A STRATIGRAPHIC AND SEDIMENTOLOGICAL STUDY OF THE DEPOSITIONAL ENVIRONMENT OF THE A REEF IN THE VENTERSBURG-HENNENMAN DISTRICT, FREE STATE GOLDFIELDS.

By

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Dissertation submitted in fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In the Faculty of Natural and Agricultural Sciences
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2014

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DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Master of Science in the University of the Free State, Bloemfontein. It has not been submitted before for any other degree or examination in any other University.

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ABSTRACT

The Ventersburg Project is located in the Free State Goldfields south of the town of Hennenman. The A Reef particularly its stratigraphic and sedimentological character is the subject of study in the project area. The reef occurs stratigraphically in the Aandenk Formation of the Central Rand Group, Witwatersrand Supergroup, South Africa. The A Reef occurs a few meters below the angular unconformity underlying the Eldorado Basal Conglomerate and above an unconformity surface between the Spes Bona and Aandenk Formations. The fact that most Witwatersrand placers occur on unconformity surfaces is well known throughout the Witwatersrand Basin (Phillips and Law, 2000).

The A Reef in the project area is a low grade, shallow ore body (less than 1000 meters below surface). Intersections of the A Reef from borehole core were used to determine the facies and sub-environments. The A Reef placer is distinctly different from the underlying polymictic Big Pebble Marker comprising mature, oligomictic, small to medium pebble conglomerates and siliceous quartzites showing upwards fining cycles, typical of braided alluvial plain environments. Sediment transport directions towards the east-south-east are similar to those in the Free State Goldfields. Channels of the A Reef are highly complex, occurring in large channel complexes of more than 500 meters wide with individual smaller channels of 200 to 500 meters wide.

The A Reef in the northern part of the project area is separated from the underlying Big Pebble Marker by between 1 to 3 meters of argillaceous quartzwacke. To the south, the A Reef is directly on top of the Big Pebble Marker. Mineralisation in the A Reef decreases to the south where it sub-outcrops against the Eldorado Basal Conglomerate and only localised higher gold grades occur within the Big Pebble Marker.

At increased high gold prices, previously uneconomic ore bodies can become renewed targets for exploration in the near future.

Key words:

Ventersburg Project, Witwatersrand Basin, Free State Goldfields, Aandenk Formation, A Reef.

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Overview and General Background

The Ventersburg Project area is situated south of Hennenman, 25 km from Welkom, between Ventersburg, Virginia and Hennenman (Figure 1-1). The Ventersburg Project (Gold One International Ltd. hereafter Gold One) consists of five prospecting rights, covering more than 14 000 hectares. The target is the A Reef in the Free State Goldfields and is situated stratigraphically in the Aandenk Formation (previously known as the Kimberley Formation) (SACS, 2006) of the Witwatersrand Basin in central South Africa.

The Free State Goldfields form the southernmost limit of the Witwatersrand Basin (Figure 1-1), which is one of the world's largest known gold reserves and has already produced more than 50 000 tons of gold (Frimmel *et al*., 2005). Gold was first discovered in 1886, near the city of Johannesburg, on the farm Langlaagte (Minter *et al*., 1986). Most of the gold occurs within placers. These placers constitute conglomeratic bands, varying in thickness, from a few centimetres to over three meters.

The A Reef has been studied since intersecting economical gold values in the placer in the mid-1940s (Greathead and Graad van Roggen, 1986). Gold distribution in the A Reef is known to be variable and a sound geological model is needed to define the distribution trends and the gold content of the reef with confidence in order to exploit the reef economically.

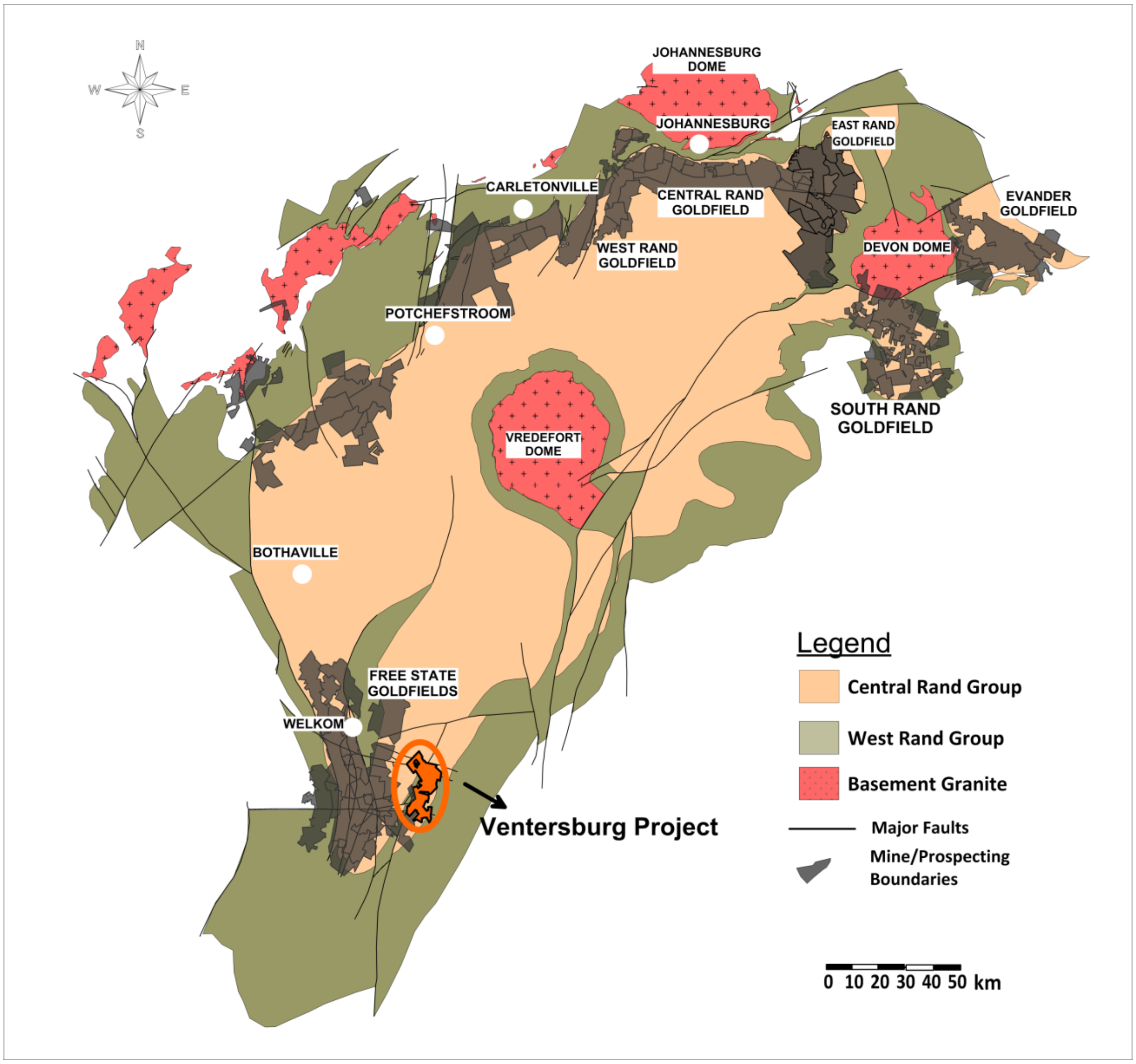


Figure 1-1: The Witwatersrand Basin and major goldfields, also depicting the locality of the Ventersburg Project (modified after McCarthy, 2006).

1.2 Geomorphology and physical features of the area

The project area is situated on the Highveld plateau, with an elevation of between 1 340 m to 1 500 m above mean sea level, mostly covered by rolling hills of grassland. Farming in the district is predominantly maize, sunflower and wheat, as well as some cattle and game farms.

The drainage of the Ventersburg Project area is towards the north-west into the Rietspruit, which is a small stream flowing into the Sand River east of Virginia. Surface geology is dominated by lower Beaufort sandstone and shales, intruded by dolerite dykes and sills. In the northern portion of the project area, calcrete was mined on the farm Whites 747. Overburden was removed to reach the shallow calcrete which was used for the manufacturing of cement. No rehabilitation was conducted and overburden dumps were not removed, nor backfilled into the quarries. These dumps now appear as protruding hills above a relatively flat landscape.

1.3 Purpose of Study

The purpose of the study is to evaluate the stratigraphy and sedimentology of the A Reef, in the Free State Goldfields, specifically for the Ventersburg Project. The Free State Goldfields are part of the southern extension of the Witwatersrand Basin in South Africa, which is one of the largest gold producing areas in the world (Frimmel *et al*., 2005).

The study will aim to:

- Describe different facies of the A Reef
- Define the depositional environment of the A Reef
- Predict channel distribution in order to define viable gold values
- Describing exploration best practices and procedures (Appendix A)

1.4 Methodology

All available historical data was reviewed and a database file with all gold and sedimentological data was compiled and updated as exploration progressed. Since most of the historical borehole core is no longer available, no detailed sedimentological studies could be performed on the historic borehole data. A small number of old boreholes was located and the physical and sedimentological features of the A Reef, as well as assay data were correlated and compared against borehole logs and sample assay sheets.

Gold One continued with an exploration drilling program from 2007 and 82 boreholes were drilled on approximately 500 m x 500 m grid spacing during the next 4 years (Figure 1-2). The A Reef zone and footwall succession were geologically logged and described.

Since there are no underground exposures of the A Reef, only borehole core was available to study the sedimentological features of the A Reef. Pebble outlines were traced on transparent graph paper in order to calculate average size, shape, roundness and general orientation. Pebble composition, the amount of internal quartzite as well as the characteristics of the matrix were also described to define different facies.

Measuring pebble sizes on borehole core does not provide the long axis or true size of the pebbles but it provides a very good relative indication of the mean pebble size. The ten largest pebbles in each reef intersection were selected. The surface square millimetres were calculated from the transparency on which the pebbles were traced for each pebble and the average of the 10 largest pebbles was calculated. The end result is an accurate representation of the pebble size distribution across a large area. From this, the main transport direction was deduced.

Data from the detailed examination of the borehole core was applied to compile contour maps to illustrate trends. Plans with different variables as discussed below were then combined to create a geological model. The following variables were illustrated on plans:

- Total channel thickness of the A Reef
- Thickness of interbedded quartzite as a percentage of the total reef thickness
- Pebble sizes (method explained above)
- Total gold grade (*g/t*)
- Gold accumulation (*cm.g/t*)**
- Correlation of reef thickness versus grade (this is a relative factor as sedimentological processes can influence this after original deposition such as reworking or migration of channel bars)
- Uranium distribution and the ratio of uranium/gold that increases downstream

1.4.1 Calculations

Channel thickness used is the true, dip corrected thickness. Dips are corrected using dip measurements from core bedding angles and the apparent thickness measured on the core.

**Centimetre grams per ton (gold accumulation) is calculated using the true, dip corrected thickness of samples times the grade of individual samples.

$$(cm \times g/t = cm.g/t)$$

The average grade over the channel thickness is the calculated grade over the true thickness of the total reef, using the weighted average of grade from individual samples over the total channel thickness (Storrar, 1981).

$$(\frac{Total\ Reef\ cm.g/t}{Channel\ Thickness\ cm} = g/t\ over\ the\ reef\ zone)$$

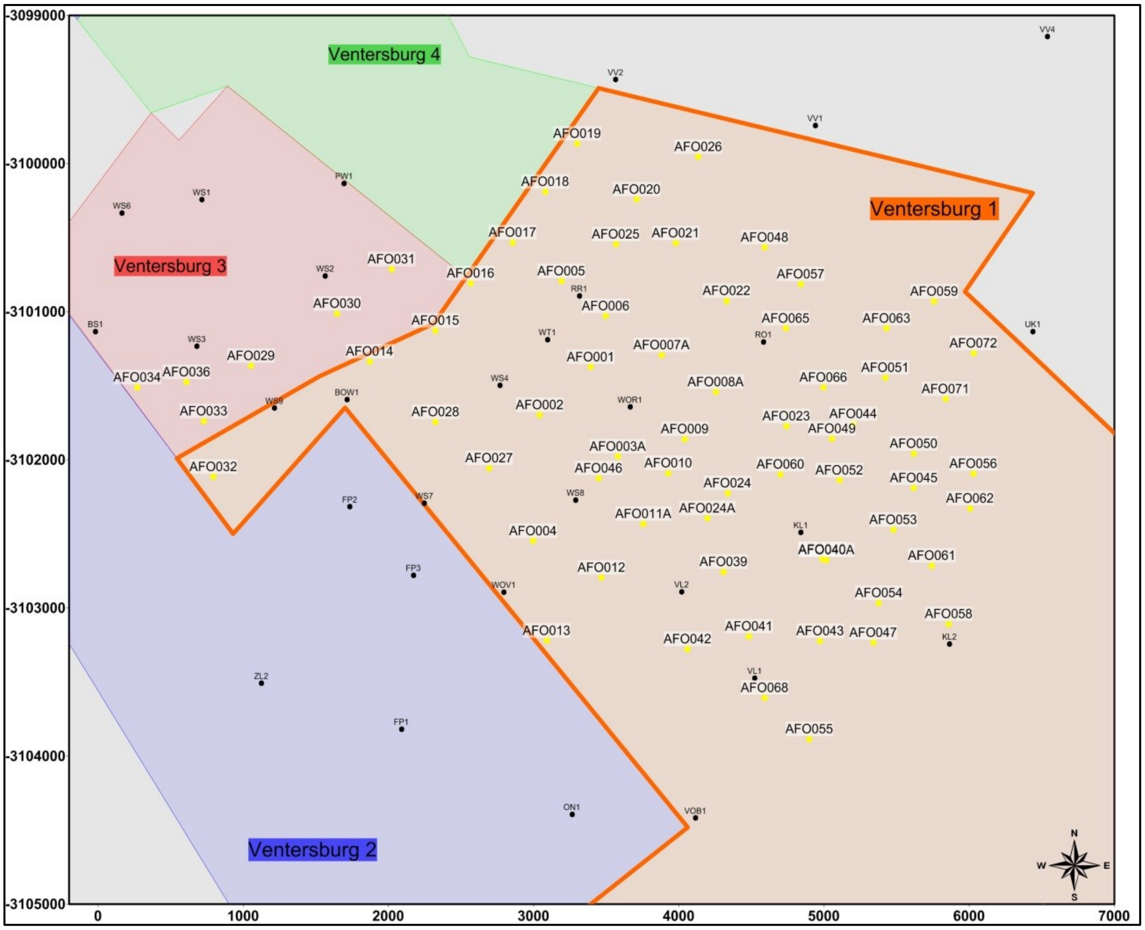


Figure 1-2: Locality of all boreholes and the four prospecting areas held by Gold One (Coordinate system used Datum WGS84 System LO27).

1.5 Historical Review

Almost 50 years after the discovery of the Witwatersrand gold in 1886, on the farm Langlaagte now Johannesburg, a historical borehole, WE1 was drilled in 1933 on the farm Aandenk, near Allanridge. This borehole proved the presence of Witwatersrand Group sediments underlying younger Ventersdorp lavas and Karoo cover (Antrobus, 1986). It was a historical moment and can be regarded as the beginning of the Free State Goldfields. Disappointingly, exploration activities stopped with the onset of World War II and only commenced again in 1946 (Coetzee, 1960). During the early ‘90s the potential for further exploration of the A Reef was low as the gold price was only around 360 $/oz. During 2012 and 2013, it rose to around 1700 $/oz. and reached a high of around 1900 $/oz. at the end of 2011. This dramatic increase in the gold price as well as the technological developments of improved mining techniques and equipment increased the economic potential of lower grade ore bodies.

1.6 Previous Work

Karpeta (1984) studied the A Reef at President Steyn Gold mine and described the reef as highly variable in gold content. He further identified two reef horizons namely the Witpan and Uitsig placers. Karpeta gave a detailed description of channel thickness as well as gold content distribution in the channels. He also noted that the most important target at President Steyn mine is the Witpan placers and that pay-shoots could be delineated using facies and total gold content during the prospecting phase before mining activities commenced. The A Reef at the Ventersburg Project has similarities to the Witpan and Uitsig placer as described by Karpeta (1984), but occurs as one unit with different lithostratigraphic features and not two distinctly different reef horizons.

A stratigraphic and sedimentological interpretation was also executed by Smith (1992), covering a large area between Hennenman and Ventersburg. This work was completed for Gold Fields of South Africa Limited and the objective was to plan an exploration program during 1992. Available data was reviewed and isopach and isopleths plans were compiled to determine sedimentary, stratigraphic and structural characteristics.

Other in-house and unpublished reports were that of A.N. Clay (1987): "The sedimentological evaluation of the A Reef on the Whites project". Clay provides an evaluation of the A Reef and noted that the A Reef consists of highly channelized, low grade conglomerates and for this reason has been largely ignored by mining companies. Clay also states that selective mining will have to be a pre-requisite for the successful economic extraction of the A Reef. Since the A Reef in the project area is shallow it can still be a valuable proposition.

Labuschagne (2003) did a report on the Ventersburg area and noted that only the Leader Reef and the A Reef are developed in the project area as units with significant gold content. With the current drilling program and the historical data, it is now evident that the Leader Reef, which is located stratigraphically below the A Reef, is of almost no economic significance in the Hennenman area. Only one borehole, namely WDR-1 on the farm Wilhelmina 548, situated 10 kilometres south of the project area, returned an above average gold value of 22.70 g/t over a channel thickness of 61.10 cm. To the northern part of the project area, where Gold One's exploration is focused, no significant Leader Reef was intersected. The best grade intersected was 0.69 g/t over a channel thickness of 14.70 cm. The positions of other historic boreholes were also found in a report by Van Collar (1988).

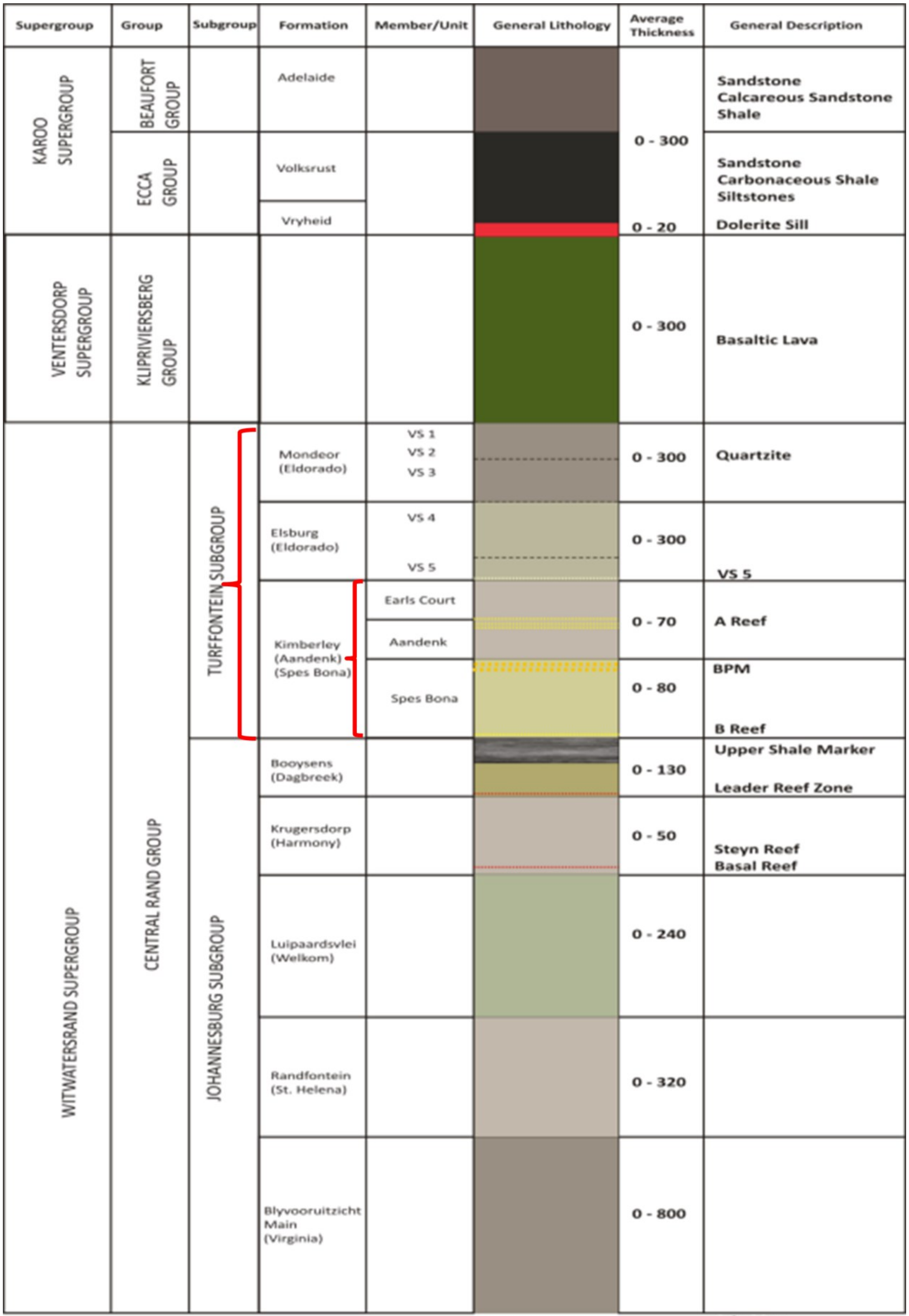
South of the farms Onverwacht 342 and Vogelsrand 720, gold concentrations in the A Reef also appear to be very low and are generally less than 1 g/t over reef thickness of less than 50 cm. Exploration is therefore still concentrated in the northern portion of the project area (Labuschagne, 2003).

2 Geological Overview of the Ventersburg Project

2.1 Introduction

The study area is located in the southern part of the Witwatersrand Basin of South Africa and forms part of the Free State Goldfields.

The Witwatersrand Supergroup (2.8 Ga) is underlain by an Archaean granite-greenstone basement (>3.1 Ga) (Allsopp *et al,*. 1986). It is overlain by rocks of the Ventersdorp Supergroup (2.7 Ga) and Karoo Supergroup (302-180 Ma). The Witwatersrand Supergroup has two subdivisions, the West and Central Rand Groups. The West Rand Group is the older part of the Witwatersrand Basin and contains almost equal amounts of quartzite and shale (Robb, 1998) and was deposited in marine to shallow marine environments. The area of study concentrates on formations in the Central Rand Group and therefore the deeper West Rand Group will not be discussed. The Central Rand Group has a quartzite to shale ratio of around 12.6 and was deposited in fluvial deltaic environments (McCarthy, 2006). The A Reef at the Ventersburg Project is located in the upper part of the Central Rand Group within the Aandenk Formation and is found below the Eldorado Formation sediments as shown in the stratigraphic column (Figure 2-1).



Supergroup	Group	Subgroup	Formation	Member/Unit	General Lithology	Average Thickness	General Description
KAROO SUPERGROUP	BEAUFORT GROUP		Adelaide			0 - 300	Sandstone Calcareous Sandstone Shale
	ECCA GROUP		Volksrust				Sandstone Carbonaceous Shale Siltstones
			Vryheid			0 - 20	Dolerite Sill
VENTERSDORP SUPERGROUP	KLIPRIVIERSBERG GROUP					0 - 300	Basaltic Lava
WITWATERSRAND SUPERGROUP	CENTRAL RAND GROUP	TURFFONTEIN SUBGROUP	Mondeor (Eldorado)	VS 1 VS 2 VS 3		0 - 300	Quartzite
			Elsburg (Eldorado)	VS 4 VS 5		0 - 300	VS 5
			Kimberley (Aandenk) (Spes Bona)	Earls Court		0 - 70	A Reef
				Aandenk			
				Spes Bona		0 - 80	BPM B Reef
		JOHANNESBURG SUBGROUP	Booysens (Dagbreek)			0 - 130	Upper Shale Marker Leader Reef Zone
			Krugersdorp (Harmony)			0 - 50	Steyn Reef Basal Reef
			Luipaardsvlei (Welkom)			0 - 240	
			Randfontein (St. Helena)			0 - 320	
			Blyvooruitzicht Main (Virginia)			0 - 800	

Ada May

Figure 2-1: Stratigraphic column for the Ventersburg Project (Modified after SACS, 2006).

2.2 General Geology

Most of the Ventersburg Project area is underlain by approximately 300 meters of sandstone and shale from the Ecca and Beaufort Groups of the Karoo Supergroup (Johnson *et al*., 2006). Two formations of the Ecca Group are found in the project area, namely the Vryheid and Volksrust Formations. In the Ventersburg Project area, only percussion chips and weathered surface outcrops of the Karoo sequence are available for study and these formations are not described in any detail.

The sediments of the Ecca Group are collectively known and described as the Ecca Shale Formation. The Vryheid Formation was deposited in a deltaic environment (Tavener-Smith *et al*., 1988). The lower part of the formation consists of carbonaceous shale and dark-grey siltstone from deposition in anoxic relatively deep water. Towards the top more sequences of sandstone and siltstone are found (Johnson *et al*., 2006). The Volksrust Formation consists of grey to black shale, with siltstone and mostly fine to medium grained sandstone lenses in the Ventersburg Project area. The Volksrust Formation represents a transgressive event. Evidence for the transgression is the fine grained upward fining lithology and according to Tavener-Smith *et al*., (1988) its upper and lower units have been deposited in a shallow marine or lacustrine environment. Coal is also found in the Vryheid and Volksrust Formations but only to the north and northeast of the Ventersburg area towards Kroonstad, Sasolburg and Vereeniging. The lowermost coal seams formed in swamps which developed in glacial valleys after the northward retreat of Dwyka glaciers (Snyman, 1998).

In the Ventersburg Project area, a glacial valley with remnants of thin coal seams is present towards the eastern limit of the project area. Overlying the Ecca Group is the Beaufort Group with the Adelaide and Tarkastad Subgroups. In the project area only the Adelaide Subgroup is present and it consists of alternating layers of sandstone and mudstone. The colour of the fine grained sandstone and mudstone in the Adelaide Subgroup is usually light to darker brown. The characteristic sedimentary structures such as cross-bedding, parallel bedding and ripple lamination are derived from a fluvial environment in meandering rivers. Vertebrate fossils as well as petrified wood are common in the Adelaide Subgroup. No economic gold occurrences are found in any of the Karoo Supergroup rocks (Johnson *et al*., 2006).

The Karoo Supergroup (Phanerozoic age) is in turn underlain by the Klipriviersberg Group basaltic lavas of the Ventersdorp Supergroup which is of late Archaean age. The age difference between the Supergroups is approximately 2000 million years. The original extent of the Ventersdorp Supergroup is not exactly known because of the massive time laps between the above mentioned Supergroups. During the time laps, denudation may have influenced the original extent of the Ventersdorp Supergroup (Van der Westhuizen *et al*., 2006). The thickness of the Ventersdorp Supergroup also varies because of post-Klipriviersberg faulting and erosion with the thickest parts preserved in graben structures (Figure 2-2) data used in Table 2-1.

The Central Rand Group rocks of the Witwatersrand Supergroup underlie the Ventersdorp Supergroup. These rocks are mostly conglomerates and quartzite with minor shale inter-beds (McCarthy, 2006).

The deepest boreholes in the Ventersburg Project area intersected the Welkom Formation consisting of informal members termed Upper Footwall 1 to 4 (UF1-4) (SACS., 2006). The Welkom Formation is made up of argillaceous quartzites, some coarse grained polymictic grits and in places small pebble conglomerates (SPC). Vein quartz, chert, quartz porphyries and chloritic schist are the main constituents. The colour of the UF quartzites in borehole core has a distinct light greenish colour. This green tint is very important to distinguish between the much younger Eldorado Formation and the underlying footwall succession.

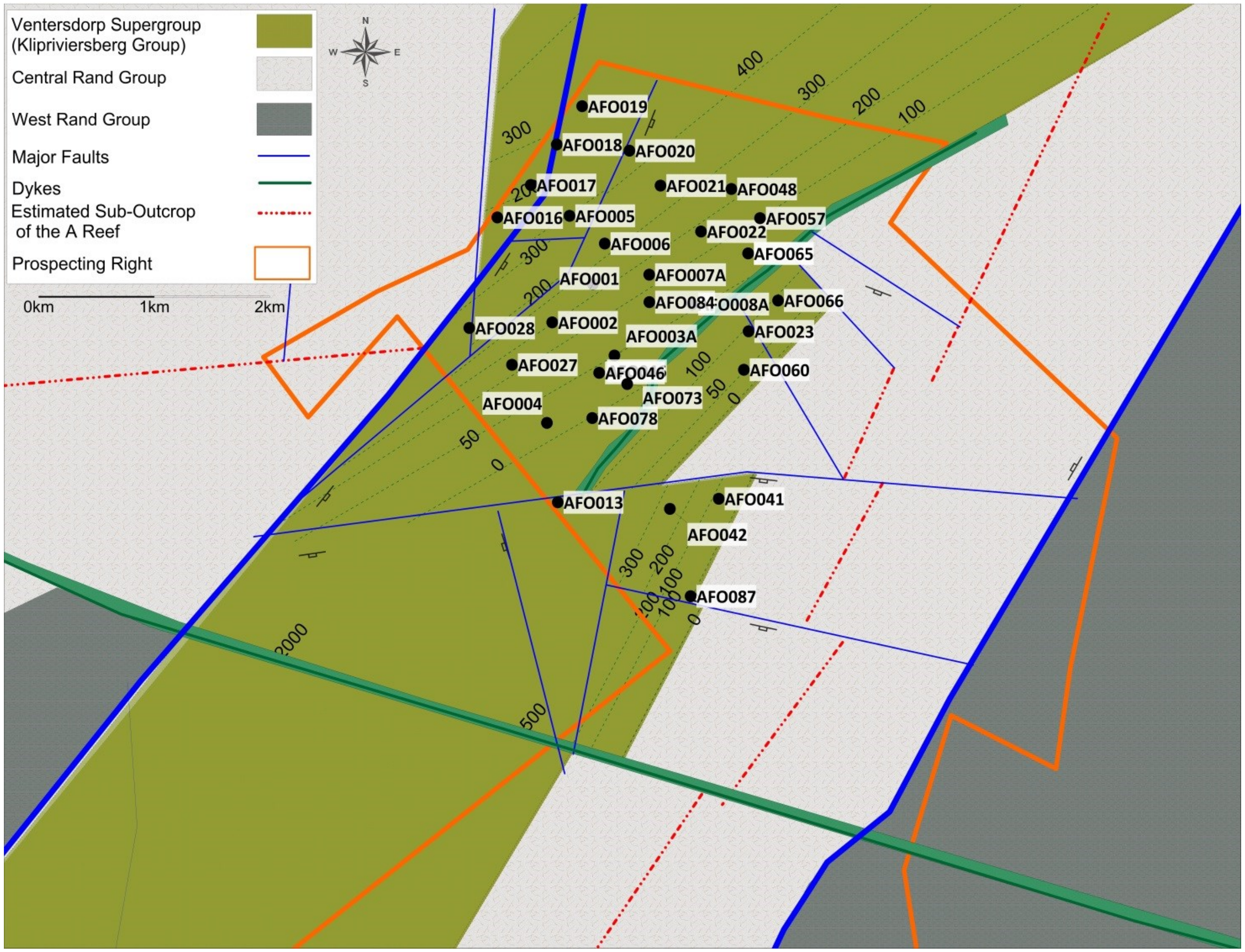


Figure 2-2: Subsurface geology beneath the Karoo Supergroup, with local structure and isopachs of the Ventersdorp lava across the project area (See table 2-1 for data).

Table 2-1:Data informing Figure 2-2 indicating the thickness of lava of the Klipriviersberg Group.

BHID	Y	X	STRAT	THICKNESS (m)
AFO001	-3393.398	3101373.980	LAVA	322
AFO002	-3042.207	3101697.610	LAVA	261
AFO003A	-3579.793	3101977.583	LAVA	126
AFO004	-2996.446	3102548.364	LAVA	33
AFO005	-3191.246	3100793.961	LAVA	399
AFO006	-3496.575	3101029.821	LAVA	360
AFO007A	-3881.422	3101293.292	LAVA	213
AFO008A	-4254.559	3101542.298	LAVA	59
AFO013	-3090.138	3103221.500	LAVA	91
AFO016	-2566.713	3100808.415	LAVA	173
AFO017	-2855.826	3100533.076	LAVA	232
AFO018	-3080.408	3100190.392	LAVA	298
AFO019	-3300.235	3099865.809	LAVA	281
AFO020	-3709.945	3100242.429	LAVA	428
AFO021	-3979.210	3100537.631	LAVA	355
AFO022	-4330.017	3100926.723	LAVA	227
AFO023	-4741.248	3101773.111	LAVA	70
AFO027	-2694.206	3102056.214	LAVA	195
AFO028	-2324.480	3101744.567	LAVA	279
AFO041	-4483.659	3103191.779	LAVA	87
AFO042	-4060.588	3103277.968	LAVA	282
AFO046	-3448.520	3102124.727	LAVA	11
AFO046	-3448.520	3102124.727	LAVA	105
AFO048	-4591.970	3100566.230	LAVA	270
AFO057	-4840.641	3100814.335	LAVA	169
AFO060	-4700.776	3102098.565	LAVA	17
AFO065	-4736.670	3101113.056	LAVA	36
AFO065	-4736.670	3101113.056	LAVA	107
AFO066	-4996.784	3101511.571	LAVA	108
AFO073	-3690.135	3102218.845	LAVA	16
AFO078	-3387.778	3102508.259	LAVA	8
AFO084	-3882.390	3101525.224	LAVA	163
AFO087	-4239.831	3104017.877	LAVA	6

The Dagbreek Formation transgresses over the Harmony Formation. The Basal Reef's sub-outcrop lies further to the west from the Ventersburg Project. There might be some Harmony Formation quartzites present below the Leader Reef zone but they are difficult to distinguish from some of the Welkom Formation sediments because of its similar appearance.

The Dagbreek Formation is present in the Ventersburg Project area, as it lies in the graben structure and was not eroded away as in the Harmony Horst to the west (Smith, 1992). The Leader Reef zone occurs at the base of the Dagbreek Formation and was intersected in two boreholes AFO-002 and AFO-016. It is however only a poorly developed, very small pebble conglomerate to gritty quartzite, with some detrital and authigenic pyrite mineralisation over less than 20 cm and is thus not a target in the area. Smith (1992) noted that the Leader Reef was identified within the project area and was described as a single clast supported oligomictic conglomerate band with pebble sizes decreasing to the north and from west to east and northeast (Sims, 1969).

