig. 3.7a), to

ca 30 m wide, fully developed, phyllonitic zones characterised by a relatively lower strain fabric (Fig. 3.7c and d). Wide S2 phyllonitic zones commonly contain asymmetrical boudins of either the granitoid Pink Gneiss, amphibolite and/or Grey Gneisses (Fig. 3.7c). These intensely sheared gneisses are observed to have been transposed as boudinaged slivers of various sizes within the wide S2 phyllonitic zones. In isolated instances, the asymmetrical boudins have been rotated thereby exhibiting a layering that is discordant to the general banding associated with the rest of the gneissic foliation. However, layer-parallel bands are also observed locally in the gneiss units. Overall, S2 phyllonites record a prominent S2-C2 fabric, with top-to-the-south kinematic movement, which is accentuated by rotated porphyroclasts, asymmetrical boudins and intrafolial F2 drag-folds (Koegelenberg *et al.*, 2019). On a deposit-scale, C2 mylonitic zones preferentially develop along S1 proto-mylonite zones, largely focused along contacts of gneisses and schistose horizons. Thus, the broader S2 phyllonitic fabric is sub-parallel to the overall D1(S1) structural grain, which seems to have focused along the base of the ore and upper footwall packages.

3.4.2 Grey Gneiss

The Grey Gneiss unit occurs in a close relationship with the Pink Hangingwall Gneiss. The Grey Gneiss is a medium to fine-grained Paleoproterozoic quartz-feldspar-biotite $\pm$ amphibole gneiss which makes up the majority of the basement lithologies in the Dome (Tripp, 2013). Tectono-stratigraphically this unit is known to occur in all the Mwombezhi Dome prospects in both the hangingwall and footwall packages as well as inside the mineralised zone (Dobrotin *et al.*, 2013). The Grey Gneiss unit, which mostly underlies the Pink Hangingwall Gneiss, displays a gradational contact with the pink gneiss down stratigraphy. The main transformation between the Grey Gneiss and the granitic Pink Hangingwall Gneiss is a decrease in the K-feldspar composition and an increase in the percentage of biotite/phlogopite and the associated fabric development. The granitic Pink Hangingwall Gneiss, which yields an age of ca. 1700 Ma (single igneous zircon population), probably intruded as sills into the preexisting basement Grey Gneiss which yields an age ca 1900 Ma (detrital spread of zircon populations) (Tripp, 2013).

The Grey Gneiss alongside the Pink Granitic Gneiss underwent similar deformation conditions described in Chapter 2, subsection 2.3.1 above. As observed in the granitic gneiss, where relict undeformed granites have been encountered during pit mapping and diamond hole logging (Fig. 3.9), it is possible to have relict schist that did not progress to produce the gneissic texture during prograde metamorphism. Dark biotite/phlogopite-rich bands are associated with the Grey Gneiss in places. However, due to intense deformation and thrusting associated with the Mwombezhi Dome, it is possible that the perceived schist bands that occur in the Grey Gneiss unit are in fact shear zones. These shear zones that are centimetres to tens of metres wide, may have acted as planes of movement associated with the north-directed fore-thrusting during the D1 event. In the hangingwall domain, the Grey Gneiss units occur alongside amphibolitic gneisses, which are likely to be the same suite of amphibolites associated with the Pink Hangingwall Gneiss. Where the Hangingwall Schist is absent, the Grey Gneiss transitions into the Ore Schist (Fig. 3.8). Sporadic sulphide mineralisation has been observed in the Grey Hangingwall Gneiss proximal to the ore contact.

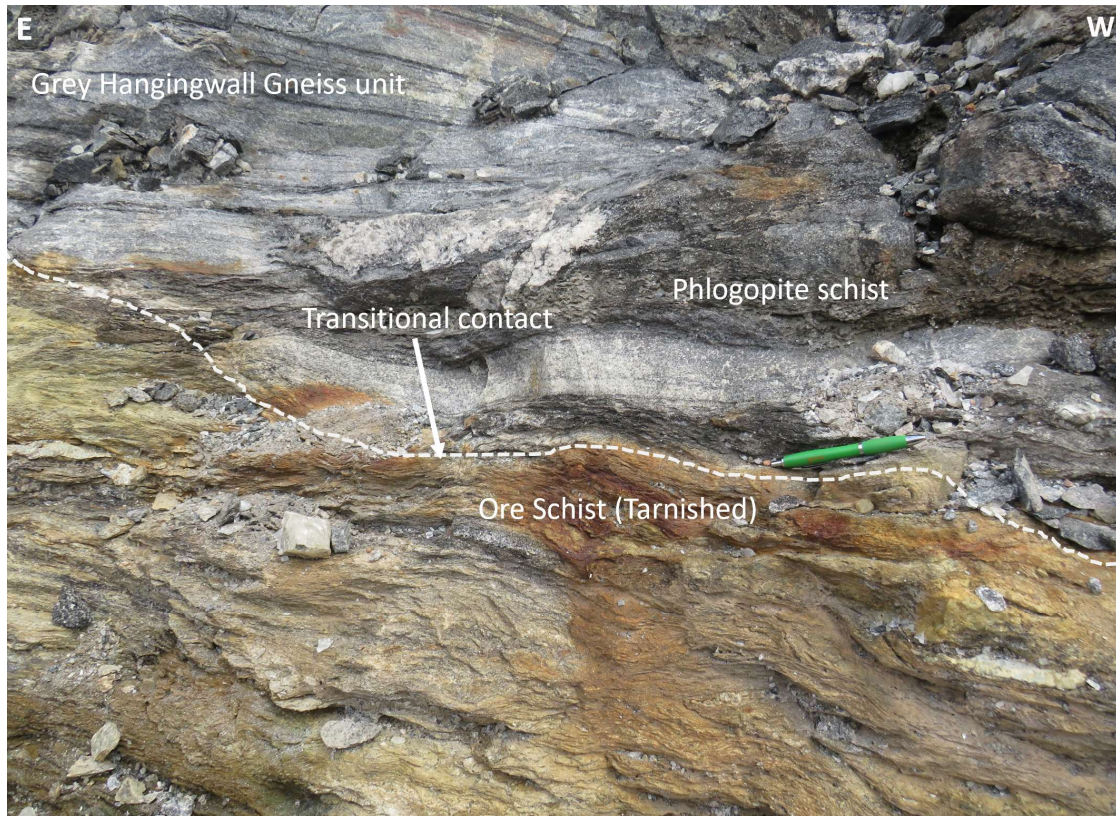


Figure 3.8. A gradational contact between the Grey Hangingwall Gneiss and the Ore Schist on the southern wall of Chimiwungo South pit. The boundary represents the extent of the main shear zone, which is overlain by a gneissic fabric.

3.4.3 Pink Hangingwall Gneiss

The pink granitoid gneiss is the dominant lithological unit in the hangingwall of the Chimiwungo deposit. This unit, which is a feldspar-quartz-biotite $\pm$ magnetite/hematite augen granitic gneiss, is also recognisable throughout other deposits within the Mwombezhi dome (Dobrotin *et al.*, 2013). The unit has earned itself the name “Pink Hangingwall Gneiss” due to the high K-feldspar content when compared to other minerals. The granite gneiss is typically a fine- to medium-grained crystalline rock of granitic composition and has a coarsely spaced S1 foliation defined by the alignment of the biotite (Fig. 3.9a). Minor patchy muscovite-chlorite alteration with massive to disseminated hematite and magnetite form altered zones locally in the granite gneiss. The medium-grained K-feldspar porphyroblasts tend to render a characteristic augen texture in certain zones of the unit. The emplacement of the granite can be associated with the post-Katangan rifting events which have been dated between 2081 ± 28 and 1836 ± 26 Ma (Master *et al.*, 2005). The assigned age was based on detrital zircon obtained from the Lufubu Metamorphic Complex of the Kafue Dome and the Bangweulu Block. The Mwombezhi Dome Pink Gneisses and associated pegmatites have been dated at between 1680 ± 23 and 1702 ± 2 Ma using igneous zircons (Tripp, 2013), implying that they are pre-Lufilian orogeny in age.

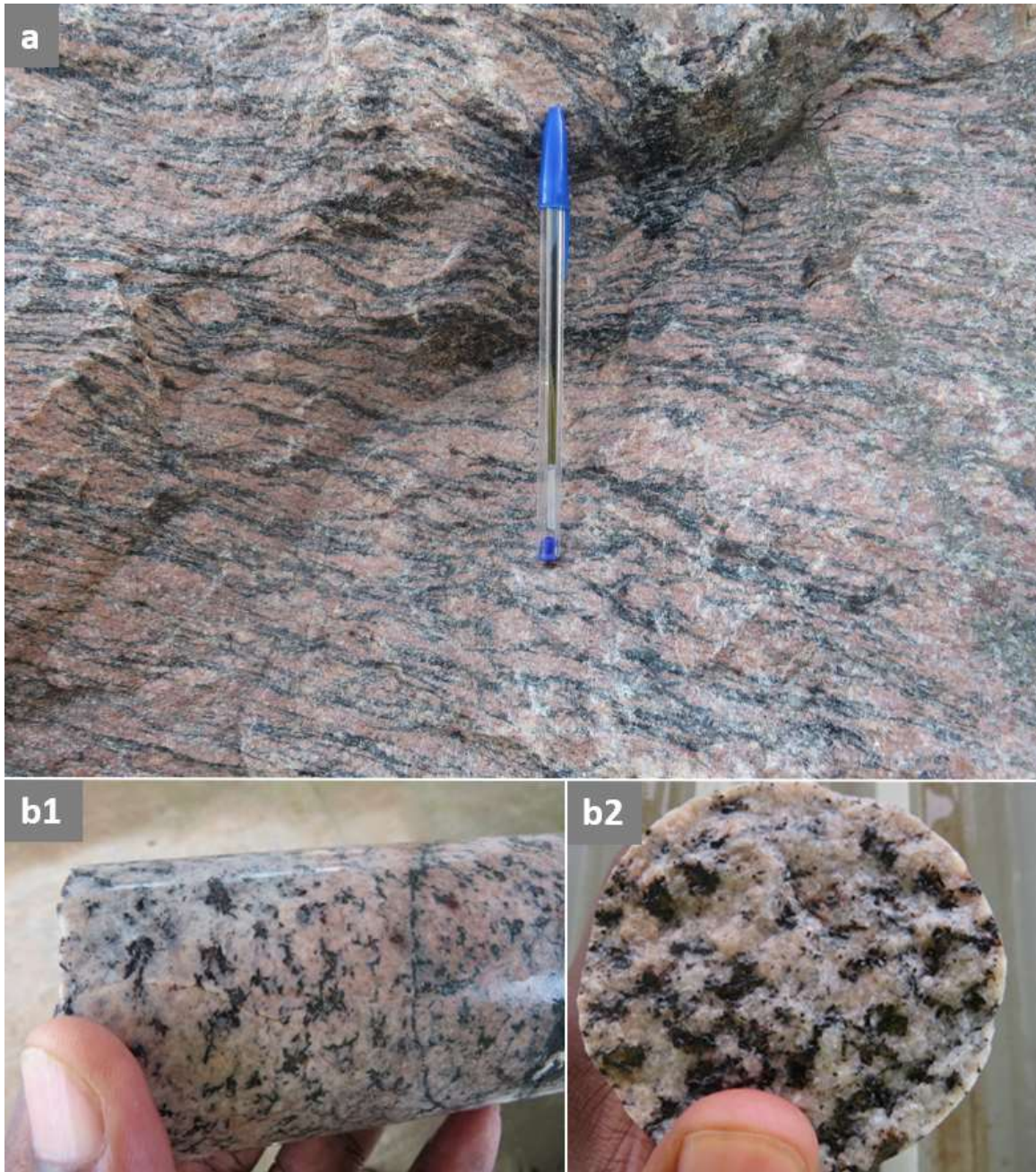


Figure 3.9. Pink Hangingwall granitoid gneiss unit. (a) K-feldspar rich granitoid gneiss showing a well-developed gneissic foliation, coupled with sporadic augens. (b1) and (b2) Preserved granitic texture in the Hangingwall Gneiss.

There is an observed heterogeneity in the intensity of shearing which has affected this unit. In the zones of less deformation and shearing, the granitic texture in the unit has been retained (Fig. 3.9b1 and b2). The occurrence and distribution of undeformed pockets of granite within the granitoid gneiss has not been fully explored, hence is not documented.

3.4.4 Discussion

The Chimiwungo Hangingwall granitoid gneiss is characterised by the presence of randomly distributed amphibolites that occur internally, ranging from a sub-metre scale to about 80 m thick (Fig. 3.10a). These seemingly less deformed suites of amphibolites are not as intensely deformed as the main shear zone (internal) amphibolites (Section 4.2.1). The amphibolites occur as sills (Fig. 3.10b) in certain sections of the stratigraphy, while elsewhere in the stratigraphy, they occur as massive boudinaged units of various thicknesses. Locally, the amphibolite boudins are enveloped by zones of high strain that occur as schistose and gneissic fabric as is the case for internal amphibolites (section 4.2.1). These zones of enveloping fabrics vary in thickness, though the trend has been such that, the larger the amphibolite boudin, the thicker the enveloping high strain zone. Mining has exposed foliation planes that dip steeply in the active mining volumes (open pits). Geotechnically, where foliation dips steeply into the pit, such a pit wall is susceptible to collapse (wall failure). This scenario, therefore, requires a detailed slope stability analysis during pit design, for the purpose of safe mining operations. Therefore, modelling and prediction of the occurrence of these unfavourable foliation planes along the pit wall designs remains one of the crucial geotechnical tasks at Lumwana Mine.

The association of these amphibolites with the granitoid gneissic unit is attributed to a bimodal volcanism event which is normally associated with areas of extensional tectonics. From field observations, the basaltic magmas post-dated the granitic magmatic event, and subsequently, the two igneous units were deformed together during the Lufilian events. This observation casts a doubt on the suggestion by Tripp (2013) that the gneiss units were intruded by amphibolite sills. There seems to be no evidence to suggest that the gneisses were intruded by basaltic magmas.

Also present in the younger Katangan rocks are basalts which are characterised by the presence of pillow structures (Fig. 4.8c). The presence of these structures suggests that the basalts were extruded in a subaqueous environment. Tembo *et al.* (1999) further described the units as having crystallised from magmas of a tholeiitic nature.

The eruption of these basaltic magmas is closely associated with the opening of the Katangan basin at ~880 Ma as constrained by the U-Pb age of the Nchanga granite (Armstrong *et al.*, 2005). The Katangan Neoproterozoic basalts are therefore not to be confused with the basement amphibolites which occur in the interior of the Dome. Generally, the division of the amphibolite suites is not easy by observation alone, but the petrographic recognition of high proportions of remnant plagioclase and titanium oxide minerals in the matrix of amphibolites points to a probable igneous protolith as first-pass distinction (Tripp, 2013).



Figure 3.10. Different forms of occurrences of the mafic units of the Mwombezhi dome. (a) A massive amphibolite exposed in the hangingwall domain of CM_5 pit. The unit was partly fragmented during mining operations activities. (b) An approximately 1 m thick amphibolite sill occurring along the gneissic foliation plane of the Pink Hangingwall Gneiss on the southern side of CM_5. (c) Pillow structures are seen preserved in the basalt outcrop hosted in the Neoproterozoic Katangan metasedimentary rocks, 4.4 km northeast of the Malundwe deposit. CM_number = Chimiwungo Main_Pit Stage Number

Chapter 4

THE INTERNAL BARREN UNITS

4.1 Introduction

The Chimiwungo mineralised shear zone hosts various lithological units which underwent little to no shear deformation during the development of the main shear zone. These mainly boudinaged lithologies generally occur spatially in association with the two shoots, even though the individual boudins appear to be randomly distributed within the shear zone. The main lithological units represented in the boudins are: amphibolites, grey gneisses, leucosomes, protomylonites and pegmatites, collectively referred to here as internal units. Previous workers described the Chimiwungo orebody as a stratiform body separated by two internal grey gneiss units (Richards, 2012). This prompted the decision to split the orebody into Upper, Middle and Lower Ore Schist layers. However, recent observations have proved that the Ore Schist is a single shear zone with a complex geometry characterised by the spatial distribution of the barren internal units. The internal units do not occur as continuous layers that partition the main shear zone, but rather as transposed and/or rotated boudins of different sizes separated by the schistose fabric.

The objective of this chapter is to describe the nature, distribution, and size of the barren internal units, and to also establish and appreciate the impact of the internal units on the overall geometry of the main shear zone. To help achieve this, pit wall mapping was conducted in the Chimiwungo Main pits, stages 2, 3 and 4 (Fig. 4.1). These pits have enabled the vertical exposure of the Roan Shoot from the hangingwall to the footwall. At the time of writing this report, the Equinox shoot had not yet been exposed. The acquired mapping data was used in collaboration with diamond drilling borehole data to build 3D models of the internal units for a better understanding of the spatial occurrence of the units.

4.2 Pit Mapping

A mapping exercise was undertaken between April 2018 and November 2020, in which a total of 9,200 mapping points were collected (Table A-1). The mapping data was composed of lithological contacts, lithologies, shear planes, faults, joints, foliation planes and Cu-sulphide mineralisation occurrences. For better capturing of the internal units, a mapping scale of 1:250 was used. Mapping of the Chimiwungo pits (Fig. 4.1) was undertaken using the Rocklogger™ software installed on a mobile Samsung Galaxy A8 device, connected to an external Bluetooth GPS (Garmin) device. Field data collected was written to a CSV Excel sheet through the Rocklogger™ software. The field mapping data was downloaded and validated by removing anomalous readings and correcting the Z values using survey-built surfaces (triangulations). In general, mapping points from the device have X-Y coordinates within ± 2 m accuracy. The bearings on the digital compass of the handheld device were corrected by factoring in a local magnetic declination of (-) 2.7° to the west. All mapping points were recorded using the local *UTM WGS 1984 35S* projection, subsequently converted to the mine grid coordinate system.



Figure 4.1. An aerial photograph of the Chimiwungo pits. The active pits are aligned linearly exploiting the Roan Shoot, while CE pits planned along the Equinox Shoot are yet to be developed. The aerial photograph is courtesy of the Lumwana Mining Company Survey team. Arc 1950/UTM 35S coordinate system. CN = Chimiwungo North; CM = Chimiwungo Main; CS = Chimiwungo South; CE = Chimiwungo East.

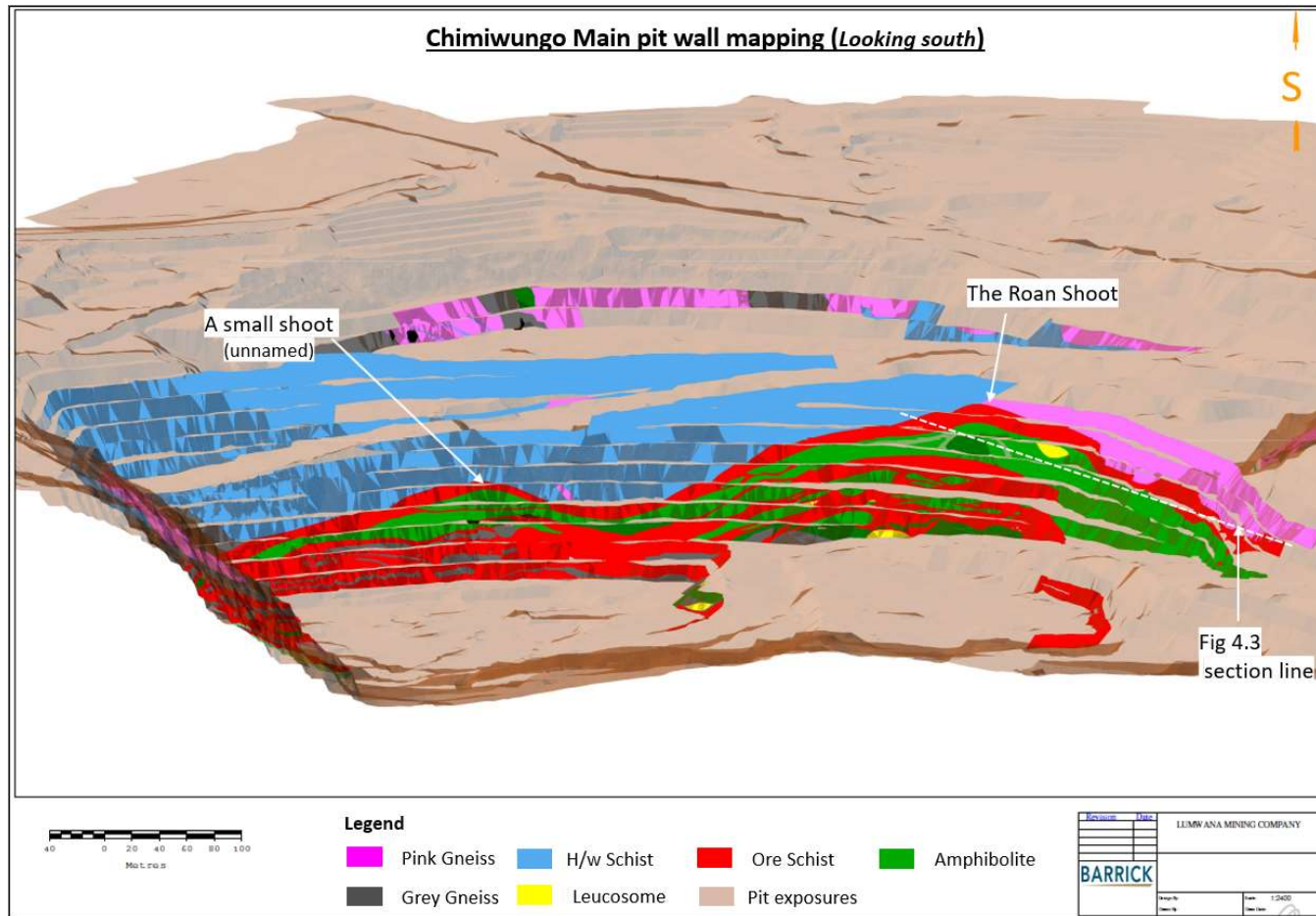


Figure 4.2. A screenshot of the digitised CM_4 pit wall map created in Vulcan™ using the mapping points. The mapping points were obtained using the Rocklogger™ application and partly using the UAV data. The pit wall map captures lithological units as they occur vertically in the partly exposed Roan Shoot. The pit wall map has been tilted to enable a vertical view (facing south) of the pit walls.

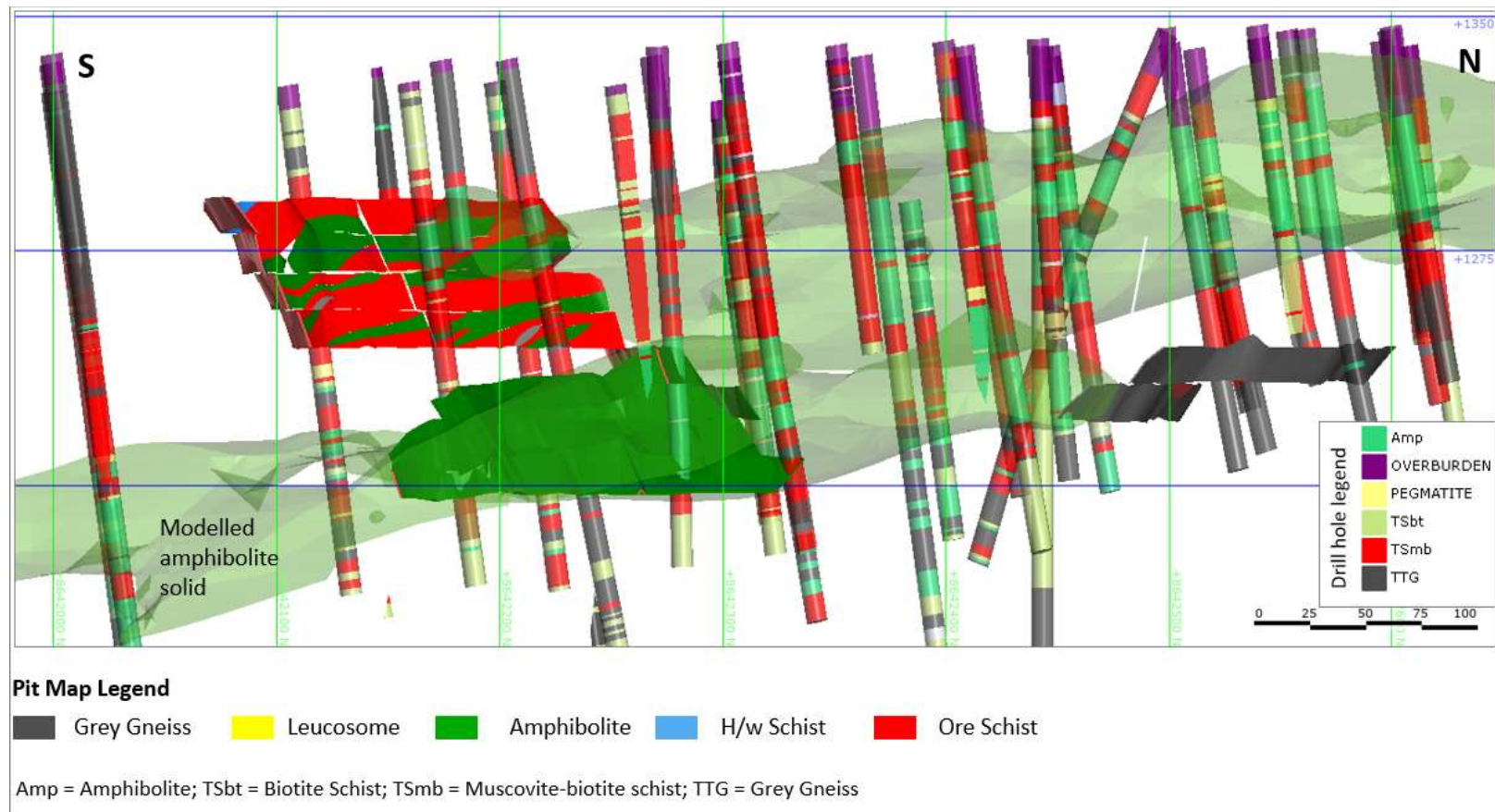


Figure 4.3. A north-south section through the western wall of CM_3 and CM_4 showing the integration of mapping data and drill hole logging data to model the internal units.

The acquired structural measurements were made available in Leapfrog Geo™ and viewed as structural discs (Fig. A.1), while data representing lithological contacts was processed using Vulcan™ mining software, where it was imported as points. The points were then used to produce pit wall maps (Fig. 4.2) through digitisation using Vulcan™ mining software. The digitised Vulcan™ mapping files were then converted to triangulations and exported into Leapfrog Geo™ for modelling purposes (Fig. 4.3). Apart from using the mobile device for mapping, field mapping was supplemented with Unmanned Aerial Vehicles (UAV) mapping data

Pit floors were rarely mapped. This is attributed to the poor availability of well-exposed pit floors which are mainly characterised by rubble, mobile mining equipment accesses and ground-water seepage from the major discontinuities. Another limiting factor to the mapping method was increased depths of the pit walls (> 60 m). At such depth, it becomes too risky to map the pit walls safely. Furthermore, the GPS receiver signal becomes weak at such depths, thereby compromising the accuracy of the coordinates obtained.

4.2.1 Internal Amphibolites

Internal amphibolitic units are among the dominant lithological units which occur internal to the Ore Schist. The amphibolites tend to display variations in texture and mineral composition due to the different degrees of strain they may have undergone. The gradational contacts between different forms of amphibolitic units, confirm that they are basically the same amphibolitic units that underwent different degrees of strain during the Lufilian events. Generally, the mafic suite at Chimiwungo can be described as consisting of massive amphibolites, amphibole-feldspar $\pm$ garnet gneisses (amphibolitic gneiss), amphibolitic protomylonites and amphibole-phlogopite $\pm$ chlorite schist. The observed different forms of occurrence are driven by: a) variation in localised shear stresses that different units were subjected to, b) variations in the thickness of the unit undergoing deformation and c) the P-T conditions associated with the deformation of the particular unit.

On the deposit scale, the spatial occurrence of amphibolites appears to be strongly linked with both the Roan and Equinox shoots. These units tend to be more massive and less deformed proximal to the shoots and more deformed (gneissic) away from the shoots. This association has been confirmed in both drilling and pit mapping data. Furthermore, the internal amphibolitic units have been observed to be closely associated with the internal Grey Gneiss unit. As in the case with the granitoid Pink Hangingwall Gneisses, the internal Grey Gneiss unit appears to have been intruded by amphibolitic sills (Fig. 3.5b). The distinctive and well-preserved sharp contacts between the massive/gneissic amphibolites and the internal Grey Gneiss consolidate the observed intrusive nature of the amphibolites.

The internal Grey Gneiss unit is a barren-to-weakly mineralised unit whose texture and mineralogy resembles the Grey Gneiss unit described in the Chimiwungo Hangingwall package above (see section 3.4.2). The unit, which is predominantly quartz-phlogopite/biotite $\pm$ muscovite $\pm$ feldspar, has been referred to as a 'banded to augen gneiss' (Bernau, 2007). Bernau (2007) also further observed that this 'banded to augen gneiss' locally also includes garnet and/or amphibole and/or sulphide mineralisation. However, this description by Bernau (2007) is synonymous with the field observations made on the

amphibolitic gneiss/protomylonite (Fig. 4.4b and c). Face mapping of the amphibolitic gneiss/protomylonite in certain pit locations has shown lithological continuity between this unit and the massively textured amphibolite.

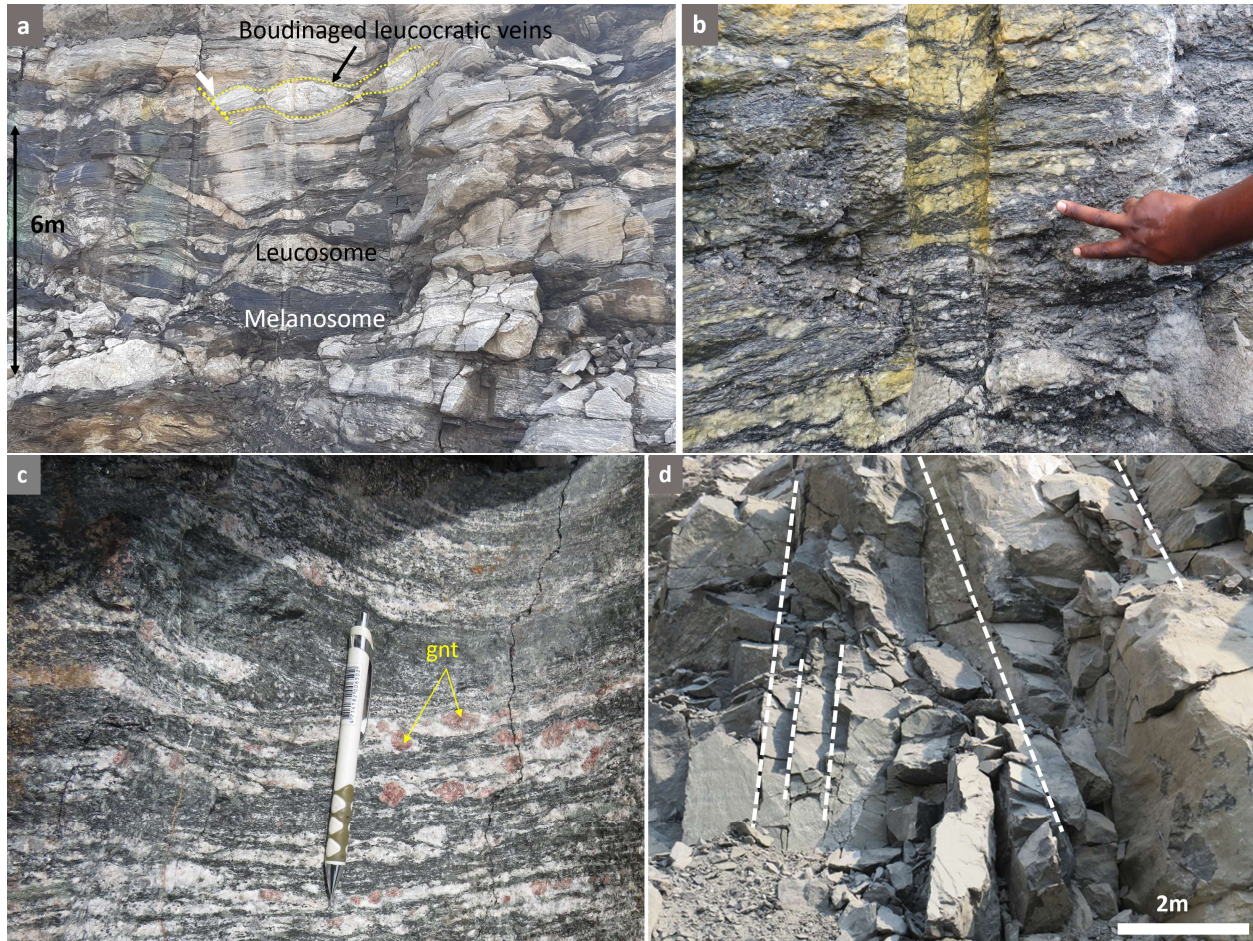


Figure 4.4. Outcrop Images depicting the different forms in which the internal amphibolite occurs. (a) Amphibolite metatextite showing the leucocratic veins in a melanocratic matrix. (b) The mylonitic texture showing the presence of porphyroclasts rich in ferroactinolite, scapolite and quartz. (c) The garnet porphyroblasts in the garnet-bearing amphibolitic mylonite. (d) Highly fractured and massively textured amphibolite. The images were taken from the western wall of CM_3 pit.

This continuity confirms that the protolith of the amphibolitic gneiss/protomylonite is the amphibolite rather than the Grey Gneiss unit. The mylonitic nature of the fabric in the amphibolitic gneiss is evident through grain size reduction coupled with grain flattening and rotation. The mylonites show overall shallow southeasterly dips, parallel to the general gneissosity. Due to lack of vertical exposure, previous workers in the Mwombezhi Dome erroneously referred to the amphibolitic gneiss and protomylonites as the “Internal Grey Gneiss”. Consequently, the presence of the internal amphibolitic units and their impact on the geometry of the orebody at the Chimiwungo deposit has been underestimated.

Spatially, the occurrence of the internal amphibolitic units appears to conform to the vertical distribution of the amphibolites which occur both in the hangingwall and footwall domains. This spatial

association suggests that the amphibolitic units of the Chimiwungo deposit may be of the same protolith despite occurring at different stratigraphic levels. The internal amphibolites vary in thickness and range from a metre thick to about 50 m thick (in the Shoots) within the ore package. The metre to tens of metres thick Ore Schist occurs as ribbons wrapped around internal amphibolites (Fig. 4.5) while crosscutting some of them.

Besides the highly deformed amphibolitic gneisses, the Chimiwungo internal amphibolites appear to have retained their massive texture in some places. Generally, the massive texture seems to be localised where the unit underwent less strain because of strain partitioning. In some of these locations, the amphibolites are characterised by the presence of high-density vertical fractures (Fig. 4.4d). The fractures can be attributed to axial failure due to the induced vertical component of the shear forces. The massively textured inner parts of the amphibolite (Fig. 4.5) tend to be enveloped by an outer deformed layer of the same unit, which assumes a gneissic foliation (Fig. 4.5). The layer, which is from a metre to tens of metres scale, represents a zone of shear deformation suffered by the amphibolitic unit. The amphibolitic gneissic layer predominantly displays two texturally similar forms, the metatexitic and mylonitic textures. The metatexitic texture is characterised by the presence of coarse-grained, igneous-textured leucocratic layers (leucosomes) embedded in a fine-grained, metamorphic textured, melanocratic layer (Kobayashi *et al.*, 2005) (Fig. 4.4a). The mylonitic texture is characterised by blastomylonites which are composed of porphyroclasts of ferroactinolite *ca.* 20%, kyanite *ca.* 5% and tremolite *ca.* 10% (Bernau, 2007) (Fig. 4.4b). The fine-grained matrix of the melanocratic layers is dominated by plagioclase, amphibole, and epidote. Some rare biotite, quartz and magnetite grains are also present (Eglinger *et al.*, 2016). The amphiboles analysed from both the ore and internal amphibolitic suite of the Chimiwungo deposit have been identified as gedrite, pargasite, tschermakite and hornblende (Bernau, 2007). This assemblage indicates a metamorphic pressure of between 8.3 to 11.8 Kbars (Bernau, 2007).

The development of this black to dark grey mylonitic unit (Fig. 4.4c) has been closely associated with progressive fabric development due to increased shear deformation along the flanks of the Roan Shoot. The observed increased deformation and fabric development has also been observed in the overlying Pink Hangingwall Gneiss units. In this region, the overlying Pink Gneiss appears to be intensely sheared and is characterised by more phlogopite-rich shear planes, which acted as planes of movement during the shear. The internal amphibolite units at Chimiwungo are locally characterised by the presence of garnet porphyroblasts commonly associated with inclusions of feldspar and quartz (Bernau, 2007) (Fig. 4.4c). The matrix of the host unit is dominated by amphibole-plagioclase-quartz-biotite $\pm$ ilmenite $\pm$ chlorite (Eglinger *et al.*, 2016). According to Eglinger *et al.* (2016), the garnets have a uniform mineral composition and contain the mineral phases in the matrix, except for ilmenite. Apart from the matrix minerals, grains of rutile are also found as inclusions in the garnets. The rutile grains have also been reported locally within matrix minerals (Eglinger *et al.*, 2016).

