

3. GEOLOGY

3.1 Introduction

This section describes the geology of the Material Properties and Exploration Properties. For each Mining Asset the nature and geometry of the orebodies being, or planned to be mined, their structural complexity and the variability of their commodity grades or qualities is discussed. In addition to this, for each Mining Asset, a brief description of the geological potential is presented. This section also describes the technical status and geological potential of the Exploration Properties.

Detailed plans are available for inspection at various operating offices of Exxaro where they remain due to the fact that many are working plans required for the continual management of the respective operations. On request, copies of specific information will be made available at Kumba Limited, Roger Dyason Road, Pretoria West, 0001, Pretoria, Gauteng Province, Republic of South Africa.

3.2 Iron Ore

3.2.1 Sishen Mine

The iron ore deposit at Sishen Mine is one of a number of genetically related high-grade haematite deposits situated in the Sishen – Postmasburg area. Superior-type banded iron formations ("BIF") of the Transvaal Supergroup crop out along the western margin of the Kaapvaal craton in the Northern Cape Province. These iron formations can be traced as a prominent range of hills in a broken arc for some 400km from Pomfret in the north, to Prieska in the south. The bulk of the hematite mineralisation is found in the vicinity of Postmasburg and Sishen Mine. Within this sub-region, iron ore and associated lithologies of the Transvaal and Olifantshoek Supergroups crop out intermittently along an arcuate belt for 60km.

The outcrops define a regional anticlinal structure known as the Maremane anticline. Sishen Mine is located at the northern end of the anticline. At this locality, the bulk of the hematite ores is buried beneath younger cover lithologies.

The Transvaal Supergroup lithologies were deposited in an extensive epeiric sea on the central part of the Kaapvaal Craton. The strata developed within two related basins of which the westernmost (the Griqualand West basin) is preserved in the Northern Cape Province. The Transvaal Supergroup, as preserved within the Griqualand West basin, comprises an extensive, basal carbonate platform sequence (the Campbell Rand Subgroup) conformably overlain by iron-formations of the Asbestos Hills Subgroup. South of Postmasburg, the BIF of the Asbestos Hills Subgroup are in turn overlain by a mixed chemical and clastic unit termed the Koegas Subgroup. The Koegas Subgroup is conformably overlain by diamictite of the Makganyene Formation upon which lavas belonging to the Ongeluk Formation have been subaqueously extruded. North of the Sishen Mine area, the Ongeluk lava is in turn conformably overlain by BIF with interbedded manganese (Hotazel Formation) and carbonates of the Moidraai Formation. The latter formations constitute the Vöelwater Group. At the Sishen Mine deposit, the upper parts of the Asbestos Hills Subgroup have been ferruginized to ore grade. These stratiform, laminated and massive ores constitute the bulk of the resource. They are unconformably overlain by a thick package of sedimentary rocks (conglomerates, shales, flagstone and quartzite) termed the Gamagara Subgroup. At Sishen Mine, diamictite of the Makganyene Formation and lavas of the Ongeluk Formation have been thrust over the sedimentary rocks of the Gamagara Subgroup. The diamictite and lava have been eroded by later events. Tillite of the Dywka Group and pebble beds, clay and calcrete of the Kalahari Group, have been deposited on these erosional unconformities.

Sishen Mine is situated on the northern extremity of the Maremane anticline. At this location the lithologies strike north-south and plunge from the centre of the anticline in a northerly direction. The bulk of the resource comprises high-grade, laminated and massive ores belonging to the Asbestos Hills Subgroup. These ores are truncated by an erosion surface upon which lower-grade conglomeratic ores and sedimentary rocks of the Gamagara Subgroup have been deposited. The orebodies are intensely folded and faulted. Dips vary according to local structures but at Sishen Mine a regional dip of 11° in a northwesterly direction prevails. Continuous, alternating basin and dome structures occur at Sishen Mine mine. These interference folds are further modified by normal faulting and low-angle thrusts. Ore bodies are best preserved in basinal and pseudo-graben type structures. The anticlinal structures normally comprise barren footwall lithologies. Highly deformed, isolated orebodies occur close to the Maremane anticline. The orebodies tend to be less deformed and more continuous, the further they are situated from the anticline. Hangingwall lithologies also thicken down plunge.

The carbonates of the Campbell Rand Subgroup are separated from the overlying BIF of the Asbestos Hills Subgroup, by a siliceous, residual breccia. This breccia is known locally as the Wolhaarkop Breccia and is developed on an irregular, karst surface. The BIF's of the Asbestos Hills Subgroup are characteristically

fractured and brecciated, especially near the contact with the Wolhaarkop breccia. Both upper and lower contacts are erosion surfaces and together with the lack of easily identifiable marker horizons, make correlation of individual beds virtually impossible. A highly altered, slickensided, intrusive sill is commonly found separating the BIF from the overlying laminated ore. At Sishen Mine it is generally less than 2m thick. The sill is invariably folded into the basinal geometry and only rarely crosscuts (intrudes) the ore bodies. The laminated and massive ores are commonly folded and faulted into basinal and pseudo-graben structures. Deep palaeosinkholes, filled with brecciated ore and Gamagara sedimentary rocks are found on the southern parts of the Sishen Mine properties. The sinkholes are restricted to antiformal structures close to the Maremane Dome on the southern portions of the mine. They are an important mechanism for preserving collapse breccia ore.

Sedimentary rocks of the Gamagara Subgroup, overlie the laminated, massive and breccia ores. Conglomerates of ore grade with well-rounded clasts and fine-grained, well-sorted, gritty ores are common at Sishen Mine. Partly ferruginized shales, interbedded with ore conglomerates and thick flagstones are also a feature of the Gamagara Subgroup. Along the western margin of Sishen Mine, Makganyene diamictite and lavas of the Ongeluk Formation have been thrust over the sediments of the Gamagara Subgroup. A few thin, diabase dykes with north south and northeast orientations, have intruded the stratigraphic sequence. They form impervious barriers and compartmentalise the groundwater. A buried glacial valley, filled with Dwyka tillite and mudstones has been identified with reconnaissance drilling. The valley is located between the mine and Kathu. It has a north-south orientation that changes to northwest between Dibeng and the mine. The valley does not fall within the planned open pit. The Kalahari Group comprises boulder beds, clays, calcrete, dolocrete and windblown sands. The Kalahari Group is developed to a maximum thickness of 60m. The clay beds at Sishen Mine can attain a thickness of up to 30m on the northern parts of the deposit. The Kalahari beds of calcrete, limestone and clay and quaternary sand and detritus, blanket more than 90% of the Sishen Mine mining area. Only scattered outcrops of iron ore and banded iron ore formation, on the south-eastern parts of the Kumba properties, and quartzite further west, crop out on the surface.