At the top of the upward fining Dagbreek Formation is the Booysens Shale or Upper Shale Marker (USM). Shale bands within the Dagbreek Formation increase towards the USM where it can be up to 35 m thick in the project area. The USM consists of khaki and darker interbedded shale, with some sporadic quartz grits. Soft sediment deformation is also visible. The Upper Shale Marker is absent where the Dagbreek Formation is less than 80 m thick and is interpreted as a transition to a pro-delta facies of a fan-delta sequence (Smith, 1992). Overlying the Dagbreek Formation are the Spes Bona and Aandenk Members which will be discussed below.

The Eldorado Formation is divided into the Elsburg and Mondeor Formations in the SACS (2006) classification and consists of four units VS1 – 4. The upper unit, VS1 is composed essentially of a light to dark argillaceous unit. The middle unit, VS2 – 4 is an alternating siliceous and argillaceous gritty unit with alternating darker medium grained quartzite containing scattered polymictic grits. It starts with a coarse grit unit approximately 330 meters above the A Reef, becoming more siliceous and being distinctly banded. Towards the bottom the unit becomes siliceous again and then grades into an argillaceous quartzite with yellow specs. The VS4 is an argillaceous unit but the top is marked by a very light grey distinctly clean siliceous quartzite approximately 11 meters above the Elsburg Basal Conglomerate. The lower unit overlies the Aandenk Formation disconformably and is composed of a course upward fining polymictic grit band also known as the Elsburg Basal Conglomerate (VS5) (Figure 2-3). In the more proximal areas to the east in the Free State Goldfields, this is a medium to large pebble conglomerate. Figure 2-4 shows the regional geology below Karoo cover across the project area.

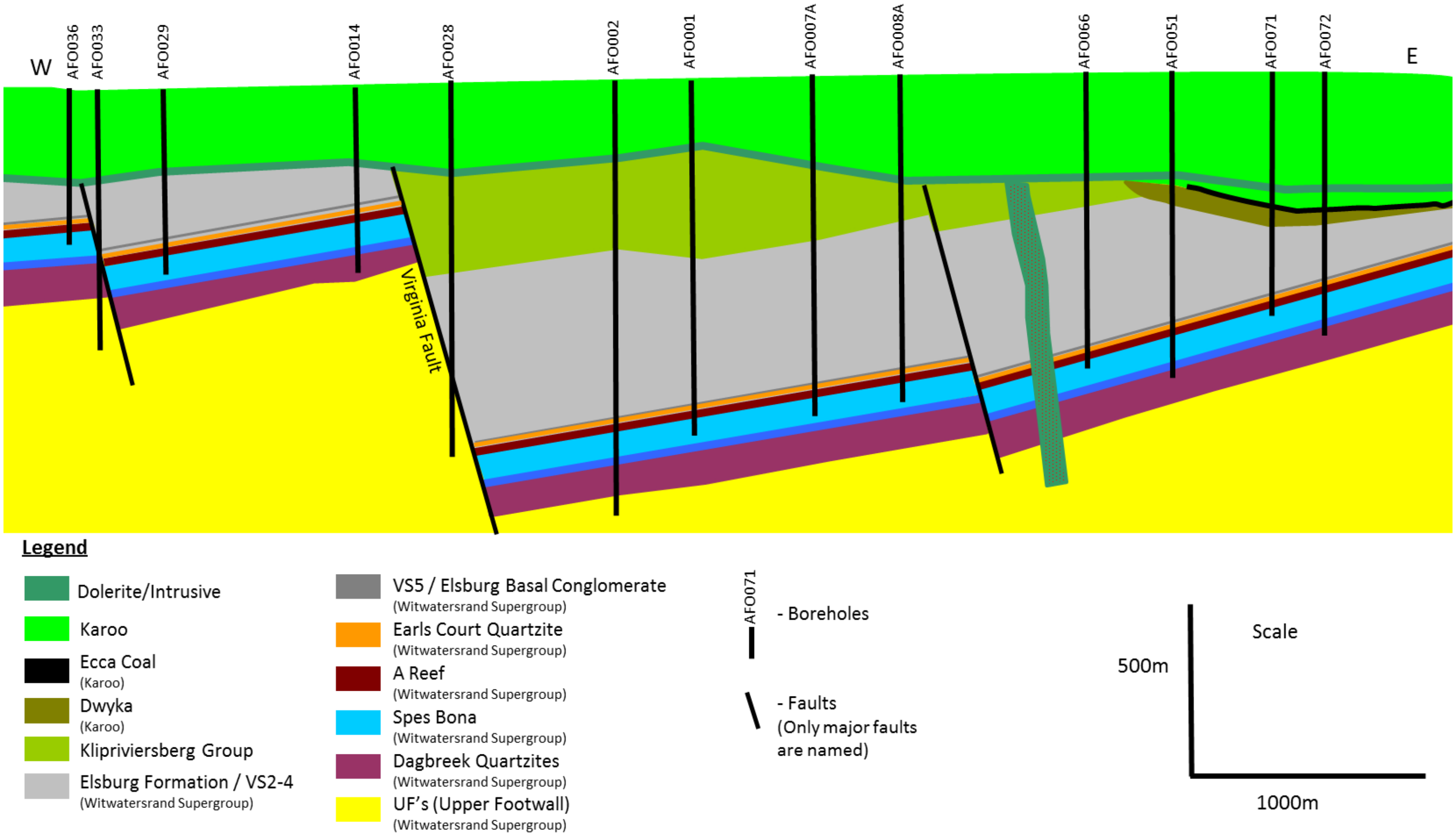


Figure 2-3: Simplified west-east section across the Ventersburg Project area (Section line indicated on Figure 2-4).

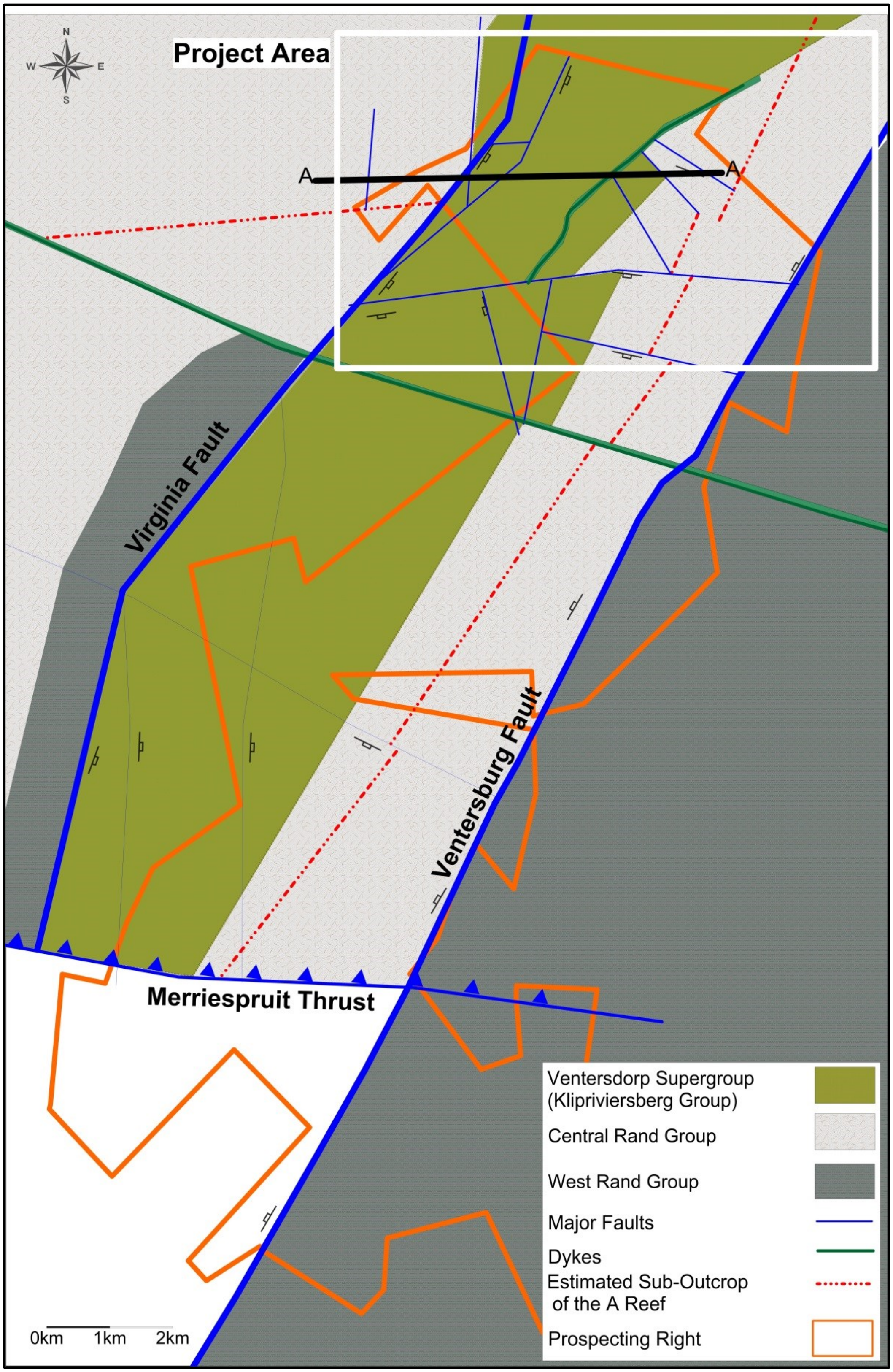


Figure 2-4: Regional general geology below Karoo Supergroup cover of the Ventersburg Project with large scale regional faulting (modified after De Bever, 1994).

2.2.1 Spes Bona Formation (Member)

The Spes Bona Formation has an unconformable relationship with the Aandenk Formation above it, as is evident by the distance of the spacing between the base of the A Reef and the Big Pebble Marker which increases in a northerly direction (Steenekamp, 1990) (Figure 2-5). In the project area the Big Pebble Marker comprise up to three large pebble to cobble bands and the total thickness is up to 25 meters. The Spes Bona Formation sub-crops against the Eldorado Basal Conglomerate just south of the Ventersburg Project area. In this area close to the sub-crop reworked Big Pebble Marker conglomerates occur directly below the A Reef. The quartzites of the Spes Bona Formation are very immature with poorly sorted polymictic conglomerates with a high sericite content as well as abundant silicified shale fragments. The Spes Bona and Aandenk Formation conglomerates, which include the B Reef at the base and the Big Pebble Marker at the top, can easily be differentiated from each other because of the abundant yellow silicified shale content in the Spes Bona Formation (Karpeta, 1984) as well as sequences of upward coarsening conglomerates. The Aandenk Formation is indicative of an upward fining sequence. The B Reef in the project area occurs 35 to 55 meters below the A Reef at the base of the Spes Bona Formation. The B Reef occurs unconformably on top of the Booysens Shale which is also known as the Upper Shale Marker (Smith, 1992). This marker divides the Central Rand Group into the Johannesburg and Turffontein Subgroups. The Spes Bona Formation in the project area is composed of mainly medium to course grained yellowish argillaceous quartzwackes and some polymictic conglomerates consisting of quartz, chert (banded, grey, black, and small white grits), yellow silicified shale fragments and some quartz porphyries.

2.2.2 Aandenk Formation (Member)

The A Reef is part of the arenitic lithologies of the Aandenk Formation. The latter comprises siliceous quartzites and conglomerates with interbedded argillaceous quartzites (Minter *et al*., 1986). The Aandenk Formation quartzites are more mature than the underlying quartzites of the Spes Bona Formation. These sediments are generally finer grained in the study area. Closer to Welkom in the east, due to the unconformable relationship of the Spes Bona and Aandenk Formations, the A Reef and Big Pebble placers are separated by more than 5 meters of immature quartzite. In the project area, the distance between these two placers decrease to less than 1 meter. In the south of the project area, the A Reef appears to have transgressed over footwall conglomerates indicating reworking of the bottom part of the A Reef and top of the footwall conglomerates (evident in some historic borehole logs ON1 and also current boreholes (Figure 2-5)). According to Karpeta (1984) there is no evidence that gold mineralisation in the A Reef was affected by palaeo-topography. In the project area, it certainly played a role in the development of channels and has controlled gold concentrations and occurrences in some way.

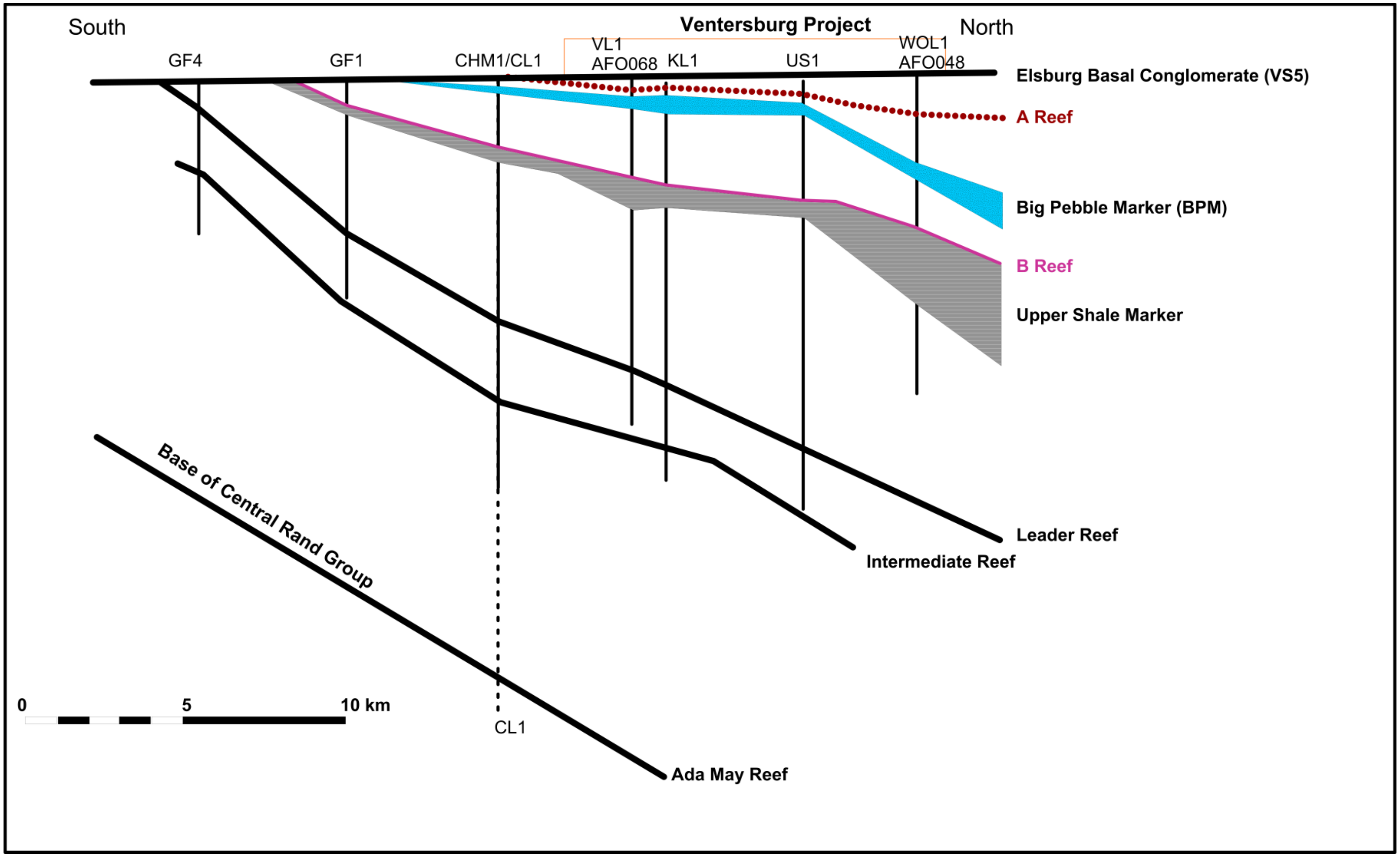


Figure 2-5: Unconformity relationships in the Ventersburg Project area. Note the unconformable relationship between the A Reef and the overlying sediments (Minter et al., 1986).

2.3 Historic Borehole Review

A number of historic boreholes were reviewed by independent contractors on Gold Ones' behalf. Figure 2-6 indicates the locality of some of the historic boreholes in the study area. Some of the borehole core was traced back to Gold Fields Ltd. and was still stored at Oberholzer Geological Centre in Carletonville and also at a core yard belonging to Rand Gold. Access to the core was gained to compare the accuracy of historical logs and to correlate the described stratigraphy specifically of the A Reef with current drilling.

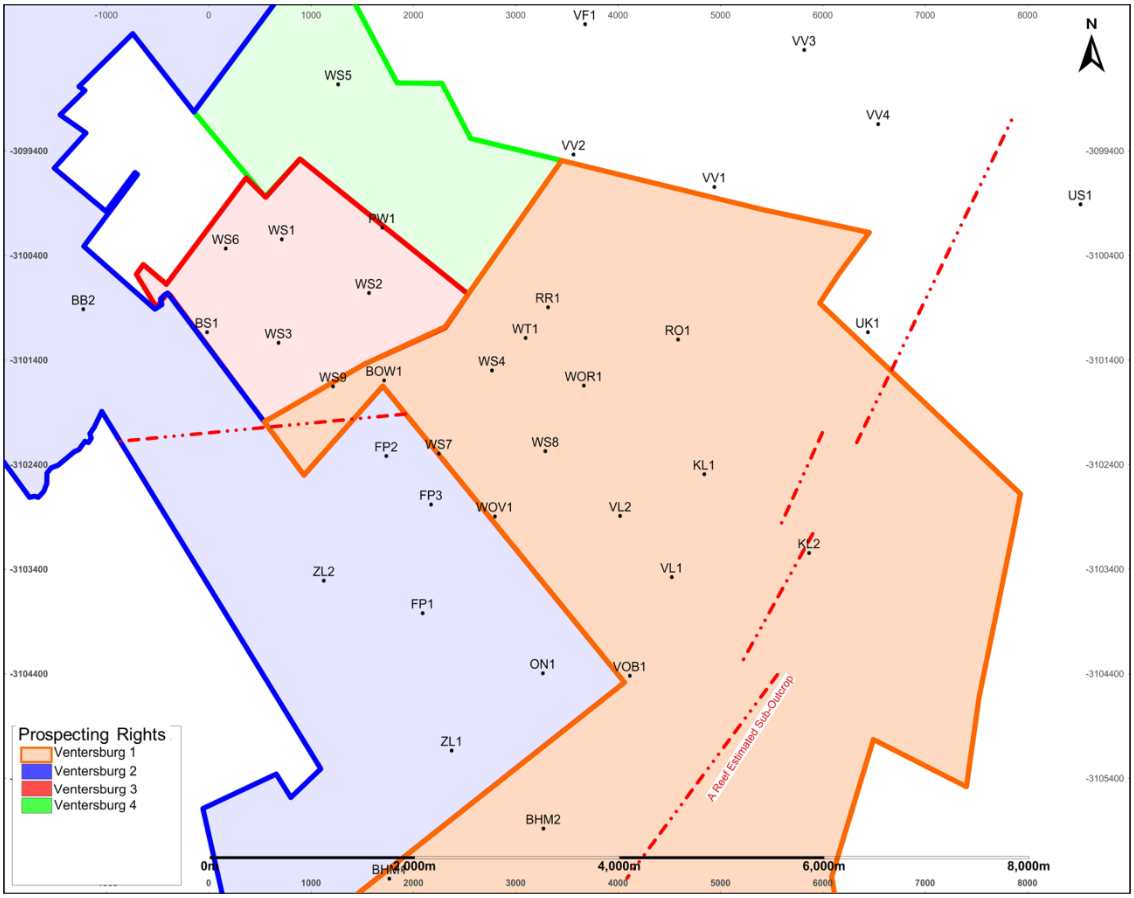


Figure 2-6: Plan showing the positions of historic boreholes in the Ventersburg Project area (Black dots).

Borehole KL1 – Two main cycles of sedimentation could be identified, each with a scour surface at its base. From the original intersection, it is evident that most of the gold is concentrated in the upper 70 cm. The A Reef is top loaded and correlates with the Uitsig Unit which can be described as a poorly sorted, clast supported, oligomictic medium pebble conglomerate with a siliceous quartzite matrix (CCOS).

Borehole VL1 - Three main cycles of sedimentation were identified. The A Reef in this borehole is an upward fining medium pebble conglomerate (MPC). Each cycle is defined by a scour surface (erosional contact) at its base. Most gold is concentrated in the upper part of the reef. The A Reef channel in this borehole is thicker than 200 cm. The lower 40 – 50 cm is poorly mineralised and more quartzitic.

Borehole VL2 - Three main cycles of upward fining sedimentation are also visible in this borehole, each marked by a scour surface at its base. This reef intersection is mineralised in the upper and middle part of the A Reef channel. The A Reef channel here is a small to medium pebble conglomerate (SPC-MPC). The bottom of the reef is a loosely packed large pebble conglomerate (LPC). The character of the sedimentation in this reef intersection places it close to an inter-channel sandbar. Some degree of migration of the bar and reworking occurred.

Borehole WS4 - This reef is unusual in character and thicknesses are comparable to AFO004, which is a main channel sand facies with more than 70%, interbedded quartzite. It is composed of two units, a lower mature unit with little conglomerate and poorly mineralised and an upper, conglomeratic unit which hosts most of the mineralisation. The total reef thickness varies between 293 cm (deflection 3) to 325 cm (deflection 1). The upper unit is only 45 cm to 86 cm thick. Although the matrix of the conglomerates is mostly argillaceous, this upper part contains more than 90% of the gold. In two intersections, the original one and deflection 4, high gold grades were recorded at 70 cm and 15 cm respectively above the base of the A Reef. Below the A Reef in WS4, there is a 2m thick shale package and the reef was probably deposited in an erosion channel (Figure 2-7).

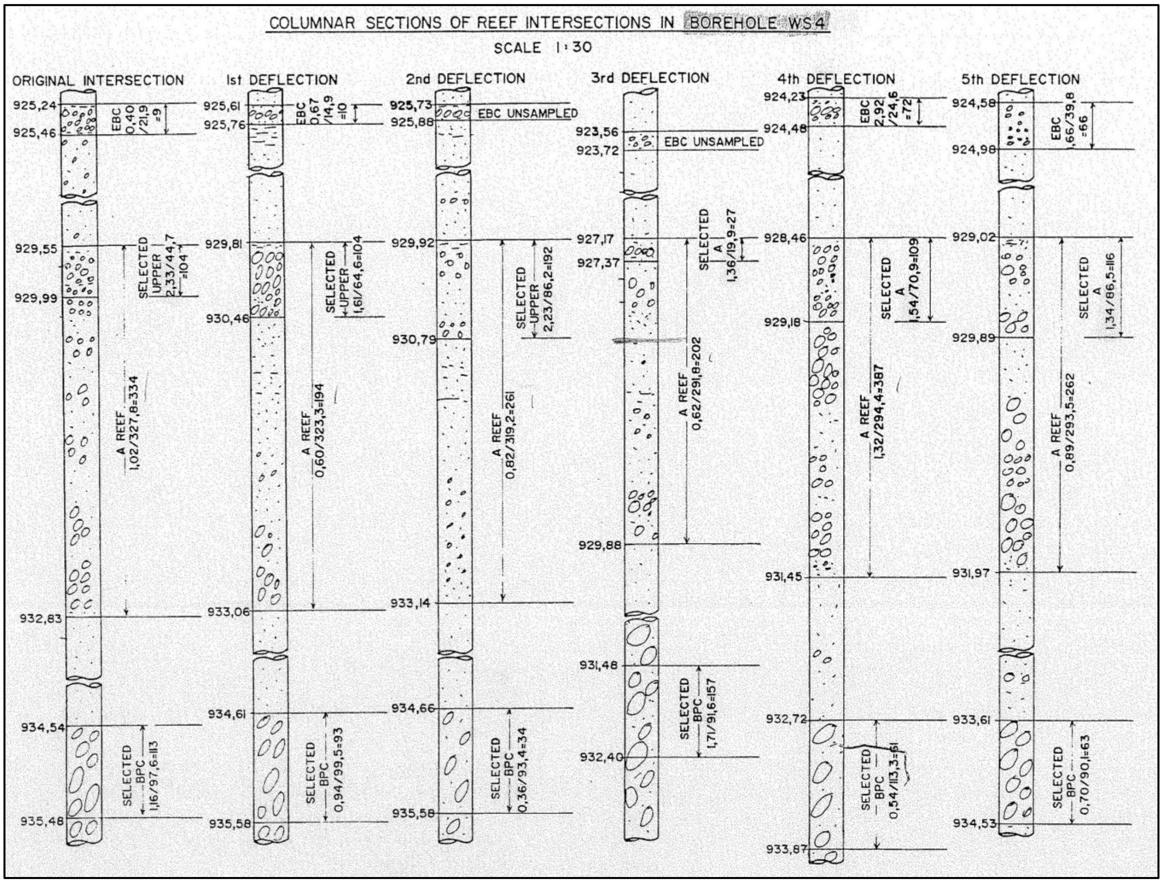


Figure 2-7: Profiles for the A Reef intersections in borehole WS4 (Historic borehole log by Harding, 1986).

Borehole WS7 – The A Reef is composed of a quartzitic lower unit and a conglomeratic upper unit, with a total thickness of between 108 cm in borehole WS7 deflection 6 to 142 cm in deflection 3. The reef in the original borehole, as well as deflection 1 and deflection 2 are partially faulted and not acceptable for evaluation. Mineralisation is concentrated in the topmost 40 cm. The bottom medium pebble conglomerate (MPC) lag of 8 cm thick in deflection 3 was not sampled by the original samplers. Thus, only deflections 4, 5 and 6 are acceptable for evaluation at this stage (Figure 2-8).

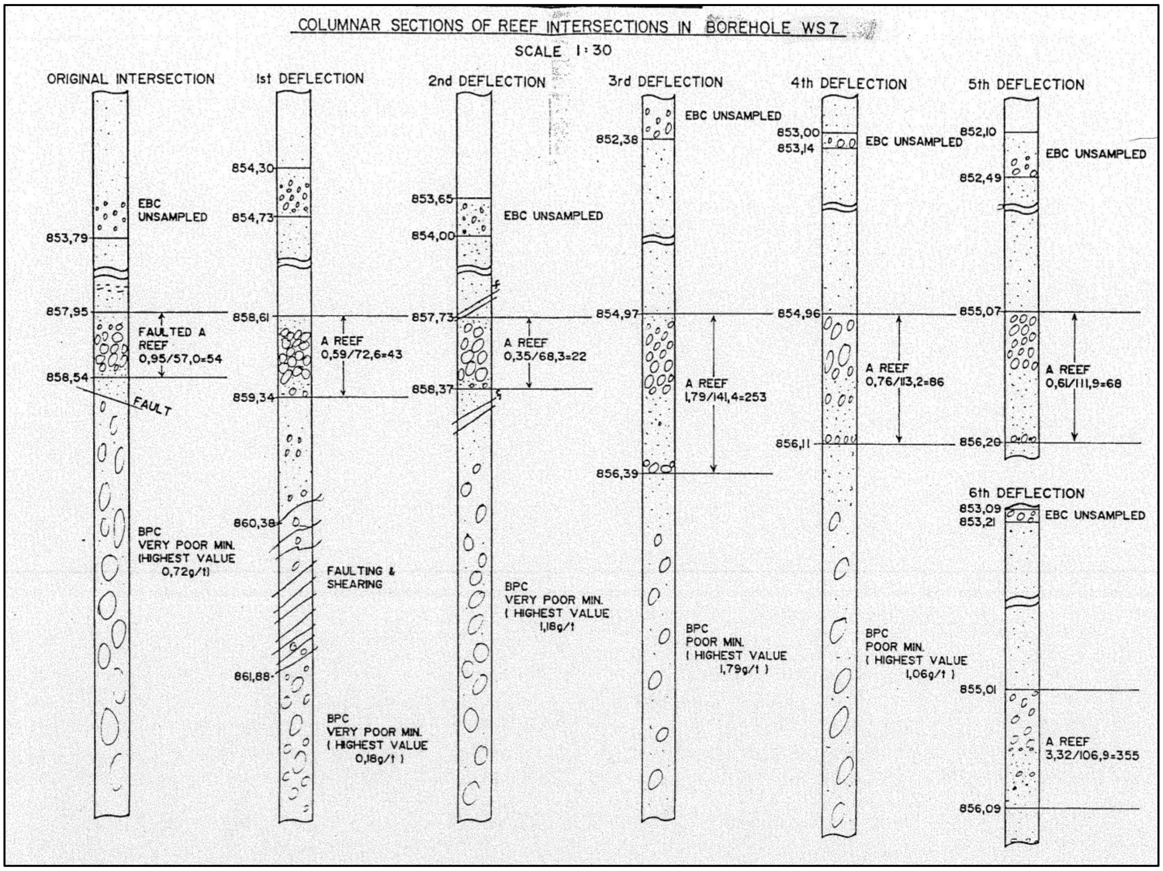


Figure 2-8: Profiles for the A Reef intersections in borehole WS7 (Historic borehole log by Harding, 1986).

Borehole WS8 – All the intersections were quartered and are difficult to log. The A Reef is well mineralised and thick, varying between 274 cm in deflection 1 and 326 cm in deflection 5. There appears to be six scour surfaces in the A Reef sequence. More than 70% of the gold is concentrated in the upper half of the reef, except deflection 3 and deflection 4, where most gold occurs in the middle part of the reef. The existing logs are of a good quality and no further research was conducted.

Borehole WS9 - Four main cycles of sedimentation could be identified in the original borehole, deflection 1 and deflection 2, each marked by a scour surface at its base. Only three cycles could be identified in the thinner intersections of deflections 3, 4 and 5. The lower unit is probably absent in the last three intersections. The A Reef is well mineralised in the first four intersections, but gold appears to be concentrated in the upper 32 cm to 40 cm in deflection 4 and deflection 5.

3 Geology of the A Reef

3.1 Introduction

The A Reef conglomerates are found between the Big Pebble Marker (BPM) in the footwall and the Eldorado Basal Conglomerate (VS5) in the hangingwall (Figure 2-1).

The lithologies of the Aandenk Formation which contain the A Reef are distinctly different from the Eldorado Formation above the A Reef and the Spes Bona Formation below the A Reef. The BPM in the Spes Bona Formation occurs below the A Reef with an immature quartzwacke between the bottom of the A Reef and the top of the BPM. The A Reef and BPM are very different in clast assemblages and gold grade as well as the matrix composition. The Earls Court Quartzite (ECQ, discussed in section 3.7) that forms part of the Aandenk Formation occurs below the Eldorado Basal Conglomerate (EBC) which is also known as the VS5. The EBC forms an angular unconformity with the underlying beds. The EBC is poorly developed across the study area and is a polymictic grit band found at the bottom of the Eldorado Formation. The EBC, although poorly developed, is a distinct hangingwall marker above the A Reef horizon. The unconformity at the base of the EBC results in the stratigraphy thinning from north to south. In order to compile isopach plans of channel thickness and to illustrate the relationship of the Eldorado Basal Conglomerate and the A Reef, the Eldorado Basal Conglomerate was used as a marker horizon.

3.2 Description of the A Reef Lithologies

The A Reef in the Ventersburg Project is located close to the eastern margin of the Witwatersrand Basin. The A Reef is the only economically viable auriferous reef in the project area. Other reefs i.e. the Leader Reef, B Reef and Elsburg Basal Conglomerate occur as poorly developed grits or very small pebble conglomerates. The Leader Reef is very poorly developed and difficult to identify with certainty.

Typically in the project area, the A Reef is a clast supported, well-packed, oligomictic conglomerate with a dark quartzitic matrix (Figure 3-1). More than 95% of the clasts consist of smokey and white vein quartz and the matrix in some areas may consist of more than 70% detrital pyrite. The pebbles are sub-rounded to sub-angular and range in size from 4 to 65 mm. Pebbles sizes are described using the Udden-Wentworth scale 1922 (Wentworth, 1922). In other areas of the Free State Goldfields the A Reef is described as a lower Witpan and an upper Uitsig placer (Karpeta, 1984) (Figure 3-2). In the project area the A Reef will be described as the A Reef Zone comprising different lithological units. The lower unit of the A Reef does not extent across the entire project area and predominantly occurs in deeper channelized areas.

Four different lithological units in the A Reef are recognised in the Ventersburg Project area. Firstly, the reworked Big Pebble Marker (BPM) occurs south from borehole FP1 and AFO087 (Figure 3-3) due to the sub-crop of the BPM conglomerates against the A Reef (Figure 3-4 shows a borehole profile of the BPM against the A Reef). The reworked BPM is polymictic with a siliceous matrix and sporadic concentrations of gold. The reworked BPM is a result of the lower part of the A Reef eroded into the footwall lithology. Care must be taken during sampling not to include this into A Reef as it is a different facies and sample populations will then be mixed.

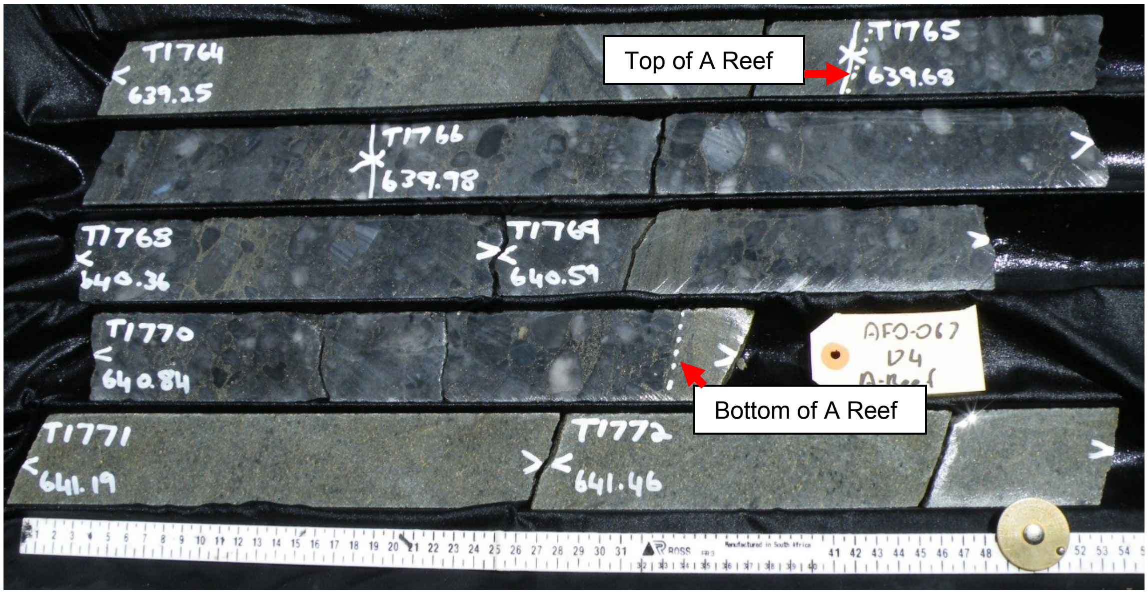


Figure 3-1: Oligomictic A Reef with well-developed small to medium pebble conglomerate with abundant detrital pyrite matrix.