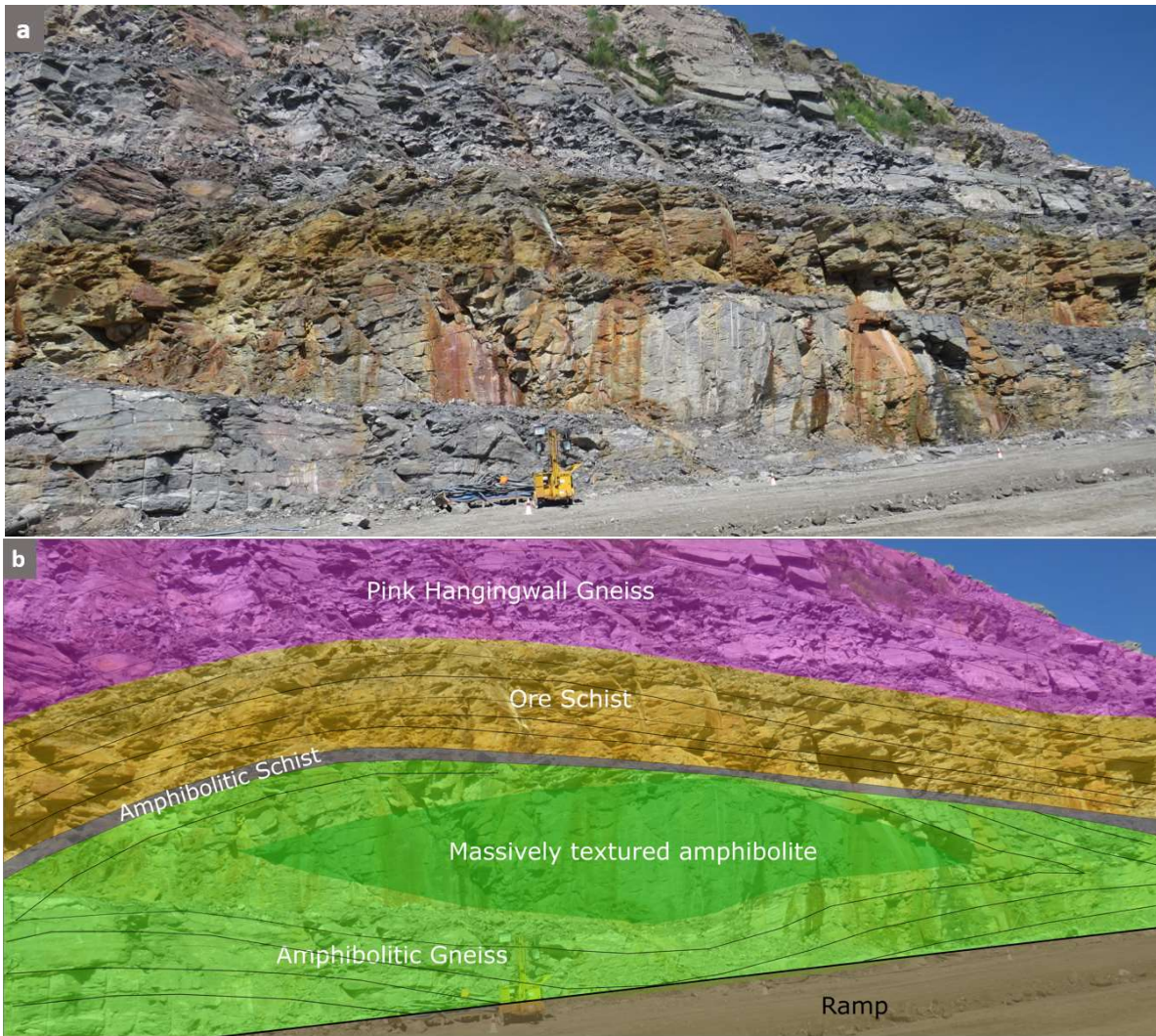


Figure 4.5. Configuration of the Ore Schist in association with the internal amphibolitic boudins in the Roan Shoot. (a) The figure shows part of the western aspect of the Roan Shoot. (b) An interpretation of the occurrence of the units in (a); The partly tarnished Ore Schist is observed wrapped around an amphibolitic boudin. The massive texture of the amphibolite is preserved in the interior, while the outer layer is deformed to an amphibolitic gneiss/mylonite/schist. The outermost layer is amphibolitic schist and is usually mineralised, and metasomatically altered. Overlying the ore schist is the hangingwall which is dominated by the Pink Hangingwall Gneiss and some minor Grey Hangingwall Gneiss units. The image was taken on the western wall of CM_2 ramp section.

The outermost layer of the amphibolitic gneisses and mylonitic units defines a strong foliation in the amphibole–biotite–epidote $\pm$ garnet $\pm$ sulphide schist that wraps around these amphibolitic units (Fig. 4.5). The centimetre to metres thick layer represents a zone of intense shear stress deformation due to strain softening, and subsequent dissolution of non-mica phases to produce an amphibole-biotite rich schistose margin. The development of this schist can be associated with the D2 synorogenic exhumation and isothermal decompression events (Eglinger *et al.*, 2016) which retrogressed the original amphibolite. The dark-coloured schist locally hosts garnets whose source can be linked to the garnet-bearing amphibolites discussed above. Apart from garnets, the unit also contains pyrite, another

common mineral in the Chimiwungo amphibolites. This thin layer of the amphibolite schist is, however, not always present around the amphibolitic units. This is because in most cases, the schist has been completely obliterated by being transposed and integrated into the S3 fabric (Ore Schist) which postdates this schist in terms of development. Therefore, the thickness of the relic layer may signify the degree to which the amphibolitic schist has been transposed. Locally, Cu mineralisation in the form of chalcopyrite and bornite has been observed in the amphibolitic schist. The probable source of the Cu sulphide mineralisation in the amphibolitic schists would be the hydrothermal fluids that deposited the sulphides in the Ore Schist. Deposition of the sulphides in the amphibolitic schist was partly necessitated by the presence of well-developed foliation planes that may have acted as conduits for fluid flow and subsequent depositional sites due to the decreased fluid pressure along these parting planes.

The transposition of the mineralogically and texturally diverse S2 fabric in the S3 fabric has contributed to the observed occasional occurrence of some deleterious minerals in the Ore Schist fabric at Lumwana. For instance, the occurrence of talc and carbon within the ore package has had a negative impact on the recovery of copper-sulphides in the flotation circuit at the process plant. According to Dobrotin (2013), the Ore Schist at Lumwana contains graphite. Further metallurgical tests carried out locally on the copper concentrate, confirmed the presence of graphite in the Ore Schist. This is therefore a potential source of carbon that has caused metallurgical challenges at the process plant during the extraction of Cu sulphides from the Ore Schist material.

Similarly, a decrease in the Cu:S ratio in the ore supplied to the metallurgical process plant presents a great challenge in the extraction of the Cu sulphides. The excess sulphur is thought to be associated with pyrite, which is one of the minerals that is usually hosted in the amphibolitic schist. Therefore, further understanding of the occurrence of transposed and integrated S2 fabric within the Ore Schist is cardinal in helping to mitigate the impact of deleterious minerals in the copper-sulphide extraction circuit. However, such a study is outside the scope of this research report. With increasing biotite content in the outermost schist layer, the originally massive intrusions become increasingly flattened in the mylonitic S1 foliation.

The central core of the amphibolites is characterised by the massively-textured largely undeformed part of the intrusive units (Fig. 4.5). The core represents a zone of minimal, to no shearing in the rock mass.

4.2.2 Leucosomes

Leucosomes have been observed as another prominent unmineralised lithology occurring internal to the Ore Schist (Fig. 4.6a) and locally in the footwall. Like the internal amphibolites, these units vary in thickness and length from a metre to tens of metres in scale. The pinch-and-swell geometry of these boudinaged units is dominant in the E-W strike direction, however, the unit also tends to display the pinch-and-swell geometry down dip. Leucosomes dip shallowly in a southern direction at $\sim 15^\circ$ and are locally dissected by an intervening S3 foliation fabric (Fig. 4.6a). These cream-white and boudinaged units are composed predominantly of feldspar and quartz generated through anatexis and crystallisation

of the partial melts. The leucosomes appear to be associated with an amphibolitic protolith, as they can be observed in the partially melted leucosome boudin in Fig. 4.7.

The amphibolitic boudin in Fig. 4.7, which is hosted in the S2 footwall fabric, was sheared, and partially melted during the HT-HP D1 events leading to the generation of the neosome and the associated components. The amphibolitic texture and mineralogy appear to be preserved due to incomplete mineral segregation in this boudin. The recorded D1 P-T conditions of 660°C and ~11 kbar (Eglinger *et al.*, 2016) were sufficient for the formation of the leucosomes, which were transposed into the S3 fabric during D3. During the D3 events, the leucosomes were further deformed through stretching and dissection as exhibited by the boudin structure (Fig. 4.6). The exposed leucosomes are localised immediately east of the Roan Shoot and are restricted to the lower portion of the orebody, a few metres (5 – 12 m) above the footwall contact. It, therefore, remains possible that the deformed amphibolites might have been transposed from the underlying footwall into the Ore Schist during the D3 events.

Locally, the leucosomes are enveloped in characteristic dark thin rims of amphibole-biotite ± garnet schist also referred to as the melanosome (Fig. 4.6b). The melanosome represents the darkest part of a partially melted rock, concentrating the existing mafic minerals during mineral segregation (Kärki, 2015). This dark portion is a residual fraction representing the solid part of the melt-solid system generated by partial melting. It is also the darkest type of the neosomes, which normally consists of biotite, garnet, cordierite, hornblende and sometimes also pyroxene or olivine (Kärki, 2015).

At the Chimiwungo deposit, the melanosome ribbon flanking the leucosome boudin is ~1m thick and represents relics of a thicker melanosome layer that has been transposed and integrated into the Ore Schist fabric. From field observations, the leucosomes at depth (> 50 m) do not exhibit the presence of the rimming schist, while the shallower units are rimmed by the schist. This could be due to increased S3 (Ore Schist) fabric development at depth, leading to the complete transposition and integration of the amphibole-biotite rimming schist into the S3 fabric. The Ore Schist fabric around these boudins is thicker and more developed at depth as compared to near-surface where it is thinner. Furthermore, the leucosomes associated with the shallow Ore Schist tend to exhibit the presence of thin melanosome bands wrapped around the smaller quartzofeldspathic boudins which are all integral parts of the main boudin unit (Fig. 4.6c).

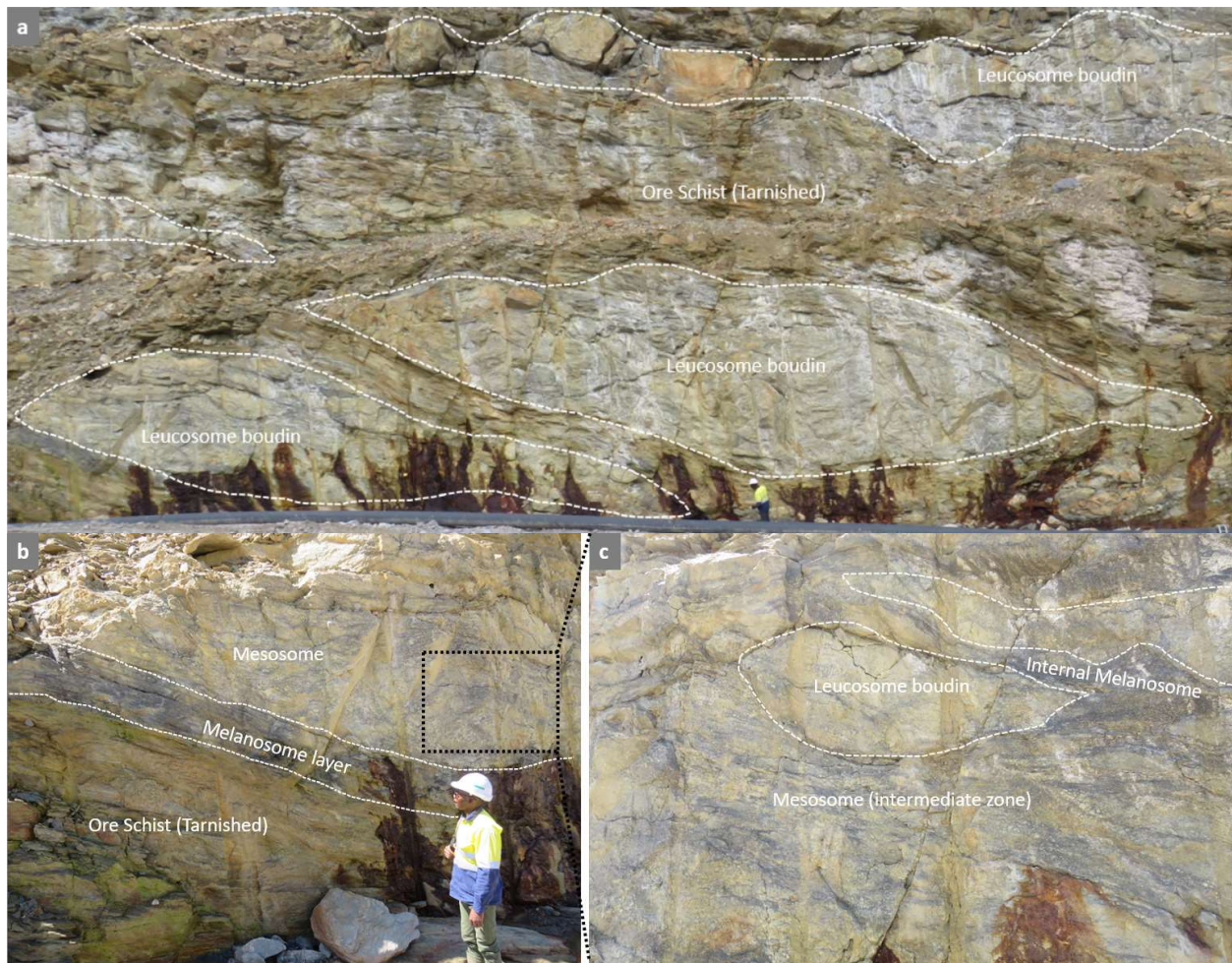


Figure 4.6. Leucosome boudins in the Ore Schist captured on the eastern wall of CM_1 pit. (a) The pinch-and-swell geometry of the leucosomes with the lower boudin truncated by the S3 fabric to form two separate boudins. (b) A biotite rich, melanosome schistose, layer underlying a leucosome boudin transitions into the Ore Schist (c) A closer view of a portion of the leucosome.

The presence of these remnant internal melanosome bands in the main leucosome implies that mineral segregation was incomplete during the development of the leucosomes. Once more, this has been observed to be associated with shallow occurring leucosome boudins. At greater depth (> 50 m), the leucosomes tend to exhibit a lack of internal melanosome bands. Apart from the internally occurring melanosomes, a phase intermediate to the leucosome and the melanosome referred to as the mesosome (Kärki, 2015) has been identified (Fig. 4.6c). The mesosome zone represents an assemblage of material generated from non-segregated partial melt or magma in which solid minerals were preserved in situ during the melting process (Kärki, 2015). These mesosome rocks may resemble the actual igneous rocks, though their chemical compositions may be different from those of a typical igneous rock series.

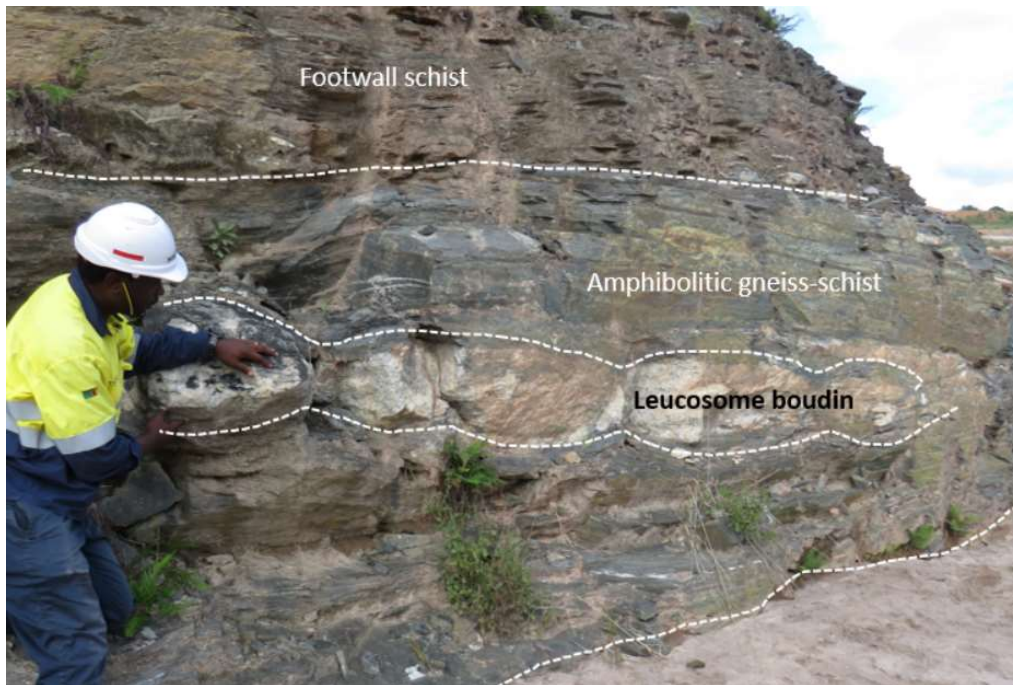


Figure 4.7. Partial melting in an amphibolite, showing incomplete mineral segregation and the development of the boudins. This exposed amphibolite occurs in the D2 footwall domain of CM_1 pit, on the northern wall.

Consequently, the texture and colour of the leucosomes observed at Chimiwungo is a function of the depth at which the unit occurs. The units at depth are white, representing a quartzofeldspathic melt which is free of mafics and the mineral grains are much coarser (3-5 cm), contrary to the units at a shallower depth which are dull white with finer (2-4 mm) mineral grains accentuated by the presence of mafic melanosome bands.

The partly sheared amphibolites of the Footwall are characterised by a schistose S2 foliation fabric around their margins. The sparsely mineralised Footwall Schist is partly composed of this S2 schistose fabric which has been integrated into the Ore Schist. The presence of actinolite and tremolite in the Footwall Schist may be attributed to the presence of the S2 schistose fabric from the footwall amphibolites. This, therefore, implies that some of these footwall amphibolites are calc-amphibolites.

Furthermore, the occurrence of talc in both the lower portions of the ore domain and the Footwall Schist is strongly attributed to the tremolite-actinolite association found in the footwall. The talc may have formed as a product of hydrothermal alteration of tremolite.

At Chimiwungo, talc occurs in discrete pockets within the Footwall Schist and has on several occasions been reported in significant amounts in the lower portions of the Ore Schist. The presence of talc in the ore schist has had negative impacts on the metallurgical process plant operations and, consequently, on the business as a whole. The metallurgical process plant at Lumwana employs the conventional floatation method which is used in the extracting of copper-sulphide minerals from the host rocks. In this method of extraction, the milled copper ore is wetted, then suspended in a slurry, and treated with reagents that render the sulphide particles hydrophobic. The now hydrophobic ore is introduced to an

aeration tank where air is constantly pushed through the slurry. The hydrophobic copper-sulphide particles then get attached to the air bubbles. Naturally, the sulphidised bubbles rise to the surface and form a froth which is then skimmed off. However, considering the low density of talc, it tends to float more than the copper-sulphides in the floatation circuits, hence it gets recovered at the expense of the copper-sulphides. This implies that the copper is lost to the tailings dam, causing production loss.

4.2.3 Pegmatites

Pegmatites occur at various stratigraphic levels of the Chimiwungo deposit. The ubiquitous K-feldspar-quartz-biotite pegmatites are most likely to be of two ages associated with the two domal granitic events. The older suite of pegmatites is closely related to the gneissic units of both the hangingwall and internal gneissic units. The pegmatites in these units are variably sheared or mylonitised and may have been emplaced together with the coarse-grained granitic gneiss which has been dated between 1680 ± 23 and 1702 ± 2 Ma (Tripp, 2013). The younger population of pegmatites is thought to be associated with the intrusion events derived from the *ca.* 900 ± 24 Ma megacrystic central granite (Dobrotin *et al.*, 2013). This population of pegmatites occurs closely associated with the amphibolites and is locally hosted in the Ore Schist, though flattened and stretched due to the shearing.

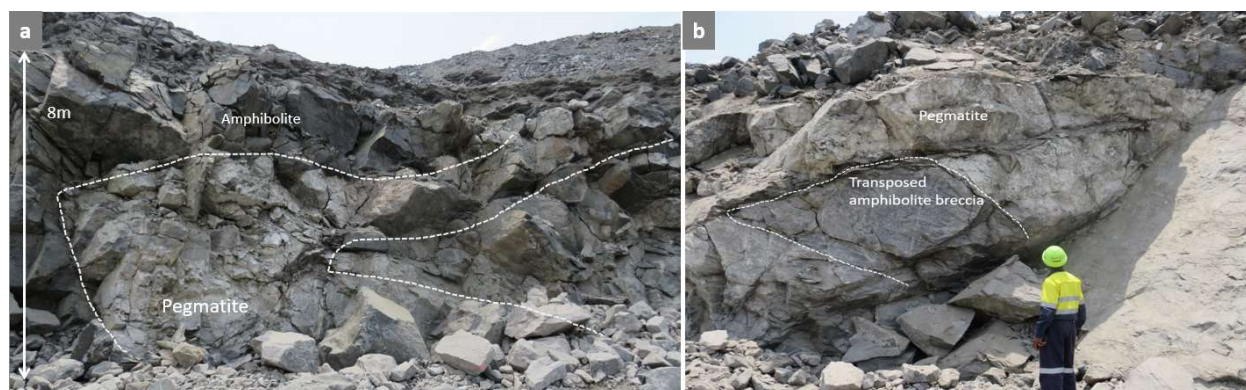


Figure 4.8. Late pegmatite intrusion brecciating amphibolite. Large amphibolite breccias are seen transposed into the pegmatite. The images were captured in the interface of CM_2 and CM_3 pits, east of the Roan Shoot.

The pegmatites associated with the gneiss units have minor muscovite alteration and a small proportion of garnet porphyroblasts (Bernau, 2007). According to Dobrotin *et al.* (2013), the Chimiwungo pegmatites cross-cut all units of the basement, except the amphibolites, which brecciate pegmatites on rare occasions. However, determining the chronological relationship between the amphibolites and the pegmatites in the field has proved challenging. As can be observed in Fig. 4.8, the pegmatite appears to have intruded the amphibolite, also brecciating it, and transposing some amphibolite breccias. These observations confirm that the pegmatites and these amphibolites were emplaced almost at the same time, 900 ± 24 Ma and 935 ± 60 Ma, respectively (Tembo *et al.*, 1999; Tripp, 2013). Therefore, it remains a possibility that the cross-cutting relationship for the two lithotypes can go either way considering the tight window in the emplacement timing.

4.3 3D modelling

A three-dimensional (3D) deposit scale model of the Chimiwungo main shear zone was constructed using Leapfrog Geo™ modelling software which applies the implicit modelling approach (Cowan and Beatson, 2002) to make 3D geological models.

The main aims of the modelling were:

- a. To visualise the 3D geometry of the orebody relative to the configuration of the internal lithologies.
- b. To appreciate the spatial distribution and geometry of the internal lithologies.
- c. To use the 3D model to help with understanding the deposit-scale controls on mineralisation, by comparing the 3D model with the Grade Control (GC) block model.

The main limitation during the construction of the model, had to do with the erroneous logging of most amphibolitic units as 'Grey Gneiss' in some cores obtained by diamond drilling. With the incorporation of mapping data and the use of some selected Reverse Circulation (RC) drilling data, the impact of this logging error was mitigated during modelling.

4.3.1. Data sets

The model area is 5 km in the N-S direction, 4.57 km in the E-W direction and 1.5 km in the Z direction. The surface elevation is ~1365 m above sea level. The model named 'The Chimiwungo Internal Units Model' has mainly been built from an extensive drillhole database, composed of numerical (collar, survey, and structural orientation) and non-numerical (lithology and structural type) data from a total of 426.8 km of both exploration and grade control diamond drillholes (DD) (Table B-1). Grade control Reverse Circulation (RC) drill holes were purposefully excluded from the dataset due to low data integrity which is caused by challenges of RC chip logging. The drill holes occur originally on a 100 m (E-W) by 200 m (N-S) exploration drill pattern, which has been reduced by the ongoing grade control diamond infill drilling at 50 m (E-W) by 100 m (N-S) spacing. The drill pattern was designed with increased drill density in the E-W direction. This was for the purpose of defining the pinch and swell geometry of the boudins, which is dominant in the E-W direction. In the southeastern part of the deposit, deep (up to 870 m) exploration holes were drilled on the original 100 m (E-W) by 200 m (N-S) grid, however, no infill drilling was carried out to further define mineralisation. The orebody has been downthrown at depth (~515 m below surface) on the southern aspect of the Equinox Shoot by the major Chimiwungo South fault (Fig. 5.1).

4.3.2. Modelling approach

All data were first verified, and errors fixed before they could be imported. The verification included checking for collars and downhole surveys. Drillhole data were automatically validated by the Leapfrog Geo™ software when imported, allowing inconsistencies in the database such as duplicates, mismatching maximum hole depths, and missing and incorrect samples to be identified and corrected.

Modelling of the required internal units proceeds firstly by defining the ore domain, which delineates the footwall and hangingwall contacts. The ore domain was originally modelled in 2018 by TECT Geological Consulting. The ore domain has since undergone several changes driven by the acquisition of data from 212 new diamond drilling holes, and mapping information acquired from new pit exposures. Updating and redefining the ore domain required the amalgamation of two grouped interval columns i.e., the LIT_LocZone (local zones) (Table C-1) and LIT_Rock (lithologies) (Table C-2), with (numeric) assay data. To create intervals from closely spaced (2 m) assay samples, an additional column called 'Cu_Cutoff' was created under the categories 'numeric'. This column was able to reassign assay intervals to categories of $\leq 0.1\%$ Cu as waste, and $> 0.1\%$ Cu as ore. The combination of these three interval columns accurately distinguished the mineralised Ore Schist package, thereby removing inconsistencies.

To collectively interpret these three columns, a merged table was created, by way of interval selection using a combination of filters. The filters made it possible to select two types of interval geological logging codes that are associated with the Ore Schist package. The first selected code was a combination that included any schist (coded Ts), LIT_Rock_Grouped - Ts with a Cu% $> 0.1\%$ (i.e., ore), followed by logged and assigned LIT_Zone_Grouped Ore Schist codes. Notably, grade control RC drilling data were excluded due to: a) the position of collars within the Ore Schist package and b) their limited depth, often with terminations within the Ore Schist. When drillholes do not intersect the Ore Schist package completely, "false" top and bottom contact points are created that misinform surface interpolation. With the Ore Schist intervals successfully selected, the hangingwall and footwall contacts were built using the vein tool. The resultant surfaces were then used to model the hangingwall, Ore Schist and footwall domains using the deposit tool in Leapfrog Geo™.

In this project, the internal lithotypes of the Ore Schist domain were built by 'refining' the Ore Schist domain solid. Modelling of the internal lithotypes was performed using a combination of the grouped LIT_Rock (lithologies) and LIT_Col (lithology colour) codes (Table C-2). For refinement of the Ore Schist package four code types were distinguished: 1) Biotite schists (Tsbt); 2) Leucosome (TTG, LIT_Col -Wh), 3) Amphibolite (AM) and 4) Grey gneiss (TTG, LIT_Col -Gy). Based on pit mapping, these units were targeted for modelling as they appeared to dominate the lithotypes of the Ore Schist. Chronologically, the Grey Gneiss was modelled as the oldest unit, which is thought to have been intruded by the amphibolite. The leucosome is thought to have developed from an amphibolitic protolith (see section 4.2.2), hence it was modelled as younger than the amphibolite. The Biotite Schist was modelled to represent S2 phyllonitic shear zones occurring within the ore package. These shear zones predominantly occur as schistose layers around gneissic boudins. Also, the Biotite Schist defines the spatial occurrence of highly sheared mafic units. The unit was modelled as the youngest lithology, being associated with the final deformation events.

4.3.3. Modelling results

The geometry of the modelled orebody confirmed the presence of two N-S trending Ore Shoots, referred to as the 'Roan Shoot' (on the west) and the 'Equinox Shoot' (on the east). These will be discussed further under the Structural Geology title in Chapter 5.

Both the mapping and the drilling data shows that the hangingwall contact is intersected at higher elevations along these shoots when compared to the contacts away from the shoots. The modelled footwall contact appeared relatively flat, with localised undulation in places. Notably, the observed shoots (ridges) are not replicated on the footwall contact. The volumes of the modelled internal units show that the Grey Gneisses are the most abundant rock type, followed by the amphibolitic units, then the Biotite Schist and, lastly, the leucosomes (Fig. B.1, - B.4). It is worth noting that, based on the mapping experience, a large amount of lithological logging data is confirmed to have been erroneously classified as Grey Gneisses instead of sheared amphibolites (see section 4.2.1). To mitigate the effects of this logging error on the modelling, some of the intervals logged as grey gneiss were reassigned to the amphibolite table using the interval selection tool. The distribution of the modelled internal units appeared to be systematic and similar across the prominent two Ore Shoots. The thick amphibolites and some of the thick Grey Gneiss units are well aligned along the trends of the Ore Shoots (Fig. B.2 and 3). In the inter-shoot zones, the Ore Schist appears to be thinner and dominated by more consistent but flattened internal units. The leucosome, though discrete in occurrence, appears to be predominantly aligned with the eastern flanks of both shoots. It occurs in larger proportions east of the Roan Shoot as compared to the eastern aspect of the Equinox Shoot.

Chapter 5

CHIMIWUNGO STRUCTURAL GEOLOGY

5.1 Introduction

The Chimiwungo deposit is endowed with diverse structural features that resulted from a complex metamorphic history, characterised by HT-HP tectono-metamorphic conditions. The development of these structural features is closely associated with the Neoproterozoic continent-continent collision between the Congo and Kalahari cratons (John *et al.*, 2004) during the Pan-African orogenic events. The multi-episode tectono-thermal Lufilian events were characterised by, among other events, thrusting, folding, volcanism, extensional detachment, and normal faulting. The structural features at the Chimiwungo deposit include foliation, lineation, mylonitisation, folding, faulting, boudinage and shear fabrics. Different researchers have attributed the presence of the structures to various domal events such as thrusting, extension, shearing and recumbent folding (Cosi *et al.*, 1992; Richards and Nisbet, 2003; Koegelenberg *et al.*, 2019). The Chimiwungo structural architecture attests to some of the events that characterised the Pan-African Lufilian orogeny. However, some of the structural features may pre-date the Lufilian events. Considering that the deposit is hosted in Paleoproterozoic basement rocks, it remains a possibility that some of the pre-Lufilian structures may have been overprinted.

The main structural features that characterise the geometry of the Chimiwungo orebody (main shear zone), are two linear NNE-SSW trending features that take the form of ridges. These linear zones, locally referred to as 'Ore Shoots', define the relatively shallow and thickest region of the orebody and are key in the determination of the parameters of the mining volume. To understand the factors responsible for the development of these 'ridges', a model of the ore package which encapsulates both drilling and mapping data was constructed (chapter 4).

Based on the modelling results, this chapter endeavours to discuss the structural characteristics of the Ore Shoots and the general structural features of the deposit as they relate to some of the known major events of the Lufilian orogeny.

5.2 The Ore Shoots

The two 'Ore Shoots', locally referred to as the Roan Shoot (western shoot) and the Equinox Shoot (eastern shoot), generally display consistent south and south-southwest shallow plunges, respectively (Fig. 5.1). The Roan Shoot displays a gentle ($\sim 13^\circ$) plunge angle, as compared to the slightly steeper ($\sim 18^\circ$) plunge angle for the Equinox Shoot. The overall plunge of each of the shoots parallels the S3 linear stretch features (L3) and the boudin long axes. The two shoots are ~ 1.7 km apart in the extreme north of the deposit, and ~ 1 km apart at the southern end of the deposit. They are generally separated by either thinner and less consistent copper grade shear zones and/or by dominantly thicker barren gneissic rocks. They are each characterised by discrete interlimb angles. The Roan Shoot is defined by a steeper-dipping eastern limb which dips towards the east-southeast ($126^\circ/35^\circ$, dip direction/dip), as

compared to the shallower west-southwest-dipping western limb ($250^{\circ}/21^{\circ}$) (Fig. 5.1). The Equinox Shoot (not yet exposed at the time of writing this report) shows a much smaller interlimb angle (Fig. 5.1). From the structural modelling point of view, the western limb has been observed to be the steepest, occurring at $250^{\circ}/50^{\circ}$ (dip direction/dip) in some places, while the eastern limb has a generally gentler ($120^{\circ}/30^{\circ}$) slope. This shoot is also narrower than the Roan Shoot and is far better defined along its axis than the broader Roan Shoot (Fig. 5.1).

The immediate overlying hangingwall of the eastern limb of the Roan Shoot is characterised by thick phyllonitic S2 zones. On its western limb, the Roan Shoot is overlain by sheared hangingwall gneisses which are accentuated by narrow bands of S2 mylonitic fabrics. These S2 bands occur largely at low-angles and/or sub-concordant to the S3 phyllonite fabric. They are generally poorly developed and depict narrow zones of shear movement.

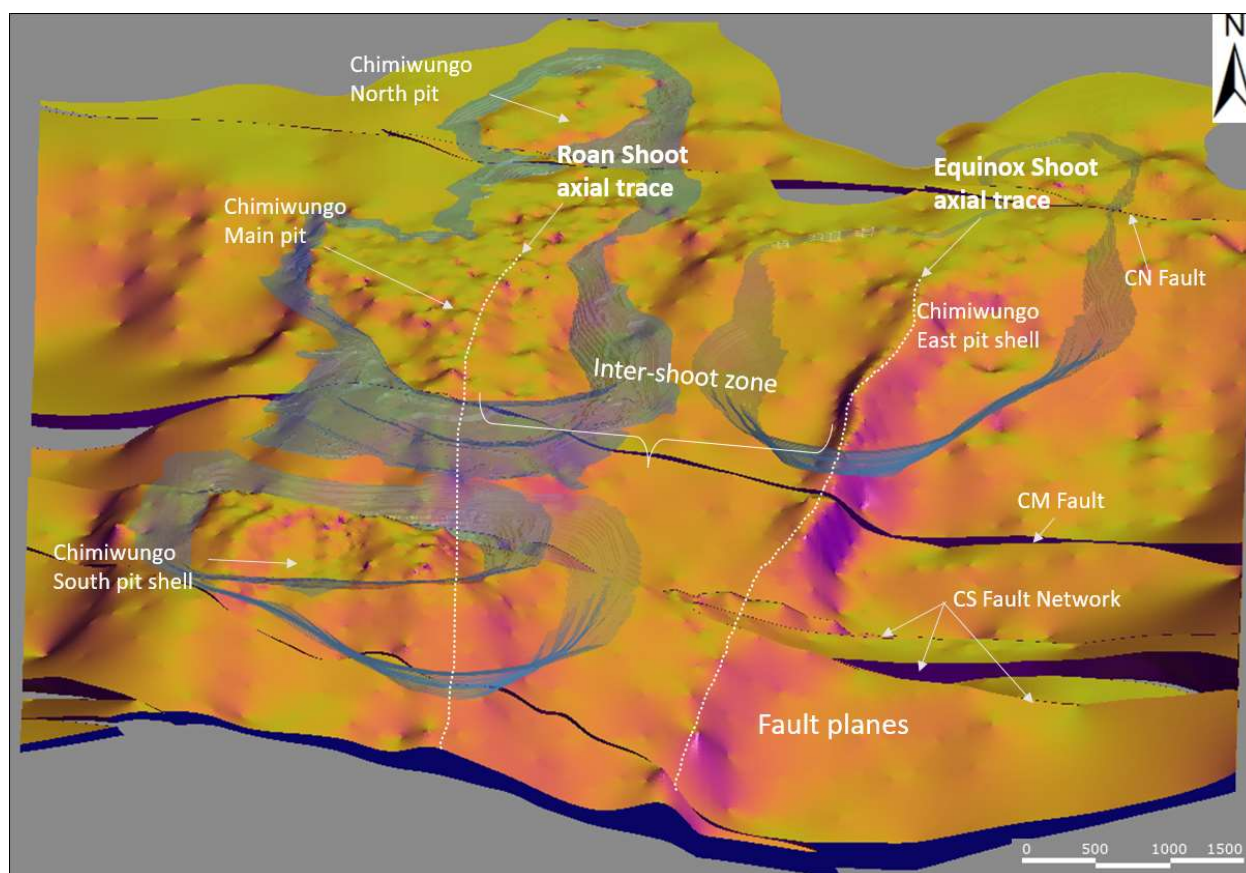


Figure 5.1. A screengrab of the Chimiwungo Leapfrog Geo™ structural model showing the general morphology of the main shear zone. The figure also depicts how the major faults, and the two shoots interact with the active and planned (Chimiwungo East) mining volumes.

The base of the main shear zone which defines the footwall–Ore schist contact, neither shows evidence of folding nor thickening downwards (Fig. 5.1), either in relation to the two shoots or otherwise. This implies that the shoots may be looked at as ‘ridges’ running in a subparallel fashion within the main

shear zone. This new observation casts a doubt on earlier suggestions that the shoots were a product of a later folding of the Ore Schist, which was interpreted to be a D1 feature (Richards and Nisbet, 2003).

5.2.1. Internal Characteristics and Evolution of the Shoots

There has been little understanding of the geological and structural nature of the Chimiwungo deposit's Ore Shoots and the associated mineralisation. According to Dobrotin *et al.* (2013), the formation of these north-south trending shoots containing thicker zones of Cu-mineralisation is poorly understood. Poulsen (2013), suggested the shoots are likely to have formed as a result of accommodation of the weaker schists in the necks between large, stiffer, granitoid sheets. He interpreted the shoots as cusped folds in boudin necks, rather than folds caused by contraction of strata. This is in line with Tripp (2013), who also suggested that the Ore Shoots represents boudin necks. However, this hypothesis is not supported by any evidence that the hangingwall granitoid gneiss is in fact a large boudin structure. Furthermore, boudin necks are primarily known to act as pressure shadows and are therefore usually closely associated with high accumulations of minerals in an ore deposit. However, the Ore Shoots at Chimiwungo are not enriched relative to other parts of the shear zone (see Chapter 6).