Table 3.1 Sishen Mine: Typical In-situ Grades

Ore type	%	Fe	SiO ₂	Al ₂ O ₃	K ₂ O	P
Conglomeratic and grit	18	62.2	5.3	2.9	0.28	0.055
Breccia	8	63.4	3.9	2.0	0.39	0.078
Massive	20	65.2	3.0	1.4	0.14	0.044
Laminated	54	66.3	2.4	0.8	0.07	0.056

The ores at Sishen Mine are composed of hematite and specular hematite with minor to trace amounts of limonite. Four distinct ore types can be classified (Table 3.1). Each has unique chemical, physical and metallurgical properties. The genesis of each ore type has been influenced by regional tectonism and the preservation of each orebody is primarily determined by local geological structures. The Laminated and Massive Ore are the most important sources of high grade, lump ore in the region. The upper portions of the Asbestos Hills Subgroup comprise fairly undisturbed, thinly laminated, hematite ore which grades upward into thickly bedded, contorted and even massive ores. Breccia ores comprise a chaotic arrangement of very angular and poorly sorted fragments of laminated and massive ore types, cemented by specular hematite. The breccias fill palaeosinkholes developed in the carbonates of the Campbellrand Subgroup. Angular fragments of BIF and some argillitic material are also found in the collapse breccia. Specularite is very common in the porous breccia matrix.

Conglomeratic ore belonging to the Gamagara Subgroup is preserved along the north, western and southern flanks of the Maremane anticline. At Sishen Mine, the conglomeratic beds occur within basinal and synclinal structures and also on the western side of major fault planes. The conglomeratic ores are invariably situated adjacent to, or are in close proximity to, laminated and massive ore bodies.

3.2.2 Sishen South Project Phase I and Phase II

Iron ore at the Sishen South Project is preserved in chemical and clastic sediments of the Proterozoic Transvaal Supergroup. These sediments define the western margin of the Kaapvaal Craton in the Northern Cape Province. The stratigraphy was deformed by thrusting from the west and has undergone extensive karstification. The thrusting produced a series of open, north-south plunging anticlines, synclines and grabens. Karstification was responsible for the development of deep sinkholes in the dolomite, within which the iron ore at Sishen South Project has been preserved from erosion. These structures are therefore extremely important targets in the prospecting process.

Almost 80% of the Sishen South Project area is covered by sand, dolocrete and calcrete of the Kalahari Group. Outcrops of the Campbell Rand Subgroup and Kuruman Formation are found on the western portion

of the prospecting area and banded iron formation of the Asbestos Hills Subgroup occur along the extreme eastern margin. Geophysical surveys and borehole drilling have established the presence of a number of covered deposits in the central and eastern parts of the prospecting area.

The only outcrops of iron ore at the Sishen South Project strike northeast-southwest across the western portion of Welgevonden 486 and Kapsteveld 451. These outcrops form part of the eastern limb of an anticlinal structure. The iron ore comprises laminated and conglomeratic types and crops out as thin, lenticular bodies that dip between 40° and 50° to the east. At depth, shale, quartzite, conglomerate and lava overlie this ore. Four distinct iron ore types have been described at Sishen South Project, with most of the ores being similar (slightly different chemistry) to those found at Sishen Mine. Sishen South Project comprises clastic-textured (28.8% of total), laminated (52.9% of total), collapse breccia (9.8% of total) and conglomeratic (8.6% of total) ores. The synclines generally preserve laminated, clastic-textured and conglomeratic ores, whereas conglomeratic ore is often preserved within the grabens. Both conglomeratic and collapse breccia ore types are found in the sinkholes. Typical hanging-wall lithologies are conglomerate, shale, quartzite, tillite, clay and calcrete, although each geological structure contains a unique combination of ore types and waste lithologies. The ore minerals at the Sishen South Project are hematite and minor specularite. Mineralogically the iron ore comprises clasts that may be both massive and featureless, or porous and distinctly laminated. The matrix comprises mostly intergrown clay minerals, together with numerous small clasts and flakes of hematite entrained in the silicate gangue material. Clasts of massive hematite are characteristically non-porous or with only low levels of porosity, and as such, there is minimal clayey gangue material incorporated into the clasts. Clasts of finely laminated ore typically contain above average levels of initial porosity, with gangue minerals often infilling or partially infilling pore space. Small amounts of specularite are often associated with this type of clast. Clay-rich clast commonly appear to have been affected by secondary ferruginisation.

3.2.3 Thabazimbi Mine

Iron ore is defined as comprising iron-rich rock characterised by an iron content exceeding 60% by weight and containing less than 15% by weight of SiO₂. Low grade iron ore is defined as having an iron content between 55%Fe and 66%Fe.

The iron ore deposits at Thabazimbi Mine are hosted within the lower parts of the Penge Formation, which is the uppermost formation of the Chuniespoort Group within the Transvaal Supergroup. The base of the Penge Formation consists of chert-rich shale unit that averages 10m in thickness. This shale member is overlain by 300m to 400m of ferruginous sediments, consisting of thick autochthonous banded iron formation interlaminated with thin units of orthochemical iron-formation. The iron-ore bodies are typically located within the basal 50m to 80m of the Penge Formation within iron-oxide dominated rhythmites. Iron ore bodies are laterally discontinuous bodies that pinch out along strike and down-dip. The ore thickness ranges from 2m to in excess of 100m; the average mineralised thickness is approximately 20m. Rocks of the Transvaal Supergroup within the Thabazimbi Mine area strike east-northeast and dip to the south at angles between 45° and 60°. The Penge Formation crops out in three easterly trending belts reflective of thrust-related duplication of the Transvaal Supergroup associated with Waterberg-age tectonism. The three belts are referred to as the Northern Range, the Central Range and the Southern Range; weathering and erosion has resulted in these three belts having prominent topographic expression.

The Thabazimbi Mine iron ore deposits are considered to be the result of initial iron deposition during primary chemical sedimentation at the top of the dolomite-dominated Chuniespoort Group, giving rise to a thick zone of banded-iron-formation. Subsequent metamorphism and supergene processes have occurred and have resulted in local chemical modification of the rocks resulting in the formation of high-grade hematite rock within localised ore-bodies. Joint systems developed with the ores are also identified within the adjacent host lithologies; in addition, there is a strong spatial association between the presence of ores and faulting and brecciation of the lower Penge Formation. Ores grade laterally into banded-iron-formation with an increase in SiO₂ and Al₂O₃ content. Geochemical considerations suggest that the ores are a result of ferruginisation, in which chert, talc and carbonates within the primary banded iron-formation lithologies were selectively replaced by hematite or martite/goethite. Minimal instances of silicification have been identified within the Thabazimbi Mine ores suggesting that SiO₂ dissolved within the ore zones was not reprecipitated, but was removed by mobile solutions. Formation of the high-grade ores resulted from the selective removal of goethite, resulting in porous hematite rich ores.