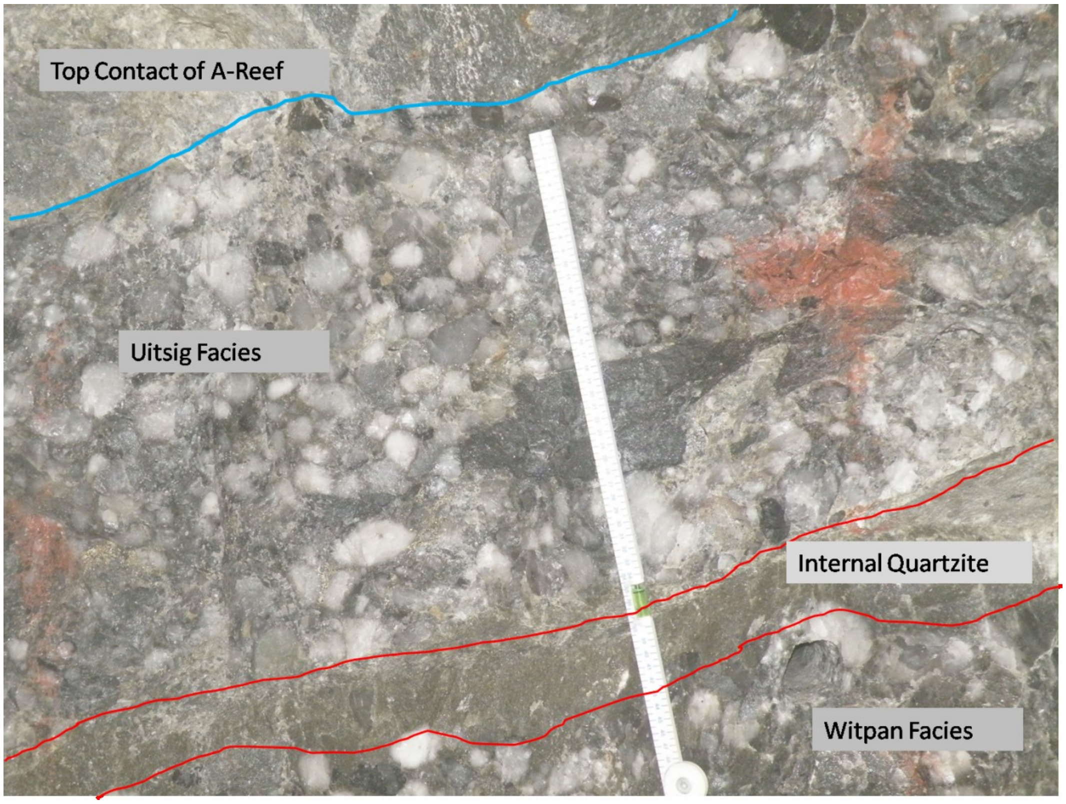


Figure 3-2: A Reef unit depicting a section of the top and bottom units and also showing the immature interbedded quartzwacke between these units (photograph was taken under ground by the author at Brand 1 Shaft where A Reef has been mined until 2010).

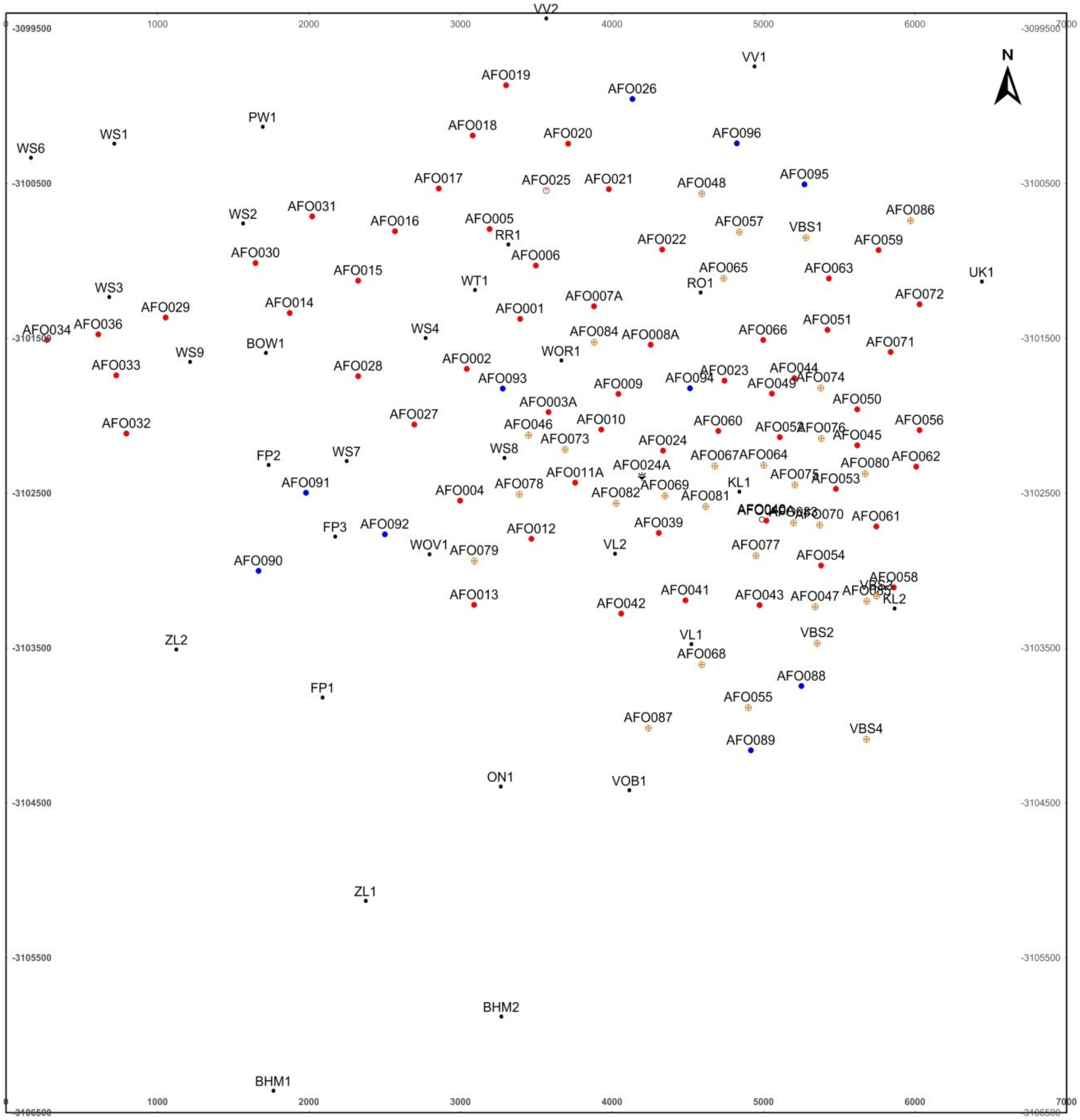


Figure 3-3: Borehole locality plan (WG27 (Hartebeesthoek 1994)).

The proper A Reef zone has three lithostratigraphic environments namely the Main Channel, Subsidiary Channel or Channel Edge and Terrace and within these are channel bars and inter-channel islands. The environments are described in terms of their different sedimentological characteristics. The lithostratigraphic environments were used to define three geological domains also called geo-zones. All three domains are distinguished based on their sedimentology, reef thickness and gold distribution patterns.

All three lithostratigraphic units of the A Reef occur together over an area in channel complexes and can be more than 1 500 meters wide. Individual channels are less than 200 to 300 meters wide. The limits of the channel complex have to be well defined to delineate a good prospecting target. For resource estimation, it was decided to model geological domains of the total A Reef because of the discontinuous nature of the main channel as well as the fact that many historical boreholes logs did not accurately describe the contact between facies.

A simplified method for facies description was adopted and modified from Miall, (1996) and applied to the A Reef in the Ventersburg Project area, (a summary of the abbreviations is given in Table 3-1). The code comprises up to three letters, each describing a different facies characteristic. The first letter is a capital letter; this describes the grain size from gravel to shale. All the letters after the first are lower case, the second letter describes the sedimentary structure and the third the packing density whether it is clast or matrix supported. The A Reef sub-environments are described in the following section.

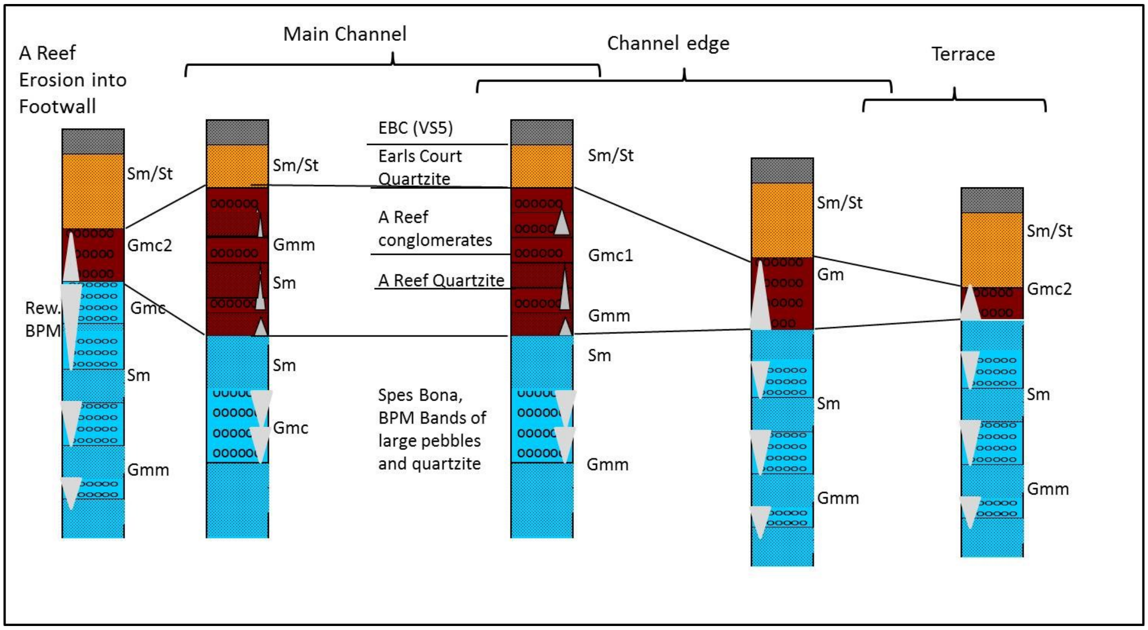


Figure 3-4: Description of the A Reef lithostratigraphic environments.

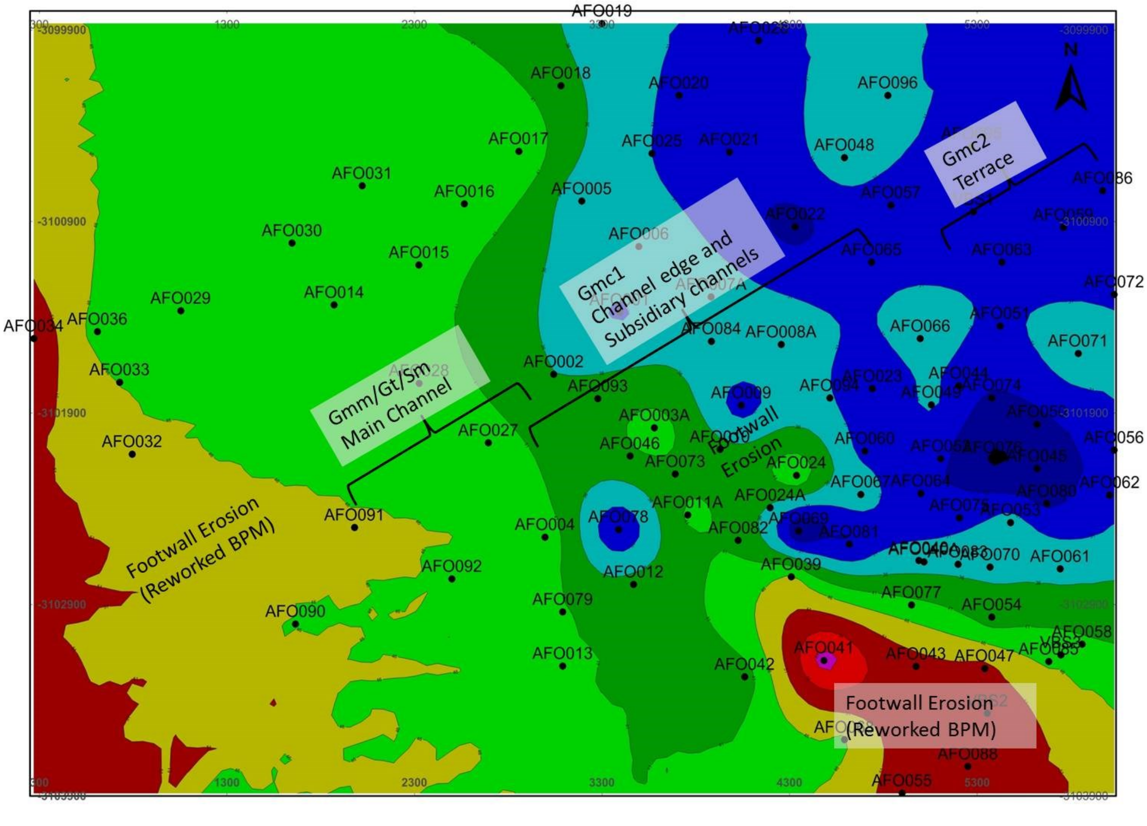


Figure 3-5: Facies distribution of the A Reef based on borehole intersections. Colours indicate the different facies as described (WG27 (Hartebeesthoek 1994)).

Table 3-1: Facies descriptions of the A Reef lithology (modified from (Miall, 1996)).

Facies Code	Description	Environment
Gmc1/2	Conglomerate (G), massive (m), and clast supported (c), well packed oligomictic.	Channel edges and subsidiary channels.
Gmm	Conglomerate (G), massive (m), matrix supported (m), poorly packed.	Main channel and inter channel islands
Gt	Conglomerate (G), through cross bedded (t) and loosely packed.	Main channel
Sm	Sand (S) massive (m) argillaceous quartzite, sericitic alteration.	Main channel
Fm	Shale, massive.	Aandenk erosional channel and Booysens shale

3.2.1 Gmm/Gt/Sm Facies

This facies is a massive matrix supported conglomerate. The matrix is mostly medium grained argillaceous quartzite, with sporadic medium to large pebble conglomerate bands and yellow silicified shale fragments near the base. The facies is upward fining (Figure 3-4) and is indicated as the main channel facies (Figure 3-5). The concentration of heavy minerals is low and is mainly concentrated in conglomerate bands. The facies has a dramatic increase in thickness from 120 cm to over 300 cm. The facies thickness increases in areas where it has eroded into the footwall sediments with a small basal scour unit, (AFO-016 (Figure 3-7), AFO-43). Where the A Reef eroded into the BPM the pebbles are polymictic with some chert and shale fragments from the underlying BPM conglomerates. The percentage of interbedded quartzite also distinguishes this facies from other facies. The facies contains more than 30% interbedded quartzite beds (Figure 3-6, Figure 3-7) which are absent in adjacent beds.

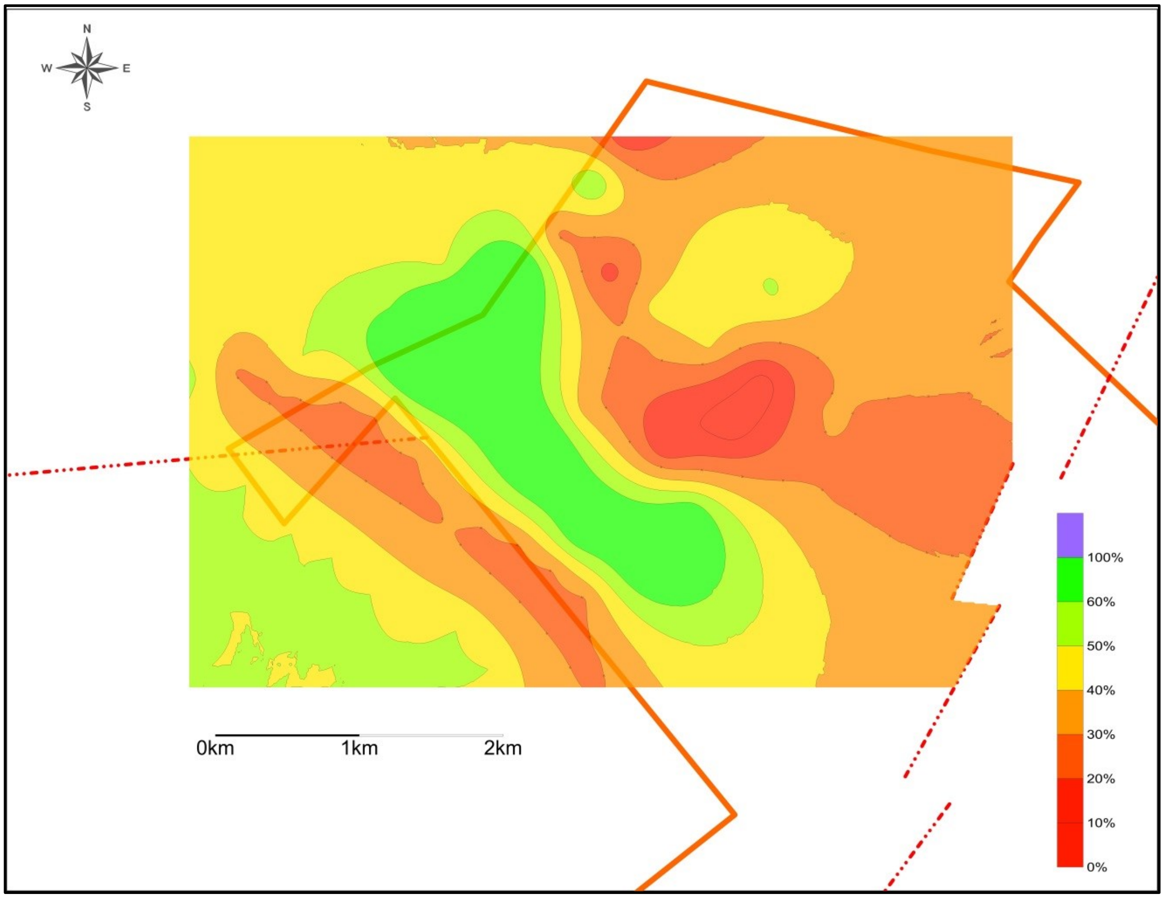


Figure 3-6: Interbedded Quartzite presented as a percentage of the total reef thickness. Clearly apparent is zones with different characteristics, the green area indicates the highest percentage interbedded quartzite and also correspond with the thicker main channel facies (WG27 (Hartebeesthoek 1994)).

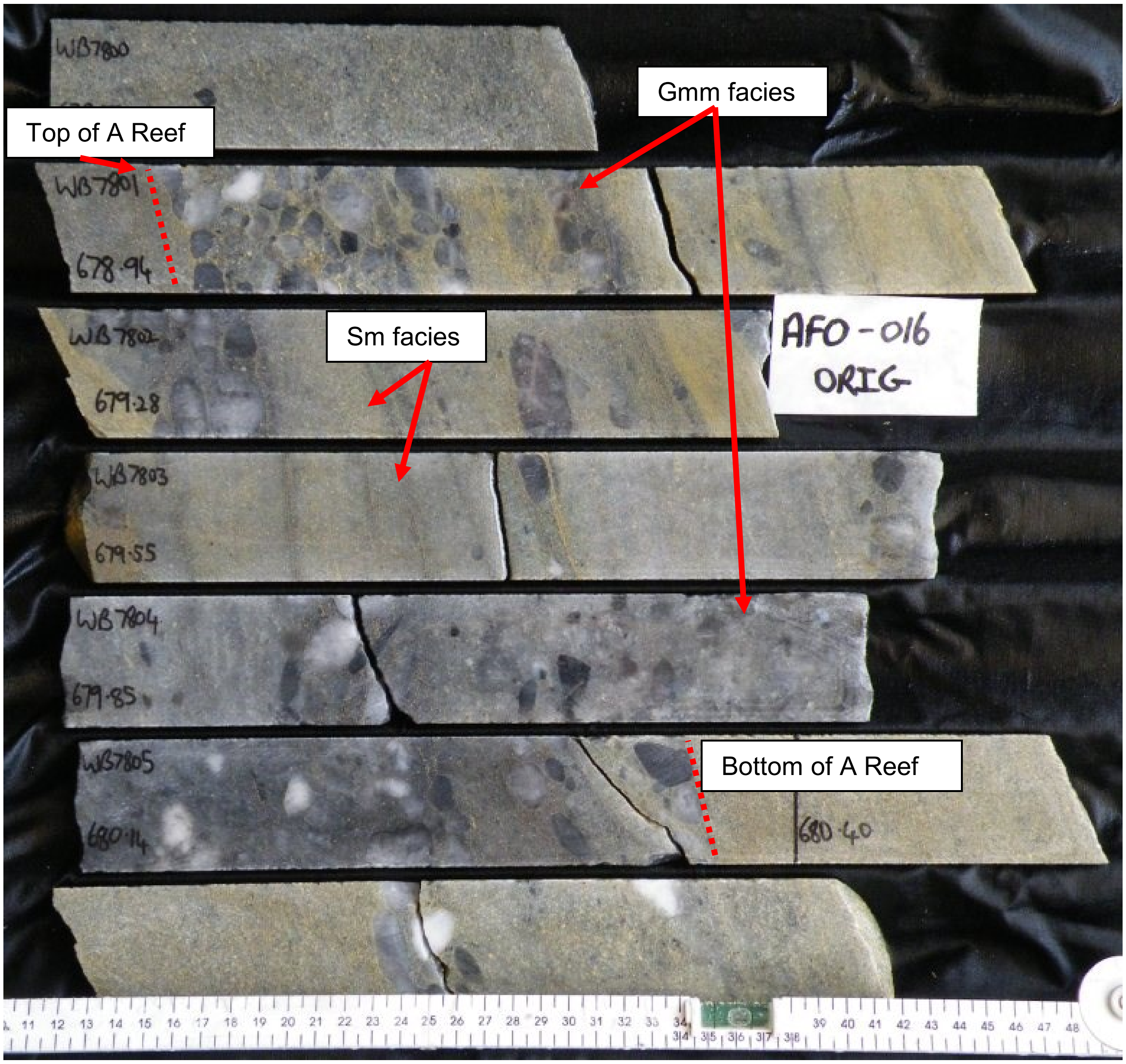


Figure 3-7: Photograph of borehole AFO-016 drilled in the main low grade channel. It has more than 40% interbedded quartzite and total channel thickness of 207 cm.

3.2.2 Gmc1 facies

There is a lateral variation and overlap between the Gmc and Gmm/Gt/Sm facies (Figure 3-4). The main difference is the decrease in the percentage of interbedded quartzite towards the edge of the facies. The facies consists of subsidiary channel areas with inter-channel bars/islands and is described as Gmc – Gmm/Gt facies (Table 3-1 for description). This facies represent a clast supported oligomictic conglomerate, massive and well packed (Figure 3-8). Some interbedded quartzite lenses may be present within this facies because of lateral migration of channels. The pebble assemblage is mostly vein quartz and smokey quartz with abundant small opalescent quartz grits. Shale fragments and chert pebbles make up less than 5% of clasts. The matrix is predominantly pyritic. Pebbles are mostly sub-rounded to rounded and this facies is upward fining (Figure 3-4).

The facies described above is similar to the Uitsig facies described at other mines for example President Steyn (Karpeta, 1984). Channel migration resulted in the reworking of channel bars to form quartzite lenses interbedded in the conglomerates (Figure 3-11). The conglomerate bands can also erode into the footwall (Figure 3-10) and this creates internal variation in reef thickness over short distances. In areas where footwall erosion occur changes in the flow regime of the stream resulted in the deposition of heavy minerals. The reef in these areas varies from 60 cm to 130 cm in thickness. Heavy minerals are concentrated in channel bars and channel edges.

The channel bars and channel edges is the most important areas for heavy minerals to concentrate. Mineralisation in the A Reef is made up of fine to medium grained rounded to sub-rounded detrital pyrite (Figure 3-9) with occasional allogenic pyrite and euhedral crystals scattered through the quartzite matrix. Secondary mineralisation is common close to fault zones and associated fractures.

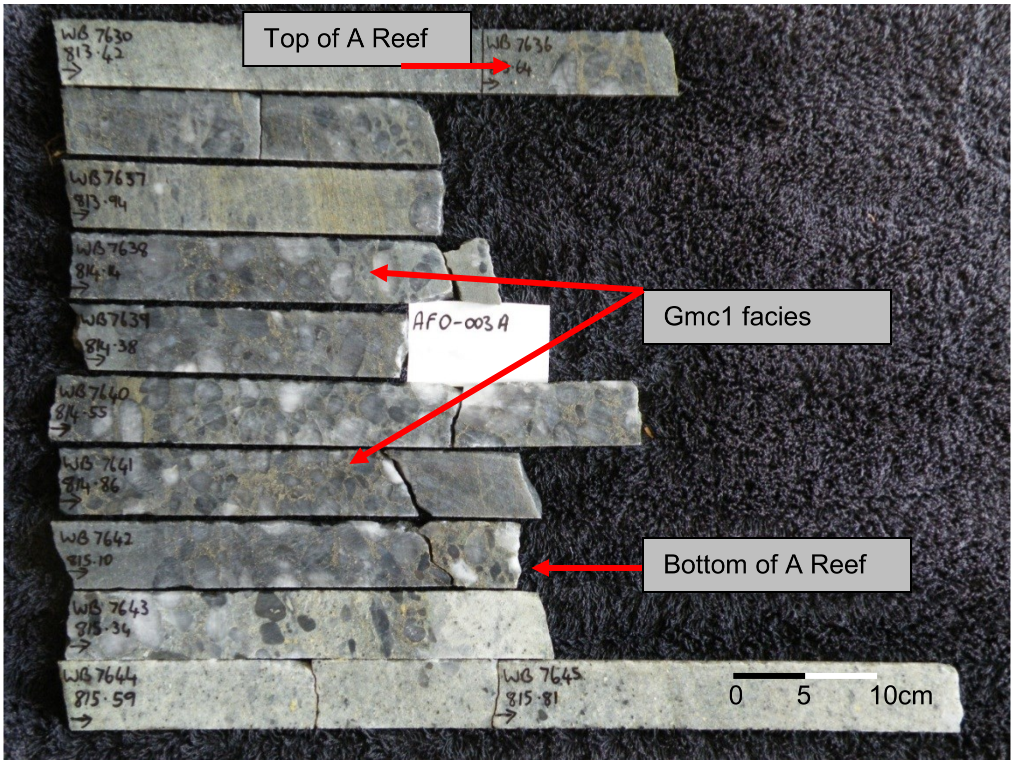


Figure 3-8: A Reef intersection in borehole AFO003A, depicting an upward fining sequence with interbedded quartzite lenses as described in sections 3.2.2.

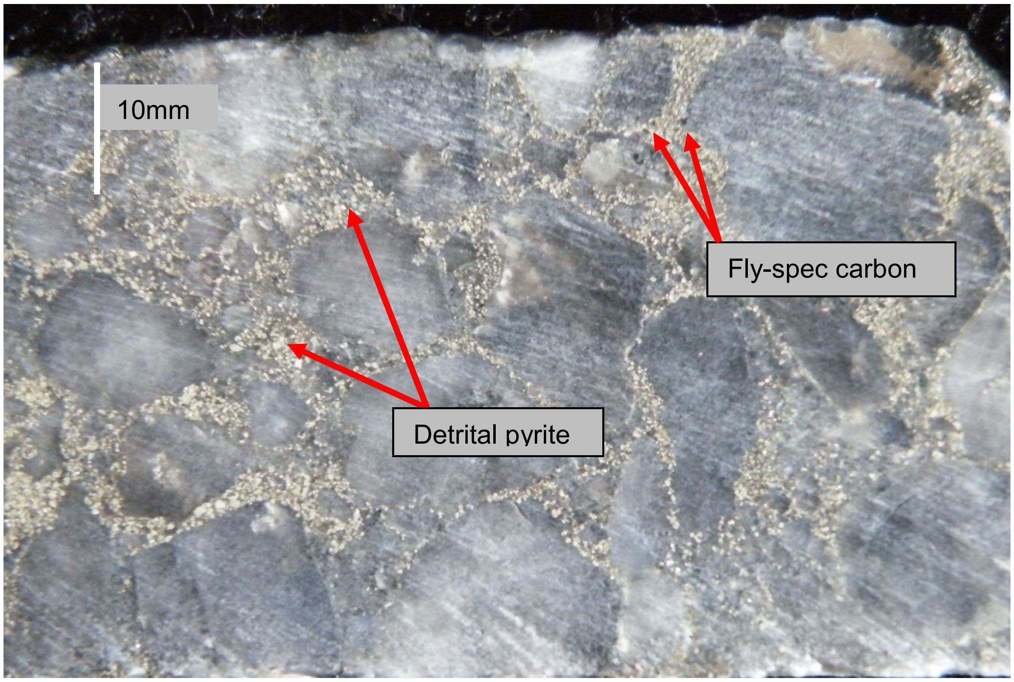


Figure 3-9: Pyritic matrix in the A Reef, borehole AFO003A.

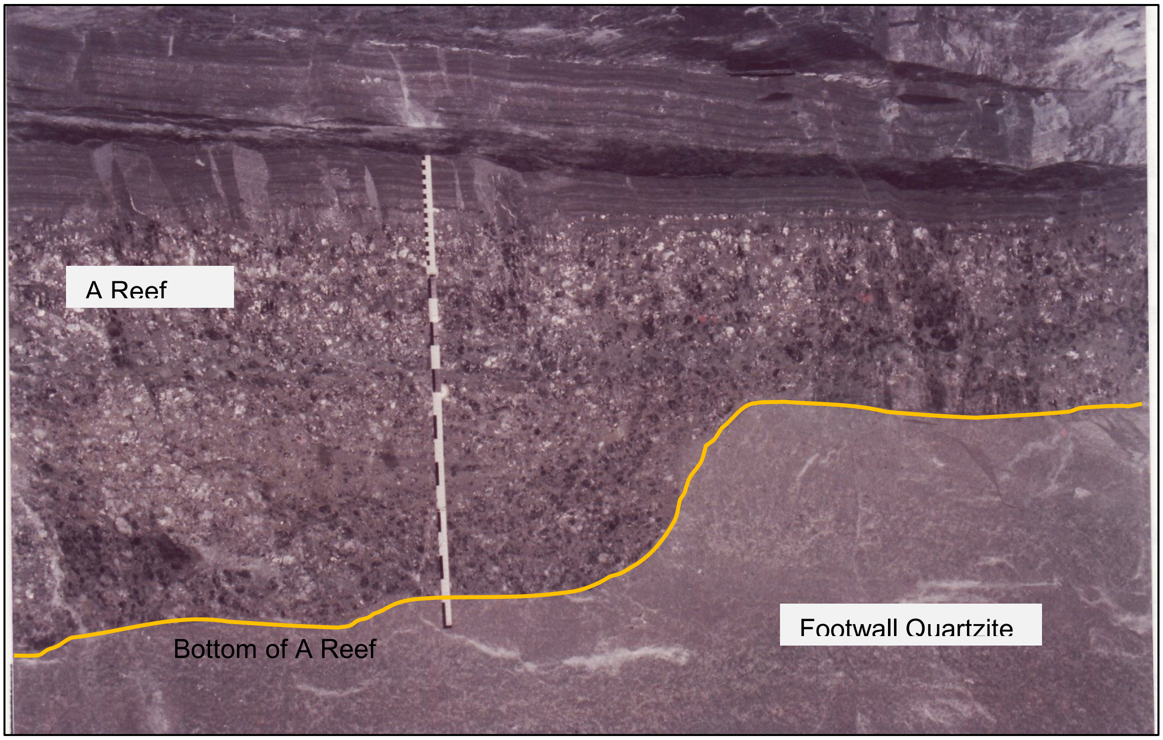


Figure 3-10: Channel erosion in the A Reef, a sudden change in thickness over a short distance (Genis, 1990).

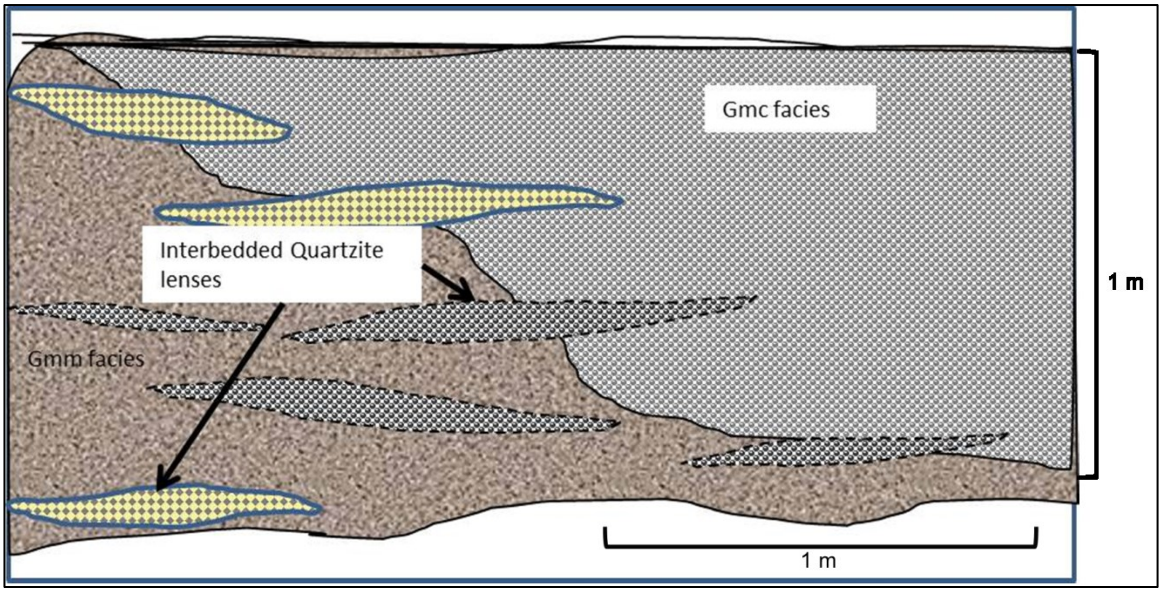


Figure 3-11: Lithological variation in the A Reef.