In this section, the internal characteristics and interpretation of the Shoots will be discussed. The discussion will be driven largely by the results of the pit mapping and the analysis of drilling data which amounted to more than 11,000 boreholes. The boreholes, which included both Reverse Circulation (RC) drilling and Diamond Drilling (DD), were used as the main source of geological data. Using only 1,141 Diamond Drilling (DD) holes (Table. B-1), a 3D Leapfrog GeoTM geological model was built for the purpose of conceptualising the occurrence of geological units in space. The 3D model limits define the economically active part of the Chimiwungo main shear zone, as depicted by the extents of the Life of Mine (LoM) planned pit designs (Fig. 5.1).

The internal architecture of the Chimiwungo Ore shoots is dominated by the presence of massive and competent asymmetrical boudins of an amphibolitic protolith. These units have been described in detail under section 3.5.1. The amphibolites appear to be thinner and more continuous on the western flanks of both shoots (Fig. 3.4). In the central region of the Ore Shoots, the units are much thicker and partly boudinaged (section 3.5.1). Towards the eastern flanks, the amphibolites have been chaotically cleaved into smaller multiple boudins which 'float' as independent units in the main shear zone. These randomly distributed units of varying sizes are concentrated partly in the centre and more or less along the eastern 'limbs' of the shoots. These smaller units which are highly deformed, also appear to have lost their original amphibolitic texture, to assume a gneissic texture (see illustration in section 4.2.1).

The occurrence of the massive amphibolites in the shoots appears to preserve two possible main magma feeder sites into the preexisting country rocks (Fig. 5.2B). Also, the occurrence of the massive hangingwall amphibolites (section 3.5.4) appears to be localised above Ore Shoots. This implies that the basaltic lavas responsible for these amphibolites may have been emplaced linearly at two distinct locations in an N-S trending fashion (Fig. 5.2B) across stratigraphy. Metamorphic processes could have

caused the deformation of these emplaced magmatic rocks along with the preexisting country rocks to yield a composition of gneissic units hosting the amphibolites.

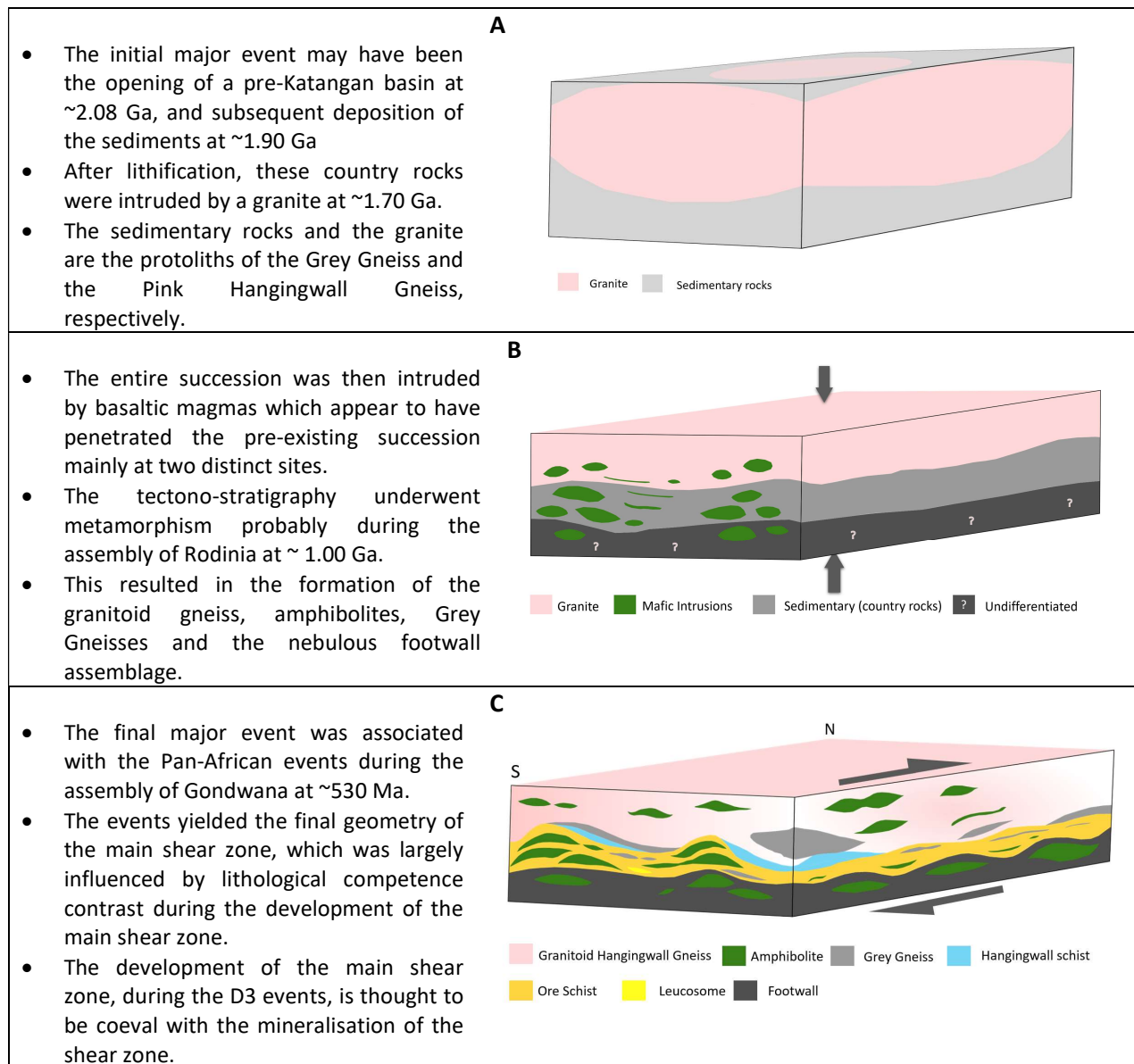


Figure 5.2. A schematic model illustrating the main stages for the development and evolution of the Shoots at the Chimiwungo deposit.

During the development of the main shear zone, the larger part of the basement gneissic units was sheared, leaving boudinaged remnant basement gneissic units, now referred to as the internal Grey Gneisses (section 3.3). Due to the lithological competence contrast, the thick amphibolites generally withstood the shearing deformation. The competence contrast was crucial in the development of the shoots, which are basically ridges within the main shear zone that are dominated by the presence of competent rock units. The ductile fabric in the shoots is dominated by a highly strained schistose to mylonitic fabric. The schistose fabric observed wrapping around the competent units of the shoots is

poorly developed when compared to the fabric peripheral to the shoots. The presence of the mylonitic fabric is indicative of intense shearing associated with the development of the fabric within the shoots, which are dominated by highly competent amphibolites. Consequently, the development of the mylonitic fabric ensued, with some of the resistant amphibolites suffering partial shearing exhibited through the development of amphibolitic protomylonites. Generally, the mylonitic fabrics are closely associated with the shoots and rarely observed elsewhere in the deposit. According to Poulsen (2013), a good volume of these mylonitic shear zones may have been progressively hydrothermally altered and overprinted, while only a few of those are mineralised with Cu-bearing sulphides.

5.3 Foliation

Foliation is the most pronounced rock fabric type in the rocks at the Chimiwungo deposit. The host rocks show a strong gneissic or schistose foliation. The amphibolite facies metamorphic grade associated with these rocks has enabled a clear distinction of various mineral assemblages associated with these well-defined fabrics. Most of the observed basement foliation fabric may have formed prior to the Lufilian orogeny, except for the shear-related fabric which is closely associated with the D2 and D3 Lufilian events. Generally, the domal basement gneisses and schist units are known to have been formed in HT-HP metamorphic conditions (Cosi *et al.*, 1992). Further HT-HP D1 Lufilian orogenic events also affected the basement gneisses and schists (Eglinger *et al.*, 2016). The general orientation of the different foliation fabrics is shown in the plotted stereonet in Fig. 5.3.

5.3.1 Gneissosity

The gneissic foliation of the Chimiwungo deposit occurs across the entire tectonostratigraphy, from the hangingwall, into the ore package and the footwall. The development of this fabric in the basement rocks may predate the Pan-African Lufilian orogenic events. The gneissic fabric is strongly registered in the Pink Hangingwall Gneiss, the Grey Gneisses and the amphibolitic gneisses. The Chimiwungo gneisses predominantly occur as massive units in the hangingwall domain and as boudins with a pronounced relic gneissic foliation within both S2 and S3 shear zones. In some sections of the hangingwall, the gneissic foliation is highly sheared when compared to other sections. Generally, the intensity of shearing observed in the hangingwall gneisses is less than the observed intensity of shearing in the gneissic fabric of the Ore Schist (main shear zone). In the wider S2 and S3 phyllonitic zones, the gneissic fabric occurs in the boudins showing a rotated relic gneissic foliation, hence occurring discordant to the surrounding foliation. The gneissic units that occur internal to the Ore Schist seldom display the presence of mylonitic fabric. Instead, the Ore Schist is in contact with the gneisses by way of gradual contacts as discussed in section 3.3 of Chapter 3. These gneissic boudinaged units which occur internal to the Ore Schist appear to be more rotated than the hangingwall gneissic boudins occurring in wide S2 zones. This may be attributed to the high intensity of shearing associated with the main shear zone. The units mainly appear as east-west trending boudins which have been truncated from place to place by late S3 phyllonites. Also typical of the characteristics of the Chimiwungo gneissic units are the F1 intrafolial, recumbent and isoclinal drag folds (Fig. 5.4). The sub-metre to metre scale north-verging F1 folds also serve as kinematic sense indicators associated with the Lufilian D1 fore-thrusting deformation event of the Paleoproterozoic gneissic fabric.

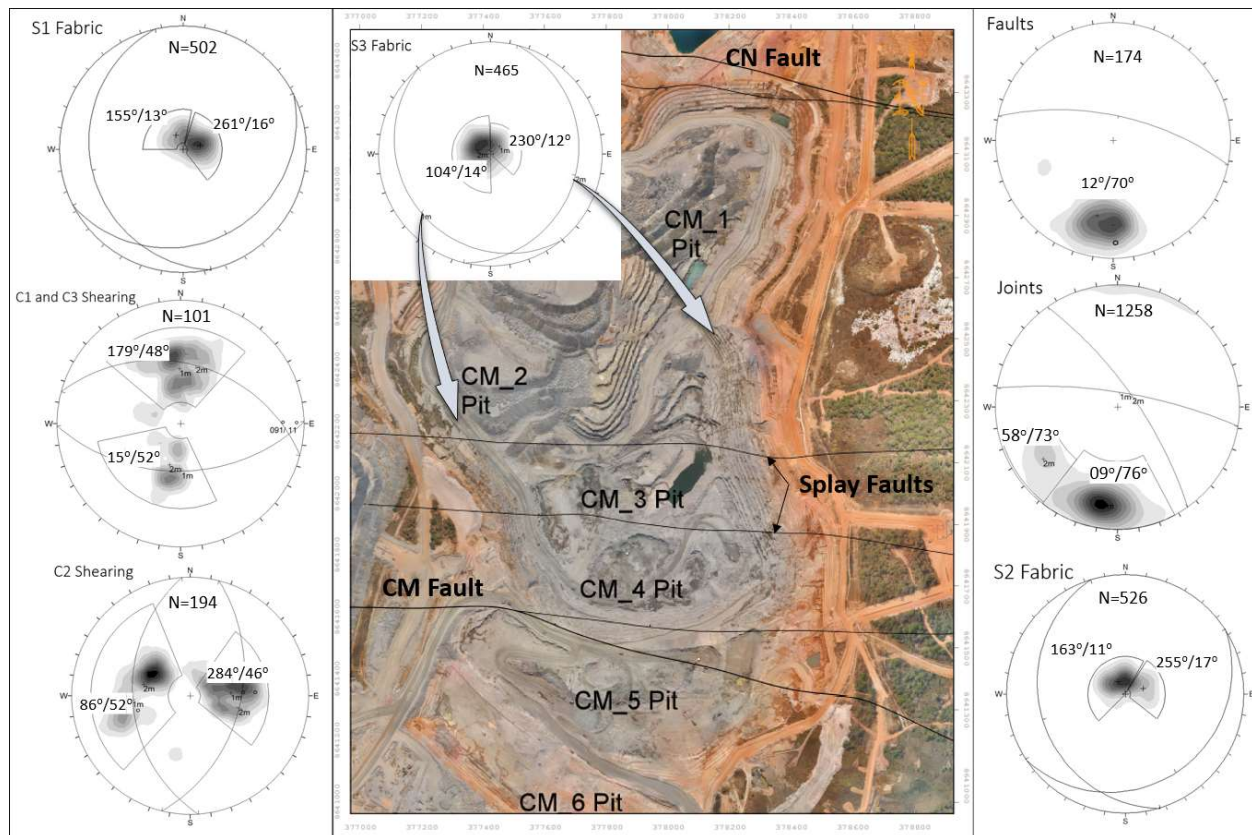


Figure 5.3. Aerial map of the Chimiungo Main pit overlaid by two major faults and some of the minor faults. The map is flanked by stereonets from mapping data. All the mapping data are from CM pit and are plotted on an equal area, lower hemisphere stereonets. They indicate mean dip direction and dip.

Where shear planes have been identified, the drag folds are represented by two oppositely-closing fold hinges which are separated by the shear plane (Fig. 5.4a). Typically, the folds which occur above the shear plane are north verging. This observation in the orientation of the drag folds conforms to the top-to-the-north sense of kinematic movement associated with the D1 events in the Dome (Eglinger *et al.*, 2016). According to Carreras *et al.* (2005), the shear-related folds are closely associated with surfaces in proximity and parallel to the shear zone boundary. These surfaces are usually characterised by newly developed shear-related foliations or banding. The late folds can also be readily identified when massively textured lithological bodies occurring in the wall rocks, become penetratively foliated in the shear zone (Carreras *et al.*, 2005). The structural measurements of the gneissic foliation (S1) appear to broadly register a southwest dip direction while plunging to the south (Fig. 5.3). The data was captured on both sides of the Roan Shoot and in the inter-shoot region. Mapping data along the eastern aspect of the shoot is represented by the dip direction /dip of $150^{\circ}/17^{\circ}$, while data from the western aspect of the shoot and the inter-shoot region yields dip direction /dip readings of $260^{\circ}/21^{\circ}$. A common feature associated with the shearing event is the folding of the stretching lineation. The L1 stretching lineation is well-defined by the orientation of elongate disseminated kyanite grains in biotite-phlogopite dominated schistose bands. The lineation (L1) has a plunge direction /plunge of $197^{\circ}/11^{\circ}$. Typical F1 fold widths (distance between two inflection points) show variation from centimetre-scale to ~ 4 m, however, up to

35 m wide folds are known to occur in the hangingwall units of the Malundwe deposit (Dobrotin *et al.*, 2013).

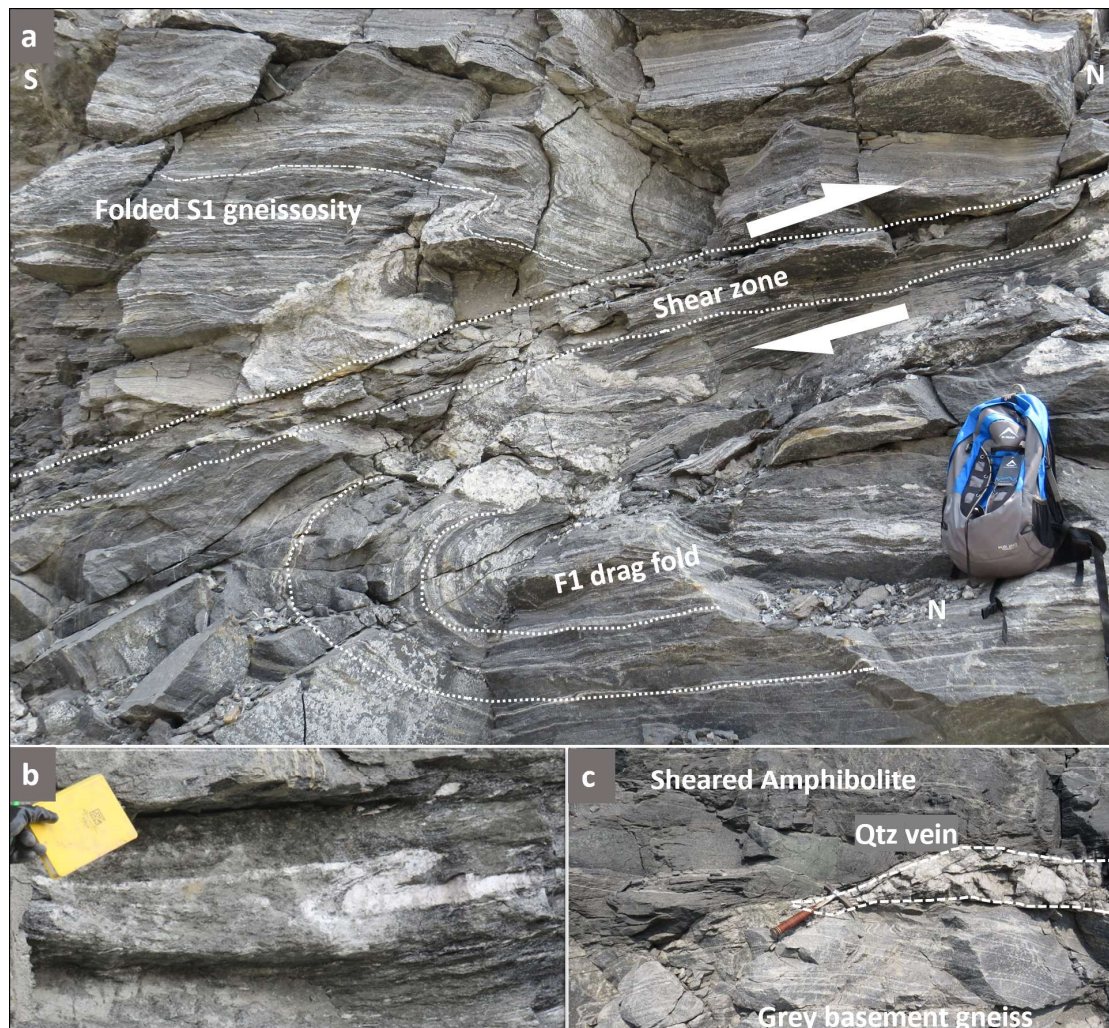


Figure 5.4. Shows the nature of the drag folds which occur proximal to shear zones in the gneissic fabric. (a) Two oppositely directed intrafolial drag folds separated by a shear zone which portrays a top-to-the-north shear direction. (b) A folded intrafolial leucocratic vein within the mylonitic unit. Stretched quartz porphyroclasts are observed in the mylonitic fabric. (c) A brecciated quartz vein is observed along the amphibolite and grey gneiss contact, which also is a plane of shear movement. The quartz vein underwent shear deformation, evidenced by the presence of deformation-induced shear planes. The pictures were taken along the western wall of CM_2 pit in the Roan Shoot.

5.3.2 Schistosity

The schistose fabric is another well-developed and easily recognisable foliation type that occurs across the entire Chimiwungo stratigraphy. The fabric that occurs conspicuously in each of the three domains (hangingwall, ore and footwall) has been interpreted as a product of intense shearing of preexisting Paleoproterozoic units during both the syn- and post-orogenic events (Eglinger *et al.*, 2016). The schistose fabric of the Mwombezi Dome displays both mineralogical and textural variation (Fig. 5.5).

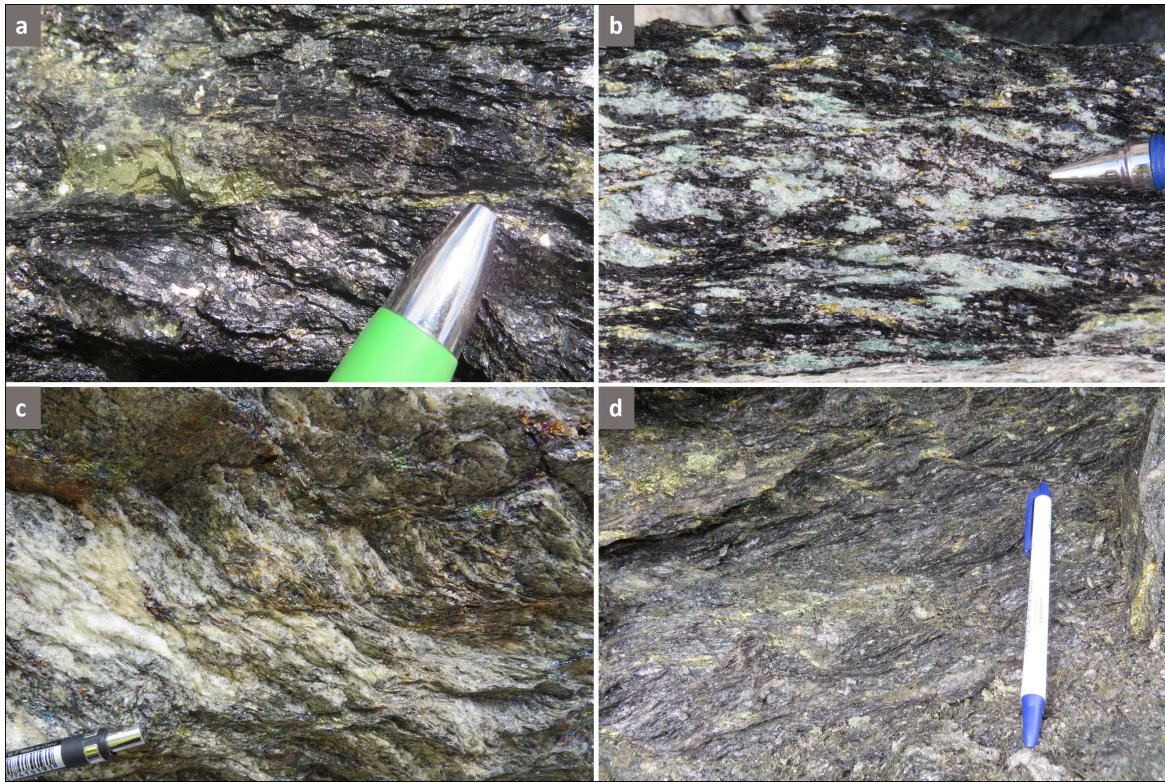


Figure 5.5. Different mineralogical and textural occurrences of the Ore Schist fabric. (a) Phlogopite/biotite schist. (b) Amphibole-biotite-quartz schist. (c) Muscovite-quartz-biotite/phlogopite schist. (d) Phlogopite-quartz schist.

This is largely driven by the shearing of different Paleoproterozoic gneisses and amphibolites which produced the diversity in the resultant schistose fabric. The variation in the mineralogical composition may also have been driven by the metasomatic processes which occurred during mineralisation (Bernau, 2007). Metasomatic processes yielded distinct textural features in the Ore Schist and to a lesser extent in the immediate footwall schistose fabric. Textural variations have also been observed to be associated with the spatial occurrence of the schistose fabric across the two shoots (Roan and Equinox). The gradual contact between the Pink Hangingwall Gneiss on the western aspect of the Roan Shoot and the Hangingwall Schist on the east showed that the schistose fabric is highly developed along the eastern flanks of shoots as compared to the western aspect of the shoot (Fig. 4.2). Development of the schistose fabric within the shoots is not as intense as has been observed along the eastern flanks. Generally, the Ore Schist appears to show the most developed and distinct schistose fabric across the stratigraphy.

During shearing, the accumulation of shear strain caused the development of slip surfaces referred to as shear bands, which commonly formed parallel to the walls of the shear zone (Fig. 5.6a). These shear bands are called ‘C bands’ (French “cisaillement” for shear) and are known to be less penetrative. The C bands are not really surfaces, but small-scale shear zones that affect the foliation within the main shear zone (Fossen, 2010). The C planes also happen to be fissile owing to shear movements which are concentrated along these bands, hence they acted as suitable parting zones in the rocks. Generally, a shear band is synthetic if it operates in the same direction and sense as the overall shear zone, and it is

antithetic if operates in an opposite sense and direction. Shear bands with normal displacement are commonly called extensional shear bands (Davis *et al.*, 2018).

At Chimiwungo, the highly metasomatised phyllonite-like unit is accentuated by the presence of the S-C and the S-C' extensional fabric with a dominant top-to-the-NNE kinematic sense of movement (Fig. 5.6a), and a strong L3 stretching lineation defined by slickenlines on C' shear planes. The structural trends for the Hangingwall Schist fabric are represented by a stereonet plot of S2 structural data in Fig. 5.3, while the Ore Schist structural data is represented by the S3 stereonet (Fig. 5.3).

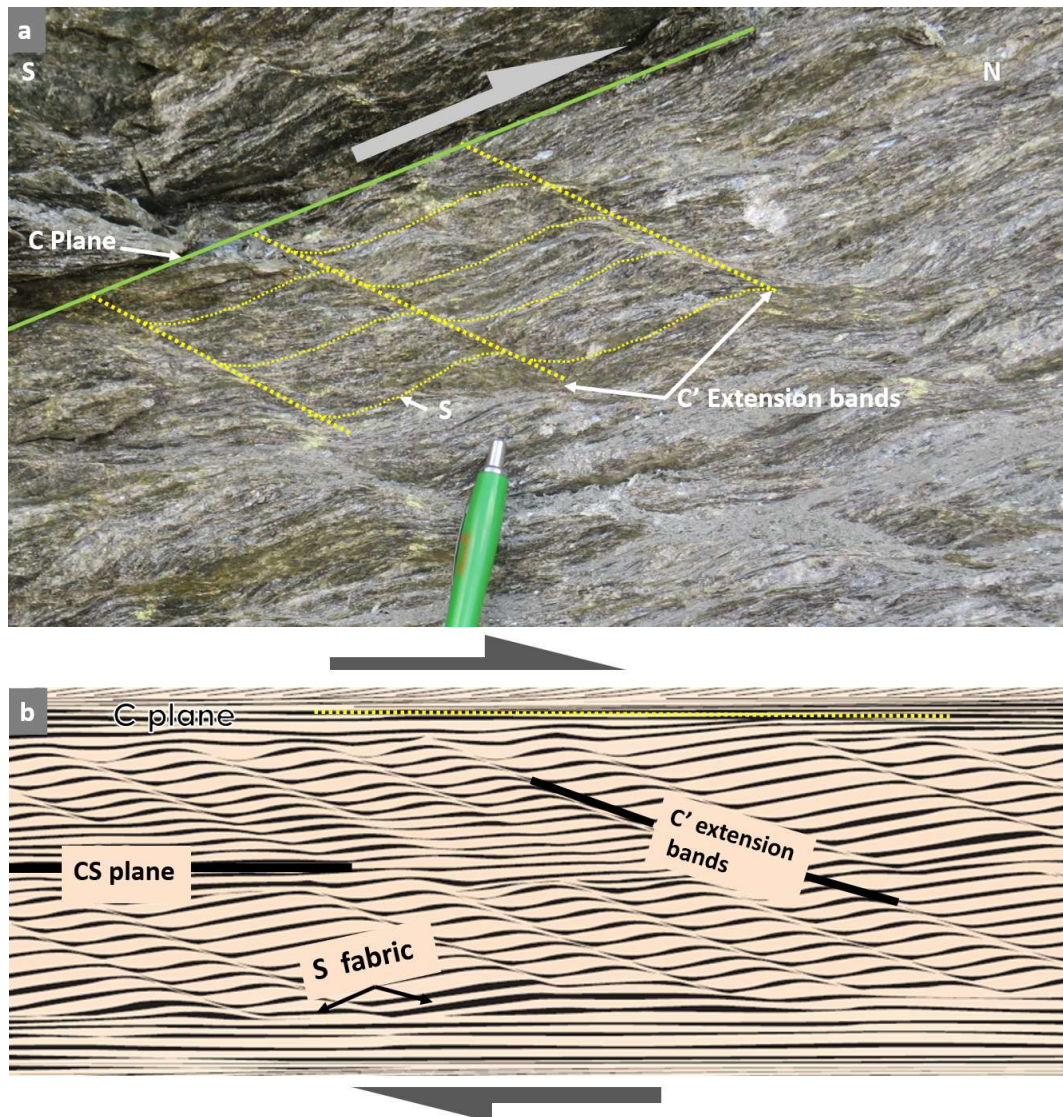


Figure 5.6 Fabric development in the Ore Schist at Lumwana Mine. (a) An image of the Chimiwungo Ore Schist taken in CM_4 on the western wall, depicting the fabric development as a result of the shearing process. (b) A schematic illustration of how fabric occurs in a shear zone modified after Fossen (2010). The S foliation is truncated by shear surfaces (C). The CS foliation forms when the S is rotated into close parallelism with C shear surface. New and oblique shear bands (C') form and back-rotate the CS foliation, which then is called S.

Developing simultaneously with the C fabric is the accompanying foliation named S (for schistosity) (Fig. 5.6a). The schistosity foliation from which the Chimiwungo 'Ore Schist' derives its name, generally occurs sub-parallel to the C zone but can show variation from this range. The increased shear strain during D3 deformation caused a rotation in the S planes, thereby reducing the angle between the C and S fabric. The C and S planes are therefore brought into near parallelism as is the case in Fig. 5.6b. This angular relationship is a frequent and reliable indicator of the relative sense of shear, with the acute angle between C and S planes indicating the direction of shear displacement (Mukherjee, 2015). Additionally, the sigmoidal shape of the foliation fabric between shear zones (or bands) shows the direction of shear. As higher shear strain intensity is approached, the C and S surfaces become sub-parallel, so that their separate foliation becomes indiscernible. A composite foliation consisting of rotated foliation and C surfaces is then formed (Mukherjee, 2015). These newly formed shear bands are referred to as C' (Fig. 5.6b) and are known as extensional shear bands. They ordinarily result from some localised slip in a component of the extension within the major flow plane. The C' shear bands are generally more discontinuous than C planes and may exist in a single set or multiple sets at shallow angles to each other (Fig. 5.4a). S-C' shear planes may indicate intense non-coaxial deformation and partitioned flow (Mukherjee, 2015). The C' shear bands accommodate normal displacement disclosing net extension parallel to the dominant fabric. The sense of shear deformation is such that C' surfaces tend to "crenulate" the pre-existing planar fabrics. In addition, heterogeneity in the deforming rock, as well as slip on micaceous elements in the foliation, perturb the flow enough to break down the simple picture seen at lower strains (Fossen, 2010).

Generally, C' shear bands seem to develop at a relatively late stage of shear activity after the strong planar anisotropy represented by the S-foliation has already been established (Fossen, 2010). The presence of these structures thus reflects the last stage of the deformation history. This happens to be the case with the Chimiwungo deposit where the D3 event (last fabric developing event) was responsible for the development of the S3 (Ore Schist), as no other fabric appears to postdate the Ore Schist fabric.

5.4 Boudinage

Boudinage is one of the best developed structural features observed throughout the basement units of the Mwombezhi Dome. The Boudins are easily observable in the pit walls and tend to occur in wide S2 schistose zones and in the mineralised S3 Ore Schist (Fig. 5.7). The boudins measure from a metre to tens of metres in both the minor and major axes. The structures, which represent an extensional regime are both symmetric and asymmetric. They are readily observed across the entire tectonostratigraphy and are composed of different lithological units (described in Chapter 3). Generally, the boudinage observed in the Mwombezhi Dome has an N-S long axis but shows stretching in both N-S and E-W directions. At Chimiwungo, the boudins are more discontinuous in the E-W direction (Fig. 5.7a), and more continuous down-dip in the N-S direction (Fig. 5.7b), a feature indicative of significant crustal vertical shortening and concurrent stretching. Asymmetrical boudins are elongated in the north-northeast direction (long-axis, minimum extension). In the Ore package, they are bisected by dominant shallowly south-dipping C3 shears, whilst the short-axes are characterised by steep easterly-dipping C

shears. Easterly-dipping C shears (Fig. 5.7a) define a component of top to the east, or eastward directed ductile flow (Koegelenberg *et al.*, 2019).



Figure 5.7. Occurrence of boudins in the schistose fabric at Lumwana mine. (a) A moderately weathered and counterclockwise rotated pink granitoid gneiss boudin in the hangingwall package of CM_5 pit. The asymmetric boudins occur in a thick schistose S2 layer, having a relic gneissic foliation moderately dipping to the east. The rotated gneissic foliation occurs discordant to the S2 schistose foliation. (b) Leucosome boudins characterised by a penetrative S3 mylonitic fabric along the eastern wall of CW_4 pit. The south-plunging long axis of the boudins display more continuity when compared to the E-W short axis.

During D2 extensional deformation, the competence contrast displayed by adjacent lithological units of different protoliths played a role in controlling boudinage development. For instance, at Chimiwungo, the Grey Gneisses deformed easily during shearing, causing the more competent amphibolites to become boudinaged. The boudin is commonly asymmetric with rotation and back-rotation of boudins within the ductile schistose fabric (Fig. 5.7). A distinctive feature in the rotated boudins is the differently oriented S1 foliation trends in the rotated boudins when compared to the general orientation of the gneissic foliation in the area. Both features are consistent with boudinage during shearing.

Locally boudins show variation between symmetric and asymmetric geometry, which is determined by whether the boudinaged layer is perpendicular or oblique to the plane of flattening.

A key aspect of the boudinage development at Chimiwungo is its influence on the distribution of copper-sulphide mineralisation. Just as boudinage is a result of extension, mylonitisation and schistosity are some of the pervasive fabrics that developed in response to shearing. The development of these fabrics is commonly associated with regimes associated with a composite of compressional and extensional deformations. It is therefore suggested that some of these observed shear fabrics have formed as a result of locally resolved compression, which developed within a broader extensional environment (Poulsen, 2013).

5.5 Mylonitisation

Mylonitisation is a ductile shear zone process that is commonly associated with a drastic reduction in grain size and the development of a well-banded and lineated rock known as mylonite (Mukherjee, 2015). Generally, ductile shear zones are known to undergo non-coaxial deformation. The scale of deformation can be from grain-scale to hundreds of kilometres in length and a few kilometres in width (Mukherjee, 2015). At the Chimiwungo deposit, mylonitisation is partly represented as an extensive anastomosed array of distinctive shallow-dipping ductile shear zones, ranging from centimetres to tens of metres in thickness. These D2-D3 structures have been observed cutting through the gneisses, pegmatites and granitoids, implying that the mylonitisation occurred after the gneisses had achieved their gneissic banding. The mylonitic foliation in the gneisses is straighter and bands are more closely spaced than in the non-mylonitised gneisses. The mylonites are not strongly registered in the intrusive amphibolites except when the intrusives occur within the shoots. Observed mylonites display a characteristic quartz and feldspar grain size reduction, strong foliation and an accompanying N-S mineral stretching lineation. The process was largely aseismic, meaning the rocks were flowing rather than breaking, requiring a reasonable depth of burial in the crust. Mylonitisation is not observed in the muscovite-biotite-kyanite-quartz type schist. This could most likely be due to intense D3 shearing, which was followed by metasomatism, causing a complete obliteration of any preexisting textures. Evidence in the drill core suggests that at several locations, hydrothermal alteration may have led to the formation of the ore schist by overprinting of the mylonitic fabric (Tripp, 2013). The Ore Schist has been through extensive and intensive layer-parallel extensional shearing.

5.6 Late brittle faulting

The Mwombezhi Dome is dominated by late dip-slip, brittle, WNW-trending faults. On the eastern margins of the dome, however, alternating dextral and sinistral normal faults have been observed

offsetting the domal lithologies between on a kilometer scale across strike. The normal faults dip steeply ($\sim 70^\circ$) to the north (Fig. 5.8) and crosscut all lithologies, fabrics and structures.



Figure 5.8. An aerial photo of the Chimiwungo pits overlaid by the major fault and some of the minor (splay) fault traces (Black lines). The aerial map is courtesy of the Lumwana Mining Company Survey team. CN = Chimiwungo North; CM = Chimiwungo Main; CS = Chimiwungo South. The section lines AA' and BB' are drawn through the high Cu concentration zones which flank the eastern aspect of both Shoots. The two section lines are shown in Figure 5.9a and b. Section line CC' defines a section across the deposit shown in figure 6.3.

At Chimiwungo, the faults partition the deposit into three main segments, namely Chimiwungo North, Chimiwungo Main and Chimiwungo South, from the north to the south (Fig. 5.8). The segments which also represent the respective mining volumes are all part of the same mineralised ore package which has been dismembered by these steep, dip-slip faults.

Chimiwungo North is the northernmost segment of the deposit and is located immediately north of the Chimiwungo North Fault (Fig. 5.8), which is a steep dip-slip fault zone. This fault, which is characterised by a network of smaller faults, has downthrown the mineralisation on the northern side of the fault by approximately 100 m, thus preserving it from erosion and oxidation. To the south of Chimiwungo North is Chimiwungo Main mineralisation which is the upthrown continuation of Chimiwungo North (Fig. 5.6). The Chimiwungo Main segment is bound between the Chimiwungo North and South Faults. The segments extend approximately 2.7 km north-south, and 5.0 km in the east-west direction, and it is open to the east and west. The deepest mineralisation is located in the southeastern part of the Chimiwungo deposit, where it has been displaced to ~700 m below surface by the Chimiwungo South Fault (Fig. 5.7b).

The Chimiwungo South mineralised zone is located south of the Chimiwungo South fault (Fig. 5.8) which has a throw of approximately 300 m (Fig. 5.9a). This brittle fault is characterised by multiple anastomosing smaller fault planes (Fig. 5.8). These splay faults interact more with the Equinox Shoot than the Roan Shoot. They have throws ranging from 80m to ~180m (Fig. 5.9b), all associated with the Equinox Shoot. The Chimiwungo Main fault separates CM_4 and CM_5. Even though the fault stretches extensively along strike, it does not significantly displace the orebody (Fig. 5.9a).