Karstification within the underlying Frisco Formation results in slumping of the Penge Formation into these features. These structures are commonly associated with an increase in iron content with depth, which is suggestive of a second stage of ferruginisation of already Fe-enriched lithologies. Gravitational collapse of iron-formation and iron-ore units into solution-cavities within the underlying Frisco Formation dolomites resulted in brecciation and fragmentation of the iron ore units and increased permeability that was subjected to a further stage of epigenetic ferruginisation by cooler groundwater circulating within the zones of enhanced permeability. Further epigenetic ferruginisation is evident around post-Karoo faults that transect the iron ore bodies.

Post-Karoo dolerite dykes transect the deformed Penge Formation lithologies and also displace ore bodies, as well as bounding ore zones in some of the deposits. In addition, the Pretoria Group unconformably overlies the Penge Formation, yet basal conglomerates of the Pretoria group contain no clasts of high-grade hematite implying that these rocks had not formed at the time of deposition of the Pretoria Group (± 2.2 Ga). There have been two major metamorphic events over the Transvaal Supergroup lithologies at Thabazimbi Mine: the first event was the Bushveld contact metamorphism (± 2.05 Ga), followed by dynamic metamorphism resulting from Waterberg tectonism.

The main ore deposits are hosted within the Northern Range and are referred to as the Kwaggashoek-East (Kwaggashoek 345KQ), East-Mine (Wachteenbietjiesdraai 350KQ and Kwaggashoek 345KQ), Donkerpoort (straddling Donkerpoort344KQ and Wachteenbietjiesdraai 350KQ) and Donkerpoort-West deposits (Donkerpoort 344KQ). These deposits share similar lithological, mineralogical and geochemical characteristics and cover a total strike length of approximately 11km. Iron ore mineralisation within the Southern Range is more sporadically distributed, when compared to the Northern Range; mineralisation is present over a strike length of approximately 5km. Mineralisation is most specifically present on Wachteenbietjiesdraai 350KQ, Buffelshoek 351KQ and Groenfontein 352KQ. Mineralisation within the Central Range has only been located on Kwaggashoek 345KQ.

Within the Northern Range, a diabase sill occurs within the iron formations of the Penge Formation approximately 90m above the basal contact of this formation with the underlying Chuniespoort Group Dolomite. The iron ore bodies are located within the basal portions of the Penge Formation.

The iron ore bodies of the Northern Range, as defined by a Fe cut-off grade of 55%, are characterised by irregular, tabular morphologies. The iron ore is commonly present, with the footwall contact of the orebody coincident with the basal shale unit of the Penge Formation. The iron ore frequently displays brecciated textures, with fragments of hematite contained in a secondary hematite matrix. Lenses of iron formation may be identified within the iron ore bodies, and locally shale may also be included within the iron ore. Thicknesses of orebodies in the Northern Range are typically in the range 15m – 30m. The iron ores near surface consist of hard, compact massive hematite rock. Down-dip, the rock textures change gradually towards more friable forms which grade into talc-hematite and calcite-hematite rocks.

Iron ore bodies within the Southern Range occur distributed within the banded iron formation and are generally significantly smaller and less laterally continuous than those of the Northern Range. The Southern Range deposits include Buffelshoek East and Buffelshoek West, Bobbejaanwater and the Meyer and Kumba Mines. The western block of Buffelshoek West comprises thick iron-ore mineralization (30m), which terminates against a diabase dyke. Structural complexities within this deposit are recognised, but have not been fully resolved. Iron ore mineralization at the Bobbejaanwater deposit consists of irregular lenses of hematite rock in shales and banded iron formations. The mineralisation consists of fine-grained hematite that yields a high proportion of fines when mined; only a small proportion of the orebody can be beneficiated and yields a minor component of lump ore.

The Thabazimbi Mine iron ore deposits are dominated by hematite as the major iron oxide mineral present. The high grade ores consist predominantly of hematite with variable textures, accompanied by minor silicate minerals. With depth, the hematite rock grades into talc-hematite rock and calcite-hematite rock. Goethite and limonite are also present within the ore and low-grade ores at Thabazimbi Mine.

3.3 Coal

3.3.1 South African Coalfields

The South African Coaliferous horizons are contained within the late Carboniferous and early Permian Eras. The sediments of this period of the Karoo Sequence are composed of primarily argillaceous and mildly arenaceous sediments that cover, with facies changes towards the distal regions of the basin, the bulk of the Southern African sub-Continent. They are related to the formation of the geosynclinal basin during the Cape Orogeny. Three major depositional regions can be identified within the basin that all have a direct relationship to the deposits being mined or explored by Kumba. They are the Cratonic Paralic basin environment of the Witbank Coalfields, The Cratonic Limnic basin of the Waterberg Coalfield and the Mobile Belt Limnic basin of the Soutpansberg Coalfield.

In general the coal bearing horizons represent the formation of peat accumulations that cap broad scale subsidence and infill of the geosynclinal basin at discrete intervals during the evolution of the Karoo Sequence. The formation of the coals are directly related to the climatic conditions that were prevalent at the time of deposition as the climate was progressing from a glacial through fluvio-glacial and deltaic to fluvial regimes. Peat accumulation and therefore coal formation was directly related to the amount of water available and the slopes of the sediment infill. Although coal was initially mined in the Natal Coalfields for energy generation, in general the exploration and extraction of coal was driven by the need for an energy source to

enable deeper level extraction of gold in the Witwatersrand. The primary large-scale coal mining occurred in the Vereeniging area and in the Brakpan/Springs region. Coal production has increased in South Africa from 0.7Mt in the period 1890 – 1894 through to 223.6Mt in 2002 (Minerals Bureau) with a total production of some 6.245Bt until 2002.

As the need increased so the coal exploration extended further east to the Witbank Coalfields and north to the Waterberg and Soutpansberg Coalfields. Mining originally was restricted to internal consumption for steam generation, however with the development of beneficiation techniques and the formation of local steel production the search for coking coal and export of coal to other parts of the world increased coal production to the high of 225Mt p.a. in 2000.