Figure 3-12 indicates the upper and lower units of the A Reef at the Ventersburg Project. The upper unit can be correlated with the Uitsig facies in other parts of the Goldfields and the lower unit marked footwall, is reworked footwall sediments i.e. BPM.

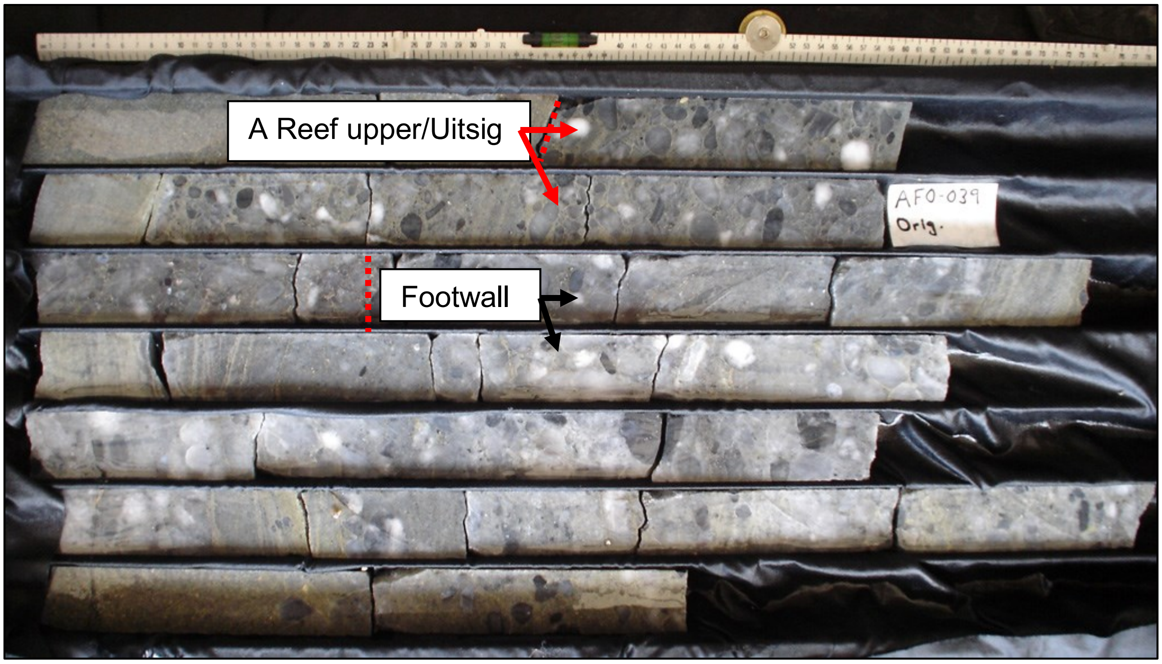


Figure 3-12: A Reef with upper Uitsig unit and reworked footwall sediments.

3.2.3 Gmc2 / Gt facies

This facies occurs in the north-east of the project area. It has a sheet-like geometry and covers a large area. Characteristically the conglomerates vary in thickness between 20 cm to 60 cm and are upward fining in nature (Figure 3-4), while channel thickness varies over short distances (Figure 3-14). The pebbles are mostly oligomictic at the top of the conglomerate and become more polymictic with shale fragments and chert grits at the bottom of the facies (Figure 3-13). When only thin channels of this facies are developed it closely resembles the Eldorado Basal Conglomerate but the presence of small opalescent quartz grains distinguishes it from the Eldorado Basal Conglomerate which is a polymictic grit.

Fly-spec carbon is present in the basal part of the conglomerate facies within a pyritic matrix. The gold tenor in the Gmc facies increase dramatically when fly-spec carbon is present as well as pebbles larger than 10 mm.

Figure 3-13: Example of Gmc facies, upward fining small pebbles and grits that occur as sheets along channel edges.

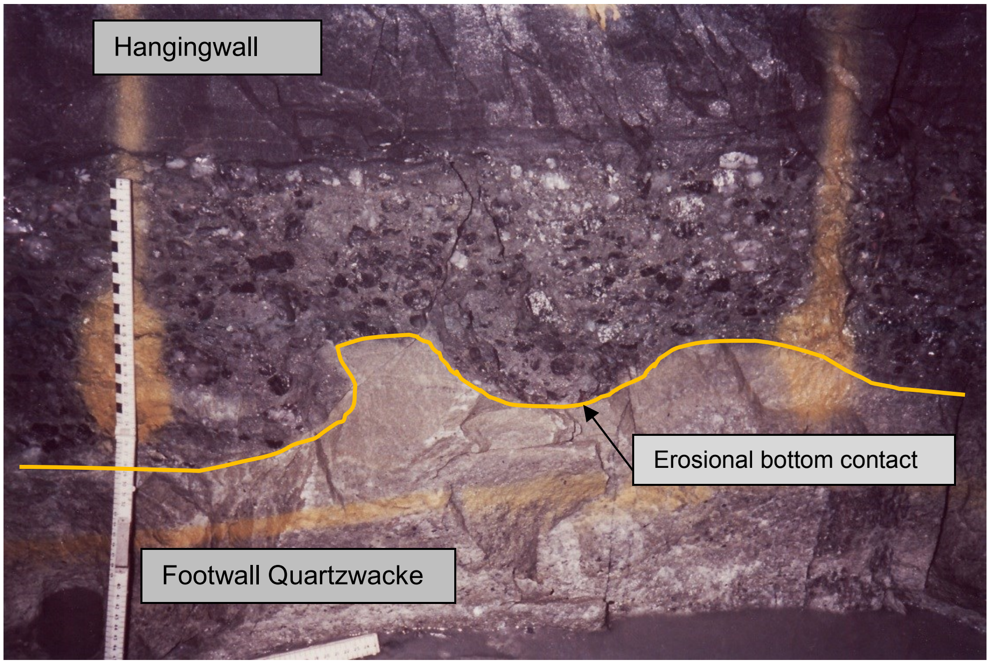


Figure 3-14: Photograph showing channel erosion in the A Reef (Genis, 1990).

3.2.4 Gmc/Fm facies: Aandenk Erosion Channel

Remnants of an Aandenk type channel occur in localised areas at the base of the Aandenk Formation below the A Reef. It is a polymictic, matrix supported conglomerate fining upwards to black interbedded shales facies. The channel erodes large parts of the Aandenk Formation and predominantly the Big Pebble Marker. At the Ventersburg Project the channel was found in the north western part of the project area (Figure 3-15). It is capped by a thin black shale facies (Fm) below the A Reef where it has eroded into the Big Pebble Marker of the Spes Bona Formation. The extent of the Aandenk channel is not known and it did not influence the A Reef in the project area.

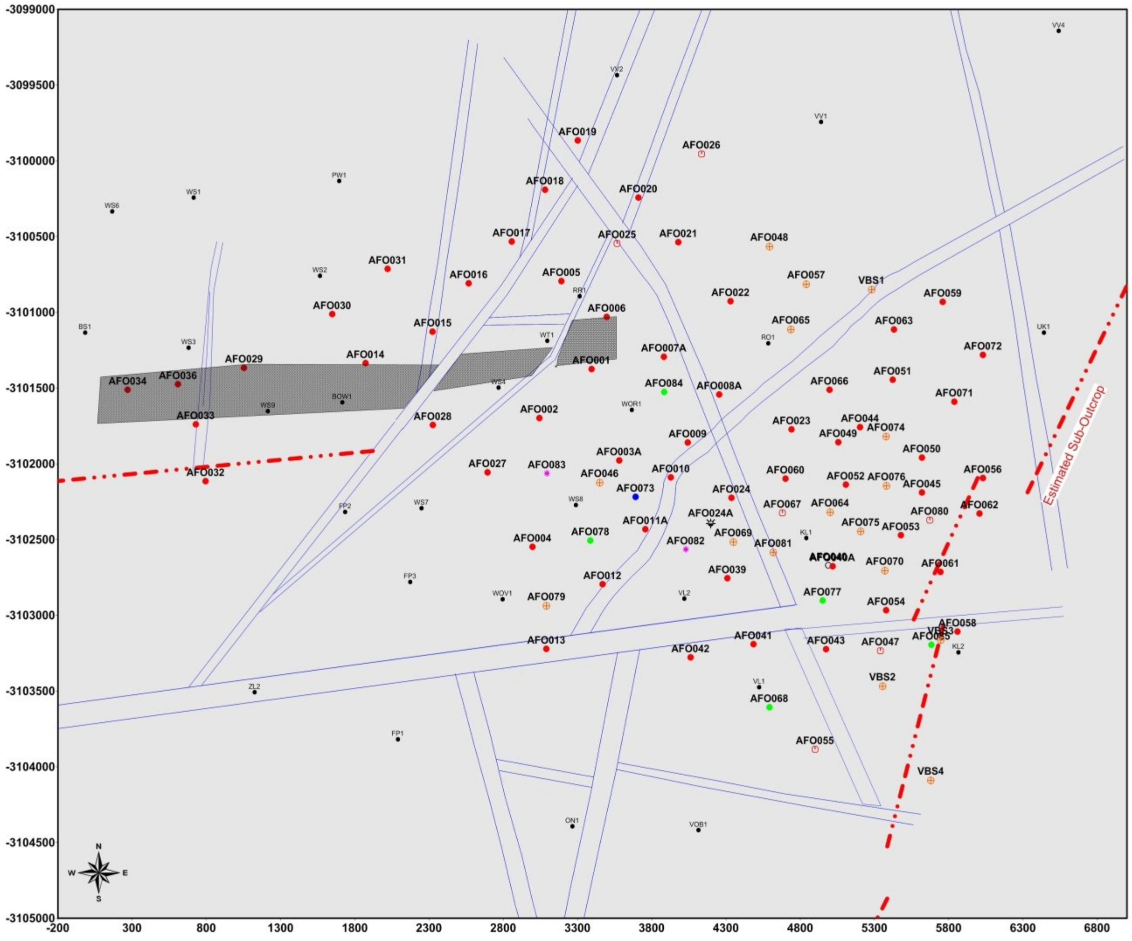


Figure 3-15: Plan showing the possible extent of the Aandenk Erosion Channel (dark grey) and major faults (Blue lines). (WG27 (Hartebeesthoek 1994)).

3.3 Sedimentology of the A Reef

Apart from sedimentological characteristics, other macroscopic features are also important. All the variables have to be considered in order to create a complete geological model for the distribution of gold in the A Reef. When each aspect of the deposit is considered on its own it has only limited use but when all the different variables are combined a geological model can be created.

The following macroscopic features are considered to be the most useful:

- Geometry of inter-channel bars as % interbedded quartzite
- Total channel thickness (see section 1.4.1)
- Pebble sizes

The graph in Figure 3-16 indicates the relationship between channel thickness and the internal quartzite as a percentage of the total reef thickness. From the graph it can be seen that thicker channels in the A Reef has a higher percentage internal quartzite. The channel thickness and internal quartzite is also related to the reef facies and gold distribution within the channels.

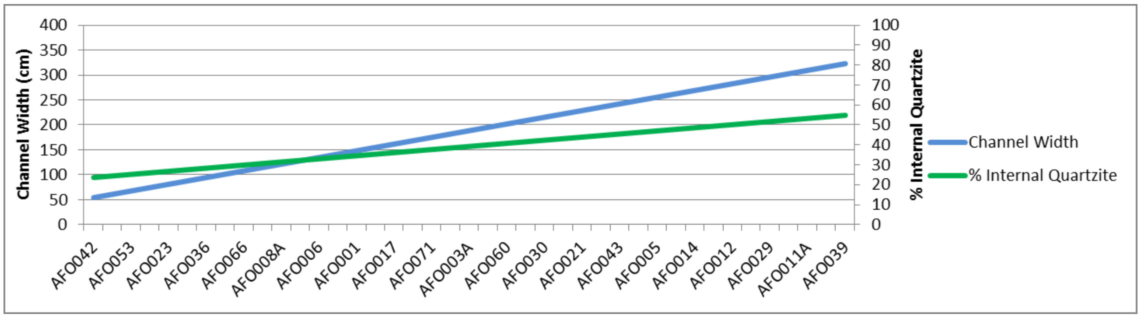


Figure 3-16: The relationship between Interbedded quartzite and channel thickness from boreholes.

Figure 3-17 is an illustration of the relationship between A Reef facies, channel thickness and gold grade. Thicker channel comprising matrix supported conglomerate will have lower gold grade and this represents the main channel facies. The clast supported facies (Gmc1) have an intermediate channel thickness as this comprise subsidiary and interchannel areas where heavy minerals will concentrate. The highest gold grades in Figure 3-17 occur where the channel thickness is less than 50 cm and correlates with the channel edge facies.

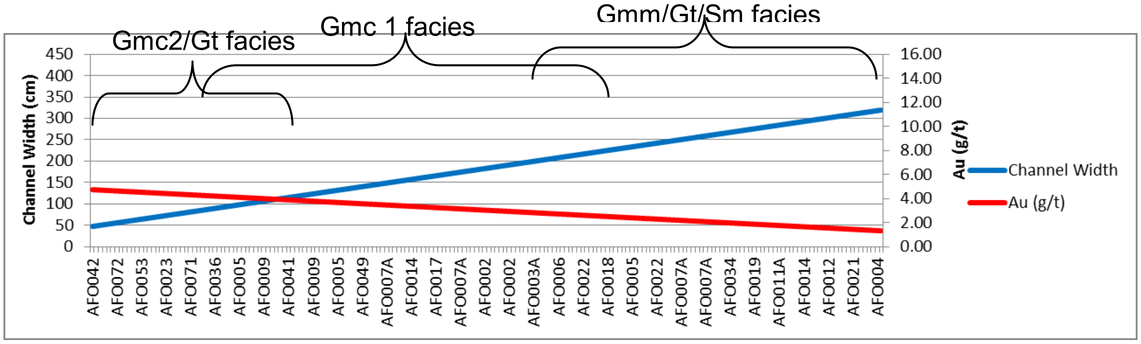


Figure 3-17: The relationship between facies, channel thickness and gold grade.

Conglomerates of the Witwatersrand are the main gold bearing horizons and a study of the pebbles is important in defining the depositional environment. The difference in pebble sizes across a placer deposit gives an indication of the palaeo flow directions. Although the pebble sizes within a reef will vary in all directions, some general assumptions can still be made. The size of pebbles will be influenced by the distance from the source as well as the energy of the stream which will influence the amount of erosion. The flow regime will influence the distance material can be transported and also how fast the pebble sizes will decrease over distance. When the velocity decrease, gravity will cause pebbles to fall out and deposition will occur.

Measuring pebble sizes in borehole core do not give the long axis or true size of the pebbles but it provides a very good indication of the mean pebble size. The ten largest pebbles in each reef intersection were selected and the surface square areas were calculated from the transparency on which the pebbles were traced. The average of the 10 largest pebbles was calculated. The use of the mean of the largest pebble sizes have been successfully used elsewhere for palaeo flow indicators (Minter, 1991). From this the main transport direction could be deduced. Pebble sizes were described by applying the Wentworth scale (Table 3-2).

Table 3-2: Pebble sizes (Udden-Wentworth grain-size scale for siliciclastic sediments (modified after Wentworth, 1922).

Code	**Description**	**Size**
Cobbles	Cobbles and boulders	>64
LPC	Large pebble conglomerate	16 mm – 32 mm
MPC	Medium pebble conglomerate	8 mm – 16 mm
SPC	Small pebble conglomerate	4 mm – 8 mm

Figure 3-18 depicts the decrease in pebble sizes from WNW to ESE. Only quartz pebbles which are durable and no shale or cherts were used in the determination of average pebble sizes to eliminate dilution due to non-durable pebbles which break apart quicker and does not give a representative true size decrease from the source.

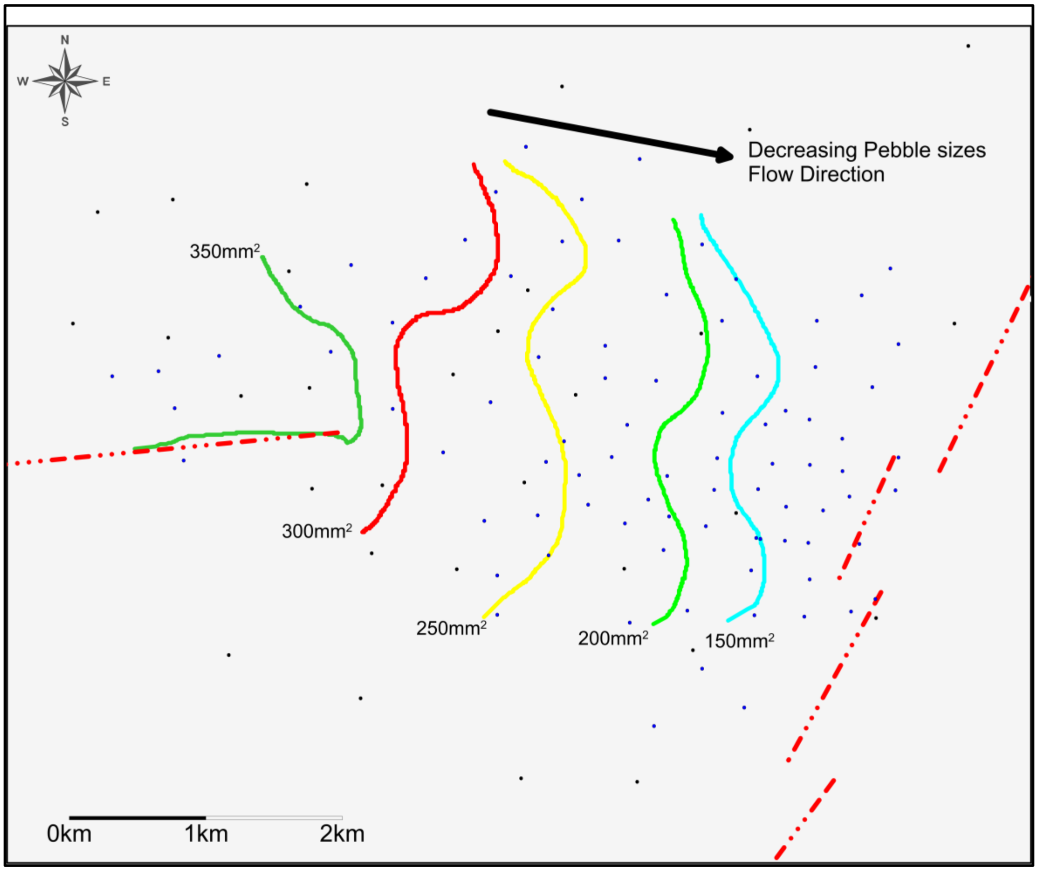


Figure 3-18: Pebble size variation in the A Reef, Ventersburg Project, indicating the palaeo flow direction from west-north-west to east-south-east (Table 3-3).

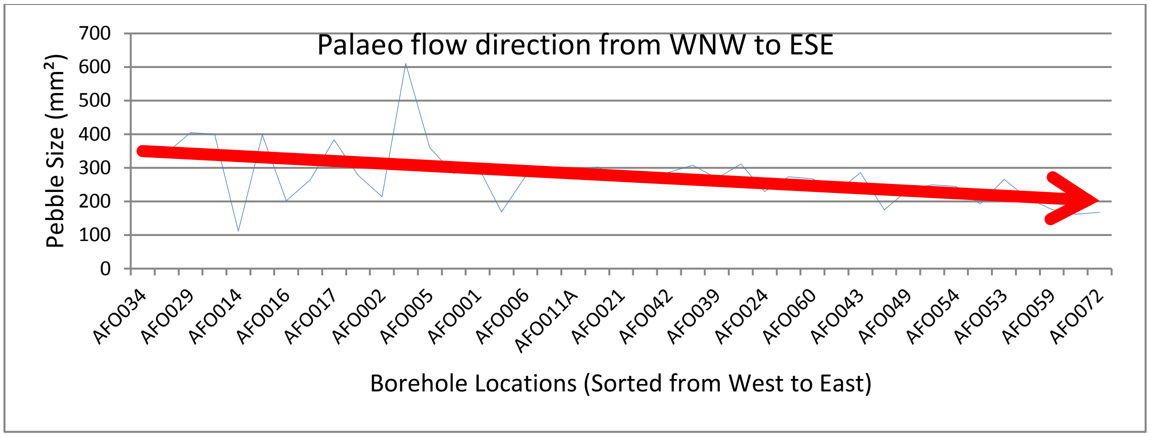


Figure 3-19: Pebble sizes decrease from WNW to ESE.

Boreholes were sorted from west to east and pebble sizes graphically illustrated above in Figure 3-19. Borehole AFO034 was drilled in the north-west of the study area and AFO072 to the east-south-east confirming the west-north-west east-south-east palaeo flow.

Table 3-3: Average size of the 10 largest pebbles in A Reef intersected in boreholes across the project area illustrated in Figure 3-18, the table is sorted with boreholes in the west on top to the east at the bottom of the table.

BHID	Y	X	A Reef 10 Largest Pebbles (mm^2)
AFO034	-270.433	3101511.65	364
AFO036	-609.086	3101475.05	345
AFO029	-1053.544	3101365.91	405
AFO030	-1647.163	3101013.00	400
AFO014	-1871.628	3101336.07	112
AFO031	-2020.905	3100713.66	398
AFO016	-2566.713	3100808.42	202
AFO027	-2694.206	3102056.21	265
AFO017	-2855.826	3100533.08	384
AFO004	-2996.446	3102548.36	278
AFO002	-3042.207	3101697.61	215
AFO018	-3080.408	3100190.39	610
AFO005	-3191.246	3100793.96	360
AFO019	-3300.235	3099865.81	283
AFO001	-3393.398	3101373.98	306
AFO012	-3467.586	3102795.49	169
AFO006	-3496.575	3101029.82	274
AFO003A	-3579.793	3101977.58	290
AFO011A	-3756.363	3102432.36	286
AFO007A	-3881.422	3101293.29	303
AFO021	-3979.21	3100537.63	267
AFO009	-4041.917	3101859.85	265
AFO042	-4060.588	3103277.97	287
AFO008A	-4254.559	3101542.30	307
AFO039	-4308.466	3102756.26	269
AFO022	-4330.017	3100926.72	312
AFO024	-4336.287	3102225.23	230
AFO041	-4483.659	3103191.78	273
AFO060	-4700.776	3102098.565	268
AFO023	-4741.248	3101773.11	227
AFO043	-4973.879	3103223.58	286
AFO066	-4996.784	3101511.57	175
AFO049	-5055.204	3101857.094	235
AFO052	-5106.363	3102138.42	250
AFO054	-5378.673	3102966.53	245
AFO063	-5431.579	3101113.035	192
AFO053	-5477.54	3102472.45	266
AFO045	-5619.086	3102190.42	210
AFO059	-5759.511	3100930.857	176
AFO071	-5838.252	3101589.68	162
AFO072	-6030.043	3101280.688	168

3.4 Gold distribution.

3.4.1 Gold Grade (g/t)

Gold grade can be interpreted in a number of different ways. From a mining perspective, selected mining horizons are considered to extract the most economical units. This can be done provided that the upper and lower contact of the reef can be clearly identified from the hangingwall and footwall. The average gold grade over the total channel thickness of each borehole intersection was used to illustrate the grade distribution within the A Reef (Figure 3-20). The gold grade can be compared with channel thickness, pebble sizes and transport direction.

Figure 3-20 shows some areas with higher gold distribution based on borehole data, calculated over the full channel thickness of each borehole reef intersection. The areas of higher gold grade have a trend from north-west to south-east. The trend is parallel to the palaeo current direction of the A Reef. In the A Reef the highest gold grades occur within medium pebble conglomerates with less than 30% interbedded quartzite and a dark pyritic matrix between pebbles. Fly-spec carbon and larger than 1 mm buckshot pyrite are also a good indication that the reef will have above average economic gold concentrations. Gold grade is also a function of the sedimentary environment and highest concentrations are found where suitable traps sites exist, for instance in conglomerate bars in subsidiary channels and channel edges (as described in section 3.2).

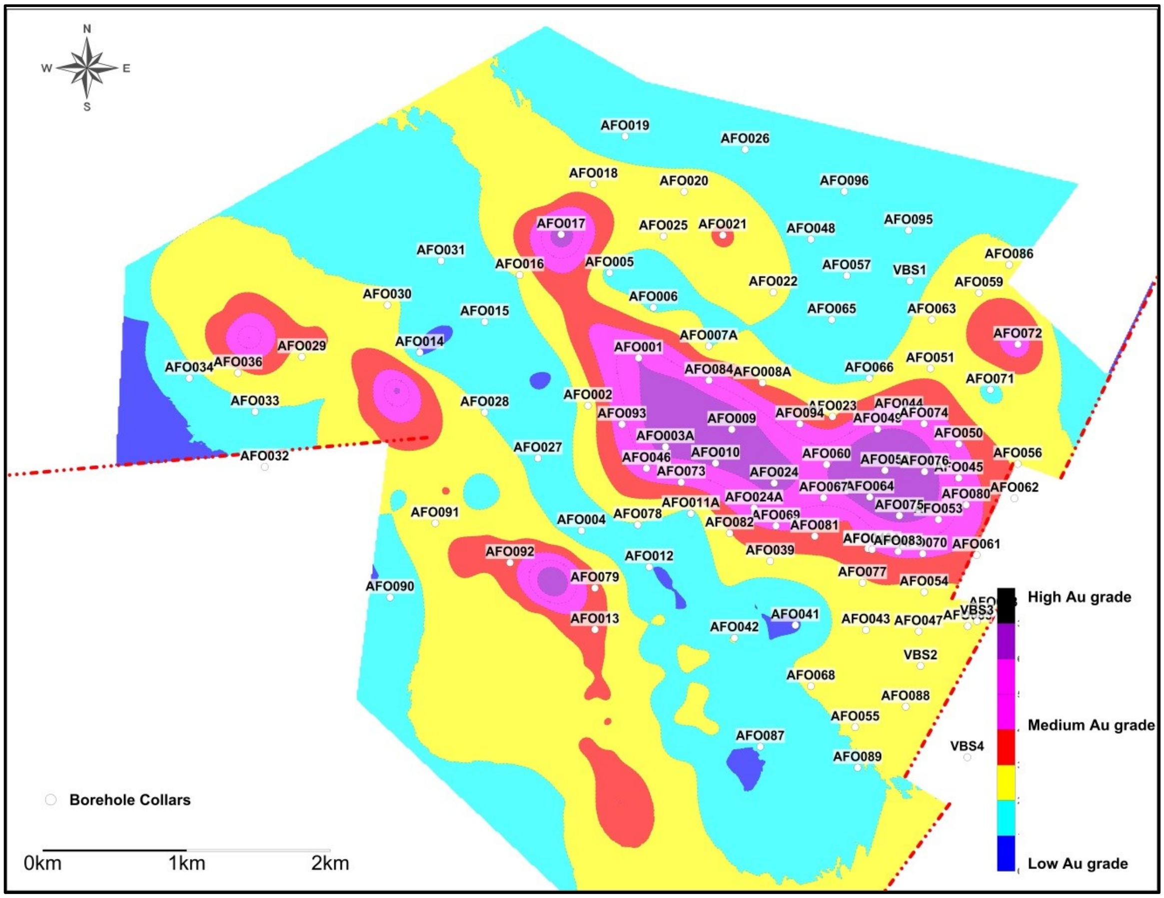


Figure 3-20: Gold distribution in the A Reef (g/t).

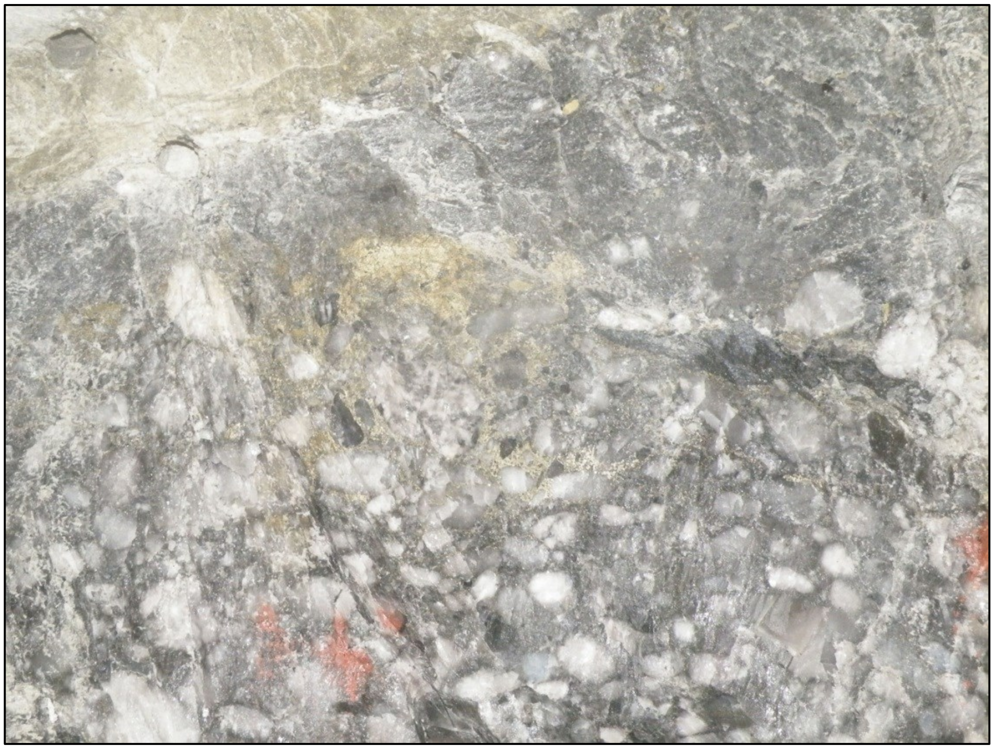


Figure 3-21: Sporadic pyrite concentration in the A Reef (photograph from underground visit to Brand 1 Shaft).

The figure above indicates the variability of pyrite in the A Reef and shows how quickly mineralisation decrease over a short distance. The mineralised area in the photograph had a face grade of around 10 g/t and just two meters to the side the grade dropped to below 5 g/t, the photo was taken at Harmony Brand 1 Shaft.

3.4.2 Gold Accumulation (cm.g/t)

Gold accumulation is a measure of the gold content in the reef, calculated by multiplying the gold grade with the reef thickness. Correlation of reef thickness versus grade is a relative factor as it does not always show direct links to the sedimentological characteristics. For the A Reef, where higher gold grades are found where reef thickness is low, the highest gold accumulation values will be found on the edges of deeper channels between the border of the main channel and subsidiary and inter-channel areas (Figure 3-22).

Zones of higher gold accumulation is visible with a trend parallel to the main palaeo flow direction from north west to south east (Figure 3-23). The higher gold accumulation also occurs next to the main channel and in the channel edges where thicker conglomerate units and higher concentration of heavy minerals occur (compare Figure 3-22 and Figure 3-23).

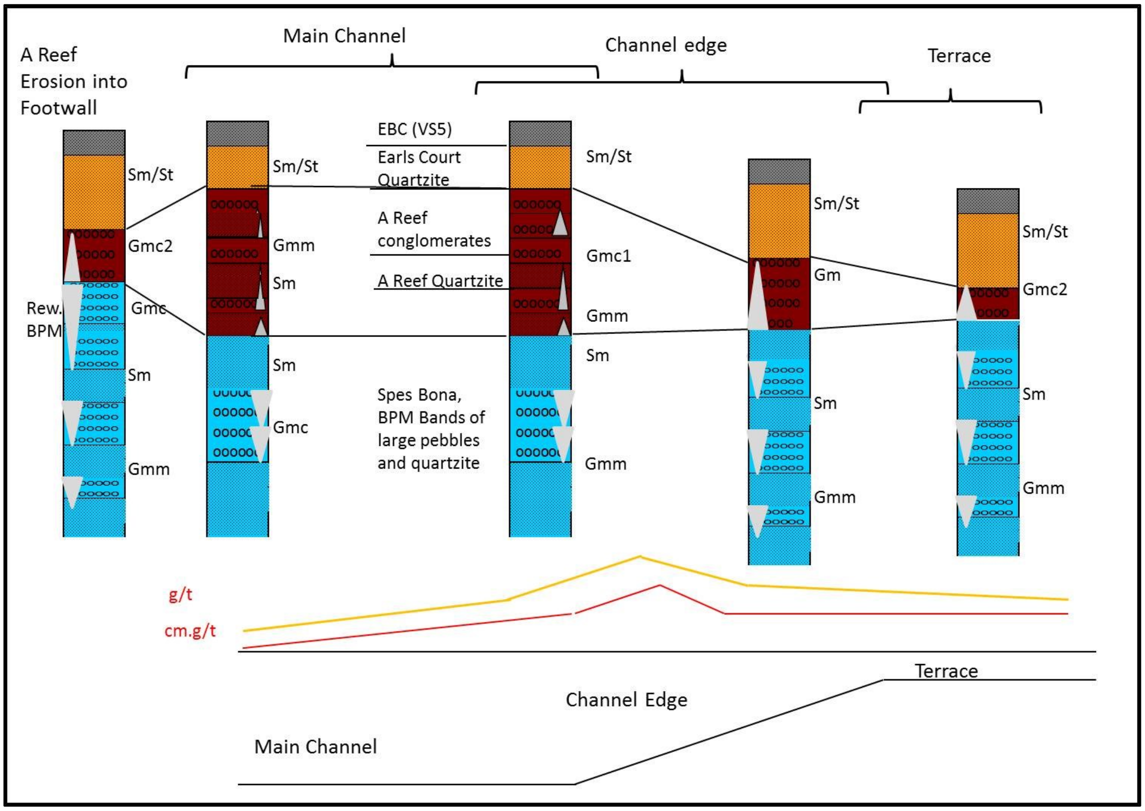


Figure 3-22: Gold accumulation trends across the A Reef. Gold accumulation (cm.g/t) is higher at the edge of the main channel and in areas around bars in the main channel because of thicker reef but increases towards the channel edges where the highest concentrations of heavy minerals occur.