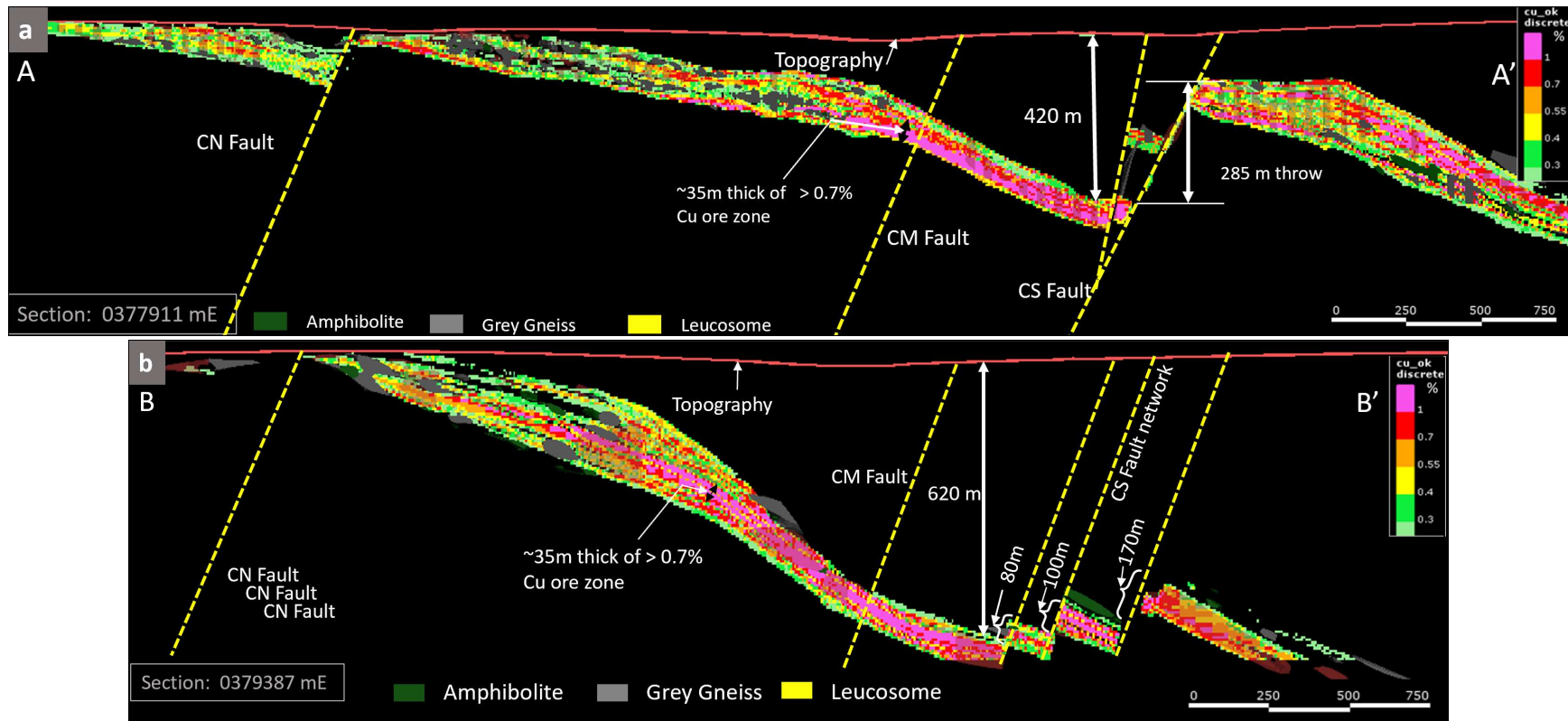


Figure 5.9. Sections through the high Cu grade zones of the Chimiwungo deposit's Grade Control block model. The sections depict how the major faults displace the ore package. (a) A section through the high Cu grade zone on the eastern flank of the Roan Shoot. (b) A section through the high Cu grade zone on the eastern flank of the Equinox Shoot. The average thickness of the high Cu grade zones that flank the eastern aspect of both shoots is ~ 35 m.

The faults which represent an extensional event may have been due to post-orogenic gravitational collapse following the Lufilian crustal thickening events (Eglinger *et al.*, 2016). There is no evidence that links mineralisation and faulting as may be the case in a wide variety of other structurally controlled deposits. The faults are locally classified into major and minor faults, based on the throw of the fault. Major faults are those with a throw of magnitude in the order tens of metres, while minor faults are the ones with a sub-bench (<12 m) throw (Fig. 5.10b).



Figure 5.10. Late brittle faults of the Chimiwungo deposit. (a) Normal drag folding of Gneissic foliation in the hangingwall of a minor normal fault observed in the saprock at the interface of CM_4 and CM_5 pits, on the western wall. Kaolinisation is observed as white bands proximal to the weathered fault plane. (b) Amphibolite sills lying concordant to the gneissic foliation displaced by a minor fault. The image was taken on the southeastern wall of CM_5.

Major normal faults are characterised by groundwater seepage, intense kaolinisation (weathering), fault breccias and fault gouge that typically contains a variable Fe-oxide content, resulting in red/brown staining (Fig. 5.10a). The lineation on the slickensides is predominantly orientated down-dip, although, in recent mapping, sinistral normal faults have been identified. Slickenlines with a plunge of between 45 - 50° to the east have been encountered. This conforms to some major sinistral normal faults observed at the eastern margin of the Mwombezhi Dome.

Minor faults have been interpreted as splay faults of the major faults and appear to be closely related to the joint network. The faults which appear to have preferentially exploited the east-west trending joints that dip NNE (~009°) at ~76°, trend more in the west-northwest direction. Some of the joints with high persistence have been crosscut by the major faults, implying that the joints formed earlier than the faults. These faults also steeply dip to the north near the surface, although down-dip fault stepping generally causes fault planes to have slightly shallower overall dipping geometries. Minor faults also attenuate down-dip within the schistose fabric.

The joints show persistence in all rock types but may locally slightly deflect depending on the lithological competence of the host rock (Koegelenberg *et al.*, 2019). The joints also tend to show high joint densities when they occur in proximity to major faults.

In day-to-day mining activities at Lumwana, the exposed minor faults are consistently monitored for geotechnical reasons. The minor faults tend to interact with C1 and C3 shear planes whose dip direction is generally to the south as depicted in the stereonet plots in Fig. 5.3. These interactions form wedges, which have previously caused wall failures which are a danger to humans and equipment. Therefore, consistent pit mapping has helped to identify potential wedges and how to mitigate wall failure. The details of such mitigating interventions are beyond the scope of this report.

Also, minor faults and joints have proved to be crucial to the mine operations as far as fragmentation of the ore bearing rocks is concerned. Poorly fragmented ore rocks are not immediately available for crushing and milling to enable the extraction of the ore minerals. This impacts the business negatively as production targets are not achieved, thereby causing a deviation from the plans. It, therefore, remains crucial for the drill and blast crew to understand the drilling and blasting parameters that apply to areas of specific joint spacing and the occurrence of minor faults.

Chapter 6

STRUCTURAL CONTROLS ON MINERALISATION

6.1 Discussion

6.1.1 Introduction

The Cu mineralisation at the Chimiwungo deposit is strongly associated with both the Roan and Equinox shoots, which are first-order structures. To help visualise the relationship between the Ore Shoots and the distribution of the Cu mineralisation, an image of the regularised grade control (GC) block model was draped on the surface (triangulation) of the modelled ore domain (Fig. 6.1). The Chimiwungo GC block model, which is a product of the Lumwana Resource Modelling team, is defined by 6.25 m x 6.25 m x 12 m block sizes. To regularise the GC block model across the deposit, Vulcan™ 3D software was used to adjust the z value upwards from the 12 m mining bench to 704 m. The 704 m z value represents the difference between the lowest part of the deposit located at 708 m RL and the highest point at 1412 m RL. This enabled the GC block model now at 6.25 m x 6.25 m x 704 m block sizes to display the Cu% values across the deposit over the 704 m z value. This regularised model was then exported and viewed in Leapfrog Geo™ where an image was extracted, georeferenced and draped on the modelled ore package triangulation (Fig. 6.1).

Superimposing this image on the modelled ore package triangulation shows that the higher copper grades are aligned predominantly and consistently along the eastern flanks of both shoots (Fig. 6.1). The major copper accumulations are associated with copper grades which are $\geq 0.7\%$ Cu. On the eastern flank of the Roan Shoot, the high copper lodes are narrower than the lodes observed on the eastern flank of the Equinox Shoot. On average, the thickness of the high copper grade zones along both shoots averages around 35 m. On the western flank, the Roan Shoot is bordered by a sparsely defined linear trend of high grade ($\geq 0.7\%$) Cu accumulations. This trend is partly replicated on the western boarder of the Equinox Shoot, which is mainly characterised by Cu grades ranging between 0.3 and 0.4% (Fig. 6.1).

The observed relatively low Cu grades associated with the axial traces of the Ore Shoots casts a doubt on earlier suggestions that the Ore Shoots are zones of high copper grade mineralisation (Richards, 2012). On the contrary, the internal waste modelling results show that the Ore Shoots are 'littered' with barren gneiss and amphibolite boudins of various sizes which are agents of ore dilution from the mining perspective. The observed relatively low Cu grade associated with the shoots shown in Fig. 6.1 is further corroborated by field mapping. The Ore Schist along the Roan Shoot does not show much copper enrichment and appears to be highly strained when compared to the same unit distal to the Roan Shoot. High strain and D3 mylonitisation of the schistose fabric appears to have been concentrated by the presence of highly competent massive amphibolitic and gneissic boudins occurring in the shoot. The highly strained and partly mylonitised Ore Schist did not undergo further fabric development during the post mineralisation D3 events. Instead, the Ore Schist fabric appears to have been sandwiched between various layers of highly competent lithological units. Consequently, the S3 foliation fabric in the shoots is generally dominated by the S and C fabrics, with minimal C-S fabric. Furthermore, it is possible that the pre-mineralisation fabric in the shoots may have been partly mylonitic in texture (section 4.2.4), which

then underwent metasomatism at the mineralisation stage. This implies that at the time of mineralisation, the preexisting fabric was not too developed in terms of foliation planes, with minimal available planes for copper-sulphide deposition. Finally, the presence of multiple unmineralised gneissic boudins in the shoots has led to a reduction in the volume of the mineralised shear zones, despite the overall ore domain being thick in the shoots.

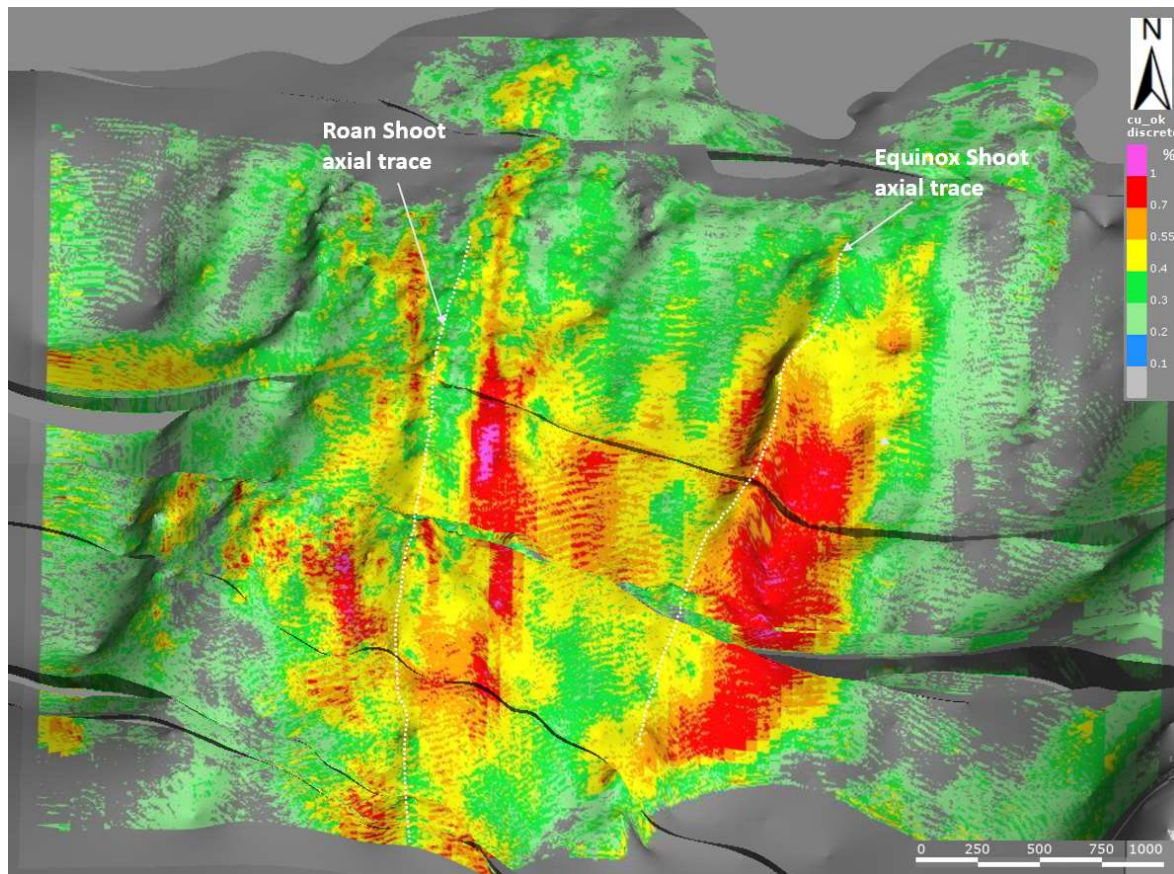


Figure 6.1. An image of the regularised grade control block model superimposed on the ore package Leapfrog Geo™ triangulation. The image depicts the distribution of the copper grades in relation to the major structural features of the ore domain.

Several factors have been closely associated with the observed occurrence of copper-sulphide concentrations along the flanks of the shoots. The discussion below will focus on factors that appear related to the copper distribution in the Chimiwungo deposit.

6.1.2 Fabric

The degree of fabric development at the Chimiwungo main shear zone has played a crucial role in the development of the copper-sulphide lodes. From the mapping point of view, the occurrence of a wide zone characterised by S2 phyllonitic fabric along the eastern flank of the Roan Shoot, in the hangingwall domain, appears to have been replicated down stratigraphy into the ore package. Along the eastern flanks of the Roan Shoot, the S2 schistosity in the hangingwall domain is very well-developed with

minimal Pink Hangingwall Gneiss boudins occurring. This is in contrast with the observed trends in the central region and western flanks of the Roan Shoot, where the S1 gneissic fabric appears to be more preserved and continuous.

Down stratigraphy in the Ore domain, the trend appears to be replicated. Along the eastern flanks of the Roan Shoot, the shallow southeasterly-dipping S3 fabric is highly developed, with minimal intervening internal gneissic units. The S3 schistose fabric is characterised by a well-developed shear zone fabric which includes S-C and S-C' fabrics (Fig. 5.4). Field mapping in these high copper grade zones shows a strong presence of copper-sulphide mineralisation in all the fabric planes. The copper-sulphide mineralisation which occurs in the form of chalcopyrite and bornite is well disseminated within the 'S' fabrics of the schistose fabric. In the much wider and more fissile C planes, mineralisation tends to occur as sub-continuous massive accumulation along the planes. Similar forms of metal sulphide occurrences have been observed in the S-C and S-C' planes which acted more or less like 'dilatational sites' during metal sulphide deposition. The occurrence of an abundance of these planes translated to an enhancement in the metal sulphide content deposited along these deposition sites.

The preferential occurrence of copper-sulphide mineralisation along these fabrics may have been promoted by the relative ease with which the mineralising hydrothermal fluids flowed in these planes. The availability of these planes played a role in facilitating the deposition of metal sulphides, through a reduction in the fluid pressure, hence enhancing the precipitation of the sulphides.

6.1.3 Remobilisation

Remobilisation of metal sulphides has played a key role in the enrichment of sulphide mineralisation on the flanks of the shoots. Remobilisation has been defined as the translocation which results in redistribution and modification in the concentration of pre-existing metalliferous concentrations (Marshall and Gilligan, 1987). The process can either proceed by chemical (liquid-state), mechanical (solid-state) and/or a combination of these processes. Liquid-state remobilisation is said to be facilitated by fluids whose source can be from metamorphic processes. These processes can involve the dissolution of minerals such as quartz, calcite and silicate which are later precipitated in tension gashes, faults, and shear zones. Metamorphism tends to promote chemical redistribution of different chemical components along their local chemical gradients (Plimer, 1987). This can result in the migration of respective chemical components across various types of boundaries, for meta-hydrothermal redistribution into veins. Similar veinlets have been observed to be closely associated with the rich copper-sulphide lodes of the Chimiwungo deposit (Fig. 6.2d). The quartz veinlets that are concordant to S3 foliation have been observed to be rich in chalcopyrite. The presence of these quartz veinlets in such a high-grade metamorphic terrain, signify liquid-state remobilisation, and limited mechanical remobilisation. Through lubrication of the S3 foliation surfaces, the meta-hydrothermal fluids facilitated the ductile flow of the copper-sulphides from their original deposition site to the highly developed fabric of the shear zone (Fig. 6.3). Remobilisation of sulphides in the Chimiwungo main shear zone may have been a long and continuous process that occurred during the retrograde clockwise P-T path. The process may have been initiated during the Lufilian syn-orogenic exhumation (D2), then continued during post-

orogenic crustal collapse (D3) (*ca.* 510–500 Ma) having been facilitated by pervasive ductile deformation (Turlin *et al.*, 2016). According to Turlin *et al.* (2016), the textural studies of the kyanite porphyroblasts in the Ore Schist led to an understanding that some Cu was present in the sedimentary protolith of the Ore Schist prior to metamorphism. This led them to suggest that part of the syn-metamorphic Cu deposition occurred by remobilisation of the pre-existing sediment-hosted sulphides. The process was propagated by the circulation of highly saline metamorphic fluids during the Pan-African orogeny. This in-situ remobilisation of Cu sulphides during metamorphism is thought to have occurred with no addition of new Cu sulphide stocks (Benham *et al.*, 1976; Bernau, 2007; Bernau *et al.*, 2013)

A final and late D3 remobilisation of sulphides is thought to have occurred during the final stage of the retrograde clockwise P-T path, during localised deformation in shallow-dipping shear zones. Accordingly, this last remobilisation of sulphides took place during post-orogenic crustal collapse and is thought to be younger than *ca.* 500 Ma (Turlin *et al.*, 2016). This remobilisation could conceivably be orebody-wide but has been observed to be structurally controlled and therefore site-specific.

At Chimiwungo, mesoscale textural evidence establishes both deformation throughout the orebody and support for local remobilisation. Mesoscale textures are readily observable in both diamond drill core, and in the pit walls. Overwhelming mesotexture evidence of post-mineralisation deformation is registered in the form of S3 drag folds, both discordant and concordant to S3 foliation quartz-sulphide veins, pressure shadows and L3 stretch lineations. Centimetre-scale folding is one of the most noticeable features of deformation associated with the sulphide-rich shear zone (Fig. 6.2c). The folds are closely associated with shearing and have axial planar orientations which occur in near parallelism to the schistosity. The drag folds are known to be associated with mineral remobilisation. The fold hinges in these intrafolial folds tend to trap remobilised sulphides during post- or syn-mineralisation shearing.

Other features characteristic of deformation in these retrograde shear zones includes the development of polished and flattened sulphide minerals on the slickensides (Fig. 6.2b). The morphological orientation of the flattened chalcopyrite is systematically related to the orientation of the micas in the Ore Schist. The L3 stretching lineation is closely associated with C3 shear planes and appears to occur subparallel to the stretch direction of both micas and sulphides. These features suggest the occurrence of post-mineralisation shear deformation, which was responsible for the remobilisation of the sulphides in the schist. Furthermore, evidence for copper remobilisation is the occurrence of late undeformed quartz-calcite-chalcopyrite $\pm$ bornite and quartz-chalcopyrite veins that occur across the stratigraphy (Fig. 3.6c and d) (section 3.3.1).

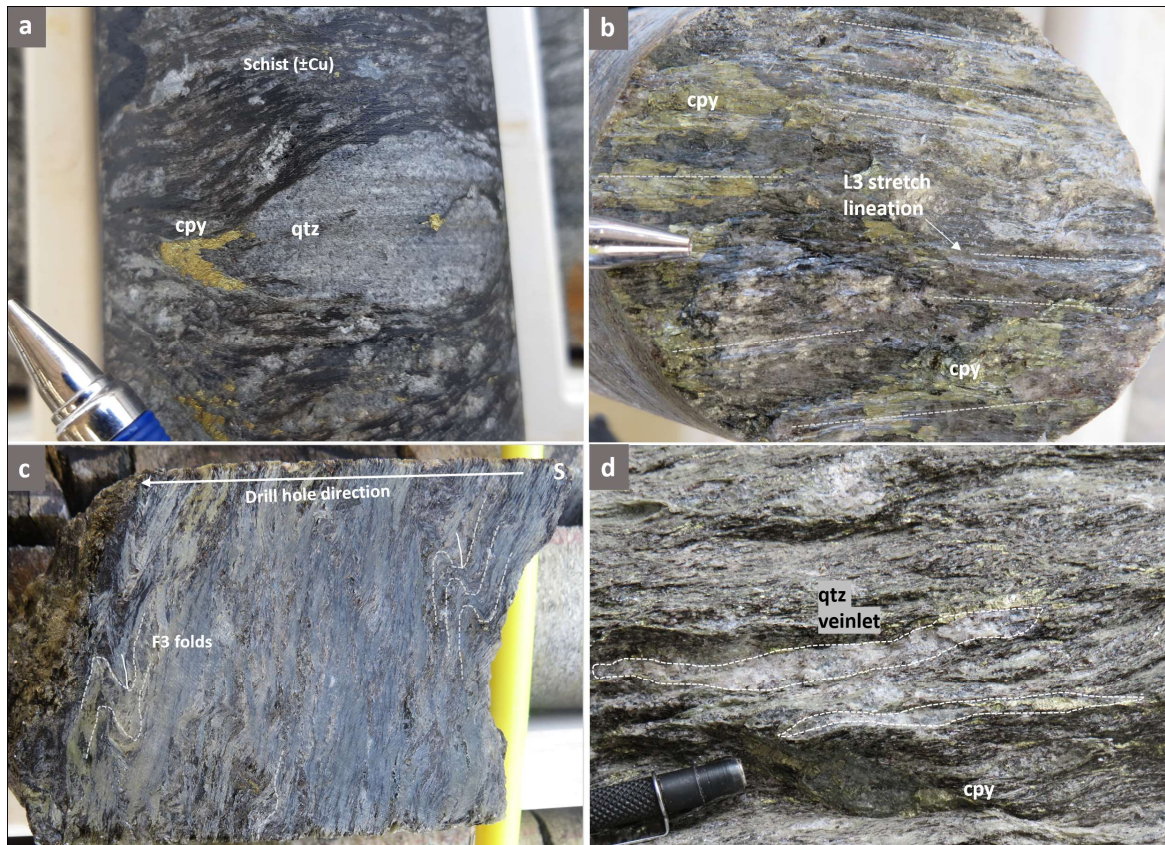


Figure 6.2. Remobilisation of sulphide mineralisation in the Ore Schist. (a) Accumulation of chalcopyrite in the pressure shadow of a boudinaged quartz porphyroblast (b) A polished slickenside with L3 lineation and elongated chalcopyrite grains occurring parallel to the S3 fabric foliation. (c) F3 drag folds in the Ore Schist, showing the folded mica-sulphide assemblage. (d) Quartz-sulphide veinlets in the Ore package. The veins occur concordant to S3 foliation.

Quartz veins within the ore and internal gneiss units locally host massive accumulations of the Cu sulphide assemblage. Vein-hosted sulphide mineralisation is the result of metamorphic fluids remobilising the sulphide phases. The remobilised sulphides were then deposited in the fractures that were developed during D3 deformation, thereby forming vein mineralisation. Conceivably, much of the remobilised sulphide in the vicinity of prograde metamorphosed sulphide enrichment could have been derived from disseminated source material or massive sulphide mineralisation (Marshall and Gilligan, 1987).

6.1.4 Development of Boudinage

Boudinage development which is evidently a result of structural extension contributed to the deposit-wide distribution of the copper-sulphide mineralisation at Chimiwungo. The section will discuss the distribution of copper-sulphide mineralisation during boudin development in the shear zone.

The successful development of boudins at Chimiwungo was largely dependent on the lithological contrast between the dominant lithotypes of the deposit. Of the main lithotypes in the shear zone, the

amphibolites and the leucosomes appeared to be the most competent units when compared to the remnants of the Grey Gneiss unit (Appendix A1). During post-mineralisation shear deformation, the Ore Schist surrounding these competent amphibolites and leucosome experienced higher compressional stresses. This process literally ‘squeezed’ the primary mineralisation from the mineralised schist between the competent units, remobilising it laterally and concentrating it on the flanks of the shoots (Fig. 6.3). Given that fluid flow must be focused through primary mineralisation to promote remobilisation, anastomosing S3 mylonitic zones could have played an important role in focusing the fluids. These anastomosing S3 mylonitic zones occur between various boudins which are also impermeable, although traces of remobilised sulphide mineralisation have been noted in the boudins.

The presence of pressure shadows around quartz and kyanite porphyroblasts in the Ore Schist further reinforces the concept of remobilisation which may have occurred concurrently with boudin formation (Fig. 6.2a). Chalcopyrite mineralisation in the pressure shadow of the quartz boudin-shaped porphyroblast in Fig. 6.2a represents the accumulation of mineralisation in less strained (low pressure) zones of the shear zone. The observed chalcopyrite grain in the centre of the porphyroblast in Fig. 6.2a suggests partial deformation suffered by the quartz porphyroblast, which was followed by deposition of chalcopyrite in the fracture. This observed pattern of mineralisation in Fig. 6.2a appears to have been replicated on the deposit scale. Concentrations of copper-sulphide lodes appear to be closely associated with both pressure shadows of boudins occurring within the ore package and along the interboudin necks. This has been further amplified by the observed spatial relationship between the modelled internal units and the 6.25 m x 6.25 m x 4 m grade control (GC) block model provided by the Lumwana Resource Modelling team. When viewed in Leapfrog Geo™, the high-grade Cu zones in the GC block model are closely associated with either the pressure shadows or the interboudin necks (Fig. 6.3).

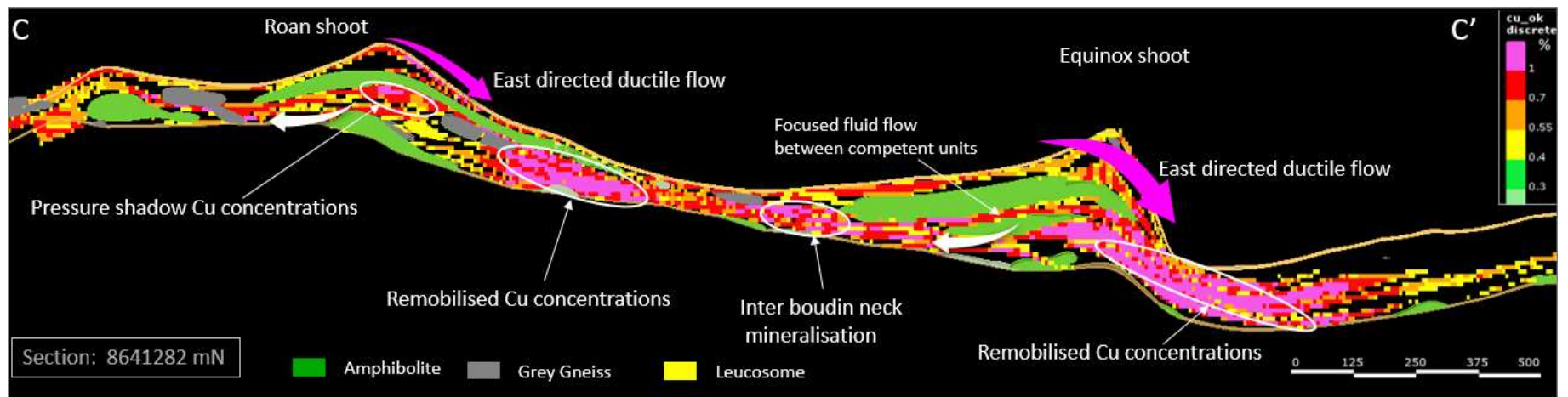


Figure 6.3. Cross section through the ore package of the Chimiwungo deposit showing the modelled internal units and how they interact with the grade control block model. The location of the cross section is shown in figure 5.6.

Chapter 7

CONCLUSIONS

7.1 Conclusions

The Chimiwungo Cu-(U) deposit is hosted in Paleoproterozoic rocks which were deformed during the Neoproterozoic Pan-African orogenic events. The basement rocks underwent three Lufilian deformation phases (D1-D3), with each deformation event producing structures and fabric specific to the prevailing deformation conditions. Overall, the amphibolite facies metamorphic events produced mylonites, intrafolial drag folds, anatexis, shear deformation and post-mineralisation faulting. Kinematic indicators suggest that the closing deformation event of the Lufilian orogeny was characterised by a top-to-the-north-northeast sense of shear movement. The D3 shear deformation event is represented by a well-developed schistose fabric, characterised by multiple S3 foliation planes. At the Chimiwungo deposit, copper-sulphide mineralisation occurred during the D3 deformation event. The copper-sulphide mineralisation is disseminated within the highly developed S3 schistose fabric, which played a role in the precipitation of the metal sulphides. The lithological competence contrast associated with the pre-deformation basement units played a critical role in the final architecture of the resultant shear zone. The final distribution of the copper-sulphide mineralisation in the shear zone, was largely influenced by the geometry of the shear zone.

Following an extensive mapping of the Chimiwungo deposit pits, the following conclusions have been drawn regarding the structural controls on the mineralisation.

- The Chimiwungo Cu-sulphide deposit is hosted in a shear zone, which is bound by basement gneisses of various protoliths. The shear zone, locally referred to as the 'Ore Schist', is host to basement quartz-feldspar-biotite $\pm$ amphibole grey gneisses, amphibolites, leucosomes, mylonites and pegmatites. The amphibolites occur as major constituents of two north-south linear trending 'ridges', locally referred to as the Roan (on the west) and Equinox (on the east) shoots. Although aligned with specific aspects of the two shoots, the barren units mainly occur randomly in the form of boudins which vary in size. The leucosomes are dominantly located in the inter-shoots' region, while the Grey Gneisses and the less abundant pegmatites occur mainly along the flanks of the shoots. Pegmatites are not common but are locally associated with amphibolites.
- Both the Equinox and Roan shoots are characterised by massive, partly deformed and boudinaged amphibolites which characterise the geometry of these ridges. The amphibolites which occur across the entire tectonostratigraphy were only deformed around their margins, leaving a massively textured core. The other less competent gneissic units underwent shear deformation, with mylonites being developed during the shearing process.
- The control on the mineralisation at Chimiwungo is largely driven by: a) the degree of development of the schistose fabric in the shear zone, b) remobilisation of the earlier disseminated copper-sulphide stocks and c) boudinage development.

- The degree of fabric development in the shear zone varies from place to place and is associated with the shoots. Within the shoots (ridges), the schistose fabric is not fully developed and is mylonitic in places, when compared to the schistose fabric in the inter-shoot region. The highly developed schistose fabric, which is also associated with high copper mineralisation, hosts copper-sulphide mineralisation along the multiple foliation planes.

The D3 north-northeast directed gravitational crustal collapse facilitated the focusing and remobilisation of much of the copper into the north-south linear trending shoots parallel to both the Roan and Equinox shoots. The competent amphibolites and the mylonitic fabric associated with the shoots assisted in focusing the fluids during the post mineralisation remobilisation of the pre-existing disseminated sulphides. The remobilised sulphides accumulated in the pressure shadows, while some of the remobilised mineralisation was redeposited in veins of both the barren internal units and the hangingwall units. The occurrence of the highest copper grades in specific structural sites such as low-strain domains, suggests a syn-to-post tectonic timing of copper mineralisation which was accompanied by the alteration of the shear zone to muscovite-biotite/phlogopite-quartz $\pm$ kyanite schist.

Boudinage development assisted in producing linear high-grade shoots that are localised along inter-boudin necks. The inter-boudin necks played a similar role to pressure shadows and provided favourable deposition sites for the remobilised copper-sulphides.

7.2 Future exploration opportunities

Regional future exploration programs around the Domes Region remain viable. The development of the Domes through exhumation was accompanied by shearing either within the basement units of the Dome or along the decollement. It, therefore, remains an open possibility for mineralisation to occur in the other shear zones associated with the pre-Katangan Domes.

- The lithological diversity of the basement units and the associated structures can play a crucial role in the discovery of deposits in the shear zones. Geophysical methods would help identify the areas with diverse lithological assemblages, especially shear zones dominated by amphibolitic units. Amphibolites provide both gravity and magnetic contrasts when carrying out geophysical investigations.
- Remobilisation of sulphides in a shear zone remains another key aspect of discovering shear zone hosted sulphide mineralisation. The enrichment of sulphide in linear zones could be associated with the remobilisation of Cu-sulphides over a wider zone of mineralisation.
- Late normal faults which have displaced mineralisation in the order of hundreds of metres have been associated with the Domes. Understanding this aspect of the distribution of mineralisation can be useful in future target generation.

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APPENDICES

Appendix A. Field mapping data

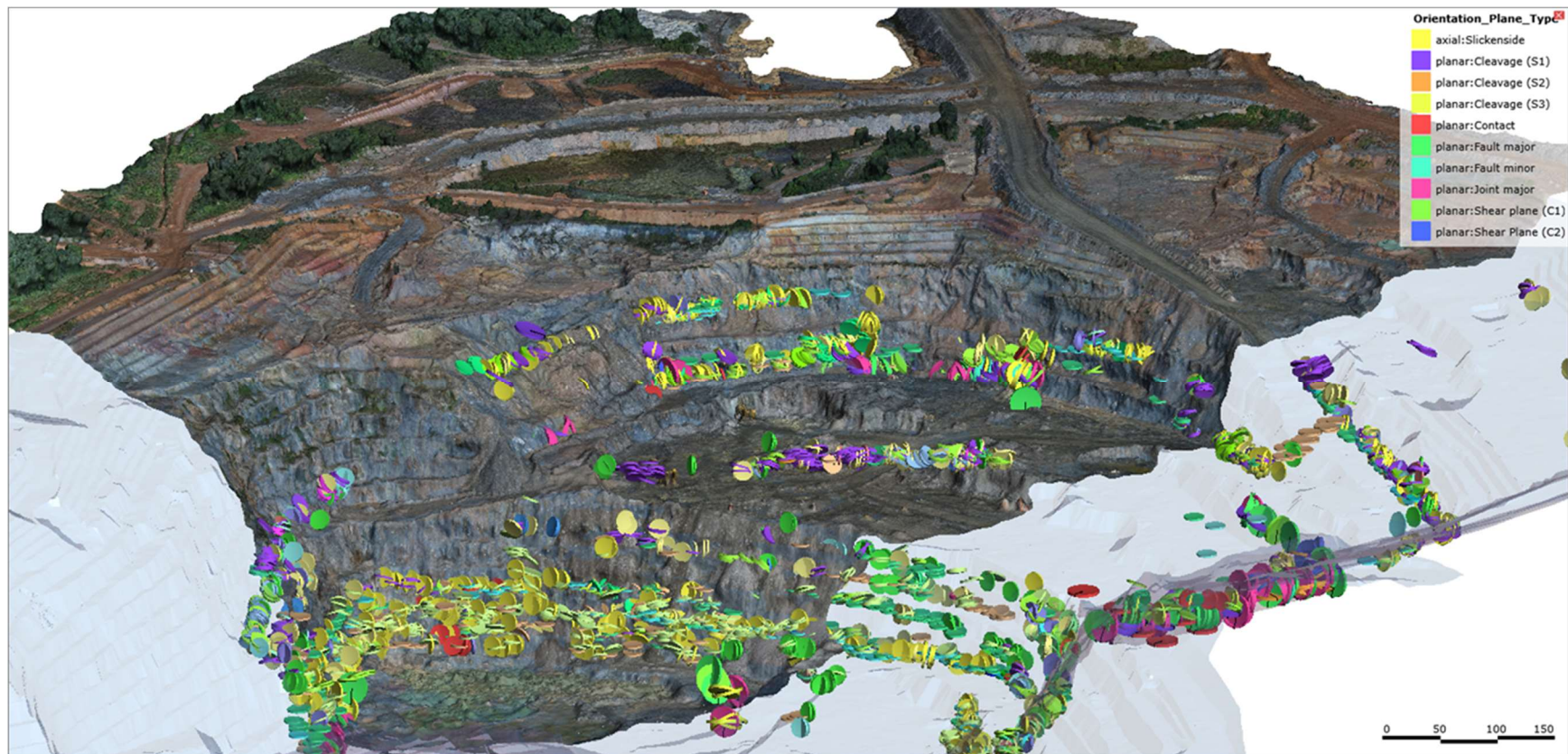


Figure A.1. An image of part of the Chimiwungo Main Pit captured using a Parrot PF728000 ANAFI Drone. Structural measurements are displayed in the form of structural discs of different colours. These data were all processed using Leapfrog GeoTM.