3.3.2 Waterberg Coalfield

The Waterberg Coalfield is situated some 400kms north west of Johannesburg. Water drilling in the 1920s indicated the presence of a large amount of coal bearing strata in the area. CSO exploration was initially undertaken in 1955 in a joint program by both Iscor and Sasol with Iscor (Kumba) opening Grootegeluk Mine in 1980. This basin is a fault bounded basin with dimensions of approximately 90kms EW x 40kms NS. The faulting plays a distinct role in the preservation and depositional characteristics of the coal occurrences in the region. The two major boundary faults are the Zoetfontein in the north and the Eenzaamheid fault in the south. The presence of post-Karoo faulting has resulted in various portions of the stratigraphy having been preserved. The current weathering surface has a major impact on the relative proportion of the stratigraphy preserved. The major formations of the Karoo Sequence are present within the Waterberg basin but with significant differences in the lithologies and are with the exception of the Lower Ecca all significantly thinner representing much slower rates of subsidence than those encountered in the main Karoo Basin with the progression from glacial through to aeolian and flood basalts being broadly represented.

The major coal bearing horizons of the Ecca Group are the Volksrust Formation (55m of intercalated mudstones and coal) and the Vryheid Formation (three major discrete Seams of approx 3m, 9m and 4m, respectively). The most significant difference to the main Karoo Basin is the fact that the Volksrust Formation is carbonaceous with this formation being represented by intercalated carbonaceous shales and coal. The vitrinite content of the coal plies to the top of the Volksrust Formation result in the upper Zones having a semi-soft coking coal yield as well as coal for thermal use. While the remainder of the Volksrust Formation yields low grade thermal coal for power station consumption. The Vryheid Formation coal Seams are composed of predominantly dull coal with minor carbonaceous mudstone intercalations again supplied as thermal coals. The Volksrust Formation coals are classified as a thick interbedded Seam deposit type and the Vryheid Formation as a multiple Seam deposit type.

- Grootegeluk Mine (six farms) occurs within the Waterberg Coalfield

Grootegeluk Mine is situated some 17kms to the west of Lephalale in the Limpopo Province. Kumba has developed a system of nomenclature that reflects the cyclical nature of the peat formation within the two Formations of the Ecca Group. Kumba has substituted the names zone and sample as opposed to Seam and ply. This has been accepted by the Coal sub-committee of SAMREC. In this regard Kumba has defined 12 major zones to represent all the coal bearing lithologies numbered from 11 at top in the full succession area and number 1 being the deepest, and zone 4 having been sub-divided. The company also takes pre-defined samples from within these zones that are determined by a specific configuration of shale and coal and the system has been rigorously applied over time with only minor evolutionary changes to the principle. The total thickness of the coal measures is in the order of 120m. The general dip of the strata is in the order of 2° to 4° to the southeast.

The Volksrust Formation from the top of Zone 4 through to zone 11 is characterised by an increasing ratio of bright coal to dull coal and the proportion of semi-soft coking coal is greater in zones 6 to 11. The Volksrust zones typically start with bright coal at the base and the ratio of coal:shale decreases from the base of the zone in an upward direction. The basal zone (zone 5) is the exception because the coal is more evenly distributed throughout the zone.

The Vryheid Formation (±55m thick), forms the lower part of the coal deposit and consists of carbonaceous shale and sandstone with five dull coal Seams varying in thickness between 1.5m to 9.0m.

These five coal Seams or zones consist predominantly of dull coal with some bright coal developed at the base of zones 2, 3 and 4. Due to lateral facies changes and changes in the depositional environment, these zones are characterised by a large variation in thickness and quality.

Zone 3 is the best-developed dull coal zone within the mine lease area and reaches a maximum thickness of 8.9m. The basal portion yields a small fraction with semi-soft coking coal properties. Zone 2 is on average 4m thick and reaches a maximum thickness of 6m in the mine lease area. The basal portion also yields a fraction with semi-soft coking coal properties. Zone 1, the basal Vryheid coal zone, has an average thickness of 1.5m.

Of the major bounding faults of the Waterberg Basin, the only one that impacts on the resources at Grootegeluk Mine is the east-west striking Eenzaamheid Fault which forms the southern boundary of the mining lease area. There is however a relatively complex structural regime that is related to the pre, syn- and post-depositional faulting within the mine. The major structural discontinuities are therefore the Eenzaamheid in the south, and the Daarby fault also forming the north-eastern boundary of the resources. The Daarby fault (200m downthrown to the north) has a strike in the west of northwest to southeast with a major trend change as it approaches the Eenzaamheid fault to southwest to northeast. At the point of inflection of the fault strike there are a number of minor sympathetic fault structures that have had an influence on the post depositional attitude of the coal resource. However due to the mining method and the bulk nature of the deposit, the minor faulting results in minor losses that are accounted for in the geological loss factors applied. The increase in depth of weathering associated with such faulting does produce problems because of the clay (weathered shale and decomposed coal) remnants in such areas. A substantial area in the 40-year pit is affected by the depth of oxidation that extends into the coal of the Volksrust Formation and this also reflects the dip of the strata to the southeast.

3.3.3 Soutpansberg Coalfield

The Soutpansberg Coalfield is situated north of the Soutpansberg mountain range in the Limpopo Province (Figure 3.1). The Coalfield has a strike length of ± 190 km and extends from Waterpoort in the west to the Kruger National Park in the east.

The Karoo Sequence rocks in the Tshikondeni Mine area unconformably overlie rocks of the $\pm 1,750$ Ma Soutpansberg Group. The Soutpansberg Group is situated on the three-point coupling zone between the Limpopo mobile belt, the Sabi monocline and the Lebombo monocline.

The north-eastern margin of the Kaapvaal craton was down-faulted into a graben structure, in which this pre-Karoo Soutpansberg Group was deposited. This faulting, which controlled graben formation, continued during the deposition of the Karoo sediments and was reactivated in post-Karoo times, resulting in a very complex structural setting. Generally the Karoo Sequence rocks dip to the north at 3° to 20° and are almost always terminated against east/west trending strike faults on the northern margins. The Soutpansberg coal Seams are thick interbedded Seam coal and mudstones in the west and grade to a multiple Seam type consisting of two discrete Seams in the Tshikondeni area. The coal, where developed, is generally bright and high in vitrinite and the coal rank increases to the east.

In the Eastern area two major coal Seams are developed, the Main Coal Seam and the Lower Coal Seam, the Main Seam has been the only economic Seam due to its coking properties and medium phosphorous content. The lower coal Seam also has coking properties but the high phosphorus content is not acceptable to the steelworks.