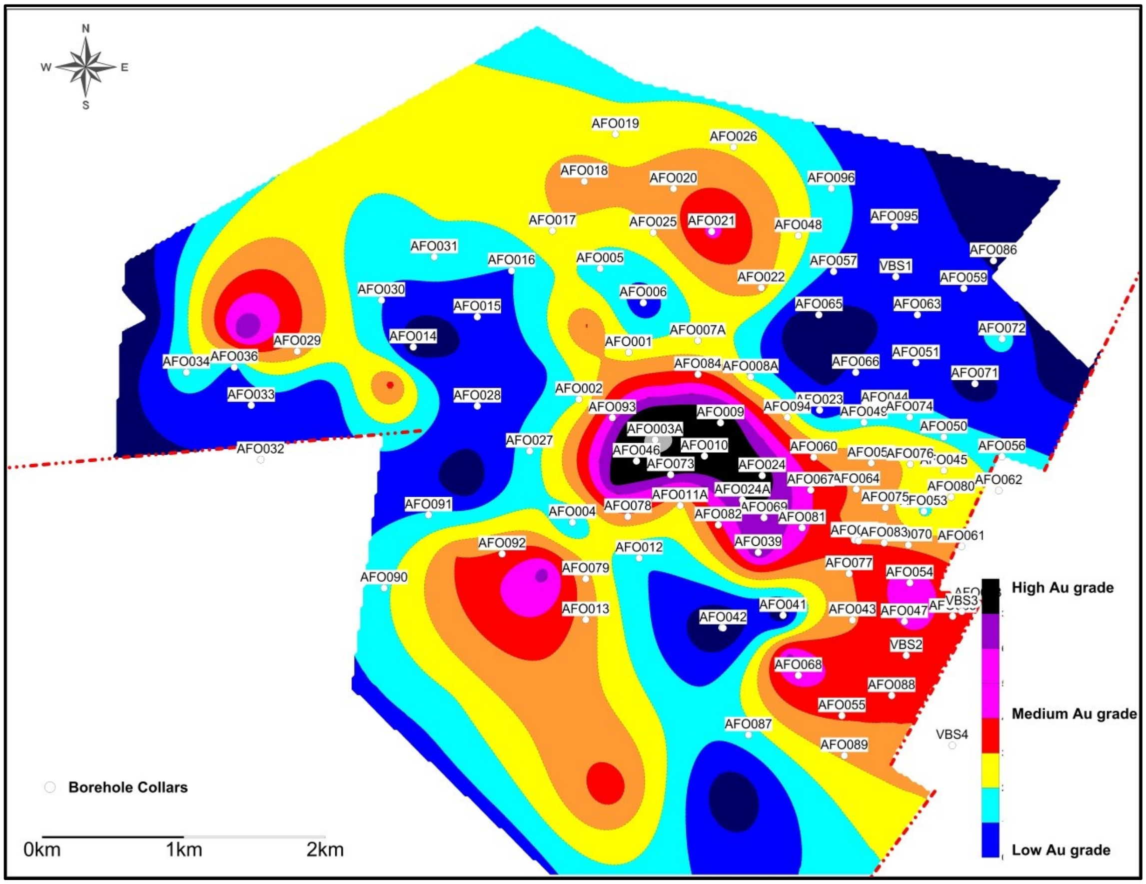


Figure 3-23: Gold accumulation (cm.g/t) (WG27 (Hartebeesthoek 1994)).

3.4.3 Geological Domains

The different variables show that the reef can be subdivided into at least 3 geological domains. The different domains were defined using sedimentary characteristics which include pebble composition, whether the reef is oligomictic or polymictic, facies, gold grade distribution as gram per ton, gold accumulation as centimetre gram per ton, pebble sizes and reef thickness.

Domains 1 and 3 (Figure 3-24 pink areas) are the western and eastern domains mainly facies Gmc1 and Gmc2 with higher grade and thin to medium reef thickness (less than 160 cm on average), less interbedded quartzite and is a clast supported conglomerate. Gold distribution is very strongly linked to sedimentology i.e. low gold values are associated with matrix supported gravels with low pyrite content. High gold values are associated with well packed clast supported conglomerate with dark arenaceous matrix and high pyrite content.

Domain 2 (Figure 3-24 green) Gmm/Gt/Sm facies has more than 50% interbedded quartzite, large pebbles, argillaceous matrix and more than one loosely packed conglomerate band. The gold grade and accumulation is also more scattered and lower than in Domain 1 and 3.

Domain 4 (Figure 3-24 blue) currently has an inferred resource status. There are only historical borehole data available; core from boreholes in this domain was not studied and sedimentological evaluation was not done. Old borehole logs was studied and confirmed the status of the A Reef to the south, although less economical than the above mentioned domains.

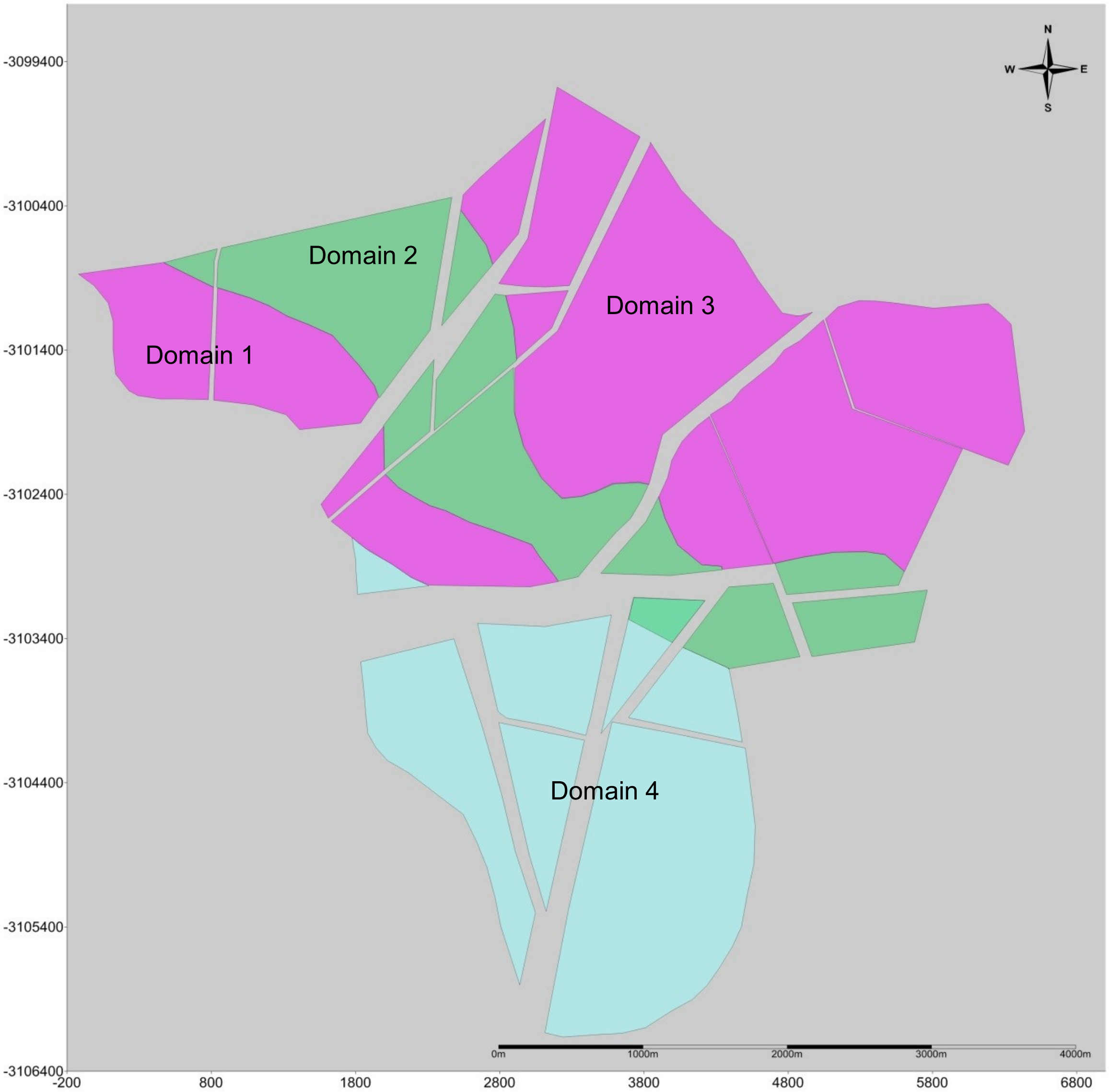


Figure 3-24: The three geological domains which have an indicated resource status and the fourth blue domain with inferred resource status (major faults are also shown).

3.5 Uranium Distribution

Uranium values in the A Reef are directly related to high gold grades. There is however, a significant increase in the U/Au ratio down the palaeoslope (Figure 3-25). The U/Au ratio was used by Minter, (1978) and Steyn, (1975) to predict where higher uranium concentrations will occur. It is calculated by dividing the gold g/t value by the uranium value as a percentage. The U/Au ratio at the Ventersburg Project in the A Reef changes from less than 20 in the proximal area to more than 50 in the distal area (Figure 3-26). This can be explained by the process of hydraulic sorting. Uranium with a specific gravity of 19.1g.cm^{-3} is less dense than gold (19.30 g.cm^{-3}). When found in the same fluvial environment, selective sorting by size and density will determine the deposition and enrichment of heavy minerals. The distance that material can be distributed will decrease with an increase of roughness of the surface of the material and thus more friction within the suspended load. Less dense material will be transported and deposited further down the palaeoslope (Slingerland, 1984).

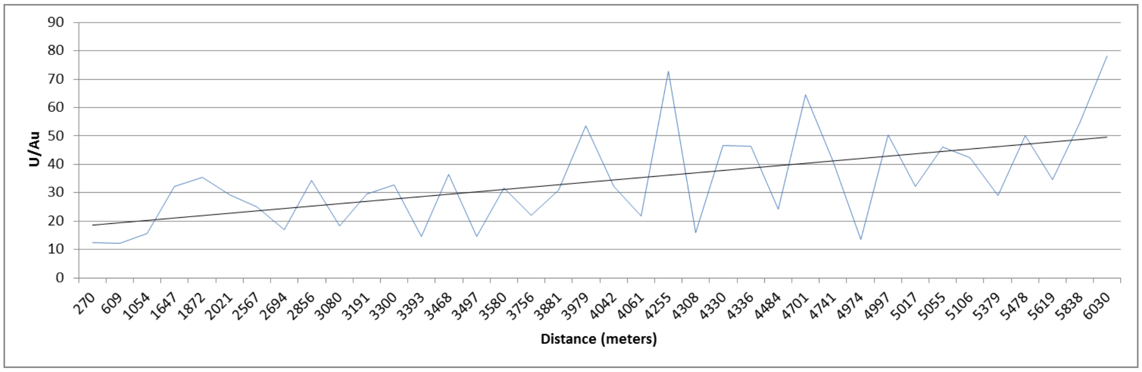


Figure 3-25: Graph showing the relationship between U/Au ratio in the A Reef at the Ventersburg Project, the ration increases down the palaeoslope from WNW to ESE.

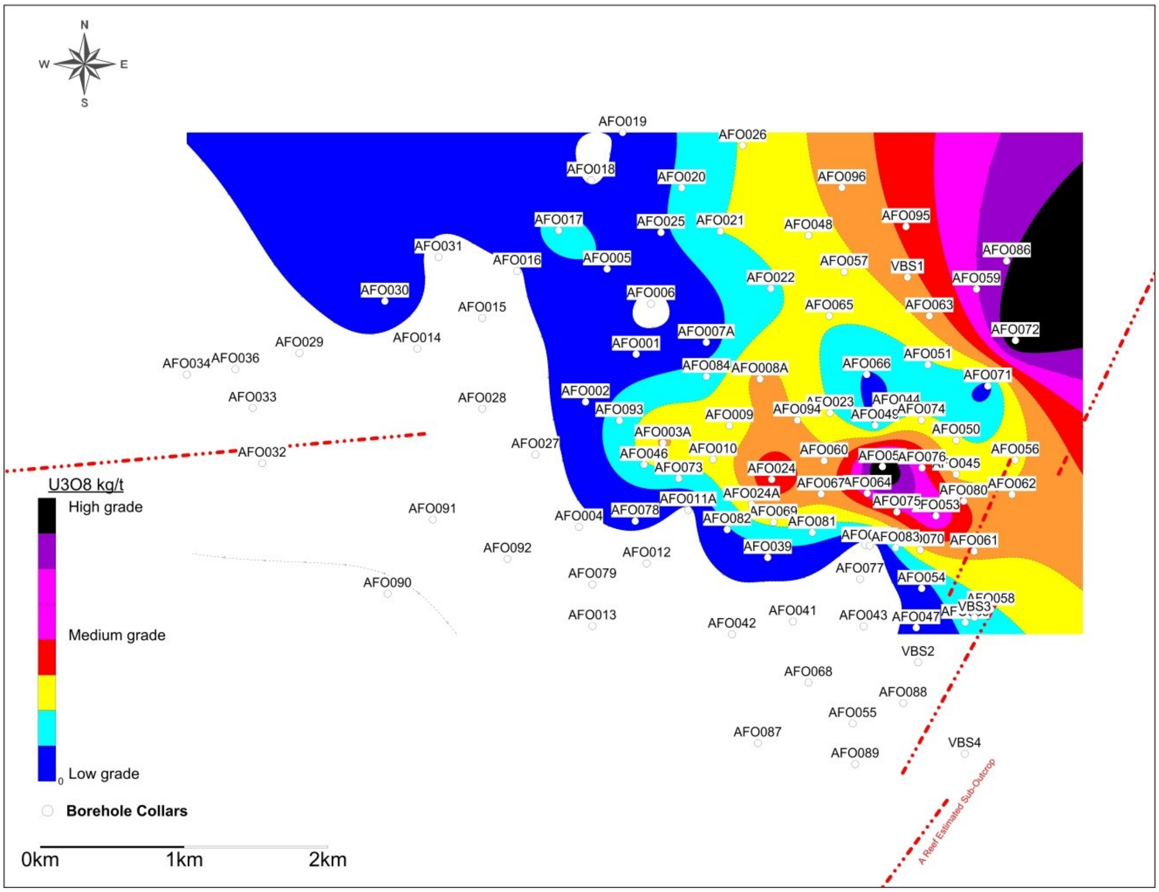


Figure 3-26: Distribution of uranium values in the project (U3O8 kg/t).

3.6 Footwall succession (Big Pebble Marker Zone)

The BPM forms part of the Spes Bona Member of the Kimberley Formation in the Witwatersrand Supergroup. The BPM is a polymictic large pebble to cobble size conglomerate. It is clear from the pebble composition and matrix of interbedded quartzwackes that the Aandenk Member unconformably overlies the Spes Bona Member because of the pebble composition which changes dramatically from polymictic to oligomictic. The BPM is composed of quartz, massive chert and banded chert pebbles and cobbles as well as shale fragments. The pebble sizes to the west near the town of Welkom are larger than 200 mm in diameter. In the project area, pebble sizes range from 50 mm up to 100 mm. Pebbles consist mainly of white and smokey vein quartz and massive and banded grey to black chert. Other rock fragments include silicified shale that are mostly yellow to orange or brown in colour with angular edges. Sericite occurs on bedding planes and the most common heavy minerals are detrital pyrite with only localised economic gold grades. This is evident from sampling BPM intersections in the project area.

In the Ventersburg area, the BPM is described as a zone of large pebble or cobble conglomerates and interbedded coarse grained sericitic quartzwackes (Figure 3-28). The BPM zone comprises a number of upward coarsening cycles. The base of the BPM is where the largest pebble conglomerates begin; below the BPM the bottom part of the Spes Bona formation is a distinctly smaller pebbly conglomerate with an immature matrix. The thickness of the BPM decreases with a general NW-SE trend and is almost parallel to the major fluvial transport direction of gold bearing material into and within the depositional basin (Minter *et al*., 1986). This is also applicable for the Ventersburg Project area. The thickness of the BPM from the bottom of the A Reef to the bottom of the BPM varies between 4 and 25 metres (Figure 3-27 and Table A-3). It thins to the south, following the regional unconformity (Figure 2-5). The top of the BPM is well defined in the north of the project area where an argillaceous quartzwacke separates the A Reef and the BPM. The unconformity below the A

Reef resulted in a progressive thinning of the argillaceous quartzwacke between the A Reef and the BPM towards the south. South of boreholes AFO087 and FP1 where the total thickness of the BPM is less than 10 m, the A Reef occurs directly on top of the reworked BPM which is a slightly more siliceous quartzite with local economic mineralisation (Figure 3-27). The A Reef has been eroded and pebbles of the A Reef occur in some of the BPM in the south. Care must be taken in this area not to confuse reworked BPM with A Reef.

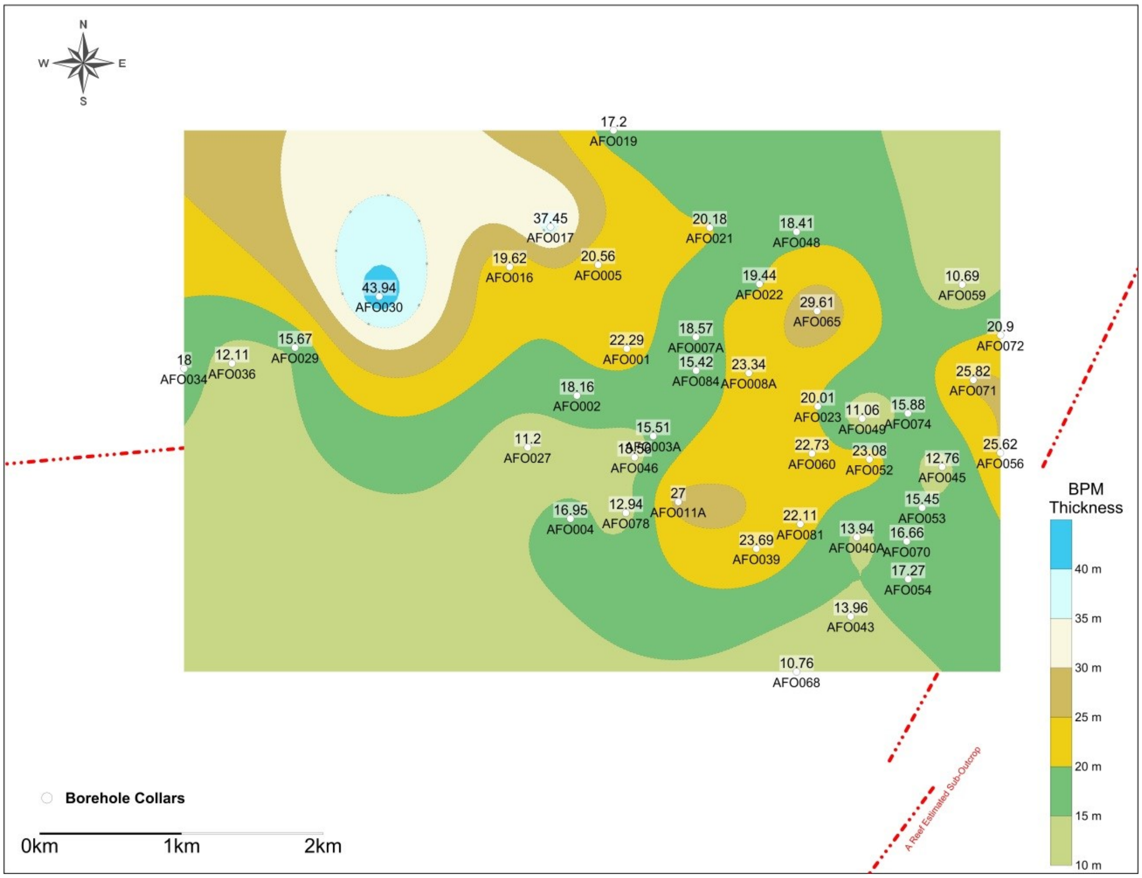


Figure 3-27: Plan showing the total thickness of the BPM across the project area (See Table 3-4 for data used).

Pebbles of the BPM are well rounded quartz and chert and angular silicified shale fragments. These fragments and the amount of chert found in the BPM are very rare in the A Reef indicating that a different source possibly existed for the A Reef. Banded chert is the second most abundant pebble type in the BPM and make up more than 90% of the BPM (Steenekamp, 1990). Archaean greenstone terrains can also contain siliceous chemical sedimentary rocks apart from the normal mafic component. The abundance of chert as well as quartz porphyry pebbles in the Big Pebble Marker are evidence that the clasts of the Big Pebble Marker have a volcanic provenance. Banded chert has been deposited in shallow water marine environments (Steenekamp, 1990). The matrix of the Big Pebble Marker and interbedded quartzwackes are immature.

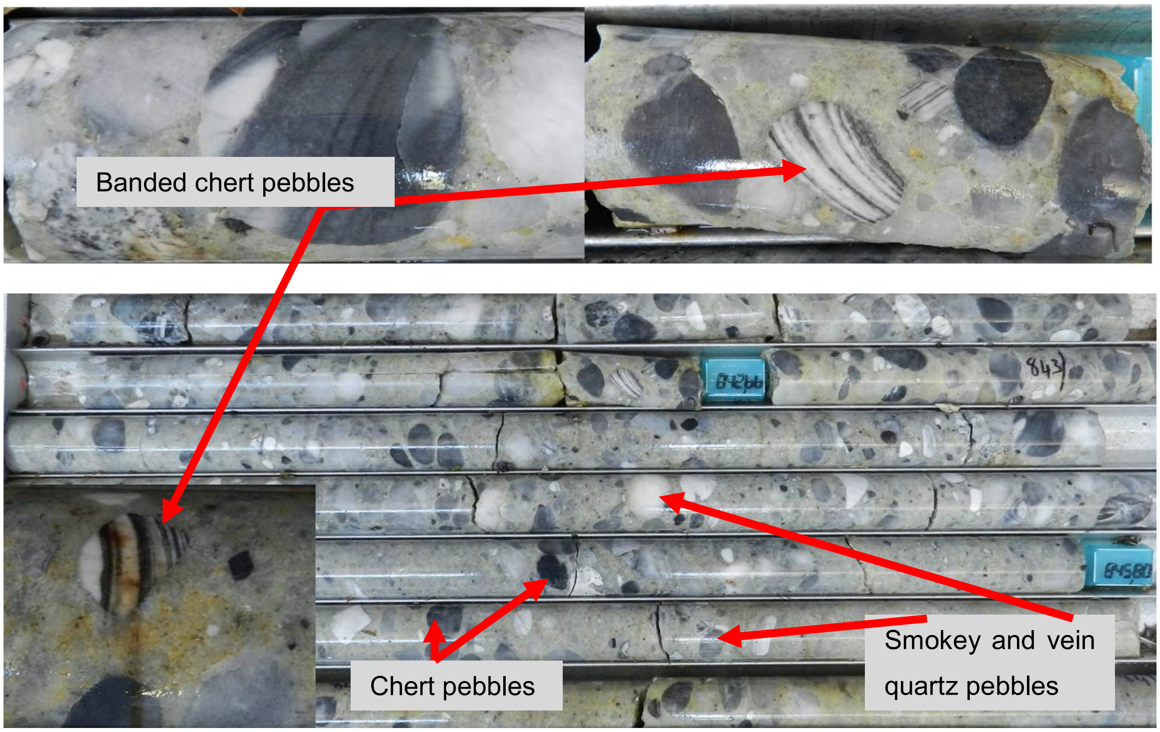


Figure 3-28: Typical Big Pebble Marker conglomerate in the project area with inserts showing banded cherts also present.

The deposition of the BPM can be interpreted as a high energy debris flow with a transport direction from NW-SE. Deposition must also have occurred over a large area attesting to the rounded shape of the pebbles as well as the size difference from the west of the basin to the east. More than one cycle of sedimentation probably occurred which could have reworked some areas giving rise to the interbedded bands of quartzwackes.

Table 3-4: The Big Pebble Marker thickness across the project area data used in Figure 3-27.

BHID	Y	X	STRAT	THICKNESS (m)
AFO001	-3393.398	3101373.980	BPM	22.29
AFO002	-3042.207	3101697.610	BPM	18.16
AFO003A	-3579.793	3101977.583	BPM	15.51
AFO004	-2996.446	3102548.364	BPM	16.95
AFO005	-3191.246	3100793.961	BPM	20.56
AFO007A	-3881.422	3101293.292	BPM	18.57
AFO008A	-4254.559	3101542.298	BPM	23.34
AFO011A	-3756.363	3102432.359	BPM	27.00
AFO016	-2566.713	3100808.415	BPM	19.62
AFO017	-2855.826	3100533.076	BPM	37.45
AFO019	-3300.235	3099865.809	BPM	17.20
AFO021	-3979.210	3100537.631	BPM	20.18
AFO022	-4330.017	3100926.723	BPM	19.44
AFO023	-4741.248	3101773.111	BPM	20.01
AFO027	-2694.206	3102056.214	BPM	11.20
AFO029	-1053.544	3101365.907	BPM	15.67
AFO030	-1647.163	3101013.003	BPM	43.94
AFO034	-270.433	3101511.653	BPM	18.00
AFO036	-609.086	3101475.045	BPM	12.11
AFO039	-4308.466	3102756.262	BPM	23.69
AFO040A	-5017.405	3102677.004	BPM	13.94
AFO043	-4973.879	3103223.584	BPM	13.96
AFO045	-5619.086	3102190.422	BPM	12.76
AFO046	-3448.520	3102124.727	BPM	13.56
AFO048	-4591.970	3100566.230	BPM	18.41
AFO049	-5055.204	3101857.094	BPM	11.06
AFO052	-5106.363	3102138.418	BPM	23.08
AFO053	-5477.540	3102472.452	BPM	15.45
AFO054	-5378.673	3102966.529	BPM	17.27
AFO056	-6029.156	3102093.746	BPM	25.62
AFO059	-5759.511	3100930.857	BPM	10.69
AFO060	-4700.776	3102098.565	BPM	22.73
AFO065	-4736.670	3101113.056	BPM	29.61
AFO068	-4591.517	3103606.692	BPM	10.76
AFO070	-5369.211	3102705.062	BPM	16.66
AFO071	-5838.252	3101589.675	BPM	25.82
AFO072	-6030.043	3101280.688	BPM	20.90
AFO074	-5377.318	3101820.883	BPM	15.88
AFO078	-3387.778	3102508.259	BPM	12.94
AFO081	-4617.901	3102585.871	BPM	22.11
AFO084	-3882.390	3101525.224	BPM	15.42

3.7 Hangingwall Succession (Elsburg Basal Conglomerate to Earls Court Quartzite)

The hangingwall quartzites are sub-mature, greyish-yellow, medium grained and sericitic (Figure 3-29). The unit is well bedded with abundant trough cross bedding and ripple cross lamination in fining upwards cycles. It also has occasional very fine crystalline pyrite stringers on bedding plane foresets. In the Ventersburg Project area there is no placers developed in the hangingwall. The only grit band is the Elsburg Basal Conglomerate but this is only a very poorly developed grit with fragments smaller than 5 mm and hold very little to no economic potential.

Occurring directly above the A Reef is the Earls Court Quartzite Member (Figure 2-1). Regionally from historic borehole logs the Earls Court Quartzite thins from north to south because of the angular unconformity of the Eldorado Basal Conglomerate (VS5) (Figure 2-5). Locally in the project area the Earls Court Quartzite unit thickens from west to east (Figure 3-30, Table 3-5 only current borehole data was used) and indicates a possible palaeo high to the west and corresponds with an area where reworking of the footwall conglomerates occurred. The Eldorado unconformity is undulating and explains the local variation of thickness seen in Figure 3-30 and Table 3-5. Because of the unconformable relationship the A Reef subcrops against the Elsburg Basal Conglomerate south of the project area close to borehole ON1 (Figure 2-5). South from this point the A Reef comprises reworked footwall conglomerates or VS5 and no longer proper A Reef. Where Earls Court Quartzite is present below the Elsburg Basal Conglomerate (VS5) proper A Reef can be expected lower down. In the south of the Free State Goldfields the VS5 becomes more economic and is mined as the Beatrix Reef.

Figure 3-29: Example of hangingwall quartzites, greyish-yellow with sericitic specs.

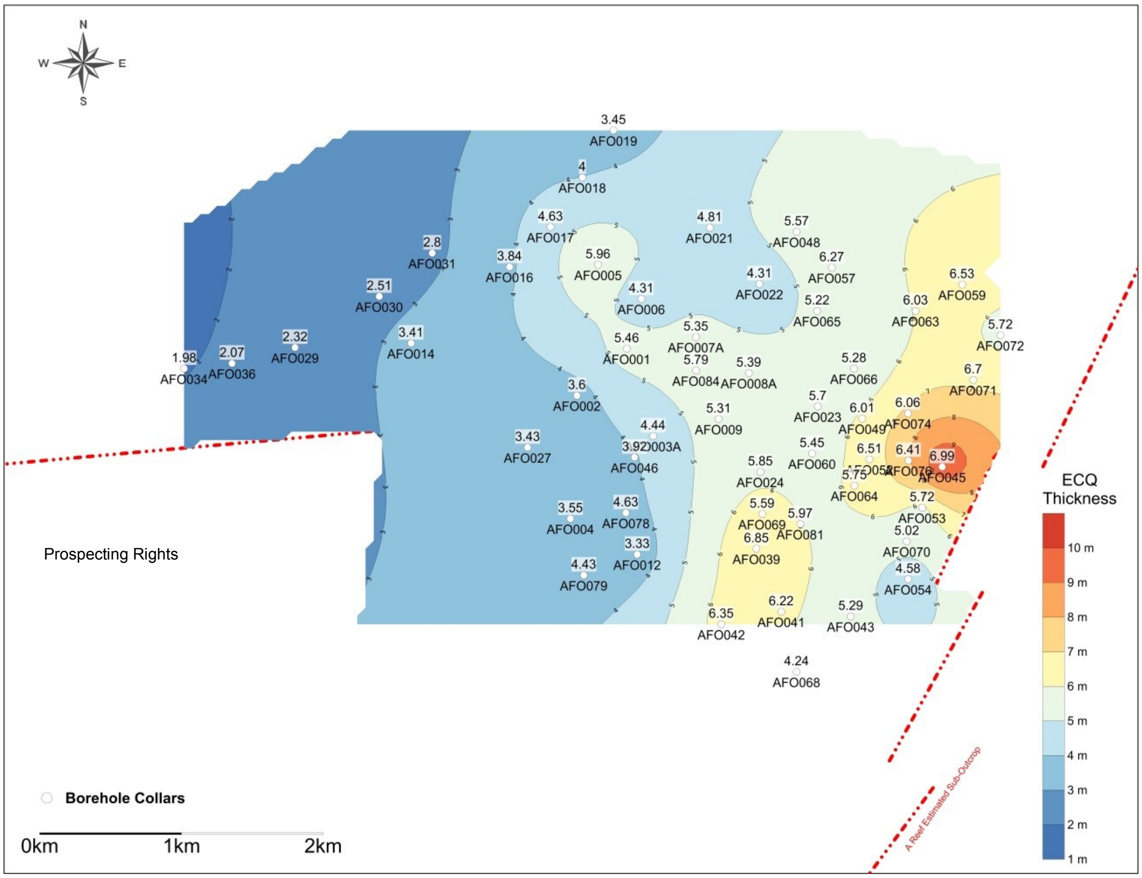


Figure 3-30: Isopachs of the Earls Court Quartzite, (distance between EBC / VS5 and Top of the A Reef) (Table 3-5).

Table 3-5: Data used to inform Figure 3-30, indicating the thickness of the Earls Court Quartzite.

BHID	Y	X	STRAT	THICKNESS (m)
AFO001	-3393.398	3101373.980	ECQ	5.46
AFO002	-3042.207	3101697.610	ECQ	3.60
AFO003A	-3579.793	3101977.583	ECQ	4.44
AFO004	-2996.446	3102548.364	ECQ	3.55
AFO005	-3191.246	3100793.961	ECQ	5.96
AFO006	-3496.575	3101029.821	ECQ	4.31
AFO007A	-3881.422	3101293.292	ECQ	5.35
AFO008A	-4254.559	3101542.298	ECQ	5.39
AFO009	-4041.917	3101859.852	ECQ	5.31
AFO012	-3467.586	3102795.486	ECQ	3.33
AFO014	-1871.628	3101336.066	ECQ	3.41
AFO016	-2566.713	3100808.415	ECQ	3.84
AFO017	-2855.826	3100533.076	ECQ	4.63
AFO018	-3080.408	3100190.392	ECQ	4.00
AFO019	-3300.235	3099865.809	ECQ	3.45
AFO021	-3979.210	3100537.631	ECQ	4.81
AFO022	-4330.017	3100926.723	ECQ	4.31
AFO023	-4741.248	3101773.111	ECQ	5.70
AFO024	-4336.287	3102225.229	ECQ	5.85
AFO027	-2694.206	3102056.214	ECQ	3.43
AFO029	-1053.544	3101365.907	ECQ	2.32
AFO030	-1647.163	3101013.003	ECQ	2.51
AFO031	-2020.905	3100713.658	ECQ	2.80
AFO034	-270.433	3101511.653	ECQ	1.98
AFO036	-609.086	3101475.045	ECQ	2.07
AFO039	-4308.466	3102756.262	ECQ	6.85
AFO041	-4483.659	3103191.779	ECQ	6.22
AFO042	-4060.588	3103277.968	ECQ	6.35
AFO043	-4973.879	3103223.584	ECQ	5.29
AFO045	-5619.086	3102190.422	ECQ	6.99
AFO046	-3448.520	3102124.727	ECQ	3.92
AFO048	-4591.970	3100566.230	ECQ	5.57
AFO049	-5055.204	3101857.094	ECQ	6.01
AFO052	-5106.363	3102138.418	ECQ	6.51
AFO053	-5477.540	3102472.452	ECQ	5.72
AFO054	-5378.673	3102966.529	ECQ	4.58
AFO057	-4840.641	3100814.335	ECQ	6.27
AFO059	-5759.511	3100930.857	ECQ	6.53
AFO060	-4700.776	3102098.565	ECQ	5.45
AFO063	-5431.579	3101113.035	ECQ	6.03
AFO064	-5000.679	3102320.016	ECQ	5.75
AFO065	-4736.670	3101113.056	ECQ	5.22
AFO066	-4996.784	3101511.571	ECQ	5.28
AFO068	-4591.517	3103606.692	ECQ	4.24
AFO069	-4348.432	3102516.812	ECQ	5.59
AFO070	-5369.211	3102705.062	ECQ	5.02
AFO071	-5838.252	3101589.675	ECQ	6.70
AFO072	-6030.043	3101280.688	ECQ	5.72
AFO074	-5377.318	3101820.883	ECQ	6.06
AFO076	-5381.085	3102146.680	ECQ	6.41
AFO078	-3387.778	3102508.259	ECQ	4.63
AFO079	-3090.433	3102938.853	ECQ	4.43
AFO081	-4617.901	3102585.871	ECQ	5.97
AFO084	-3882.390	3101525.224	ECQ	5.79

4 Depositional Model

4.1 Introduction

The aim of the sedimentological model is to relate sedimentological features to gold distribution which can be used as an exploration tool and to outline boundaries in which to define a mineral deposit for further resource calculations.