Table A-1. Raw pit mapping data as collected in the CSV file using the Rocklogger™ mobile application installed on a mobile device

TEMP_ID	Altitude (m)	GPS Accuracy (m)	Dip Angle (deg)	Dip Direction (deg)	Dip Angle (strike mode)	Strike (deg)	Compass Accuracy (0-3)	Orientation & Plane Type	Lith local zone (dropdown)	Lith Name (dropdown)	Protocolh (dropdown)	Strain (dropdown)	Cu Mineralisation (dropdown)	Logger	UTM_X	UTM_Y
1	1316	2	37.3	117.2 37.3°E		27.2		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377658.2261	8641459.553
2	1316	3	46.1	117.9 46.1°E		27.9		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377658.1183	8641459.331
3	1316	3	42.7	141 42.7°S		51		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377653.8692	8641461.083
4	1315	4	28.1	123.5 28.1°E		33.5		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377650.586	8641465.936
5	1315	3	39.4	142.7 39.4°S		52.7		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377650.3685	8641465.935
6	1313	3	38.1	168.7 38.1°S		78.7		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377650.3584	8641468.368
7	1313	3	33.8	134.5 33.8°E		44.5		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377649.4786	8641470.687
8	1314	3	21	90.7 21.0°E		0.7		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377646.9706	8641472.225
9	1313	2	56.8	69.6 56.8°E		339.6		3 planar: Shear Plane (C2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377645.0004	8641475.203
10	1312	3	45.3	63 45.3°E		333		3 planar: Shear Plane (C2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377643.9073	8641476.526
11	1312	3	44.4	67.8 44.4°E		337.8		3 planar: Shear Plane (C2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377642.927	8641476.853
12	1313	3	33.8	135.3 33.8°S		45.3		3 planar: Shear Plane (C2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377639.2213	8641478.718
13	1313	3	85.5	7 85.5°N		277		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377639.3305	8641478.608
14	1313	3	80.4	1.2 80.4°N		271.2		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377638.895	8641478.717
15	1313	3	44.4	135.7 44.4°S		45.7		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377638.895	8641478.717
16	1313	3	37.9	118.4 37.9°E		28.4		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377637.6843	8641482.14
17	1313	2	43.1	125.3 43.1°E		35.3		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377637.6843	8641482.14
18	1313	3	46.9	115.5 46.9°E		25.5		3 planar: Cleavage (S2)	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377634.3021	8641484.67
19	1313	3	50	100.7 50.0°E		10.7		3 planar: Cleavage (S2)	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377634.4109	8641484.67
20	1313	4	36.7	136.1 36.7°S		46.1		3 planar: Cleavage (S2)	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377632.1213	8641485.988
21	1313	3	0	0		0	0	0 axial: Point	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377629.0631	8641489.072
22	1314	3	0	0		0	0	0 axial: Point	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377623.6098	8641492.699
23	1312	3	0	0		0	0	0 axial: Point	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377625.4666	8641490.827
24	1312	4	42.7	140.9 42.7°S		50.9		3 planar: Cleavage (S2)	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377622.5236	8641492.363
25	1313	3	33.2	150.1 33.2°S		60.1		3 planar: Cleavage (S2)	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377622.6323	8641492.363
26	1313	5	37.7	142.5 37.7°S		52.5		3 planar: Cleavage (S2)	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377622.1977	8641492.251
27	1312	3	30.6	129.5 30.6°E		39.5		3 planar: Cleavage (S2)	CHWS	Tssq	Grey Gneiss	High	N/A	LM	377622.3074	8641492.03
28	1312.7484	3	32.8	49.6 32.8°E		319.6		3 planar: Contact	CHWGN	Tgqfb	granitic	medium	N/A	LM	377621.3119	8641496.008
29	1312.1212	3	41.2	17.1 41.2°N		287.1		3 planar: Contact	CHWGN	Tgqfb	granitic	medium	N/A	LM	377614.8779	8641500.073
30	1311.5838	3	54.2	53.7 54.2°E		323.7		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377608.2204	8641505.575
31	1309	3	0	0		0	0	0 planar: Contact	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377608.4564	8641505.356
32	1309	3	0	0		0	0	0 planar: Contact	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377609.2043	8641504.363
33	1310.7516	2	42.6	50.6 42.6°E		320.6		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377607.0152	8641507.672
34	1307	3	57.3	53.8 57.3°E		323.8		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377606.7977	8641507.671
35	1310.7516	3	59.4	49.3 59.4°E		319.3		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377606.7977	8641507.671
36	1310.0377	3	0	0		0	0	0 planar: Contact	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377601.1241	8641511.961
37	1309.6411	3	0	0		0	0	0 planar: Contact	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377597.6308	8641515.043
38	1309.3443	3	0	0		0	0	0 planar: Contact	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377589.0063	8641522.749
39	1308.8751	3	47.5	357.1 47.5°N		267.1		3 planar: Fault minor	CHWCPG	Tgqfb	granite	medium	N/A	LM	377579.7385	8641528.24
40	1308.8751	4	44.2	357.7 44.2°N		267.7		3 planar: Fault minor	CHWCPG	Tgqfb	granite	medium	N/A	LM	377579.9574	8641527.909
41	1308.8751	3	36.7	3 36.7°N		273.7		3 planar: Fault minor	CHWCPG	Tgqfb	granite	medium	N/A	LM	377579.9523	8641529.126
42	1305	3	0	0		0	0	0 planar: Fault minor	CHWCPG	Tgqfb	granite	medium	N/A	LM	377572.7246	8641540.93
43	1307.5093	3	0	0		0	0	0 planar: Fault minor	CHWCPG	Tgqfb	granite	medium	N/A	LM	377572.6158	8641540.93
44	1307.4383	3	64.6	53.4 64.6°E		323.4		3 planar: Joint major	CBGA	Ttys	Basalt	low	pyr	LM	377565.7366	8641547.426
45	1307.4383	3	64	52.4 64.0°E		322.4		3 planar: Joint major	CBGA	Ttys	Basalt	low	pyr	LM	377565.8458	8641547.316
46	1307.4383	3	70.7	49.2 70.7°E		319.2		3 planar: Joint major	CBGA	Ttys	Basalt	low	pyr	LM	377565.4075	8641548.089
47	1306	3	66.3	62 66.3°E		332		3 planar: Joint major	CBGA	Ttys	Basalt	low	pyr	LM	377569.216	8641547.662
48	1307	3	70.8	55.6 70.8°E		325.6		3 planar: Joint major	CBGA	Ttys	Basalt	low	pyr	LM	377569.4368	8641546.889
49	1306	3	0	0		0	0	0 planar: Contact	CBGA	Ttys	Basalt	low	pyr	LM	377564.64	8641548.86
50	1306	3	0	0		0	0	0 planar: Contact	CBGA	Ttys	Basalt	low	pyr	LM	377555.7834	8641560.768
51	1306	3	0	0		0	0	0 planar: Contact	CBGA	Ttys	Basalt	low	pyr	LM	377552.3956	8641564.624
52	1306.1334	3	0	0		0	0	0 planar: Contact	CBGA	Ttys	Basalt	low	pyr	LM	377542.141	8641571.992
53	1305.2444	3	0	0		0	0	0 planar: Contact	CBGA	Ttys	Basalt	low	pyr	LM	377519.789	8641585.281
54	1310	3	76.6	22 76.6°N		292		3 planar: Fault minor	CBGA	Ttys	Basalt	low	pyr	LM	377528.401	8641580.561
55	1310	3	75.3	12 75.3°N		282		3 planar: Fault minor	CBGA	Ttys	Basalt	low	pyr	LM	377528.0766	8641580.118
56	1309	3	72.4	15.4 72.4°N		285.4		3 planar: Fault minor	CBGA	Ttys	Basalt	low	pyr	LM	377529.0601	8641579.016
57	1307	3	24.8	124 24.8°E		34		3 planar: Cleavage (S2)	CHWS	Ttys	Grey Gneiss	High	N/A	LM	377514.4403	8641589.904
58	1306	3	65.2	51.1 65.2°E		321.1		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377508.862	8641597.402
59	1305	3	61.7	51.9 61.7°E		321.9		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377508.9763	8641596.075
60	1305	3	83.5	61.8 83.5°N		276.1		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377504.5073	8641598.379
61	1305	4	71.7	66.6 71.7°E		336.6		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377504.3986	8641598.378
62	1307	2	29.3	142.1 29.3°S		52.1		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377497.953	8641605.209
63	1305	2	68.7	17.9 68.7°N		282		3 planar: Joint minor	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377492.8268	8641608.616
64	1305	4	72.5	36 72.5°N		296		3 planar: Joint minor	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377491.3023	8641609.052
65	1305	3	69.6	57.2 69.6°E		327.2		3 planar: Joint minor	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377490.1009	8641610.264
66	1304	2	69.2	60.1 69.2°E		330.1		3 planar: Joint minor	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377489.8778	8641611.59
67	1305	3	67.3	58.7 67.3°E		328.7		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377485.0756	8641615.551
68	1307	2	75.2	54.2 75.2°E		324.2		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377485.5176	8641613.894
69	1307	2	20.8	328.1 20.8°N		238.1		3 planar: Cleavage (S2)	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377484.9733	8641614.003
70	1303	2	73.4	61.9 73.4°E		331.9		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377481.0468	8641616.641
71	1303	3	73.6	47.9 73.6°E		317.9		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377480.9339	8641617.636
72	1303	3	69.2	50.7 69.2°E		320.7		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377480.0619	8641618.074
73	1304	3	69.3	79.8 69.3°E		349.8		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377475.8082	8641620.932
74	1304	3	70.2	66.8 70.2°E		336.8		3 planar: Joint major	CHWS	Tsbq	Grey Gneiss	High	N/A	LM	377475.6999	8641620.821
75	1306	3	65.6	70.2 65.6°E		340.2		3 planar: Joint minor	CHWS	Tsbqf	Grey Gneiss	High	N/A	LM	377473.1956	8641621.474
76	1305	4	72.2	55.3 72.2°E		325.3		3 planar: Joint minor	CHWS	Tsbqf	Grey Gneiss	High	N/A	LM	377472.649	8641622.136

77	1305	4	14.7	248.3 14.7°W		158.3	3 planar: Cleavage (S2)	CHWS	Ttsbqf	Grey Gneiss	High	N/A	LH	377473.5136	8641623.466
78	1305	3	0	0	0	0	0 axial: Point	CHWCPG	Ttqgfb	Grey Gneiss	High	N/A	LH	377470.5696	8641625.224
79	1306	3	0	0	0	0	0 axial: Point	CHWCPG	Ttqgfb	granite	medium	N/A	LH	377468.0565	8641627.978
80	1306	3	0	0	0	0	0 axial: Point	CHWCPG	Ttqgfb	granite	medium	N/A	LH	377465.2223	8641629.515
81	1307	3	5.5	323.4 5.5°N		233.4	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377463.8037	8641630.615
82	1307	3	74.3	20.8 74.3°N		290.8	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377463.3659	8641631.277
83	1307	2	6.2	52 6.2°E		222	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377460.8542	8641633.699
84	1306	3	13.1	288.1 13.1°W		198.1	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377456.8069	8641639.213
85	1307	2	21.7	296.4 21.7°W		206.4	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377455.7128	8641640.756
86	1309	2	72.9	348.2 72.9°N		258.2	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377457.2452	8641638.44
87	1312	2	30.1	4.6 30.1°N		274.6	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377454.0624	8641645.284
88	1312	2	64.6	72.4 64.6°E		342.4	3 planar: Fault minor	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377452.6466	8641645.721
89	1311	2	61	74.2 61.0°E		344.2	3 planar: Fault minor	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377451.988	8641647.156
90	1310	2	27.6	265.5 27.6°W		175.5	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377451.7627	8641649.035
91	1310	3	8.2	301.1 8.2°W		211.1	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377450.1229	8641651.019
92	1312	3	21.7	250.8 21.7°W		160.8	3 planar: Shear Plane (C2)	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377443.4602	8641657.738
93	1308	2	87.1	314.1 87.1°W		224.1	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377432.7654	8641666.32
94	1308	3	77.3	349.3 77.3°N		259.3	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377432.7654	8641666.32
95	1311	2	80.7	29.1 80.7°N		299.1	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377424.5768	8641673.807
96	1311	2	78.5	16.8 78.5°N		286.8	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	High	N/A	LH	377424.2496	8641674.026
97	1309	3	30.9	238.5 30.9°W		148.5	3 planar: Cleavage (S1)	CHWGN	Ttqgfb	Granite	medium	N/A	LH	377420.3236	8641676.554
98	1306	2	0	0	0	0	0 axial: Point	CHWGN	Ttqgfb	Granite	medium	N/A	LH	377413.4517	8641681.281
99	1309	2	77.6	43.2 77.6°N		313.2	3 planar: Joint major	CHWGN	Ttqgfb	Granite	medium	N/A	LH	377403.7566	8641684.89
100	1309	3	72.7	57.6 72.7°E		327.6	3 planar: Joint major	CHWGN	Ttqgfb	Granite	medium	N/A	LH	377402.3339	8641686.986
101	1308	3	72.7	62 72.7°E		332	3 planar: Joint major	CHWGN	Ttqgfb	Granite	medium	N/A	LH	377400.8015	8641689.302
102	1308	3	51.2	101 51.2°E		11	3 planar: Cleavage (S2)	CHWS	Ttsbq	Grey Gneiss	high	N/A	LH	377397.9668	8641690.949
103	1308	2	69.7	48.4 69.7°E		318.4	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	high	N/A	LH	377394.1555	8641692.039
104	1309	3	77	22.7 77.0°N		292.7	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	high	N/A	LH	377390.6552	8641696.78
105	1309	3	75.1	46 75.1°E		316	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	high	N/A	LH	377387.2692	8641700.195
106	1311	3	71.2	52.9 71.2°E		322.9	3 planar: Joint major	CHWS	Ttsbq	Grey Gneiss	high	N/A	LH	377381.4798	8641706.143
107	1312	2	79.2	54.6 79.2°E		324.6	3 planar: Joint major	CHWCPG	Ttqgfb	Granite	medium	N/A	LH	377379.4036	8641708.457
108	1313	2	71.1	54.2 71.1°E		324.2	3 planar: Joint major	CHWCPG	Ttqgfb	Granite	medium	N/A	LH	377378.4187	8641709.891
109	1219	5	68.1	21.5 68.1°N		291.5	5 planar: Fault major	CBX	Ttsq	gneiss	medium	N/A	LH	377629.464	8641951.648
110	1219	5	56.6	21.3 56.6°N		291.3	3 planar: Fault major	CBX	Ttsq	gneiss	medium	N/A	LH	377629.683	8641951.317
111	1218	5	64.7	21.6 64.7°N		291.6	3 planar: Fault major	CBX	Ttsq	gneiss	medium	N/A	LH	377630.1162	8641951.762
112	1218	5	0	0	0	0	0 planar: Fault major	CBX	Ttsq	gneiss	medium	N/A	LH	377629.7954	8641950.433
113	1218	5	26.3	33 26.3°N		303	3 planar: Cleavage (S3)	COS	Ttsq	Schist	medium	Cpy	LH	377627.4142	8641987.658
114	1216	3	14.9	49.3 14.9°E		319.3	3 planar: Cleavage (S3)	COS	Ttsq	Schist	medium	Cpy	LH	377627.2022	8641986.33
115	1216	3	25.7	10.6 25.7°N		280.6	3 planar: Cleavage (S3)	COS	Ttsq	Schist	medium	Cpy	LH	377628.4004	8641985.893
116	1216	5	46.4	26.7 46.4°N		296.7	3 planar: Cleavage (S3)	COS	Ttsq	Schist	medium	Cpy	LH	377628.73	8641985.12
117	1215	3	15.5	312.9 15.5°W		222.9	3 planar: Cleavage (S3)	COS	Ttsq	Schist	medium	Cpy	LH	377629.0706	8641981.693
118	1216	5	26.3	341.8 26.3°N		251.8	3 planar: Cleavage (S3)	COS	Ttsq	Schist	medium	Cpy	LH	377632.4432	8641981.485
119	1216	5	27.6	10 27.6°N		280	3 planar: Cleavage (S3)	COS	Ttsq	Schist	medium	Cpy	LH	377632.3344	8641981.485
120	1216	5	0	0	0	0	0 planar: Contact	COS	Ttsq	gneiss	HIGH	Cpy	LH	377626.6538	8641987.434
121	1217.612	5	0	0	0	0	0 planar: Contact	COS	Ttsq	gneiss	HIGH	Cpy	LH	377630.6777	8641991.846
122	1217	4	0	0	0	0	0 planar: Contact	COS	Ttsq	gneiss	HIGH	Cpy	LH	377640.3962	8641978.311
123	1215	5	4.8	201.4 4.8°S		111.4	3 planar: Cleavage (S3)	COS	Ttsq	Schist	HIGH	Cpy	LH	377646.6387	8641968.051
124	1215	3	1.3	82.1 1.3°E		352.1	3 planar: Cleavage (S3)	COS	Ttsq	Schist	HIGH	Cpy	LH	377645.4423	8641968.046
125	1215	3	81.3	34.6 81.3°N		304.6	3 planar: Joint minor	COS	Ttsq	gneiss	HIGH	Cpy	LH	377648.4366	8641969.826
126	1213	3	6.4	149.4 6.4°S		59.4	3 planar: Cleavage (S3)	COS	Ttsq	Schist	HIGH	Cpy	LH	377652.341	8641956.904
127	1213.058	3	17.3	108.4 17.3°E		18.4	3 planar: Cleavage (S3)	COS	Ttsq	Schist	HIGH	Cpy	LH	377655.2795	8641956.474
128	1212	3	16.1	20.9 16.1°N		290.9	3 planar: Cleavage (S3)	COS	Ttsq	Schist	HIGH	Cpy	LH	377661.7209	8641950.639
129	1213	3	0	0	0	0	0 planar: Boudin toe contact	CBG	Ttqgfb	gneiss	LOW	N/A	LH	377662.1578	8641950.199
130	1212.9043	3	0	0	0	0	0 axial: Boudin maximum thickness point	CBG	Ttqgfb	gneiss	LOW	N/A	LH	377669.4773	8641942.487
131	1212	5	0	0	0	0	0 axial: Point	CBG	Ttqgfb	gneiss	LOW	N/A	LH	377670.4376	8641946.915
132	1211	2	0	0	0	0	0 axial: Boudin maximum thickness point	CBG	Ttqgfb	gneiss	LOW	N/A	LH	377673.4941	8641944.274
133	1211	3	0	0	0	0	0 planar: Boudin	CBG	Ttqgfb	gneiss	LOW	N/A	LH	377686.1272	8641940.345
134	1212	4	0	0	0	0	0 planar: Contact	CBG	Ttqgfb	gneiss	LOW	N/A	LH	377687.548	8641938.692
135	1212	3	0	0	0	0	0 planar: Contact	CBG	Ttqgfb	gneiss	LOW	N/A	LH	377684.6338	8641932.748
136	1212.4547	3	80.9	18.2 80.9°N		288.2	3 planar: Joint major	CBGA	Ttyabag	gneiss	LOW	Cpy	LH	377702.1688	8641927.582
137	1212.4547	3	79.8	4.4 79.8°N		274.4	3 planar: Joint major	CBGA	Ttyabag	gneiss	LOW	Cpy	LH	377701.8421	8641927.691
138	1214.073	3	77.5	12.2 77.5°N		282.2	3 planar: Joint major	CBGA	Ttyabag	gneiss	LOW	Cpy	LH	377705.8797	8641924.501
139	1214.073	3	80.9	22.1 80.9°N		292.1	3 planar: Joint major	CBGA	Ttyabag	gneiss	LOW	Cpy	LH	377706.2134	8641922.513
140	1208.0022	3	0	0	0	0	0 axial: Point	CBGA	Ttyabag	gneiss	LOW	Cpy	LH	377724.2615	8641924.356
141	1207	4	0	0	0	0	0 planar: Contact	COS	Ttyabag	gneiss	LOW	Cpy	LH	377731.6901	8641916.534
142	1207.1421	3	0	0	0	0	0 planar: Contact	COS	Ttyabag	gneiss	LOW	Cpy	LH	377737.896	8641915.012
143	1205	5	39.3	94.1 39.3°E		4.1	3 planar: Cleavage (S3)	COS	Ttyabag	Schist	LOW	Cpy	LH	377737.9048	8641912.911
144	1207.2553	5	37.6	93.8 37.6°E		3.8	3 planar: Cleavage (S3)	COS	Ttyabag	Schist	High	Cpy	LH	377737.9048	8641912.911
145	1206	3	14.3	281.6 14.3°W		191.6	3 planar: Cleavage (S3)	COS	Ttyabag	Schist	High	Cpy	LH	377744.332	8641910.504
146	1207	3	8.8	53.9 8.8°E		323.9	3 planar: Cleavage (S3)	COS	Ttsq	Schist	High	Cpy	LH	377745.9666	8641909.737
147	1206	3	24.1	44 24.1°N		314	3 planar: Cleavage (S3)	COS	Ttsq	Schist	High	Cpy	LH	377749.8881	8641908.315
148	1208.5758	3	22.6	3.3 22.6°N		273.3	3 planar: Point	COS	Ttsq	gneiss	High	Cpy	LH	377647.4529	8642059.522
149	1210	3	62	63.8 62.0°E		331.8	3 planar: Joint minor	COS	Ttsq	gneiss	High	Cpy	LH	377659.3148	8642031.922
150	1212.911	3	65.1	64.7 65.1°E		334.7	3 planar: Joint minor	COS	Ttsq	gneiss	High	Cpy	LH	377659.2074	8642031.589
151	1211	3	59.7	56.7 59.7°E		326.7	3 planar: Joint minor	COS	Ttsq	gneiss	High	Cpy	LH	377658.1083	8642034.35
152	1213	3	75.8	2.1 75.8°N		272.1	3 planar: Joint minor	COS	Ttsq	gneiss	High	Cpy	LH	377656.0348	8642036
153	1214	3	21.7	250.4 21.7°W		160.4	3 planar: Cleavage (S3)	COS	Ttsq	Schist	High	Cpy & brn	LH	377655.8145	8642036.663

231	1209.8255	4	15.5	138.4 15.5°S	48.4	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377581.9154	8642230.239
232	1209.4207	4	89.8	17 89.8°N	287	3 planar: Fault minor	COS	Tssq	gneiss	High	Cpy	LH	377582.2348	8642231.899
233	1209.4207	4	88.3	90.7 88.3°E	0.7	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377582.2348	8642231.899
234	1209.5425	4	24.5	104.9 24.5°E	14.9	3 planar: Shear plane (C3)	COS	Tsbq	gneiss	High	Cpy	LH	377582.2348	8642231.899
235	1209.6031	4	0	0	0	0 planar: Contact	COS	Tsbq	gneiss	High	Cpy	LH	377582.2348	8642231.899
236	1209.6031	4	6.9	24.9 6.9°N	294.9	3 planar: Contact	COS	Tsbq	gneiss	High	Cpy	LH	377582.2348	8642231.899
237	1209.4207	4	0	0	0	0 planar: Contact	COS	Tsbq	gneiss	High	Cpy	LH	377582.2348	8642231.899
238	1209.6031	3	0	0	0	0 planar: Contact	COS	Tsbq	gneiss	High	Cpy	LH	377571.0686	8642239.05
239	1210.0395	3	0	0	0	0 planar: Contact	COS	Tsbq	gneiss	High	Cpy	LH	377574.1419	8642242.483
240	1210.0395	4	6.6	351.8 6.6°N	261.8	3 planar: Contact	COS	Tsbq	gneiss	High	Cpy	LH	377574.9083	8642241.049
241	1210.0395	5	77.7	18.3 77.7°N	288.3	3 planar: Joint major	COS	Tsbq	gneiss	High	Cpy	LH	377575.5595	8642241.604
242	1210.0395	5	85.1	327.9 85.1°N	237.9	3 planar: Joint minor	COS	Tsbq	gneiss	High	Cpy	LH	377573.3667	8642245.798
243	1210.0395	3	40.4	99.1 40.4°E	9.1	3 planar: Shear plane (C3)	COS	Tsbq	gneiss	High	Cpy	LH	377573.2588	8642245.355
244	1210.0395	5	80.8	12 80.8°N	282	3 planar: Joint minor	COS	Tsbq	gneiss	High	Cpy	LH	377573.0321	8642247.787
245	1212.0186	5	15.6	217.4 15.6°S	127.4	3 planar: Cleavage (S3)	COS	Tsbq	Schist	High	Cpy	LH	377570.5213	8642249.989
246	1212.0186	3	19.2	158.3 19.2°S	68.3	3 planar: Cleavage (S3)	CBS	Tsbq	Schist	High	N/A	LH	377571.9153	8642254.751
247	1212.0186	4	25.8	173.4 25.8°S	83.4	3 planar: Cleavage (S3)	CBS	Tssq	Schist	High	N/A	LH	377571.4724	8642256.629
248	1212.0186	4	0	0	0	0 planar: Contact	CBGA	Ttyag	Schist	High	N/A	LH	377570.5995	8642257.289
249	1211.3845	3	0	0	0	0 planar: Contact	COS	Tssq	gneiss	High	Cpy	LH	377570.1575	8642258.946
250	1211.4618	5	79.4	22.7 79.4°N	292.7	3 planar: Joint major	COS	Tssq	gneiss	High	Cpy	LH	377568.9519	8642261.153
251	1210.6897	4	0	0	0	0 axial: Point	CBGA	Ttyag	Schist	High	N/A	LH	377569.4948	8642261.377
252	1210.1814	4	25.6	74.5 25.6°E	344.5	3 planar: Cleavage (S3)	COS	Tsbq	Schist	High	Cpy	LH	377569.1523	8642265.246
253	1209.8529	4	0	0	0	0 planar: Points	COS	Tssq	gneiss	High	Cpy	LH	377575.7557	8642270.701
254	1209.9148	4	0	0	0	0 planar: Points	COS	Tssq	gneiss	High	Cpy	LH	377574.1918	8642230.538
255	1209.9148	4	0	0	0	0 planar: Points	COS	Tssq	gneiss	High	Cpy	LH	377574.7176	8642234.854
256	1210.8602	4	0	0	0	0 planar: Points	COS	Tssq	gneiss	High	Cpy	LH	377573.9689	8642257.856
257	1211.0817	5	0	0	0	0 planar: Points	COS	Tssq	gneiss	High	Cpy	LH	377573.967	8642258.299
258	1210.1299	4	12.6	167.9 12.6°S	77.9	3 planar: Points	COS	Tssq	gneiss	High	Cpy	LH	377574.7067	8642263.5
259	1209	6	66.6	40.3 66.6°N	310.3	3 planar: Joint major	COS	Tssq	gneiss	High	Cpy	LH	377581.683	8642207.786
260	1209.7403	4	11.9	133.9 11.9°E	43.9	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377579.9178	8642213.751
261	1209.7642	4	21.7	84.3 21.7°E	354.3	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377580.2247	8642218.397
262	1209.8192	4	19.3	129.4 19.3°E	39.4	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377578.4623	8642223.699
263	1209.7971	4	32.6	152.5 32.6°S	62.5	3 planar: Shear plane (C3)	COS	Tssq	gneiss	High	Cpy	LH	377577.3696	8642224.911
264	1207	4	84	51.9 84.0°E	321.9	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377577.5746	8642227.898
265	1206	4	78.7	13.3 78.7°N	283.3	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377578.323	8642230.998
266	1206	4	88.6	13.9 88.6°N	283.9	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377578.323	8642230.998
267	1206	4	17.1	187.6 17.1°S	97.6	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377578.9756	8642231.001
268	1206	4	16.3	148.8 16.3°S	58.8	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377578.9756	8642231.001
269	1209.5425	4	27.3	100 27.3°E	10	3 planar: Shear plane (C3)	COS	Tssq	gneiss	High	Cpy	LH	377577.8829	8642232.213
270	1206	4	88.2	115.3 88.2°E	25.3	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377577.8806	8642232.766
271	1209.4164	4	4.8	222.4 4.8°S	132.4	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377576.6754	8642234.862
272	1207	4	13.9	103.6 13.9°E	13.6	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377577.3247	8642235.639
273	1209.5624	4	0	0	0	0 planar: Contact	CBG	Ttqgbag		Medium	Cpy	LH	377577.327	8642235.086
274	1209.5624	4	10.5	148.5 10.5°S	58.5	3 planar: Contact	CBG	Ttqgbag		Medium	Cpy	LH	377576.2311	8642237.072
275	1209.5624	4	0	0	0	0 planar: Contact	CBG	Ttqgbag		Medium	Cpy	LH	377575.7909	8642238.287
276	1209.5624	4	0	0	0	0 planar: Contact	CBG	Ttqgbag		Medium	N/A	LH	377575.4489	8642242.046
277	1209.5624	4	0	0	0	0 planar: Contact	CBG	Ttqgbag		Medium	N/A	LH	377575.3402	8642242.046
278	1209.5624	5	0	0	0	0 planar: Contact	CBG	Ttqgbag		Medium	N/A	LH	377575.0097	8642243.04
279	1209	3	83.8	35.1 83.8°N	305.1	3 planar: Joint major	COS	Tssq	gneiss	High	Cpy	LH	377575.4369	8642244.922
280	1210	3	82.8	37.1 82.8°N	307.1	3 planar: Joint major	COS	Tssq	gneiss	High	Cpy	LH	377574.8917	8642245.251
281	1210	4	9.8	223.3 9.8°S	133.3	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377574.4516	8642246.466
282	1210	4	14.3	179.1 14.3°S	89.1	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377574.8838	8642247.132
283	1210	4	14.1	179.1 14.1°S	89.1	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377574.8838	8642247.132
284	1210	4	18.1	215.1 18.1°S	125.1	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377574.8737	8642249.565
285	1210	4	16.6	201.9 16.6°S	111.9	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377574.9815	8642249.786
286	1210	4	7.9	225.8 7.9°W	135.8	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377574.7626	8642250.117
287	1210	4	76.5	24 76.5°N	294	3 planar: Joint minor	COS	Tssq	gneiss	High	Cpy	LH	377574.9709	8642252.33
288	1209	4	17.9	206 17.9°S	116	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377573.6532	8642255.311
289	1211.983	3	0	0	0	0 axial: Point	COS	Tssmq	gneiss	High	cpy traces	LH	377575.7202	8642255.209
290	1210.916	3	0	0	0	0 axial: Point	CBS	Tssmq	gneiss	High	N/A	LH	377577.5539	8642258.867
291	1212	4	0	0	0	0 axial: Point	CBS	Tssmq	gneiss	High	N/A	LH	377578.0751	8642264.288
292	1213	3	0	0	0	0 axial: Point	CBS	Tssmq	gneiss	High	N/A	LH	377578.0751	8642264.288
293	1213	3	15.1	174 15.1°S	84	3 planar: Cleavage (S3)	COS	Tssq	gneiss	High	N/A	LH	377576.7792	8642262.071
294	1212	3	14.1	136.8 24.1°S	46.8	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	N/A	LH	377576.8953	8642260.302
295	1210	4	32.8	222.5 22.8°S	132.5	3 planar: Cleavage (S3)	CBS	Tsbq	Schist	High	N/A	LH	377576.3529	8642259.968
296	1210	3	21.5	220.6 21.5°S	130.6	3 planar: Cleavage (S3)	CBS	Tsbq	Schist	High	N/A	LH	377576.3529	8642259.968
297	1210	4	12.8	105.1 12.8°E	15.1	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377576.4612	8642260.079
298	1210	3	23.6	200.6 23.6°S	110.6	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377575.5906	8642260.186
299	1210	3	77.9	12.2 77.9°N	282.2	3 planar: Joint major	COS	Tssq	gneiss	High	Cpy	LH	377573.7329	8642262.279
300	1210	3	79.2	20 79.2°N	290	3 planar: Joint major	COS	Tssq	gneiss	High	Cpy	LH	377573.7329	8642262.279
301	1210	4	18.5	177 18.5°S	87	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377573.514	8642262.61
302	1210	4	18	174.2 18.0°S	84.2	3 planar: Cleavage (S3)	COS	Tssq	Schist	High	Cpy	LH	377573.514	8642262.61
303	1209.465	4	0	0	0	0 planar: Contact	COS	Tssq	gneiss	High	Cpy	LH	377570.5607	8642266.579
304	1209.294	4	0	0	0	0 planar: Contact	CBS	Tssq	gneiss	High	N/A	LH	377570.6699	8642266.469
305	1206	4	83.9	28 83.9°N	298	3 planar: Joint major	CBS	Tssq	gneiss	High	N/A	LH	377569.7975	8642267.019
306	1206	4	75.7	12.9 75.7°N	282.9	3 planar: Joint major	CBS	Tssq	gneiss	High	N/A	LH	377569.5786	8642267.35
307	1210.1299	4	48.4	20.7 48.4°N	290.7	3 planar: Shear plane (C3)	CBS	Tssq	gneiss	High	N/A	LH	377566.6336	8642269.328

308	1210.1299	4	0	0	0	0	0	0	planar:Points	CBS	Tssq	gneiss	High	N/A	LH	377566.7341	8642271.319
309	1210.1299	4	0	0	0	0	0	0	planar:Points	CBS	Tssq	gneiss	High	N/A	LH	377565.2072	8642272.308
310	1205	4	65.2	14.1 65.2°N			284.1		3 planar:Joint major	COS	Tssq	gneiss	High	Cpy	LH	377565.6423	8642272.31
311	1205	3	72.5	358.7 72.5°N			268.7		3 planar:Joint major	COS	Tssq	gneiss	High	Cpy	LH	377565.752	8642272.089
312	1207	4	0	0	0	0	0	0	planar:Points	CBG	Tgggbag	gneiss	Medium	N/A	LH	377570.3187	8642272.44
313	1210.1299	3	0	0	0	0	0	0	planar:Points	CBG	Tgggbag	gneiss	Medium	N/A	LH	377568.5803	8642271.991
314	1207	3	80	10.7 80.0°N			280.7		3 planar:Joint major	CBG	Tgggbag	gneiss	Medium	N/A	LH	377567.5982	8642272.761
315	1207	3	75.9	8.9 75.9°N			278.9		3 planar:Joint major	CBG	Tgggbag	gneiss	Medium	N/A	LH	377567.5982	8642272.761
316	1210.87	4	0	0	0	0	0	0	planar:Points	CBG	Tgggbag	gneiss	Medium	N/A	LH	377566.9479	8642272.205
317	1212.076	4	0	0	0	0	0	0	planar:Points	CBG	Tgggbag	gneiss	Medium	N/A	LH	377565.5307	8642272.973
318	1205.855	4	0	0	0	0	0	0	planar:Points	GPG	Q-F-B-A Pegmatite		low	N/A	LH	377567.8111	8642273.868
319	1209.7171	4	0	0	0	0	0	0	planar:Points	GPG	Q-F-B-A Pegmatite		low	N/A	LH	377566.2805	8642275.741
320	1207	4	0	0	0	0	0	0	planar:Points	GPG	Q-F-B-A Pegmatite		low	N/A	LH	377566.281	8642275.631
321	1208	4	86.9	57.2 86.9°E			327.2		3 planar:Joint minor	GPG	Q-F-B-A Pegmatite		low	N/A	LH	377565.2021	8642273.525
322	1206	4	36.2	350.6 36.2°N			260.6		3 planar:Joint major	COS	Tssq		High	Cpy	LH	377566.1681	8642276.626
323	1209.9764	4	17.4	213.4 17.4°S			123.4		3 planar:Joint major (S3)	COS	Tssq	Schist	High	Cpy & brn	LH	377566.1671	8642276.847
324	1206	4	51.6	353.5 51.6°N			263.5		3 planar:Joint major	COS	Tssq	gneiss	High	Cpy & brn	LH	377566.4944	8642276.627
325	1210.869	4	0	0	0	0	0	0	planar:Points	GPG	Peg: Pegmatite		low	Cpy	LH	377567.4575	8642280.392
326	1205	7	82.8	5.2 82.8°N			275.2		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377566.1431	8642282.598
327	1206	9	75	23.7 75.0°N			293.7		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377565.7053	8642283.26
328	1206	7	76.9	15 76.9°N			285		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377566.0311	8642283.372
329	1207	7	73.7	13.3 73.7°N			283.3		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377563.9674	8642282.7
330	1206	7	81.9	20.6 81.9°N			290.6		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377563.0769	8642287.562
331	1206	7	81.7	13.6 81.7°N			283.6		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377563.0769	8642287.562
332	1206	7	74.9	25.6 74.9°N			295.6		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377560.897	8642288.659
333	1206	7	85.7	41.3 85.7°N			311.3		3 planar:Joint major	CBG	Tgggba		Medium	N/A	LH	377560.5689	8642289.1
334	1209.9685	7	20.1	221 20.1°S			131		3 planar:Joint major (S3)	CBG	Tssq	Schist	high		LH	377560.2477	8642287.882
335	1209.9685	7	7.8	222.6 7.8°S			132.6		3 planar:Joint major (S3)	CBG	Tssq	Schist	high	N/A	LH	377560.1366	8642288.435
336	1209.9685	7	14	143.8 14.0°S			53.8		3 planar:Joint major (S3)	CBG	Tssq	Schist	high	N/A	LH	377560.1366	8642288.435
337	1210.0541	8	8.8	194.2 8.8°S			104.2		3 planar:Contact	CBG	Tssq	gneiss	high	N/A	LH	377561.0099	8642287.664
338	1209.9685	5	1.3	210.9 1.3°S			120.9		3 planar:Joint major (S1)	CBG	Tgggba	gneiss	Medium	N/A	LH	377563.1912	8642286.236
339	1209.9685	8	12.9	188.6 12.9°S			98.6		3 planar:Joint major (S1)	CBG	Tgggba	gneiss	Medium	N/A	LH	377565.1522	8642285.47
340	1209.9685	8	4.8	188.9 4.8°S			98.9		3 planar:Joint major (S1)	CBG	Tgggba	gneiss	Medium	N/A	LH	377564.9384	8642284.584
341	1210.1758	8	0	0	0	0	0	0	planar:Contact	CBG	Tssq	gneiss	high	N/A	LH	377565.0485	8642284.253
342	1211	4	79.3	33.5 79.3°N			303.5		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377578.1539	8642193.393
343	1211	4	20.8	84.6 20.8°E			354.6		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377579.5729	8642192.182
344	1211	4	26.3	88 26.3°E			358		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377579.5729	8642192.182
345	1211	4	0.2	172.7 0.2°S			82.7		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377579.0351	8642190.742
346	1211	4	79.4	16.8 79.4°N			286.8		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377577.7336	8642189.852
347	1211	4	83.2	6.8 83.2°N			276.8		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377577.0954	8642186.42
348	1210	4	85.4	10.9 85.4°N			280.9		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377577.3138	8642186.2
349	1210	4	8.3	279.3 8.3°W			189.3		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377577.6448	8642185.096
350	1209	4	15.2	204.1 15.2°S			114.1		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377578.9578	8642183.221
351	1213	4	84.3	37.2 84.3°N			307.2		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377573.4594	8642171.585
352	1213	4	82.8	346.2 82.8°N			256.2		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377572.2653	8642171.027
353	1214	4	19	127.2 19.0°E			37.2		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377572.1588	8642170.473
354	1214	4	16.2	303.8 16.2°W			213.8		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377573.1789	8642160.634
355	1214	4	83.2	7 83.2°N			277		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377573.0752	8642159.417
356	1214	4	80.5	34.6 80.5°N			304.6		3 planar:Joint minor	COS	Tssq	gneiss	high	Cpy	LH	377572.8637	8642157.978
357	1214	4	85.8	44.9 85.8°N			314.9		3 planar:Joint minor	COS	Tssq	gneiss	high	Cpy	LH	377572.3249	8642156.759
358	1215	4	21.7	117.3 21.7°E			27.3		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377572.3254	8642156.649
359	1215	4	0	0	0	0	0	0	planar:Points	COS	Tssq	gneiss	high	Cpy	LH	377582.9281	8642144.084
360	1213	4	80.7	18.7 80.7°N			288.7		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377582.606	8642143.088
361	1213	4	83.5	34.8 83.5°N			304.8		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377592.4816	8642145.327
362	1211	4	0	0	0	0	0	0	planar:Points	COS	Tssq	gneiss	high	Cpy	LH	377591.1159	8642136.819
363	1212.5164	4	75.5	17 75.5°N			287		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377600.6394	8642129.335
364	1212.5164	4	87	340.1 87.0°N			250.1		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377593.3295	8642127.648
365	1209.1534	4	7.5	176.4 7.5°S			86.4		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377594.0992	8642125.661
366	1205	4	9.4	61.4 9.4°E			331.4		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377596.8728	8642112.621
367	1205	4	26.1	95.4 26.1°E			5.4		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377596.8728	8642112.621
368	1209.9023	4	53.5	21.3 53.5°N			291.3		3 planar:Joint minor	COS	Tssq	gneiss	high	Cpy	LH	377596.8696	8642109.42
369	1205	5	14.8	121.7 14.8°E			31.7		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377598.9523	8642109.533
370	1210.3878	5	89.9	293.9 89.9°W			203.9		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377598.3002	8642109.42
371	1205	5	83.2	340.5 83.2°N			250.5		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377599.2832	8642108.428
372	1210.3878	5	88.4	79.5 88.4°E			349.5		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377599.609	8642108.54
373	1209.589	5	12.2	157.1 12.2°S			67.1		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377603.8679	8642104.466
374	1211.3096	5	74	20 74.0°N			290		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377607.2437	8642103.485
375	1207	4	65.5	0 65.5°N			269.6		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377615.413	8642100.643
376	1207	4	74.4	13.1 74.4°N			283.1		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377615.413	8642100.643
377	1208	3	13.1	296.1 13.1°W			206.1		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377617.1744	8642095.563
378	1208	3	28.1	286.7 28.1°W			196.7		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377619.5714	8642094.577
379	1208	3	10.9	291.1 10.9°W			201.1		3 planar:Joint major (S3)	COS	Tssq	Schist	high	Cpy	LH	377619.7903	8642094.246
380	1208	3	82.8	6.9 82.8°N			278.9		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377623.9371	8642090.946
381	1208	3	13.9	222.3 13.9°S			132.3		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377624.2639	8642090.836
382	1208	3	23.5	179.9 23.5°S			89.9		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377624.461	8642090.948
383	1208.2567	3	12.8	318 12.8°N			228		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377625.5991	8642083.653
384	1206	4	15.1	300.3 15.1°W			210.3		3 planar:Joint major	COS	Tssq	gneiss	high	Cpy	LH	377625.7079	8642083.653