- Tshikondeni Mine occurs within the Soutpansberg Coalfield

The mine is situated on the north eastern edge of the Soutpansberg Coalfield. The Karoo rocks in the Tshikondeni Mine mining area unconformably overlie rocks of the $\pm 1,750$ Ma Soutpansberg Group. The Soutpansberg Group is situated on the three-point coupling zone between the Limpopo mobile belt, the Sabi monocline and the Lebombo monocline. The north-eastern margin of the Kaapvaal craton was down-faulted into a graben structure, in which this pre-Karoo Soutpansberg Group was deposited. This faulting, which controlled graben formation, continued during the deposition of the Karoo sediments and was reactivated in post-Karoo times, resulting in a very complex structural setting (ex-Kumba Geology Department). Generally the Karoo Sequence rocks dip to the north at 3° to 20° and are almost always terminated against east/west trending strike faults on the northern margins.

Locally two major coal Seams are developed, the Main Coal Seam and the Lower Coal Seam, the Main Seam has been the only economic Seam due to its coking properties and medium phosphorous content. These coal Seams occur in the Madzaringwe Formation which is roughly correlatable to the Vryheid Formation. The Main Coal Seam is situated in the stratigraphic centre of the Formation and the Lower Coal Seam at the base. As is the Kumba standard in the Northern Limpopo Province specific samples are taken at specific stratigraphic intervals and a great emphasis is placed on the correlation of the individual samples. A selected mining horizon is determined at the boundaries of the samples 7B and 7C. The selected Seam thicknesses are generally in the order of 2.6 to 2.7m thick and consist of a very high vitrinite content of approximately 80% and a free swelling index of nine. Generally the coal qualities are consistent across the mine area.

Structurally the mine is very complex with faulting and intrusives having a significant impact on mining with both displacement and devolatilisation of the coal. Major faults in the area tend to be listric normal faults forming steps and grabens which delineate the different mining blocks. Intrusives occur in the form of dolerite dykes and sills with thicknesses of up to 15 – 30m, respectively. The intrusives result in a devolatilisation halo which is related to the thickness and/or dip of the intrusive.

The Mutale sill in the northern areas of the mining authorisation has devolatilised large areas of the coal as it closely follows the dip of the coal Seam. Strata control problems are encountered in close proximity to faults and dykes due to brecciation and fracturing.

The Lower Coal Seam is located at the base of the Madzaringwe Formation some 100m below the Main Seam. It has an average thickness of 2.5m and is characterised by lower vitrinite content (69%) and lower yields at a 16% ash. Recent investigations into the viability of mining this coal Seam are dependant on the ability to find a market that will accept coal with a medium to high phosphorous content. All exploration drilling has ceased at the mine and only in-fill structure drilling is done in areas of complex geology.

3.3.4 Witbank Coalfield

The Witbank Coalfield is a basin like feature that extends from Brakpan in the West through to Belfast in the East. The northern boundary is the sub-crop against the pre-Karoo basement rocks of predominantly the Waterberg sandstones and the south is a prominent pre-Karoo basement ridge called the Smithfield ridge. The basin was formed in the shallow cratonic paralic environment with slow but consistent subsidence during the late Carboniferous and early Permian. This basin was first exploited before the beginning of the 20th Century in the Brakpan (Apex Mines region) and has been the focus of concerted exploration and exploitation since. The basin is the type area for the multiple Seam deposit type with the development of five major Seam horizons which may in places be composite Seams. The major controls on the development of the coal are proximity to undulations of the "basement" topography, through erosion channeling and sediment influx into swamp beds and finally erosion of the current erosion surface. The primarily economic coal Seams have been the No. 2 Seam, The No. 4 and No. 4 Lower Seam and in places the No. 5 Seam. Structurally the coal horizons are undeformed with each displaying a very slight dip to the south east of less than a degree and minor discrete faulting events that have a southwest to northeast trend of graben features and other minor faulting events. The most distinctive post-depositional feature is the intrusion of dolerites related to the Lesotho Basalts that have resulted in a variety of sills and dykes of various ages. The most prominent of the dykes in the area is the Ogies dyke a 12 to 20m thick essentially vertical intrusion with an east-west strike. The No. 4 Dolerite sill, a 20 to 70m thick multiple flow event, has a preferential intrusion horizon above the No. 5 coal Seam, but in places it transgresses through the coal bearing strata to the pre-Karoo basement and forms in other places a barrier to erosion. The large amount of exploitation in the region has resulted in the development of an efficient coal transportation infrastructure that is now resulting in previously uneconomic coal Seams such as the No. 1 and No. 2 Lower coal Seams becoming economic propositions.

Operations and Projects within the Witbank Coalfield include:

- Leeuwpan Mine

Leeuwpan Mine is situated on the western edge of the Witbank Coalfield. The mine is unique in this area as it is located in the region of the Palaeo-outcrop of the Malmani dolomites of the Transvaal Sequence. This has resulted in a Palaeo-karst topography on which the Karoo Sequence sediments were deposited. Thus the primary control on the development of the peat was this highly variable topographic surface. The Karoo Sequence in the area is represented by the Dwyka Formation and the Middle Ecca with little or no lower Ecca Development. The Middle Ecca sequence of coal horizons interbedded with sediments is highly truncated with limited sediment deposition between the major peat development events. This resulted in a very sheltered environment in which the peat accumulated but with highly variable coal thicknesses due to the irregular floor topography. Subsequent intrusion of the No. 4 Dolerite Sill very close to the pre-Karoo contact has resulted in large areas of the Bottom Coal being devolatilised although this has not resulted, in the majority of the resource areas, in a physical burning of the coal. Associated with the sill are a number of thin dolerite dyke like structures that crosscut the stratigraphy.

The dolerite sill appears to break through the coal horizons to the south of the Mining Authorisation area and this is supported by information from the other mines in the region. In general the dolerite sill appears to have a thickness of 10 to 20m. The coal measures are approximately 16m thick and are divided on site into a Bottom Coal Seam (± 8 m thick, max 20m) and a Top Coal Zone (± 8 m thick, max 17m). The Bottom Coal Seam is correlated with No. 2 Seam of the Witbank Coalfield (Snyman 1998) and is a lower ash higher yield coal with higher vitrinite contents towards the base. The Top Coal Zone can be correlated with the No. 4 Lower Seam, No. 4 Upper Seam and No. 5 Seam of the Witbank Coalfield and tends to be a higher ash content lower yield coal, but substantially higher in volatile content. The Seam has a vitrinite band close to the top of the Seam in a layer that is higher in sulphur. In the Top Coal sequence a number of correlateable partings are encountered at specific levels, although they are not always developed (ex-Kumba). The lowermost shale parting is named the "O" parting and the upper the "X" parting. The identified coal resource blocks in the area have been well-delineated.