4.2 The Big Pebble Marker

Figure 4-4 Event 1: Only severe erosion of the source rocks can explain the large pebbles, cobbles and boulders in the BPM. An alluvial fan deposit eroded the source of the BPM and as the basin filled up, large pebbles were distributed to the distal parts of the basin in the east and south east through large channel systems. The BPM zone became incorporated with interbedded sediments in the distal part of the deposit forming upward coarsening units. Sediments in the BPM were reworked by degradation of the older conglomerates increasing the maturity of the sediments and deriving heavy minerals from underlying sediments. This explains the localised sporadic occurrences of higher concentrations of economic minerals in cleaned up zones of the BPM in the Ventersburg Project.

4.3 The A Reef

The source rocks were situated towards the western margin of the Witwatersrand Basin and were dispersed by braided alluvial systems (Minter and Leon, 1991). Evidence for this is the decrease in pebble size from the WNW resulting in smaller, sub-rounded to rounded pebbles and the mature siliceous matrix. The largest pebbles from the source would be deposited closer to the place from where they originated. As the river progress from an alluvial fan to a braided plain environment, local sediments will be picked up and transported (also heavy minerals), resulting that distal environments be relatively enriched in heavy mineral concentrations Figure 4-1 is an illustration of sediment transport from source to deposition.

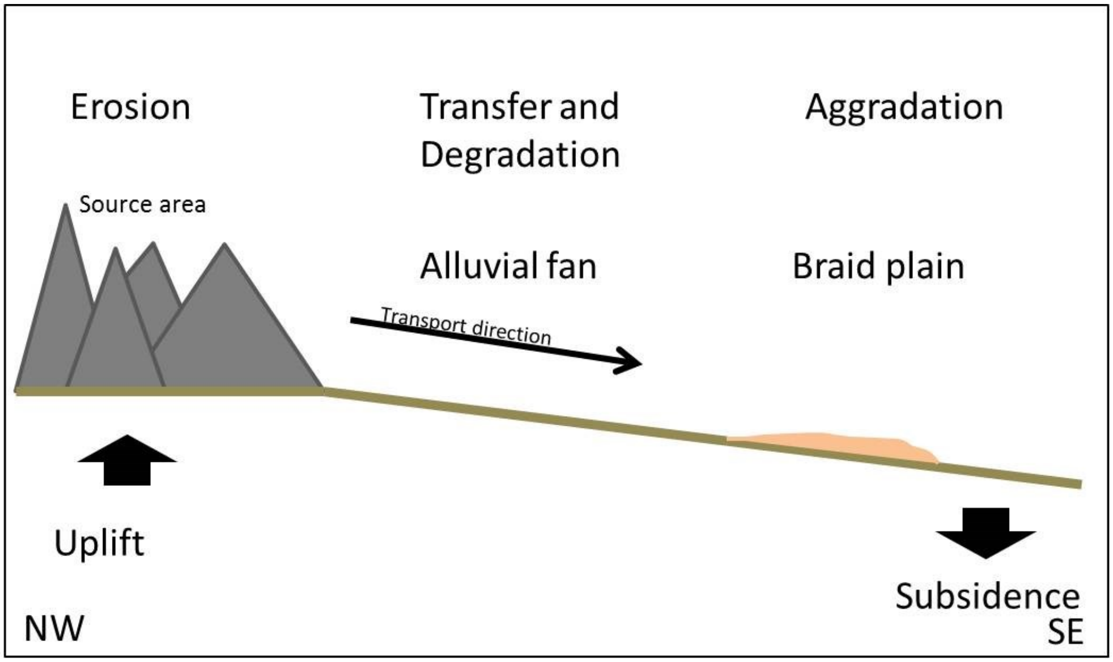


Figure 4-1: Generalised geological model from source to deposition.

The A Reef is mature compared to footwall conglomerates; pebble sizes are also smaller and well sorted. Heavy minerals present in the distal parts of the deposit were probably picked up during transport while eroding existing sediments. The sediments were transported over a large distance in a high energy flow regime giving rise to the narrow main channel, inter-channel and subsidiary channel areas. Internal erosional contacts and quartz arenitic lenses in the reef would result in the reworking of inter-channel bars caused by the migration of channels.

Areas with a high gold grade are linked to well packed conglomerates around channel edges and sand bars as well as any area where there was a change in slope or flow velocity. In areas where the reef is thicker due to an increase in sediment influx and erosion into the footwall, a small basal scour unit is visible (AFO-021, AFO-43). The well mineralised conglomerates are not spread across the total area and occur in the channel edge and subsidiary areas. The well-developed reef zone is approximately 120 cm thick.

From the plans a number of trends can be observed in the form of channels and gold distribution. The distribution of channels and inter-channel areas indicate a braided river complex. Braided river complexes have a distinct character in the shape of channels with internal bars and inter-channel areas. The channels can criss-cross a large area and transport large volumes of sediment and depositing it over wide spread areas. Areas of flow convergence and divergence are the most important part of a braided complex and can change over short distances. Sediment is deposited from the main channel and deposited on channel edges and bars. The character and shape of channels changes regularly but mostly during major flood events. The regular changing of channels has the effect that bars can be reworked and new bars deposited on top of previously formed bars Figure 4-2 and Figure 4-3.

Figure 4-4 Event 2: After deposition of the footwall sediments there was a period of no deposition creating the unconformity below the A Reef. The lower A Reef began as a braided river complex deposited on top of the footwall sediments. The footwall Big Pebble Marker has more than 30% chert pebbles and if the A Reef cannibalised the footwall, the same pebbles should be found in the A Reef. The A Reef however has very little chert pebbles and are mostly oligomictic. This shows that there were different source areas for the Spes Bona and Aandenk Formations. The lower A Reef is a large pebble conglomerate and occurs in the main channel as the Gmm/Gt/Sm facies. The Reef is an upward fining large to medium pebble conglomerate and has an immature quartz arenite top. This interbedded quartz arenite, was likely deposited during a rapid flood event and is present mainly in the main channel areas (event 3, Figure 4-4). The deposition of the lower A Reef was followed by the deposition of the top, medium to small pebble conglomerates creating the Gmc facies. If transgression occurred, parts of the lower deposit could have been reworked and deposited as a later braided river deposit on top of the lower deposit. Heavy mineral deposition occurred around bars and channel edges.

Some evidence exist that the A Reef did sporadically cut into the footwall. An example is AFO-021, where a bottom scour surface exists with some small shale fragments from the footwall, scattered between pebbles of the A Reef's basal scour unit, causing some enrichment in the bottom part of the A Reef. The A Reef is generally a top loaded reef.

During the last stage of deposition, small to medium pebbles with heavy minerals transgressed over a large area and were deposited on top of the first two stages accounting for the mostly top-loaded (gold grade at the top of the reef) nature of the A Reef in the project area. To the eastern margin, close to the sub-outcrop there is a bimodal distribution of gold grade in the A Reef. The bimodal nature indicates reworking of the A Reef and the sediments deposited as a sheet-like deposit. Deposition continued with lower energy and the top of the reef thins out to form a sheet deposit with conglomerates less than 70 cm thick (Figure 4-5).

Figure 4-2: Depiction of braided alluvial plain. Hatched grey areas are inter-channel bars with the main channel area indicated with yellow lines (WG27 (Hartebeesthoek 1994)).

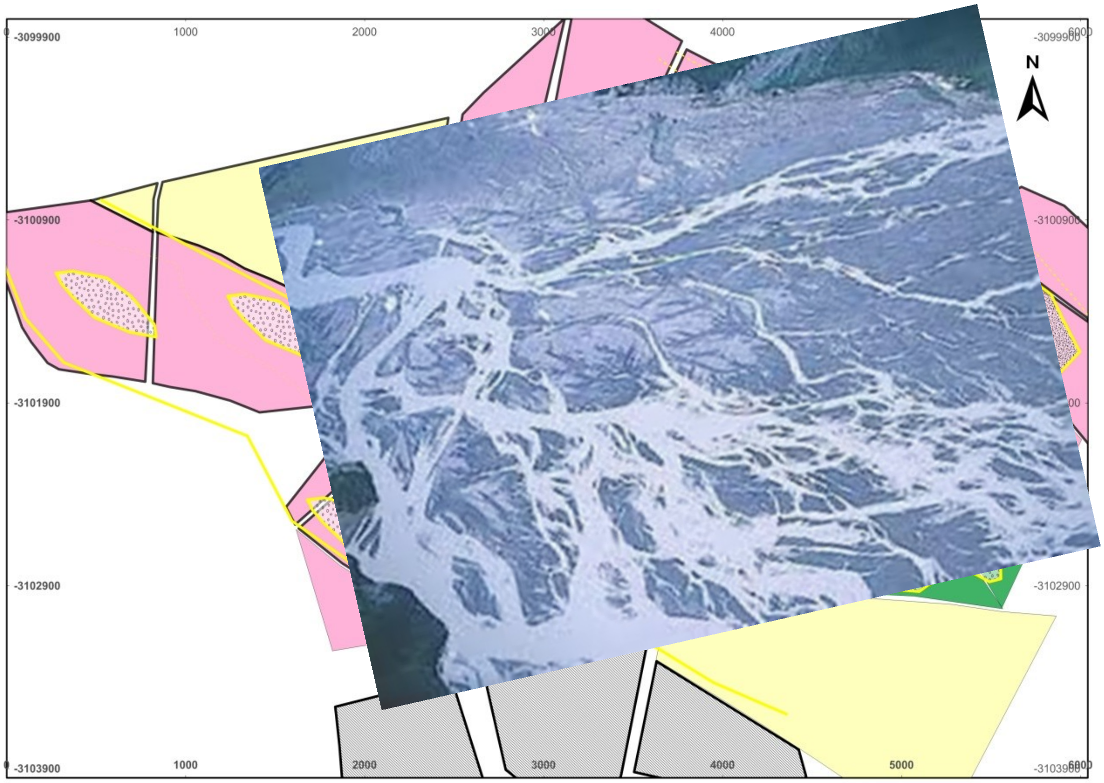
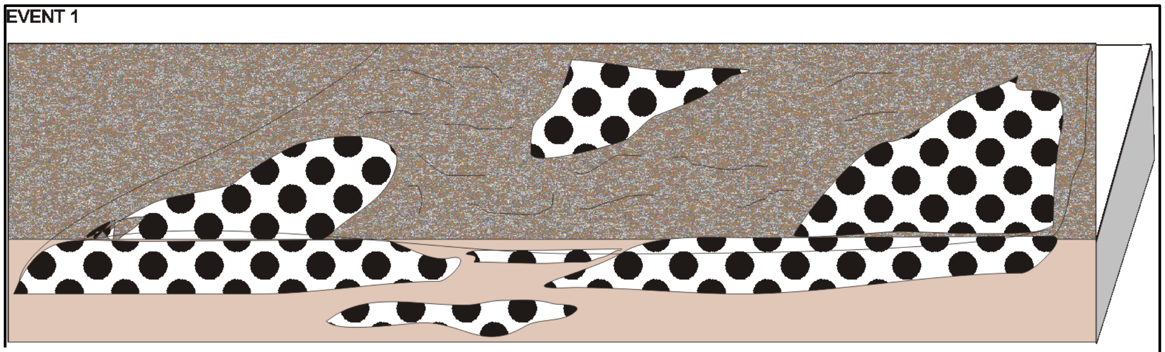


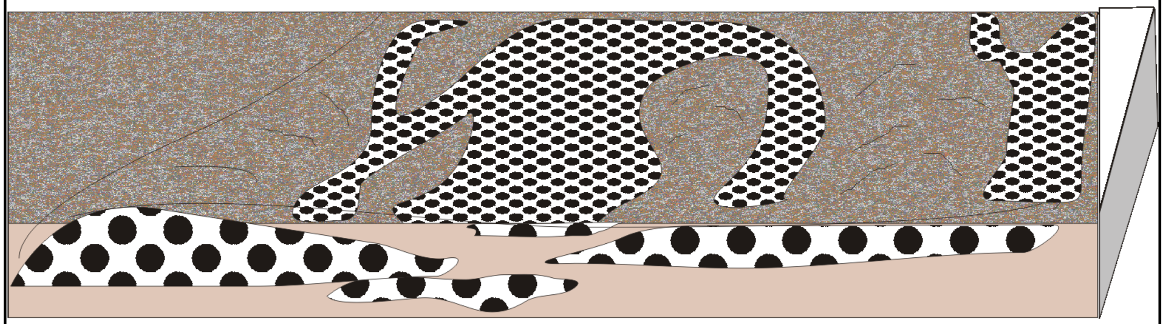
Figure 4-3: Example of a modern braided alluvial plain, showing distributary channels with inter-channel bars and channel edges (WG27 (Hartebeesthoek 1994)).

EVENT 1



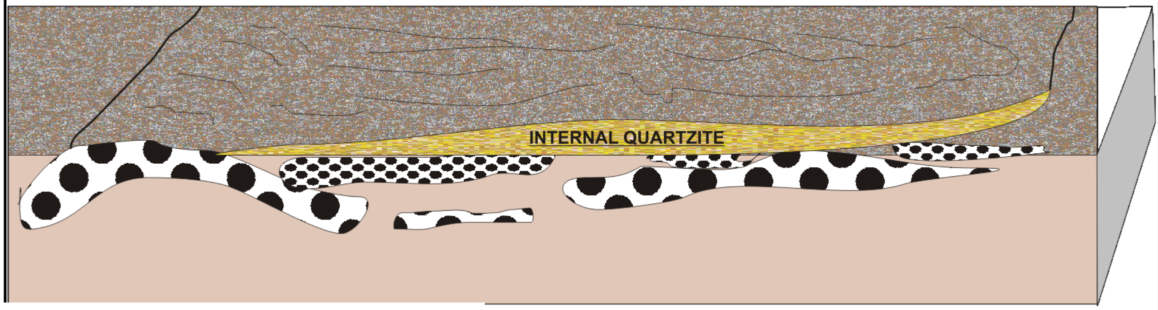
Deposition of footwall BPM.

EVENT 2



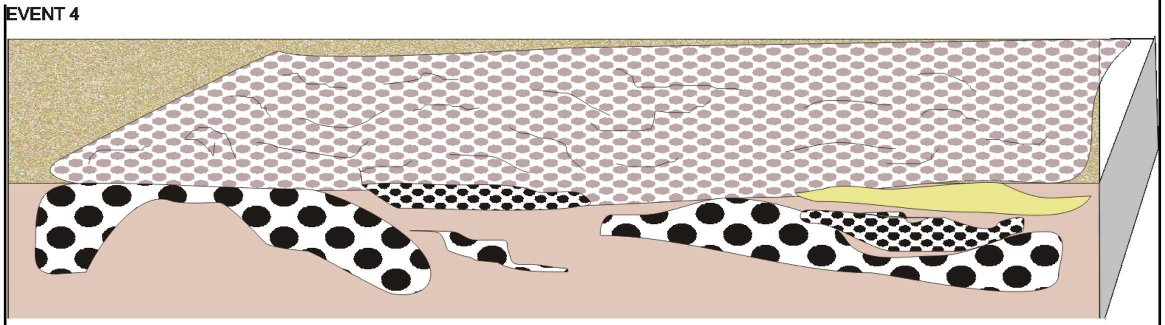
Deposition of the lower A Reef.

EVENT 3



Deposition of interbedded quartzite, flood event.

EVENT 4



Deposition of upper A Reef in braided streams, reworking may occur and deposition is mainly around bars and palaeo-highs

Figure 4-4: Block diagrams of the deposition of the A Reef sequence (modified from Karpeta, 1984).

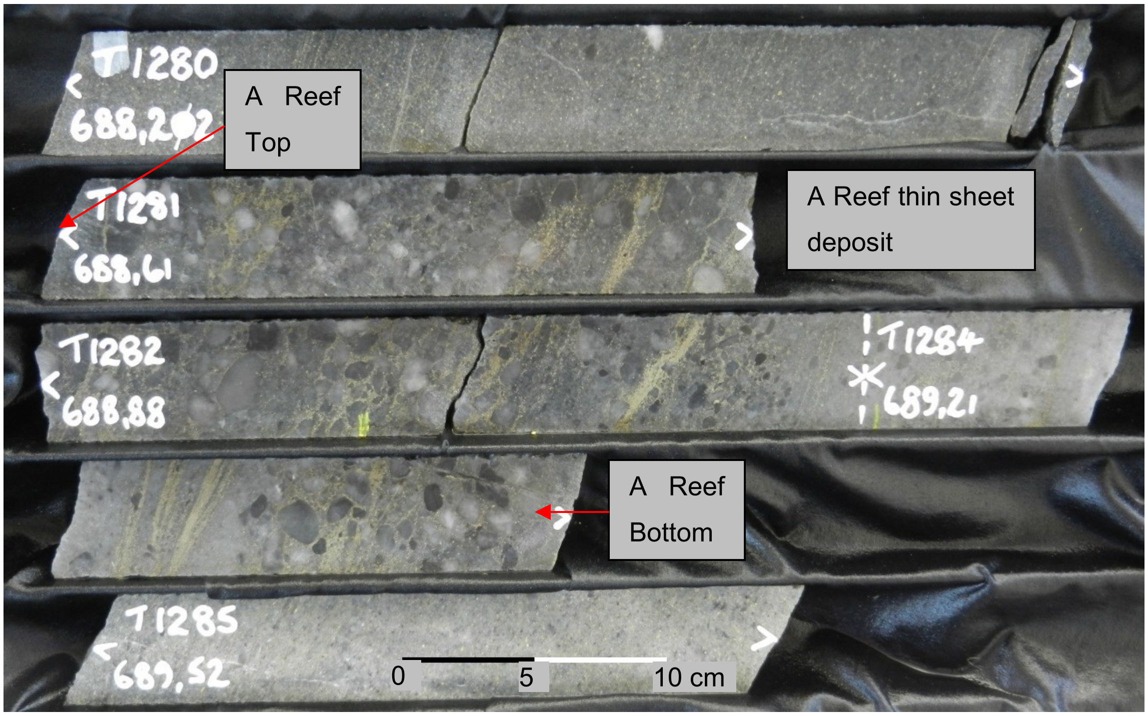


Figure 4-5: Sheet deposit. A Reef is less than 60 cm thick.

5 Mineralogy

5.1 Mineral Description

Polished thin sections were made from selected intersections of reef and footwall lithologies. Most of the minerals in the sections are commonly found in all the stratigraphic units described in the study area.

5.1.1 Quartz

Quartz is the most common mineral in the Witwatersrand quartzites as seen in Figure 5-1 with mostly quartz grains visible with secondary ore minerals. It occurs as detrital grains of less than a millimetre to more than 5 cm. Quartz is also found to make up a large portion of the very fine-grained (<0.05 mm) matrix as intergrowths in the interstitial matrix. More than 90% of the quartz have been found to be vein quartz. Poly-crystalline quartz is the least common and chert is the second most common variety.

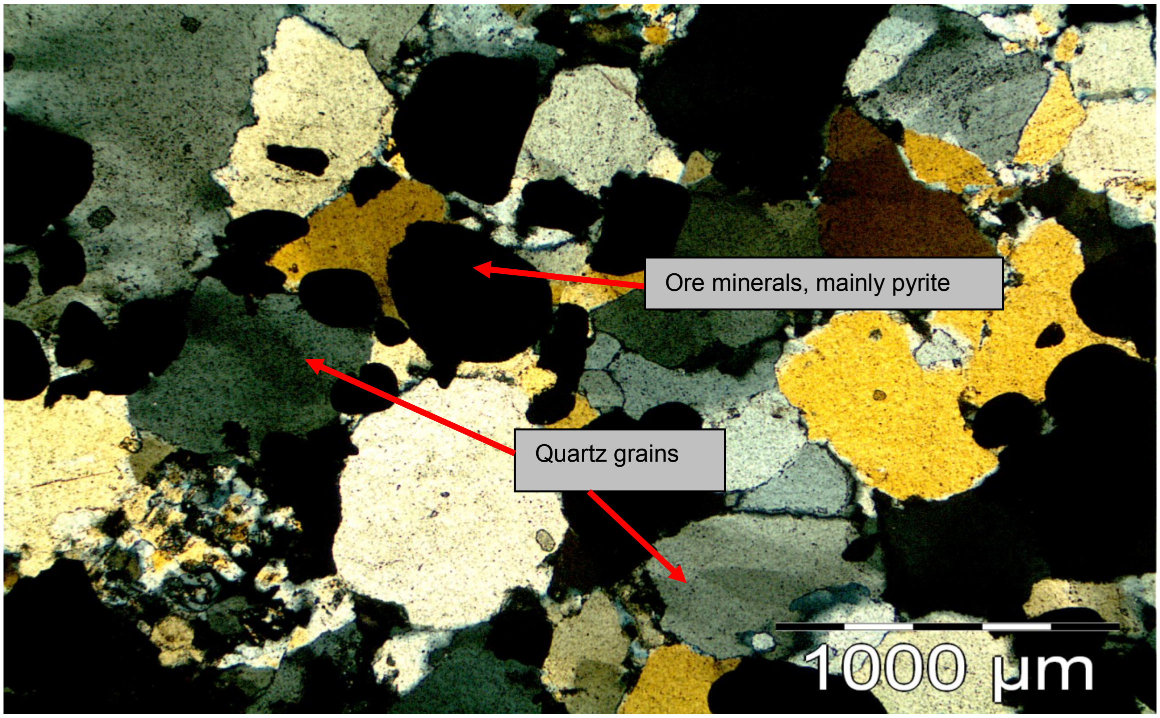


Figure 5-1: Photomicrograph of the A Reef showing mostly quartz and abundant ore minerals (pyrite).

5.1.2 Pyrite

Pyrite is the most abundant ore mineral found in the matrix of the A Reef. More than 90% of the pyrite occurs as rounded detrital grains in the interstitial matrix of pebbles (Figure 5-2). The other 10% pyrite occurs as crystals less than one millimeter in diameter. Infill of pyrite is also common, usually close to fault zones and fractures which acted as fluid path ways. Pyrite has then replaced most of the immediately surrounding minerals by sulphidation. Euhedral pyrite occurs as disseminated grains spread through the quartzites. They sometimes form small clusters of euhedral grains grouped together or separately spread out in the quartzites. The individual grains can be up to 3 mm across.

Pyrite occurs as:

- Detrital grains.
- Euhedral Crystals.

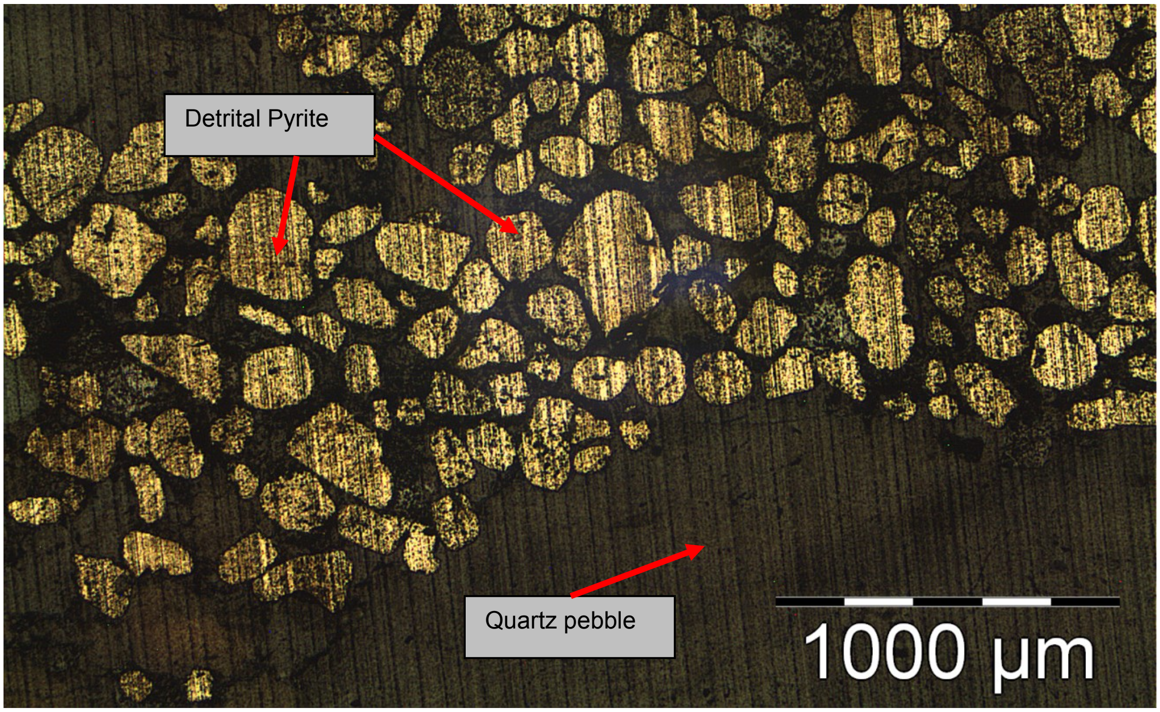


Figure 5-2: Photomicrograph showing detrital pyrite matrix between quartz pebbles.

5.1.3 Pyrophyllite

Pyrophyllite was noted in many of the samples and occurs as large megacrysts in a fine grained mineral matrix (Figure 5-3).

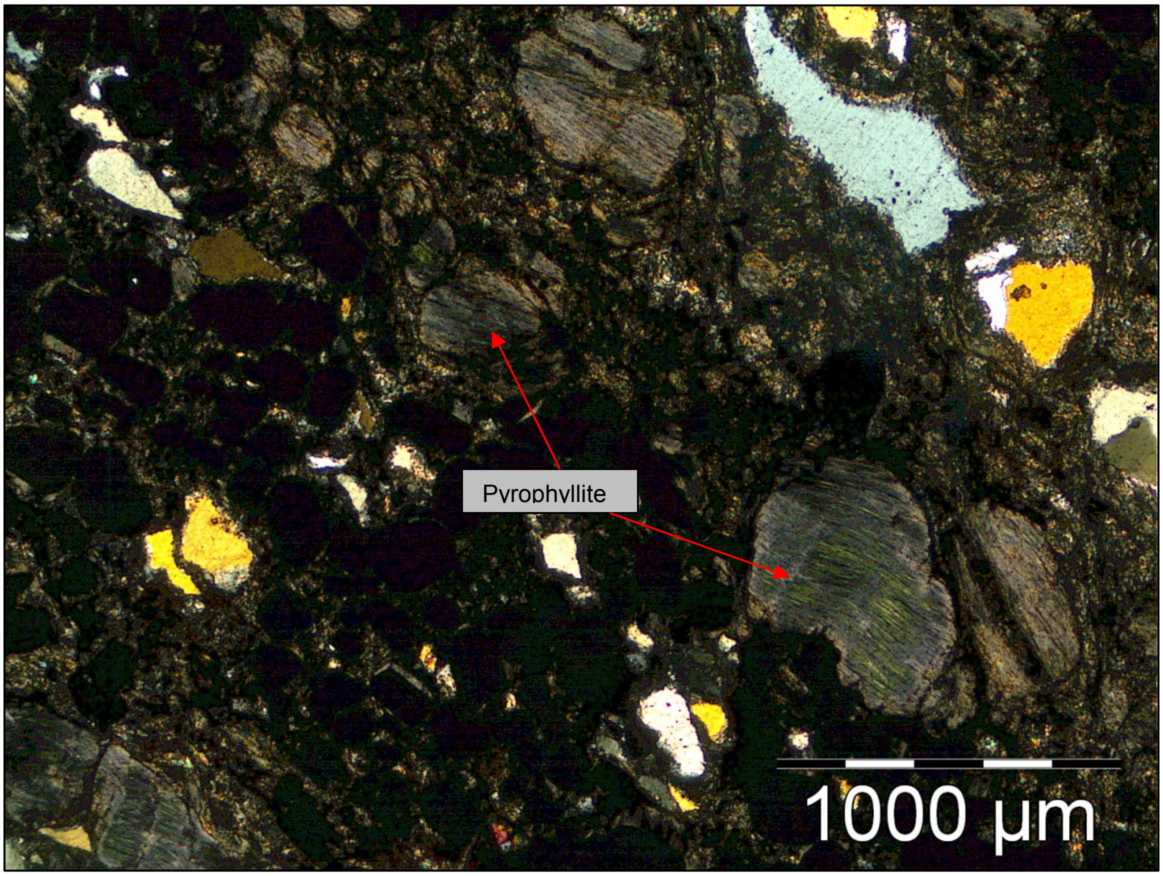


Figure 5-3: Photomicrograph of a couple of Pyrophyllite in a fine grained mineral matrix.

5.1.4 Chloritoid

Chlorite and chloritoid are common in the Eldorado Formation and occurs around fractures and fault zones, as well as where fluid has passed through shale bands and at mylonitic shear zones. The surrounding rocks usually have a light green colour.

6 Structure

6.1 Introduction

Because this thesis is based on the sedimentology and depositional environment of the A Reef in the study area the author will do a regional review of some structures in the goldfields and then aim to compare it to the local structure found in the Ventersburg Project Area.

6.2 Regional Structure

Regionally, well-known faults which dominate the Free State Goldfields are the De Bron Fault (with a down throw of over a thousand meters in places) the Ararat, Stuurmanspan and Dagbreek Faults (Figure 6-1). They are of middle Ventersdorp age (Olivier, 1965). Most of these major faults in the Free State Goldfields are northerly striking with large dextral displacement with older east-west faults (see Figure 6-2) (Tweedie, 1986). Central Rand Group sediments in horst blocks were to a large extent eroded during Ventersdorp times but blocks are in many cases structurally preserved in the grabens or valleys (Minter *et al*., 1986). Tweedie (1986) recognised three main deformation events in the Witwatersrand Supergroup (Figure 6-3) namely syn-depositional compression, folding and the development of unconformity surfaces (Tweedie, 1986). During Ventersdorp times there were extension and rifting with mostly northerly striking normal faults. Outpour of basaltic and andesitic Ventersdorp lavas followed the extensional tectonics and these were deposited in grabens and half grabens on top of the Witwatersrand Supergroup. Tectonic structures possibly acted as pathways for the magmas (Johnson *et al*., 2006). The third event is a deformational event caused by the impact of the Vredefort meteorite. Fault reactivation, brecciation and to an extent close to the impact, some remobilisation of minerals such as gold and uranium occurred. Faults were also pathways for dykes and sills and sometimes kimberlite fissures. In cases dolerite dykes intruded into the Karoo sediments along weak zones in the underlying formations.

The Karoo sediments are however usually not displaced. The faults and weak areas are also good pathways for natural occurring gasses.

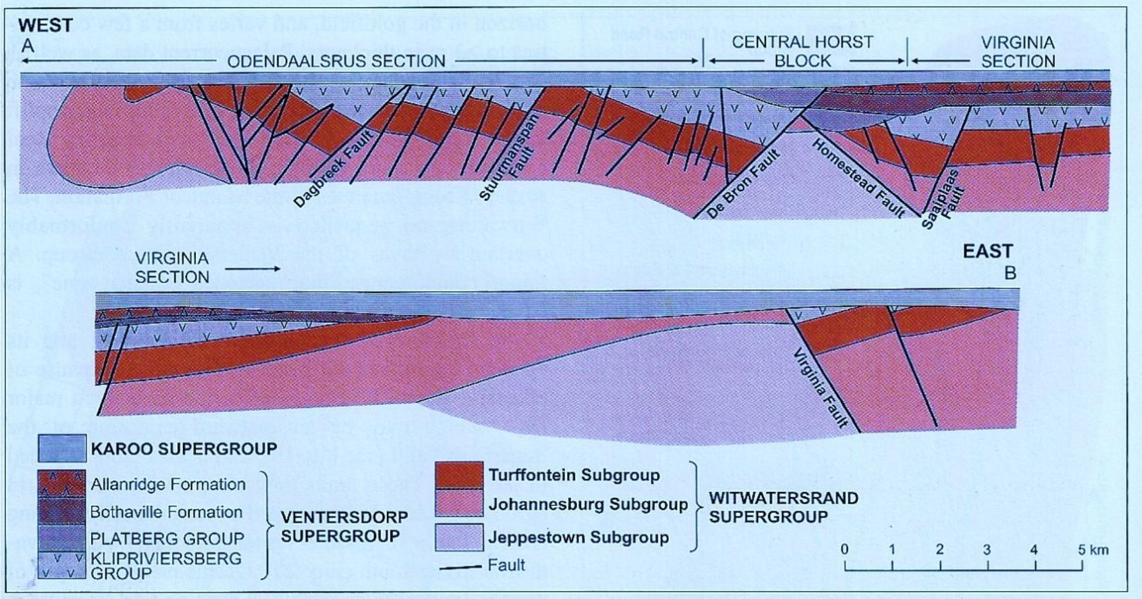


Figure 6-1: West-east section across the Free State Goldfields (from Minter et al., 1986).