385	1213	2	0	0	0	0	0	0	planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	377655.8914	8642044.295
386	1213	3	55.1	16.3 55.1°N		286.3			3 planar:Shear plane (C3)	COS	Ttsq	gneiss	high	Cpy	LH	377652.4004	8642046.824
387	1213	3	66.7	18.5 66.7°N		288.5			3 planar:Shear plane (C3)	COS	Ttsq	gneiss	high	Cpy	LH	377652.2921	8642046.713
388	1212	3	46.7	349 46.7°N		259			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377650.227	8642046.372
389	1212	3	86.1	53.1 86.1°E		323.1			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377650.0099	8642046.261
390	1213	3	72.7	11.4 72.7°N		281.4			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377650.8754	8642047.371
391	1216	3	24.1	37 24.1°N		307			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	377653.4922	8642045.833
392	1214	3	84.4	343 84.4°N		253			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377649.4541	8642049.134
393	1214	3	78.5	9.3 78.5°N		279.3			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377649.4541	8642049.134
394	1212	2	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	377647.0479	8642052.332
395	1209	3	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	377641.2585	8642058.28
396	1209	3	14.3	138.1 14.3°S		48.1			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	377641.5746	8642060.714
397	1209	3	13.5	250.2 13.5°W		160.2			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	377641.5746	8642060.714
398	1209	3	11	162.1 11.0°S		72.1			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	377640.9202	8642061.154
399	1212	2	8.8	67.9 8.8°E		337.9			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	377638.8153	8642070.325
400	1212	3	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	377624.7142	8642087.188
401	1210	3	88.8	65.4 88.8°E		335.4			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377642.7784	8642058.95
402	1210	3	57.4	101.3 57.4°E		11.3			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377642.7784	8642058.95
403	1210	3	82.9	30.8 82.9°N		300.8			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377643.7601	8642058.29
404	1210	3	69.9	77.6 69.9°E		347.6			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377643.7601	8642058.29
405	1210	3	82.8	10.7 82.8°N		280.7			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377643.7601	8642058.29
406	1209	2	73.6	357.9 73.6°N		267.9			3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	377644.1979	8642057.629
407	1209	9	0	0		0			0 planar:Points	CBGA	Ttya	gneiss	Low	N/A	LH	377712.4999	8641927.957
408	1208	3	0	0		0			0 planar:Points	CBGA	Ttya	gneiss	Low	N/A	LH	377715.0042	8641927.304
409	1211.0671	3	0	0		0			0 planar:Points	CBGA	Ttya	gneiss	Low	N/A	LH	377706.6276	8641927.711
410	1211.0671	3	0	0		0			0 planar:Points	CBGA	Ttya	gneiss	Low	N/A	LH	377697.5879	8641930.66
411	1211.0671	4	0	0		0			0 planar:Points	CBGA	Ttya	gneiss	Low	N/A	LH	377692.8083	8641929.202
412	1211.0671	3	0	0		0			0 planar:Points	CBGA	Ttya	gneiss	Low	N/A	LH	377700.5305	8641929.234
413	1212	3	76.2	353.3 76.2°N		263.3			3 planar:Joint major	CBGA	Ttya	gneiss	Low	N/A	LH	377705.8432	8641933.238
414	1211	3	8.1	221.8 8.1°S		131.8			3 planar:Contact	CBGA	Ttya	gneiss	Low	N/A	LH	377706.2681	8641935.673
415	1212	4	72.8	14.7 72.8°N		284.7			3 planar:Joint major	CBGA	Ttya	gneiss	Low	Cpy & btm	LH	377707.3631	8641933.908
416	1211	3	78.5	10.2 78.5°N		280.2			3 planar:Joint major	CBGA	Ttya	gneiss	Low	Cpy	LH	377719.5547	8641931.526
417	1208	3	0	0		0			0 planar:Points	CBGA	Ttyag	gneiss	Low	Cpy	LH	377728.8327	8641923.601
418	1207	3	0	0		0			0 planar:Points	CBGA	Ttyag	gneiss	Low	Cpy	LH	377732.1021	8641922.066
419	1206	3	0	0		0			0 planar:Points	CBGA	Ttyag	gneiss	Low	Cpy	LH	377734.1801	8641919.31
420	1206	3	86.7	314.4 86.7°W		224.4			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377735.0414	8641921.415
421	1206	4	89.4	122.5 89.4°E		32.5			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377735.0414	8641921.415
422	1207	7	49.8	140.1 49.8°S		50.1			3 planar:Contact	CBGA	Ttyag	gneiss	Low	Cpy	LH	377735.8069	8641920.423
423	1207	3	39.5	128.7 39.5°E		38.7			3 planar:Contact	CBGA	Ttyag	gneiss	Low	Cpy	LH	377736.5738	8641919.099
424	1207.622	3	0	0		0			0 planar:Contact	CBGA	Ttyag	gneiss	Low	Cpy	LH	377731.1297	8641920.514
425	1207.4155	3	0	0		0			0 planar:Contact	CBGA	Ttyag	gneiss	Low	Cpy	LH	377728.5189	8641920.613
426	1206	3	0	0		0			0 planar:Contact	CBGA	Ttyag	gneiss	Low	Cpy	LH	377741.0502	8641915.025
427	1208	3	0	0		0			0 planar:Contact	CBGA	Ttyag	gneiss	high	Cpy	LH	377740.623	8641913.143
428	1211	4	17.3	42.6 17.3°N		312.6			3 planar:Cleavage (S3)	CBGA	Ttsq	Schist	high	Cpy	LH	377754.4579	8641907.892
429	1211	4	12.8	4.7 12.8°N		274.7			3 planar:Cleavage (S3)	CBGA	Ttsq	Schist	Low	Cpy	LH	377754.8916	8641908.226
430	1209	3	0	0		0			0 planar:Points	CBGA	Ttyag	gneiss	Low	Cpy	LH	377755.5428	8641908.56
431	1209	3	0	0		0			0 planar:Points	CBGA	Ttyag	gneiss	Low	Cpy	LH	377753.368	8641908.44
432	1205	4	77.9	67.7 77.9°E		337.7			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377768.8183	8641907.087
433	1205	4	76	67.2 76.0°E		337.2			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377768.8183	8641906.516
434	1205	4	70.2	65.2 70.2°E		335.2			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377768.2561	8641906.405
435	1204	4	66.9	63.9 66.9°E		333.9			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377774.0523	8641903.881
436	1204	4	75	57.6 75.0°E		327.6			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377774.1624	8641903.55
437	1204	3	72.4	62.6 72.4°E		332.6			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377774.1624	8641903.55
438	1205	4	71	66.3 71.0°E		336.3			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377782.0053	8641900.707
439	1205	4	73.9	51.1 73.9°E		321.1			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377782.0053	8641900.707
440	1203	4	86.3	340.9 86.3°N		250.9			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377787.6656	8641899.625
441	1203	4	74.8	64.1 74.8°E		334.1			3 planar:Joint minor	CBGA	Ttyag	gneiss	Low	Cpy	LH	377791.3653	8641899.188
442	1203	4	71.3	72.4 71.3°E		342.4			3 planar:Joint minor	CBGA	Ttyag	gneiss	Low	Cpy	LH	377791.3653	8641899.188
443	1202	5	68.1	354.3 68.1°N		264.3			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377796.7984	8641900.437
444	1202	4	72.2	348.7 72.2°N		258.7			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377799.4077	8641900.669
445	1203	4	63.8	358.7 63.8°N		268.7			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377802.99	8641902.343
446	1203	4	70.3	2.4 70.3°N		272.4			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377804.073	8641903.454
447	1204	4	82.2	349.1 82.2°N		259.1			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377803.3112	8641903.561
448	1204	4	80.7	2.6 80.7°N		272.6			3 planar:Joint major	CBGA	Ttyag	gneiss	Low	Cpy	LH	377803.3112	8641903.561
449	1209.8725	4	20.7	18.2 20.7°N		288.2			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378002.7315	8641890.236
450	1209.8725	5	4.1	257.3 4.1°W		167.3			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378000.8816	8641890.449
451	1208.7729	4	28.2	292.7 28.2°W		202.7			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	377997.5063	8641891.32
452	1208.7729	4	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	377999.9046	8641890.003
453	1208.7729	4	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378005.0169	8641889.913
454	1208.0847	3	13.8	53.9 13.8°E		323.9			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378013.816	8641892.494
455	1208.0847	3	11.2	30.7 11.2°N		300.7			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378014.2681	8641888.404
456	1208.0847	3	8.9	24 8.9°N		294			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378013.9386	8641889.176
457	1207.9044	3	12.7	159 12.7°S		69			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378015.5673	8641889.847
458	1207	4	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378013.7211	8641889.175
459	1207	3	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378014.8073	8641889.512
460	1208	4	0	0		0			0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378020.4611	8641889.978
461	1208.0352	5	4.7	286.1 4.7°W		196.1			3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378022.1036	8641887.33

462	1208.4059	5	18.9	56.7 18.9°E	326.7	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378021.0169	8641887.104
463	1208.0352	5	10.9	336.3 10.9°N	246.3	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378025.3692	8641886.68
464	1208.0352	5	6.4	150.2 6.4°S	60.2	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378025.6951	8641886.792
465	1208.6783	9	12.8	203.3 12.8°S	113.3	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378027.2062	8641889.563
466	1208.6783	7	11.9	58.5 11.9°E	328.5	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378028.7261	8641890.233
467	1208.6783	8	1.2	340.5 1.2°N	250.5	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378031.6627	8641890.246
468	1208.6783	7	11.9	263.1 11.9°W	173.1	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378033.5089	8641890.917
469	1208.6783	8	1.8	234.4 1.8°W	144.4	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378032.524	8641892.351
470	1208.0102	5	0	0	0	0 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378029.269	8641890.457
471	1207	4	0	0	0	0 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378030.6774	8641891.79
472	1208	4	0	0	0	0 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378034.5841	8641893.908
473	1208	5	0	0	0	0 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378039.9153	8641893.487
474	1213	5	78.1	16.4 78.1°N	286.4	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378025.8849	8641893.429
475	1213	5	88.2	308.9 88.2°W	218.9	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378024.8033	8641891.987
476	1212	5	81.4	4.2 81.4°N	274.2	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378021.11	8641890.865
477	1212	5	76.5	11.7 76.5°N	281.7	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378021.11	8641890.865
478	1211	5	71.4	19 71.4°N	289	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378020.5639	8641891.416
479	1207	4	11.5	96.1 11.5°E	6.1	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378045.5534	8641897.714
480	1208	4	6.4	295.3 6.4°W	205.3	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378045.1257	8641898.044
481	1208.5346	4	0.7	128 0.7°E	38	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378046.4451	8641892.519
482	1206	4	44.1	166.6 44.1°S	76.6	3 planar: Shear plane (C3)	COS	Ttssq	gneiss	high	Cpy	LH	378051.8625	8641897.519
483	1208.511	6	44.7	165.1 44.7°S	75.1	3 planar: Shear plane (C3)	COS	Ttssq	gneiss	high	Cpy	LH	378048.8236	8641895.958
484	1208.511	5	34.4	169.5 34.4°S	79.5	3 planar: Shear plane (C3)	COS	Ttssq	gneiss	high	Cpy	LH	378049.2596	8641895.738
485	1208.9766	4	0	0	0	0 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378055.0194	8641896.868
486	1209.0184	4	65	13.8 65.0°N	283.8	3 planar: Joint major	CBGA	Trya	N/A	Low	N/A	LH	378053.9304	8641897.196
487	1209.5254	4	87.8	26.7 87.8°N	296.7	3 planar: Joint major	CBGA	Trya	N/A	Low	N/A	LH	378059.3736	8641896.002
488	1209.5254	4	81.3	13.6 81.3°N	283.6	3 planar: Joint major	CBGA	Trya	N/A	Low	N/A	LH	378059.3736	8641896.002
489	1209.2131	8	28.2	176.3 28.2°S	86.3	3 planar: Cleavage (S1)	CBGA	Tryag	N/A	medium	N/A	LH	378061.6479	8641898.334
490	1209.2131	4	12.7	163.1 12.7°S	73.1	3 planar: Cleavage (S1)	CBGA	Tryag	N/A	medium	N/A	LH	378063.3904	8641897.788
491	1209.3232	4	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378065.8878	8641898.794
492	1208	5	58.9	183.5 58.9°S	93.5	3 planar: Shear plane (C3)	CBGA	Tryag	N/A	medium	N/A	LH	378077.0852	8641900.057
493	1210.0827	5	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378080.561	8641901.178
494	1209.9955	5	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378082.1855	8641902.843
495	1210.0584	4	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378083.1639	8641902.958
496	1209.8032	4	2.8	148.6 2.8°S	58.6	3 planar: Cleavage (S1)	CBGA	Tryag	N/A	medium	N/A	LH	378090.2183	8641906.637
497	1210	5	8.7	116.6 8.7°E	26.6	3 planar: Cleavage (S1)	CBGA	Tryag	N/A	medium	N/A	LH	378089.1187	8641909.508
498	1206	4	87.2	161 87.2°S	71	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378090.9575	8641911.949
499	1206	5	51.9	100 51.9°E	10	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378089.9906	8641909.07
500	1206	5	64.7	192.4 64.7°S	102.4	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378093.1346	8641911.516
501	1207	4	69.8	206.4 69.8°S	116.4	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378093.1346	8641911.516
502	1207	4	77.2	198.2 77.2°S	108.2	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378095.9647	8641910.975
503	1207	5	87.7	149 87.7°S	59	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378095.9647	8641910.975
504	1206	4	86.1	208.5 86.1°S	118.5	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378095.9647	8641910.975
505	1209.5521	4	89.6	294.2 89.6°W	204.2	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378099.6645	8641910.548
506	1209	9	4.8	53.2 4.8°E	323.2	3 planar: Cleavage (S1)	CBGA	Tryag	N/A	medium	N/A	LH	378103.4505	8641915.541
507	1209	5	87.5	20.1 87.5°N	290.1	3 planar: Joint minor	CBGA	Tryag	N/A	medium	N/A	LH	378106.0456	8641919.201
508	1210	9	71.8	202.1 71.8°S	112.1	3 planar: Shear plane (C1)	CBGA	Tryag	N/A	medium	N/A	LH	378105.0644	8641919.75
509	1208	5	10.8	118.7 10.8°E	28.7	3 planar: Cleavage (S1)	CBGA	Tryag	N/A	medium	N/A	LH	378110.5205	8641915.459
510	1209.6223	5	53.3	80 53.3°E	350	3 planar: Joint major	CBGA	Tryag	N/A	medium	N/A	LH	378111.9339	8641915.576
511	1209.9544	4	70.5	354.1 70.5°N	264.1	3 planar: Joint major	CBGA	Tryag	N/A	medium	N/A	LH	378112.9119	8641915.801
512	1209.9544	4	73.5	341.1 73.5°N	251.1	3 planar: Joint major	CBGA	Tryag	N/A	medium	N/A	LH	378114.2165	8641915.917
513	1209.3936	5	0	0	0	0 planar: Points	CBG	Ttqgb	N/A	medium	N/A	LH	378119.3238	8641917.044
514	1209.3823	5	8.9	101.7 8.9°E	11.7	3 planar: Cleavage (S1)	CBGA	Ttqgb	N/A	medium	N/A	LH	378118.7809	8641916.821
515	1209.3936	4	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378125.5154	8641918.95
516	1211	5	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378107.5945	8641912.903
517	1213	5	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378125.3804	8641925.254
518	1213	5	0	0	0	0 planar: Points	CBGA	Tryag	N/A	medium	N/A	LH	378120.8253	8641922.138
519	1215	5	82.5	13.5 82.5°N	283.5	3 planar: Joint major	CBGA	Tryag	N/A	medium	N/A	LH	378132.6458	8641930.483
520	1215	5	78.5	22.4 78.5°N	292.4	3 planar: Joint major	CBGA	Tryag	N/A	medium	N/A	LH	378132.6458	8641930.483
521	1215	5	81.3	18.9 81.3°N	288.9	3 planar: Joint major	CBGA	Tryag	N/A	medium	N/A	LH	378132.7546	8641930.483
522	1214	5	18.3	15.3 18.3°N	285.3	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378133.4086	8641930.154
523	1217	5	74.5	13.1 74.5°N	283.1	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378140.3482	8641935.271
524	1217	5	79.5	18.1 79.5°N	288.1	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378140.3482	8641935.271
525	1217	5	73.5	10.8 73.5°N	280.8	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378140.7837	8641935.162
526	1208	4	84.2	355.9 84.2°N	265.9	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378165.2156	8641944.775
527	1208	3	84.6	350.7 84.6°N	260.7	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378165.2156	8641944.775
528	1208	3	77	264.6 77.0°W	174.6	3 planar: Joint minor	COS	Ttssq	gneiss	high	Cpy	LH	378168.4808	8641944.236
529	1208	3	9.1	125.8 9.1°E	35.8	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378168.6965	8641944.679
530	1208.5769	4	75.8	21.8 75.8°N	291.8	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378175.9891	8641943.382
531	1206	4	78.6	20.1 78.6°N	290.1	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378176.0988	8641943.161
532	1207.9723	3	0	0	0	0 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378161.6329	8641943.212
533	1207.6748	3	9.2	309.4 9.2°W	219.4	3 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378180.3055	8641951.585
534	1206	3	9.9	355.4 9.9°N	265.4	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378183.7717	8641955.028
535	1207.1751	4	18.7	34 18.7°N	304	3 planar: Cleavage (S3)	COS	Ttssq	Schist	high	Cpy	LH	378185.1911	8641953.706
536	1205	3	77.1	11.5 77.1°N	281.5	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378186.4843	8641956.587
537	1206	4	77.7	0.8 77.7°N	270.8	3 planar: Joint major	COS	Ttssq	gneiss	high	Cpy	LH	378187.3516	8641957.255
538	1207	5	0	0	0	0 planar: Points	COS	Ttssq	gneiss	high	Cpy	LH	378185.8257	8641958.023

539	1204	3	77	8.7 77.0°N		278.7	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378190.4924	8641960.475
540	1208.457	4	0	0	0	0	0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378161.0914	8641942.657
541	1207	4	82.9	1.1 82.9°N		271.1	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378166.1917	8641945.443
542	1207	4	85.6	35.1 85.6°N		305.1	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378166.8503	8641944.008
543	1209	14	25.1	109.7 25.1°E		19.7	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378168.2541	8641946.447
544	1208	3	7.4	143.5 7.4°S		53.5	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378168.6891	8641946.449
545	1208	4	80.1	0.1 80.1°N		270.1	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378172.694	8641951.111
546	1210	5	0	0	0	0	0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378176.5081	8641949.357
547	1209	7	24.9	98.3 24.9°E		8.3	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378182.6873	8641954.249
548	1208	4	0	0	0	0	0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378185.1929	8641953.264
549	1208	4	77.8	1.1 77.8°N		271.1	3 planar:Fault major	COS	Ttsq	gneiss	high	Cpy	LH	378185.4114	8641953.044
550	1208	4	76.8	1.2 76.8°N		271.2	3 planar:Fault major	COS	Ttsq	gneiss	high	Cpy	LH	378185.9538	8641953.378
551	1208	4	0	0	0	0	0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378195.6144	8641958.063
552	1208	4	0	0	0	0	0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378196.8094	8641958.4
553	1208	5	29.1	49.3 29.1°E		319.3	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378198.2224	8641958.627
554	1209	4	72.5	1.4 72.5°N		271.4	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378197.6707	8641960.505
555	1208	3	6.6	170.2 6.6°S		80.2	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378202.6766	8641959.862
556	1208	3	16.7	123.5 16.7°E		33.5	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378202.5678	8641959.862
557	1208	3	0	0	0	0	0 planar:Contact	COS	Ttsq	gneiss	high	Cpy	LH	378202.7816	8641960.748
558	1208	4	80.1	359.4 80.1°N		269.4	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378203.3167	8641962.851
559	1209	3	79.1	11.2 79.1°N		281.2	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378204.0776	8641962.965
560	1209	3	15.2	99.5 15.2°E		9.5	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378204.0776	8641962.965
561	1209	3	0	0	0	0	0 planar:Boudin toe contact	COS	Ttsq	gneiss	high	Cpy	LH	378203.414	8641965.617
562	1209	3	0	0	0	0	0 planar:Boudin toe contact	COS	Ttsq	gneiss	high	Cpy	LH	378203.5218	8641965.838
563	1210	3	76.4	5.5 76.4°N		275.5	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378208.8323	8641970.395
564	1211	3	0	0	0	0	0 planar:Points	COS	Ttsq	gneiss	high	Cpy	LH	378206.2358	8641967.066
565	1209	4	79	354.4 79.0°N		264.4	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378215.2364	8641973.519
566	1207	4	83.2	354.1 83.2°N		264.1	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378216.3812	8641972.42
567	1207	5	74.2	159.5 74.2°S		69.5	3 planar:Shear plane (C3)	COS	Ttsq	gneiss	high	Cpy	LH	378224.2513	8641976.542
568	1209	5	36.4	22.8 36.4°N		292.8	3 planar:Joint major	COS	Ttsq	gneiss	high	Cpy	LH	378224.0342	8641976.431
569	1208	4	20.8	68.8 20.8°E		338.8	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378225.7703	8641977.433
570	1208	4	51.2	279.8 51.2°W		189.8	3 axial:Slipenside	COS	Ttsq	gneiss	high	Cpy	LH	378223.9232	8641976.983
571	1208	4	13.3	118 13.3°E		28	3 planar:Cleavage (S3)	COS	Ttsq	Schist	high	Cpy	LH	378224.4651	8641977.428
572	1208.8864	5	0	0	0	0	0 planar:Contact	COS	Ttsq	gneiss	high	Cpy	LH	378228.2691	8641978.107
573	1207	3	11.3	51.3 11.3°E		321.3	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378230.5443	8641980.218
574	1208.608	4	22.7	75.4 22.7°E		345.4	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378238.0591	8641977.816
575	1208.7951	4	36.7	92.1 36.7°E		2.1	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378239.4716	8641978.154
576	1208.54	3	75	358.4 75.0°N		269.4	3 planar:Fault minor	CHWS	Ttsbq	gneiss	high	N/A	LH	378244.4466	8641984.921
577	1208.4548	3	33.3	40.1 33.3°N		310.1	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378244.2314	8641984.367
578	1210	3	77.4	6.4 77.4°N		276.4	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378237.4739	8641987.768
579	1210	3	76.2	13.4 76.2°N		283.4	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378237.4739	8641987.768
580	1210	4	66	352.9 66.0°N		262.9	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378245.0849	8641988.353
581	1211	3	89.5	90.9 89.5°E		0.9	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378249.8507	8641993.128
582	1212	3	21.4	149.3 21.4°S		59.3	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378249.3124	8641991.799
583	1212	3	27	153.4 27.0°S		63.4	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378249.3124	8641991.799
584	1213	3	49.4	10.7 49.4°N		280.7	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378250.401	8641991.582
585	1211	3	4.1	207.5 4.1°S		117.5	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378251.6896	8641995.569
586	1212	3	89	323.1 89.0°N		233.1	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378261.4644	8641998.928
587	1212	3	80.9	25.2 80.9°N		295.2	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378261.9004	8641998.708
588	1212	4	10.3	177.4 10.3°S		87.4	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378262.4423	8641999.153
589	1215	3	62.7	0.9 62.7°N		270.9	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378269.2737	8642004.159
590	1215	4	18.2	179.5 18.2°S		89.5	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378269.2737	8642004.159
591	1213	3	29.1	246.3 29.1°W		156.3	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378276.6873	8642026.089
592	1211	3	21.5	121.7 21.5°E		31.7	3 planar:Cleavage (S2)	CHWS	Ttsbq	gneiss	high	N/A	LH	378277.45	8642025.76
593	1207	3	69.5	359.3 69.5°N		269.3	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378275.0476	8642028.073
594	1206	3	60.3	3.1 60.3°N		273.1	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378275.8915	8642034.38
595	1205	3	65.4	7.6 65.4°N		277.6	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378277.4231	8642058.387
596	1205	3	65.9	6.9 65.9°N		276.9	3 planar:Joint major	CHWS	Ttsbq	gneiss	high	N/A	LH	378277.5324	8642058.277
597	1305	2	67.7	4.8 67.7°N		274.8	3 planar:Joint major	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378248.0141	8641833.191
598	1306	2	69.3	354.9 69.3°N		264.9	3 planar:Joint major	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378248.9879	8641834.411
599	1307	4	84.9	4 84.9°N		274	3 planar:Joint major	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378290.3641	8641797.2
600	1310	4	38.4	268.2 38.4°W		178.2	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378296.6516	8641802.203
601	1310	3	34.9	271.6 34.9°W		181.6	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378295.7852	8641801.315
602	1310	3	37.4	273.7 37.4°W		183.7	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378293.6979	8641801.604
603	1310	2	79.9	248.4 79.9°W		158.4	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378296.0228	8641822.662
604	1311	2	27.3	242.4 27.3°W		152.4	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378296.2412	8641822.442
605	1312	3	29.5	254.29.5°W		164	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378297.2224	8641821.893
606	1312	3	26	259.9 26.0°W		169.9	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378296.6822	8641821.006
607	1312	3	27.8	257.2 27.8°W		167.2	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378296.6822	8641821.006
608	1304	3	61.1	288.7 61.1°W		198.7	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378286.4629	8641793.755
609	1306.3547	2	43.6	290.5 43.6°W		200.5	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378286.3579	8641792.87
610	1306.3547	2	48.5	303 48.5°W		213	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378286.3579	8641792.87
611	1304	3	85.4	25.7 85.4°N		295.7	3 planar:Joint major	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378285.2767	8641791.317
612	1305	3	85.8	37.3 85.8°N		307.3	3 planar:Joint major	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378285.603	8641791.319
613	1306	2	82.3	31.6 82.3°N		301.6	3 planar:Joint minor	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378281.9405	8641782.787
614	1308	3	71.9	19.4 71.9°N		289.4	3 planar:Joint minor	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378282.2737	8641781.129
615	1308	3	62	274.6 62.0°W		184.6	3 planar:Cleavage (S2)	CHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378282.4935	8641780.577

616	1308	4	43.4	292 43.4*W	202	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378282.4935	8641780.577
617	1308	3	38.3	290.1 38.3*W	200.1	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378282.9207	8641782.459
618	1309	3	84.2	33.8 84.2*N	303.8	3 planar: Joint major	OHW	Ttqgb	Pink Gneiss	Medium	N/A	LH	378281.3109	8641777.254
619	1308	4	87.1	58.2 87.1*E	328.2	3 planar: Joint minor	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378281.9768	8641774.05
620	1307	3	26.8	239.6 26.8*W	149.6	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.3642	8641769.508
621	1308	2	35.1	217.2 35.1*S	127.2	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.6969	8641767.961
622	1308	3	49	212.1 49.0*S	122.1	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.6969	8641767.961
623	1308	3	31.4	221.1 31.4*S	131.1	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.808	8641767.409
624	1308	4	45.2	233 45.2*W	143	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.808	8641767.409
625	1308	4	24.7	199.1 24.7*S	109.1	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.808	8641767.409
626	1307	4	22.1	212.5 22.1*S	122.5	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.8094	8641767.077
627	1307	2	22.2	238.3 22.2*W	148.3	3 planar: Cleavage (S2)	OHW	Ttqgb	Pink Gneiss	High	N/A	LH	378280.3771	8641766.411
628	1307	3	29.9	246.7 29.9*W	156.7	3 planar: Cleavage (S2)	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378277.6971	8641756.999
629	1304	3	69.3	358.7 69.3*N	268.7	3 planar: Joint major	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378275.6785	8641745.488
630	1307.085	3	16.9	248 16.9*W	158	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378276.9928	8641743.282
631	1307.8698	3	23.1	255.5 23.1*W	165.5	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378277.1025	8641743.061
632	1307.0185	3	28.1	243.4 28.1*W	153.4	3 planar: Cleavage (S2)	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378274.3014	8641736.634
633	1307.0185	3	22.3	231.3 22.3*W	141.3	3 planar: Cleavage (S2)	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378273.8691	8641735.969
634	1306.7582	3	25.7	231.3 25.7*W	141.3	3 planar: Cleavage (S2)	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378272.4809	8641729.769
635	1306.7582	3	15.7	197.4 15.7*S	107.4	3 planar: Cleavage (S2)	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378272.8178	8641727.227
636	1306.5368	3	71.6	358.4 71.6*N	268.4	3 planar: Joint major	OHW	Ttbaqf	Pink Gneiss	High	N/A	LH	378272.7095	8641727.116
637	1306.8551	3	18.7	220.3 18.7*S	130.3	3 planar: Cleavage (S2)	OHW	Ttbaqf	Schist	High	N/A	LH	378274.0252	8641724.578
638	1306.6845	3	20.5	223 20.5*S	133	3 planar: Cleavage (S2)	OHW	Ttbaqf	Schist	High	N/A	LH	378274.0252	8641724.578
639	1304	3	77.5	7 77.5*N	277	3 planar: Joint major	OHW	Ttbaqf	Schist	High	N/A	LH	378273.9994	8641724.466
640	1306.6485	3	45.8	193.6 45.8*S	103.6	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Schist	High	N/A	LH	378273.9339	8641720.374
641	1306.9249	3	72.9	357.4 72.9*N	267.4	3 planar: Joint major	OHW	Ttbaqf	Schist	High	N/A	LH	378272.666	8641711.41
642	1306.9875	3	18.4	284.9 18.4*W	194.9	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Schist	High	N/A	LH	378269.9847	8641702.33
643	1306.9875	3	19.3	279.4 19.3*W	189.4	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Schist	High	N/A	LH	378270.2059	8641701.446
644	1306.6785	3	18.6	296.5 18.6*W	206.5	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Schist	High	N/A	LH	378270.2059	8641701.446
645	1306.6785	3	76.2	13 76.2*N	283	3 planar: Joint minor	OHW	Ttbaqf	Schist	High	N/A	LH	378270.0999	8641700.782
646	1304	3	49.2	4.4 49.2*N	274.4	3 planar: Joint minor	OHW	Ttbaqf	Schist	High	N/A	LH	378269.1486	8641694.142
647	1304	3	75	217.7 75.0*S	127.7	3 planar: Joint minor	OHW	Ttbaqf	Schist	High	N/A	LH	378269.1486	8641694.142
648	1304	3	77.8	205.4 77.8*S	115.4	3 planar: Joint minor	OHW	Ttbaqf	Schist	High	N/A	LH	378268.2937	8641690.489
649	1307.3626	3	31.8	281.7 31.8*W	191.7	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378263.4455	8641679.408
650	1307.1847	3	37.9	290.5 37.9*W	200.5	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378263.4455	8641679.408
651	1307	3	31.6	292.9 31.6*W	202.9	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378262.1491	8641677.301
652	1307	3	40.6	286.8 40.6*W	196.8	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378262.1491	8641677.301
653	1307	3	29.7	290.7 29.7*W	200.7	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378260.5429	8641671.212
654	1307	2	66.5	209.9 66.5*S	119.9	3 planar: Joint major	OHW	Ttbaqa	Schist	High	N/A	LH	378260.7628	8641670.66
655	1307	3	69.7	210.8 69.7*S	120.8	3 planar: Joint major	OHW	Ttbaqa	Schist	High	N/A	LH	378260.7628	8641670.66
656	1307	2	75.5	208.3 75.5*S	118.3	3 planar: Joint major	OHW	Ttbaqa	Schist	High	N/A	LH	378260.7664	8641669.775
657	1307	2	29.5	300.5 29.5*W	210.5	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378260.7664	8641669.775
658	1306	3	28.3	292.3 28.3*W	202.3	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378259.1488	8641666.45
659	1306	3	30.5	295.1 30.5*W	205.1	3 planar: Shear Plane (C2)	OHW	Ttbaqa	Schist	High	N/A	LH	378259.2576	8641666.45
660	1306	3	82.7	206 82.7*S	116	3 planar: Joint minor	OHW	Ttbaqa	Schist	High	N/A	LH	378259.3741	8641664.571
661	1306	3	25.8	135.5 25.8*S	45.5	3 planar: Cleavage (S2)	OHW	Ttbaqa	Schist	High	N/A	LH	378247.4449	8641603.911
662	1307	2	26.2	147.9 26.2*S	57.9	3 planar: Cleavage (S2)	OHW	Ttbaqa	Schist	High	N/A	LH	378246.7951	8641603.245
663	1307	2	72.3	12.4 72.3*N	282.4	3 planar: Joint major	OHW	Ttbaqa	Schist	High	N/A	LH	378248.5068	8641610.11
664	1308	3	77.6	196 77.6*S	106	3 planar: Joint major	OHW	Ttbaqa	Schist	High	N/A	LH	378246.3573	8641603.907
665	1312	3	70.2	9.4 70.2*N	279.4	3 planar: Joint major	OHW	Ttbaqa	Schist	High	N/A	LH	378245.1656	8641602.796
666	1313	3	75.8	24.9 75.8*N	294.9	3 planar: Joint major	OHW	Ttbaqf	Schist	High	N/A	LH	378241.5981	8641597.583
667	1313	3	9.5	204 9.5*S	114	3 planar: Cleavage (S2)	OHW	Ttbaqf	Schist	High	N/A	LH	378241.1681	8641596.364
668	1313	3	8	211.2 8.0*S	121.2	3 planar: Cleavage (S2)	OHW	Ttbaqf	Schist	High	N/A	LH	378241.1681	8641596.364
669	1314	3	13.7	218.8 13.7*S	128.8	3 planar: Cleavage (S2)	OHW	Ttbaqf	Schist	High	N/A	LH	378240.8487	8641594.704
670	1312	3	18.6	256.2 18.6*W	166.2	3 planar: Cleavage (S2)	OHW	Ttbaqf	Schist	High	N/A	LH	378238.2536	8641591.043
671	1312	3	87.3	160 87.3*S	70	3 planar: Joint major	OHW	Ttbaqf	Schist	High	N/A	LH	378238.255	8641590.712
672	1312	3	83.7	16.3 83.7*N	286.3	3 planar: Joint major	OHW	Ttbaqf	Schist	High	N/A	LH	378238.6933	8641589.939
673	1312	3	21.7	305.7 21.7*W	215.7	3 planar: Cleavage (S2)	OHW	Ttbaqf	Schist	High	N/A	LH	378238.367	8641589.938
674	1312	2	77.5	216.5 77.5*S	126.5	3 planar: Joint major	OHW	Ttbaqf	Schist	High	N/A	LH	378238.3674	8641589.827
675	1311	2	76.1	14.5 76.1*N	284.5	3 planar: Fault minor	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378230.2656	8641576.521
676	1310	3	66.6	354.5 66.6*N	264.5	3 planar: Fault minor	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378227.1285	8641572.416
677	1310	3	63.6	68.9 63.6*E	338.9	3 planar: Joint major	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378227.1285	8641572.416
678	1310	3	67.3	2.7 67.3*N	272.7	3 planar: Fault minor	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378227.1285	8641572.416
679	1310	2	32	285.7 32.0*W	195.7	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378226.2755	8641568.32
680	1309	3	38.9	295.5 38.9*W	205.5	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378226.2768	8641567.988
681	1308	4	71.8	217.3 71.8*S	127.3	3 planar: Joint minor	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378224.8788	8641564.886
682	1308	3	30.6	286.6 30.6*W	196.6	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378225.6344	8641565.553
683	1308	3	25	278.6 25.0*W	188.6	3 planar: Shear Plane (C2)	OHW	Ttbaqf	Grey Gneiss	High	N/A	LH	378225.6344	8641565.553
684	1309	2	0	0	0	0 planar: Contact	OHW	Ttqgb	Grey Gneiss	High	N/A	LH	378217.5824	8641566.404
685	1310	2	0	0	0	0 planar: Contact	OHW	Ttqgb	Grey Gneiss	High	N/A	LH	378205.0121	8641555.291
686	1311	3	73	193.7 73.0*S	103.7	3 planar: Joint major	OHW/CPG	Ttqgb	Pink Gneiss	Medium	N/A	LH	378152.9076	8641504.751
687	1310	3	41.9	288.3 41.9*W	198.3	3 planar: Cleavage (S1)	OHW/CPG	Ttqgb	Pink Gneiss	Medium	N/A	LH	378149.4632	8641496.11
688	1309	3	50.9	274.4 50.9*W	184.4	3 planar: Cleavage (S1)	OHW/CPG	Ttqgb	Pink Gneiss	Medium	N/A	LH	378149.2498	8641495.113
689	1309	2	47.8	284.9 47.8*W	194.9	3 planar: Cleavage (S1)	OHW/CPG	Ttqgb	Pink Gneiss	Medium	N/A	LH	378147.5128	8641494.332
690	1309	3	79.6	195.4 79.6*S	105.4	3 planar: Joint major	OHW/CPG	Ttqgb	Pink Gneiss	Medium	N/A	LH	378147.5138	8641494.111
691	1309	3	47.9	283.7 47.9*W	193.7	3 planar: Shear Plane (C2)	OHW/CPG	Ttqgb	Pink Gneiss	Medium	N/A	LH	378147.8419	8641493.67
692	1309	3	53.5	274.9 53.5*W	184.9	3 planar: Shear Plane (C2)	OHW/CPG	Ttqgb	Pink Gneiss	Medium	N/A	LH	378147.8419	8641493.67