- Arnot Colliery

The Arnot Colliery coal Seams occur within Karoo-aged strata of the Karoo Supergroup, comprising, in this area, the basal Dwyka Group, conformably overlain by the Vryheid Formation of the Ecca Group. Sediments of the Karoo Supergroup were deposited unconformably over an undulating pre-Karoo basement. The pre-Karoo consists of both felsite and diabase intrusives associated with the Transvaal Supergroup and the Bushveld Igneous Complex, respectively. The felsites are pink, finely crystalline and occur in isolated patches. The diabase is greyish-green, medium to coarse crystalline and occurs over most of the area as “dyke” and “plug” like bodies. The top of the pre-Karoo is undulating forming palaeo-valleys and palaeo-highs and a gentle regional dip from the northeast to southwest is noted. The Dwyka Group is a conglomerate with the matrix ranging from sandstone to shale. The clasts are generally of pre-Karoo origin with sizes ranging from angular fragments to boulders. The Dwyka Group attains a maximum thickness of 2m and is generally absent over palaeo-highs. The Vryheid Formation consists of a number of depositional sequences (culminating in a Peat formation) and is overlain by a number of transgressive events. The Vryheid Formation conformably overlies the Dwyka Group, with the conglomerates grading into a gritty sandstone and minor shale lenses capped by the No. 1 Seam. The depth to the top of the No. 2 Seam depends largely on local surface topography and reaches a maximum depth of 80m along the eastern boundary of the lease area. Incision by the Klein Olifants River and associated tributaries has eroded significant areas of the original extent of the upper coal Seams. In general, the No. 2 Seam sub-outcrops along all the deeply incised valleys. The depth to the top of coal in the sub-outcrop areas is typically 10 metres, but varies between 4m and 20m in depth. In the topographically elevated areas the No. 5 Seam and No. 4 Seam are present some 30m above the No. 2 Seam. The No. 1 Seam is generally 1.1m thick and consists of a hard, good quality mixed bright and dull banded coal with an average calorific value of 25MJ/kg to 29 MJ/kg (dry contaminated). The P1 Parting between the No. 2 Lower Seam and the No. 1 Seam consists of a shale unit between 0.7m and 1.5m in thickness, increasing up to 5m on the fringes of the No. 1 Seam outcrop area. The No. 1 Seam is consistently developed in the western half of the Arnot Coalfield whilst in the eastern portion only occurs as isolated patches.

The No. 2 Seam is continuous across the Arnot Mining Authorisation area. The Seam has been subdivided into the S2L, S2U and S2A Seams by a number of internal partings termed P2 and P3, respectively. The No. 2 Lower Seam varies from less than 1.0m to 4.5m in thickness, with an average of 3.1m. The No. 2 Lower Seam constitutes more than two-thirds of the coal reserves in the Arnot area. The No. 2 Lower Seam consists of hard, dull to lustrous coal with several bright coal bands and occasional stone partings. The average calorific value of the No. 2 Lower Seam varies between 22 MJ/kg and 26 MJ/kg (dry contaminated). The No. 2 Lower Seam is often split into two different sub-Seams, the No. 2 Lower Upper Seam and the No. 2 Lower Lower Seam. The PL Parting between these two sub-Seams consists of siltstone and shale and is typically 1.0m in thickness. In the underground mining area the PL Parting delineates the extent of the mining operations where the parting thickness exceeds 0.3m.

The No. 4 Seam occurs erratically across the lease area with an average thickness of 0.4m. The Seam is often split by internal clastic partings into S4L and S4U Seams. The No. 4 Seam is overlain by interlaminated units of siltstone and shale with the No. 5 Seam sporadically developed in areas.

A limited number of dolerite dykes are known to have intruded the Karoo sediments in the area, with only six dykes having been intersected in the U3 underground workings to date. Dykes lack magnetic signature and are not responsive to geophysical method of detection.

A well-developed dolerite sill is present some 15m to 20m above the No. 2 Lower Seam in the topographically elevated areas in the south-eastern portion of the Coalfield. This feature is 5 – 40 metres thick and has resulted in devolatilisation and minor reserve loss where volatiles <18%. Feeder dykes are expected to occur in the vicinity of the sill.

Faults with displacement in excess of 2.5m are rare and to date only six have been encountered in the underground mine. A high density of compactional structures (i.e. slips and faults) occur in zones adjacent to pre-Karoo highs. Similar features are observed on flanks of relatively large floor rolls, scour and dome structures.

- New Clydesdale Colliery

The coal succession occurs within the Permian-age Vryheid Formation of the Ecca Group, which overlies the Dwyka Group. The two stratigraphic units occur within the Karoo Supergroup. The sediments of the Karoo Supergroup were deposited on an irregular Pre-Karoo basement, which to some extent influenced the distribution of the overlying lithologies. The pre-Karoo basement rocks generally comprise gabbros, diabases and felsites associated with the Bushveld Igneous Complex. The generally flat-lying Vryheid formation sedimentary rocks consist of sandstones, thinly laminated siltstones and mudstones and coal Seams. The Sequence in the area consists of three well-developed Seams, i.e. the upper most No. 2 Seam, the No. 2A Seam and the basal No. 1 Seam. The coal reserves are limited mainly by the fluvial

system of the Olifants River and its tributaries. The No. 2 Seam has been further divided into an upper zone referred to as No. 2 Seam Top Coal and the lower zone No. 2 Seam Select. The overburden comprises massive sandstones with laminated mudstones closer to the top coal. The limit of weathering varies from 1.2m to 8m below surface.

Due to the erosive basal contact the No. 1 Seam has a varying thickness, from 1.05m to 4.57m, with an average of 2.90m. The upper 1.0m is typically a bright-banded coal with calcite cleats. The lower ± 2.0 m is a dull lustrous coal with mudstone bands very common.

The No. 2A Seam has a thickness range from 0.52m to 1.80m with an average of 1.2m, however the Seam pinches out in the eastern portion of the reserve area. The mudstone parting that separates the Nos. 2A and 2 Seams is as little as 0.20m to 1.20m and in some cases pinches out completely. Typically the Seam is a mixed coal with alternating dull and bright bands, with only the lower 0.30m with bright coal. The basal contact of the Seam is a typical gritty sandstone.

The No. 2 Seam has been divided into two zones based on the different inherent qualities. There are no marker bands distinguishing the two zones referred to as the No. 2 Seam Top Coal and the No. 2 Seam Select. Currently the top coal with an average thickness of 2.0m will be discarded due to the poor qualities, i.e. an average volatile matter of 19.0 %, with a raw Calorific value of 19.5MJ/kg dry base. The No. 2 Seam Select has an average thickness of 3.2m. The range here does not vary significantly with an exception to the areas close to the basin edges.