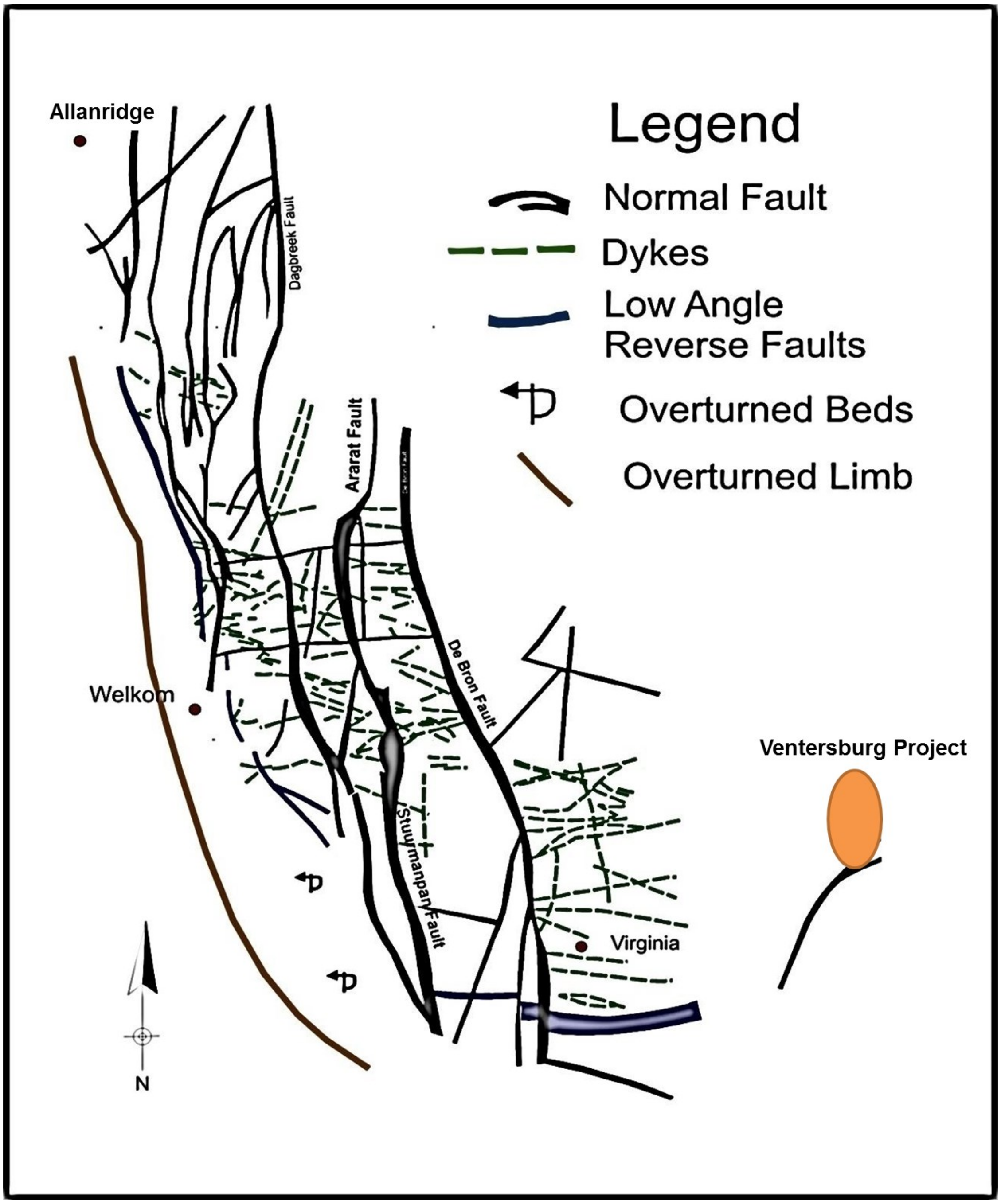


Figure 6-2: Major faults and structure of the Free State Goldfields (modified from Minter et al., 1986).

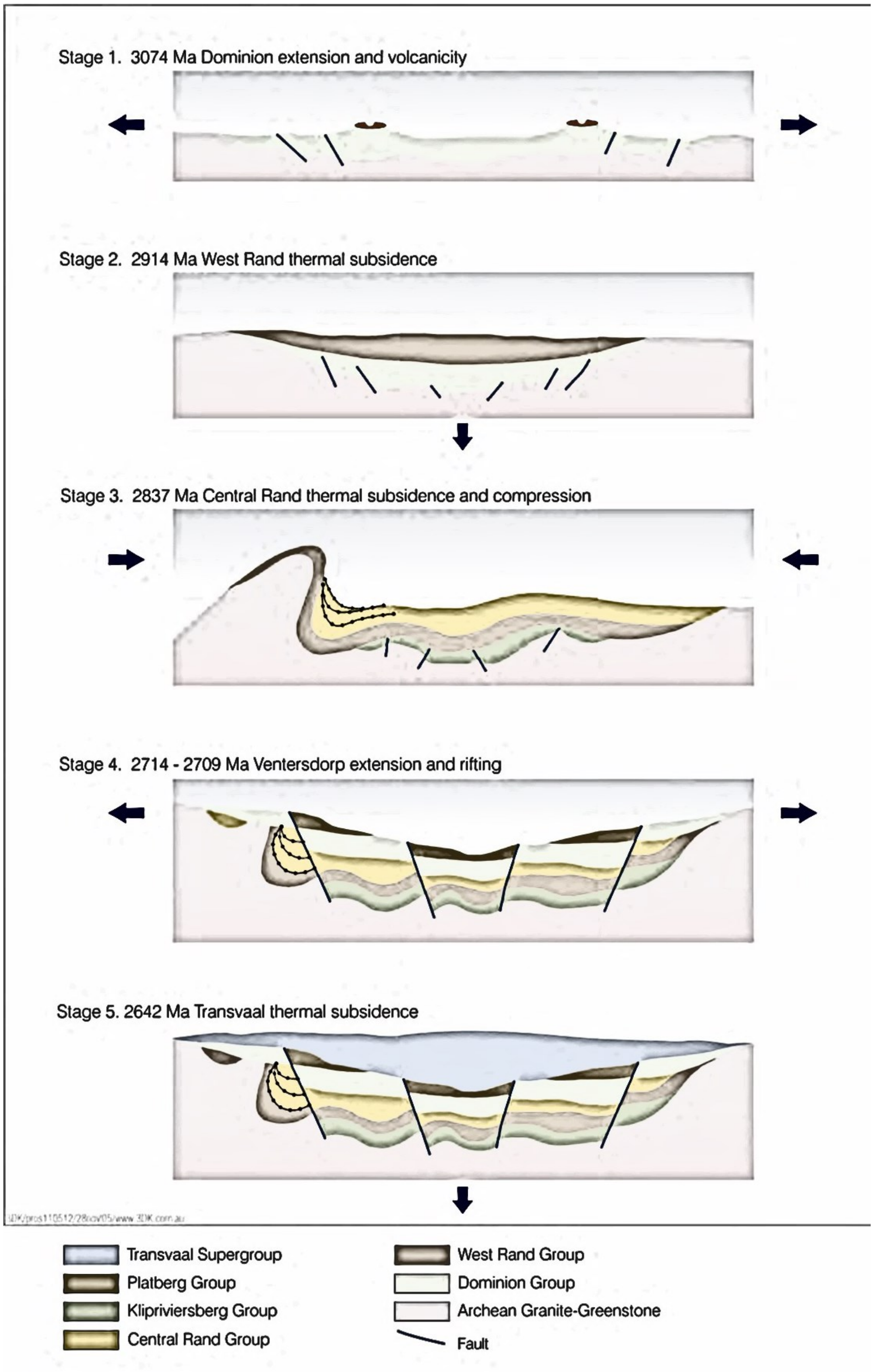


Figure 6-3: Tectonic evolution of the Kaapvaal Craton 3 074 Ma to 2 600 Ma (Tweedie, 1986).

6.3 Geological Structures of the Ventersburg Project

The Ventersburg Project is situated in a graben structure bounded to the east by the Ventersburg Fault with a north-northeast trend and a down throw of 300 to 1 000 meters to the west. The Virginia Fault (Figure 6-4) is situated on the western limit of the study area with a down throw to the east ranging from 100 m to a few hundred metres.

The Ventersburg graben has preserved the Ventersdorp and Witwatersrand Supergroup. The large northerly trending faults transgress the entire study area with smaller synthetic east-west trending faults between the previously mentioned northerly trending faults. The east-west trending faults resulted in the study area being divided into smaller ore blocks. The average dip of the A Reef is 17˚ to the north-west. Fault blocks have been tilted to the west sometime after deposition.

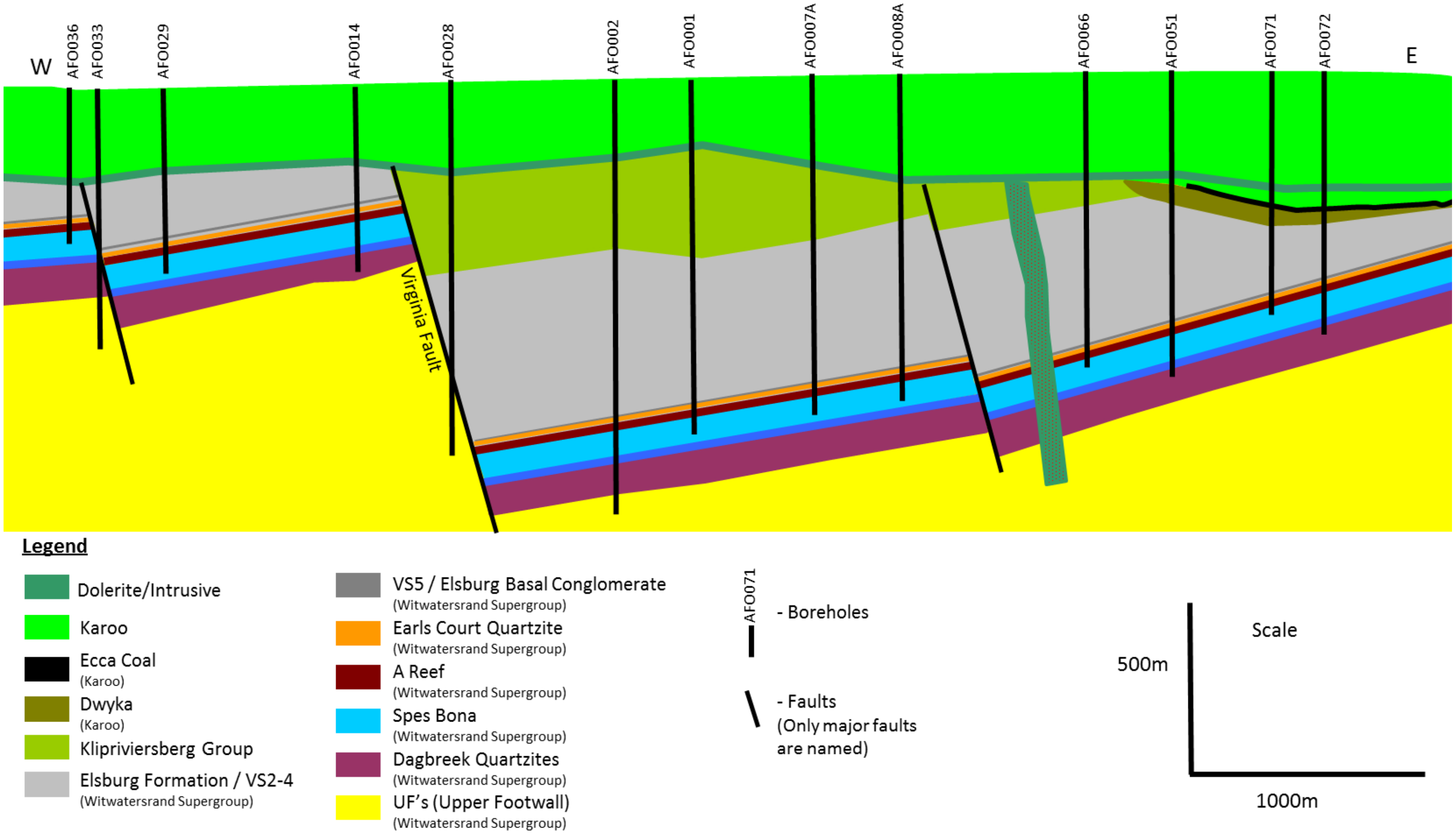


Figure 6-4: Simplified west-east section across the Ventersburg Project area.

6.4 Karoo aged dolerite dykes and sills

The Ventersburg Project area is underlain by Karoo Supergroup sandstone and shale of the Ecca and Beaufort Groups. The lower contact of the Karoo sediments is uneven and follows the palaeo topography of the stratigraphy below. No large scale faulting is present.

The lower part of the Ecca Group, where coal is usually developed is mostly absent from the study area (Table 6-1). In a glacial valley on the eastern limit of the current exploration area some lower Ecca and Dwyka Group sediments were preserved (Figure 6-4). In this area a 10 m thick low grade coal seam have been intersected in borehole AFO059 and AFO086.

Dolerite dykes, dolerite sills and kimberlite fissures are the main intrusive rocks in the area. The dolerite dykes and sills intruded during Drakensberg Group times and are basaltic in composition. The kimberlite dykes and fissures occur mostly just north of Theunissen and are part of the Kimberley province kimberlites dated at 99 – 70 Ma, which are post Karoo (550 – 170 Ma) in age (Skinner *et al.*, 1991).

Figure 6-5 indicates the thickness of a dolerite sill occurring at the base of the Karoo Supergroup across the entire study area. The average thickness of the dolerite sill in the project area is 17 meters but a maximum of 117 meters have been intersected in borehole AFO050 (Figure 6-5). From all the available borehole data it is evident that sills intrude along weaker zones or contacts. In the study area this is the bottom contact of the Karoo Supergroup (Figure 6-6).

Table 6-1: Basic Karoo stratigraphy as intersected in in the project area (from borehole chips and drill core).

SUPERGROUP	GROUP	FORMATION		DESCRIPTION
KARROO	**BEAUFORT**	**ADELAIDE**		Sandstone
				Calcareous Sandstone
				Shale
	ECCA	**VOLKSRUST**		Sandstone
				Carbonaceous Shale
				Siltstone
		VRYHEID	🟩	Clean fine grained off-white massive sandstone
			▤	Dull coal underlain by medium brown shales and siltstones
	DWYKA		Δ Δ Δ Δ Δ Δ	Pale grey tillite comprising blocks of lava and quartzite in a clayey matrix

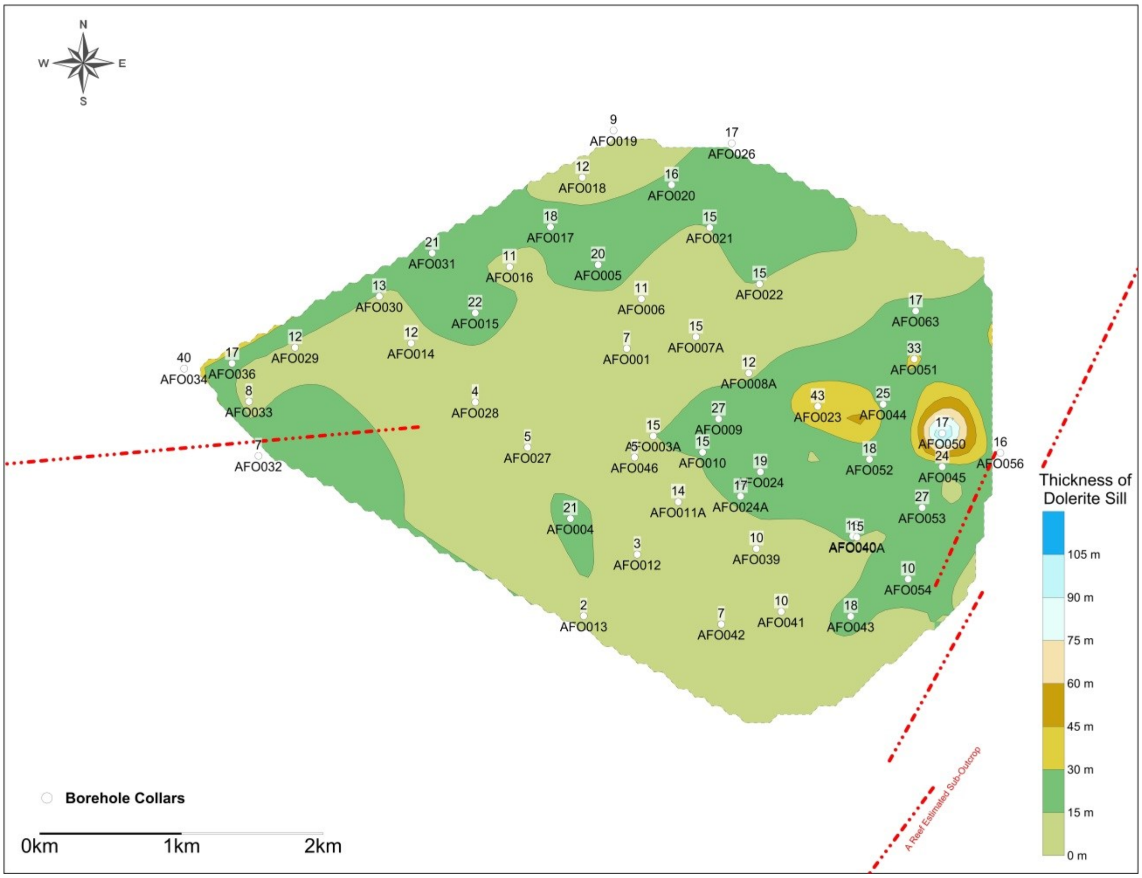
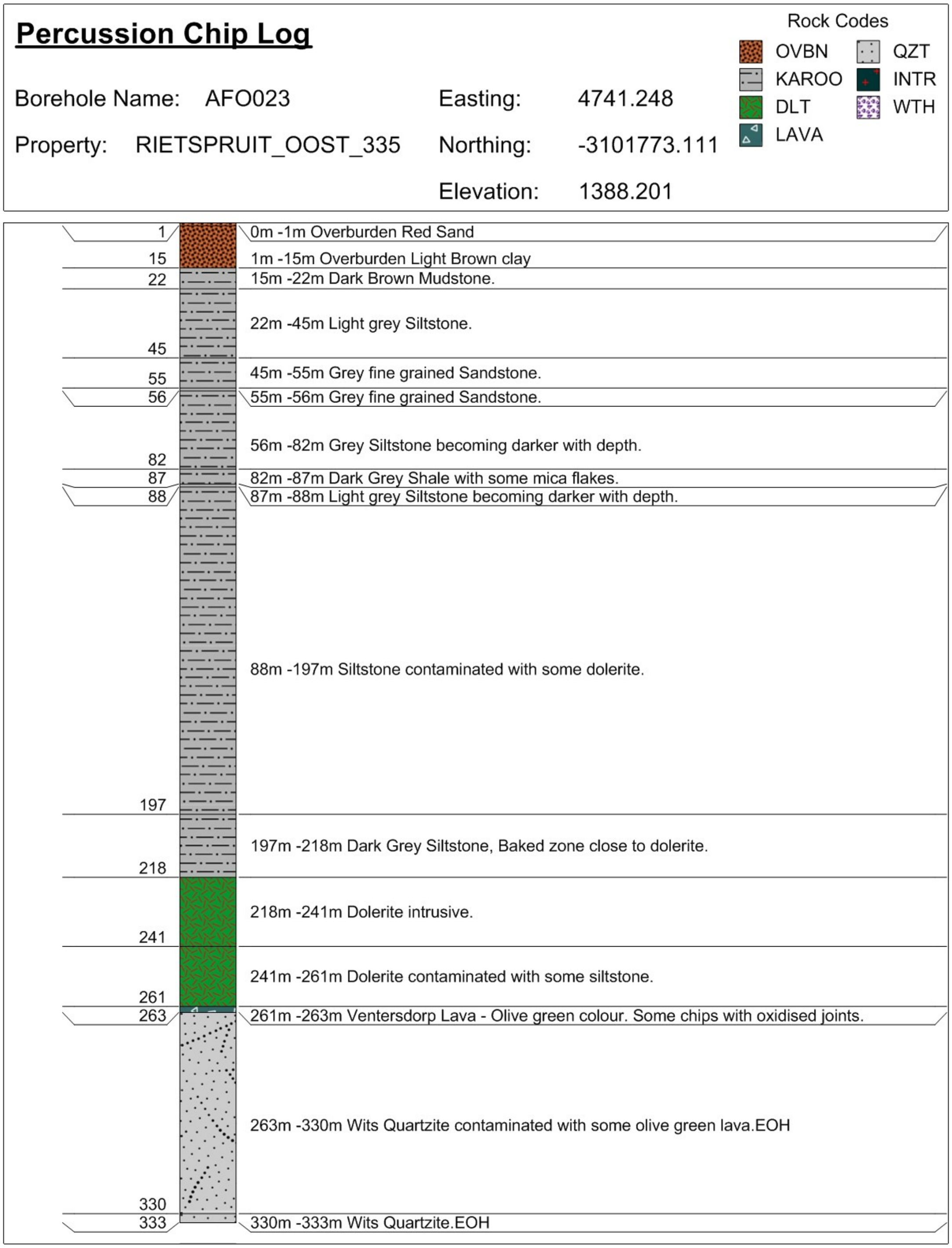


Figure 6-5: Isopachs of the dolerite sill at the lower contacts of the Karoo Supergroup, only data from current borehole intersections were used (Table 6-2).

Table 6-2: Borehole data indicating the thickness of a dolerite sill at the base of the Karoo Supergroup sediments across the project area.

BHID	Y	X	STRAT	THICKNESS (m)
AFO001	-3393.398	3101373.980	DLT	7
AFO003A	-3579.793	3101977.583	DLT	15
AFO004	-2996.446	3102548.364	DLT	21
AFO005	-3191.246	3100793.961	DLT	20
AFO006	-3496.575	3101029.821	DLT	11
AFO007A	-3881.422	3101293.292	DLT	15
AFO008A	-4254.559	3101542.298	DLT	12
AFO009	-4041.917	3101859.852	DLT	27
AFO010	-3928.433	3102090.004	DLT	15
AFO011A	-3756.363	3102432.359	DLT	14
AFO012	-3467.586	3102795.486	DLT	3
AFO013	-3090.138	3103221.500	DLT	2
AFO014	-1871.628	3101336.066	DLT	12
AFO015	-2324.010	3101127.515	DLT	22
AFO016	-2566.713	3100808.415	DLT	11
AFO017	-2855.826	3100533.076	DLT	18
AFO018	-3080.408	3100190.392	DLT	12
AFO019	-3300.235	3099865.809	DLT	9
AFO020	-3709.945	3100242.429	DLT	16
AFO021	-3979.210	3100537.631	DLT	15
AFO022	-4330.017	3100926.723	DLT	15
AFO023	-4741.248	3101773.111	DLT	43
AFO024	-4336.287	3102225.229	DLT	19
AFO024A	-4196.859	3102394.762	DLT	17
AFO026	-4134.542	3099954.714	DLT	17
AFO027	-2694.206	3102056.214	DLT	5
AFO028	-2324.480	3101744.567	DLT	4
AFO029	-1053.544	3101365.907	DLT	12
AFO030	-1647.163	3101013.003	DLT	13
AFO031	-2020.905	3100713.658	DLT	21
AFO032	-794.700	3102114.944	DLT	7
AFO033	-727.936	3101739.397	DLT	8
AFO034	-270.433	3101511.653	DLT	40
AFO036	-609.086	3101475.045	DLT	17
AFO039	-4308.466	3102756.262	DLT	10
AFO040	-4988.000	3102670.000	DLT	16
AFO040A	-5017.405	3102677.004	DLT	15
AFO041	-4483.659	3103191.779	DLT	10
AFO042	-4060.588	3103277.968	DLT	7
AFO043	-4973.879	3103223.584	DLT	18
AFO044	-5202.624	3101757.710	DLT	25
AFO045	-5619.086	3102190.422	DLT	24
AFO046	-3448.520	3102124.727	DLT	5
AFO050	-5618.383	3101958.592	DLT	17
AFO051	-5422.062	3101445.473	DLT	33
AFO052	-5106.363	3102138.418	DLT	18
AFO053	-5477.540	3102472.452	DLT	27
AFO054	-5378.673	3102966.529	DLT	10
AFO056	-6029.156	3102093.746	DLT	16
AFO063	-5431.579	3101113.035	DLT	17



Percussion Chip Log

Borehole Name: AFO023
Property: RIETSPRUIT_OOST_335
Easting: 4741.248
Northing: -3101773.111
Elevation: 1388.201

Depth	Description
1	0m -1m Overburden Red Sand
15	1m -15m Overburden Light Brown clay
22	15m -22m Dark Brown Mudstone.
45	22m -45m Light grey Siltstone.
55	45m -55m Grey fine grained Sandstone.
56	55m -56m Grey fine grained Sandstone.
82	56m -82m Grey Siltstone becoming darker with depth.
87	82m -87m Dark Grey Shale with some mica flakes.
88	87m -88m Light grey Siltstone becoming darker with depth.
197	88m -197m Siltstone contaminated with some dolerite.
218	197m -218m Dark Grey Siltstone, Baked zone close to dolerite.
241	218m -241m Dolerite intrusive.
261	241m -261m Dolerite contaminated with some siltstone.
263	261m -263m Ventersdorp Lava - Olive green colour. Some chips with oxidised joints.
330	263m -330m Wits Quartzite contaminated with some olive green lava.EOH
333	330m -333m Wits Quartzite.EOH

Figure 6-6: Strip-log of the chips logged from AFO023. Note the dolerite sill at the base of the Karoo Supergroup (Easting, Northing and Elevation in the title indicate the collar coordinates in WGS84, Lo27).

6.5 Natural Gas Occurrences

The Free State Goldfields is well known for the occurrences of natural gas in underground mining operations. The origin of the natural gas has long been a much debated subject that will most likely still continue for some time.

A number of boreholes in the Ventersburg Project area have yielded natural gas at the contact between the Karoo Supergroup and Witwatersrand Supergroup. Drilling through carbonaceous matter in the lower Ecca Group did not yield gas in the project area; this indicates that coal bed methane is not the origin of the gas. A deep seated source in the Witwatersrand Basin or upper crust is proposed.

The natural gas occurring in the Free State is made up of a number of constituents and it is listed along with relative percentages in Table 6.2 below. (Hugo, 1963).

Table 6-3: Analysis of gas from a borehole drilled at Virginia Mine in 1957 (Hugo, 1963).

Constituents	Chemical Analysis	Analysis by mass spectrometer
Methane	78.4%	76.6%
Nitrogen	12.1%	13.9%
Helium	8.0%	8.3%
Hydrogen	0.1%	0.1%
Oxygen	0.1%	0.2%
Argon	0.3%	0.5%
Carbon dioxide	0.8%	0.4%
Carbon monoxide	0.2%	-
Totals	100%	100%

7 Summary and Conclusion

The Ventersburg Project, close to the town of Hennenman, in the Free State Goldfields, was extensively drilled for A Reef from 2009 to 2012 by Gold One. Historic exploration also occurred from the 1940s. Other reefs, mainly known from mining further to the west in the Free State Goldfields, were intersected i.e. B Reef, Leader Reef and Basal Reef, but they are all poorly developed in the project area due to their distal setting in the basin. The A Reef had the most promising results in terms of economic gold grades and depth below surface, thus making it the primary target.

Understanding sedimentary environments and facies are important in the successful exploration for mineral deposits and even more so in channelised placer deposits like the A Reef. From this came the objective to better understand the stratigraphy and sedimentology of the A Reef and to describe facies and delineate geological domains which can be used for resource purposes. Sound exploration practices and procedures are also important in acquiring a final outcome for an exploration program (Appendix A).

Different sedimentary environments occur within the A Reef. These are characterised by different facies. Heavy mineral distribution is linked to the character of facies and sedimentary structures. The different sub-environments are main channel, subsidiary channel or channel edge and terraces.

The A Reef is a mature, small to medium pebble, oligomictic conglomerate, with siliceous quartzites and is an upward fining sequence. The facies in the A Reef differ in terms of the amount of conglomerate, matrix and heavy minerals. The main facies in the reef is the Gmc facies occurring in areas of flow convergence i.e. channel edges and around inter-channel bars; this is a clast supported oligomictic conglomerate, massive and well packed. Some interbedded quartzite lenses may be present within this facies caused by lateral movement of channels. This facies comprises well-developed conglomerates with high pyrite content, visible fly-spec carbon and a higher gold grade. The Gmc facies is divided into Gmc1 and Gmc2 across the project area, because of variable channel thickness and pebble size. The Gmc2 facies is thinner with smaller pebbles, but is still a well-developed and well mineralised conglomerate. The matrix supported conglomerate facies Gmm, is poorly sorted and not as well developed as the Gmc facies. The heavy mineral content is also substantially less and so also the gold grade. Based on the measured sizes of the 10 largest pebbles an overall decrease in pebble size was found from west-north-west to east-south-east.

The project area lies on the eastern edge of the Witwatersrand basin and for most of the gold bearing placers this means that it is too distal for the development of economic heavy mineral placers. The A Reef most likely eroded and transported some sediment containing heavy minerals from local sources and through heavy mineral or hydraulic sorting heavy minerals were deposited in the A Reef.

Structurally the A Reef in the Ventersburg Project is shallow but still preserved in a graben bounded by the Virginia and Ventersburg Faults. In the exploration for other similar targets these criteria should also be considered.

In summary, braided alluvial environments contain heavy mineral accumulations, through controlling sedimentological processes. On small scale, heavy minerals are concentrated between pebbles and along sedimentary bedding structures and bedding planes. In channel complexes the distribution of heavy minerals can also be seen where there were sudden changes in flow direction. Due to the complex nature of the depositional environment channels and bars shift over time and distribute heavy minerals away from original deposition sites. Therefore, a certain amount of anticipation does exist in predicting occurrences of “payshoots”. Even so, accuracy of predictions can be increased through the study of the depositional environments and sedimentological features of placers.

8 Recommendations

Successful exploration depends on a good understanding of the geology from the beginning of the project and each data point whether borehole intersections or underground samples. All information must be used to plan the exploration program. The following are good starting points and should be built upon to complete a sound geological model:

- Geological Description of the area and Stratigraphy
- Isopach plans of all overlying sediments – this can indicate directional trends in deposition
- Facies description and plans
- Sedimentological data, pebble sizes, cross bedding grain sizes
- Carbon content/distribution
- Size of Buckshot pyrite – specific to reef types
- Reef thickness
- Pebble size distribution
- Grade distribution contours
- Structures

Once the palaeo current direction has been established it is important to drill perpendicular to the direction of deposition and to locate payshoots. After the location of payshoots has been regionally located, a drilling pattern on a specific grid can commence.

During mining operations it will be very important for the geology department to keep up to date with detailed mapping at the stope faces. This will ensure that development and mining stay on reef and also identify new high grade pay zones. During detailed mapping it will be important to measure pebble sizes as well as any palaeocurrent indicators.

Detailed mapping of channels and pebble orientation measurements were not possible as only exploration borehole core are available. At the time of shaft sinking, detailed underground mapping will add extra value to the project. Seismic surveys in 2D or 3D could also be advantageous in the orientation of major structures and dykes.

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10 Acknowledgements

I would like to thank Gold One International Ltd. for the opportunity to conduct the study, also for their financial support and help with all resources during the project.

This thesis would not have been possible without the help of my supervisors and work colleagues. I would like to thank Dr. Leon Nel who spent many hours driving to the project area for discussions and guidance and to share his ideas and knowledge, also for his patience in reading many draft copies. Many thanks to Prof. Willem van der Westhuizen for his encouragement and guidance.

At Gold One, Quartus Meyer for sharing his experience with gold mining and exploration, all his encouragement and discussions, not only about geology, exploration and mining but also life lessons.

I would like to thank my parents who prepared me for life, who always taught me that I can do anything, there only needs to be a willingness to learn. My sister for being an inspiration and showing me that you never have to give up, because God is always by your side. Finally a special thanks to my loving wife for all her patience and support.

We shall not cease from exploration and the end of all our exploring will be to arrive where we started… and know the place for the first time.” — T. S. Eliot

APPENDIX A

Exploration Policies and Procedures

Exploration Process

Exploration drilling is conducted to locate and prove the existence of an ore body. Samples derived from diamond drill core are then used to evaluate the economic auriferous horizons. Procedures to ensure the integrity of the data must be followed at all times. At the Ventersburg Project two drilling methods are used. This is mainly to save some time on each drill hole as drilling through Karoo sediment has the risk of caving and resulting in rods being stuck and borehole can be lost. A percussion pilot hole is drilled through the Karoo sediments into either the Ventersdorp Supergroup lavas or Witwatersrand Supergroup quartzites. The hole is then cased to prevent caving from Karoo sandstones and shales. Methane (CH_4) and water intersections can also be sealed off more easily during percussion drilling because of compressed air being used. After the percussion hole is drilled it is cleaned and a steel casing inserted. The diamond drill rig can then be moved onto the site to complete the hole.

Any exploration process must start with finding available data and doing a desktop study to generate target areas with highest priority. On a greenfields project where no prior exploration has been conducted only geological plans may be available. When a project is started where previous work has been done, there might be borehole core available and also borehole logs as well as assay data. This historical data can be very useful and can be used to quickly identify target areas. Old plans should be updated and re-interpreted. In the case of placers being investigated, channel thickness, grade, pebble sizes and composition and other geological features like structures, can be used to delineate potential high grade channels. It is important to obtain encouraging results in the early stages of an exploration project. This highlights the importance of targeting high grade areas. After initial results have been interpreted drilling should be planned to delineate the width of the channels and then follow the channels along the palaeoflow direction. It is important to delineate channel edges and thus boundaries for resource domains.