693	1308.2315	3	79.2	357.6 79.2*N	267.6	3 planar:Joint major	CHWCOPG	Ttggfb	Pink Gneiss	Medium	N/A	LH	378099.6115	8641453.099
694	1308.2315	3	85.7	19.6 85.7*N	289.6	3 planar:Joint major	CHWCOPG	Ttggfb	Pink Gneiss	Medium	N/A	LH	378099.6115	8641453.099
695	1214	5	27.9	131 27.9*E	41	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Low	Cpy	LH	378169.8138	8642303.586
696	1214	5	17.5	129.5 17.5*E	39.5	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Low	Cpy	LH	378169.8138	8642303.586
697	1214	5	79.3	9.5 79.2*N	279.5	3 planar:Joint major	COS	Ttsmq	Schist	Low	Cpy	LH	378169.8138	8642303.586
698	1214	5	0	0	0	0 planar:Point	COS	Ttsmq	Schist	Low	Cpy	LH	378169.8138	8642303.586
699	1214	5	14.4	113.3 14.4*E	23.3	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
700	1214	5	17.9	134.6 17.9*E	44.6	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
701	1214	5	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
702	1214	5	78.5	11.2 78.5*N	281.2	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
703	1214	5	21.3	117.5 21.3*E	27.5	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
704	1214	5	24.1	130.9 24.1*E	40.9	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
705	1214	5	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
706	1214	5	79.1	22.1 79.1*N	292.1	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378169.8138	8642303.586
707	1208	3	13.4	95.4 13.4*E	5.4	3 planar:Cleavage (S1)	CMGN	Ttggba	Grey Gneiss	Medium	Cpy	LH	378190.7293	8642269.608
708	1208	3	13.8	118.9 13.8*E	28.9	3 planar:Cleavage (S1)	CMGN	Ttggba	Grey Gneiss	Medium	Cpy	LH	378191.8188	8642269.17
709	1209	3	23	132.4 23.0*E	42.4	3 planar:Cleavage (S1)	CMGN	Ttggba	Grey Gneiss	Medium	Cpy	LH	378194.4494	8642264.314
710	1210	3	0	0	0	0 planar:Contact	CMGN	Ttggba	Grey Gneiss	Medium	Cpy	LH	378195.5568	8642259.563
711	1211	2	12.5	107.8 12.5*E	17.8	3 planar:Cleavage (S3)	CMGN	Ttsmq	Schist	Medium	Cpy	LH	378197.2011	8642256.473
712	1212	3	18.3	109.4 18.3*E	19.4	3 planar:Cleavage (S3)	CMGN	Ttsmq	Schist	Medium	Cpy	LH	378197.8337	8642256.476
713	1212	3	13.1	91.3 13.1*E	1.3	3 planar:Cleavage (S3)	CMGN	Ttsmq	Schist	Medium	Cpy	LH	378197.8337	8642256.476
714	1209	3	75	10.2 75.0*N	280.2	3 planar:Joint major	CMGN	Ttsmq	Schist	Medium	Cpy	LH	378211.1631	8642220.696
715	1209	3	0	0	0	0 planar:Contact	CMGN	Ttsmq	Schist	Medium	Cpy	LH	378211.1631	8642220.696
716	1209.0091	3	0	0	0	0 planar:Contact	CMGN	Ttsmq	Schist	Medium	Cpy	LH	378184.3709	8642281.637
717	1211	3	10.3	87 10.3*E	357	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378201.0713	8642241.226
718	1211	3	23.9	25.1 23.9*N	295.1	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378203.4678	8642240.351
719	1211	3	10.3	65.2 10.3*E	335.2	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378204.3457	8642238.475
720	1210	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378210.2746	8642225.116
721	1212	3	27.8	104.4 27.8*E	14.4	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378216.5753	8642200.81
722	1209	3	73.7	9.8 73.7*N	279.8	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378218.3012	8642204.246
723	1207	3	80.3	10.1 80.3*N	280.1	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378217.5477	8642202.363
724	1204	3	77.8	10.6 77.8*N	280.6	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378220.8414	8642194.966
725	1206	4	71.4	5.9 71.4*N	275.9	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378229.8101	8642182.948
726	1205	3	63.2	16.9 63.2*E	286.9	3 planar:Fault minor	COS	Ttsmq	Schist	Medium	Cpy	LH	378233.7001	8642162.945
727	1207	3	64.1	12.2 64.1*N	282.2	3 planar:Fault minor	COS	Ttsmq	Schist	Medium	Cpy	LH	378235.2154	8642164.721
728	1208.3458	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378228.2985	8642180.287
729	1209	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378247.1671	8642141.544
730	1209.0979	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378266.5788	8642076.813
731	1209	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378258.085	8642080.801
732	1208	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378267.1001	8642082.234
733	1208.8124	4	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378261.5944	8642098.47
734	1208.3429	4	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378258.404	8642107.194
735	1208.5951	4	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378253.4618	8642118.676
736	1208.8466	4	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378253.9822	8642124.319
737	1209.0937	3	78.2	8.2 78.2*N	278.2	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378254.0693	8642129.518
738	1208.4567	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378246.1832	8642142.757
739	1208.3508	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378221.5885	8642198.398
740	1207.7179	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378214.6513	8642218.83
741	1213	3	81	359 81.0*N	269	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378172.4145	8642305.919
742	1212	3	80.1	343.6 80.1*N	253.6	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378174.2611	8642306.48
743	1212	3	27.2	137.9 27.2*E	47.9	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378174.2611	8642306.48
744	1212	3	29.2	150 29.2*E	60	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378176.894	8642301.071
745	1210	5	82	0 82.0*N	269.9	3 planar:Joint minor	COS	Ttsmq	Schist	Medium	Cpy	LH	378176.7728	8642304.057
746	1209	3	19.9	139.6 19.9*E	49.6	3 planar:Joint minor	COS	Ttsmq	Schist	Medium	Cpy	LH	378177.0088	8642299.634
747	1209	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378183.3847	8642283.402
748	1209	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378179.6545	8642291.129
749	1210	3	76.2	18.3 76.2*N	288.3	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378182.8247	8642287.271
750	1210	4	20.1	135.2 20.1*E	45.2	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378183.5069	8642286.603
751	1210	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378187.4301	8642278.331
752	1209	3	74.2	15.4 74.2*N	285.4	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378186.4507	8642278.438
753	1209.653	3	77.6	9.2 77.6*N	279.2	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378190.8179	8642274.474
754	1211.3014	4	8.9	124 8.9*E	34	3 planar:Cleavage (S1)	CMGN	Ttggab	Amphibolitic gneiss	Medium	Cpy	LH	378195.3075	8642267.193
755	1210.9292	3	13.8	117.3 13.8*E	27.3	3 planar:Cleavage (S1)	CMGN	Ttggab	Amphibolitic gneiss	Medium	Cpy	LH	378195.749	8642265.647
756	1211.0825	4	17.8	107.9 17.8*E	17.9	3 planar:Cleavage (S1)	CMGN	Ttggab	Amphibolitic gneiss	Medium	Cpy	LH	378196.1983	8642262.22
757	1208	4	0	0	0	0 planar:Contact	CMGN	Ttggab	Amphibolitic gneiss	Medium	Cpy	LH	378194.0088	8642265.64
758	1216	4	0	0	0	0 planar:Contact	CMGN	Ttggab	Amphibolitic gneiss	Medium	Cpy	LH	378213.1217	8642220.483
759	1217	3	74.4	4.3 74.4*N	274.3	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378228.1814	8642182.277
760	1216	3	38.6	142.3 38.6*E	52.3	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378267.1887	8642087.101
761	1215	3	23.3	181.4 23.3*E	91.4	3 planar:Cleavage (S3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378265.9854	8642088.755
762	1210	5	39.1	33.5 39.1*N	303.5	3 planar:Shear plane (C3)	COS	Ttsmq	Schist	Medium	Cpy	LH	378211.3328	8642232.199
763	1209.2738	3	0	0	0	0 planar:Contact	COS	Ttsmq	Schist	Medium	Cpy	LH	378189.1744	8642277.343
764	1208	3	67.2	16.5 67.2*N	286.5	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378195.3898	8642247.396
765	1208	3	72	14 72.0*N	284	3 planar:Joint major	COS	Ttsmq	Schist	Medium	Cpy	LH	378195.3898	8642247.396
766	1202	6	85.3	350.1 85.3*N	260.1	3 planar:Joint major	CBGA	Thya	Undifferentiated	Low	N/A	LH	377805.9427	8641898.484
767	1203	4	78.2	9 78.2*N	279	3 planar:Joint major	CBGA	Thya	Undifferentiated	Low	Cpy	LH	377807.7963	8641897.386
768	1199.6587	3	80.7	355.7 80.7*N	265.7	3 planar:Joint major	CBGA	Thya	Undifferentiated	Low	Cpy	LH	377818.5822	8641901.415
769	1199	5	0	0	0	0 planar:Points	CBGA	Thya	Undifferentiated	Low	Cpy	LH	377811.2564	8641902.267

770	1198	3	0	0	0	0	0	0	planar:Points	CBGA	TtYa	Undifferentiated	Low	Cpy	LH	377821.2542	8641904.3
771	1199	5	0	0	0	0	0	0	0 planar:Contact	CBGA	TtYa	Undifferentiated	Low	Cpy	LH	377822.0192	8641903.418
772	1197	3	0	0	0	0	0	0	0 planar:Points	CBGA	TtYa	Undifferentiated	Low	Cpy	LH	377828.3108	8641907.426
773	1196.3938	3	0	0	0	0	0	0	0 planar:Points	CBGA	TtYa	Undifferentiated	Low	Cpy	LH	377840.2968	8641902.167
774	1195.7758	3	0	0	0	0	0	0	0 planar:Points	CBGA	TtYa	Undifferentiated	Low	Cpy	LH	377840.2968	8641902.167
775	1196.1719	3	0	0	0	0	0	0	0 planar:Points	CBGA	TtYa	Undifferentiated	Low	Cpy	LH	377841.7223	8641899.408
776	1196	3	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377842.4864	8641898.748
777	1196	2	19	162.4 19.0°S			72.4		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377842.2689	8641898.747
778	1196	11	17	138.2 17.0°S			48.2		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377844.1298	8641895.879
779	1196	11	16.4	141.1 16.4°S			51.1		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377844.1298	8641895.879
780	1199.3875	4	12.9	85.9 12.9°E			355.9		3 planar:Clearance (S1)	COS	Ttssq	Gneiss	high	Cpy	LH	377845.4115	8641896.441
781	1197	3	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377850.9763	8641897.235
782	1195	4	0	0	0	0	0	0	0 planar:Contact	COS	Ttssq	Gneiss	high	Cpy	LH	377849.3421	8641897.891
783	1195	4	7.3	112.8 7.3°E			22.8		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377850.5449	8641896.348
784	1195	6	7.4	112.8 7.4°E			22.8		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377850.5449	8641896.348
785	1194	10	24.9	86.5 24.9°E			356.5		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377854.591	8641896.095
786	1196.0869	4	0	0	0	0	0	0	0 planar:Contact	COS	Ttssq	Gneiss	high	Cpy	LH	377854.1466	8641893.377
787	1198.9716	4	89.1	346.6 89.1°N			256.6		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377854.1466	8641893.377
788	1197.5787	4	83.9	15 83.9°N			285		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377858.1258	8641896.366
789	1196.0869	4	0	0	0	0	0	0	0 planar:Contact	COS	Ttssq	Gneiss	high	Cpy	LH	377860.8875	8641893.958
790	1199.3069	3	0	0	0	0	0	0	0 planar:Contact	COS	Ttssq	Gneiss	high	Cpy	LH	377850.4486	8641893.361
791	1198	7	0	0	0	0	0	0	0 planar:Contact	COS	Ttssq	Gneiss	high	Cpy	LH	377865.2454	8641892.206
792	1196	7	29	170.7 29.0°S			80.7		3 planar:Shear plane (C3)	COS	Ttssq	Gneiss	high	Cpy	LH	377875.1854	8641893.479
793	1197	5	14.6	76.5 14.6°E			346.5		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377875.8429	8641892.857
794	1197	5	23.7	55.2 23.7°E			325.2		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377875.3548	8641893.062
795	1197	5	27	70.7 27.0°E			340.7		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377877.0051	8641889.048
796	1198	5	18.6	78.2 18.6°E			348.2		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377877.548	8641889.271
797	1199	3	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377858.2795	8641893.394
798	1198	3	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377860.8861	8641894.29
799	1200	5	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377874.3828	8641891.913
800	1202	5	27.2	75.7 27.2°E			345.7		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377879.6038	8641891.824
801	1202	5	21.1	32.6 21.1°N			302.6		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377879.6038	8641891.824
802	1202	5	15.8	77.7 15.8°E			347.7		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377878.3001	8641891.487
803	1201	5	0	0	0	0	0	0	0 planar:Contact	COS	Ttssq	Gneiss	high	Cpy	LH	377882.3335	8641889.291
804	1200	5	75.1	14.1 75.1°N			284.1		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377889.3901	8641892.418
805	1200	5	76	8 76.0°N			278		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377889.5021	8641891.644
806	1200	5	22.9	48.4 22.9°E			319.4		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377889.5021	8641891.644
807	1197.3776	5	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377884.8237	8641893.169
808	1200	5	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377900.2714	8641891.246
809	1200	9	16.1	112.5 16.1°E			22.5		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377898.9691	8641890.577
810	1200	5	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377898.7529	8641890.245
811	1203.9029	5	82.8	356.6 82.8°N			266.6		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377902.6711	8641889.597
812	1201	5	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377912.1318	8641895.402
813	1206	5	79.1	5.4 79.1°N			275.4		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377913.5391	8641891.634
814	1208	5	77.8	3.3 77.8°N			273.3		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377912.4385	8641894.726
815	1209	5	76.1	9.1 76.1°N			279.1		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377912.5454	8641895.169
816	1209	5	8.2	55 8.2°E			325		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377912.5454	8641895.169
817	1208	5	21.8	84.7 21.8°E			354.7		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377913.4174	8641894.73
818	1203	5	33.3	72.1 33.3°E			342.1		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377919.197	8641891.104
819	1203	5	18.1	64.1 18.1°E			334.1		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377919.0887	8641890.993
820	1203	5	11.9	346.8 11.9°N			256.8		3 axial:Lineation (L3)	COS	Ttssq	Gneiss	high	Cpy	LH	377919.1975	8641890.594
821	1203	5	15.2	349.1 15.2°N			259.1		3 axial:Lineation (L3)	COS	Ttssq	Gneiss	high	Cpy	LH	377919.3095	8641890.22
822	1203	5	9.5	45.8 9.5°E			315.8		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377921.3653	8641892.772
823	1203	5	15.5	133.8 15.5°E			43.8		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377921.3653	8641892.772
824	1202	5	30.7	111.7 30.7°E			21.7		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377927.7502	8641893.011
825	1203	5	24.8	91.3 24.8°E			1.3		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377933.0052	8641892.268
826	1203	5	10.7	57.6 10.7°E			327.6		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377933.4403	8641892.27
827	1202	5	27	68.1 27.0°E			338.1		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377935.3943	8641893.163
828	1202	5	16	19.5 16.0°N			289.5		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377934.9739	8641895.339
829	1202.1911	5	10.8	92.7 10.8°E			2.7		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377936.5623	8641895.698
830	1200	5	19	97.9 19.0°E			7.9		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377936	8641896.274
831	1202.7983	5	10	260.9 10.0°W			170.9		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377938.6639	8641897.628
832	1198.5539	5	68.3	12.6 68.3°N			282.3		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377950.2011	8641898.418
833	1198.5539	5	70.2	20.4 70.2°N			290.4		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377942.4368	8641899.152
834	1198.5539	4	70.4	11.9 70.4°N			281.9		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377949.86	8641899.806
835	1197.12	4	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377928.593	8641895.767
836	1196.7491	4	0	0	0	0	0	0	0 planar:Points	COS	Ttssq	Gneiss	high	Cpy	LH	377937.5595	8641898.866
837	1197.1785	4	18.4	278.4 18.4°W			188.4		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377944.6418	8641892.537
838	1197.1785	4	15.2	322.8 15.2°N			232.8		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377942.4875	8641899.682
839	1197.1785	4	3.8	312.5 3.8°W			222.5		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377943.4712	8641899.761
840	1199.5873	5	32	73.4 32.0°E			343.4		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377944.8108	8641899.733
841	1201.0216	4	15.9	86 15.9°E			356		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377949.1031	8641899.825
842	1200.2262	5	17.6	110.3 17.6°E			20.3		3 planar:Clearance (S3)	COS	Ttssq	Gneiss	high	Cpy	LH	377946.2598	8641898.505
843	1199	6	85	65.2 85.0°E			335.2		3 planar:Joint minor	COS	Ttssq	Gneiss	high	Cpy	LH	377945.3533	8641899.011
844	1200	7	73.8	10 73.8°N			280		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377954.031	8641899.818
845	1200	6	73.8	11.9 73.8°N			281.9		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377954.196	8641899.811
846	1200	5	71.5	12.7 71.5°N			282.7		3 planar:Joint major	COS	Ttssq	Gneiss	high	Cpy	LH	377953.9806	8641896.116

847	1200	4	0	0	0	0	0 planar/Points	COS	Ttsq	Gneiss	high	Cpy	LH	377953.9756	8641897.332
848	1199	4	0	0	0	0	0 planar/Points	COS	Ttsq	Gneiss	high	Cpy	LH	377955.0661	8641897.835
849	1197.5723	4	16.8	269.3 16.8*W		179.3	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377958.7124	8641902.363
850	1197.2337	4	20.6	299.2 20.6*W		209.2	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377959.2439	8641901.748
851	1198.9344	4	19.2	196.5 19.2*E		106.5	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377958.9042	8641901.663
852	1197.8109	4	82.6	0 82.6*N		270	3 planar/Joint major	COS	Ttsq	Gneiss	high	Cpy	LH	377964.7381	8641904.433
853	1197.7333	4	79.3	1.3 79.3*N		271.3	3 planar/Joint major	COS	Ttsq	Gneiss	high	Cpy	LH	377966.1813	8641896.056
854	1196	5	83.5	14.5 83.5*N		284.5	3 planar/Joint major	COS	Ttsq	Gneiss	high	Cpy	LH	377965.8822	8641904.75
855	1198.6171	4	69.1	12.9 69.1*N		282.9	3 planar/Joint major	COS	Ttsq	Gneiss	high	Cpy	LH	377966.1919	8641903.787
856	1197.4668	5	4.7	3.2 4.7*W		273.2	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377964.4772	8641904.411
857	1196	4	3.3	299.9 3.3*W		209.9	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377964.4498	8641904.507
858	1197.4668	4	3.4	195.4 3.4*E		105.4	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377963.4308	8641904.077
859	1197.4668	5	11.1	263.7 11.1*W		173.7	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377963.9125	8641904.212
860	1197.1953	3	21	193.3 21.0*E		103.3	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377967.6356	8641904.587
861	1197.0958	4	16.6	161.3 16.6*E		71.3	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377963.9592	8641903.01
862	1199.8699	3	8.7	222.6 8.7*E		132.6	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377969.9622	8641904.765
863	1198.2108	7	23.5	73.1 23.5*E		343.1	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	377971.1948	8641906.12
864	1200.3978	6	89.1	138.6 89.1*E		48.6	3 planar/Joint minor	COS	Ttsq	Gneiss	high	Cpy	LH	377971.9648	8641904.306
865	1197.7749	6	5.2	135.1 5.2*E		45.1	3 planar/Joint minor	COS	Ttsq	Gneiss	high	Cpy	LH	377978.6294	8641906.377
866	1196.9303	6	6.3	1.7 6.3*N		271.7	3 planar/Joint minor	COS	Ttsq	Gneiss	high	Cpy	LH	377978.6323	8641906.363
867	1197.7749	6	10.4	102.6 10.4*E		12.6	3 planar/Joint minor	COS	Ttsq	Gneiss	high	Cpy	LH	377980.7509	8641906.386
868	1194	4	9.6	191.5 9.6*E		101.5	3 planar/Joint minor	COS	Ttsq	Gneiss	high	Cpy	LH	377986.3552	8641908.419
869	1200.2511	6	28.9	167.5 28.9*E		77.1	3 planar/Shear plane (C3)	COS	Ttsq	Gneiss	high	Cpy	LH	377991.0769	8641894.279
870	1197.1714	6	0	0	0	0	0 planar/Points	COS	Ttsq	Gneiss	high	Cpy	LH	377989.4686	8641904.784
871	1197	6	80.3	4.8 80.3*N		274.8	3 planar/Joint major	COS	Ttsq	Gneiss	high	Cpy	LH	377998.0543	8641905.794
872	1200.2606	6	0.4	150.8 0.4*E		60.8	3 planar/Cleavage (S3)	COS	Ttsq	Gneiss	high	Cpy	LH	378003.9928	8641904.383
873	1201	5	17.2	298.1 17.2*W		208.1	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	377978.6282	8641906.173
874	1202	5	18.2	141.4 18.2*E		51.4	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	377978.1973	8641905.175
875	1199	5	4.6	306.6 4.6*W		216.6	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	377979.6038	8641906.951
876	1199	3	15.6	185.1 15.6*E		95.1	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	377980.8044	8641905.96
877	1198	3	17.2	137.7 17.2*E		47.7	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	377982.009	8641903.975
878	1201.3717	5	23.8	304.1 23.8*W		214.1	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	377988.9915	8641898.805
879	1196.5959	5	84.9	343.1 84.9*N		253.1	3 planar/Joint major	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	377980.8473	8641909.115
880	1196.5959	5	85.8	357.2 85.8*N		267.2	3 planar/Joint major	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	377990.8367	8641906.612
881	1202	4	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378054.277	8641918.433
882	1203	3	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378051.3524	8641919.749
883	1198	3	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378034.0164	8641910.166
884	1198	4	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378031.0344	8641913.353
885	1197	4	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378051.3556	8641914.771
886	1200	3	60.2	149.8 60.2*E		59.8	3 planar/Shear plane (C3)	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378059.6091	8641917.791
887	1201	4	65.1	139.2 65.1*E		49.2	3 planar/Shear plane (C3)	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378059.5008	8641917.68
888	1202	3	16	93.2 16.0*E		3.2	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378057.9791	8641917.453
889	1202	4	40.7	99.2 40.7*E		9.2	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378057.6542	8641917.119
890	1202	3	13.4	129.7 13.4*E		39.7	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378059.5123	8641914.915
891	1202	4	75.6	11.7 75.6*N		281.7	3 planar/Joint major	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378051.6819	8641914.772
892	1199	4	20.8	104.5 20.8*E		14.5	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378044.4031	8641912.751
893	1199	4	15.5	111.1 15.5*E		21.1	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378044.6216	8641912.531
894	1199	4	20.9	142.7 20.9*E		52.7	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378044.6216	8641912.531
895	1199	5	21.7	146.5 21.7*E		56.5	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378044.4068	8641911.866
896	1199	3	9.3	157.2 9.3*E		67.2	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378044.8442	8641911.315
897	1199	3	22.2	144. 22.2*E		54	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378043.3642	8641911.18
898	1196.9022	4	25.9	218.8 25.9*E		128.8	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378036.3658	8641910.063
899	1198.7011	4	14.1	3.4 14.1*N		273.4	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378036.3658	8641910.063
900	1196.8357	3	32	173.5 32.0*E		83.5	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378037.1276	8641909.955
901	1198	3	85.6	358.7 85.6*N		268.7	3 planar/Joint minor	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378032.2296	8641910.82
902	1198	3	87	32.5 87.0*N		302.5	3 planar/Joint minor	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378031.9024	8641911.04
903	1198	3	18.4	214.8 18.4*E		124.8	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378031.9015	8641911.261
904	1197	3	21.6	62.9 21.6*E		332.9	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378030.2686	8641911.586
905	1197	3	82.1	304.9 82.1*W		214.9	3 planar/Joint major	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378027.6676	8641909.363
906	1197	3	79.6	294.7 79.6*W		204.7	3 planar/Joint major	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378027.6676	8641909.363
907	1198.6464	3	29.2	331.4 29.2*N		241.4	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378026.8044	8641907.7
908	1196	3	22.2	216.3 22.2*E		126.3	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378025.39	8641907.805
909	1196	3	22.1	256 22.1*W		166	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378025.2812	8641907.805
910	1197.3011	4	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378020.1841	8641904.244
911	1196.9039	15	16	164.5 16.0*E		74.5	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	377995.9	8641908.992
912	1196.1922	7	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378005.6766	8641906.78
913	1196.2543	7	0	0	0	0	0 planar/Points	COS	Ttsq	Grey Gneiss	Medium	Cpy	LH	378002.3217	8641906.254
914	1196.8095	7	19.7	160.4 19.7*E		70.4	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378022.1354	8641905.801
915	1196.8095	7	23.4	71.6 23.4*E		341.6	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378022.2446	8641905.691
916	1196.6976	7	26.7	68.3 26.7*E		338.3	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378021.7022	8641905.357
917	1196.8095	7	16.9	144.3 16.9*E		54.3	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378020.0708	8641905.35
918	1196.9858	7	15.9	146.9 15.9*E		56.9	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378020.0708	8641905.35
919	1196.7666	7	21	221.2 21.0*E		131.2	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378018.3315	8641905.121
920	1196.6382	8	12.4	160 12.4*E		70	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378018.5499	8641904.901
921	1197.0864	8	16.7	45.7 16.7*E		315.7	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378017.8988	8641904.567
922	1197.4976	8	24.7	111.3 24.7*E		21.3	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378013.9865	8641903.776
923	1200.9118	9	31.3	27.9 31.3*N		297.9	3 planar/Cleavage (S3)	COS	Ttsq	Schist	Medium	Cpy	LH	378010.0711	8641903.76

924	1197	8	19.1	111.4 19.1°E	21.4	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378009.9614	8641903.98
925	1197.8916	4	22.1	78.9 22.1°E	348.9	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378009.0941	8641903.313
926	1197	3	8.7	219.4 8.7°S	129.4	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378008.8761	8641903.423
927	1196.6214	5	34.7	178.9 34.7°S	88.9	3 planar/Shear plane (C3)	COS	Tssq	Grey Gneiss	Medium	Cpy	LH	378006.6958	8641904.63
928	1196.6661	5	9.3	346 9.3°N	256	3 planar/Points	COS	Tssq	Grey Gneiss	Medium	Cpy	LH	378016.6923	8641908.433
929	1197.2421	5	0	0	0	0 planar/Contact	COS	Tssq	Grey Gneiss	Medium	Cpy	LH	378012.7829	8641909.086
930	1196.3752	5	0	0	0	0 planar/Contact	COS	Tssq	Grey Gneiss	Medium	Cpy	LH	377997.3083	8641906.255
931	1196.3546	5	0	0	0	0 planar/Contact	COS	Tssq	Grey Gneiss	Medium	Cpy	LH	377993.2435	8641906.565
932	1196.5552	5	0	0	0	0 planar/Contact	COS	Tssq	Grey Gneiss	Medium	Cpy	LH	378008.5574	8641907.968
933	1196.2507	7	0	0	0	0 planar/Contact	COS	Tssq	Grey Gneiss	Medium	Cpy	LH	377991.0608	8641906.818
934	1203.3092	4	0	0	0	0 planar/Points	CBG	Peg. Pegmatite	Low	N/A	LH	377777.8917	8641896.045	
935	1203.163	4	0	0	0	0 planar/Points	CBG	Peg. Pegmatite	Low	N/A	LH	377773.4232	8641898.238	
936	1201.6509	4	77.2	65.8 77.2°E	335.8	3 planar/Joint major	CBG	Peg. Pegmatite	Low	N/A	LH	377773.3679	8641903.586	
937	1201.6509	4	77.5	65.9 77.5°E	335.9	3 planar/Joint major	CBG	Peg. Pegmatite	Low	N/A	LH	377772.6509	8641904.032	
938	1201.6509	4	72	70.6 72.0°E	340.6	3 planar/Joint major	CBG	Peg. Pegmatite	Low	N/A	LH	377772.9982	8641903.552	
939	1201.6509	4	72.1	71.7 72.1°E	341.7	3 planar/Joint major	CBG	Peg. Pegmatite	Low	N/A	LH	377773.1988	8641903.829	
940	1201.6509	4	69.7	64.6 69.7°E	334.6	3 planar/Joint major	CBG	Peg. Pegmatite	Low	N/A	LH	377773.9273	8641903.478	
941	1200.9574	4	75.5	64.7 75.5°E	334.7	3 planar/Joint major	CBG	Peg. Pegmatite	Low	N/A	LH	377780.8055	8641902.45	
942	1204.2543	4	0	0	0	0 planar/Points	CBG	Peg. Pegmatite	Low	N/A	LH	377781.8035	8641896.946	
943	1202.5411	4	0	0	0	0 planar/Points	CBG	Peg. Pegmatite	Low	N/A	LH	377776.0354	8641897.807	
944	1204.8703	4	0	0	0	0 planar/Points	CBG	Peg. Pegmatite	Low	N/A	LH	377768.6331	8641899.324	
945	1204	4	0	0	0	0 planar/Points	CBG	Peg. Pegmatite	Low	N/A	LH	377754.0303	8641906.121	
946	1293	2	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377916.6292	8641437.516	
947	1294	2	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377903.3609	8641437.35	
948	1294	5	84.4	184.8 84.4°S	94.8	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377891.3931	8641438.295	
949	1295	5	89.7	49.5 89.7°E	319.5	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377892.0604	8641434.759	
950	1296	5	70.8	60.9 70.8°E	330.9	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377892.1719	8641434.096	
951	1296	5	67	51.9 67.0°E	321.9	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377892.1719	8641434.096	
952	1295	5	18.2	226.2 18.2°W	136.2	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377892.8282	8641433.214	
953	1296	4	4.3	180.8 4.3°S	90.8	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377893.372	8641433.216	
954	1296	5	20.4	255.1 20.4°W	165.1	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377891.4115	8641433.871	
955	1292	2	66.2	58.8 66.2°E	328.8	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377887.0749	8641430.535	
956	1291	4	89.9	119.1 89.9°E	29.1	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377884.8896	8641432.959	
957	1291	5	23.2	293.3 23.2°W	203.3	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377883.6964	8641432.18	
958	1291	3	14.3	202 14.3°S	112	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377879.2409	8641431.277	
959	1291	3	14.2	266.7 14.2°W	176.7	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377879.1322	8641431.276	
960	1291	4	77.4	220.6 77.4°S	130.6	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377879.1313	8641431.498	
961	1292	5	21.7	278.1 21.7°W	188.1	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377878.5847	8641432.159	
962	1292	3	14.7	276.1 14.7°W	186.1	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377878.3681	8641431.937	
963	1294	5	19.3	183.5 19.3°S	93.5	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377875.4306	8641432.146	
964	1294	5	67.3	39.9 67.3°N	309.9	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377875.32	8641432.588	
965	1295	5	66.1	38.6 66.1°N	308.6	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377874.6675	8641432.585	
966	1295	3	89.8	120 89.8°E	30	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377874.3389	8641433.137	
967	1296	4	88	180 88.0°S	90	3 planar/Joint minor	CHWCGS	Tggb	Low	N/A	LH	377873.0268	8641434.79	
968	1296	3	82.5	33.8 82.5°N	303.8	3 planar/Joint minor	CHWCGS	Tggb	Low	N/A	LH	377872.3715	8641435.451	
969	1299	5	59.1	43.1 59.1°N	313.1	3 planar/Joint minor	CHWCGS	Tggb	Low	N/A	LH	377866.4929	8641436.754	
970	1299	5	66.2	39.1 66.2°N	309.1	3 planar/Joint minor	CHWCGS	Tggb	Low	N/A	LH	377866.4929	8641436.754	
971	1299	3	23.9	289.8 23.9°W	199.8	3 planar/Cleavage (S1)	CHWCGS	Tggb	Low	N/A	LH	377865.838	8641437.304	
972	1302	3	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377886.7117	8641439.382	
973	1300	3	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377867.3482	8641440.297	
974	1300	2	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377862.8839	8641441.495	
975	1299	2	49.9	20.2 49.9°N	290.2	3 planar/Shear plane (C1)	CHWCGS	Tggb	Low	N/A	LH	377855.5873	8641443.787	
976	1299	2	53.7	25 53.7°N	295	3 planar/Shear plane (C1)	CHWCGS	Tggb	Low	N/A	LH	377856.0219	8641443.899	
977	1299	3	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377852.86	8641445.766	
978	1299	2	64.7	66.4 64.7°E	336.4	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377847.8633	8641443.755	
979	1300	4	89.4	83.8 89.4°E	333.6	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377845.5739	8641445.515	
980	1300	4	89.1	55.1 89.1°E	325.1	3 planar/Joint major	CHWCGS	Tggb	Low	N/A	LH	377845.5739	8641445.515	
981	1299	3	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377841.7691	8641445.056	
982	1299	3	0	0	0	0 planar/Points	CHWCGS	Tggb	Low	N/A	LH	377838.1773	8641445.705	
983	1301	3	71.6	33.9 71.6°N	303.9	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377836.3366	8641443.706	
984	1301	3	70.3	234.2 70.3°W	144.2	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377836.3376	8641443.485	
985	1300	2	89.7	297.7 89.7°W	207.7	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377830.0271	8641444.012	
986	1298	4	45.8	100.9 45.8°E	10.9	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377827.9778	8641439.911	
987	1292	3	0	0	0	0 planar/Points	CHWCPG	Tggb	Low	N/A	LH	377802.6585	8641460.599	
988	1292	3	70.7	68.8 70.7°E	338.8	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377768.9325	8641462.891	
989	1293	4	55.7	67.7 55.7°E	337.7	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377767.0817	8641462.995	
990	1293	3	83.4	356.5 83.4°N	266.5	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377767.0817	8641463.326	
991	1292	3	88.2	357.4 88.2°N	267.4	3 planar/Joint major	CHWCPG	Tggb	Low	N/A	LH	377763.1525	8641466.627	
992	1205	4	8.4	180.2 8.4°S	90.2	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378232.3491	8642147.787
993	1214	4	17.4	199.8 17.4°S	109.8	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378228.1989	8642125.76
994	1224	6	17.4	203.1 17.4°S	113.1	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378232.6168	8642135.733
995	1225	14	18.1	113.3 18.1°E	23.3	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378234.9714	8642144.922
997	1236	11	11.1	196.4 11.1°S	106.4	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378227.002	8642125.866
998	1200	5	20.9	206.9 20.9°S	116.9	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378240.9488	8642146.053
999	1200	5	19.8	191.4 19.8°S	101.4	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378238.7795	8642144.606
1000	1199	4	22.4	112 22.4°E	22	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378238.5569	8642145.822
1001	1198	4	14.7	148 14.7°S	58	3 planar/Cleavage (S3)	COS	Tssq	Schist	Medium	Cpy	LH	378239.7634	8642143.394

Appendix B. Modelled internal units and the input drill hole identities.