The Nos. 4 and 5 Seams are limited to the topographically elevated areas. Typically, the No. 4 Seam is characterised by a number of intra-Seam sandstone/siltstone partings, which divide the Seam into the No. 4a, No. 4 Upper and No. 4 Lower Seams.

The No. 4 Seam at New Clydesdale Colliery is of poor quality but requires further economic evaluation. In certain areas however, the quality of the No. 4 Lower Seam is good enough to satisfy most of the domestic market or as a blend to the higher quality coal Seams.

The No. 5 Seam also exists at New Clydesdale Colliery, but due to the in Seam parting and average Seam thickness of 1.0m, it has been excluded from the current New Clydesdale Colliery reserves. However, this Seam is of a good quality and still to be fully evaluated.

The episodic intrusion of dolerite dykes and sills have further complicated the geology, causing minor faults, where the displacement is less than the Seam thickness. However the current mining area is surrounded by dolerite dykes, with only one major sill on average 0.8m thick below the No. 1 Seam in the eastern part of the reserve area. The effect of the sill intrusion on the volatile matter of the coal Seam has been confined to the lower most part of the Seam and in some cases very little effect on the volatile matter. An aeromagnetic survey revealed the dolerites on the margins of the reserve area, therefore an extensive surface drilling program of about 110 boreholes within the 85Ha reserve area was completed.

- North Block Complex

The coal succession occurs within the Permian-age Vryheid Formation of the Ecca Group, which overlies the Dwyka Group. The two stratigraphic units occur within the Karoo Supergroup. The sediments of the Karoo Supergroup were deposited on an irregular pre-Karoo basement, which to some extent influenced the distribution of the overlying strata and coal Seams.

The pre-Karoo basement rocks generally comprise gabbros, diabases and felsites associated with the Bushveld Igneous Complex. The generally flat-lying Vryheid formation sedimentary rocks consist of sandstones, thinly laminated siltstones and mudstones and coal Seams.

The Eerstelingsfontein block is composed of gently sloping topography. The coal reserve at Eerstelingsfontein is contained in a single Seam, the No. 2 Seam. The No. 2 Seam occurs as an erosional remnant on high ground at shallow depths, suitable for opencast mining. The thickness of coal ranges from 0.46m to 3.10m (this is inferred from borehole data) with an average thickness of 2.29m. The coal Seam is overlain by a medium to fine-grained sandstone with shaly bands. On top of the whole succession is the overburden material made of sandy soil and regolith.

The average total depth to coal is relatively shallow at 10.69m. The maximum depth to top of coal in the area is 17.79m.

- Inyanda Coal Project

Coal bearing strata of the Vryheid Formation occurs in two areas on the farm Kalbasfontein 284JS, Witbank district 14km north of Witbank. Both areas can be described as outliers unaffected by weathering.

The southern area ± 137 Ha in extent, contains the majority of the Coal Reserves. The northern area (16.44Ha) straddles the Kalbasfontein/Geluk boundary. No coal occurs between these two areas. Two well-developed coal Seams are present. The bottom coal Seam is called the No. 1 Seam and the top Seam the No. 2 Seam.

In the southern area both the No. 1 Seam and No. 2 Seam are well-developed. The sub-outcrop of both Seams is defined by weathering. The coal Seams are close to horizontal, but gently dipping in a southerly direction. No structural disturbances such as faulting or folding have to date been encountered. Although no dolerite dykes or sills have been intersected in any borehole in the mine area, water boreholes intersected a dolerite sill, at least 100m thick indicating the extent of the sill to be confined to the southern area. Airborne magnetic data indicates the presence of such a sill underneath the southern coal deposit. The borehole intersection indicates that the sill occurs stratigraphically below the diamictite (Dwyka Formation). And has not had a negative effect on the volatile content of the coal. The bottom coal Seam (No. 1 Seam) has an average thickness of 3.48m, extending over an area of ±137Ha. The sandstone parting separating the No. 1 and No. 2 coal varies in thickness from 0.30m to 1.13m and averages 0.49m. The top coal Seam (No. 2 Seam) has an average thickness of 4.66m and due to weathering occurs over a smaller area (118Ha) than the No. 1 Seam. The overburden above No. 2 Seam has a maximum thickness of 29.87m in the central part of the mine area but diminishes to between 10 – 14m towards the sub outcrop of the No. 2 Seam. The No. 2 Seam has an average 87% yield at a 14% ash product and the No. 1 Seam an average 80% yield at a 14% ash product.

- Mafube JV Phase II Project

The primary control on the development of the peat in this area is the pre-Karoo basement palaeotopography of the Bushveld Igneous Complex lithologies and the current weathering induced by the current erosion surface. The Karoo Sequence in the area is represented by the Dwyka Formation and the Middle Ecca with little or no lower Ecca Development. The Middle Ecca sequence of coal horizons interbedded with sediments is highly truncated due to erosion with only very minor areas where the full sequence is developed. Subsequent intrusion of a Dolerite Sill very close to the pre-Karoo contact has resulted in an area in the southwest of the project area being heat affected and faulted.

The coal horizons developed consist of the lowermost No. 1 Seam (±0.75m) separated from the No. 2 Lower Seam by a ±1m argillaceous parting, the No. 2 Lower Seam (±4.6m) which has an upper ply in certain discrete areas called the No. 2 Lower Upper Seam separated from the lower ply by a moderately arenaceous sandstone (±0.24m). The No. 3 and the No. 4 Seams are sporadically preserved especially in the north due to the current erosion surface. The No. 2 Lower Seam (2L and 2LU) are considered to be the economic horizon on which the resources have been determined.

The project consists of three discrete peat accumulation areas that are separated by palaeotopographic highs. Two of these areas (named for the farms on which they occur), Springboklaagte and Nooitgedacht, form the project area. The coal is a sub-bituminous coal with an average A grade yield of 41.6% and a secondary 20.5 MJ/kg yield of 32.9%. The overburden thickness varies in the Springboklaagte area from ± 10m to ± 30m and in the Nooitgedacht area from ±10m to ±50m. All mining within this resource area is scheduled to be undertaken by truck and shovel opencast mining methods.