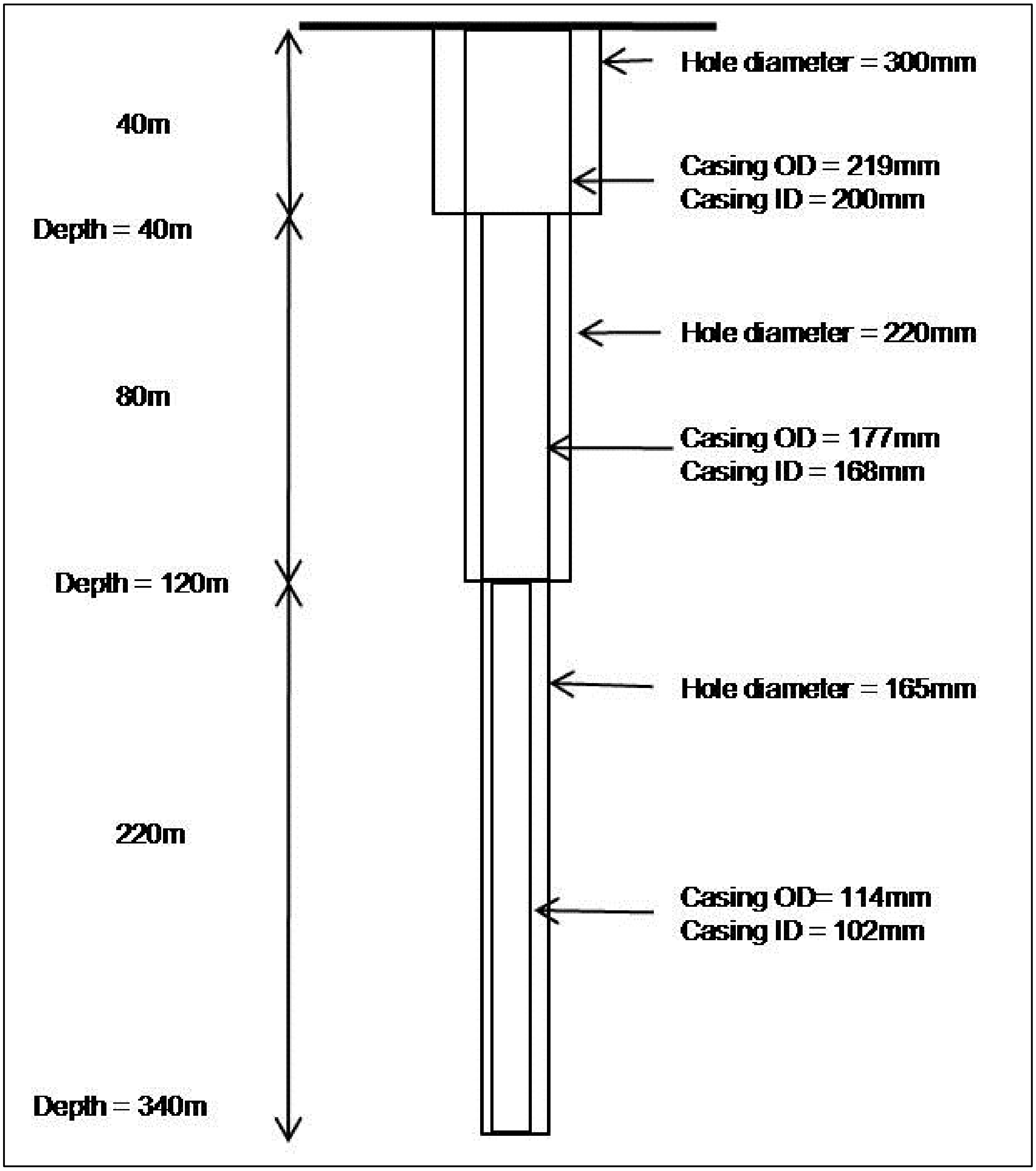
With the Ventersburg A Reef project, a drill spacing of 500m x 500m was adequate for prefeasibility phase. This grid will be reduced to 250m x 250m during the feasibility phase. The geology and geostatistical character of an orebody must dictate the exploration methods and drilling grids.

Percussion Drilling Procedures

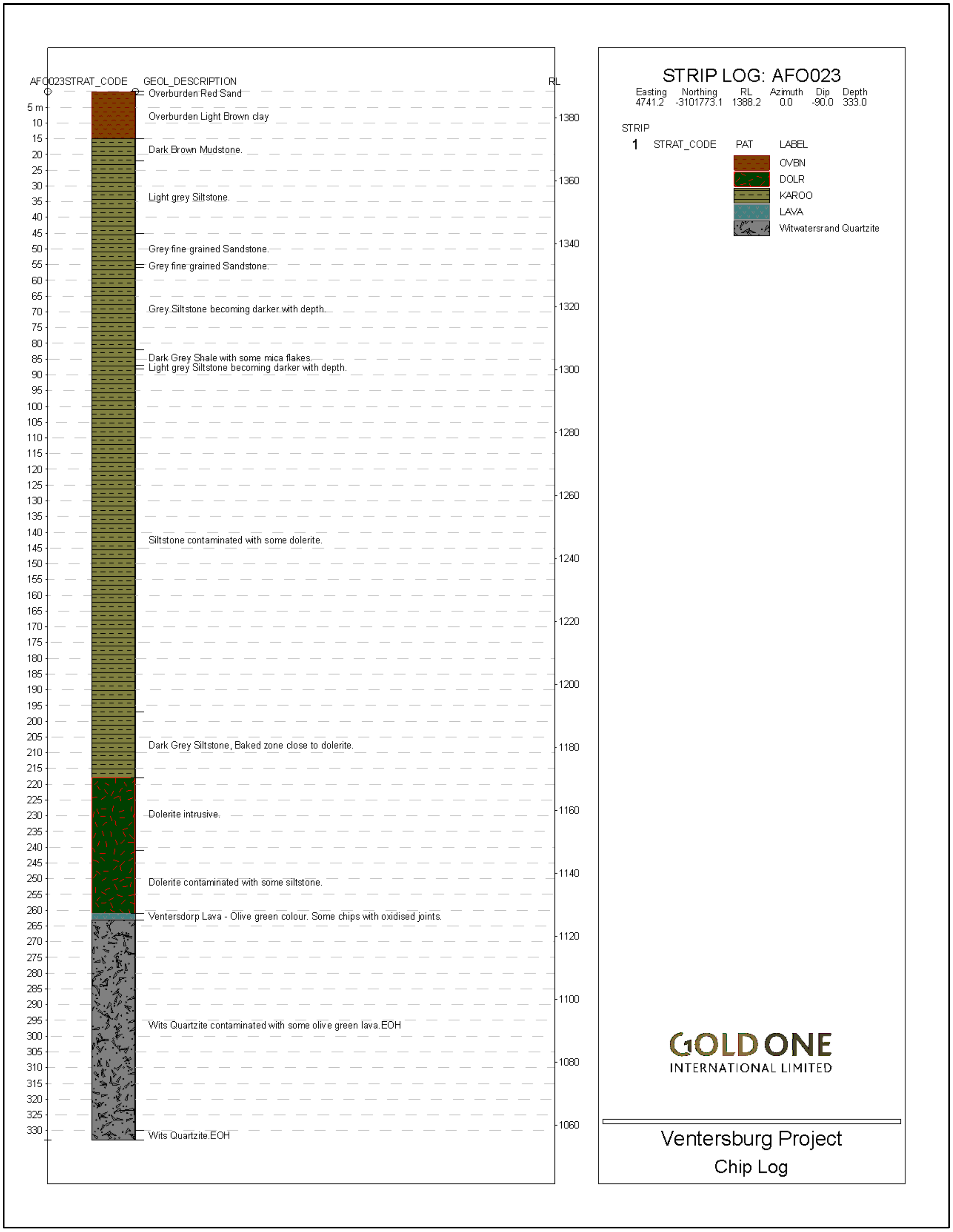
All borehole collar positions must be carefully planned before drilling can commence to ensure the highest rate of success in evaluating the ore body. A structural plan indicating historic boreholes, prospecting right areas, farm boundaries and all other available information is essential when proposed boreholes are planned. Also important is the inter borehole spacing required between holes. Satellite images are very helpful with terrain identification to indicate any obstructions like old mine dumps, farm houses or roads. It can also be utilized to identify current land use i.e. crops or grazing. Aeromagnetic data is also used as this can indicate possible structures like faulting or dykes which can then be avoided if the hole is moved away from these features. The coordinates are then transferred onto a handheld GPS (Global Positioning System). The correct coordinate system must be used at all times. In this case the projection is South African Grid WG27° System (Hartebeesthoek94 Datum) and the Ellipse is WGS 1984. When siting the borehole in the field, the location must be marked with a steel peg and clearly marked with a flag and/or reflective tape. The relevant land owners should be consulted before siting and the percussion rig foreman should be present. It is vital to adhere to all environmental management plan rules and to make sure the area is rehabilitated to conditions before drilling took place. Photographs are always taken of the site before drilling starts and again after rehabilitation to make sure the site are rehabilitated to the required standard.

The diamond drill rig utilizes water as a cutting medium and as lubrication to the bit. If a pilot hole intersects a suitable ground water source, it is often used as a water supply. The rig is then moved a few metres away to drill a new pilot hole for the diamond drill rig. An example of the standard percussion drill hole casing configuration is depicted in. It is important that the percussion drill hole is never stopped in Karoo rocks but always in competent rock. At the Ventersburg Project this is either Ventersdorp lava or Witwatersrand quartzite. This ensures that the casing is stable and any possibility for caving or breakage is thus kept to a minimum. It is very important that the progress of the percussion hole be monitored daily to make sure the hole is stopped at the correct depth.

After completing the percussion hole, it is cleaned with compressed air in the presence of the percussion drill foreman and the diamond drill foreman. It is then sealed with a steel cap until the diamond drill rig is moved on site. All relevant parties then sign off on a clearance form that the hole has been cleaned and sealed. A steel marker with borehole identification and reflective tape for visibility is planted at the collar position. The percussion rig foreman must ensure that every meter of chips drilled is displayed in neat rows for easy logging. A small amount of every meter of chips is washed and stored in plastic chip trays clearly marked and numbered; these are then logged by the geologist and then stored for reference. The figure below is an example of a chip log profile.



Casing configuration of a standard percussion pilot borehole.



Example of a chip log profile (created using Target for ArcGIS software).

Methane detection and capping

During drilling, all drill rig operators and staff must be made aware of the possibility of intersecting methane while drilling. They have to be in possession of an approved methane meter at all times and should know how to use it. Constant readings should be taken approximately 0.5m from the borehole collar before and during drilling.

In the case of methane being present all relevant information i.e. depth, time, concentration and any other features associated with the methane must be recorder on the daily drilling log sheet.

All drilling should be stopped if methane is found to be above 1.25% within a 0.5m radius from the collar. In the case of percussion drilling the hole can be flushed with air to try to lower the methane concentrations and reduce the risk. All personnel are to be moved to a safety area away from any methane concentrations.

A decision to continue drilling can only be made after the methane concentrations have decreased below 1.25% within a radius of 0.5m from the collar. Instructions from the safety officer or field manager will be given to the drilling foreman. Other risks to consider which can lead to ignition are the recoverability of the drill rods and inserting final casings.

If the hole is not at its end depth and a decision is made to continue drilling and to install the final casings, a methane deflector must be used. The deflector is bolted on to the last casing on surface. This is done before installing the 114 mm casing to seal of the methane intersection. The inner casing can then be installed trough the methane deflector seal and any methane from the hole is piped away from the hole. When welding is done while lowering the casing compressed air is also used to make sure no methane is present at the collar. During casing installation constant methane tests should be done and also after the casing is fully installed to make sure the methane intersection have been completely sealed off.

In the event of methane being intersected a methane deflector is used to deflect the methane away from the hole and drilling/inserting casings can continue.

If the amount of methane from the hole is unsafe and it cannot be sealed off safely to continue diamond drilling the following should be done.

- Cordon off the hole with a 6.0m x 6.0m x 2.0m wire fence with a lockable gate and all necessary safety and warning signs
- An approved gas venting pipe (extended 2m above surface) is to be installed on the borehole. Monthly measurements of the flow rate and quantity to be carried out and reported in the methane log book.

GAS ARRESTOR

Suggested method to seal and monitor gas on a drilled hole:

- Pre construct complete pressure valve as in drawing.
- Without removing 20m gas outlet pipe, excavate a 1.0m^3 hole around the Ø210mm casing pipe.
- Place the Ø220mm x 1.3m long pipe with flange at top end over the Ø210mm.
- The Ø220mm pipe fitted with 4 locking bolts is secured to the Ø210mm casing pipe.
- Fit the pre-constructed pressure unit onto the Ø220mm flange side and secure.
- Outlet control valve must be fully open.
- Pour in concrete to cure for seven days, while valve remains open.

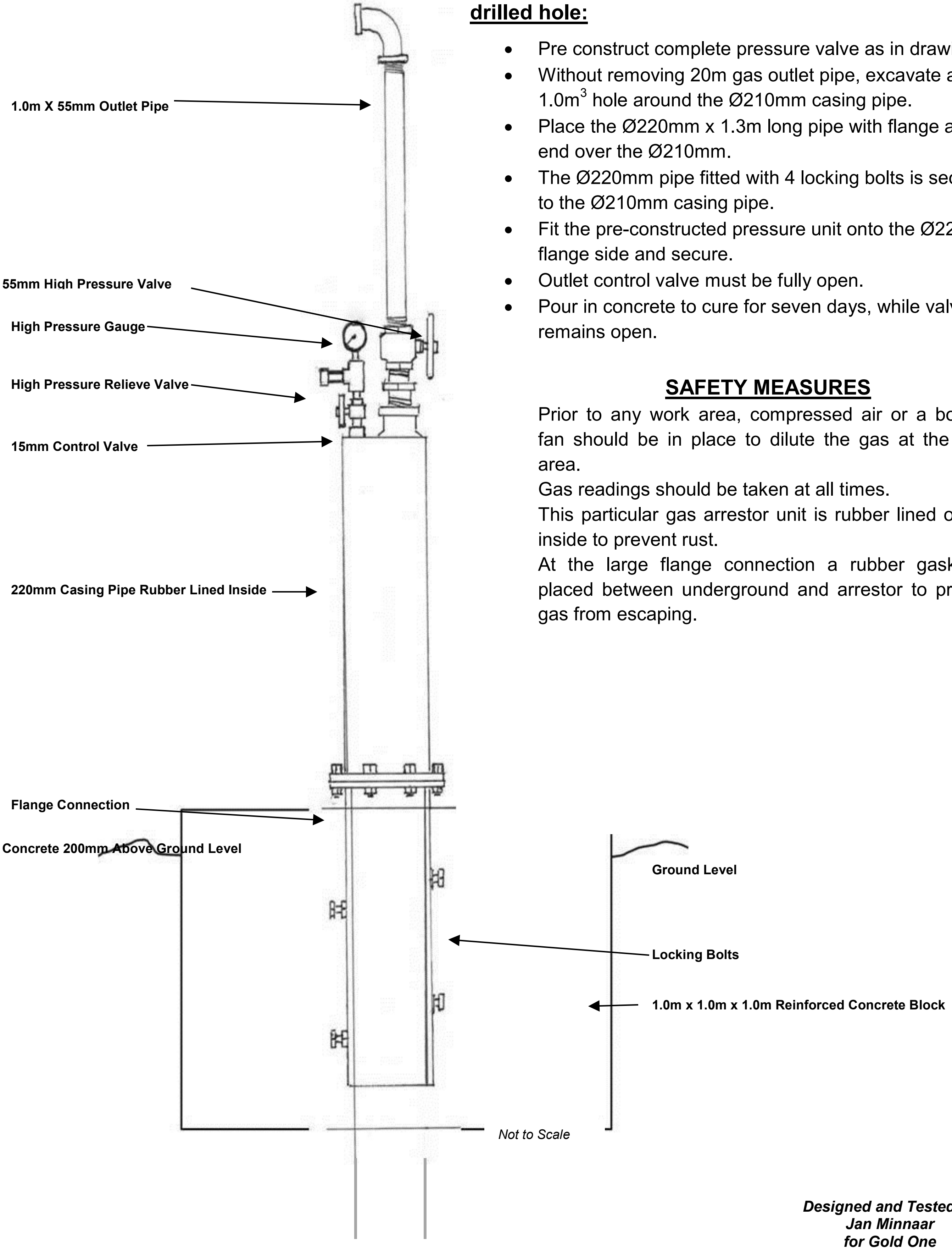
SAFETY MEASURES

Prior to any work area, compressed air or a booster fan should be in place to dilute the gas at the work area.

Gas readings should be taken at all times.

This particular gas arrestor unit is rubber lined on the inside to prevent rust.

At the large flange connection a rubber gasket is placed between underground and arrestor to prevent gas from escaping.



Not to Scale

Designed and Tested by
Jan Minnaar
for Gold One

Diamond Drilling Procedures

Drillhole depth accuracy checks

Drill sites are visited on regular basis and drill reports are checked on a daily basis to correlate the depth on the core with the drillers' "stick-up" and total meters drilled.

- Standard length of rods used by Percusso-Bor is 6m
- Core rod's length is 7.3m (Rod + drill bit + coupling)
- A 6m or 3m core barrel is used depending on the "Reef Run" instruction given by the geologist

The length of the rod still in the chuck of the drill is checked.

After the final depth of the hole is reached, a multi-shot survey is done on the mother hole.

All the rods are then pulled from the hole and their lengths checked and the amount of rods counted.

The core rod is also measured.

The actual depth is calculated by using the following equation:

$$(Number\ of\ rods \times lentgh\ of\ rods\ 6m) + (Core\ rod\ 7.3m) - (Stick\ up) = Depth\ of\ hole$$

Any mistakes are double checked and then corrected immediately.

Standard method for marking and numbering drill core

Core is delivered to the core yard and received by the geologist. The following standard procedures should be followed:

- Core must fitted together to make sure the core has not been mixed up.
- All markings on core are to be done with a permanent non fading paint marker.
- Core Trays clearly numbered with the Hole Number, Box Number, from and to depth.
- Core is to be packed from the top left to the bottom right and depths should follow from left to right in sequence.

- Core is to be meter marked. The geologist should make sure all depth markings are correct by measuring up from bottom breaks. A bottom break is the point where breaks the core at the bottom of the hole after each run when the core barrel is full, the core breaks in a certain way and can be easily recognised.
- Plastic core blocks have to be placed after each run.

Drill rods from hole after drilling.

Sampling Procedures

It is extremely important to have standardisation across the core sample taking and logging process. If any mistakes occur it can lead to incorrect data interpretations and valuation of the ore body. Correlations between sample data and geology might then be wrong and this will have an impact on the final outcome of the geological model and understanding of the ore body.

Sample taking and logging

Sampling is done at the exploration office where all staff and required equipment i.e. core cutters and logging tables are available.

Sampling is done systematically and before commencing with marking and halving the core the following important steps need to be taken.

1. Remove or cover up all gold jewellery before handling the core.
2. All the breaks in the core are fitted together to make sure that core is not mixed up and placed in trays upside down, added or lost.
3. Depths are checked measuring back from proper bottom breaks. Core is then fitted together in an angle iron channel fitted to a steel table, the core is orientated so that the low point of the bedding faces up and the dip is measured and noted to be able to calculate the true thickness of the reef. Dip is measured relative perpendicular to core's long axis.
4. A line is then drawn on the core through the low point of the bedding thus dividing the core in half and creating two samples which are mirror images of each other when cut. One half is for record and the other is sent to a laboratory for analysis.
5. More samples above or below the reef is sometimes taken at random or in specific zones to check for gold values.
6. Samples may not be shorter than 10 cm or at least 150 g to make sure enough material is available for at least a single analysis.
7. Sample intervals are based on geological factors such as sedimentology where ever possible to make sure that continuity is kept and to be able to compare geological units with each other. Sample lengths' should not

normally be more than 40 cm in the reef horizon and 50 cm in un-mineralised samples.

8. Mineralised conglomerates should be bracketed by 2-3 cm of unmineralised f/w or h/w to ensure all contacts are properly contained within the mineralised sample)
9. Core recovery is also noted on the sample sheets
10. When sample is taken, it is geologically logged on a sample sheet the sample number is noted and the corresponding half is marked with a non-fading paint marker. Reef intersections are photographed for a permanent record. Recovery and acceptability: firstly core loss, grinding, chip loss and faulting are noted.

Halved core marked and stored for record.

Table of sample recovery descriptions used on the sample sheets.

Recovery	**Description of Representativeness**	**Code**
No breaks	Complete Representative	C Rep
No breaks	Virtually Complete Representative	VC Rep
No breaks	Small Chips Lost Incomplete Representative.	SCL IC Rep
1 Break	Complete Representative	C Rep
1 Break	Virtually Complete Representative	VC Rep
1 Break	Small Chips Lost Incomplete Representative.	SCL IC Rep
1 Break	Incomplete Representative	IC Rep
1 Break	Chips lost Non Representative	CL Non Rep
2 Breaks	Complete Representative	C Rep
2 Breaks	Virtually Complete Representative	VC Rep
2 Breaks	Small Chips Lost Incomplete Representative.	SCL IC Rep
3 Breaks	Virtually Complete Representative	VC Rep
3 Breaks	Complete Representative	C Rep
Many Breaks	Incomplete Representative	IC Rep
Many Breaks	Small Chips Lost IC non Rep.	SCL IC Non Rep
Many Breaks	Incomplete Non Representative	IC Non Rep
Faulted	Incomplete Non Representative	IC Non Rep
Faulted	Incomplete Non Representative	IC Non Rep
Sheared	Incomplete Non Representative	IC Non Rep
Sheared	Incomplete Non Representative	IC Non Rep
Intruded by Dyke	Incomplete Non Representative	IC Non Rep
Intruded by Dyke	Incomplete Representative	IC Rep

Sample preparation for laboratory

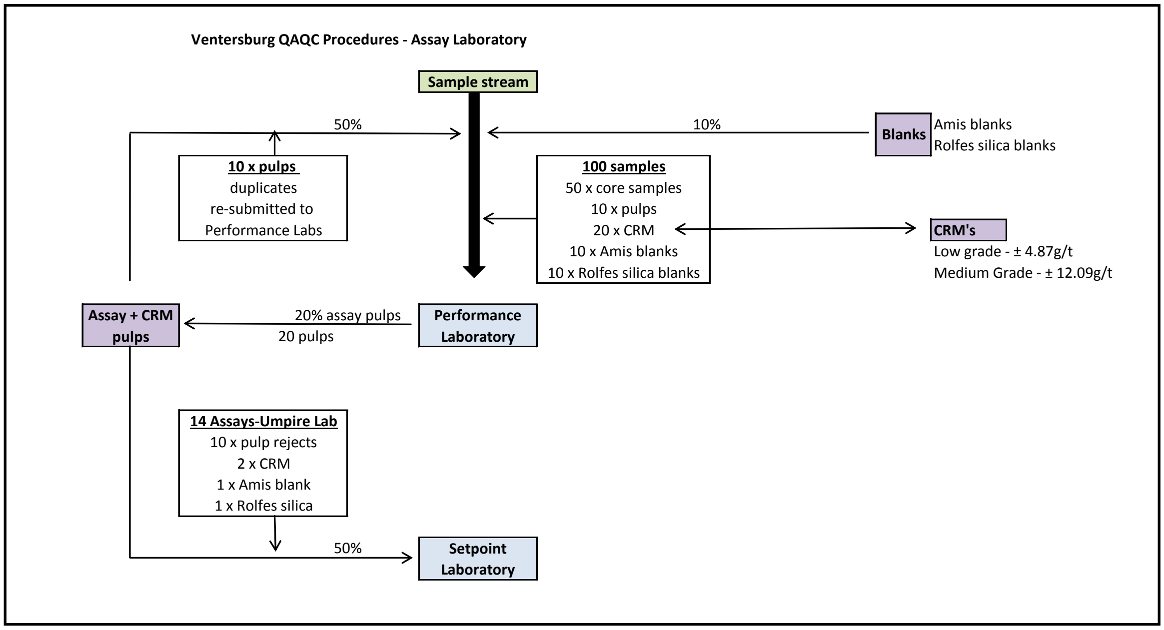
Each sample half of the core is placed in a plastic sample bag with a sample number. The sample ticket is placed in the top of the bag which is then double folded and stapled closed so that nothing can be placed in or removed from the bag without damaging it. Samples are numbered in sequence with certified reference material or CRM's included in certain intervals according to the Quality Assurance and Quality Control (QA/QC) process. All the samples are weighed which helps to calculate losses before and after analyses to make sure that a good representation of each sample is analysed.

A covering letter (assay request / sample to lab sheet) in duplicate stating sample numbers, amount of samples and analytical work required must be sent with the samples to the laboratory. The assay request is to be signed by the geologist and laboratory staff. Samples to be transported in locked bin. A duplicate set of keys are kept at the Ventersburg exploration office and also at Performance Labs.

Sample QA/QC Procedures

Diagram 2 is a flow chart of the QA/QC process followed during exploration sampling by Gold One.

- The Main sample stream will have a 20% to 30% certified reference material (CRM's) inserted in random places. Values of the CRM's should be across the range of values expected in the drill core samples submitted. The laboratory does not know the value of these samples.
- After analyses is received back from the main laboratory, 20% of the pulps are sent back to be re-assayed. Half of these are sent back to the main laboratory with new sample numbers and half is sent to another laboratory. New CRM's are included in the batches.
- The sample pulps sent back to the laboratories must first undergo particle size analyses and the results should be more than 90% of each sample must be less than 75µm. The next step is to mill al the pulps again to make sure all of them comply with the 90% less 75µm rule.



Flow chart showing the QA/QC process.

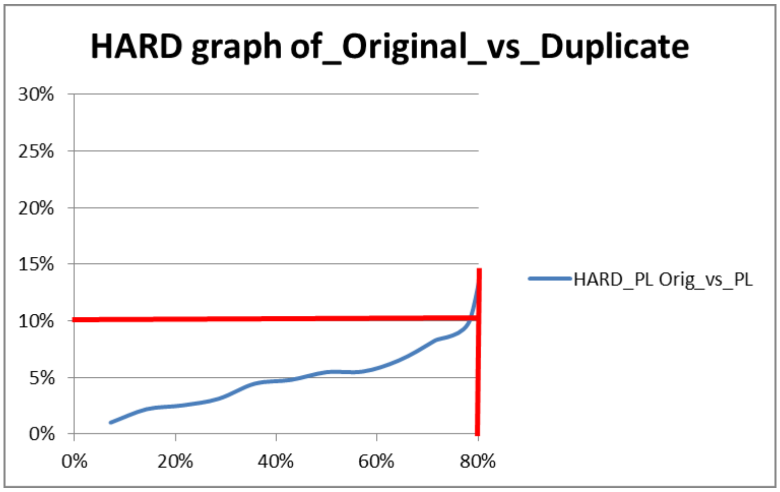
QAQC Control Charts

All CRM's are compared against their certified value and displayed on control charts. The CRM's were analysed by a large number of laboratories and the acceptable standard deviation is supplied with each group of CRM's. Results plotted on control charts from routine sample analyses gives immediate and continuous assessment of the reliability of the analyst and analytical methods used. Results must be within the following parameters to either "Pass" or "Fail". If the samples fail immediate action must be taken, the lab queried and assayed in duplicate to make sure any inaccurate values are corrected.

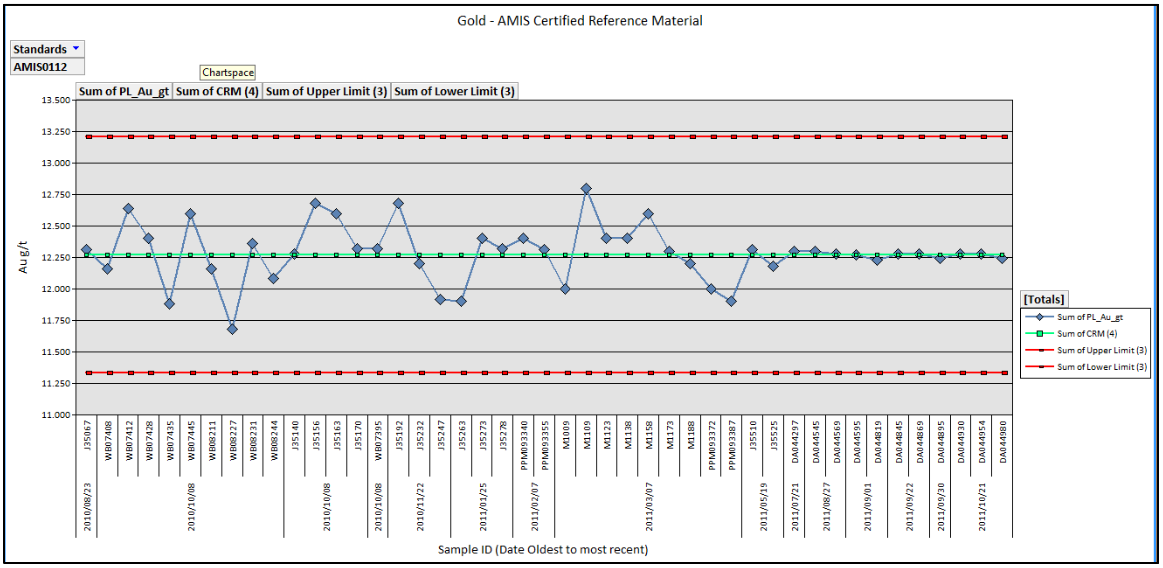
a) Precision and Accuracy

This is the reproducibility of the results. One method to check this is by inserting CRM's in the main sample stream and plotting graphs to check the deviation from the experimental value. If points fall outside the two standard deviation warning lines occasionally it can be tolerated. But if it happens during a small time span or fall on one side of the zero line the analyses is suspect. Outside the three standard deviation "Action" lines, immediate steps must be taken. If sample results fall within the two standard deviation lines then it is accurate. If points fall predominantly on one side of the zero line it indicates an analytical bias. Points outside the three standard deviation lines call for immediate action for example re-analysing any inaccurate sample batch.

The second method to check the precision and accuracy is by submitting duplicate samples to the same and umpire laboratories. Original sample pulps are re-numbered and send for duplicate analyses, thus the laboratory knows they have already analysed the samples but they will not know the results. The values are then placed on a hard graph which measures the difference between individual results as well as number of results in a population which falls outside an acceptable deviation. Ideally 90% of the results should differ with less than 10% but because of different factors, for example the nugget effect in gold ore and also the exact same conditions cannot always be 100% achieved. In an ideal world all factors should be kept the same but realistically this is not possible. As a rule if duplicate sample analyses differ with more than 10% from the original value those samples must be sent back to the lab for repeat check, the sample pulp must be homogenised before repeat analyses carried out (Lenahan, W.C.; Murray-Smith, R. de L., 1986).



Example of a precision control chart, 90% of the values should ideally have a difference of less than 10%.



Shows an example of an accuracy control chart of a number of samples over a period of time.

The SAMREC code

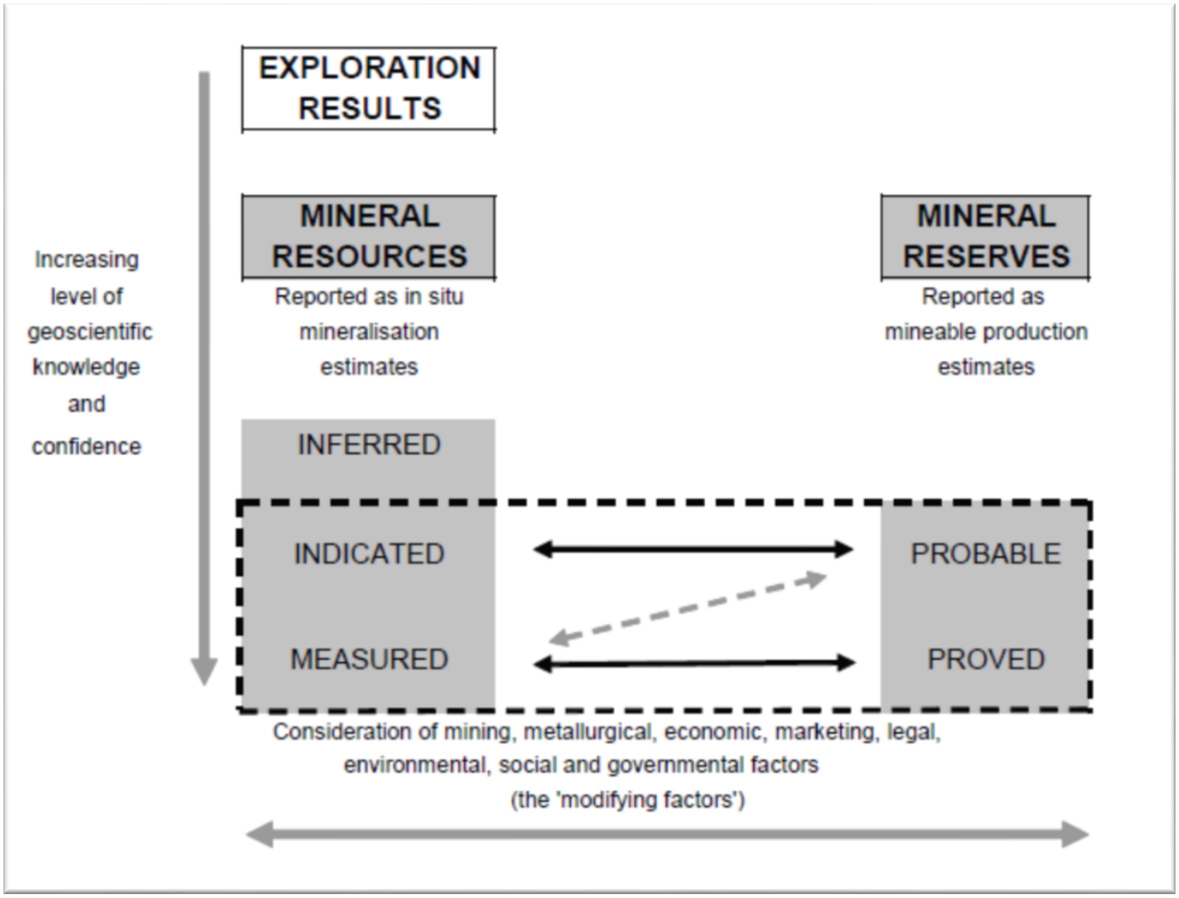
The SAMREC Code states the following for reporting terminology and classification:

A 'Mineral Resource' is a concentration or occurrence of material of economic interest in or on the earth's crust in such form, quality and quantity that there are reasonable and realistic prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a Mineral Resource are known, or estimated from specific geological evidence, sampling and knowledge interpreted from an appropriately constrained and portrayed geological model. Mineral Resources are subdivided and must be so reported, in order of increasing confidence in respect of geoscientific evidence, into Inferred, Indicated and Measured categories.

A 'Measured Mineral Resource' is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. It is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are spaced closely enough to confirm geological and grade continuity.

An 'Indicated Mineral Resource' is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed.

An 'Inferred Mineral Resource' is that part of a Mineral Resource for which volume and/or tonnage, grade and mineral content can be estimated with a low level of confidence. It is Inferred from geological evidence and sampling and assumed but not verified geologically and/or through analyses of grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes that may be limited in scope or of uncertain quality and reliability.



Reporting terminology and the relationship between Exploration Results, Mineral Resources and Mineral Reserves (The SAMREC Code, 2006).