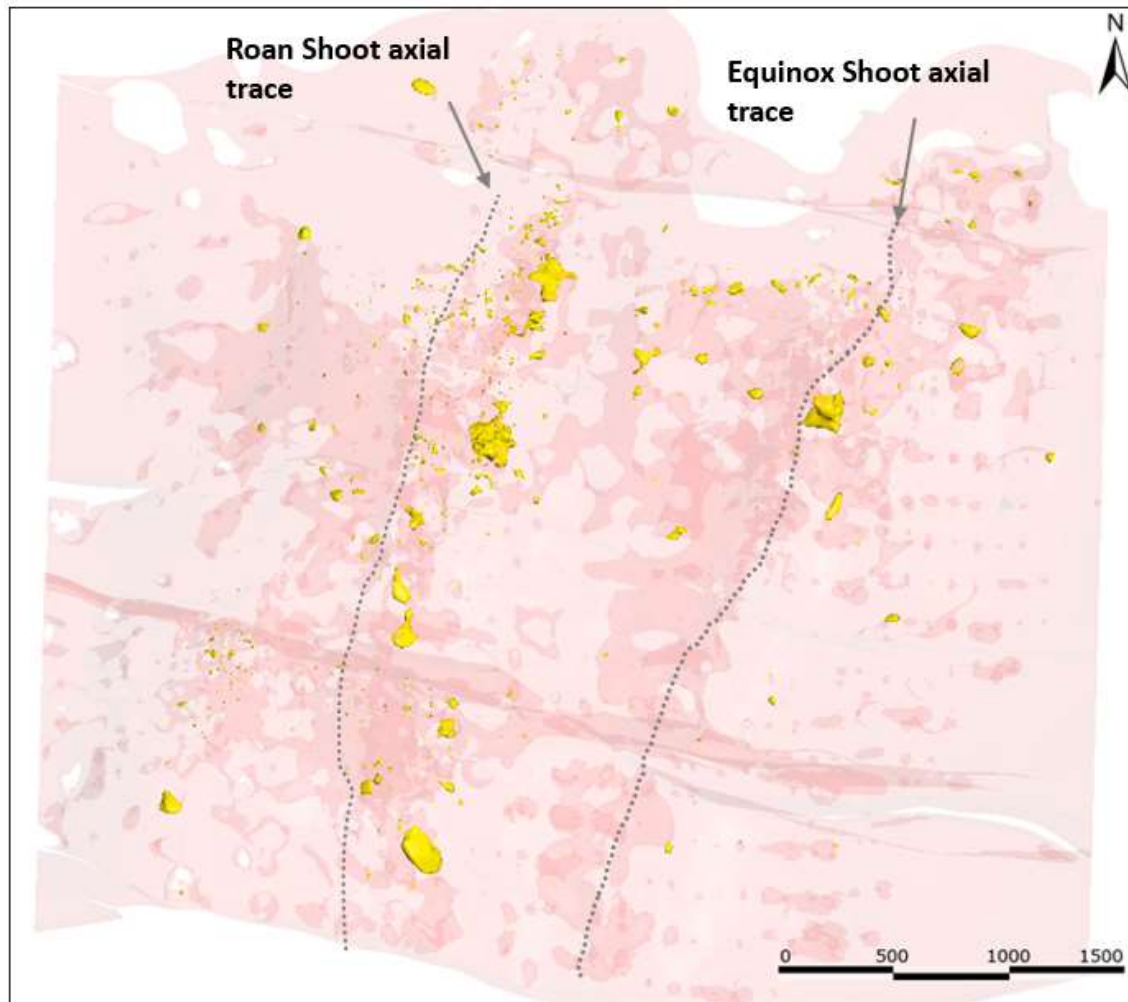


Figure B.1. Modelled leucosome boudins. The unit is mainly aligned with the eastern flanks of the two shoots. However, the Equinox Shoot is not yet as well drilled out as the Roan Shoot; hence the unit appears to be poorly registered along this shoot.

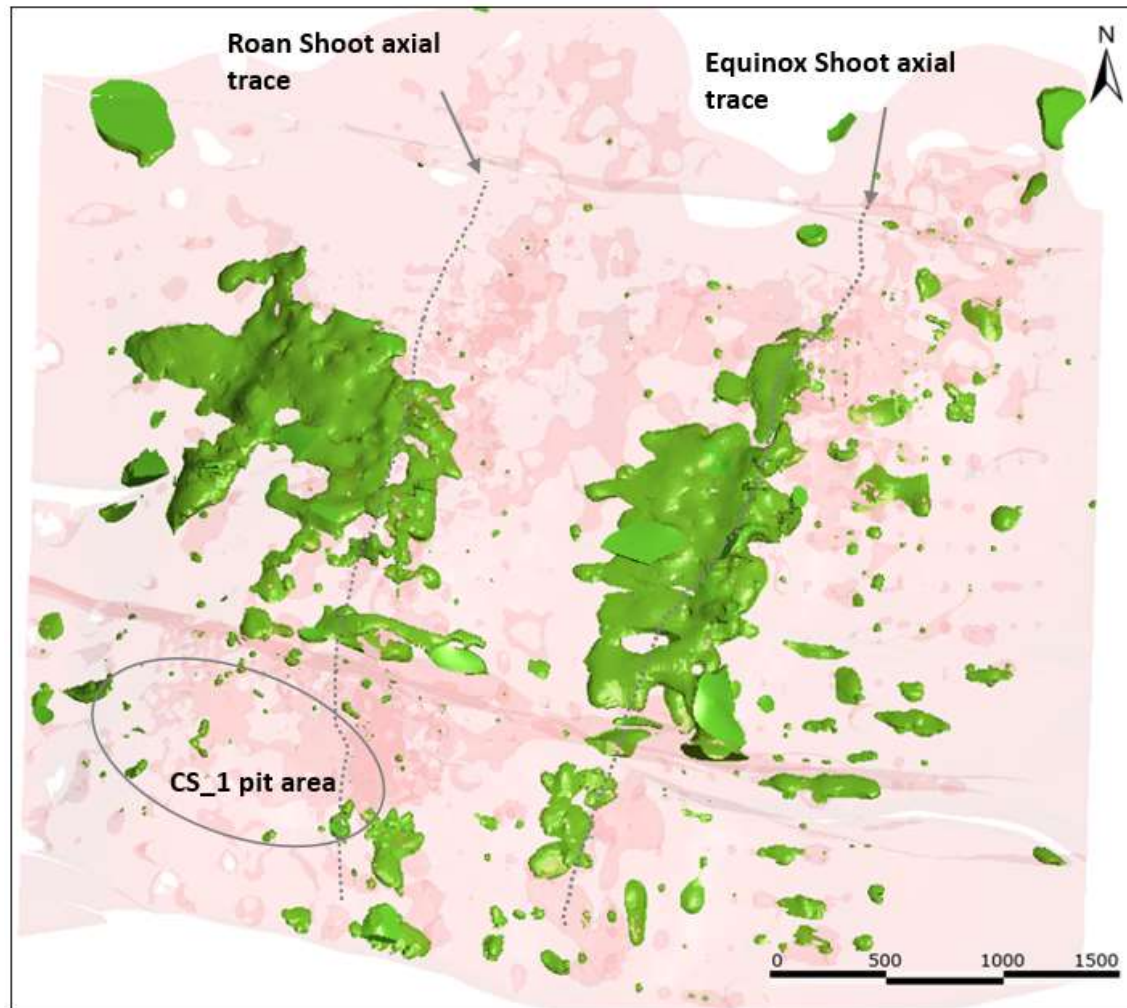


Figure B.2. Modelled amphibolites. The amphibolites show a strong correlation with the two shoots. They are the dominant units in the two shoots and largely responsible for their development. In the Chimiwungo South_1 pit area, the amphibolites appear to be less present. This is because of lack of mapping data to validate the drill hole logging data.

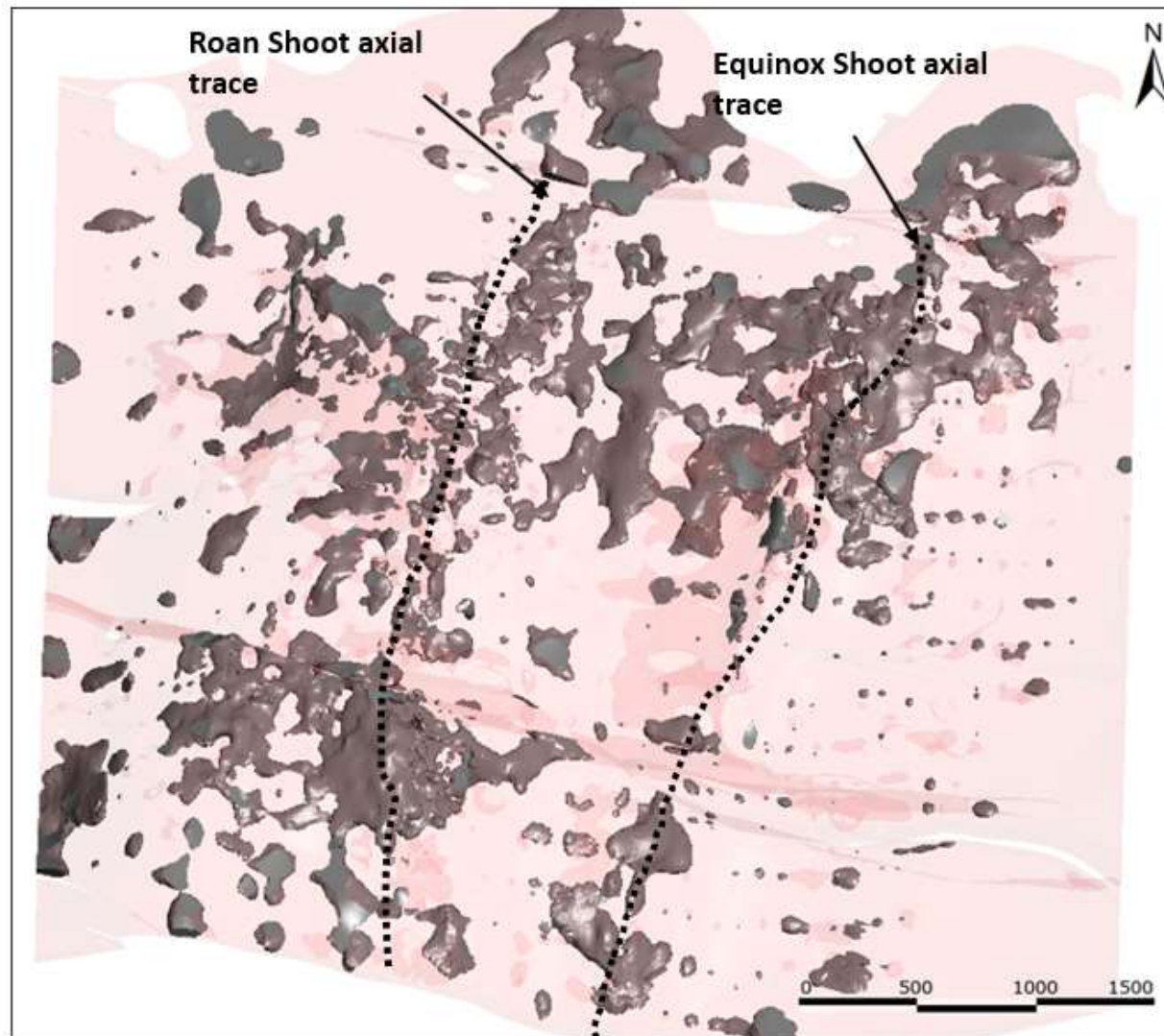


Figure B.3. The Grey Gneiss model. The Grey Gneiss represents one of the major units in the shear zone. It is also one of the units which is responsible for the structural configuration of the Chimiwungo mineralised shear zone.

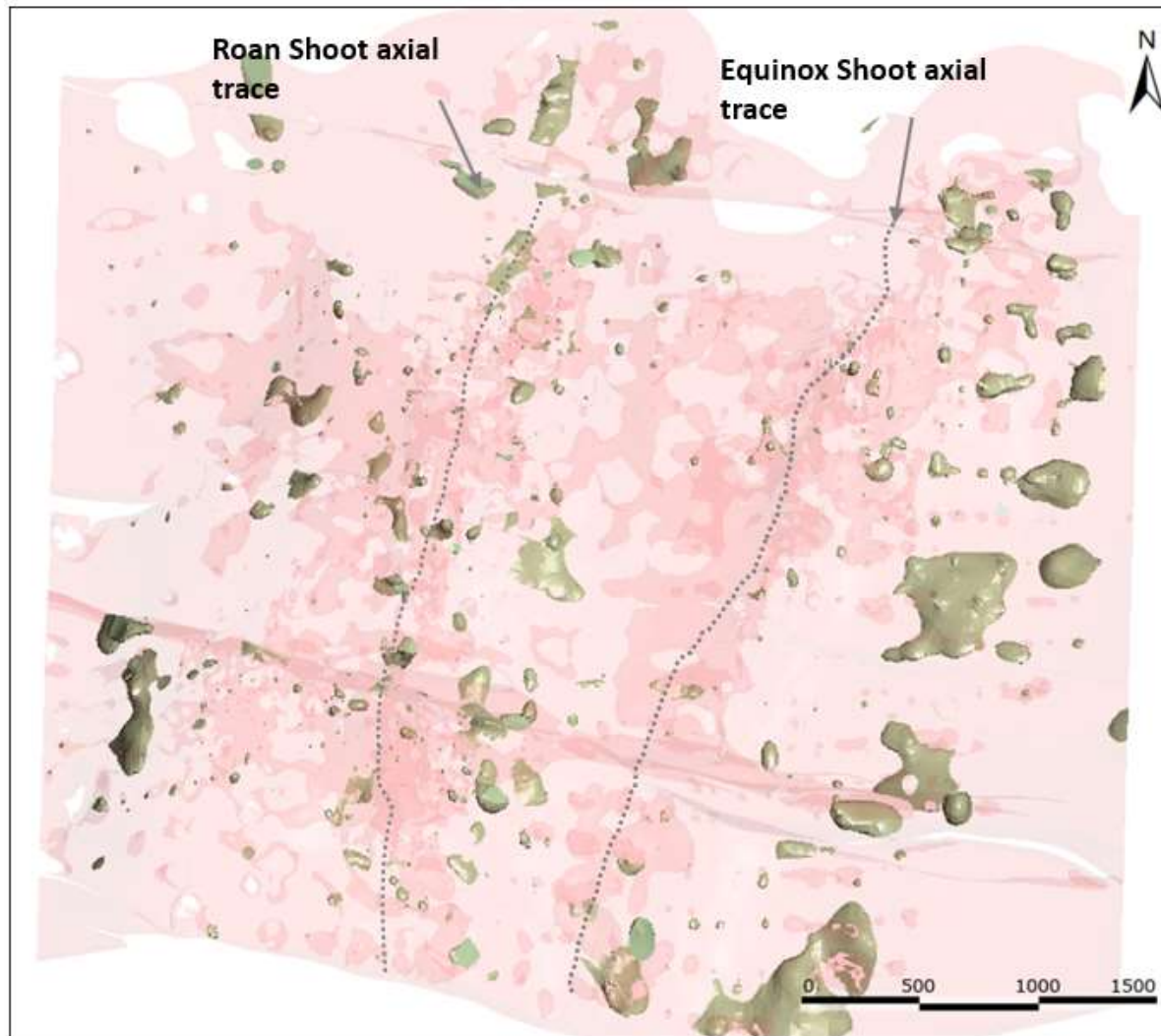


Figure B.4. Biotite Schist model. This unit represents layers of the either the retrogressed part of the amphibolites and/or shear zones dominated by phlogopite/biotite assemblages. The unit is dominant on the eastern aspect on the Equinox shoot, rightly so being the direction of ductile flow and shear fabric development.

Table B-1. List of Diamond Drill holes used for modelling internal units

MMC479	MMC784	CSA043	CEA094	CHM0116	CHM0217	EQCHI037	EQCHI084	EQCHI136	EQCHI198	EQCHI265	CHI0962
MMC590	MMC786	CSA002	CEA095	CHM0117	CHM0218	EQCHI038	EQCHI085	EQCHI137	EQCHI199	EQCHI266	CHI0963
MMC591	PHC001	CSA007	CEA096	CHM0118	CHM0223	EQCHI039	EQCHI086	EQCHI138	EQCHI200	EQCHI267	CHI0964
MMC592	PHC002	CSA008	CEA097	CHM0119	CHM0227	EQCHI040	EQCHI087	EQCHI139	EQCHI201	EQCHI268	CHI0965
MMC593	PHC003	CSA011	CEA100	CHM0120	CHM0228	EQCHI041	EQCHI088	EQCHI140	EQCHI202	EQCHI269	CHI0966
MMC594	PHC005	CSA012	CEA101	CHM0121	CHM0229	EQCHI042	EQCHI089	EQCHI141	EQCHI203	EQCHI270	CHI0967
MMC595	PHC006	CSA013	CEA102	CHM0122	CHM0234	EQCHI043	EQCHI090	EQCHI142	EQCHI204	EQCHI271	CHI0968
MMC596	PHC007	CSA014	CEA103	CHM0123	CHM0235	EQCHI044	EQCHI091	EQCHI143	EQCHI205	EQCHI272	CHI0969
MMC597	PIEZ09	CSA016	CMW200	CHM0124	CHM0236	EQCHI045	EQCHI092	EQCHI144	EQCHI206	EQCHI273	CHI0970
MMC633	PIEZ09C	CSA017	CMW201	CHM0125	CHM0240	EQCHI046	EQCHI093	EQCHI145	EQCHI207	EQCHI274	CHI0971
MMC661	CMW002	CSA018	CMW202	CHM0126	CHM0246	EQCHI047	EQCHI094	EQCHI146	EQCHI208	EQCHI278	CHI0972
MMC666	CMW003	CSA019	CMW203	CHM0127	CHM0247	EQCHI048	EQCHI095	EQCHI147	EQCHI209	EQCHI279	CHI0973
MMC670	CMW005	CSA020	CMW218	CHM0128	CHM0248	EQCHI049	EQCHI096	EQCHI148	EQCHI215	EQCHI280	CHI0974
MMC672	CMW006	CSA022	CSA001	CHM0129	CHM0254	EQCHI050	EQCHI097	EQCHI151	EQCHI216	EQCHI281	CHI0976
MMC674	CMW007	CSA023	CSA003	CHM0130	CHM0255	EQCHI051	EQCHI098	EQCHI152	EQCHI217	EQCHI282	CHI0977
MMC704	CMW205	CSA026	CSA006	CHM0131	CHM0261	EQCHI052	EQCHI099	EQCHI153	EQCHI218	EQCHI283	CHI0978
MMC705	CMW207	CSA027	CSA021	CHM0132	CHM0317	EQCHI053	EQCHI100	EQCHI154	EQCHI219	EQCHI284	CHI0979
MMC706	CMW215	CSA028	CSA024	CHM0133	CHM0318	EQCHI054	EQCHI101	EQCHI156	EQCHI220	EQCHI285	CHI0980
MMC707	CMW219	CSA029	CSA025	CHM0134	CHM0319	EQCHI055	EQCHI103	EQCHI157	EQCHI221	EQCHI286	CHI0981
MMC708	CMW220	CSA030	CSA031	CHM0136	CHM0320	EQCHI056	EQCHI104	EQCHI158	EQCHI222	EQCHI287	CHI0982
MMC709	CEA032	CSA032	CSA034	CHM0137	CHM0322	EQCHI057	EQCHI105	EQCHI159	EQCHI223	EQCHI288	CHI0983
MMC710	CEA033	CSA033	CSA038	CHM0138	CHM0323	EQCHI058	EQCHI106	EQCHI160	EQCHI224	EQCHI289	CHI0984
MMC723	CEA034	CSA035	CSA045	CHM0139	CHM0324	EQCHI059	EQCHI108	EQCHI161	EQCHI225	EQCHI290	CHI0985
MMC725	CEA035A	CSA036	CSA048	CHM0140	CHM0327	EQCHI060	EQCHI109	EQCHI162	EQCHI226	EQCHI291	CHI0986
MMC740	CEA037	CSA037	CEA052	CHM0141	CHM0328	EQCHI061	EQCHI110	EQCHI163	EQCHI227	EQCHI292	CHI0987
MMC743	CEA038	CSA040	CEA053	CHM0143	CHM0329	EQCHI062	EQCHI111	EQCHI164	EQCHI228	EQCHI293	CHI0988
MMC745	CEA039	CSA041	CEA062	CHM0145	CHM0331	EQCHI063	EQCHI112	EQCHI165	EQCHI229	EQCHI294	CHI0989
MMC748	CEA040	CSA042	CEA063	CHM0146	CHM0332	EQCHI064	EQCHI113	EQCHI166	EQCHI230	EQCHI295	CHI0990
MMC752	CEA041	CEA046	CEA064	CHM0150	CHM0333	EQCHI065	EQCHI115	EQCHI167	EQCHI231	EQCHI301	CHI0991
MMC754	CEA042	CEA047	CEA070	CHM0151	CHM0336	EQCHI066	EQCHI116	EQCHI168	EQCHI232	EQCHI302	CHI0992
MMC758	CEA043	CSA015	CEA071	CHM0154	CHM0338	EQCHI067	EQCHI117	EQCHI169	EQCHI237	EQCHI303	CHI0993
MMC761	CEA044	CEA048	CEA076	CHM0156	CHM0340	EQCHI068	EQCHI118	EQCHI170	EQCHI238	EQCHI304	CHI0994
MMC766	CEA045	CEA054	CEA081	CHM0160	CHM0342	EQCHI069	EQCHI119	EQCHI171	EQCHI239	EQCHI305	CHI0995
MMC769	CEA049	CEA055	CEA082	CHM0162	CHM0344	EQCHI070	EQCHI120	EQCHI172	EQCHI240	EQCHI306	CHI0996
MMC770	CMW001	CEA056	CEA084A	CHM0163	CHM0348	EQCHI071	EQCHI121	EQCHI177	EQCHI244	EQCHI307	CHI0997
MMC771	CMW011	CEA057	CEA104	CHM0166	CHM0351	EQCHI072	EQCHI122	EQCHI182	EQCHI245	EQCHI308	CHI0998
MMC772	CMW018	CEA065	CEA105	CHM0168	CHM0355	EQCHI073	EQCHI123	EQCHI183	EQCHI246	EQCHI309	CHI0571
MMC773	CMW206	CEA066	CEA109	CHM0169	CHM0370	EQCHI074	EQCHI124	EQCHI184	EQCHI247	EQMET025	CHI0572
MMC774	CMW209	CEA072	CEA111	CHM0175	CHM0404	EQCHI075	EQCHI125	EQCHI185	EQCHI248	EQMET029	CHI0573
MMC775	CMW211	CEA073	CMW224	CHM0178	CHM0405	EQCHI076	EQCHI126	EQCHI186	EQCHI249	EQMET030	CHI0575
MMC777	CMW222	CEA074	CSA004	CHM0182	EQCHI030	EQCHI077	EQCHI127	EQCHI188	EQCHI251	EQMET033	CHI0576
MMC778	CMW223	CEA075	CSA005	CHM0184	EQCHI031	EQCHI078	EQCHI128	EQCHI189	EQCHI252	EQMET034	CHI0577
MMC779	CN2004	CEA083	CSA009	CHM0185	EQCHI032	EQCHI079	EQCHI129	EQCHI190	EQCHI260	GGD19	CHI0578
MMC780	CN2005	CEA085	CSA044	CHM0186	EQCHI033	EQCHI080	EQCHI131	EQCHI191	EQCHI261	LGD15	CHI0579
MMC781	CN2006	CEA086	CSA046	CHM0198	EQCHI034	EQCHI081	EQCHI132	EQCHI195	EQCHI262	LGD17	CHI0580
MMC782	CN2008	CEA092	CSA047	CHM0207	EQCHI035	EQCHI082	EQCHI133	EQCHI196	EQCHI263	LGD18	CHI0581
MMC783	CSA039	CEA093	CSA049	CHM0216	EQCHI036	EQCHI083	EQCHI135	EQCHI197	EQCHI264	LGD19	CHI0582

CHI0109	CHI0365	CHI0186	CHI0295	CHI0444	CHI0507	CHI0592	CHI0652	CHI0906	CHI0726	CHI0780	CHI0829	CHI0897
CHI0110	CHI0366	CHI0187	CHI0296	CHI0445	CHI0508	CHI0593	CHI0653	CHI0907	CHI0727	CHI0781	CHI0830	CHI0898
CHI0111	CHI0367	CHI0188	CHI0298	CHI0446	CHI0516	CHI0594	CHI0654	CHI0908	CHI0728	CHI0782	CHI0832	CHI0899
CHI0112	CHI0368	CHI0189	CHI0299	CHI0452	CHI0517	CHI0595	CHI0655	CHI0909	CHI0729	CHI0783	CHI0833	CHI0900
CHI0113	CHI0369	CHI019	CHI0300	CHI0453	CHI0518	CHI0596	CHI0657	CHI0911	CHI0730	CHI0784	CHI0834	CHI0901
CHI0114	CHI0370	CHI0190	CHI0301	CHI0454	CHI0519	CHI0601	CHI0662	CHI0912	CHI0731	CHI0785	CHI0835	CHI0902
CHI0115	CHI0371	CHI0191	CHI0302	CHI0455	CHI0520	CHI0602	CHI0663	CHI0913	CHI0732	CHI0786	CHI0836	CHI0903
CHI0116	CHI0372	CHI0192	CHI0303	CHI0456	CHI0523	CHI0603	CHI0664	CHI0914	CHI0733	CHI0787	CHI0837	CHI0904
CHI0117	CHI0373	CHI0193	CHI0304	CHI0458	CHI0524	CHI0604	CHI0665	CHI0918	CHI0734	CHI0790	CHI0838	CHI0905
CHI0118	CHI0374	CHI0194	CHI0305	CHI0459	CHI0525	CHI0610	CHI0666	CHI0919	CHI0735	CHI0791	CHI0839	CHI0591
CHI0119	CHI0375	CHI0195	CHI0306	CHI0460	CHI0526	CHI0611	CHI0667	CHI0920	CHI0737	CHI0792	CHI0840	CHI0583
CHI0120	CHI0376	CHI0196	CHI0307	CHI0461	CHI0528	CHI0612	CHI0668	CHI0921	CHI0738	CHI0793	CHI0841	CHI0584
CHI0121	CHI0379	CHI0197	CHI0308	CHI0462	CHI0529	CHI0613	CHI0669	CHI0923	CHI0739	CHI0794	CHI0842	CHI0585
CHI0122	CHI0381	CHI0198	CHI0309	CHI0463	CHI0530	CHI0614	CHI0670	CHI0924	CHI0740	CHI0795	CHI0844	
CHI0123	CHI0382	CHI0199	CHI0310	CHI0464	CHI0531	CHI0616	CHI0671	CHI0925	CHI0746	CHI0796	CHI0845	
CHI0124	CHI0383	CHI020	CHI0311	CHI0465	CHI0532	CHI0617	CHI0672	CHI0926	CHI0747	CHI0797	CHI0846	
CHI0125	CHI0385	CHI0200	CHI0312	CHI0466	CHI0533	CHI0618	CHI0673	CHI0927	CHI0748	CHI0798	CHI0847	
CHI0126	CHI0386	CHI0201	CHI0313	CHI0467	CHI0534	CHI0619	CHI0674	CHI0928	CHI0749	CHI0799	CHI0848	
CHI0127	CHI0387	CHI0202	CHI0314	CHI0468	CHI0536	CHI0621	CHI0675	CHI0929	CHI0750	CHI0800	CHI0849	
CHI0128	CHI0388	CHI0204	CHI0315	CHI0469	CHI0537	CHI0622	CHI0676	CHI0930	CHI0751	CHI0801	CHI0850	
CHI0129	CHI015	CHI0205	CHI0316	CHI0470	CHI0538	CHI0623	CHI0677	CHI0931	CHI0752	CHI0802	CHI0851	
CHI013	CHI0150	CHI0206	CHI0325	CHI0471	CHI0539	CHI0625	CHI0678	CHI0932	CHI0753	CHI0803	CHI0852	
CHI0130	CHI0151	CHI0207	CHI0335	CHI0478	CHI0540	CHI0626	CHI0679	CHI0933	CHI0754	CHI0804	CHI0853	
CHI0131	CHI0152	CHI0208	CHI0337	CHI0479	CHI0541	CHI0627	CHI0686	CHI0934	CHI0755	CHI0805	CHI0854	
CHI0132	CHI0153	CHI0209	CHI0338	CHI0480	CHI0542	CHI0628	CHI0687	CHI0935	CHI0756	CHI0806	CHI0855	
CHI0133	CHI0154	CHI021	CHI0339	CHI0481	CHI0543	CHI0629	CHI0688	CHI0936	CHI0757	CHI0807	CHI0856	
CHI0134	CHI0155	CHI0210	CHI0352	CHI0482	CHI0544	CHI0630	CHI0689	CHI0937	CHI0758	CHI0808	CHI0857	
CHI0135	CHI0156	CHI0212	CHI0353	CHI0483	CHI0545	CHI0631	CHI0690	CHI0938	CHI0759	CHI0809	CHI0858	
CHI0136	CHI0157	CHI022	CHI0354	CHI0484	CHI0546	CHI0632	CHI0691	CHI0939	CHI0761	CHI0810	CHI0859	
CHI0137	CHI0159	CHI023	CHI0355	CHI0489	CHI0547	CHI0633	CHI0692	CHI0941	CHI0762	CHI0811	CHI0860	
CHI0138	CHI016	CHI0239	CHI0389	CHI0490	CHI0549	CHI0634	CHI0694	CHI0942	CHI0763	CHI0812	CHI0861	
CHI0139	CHI0161	CHI0253	CHI0390	CHI0491	CHI0550	CHI0635	CHI0695	CHI0943	CHI0764	CHI0813	CHI0862	
CHI014	CHI0162	CHI0254	CHI0391	CHI0492	CHI0551	CHI0636	CHI0696	CHI0944	CHI0765	CHI0814	CHI0863	
CHI0140	CHI0163	CHI0255	CHI0392	CHI0493	CHI0552	CHI0637	CHI0697	CHI0945	CHI0766	CHI0815	CHI0864	
CHI0141	CHI017	CHI026	CHI0394	CHI0495	CHI0553	CHI0638	CHI0698	CHI0946	CHI0767	CHI0816	CHI0865	
CHI0142	CHI0170	CHI0271	CHI0395	CHI0496	CHI0554	CHI0639	CHI0699	CHI0949	CHI0768	CHI0817	CHI0866	
CHI0143	CHI0174	CHI0272	CHI0396	CHI0497	CHI0555	CHI0640	CHI0700	CHI0950	CHI0769	CHI0818	CHI0867	
CHI0144	CHI0176	CHI0273	CHI0397	CHI0498	CHI0556	CHI0641	CHI0701	CHI0951	CHI0770	CHI0819	CHI0868	
CHI0145	CHI0177	CHI0275	CHI0398	CHI0499	CHI0560	CHI0642	CHI0702	CHI0952	CHI0771	CHI0820	CHI0869	
CHI0146	CHI0178	CHI0277	CHI0400	CHI0500	CHI0561	CHI0643	CHI0703	CHI0954	CHI0772	CHI0821	CHI0870	
CHI0147	CHI0179	CHI0278	CHI0403	CHI0501	CHI0562	CHI0644	CHI0704	CHI0955	CHI0773	CHI0822	CHI0871	
CHI0148	CHI017W2	CHI0285	CHI0404	CHI0502	CHI0563	CHI0645	CHI0705	CHI0956	CHI0774	CHI0823	CHI0879	
CHI0149	CHI018	CHI0286	CHI0438	CHI0506	CHI0564	CHI0646	CHI0706	CHI0957	CHI0775	CHI0824	CHI0887	
CHI0359	CHI0180	CHI0287	CHI0439	CHI0586	CHI0567	CHI0647	CHI0722	CHI0958	CHI0776	CHI0825	CHI0888	
CHI0360	CHI0181	CHI0289	CHI0440	CHI0587	CHI0568	CHI0649	CHI0723	CHI0959	CHI0777	CHI0826	CHI0889	
CHI0361	CHI0182	CHI0290	CHI0442	CHI0589	CHI0569	CHI0650	CHI0724	CHI0960	CHI0778	CHI0827	CHI0895	
CHI0362	CHI0183	CHI0294	CHI0443	CHI0590	CHI0570	CHI0651	CHI0725	CHI0961	CHI0779	CHI0828	CHI0896	

Appendix C. Modelling codes

Table C-1. Modelling codes for grouped lithological Local Zones (Domains).

	Ore schist	Fault Breccia	Gneiss Undifferentiated	Gneiss Massive Pink	Amphibolite	Barren Schist	Barren Gneiss	Overburden
LIT_LocZone_Grouped	CBOOZ	CBX	CFW	CHWGM	CBGA	CBS	CBG	COB
	CBOZ		CFWGN	CFWGN		CFWMS	CGF	
	CBSOZ		CHW	CHWMGN		CFWS	CLGN	
	CFWMQS		CHWG			CMS	CMGN	
	CGO					CSF		
	CHWOS							
	CLOS							
	CLOSC							
	COG							
	COGB							
	COOS							
	COS							
	COSB							
	CSO							
	CTOS							
	CUOS							

Table C-2. Modelling codes for grouped lithologies (Rock types)

	Amphibolite	Breccia	Granofels-Quartzite	Biotite Schist	Muscovite Schist	Chlorite Schist	Talc Schist	Schist Undifferentiated	Gneiss Undifferentiated
LIT_Rock_Grouped	Tma	Btcbxx	Tty	Ttsb	Ttsmoq	Ttsao	Ttst	Tts	Ttg
	Tma3	Btchjq	Ttya	Ttsb3	Ttsmq	Ttso	Ttsth		Ttga
	Tmag	BtcHox	Ttyab	Ttsba	Ttsmqg	Ttsoh	Ttstk		Ttgab
	Ttga	Btchox	Ttyabq	Ttsbaf	Ttsmqh		Ttstkq		Ttgab3
	Ttgab	BtcHq1	Ttyabqz	Ttsbag	Ttsmqht		Ttsto		Ttgabg
	Ttgab3	BtcHqx	Ttyabz	Ttsbak	Ttsmqk		Ttstoh		Ttgabg3
	Ttgabg	Btchqx	Ttyac	Ttsbao	Ttsmqt		Ttstq		Ttgabgf

	Amphibolite	Breccia	Granofels- Quartzite	Biotite Schist	Muscovite Schist	Chlorite Schist	Talc Schist	Schist Undifferentiated	Gneiss Undifferentiated
LIT_Rock_Grouped	Ttgabg3	BtcHxx	Ttyacb	Ttsbaq	Ttsmqth		Ttstqk		Ttgabo
	Ttgabgf	Btchxx	Ttyacbg	Ttsbaqf	Ttsmqz				Ttgabq
	Ttgabo	BtcjH2	Ttyacbi	Ttsbaqk	Ttsmt				Ttgabqg
	Ttgabq	Btcox	Ttyacbi	Ttsbfk	Ttsmth				Ttgaf
	Ttgabqg	BtcqjH	Ttyacbp	Ttsbg	Ttsmtk				Ttgafb
	Ttgaf	Btcxxx	Ttyacbi	Ttsbgk	Ttsmqz				Ttgafs
	Ttgafb	Btcyxx	Ttyacs	Ttsbk	Ttsak				Ttgag
	Ttgafs	Btkbi2	Ttyacsi	Ttsbkg	Ttsaz				Ttgamg
	Ttgag	Btkbxx	Ttyaq	Ttsbo	Ttssg				Ttgaq
	Ttgamg	BtkHjq	Ttybc	Ttsboag	Ttssh				Ttgas
	Ttgaq	Btkhj	Ttyc	Ttsboqk	Ttssq				Ttgasg
	Ttgas	Btkhjx	Ttyca	Ttsbq	Ttssqak				Ttgaz
	Ttgasg	BtkHox	Ttycb	Ttsbqa	Ttssqf				Ttggb
	Ttgaz	Btkhox	Ttycbg	Ttsbqag	Ttssqfa				Ttgqaoi
	Ttya	BtkHqj	Ttycbgi	Ttsbqk	Ttssqg				Ttgqas
	Ttayb	Btkhqj	Ttycbgz	Ttsbqf	Ttssqk				Ttgqb
	Ttba	Btkhqx	Ttycbi	Ttsbqfk	Ttssqkg				Ttgqba
	Ttbac	BtkHxx	Ttycbq	Ttsbqg	Ttsszq				Ttgqbag
	Ttbacb	Btkhxx	Ttycbqg	Ttsbqgk	Ttszqbk				Ttgqbg
	Ttbacbi	BtkjH2	Ttycbqi	Ttsbqgz	Ttsbqgz				Ttgqbgg
	Ttbaci	BtkjHq	Ttyq	Ttsbqk	Ttbc				Ttgqbgk
	Ttbacq	Btkjh	Ttyqag	Ttsbqkg	Ttbc				Ttgqbk
	Ttbacs	Btkjq2	Ttyqh	Ttsbqkt	Ttbcot				Ttgqbz
	Ttbai	BtkjqH	Ttyqi	Ttsbqz	Ttbcq				Ttgqf
	Ttbaqo	Btkjxx	Ttyqm	Ttsbqzm	Ttbq				Ttgqfb
	Ttbao	Btkox	Ttyqmh	Ttsbz	Ttbc				Ttgqfba
	Ttbao	BtkqjH	Ttyqmt	Ttsbzg	Ttbqfs				Ttgqfbg
	Ttbca	Btkxxx	Ttyqmth		Ttbqog				Ttgqfbgk
	Ttbqaoi	Btkyxx			Tlb				Ttgqfbk
		Btm2hi			Tlf				Ttgqfg
		Btmbxx			Tlg				Ttgqfm
		Btmh2i			Ttbqfs				Ttgqfmk
		Btmh2x			Ttbqog				Ttgqfs
		Btmhfx			Ttbc				Ttgqfsk
		BtmHox							Ttgqg
		Btmhox							Ttgqm
		BtmHq2							Ttgqmh
		Btmhq2							Ttgqmk
		Btmhqf							Ttgqmt

	Amphibolite	Breccia	Granofels- Quartzite	Biotite Schist	Muscovite Schist	Chlorite Schist	Talc Schist	Schist Undifferentiated	Gneiss Undifferentiated
LIT_Rock_Grouped		Btmhqx							Ttgqmh
		Btmhs2							Ttgqs
		BtmHxx							Ttgqsa
		Btmhxx							Ttgqsag
		Btmihq							Ttgqsak
		Btmjq1							Ttgqsg
		BtmjqH							Ttgqsga