- Belfast Project

The primary coal Seam development is on the No. 2 Seam. Due to the proximity to the northern edge of the Witbank Basin, the primary control on the coal development is the current weathering surface. Therefore the deposit is divided by a perennial stream into two resource blocks under two distinct spurs in the surface topography. The Karoo Sequence in the area is represented by the Dwyka Formation and the Middle Ecca with little or no lower Ecca Development. The Middle Ecca sequence of coal horizons interbedded with sediments is highly truncated due to erosion with only very minor areas where the full sequence is developed. The No. 2 Seam dips gently to the south. The limit of weathering intersection with the top of the No. 2 Seam has been taken as the limit of potential. Although there is no indication of any faulting from the borehole information, there are potential intrusions of dolerite dykes that are indicated by the airborne magnetics that were done over the area. In addition the regional aero-magnetic compilation done for Coaltech 2020 indicates that there is a regional North-South dyke trend in the region. This is borne out by the dry ash free volatile content which is low in some three boreholes in the centre of the project area; 48 of the 381 boreholes predominantly in the far south west of the project area have dolerite logged in the borehole descriptions. This is generally the No. 4 Dolerite sill which forms a cap in most of the high lying areas.

The coal horizons developed consist of the No. 1 Seam which is sporadically developed occurring in 65 boreholes with an average thickness of 0.48m at an average depth of 35m. The No. 2 Seam is consistently developed except in the areas where it has been eroded and has an average thickness of 2.79m at an average depth of 30.41m. The No. 3 Seam is also sporadically developed due to erosion and has an average thickness of 0.60m at an average depth of 18.05m.

The No. 2 Seam is a sub-bituminous to bituminous coal with an average A grade practical yield of 53% and middlings yield of 21 MJ/kg product of 28%.

3.3.5 Ermelo Coalfield

The Ermelo Coalfield is situated in south east Mpumalanga Province between Carolina in the north and Dirkiesdorp in the south, Morgenzon in the west and Amsterdam in the east. The northern and eastern boundaries are defined by the sub-outcrop of the coal-bearing strata against pre-Karoo rocks. The western and southern boundaries are rather arbitrarily defined as straight lines forming the western boundary with the Highveld Coalfield and the southern boundary with the Coalfields of KwaZulu-Natal.

All of the coal Seams occur within the Vryheid Formation of the Ecca Group (Karoo Supergroup). The Karoo Supergroup comprises the following Groups (decreasing age): Dwyka; Ecca; Beaufort; Stormberg and Drakensberg. The Ecca Group comprises the following Formations (decreasing age): Pietermaritzburg; Vryheid and Volksrust.

Within the Ermelo Coalfield, only the Pietermaritzburg and Vryheid Formations are present with the Volksrust Formation having been eroded away. The Pietermaritzburg Formation, however, is only well-developed in the southern parts of the Coalfield. There are five major coal Seams developed in the Ermelo Coalfield, named from the base up: the E Seam; the D Seam; the C Seam; the B Seam and the A Seam.

The B and C Seams have previously been described as coal zones since these Seams are often locally split by clastic partings resulting in several coal "Seams" separated by thin sand and siltstone partings. These Seams are then renamed as the B Upper and B Lower Seams, or C Upper and C Lower Seams.

Basement topography and the present-day erosional surface control the distribution of the coal Seams and not all five Seams may be present at any one locality. The D and E Seams are thin to absent over much of the Coalfield and only the E Seam reaches mineable thicknesses in isolated patches in the northern parts of the Coalfield. The B and C Seams are most widely developed, and to mineable thicknesses, in the Coalfield. The A Seam has, over large areas of the northern and central areas of the Coalfield, been removed by erosion. Although to a lesser extent, the B and C Seams have also been removed by erosion.

Locally, fluvial channels cause erosion resulting in the non-deposition and thinning of coal Seams. The effects of channelling are evident in the central parts of the Coalfield where thick channel sandstones have been delineated which affect the C and C Lower Seams.

The coal Seams are generally flat-lying to gently undulating with a regional dip to the south-west. The Seams are relatively unaffected by folding although faulting and associated dolerite (igneous) intrusions are common throughout the Coalfield. Dolerite intrusions take the form of vertical to near vertical dykes, often intruding existing faults, and sills, which are parallel to bedding planes. Sills are also often transgressive resulting in the relative displacement of strata. The number of sills increase to the south and up to eight major sills have been identified. An additional effect of dolerite intrusions is the burning or devolatilisation of coal in close proximity to the dolerites. Large areas of coal in the south have either been completely destroyed (burnt) or devolatilised by numerous dykes ranging in thickness from 3 – 5m. Dolerite intrusions not only sterilise available resources but also disrupt mining activities.

- The Incgambu Project occurs within the Ermelo Coalfield

The surface topography is the primary controlling factor on the preservation of the various coal horizons. The Karoo Sequence is represented in this region by the Lower and Middle Ecca Formations. Almost the entire sequence of the Middle Ecca Formation is preserved in areas in the region as the surface topography is highly dissected due to the proximity to the Gondwanaland Escarpment. On portion 26 of the Farm Uitgevallen, both the C Lower and Upper Seams sub-outcrop against the surface weathering horizon and are quite rapidly covered by overburden as the topography rises to the northeast. Although the topography suggests and reconnaissance drilling on the remainder of Uitgevallen indicates that there are coal resources available this has not been included in this report as the only drilling that has sufficient confidence occurs on portion 26. The C Lower Seam is a high quality coal Seam with good wash characteristics and high yields at an A grade and consists primarily of mixed coal. The Seam is generally thin with an average thickness of 1.3m. The C Upper Seam is generally of a lower quality than the C Lower it does satisfy the coal requirements for Camden Power station as a raw product. The C Upper has an average thickness of 1.4m. The parting between the two coal Seams is generally in the order of 3m to 5m.

3.3.6 Highveld Coalfield

The Highveld Coalfield is located in south-eastern Mpumalanga Province, immediately south of the Witbank Coalfield. The width of the coalfield is some 95km, stretching from Nigel and Greylingstad in the west to Davel in the east, and is about 90km long, from just north of Kriel to beyond Standerton in the south and covers an area of approximately 7,000km². After the Witbank Coalfield, the Highveld Coalfield is the next largest producing coalfield, on a tonnage basis, in South Africa.

The coalfield is host to up to five coal Seams contained within the middle Ecça Group sediments of the Karoo Supergroup. The Karoo Supergroup comprises sediments ascribed to deposition in glacial to fluvio-glacial and from shallow marine to fluvio-deltaic environments. The Karoo Supergroup comprises the following Groups (in decreasing age), although not all Groups are completely represented in the Highveld Coalfield to the present day erosion surface: Dwyka; Ecça; Beaufort; Stormberg and Drakensberg.

The Ecça Group comprises sediments from the following formations (in decreasing age): Pietermaritzburg; Vryheid and Volksrust.

The five identified coal Seams contained in the Vryheid Formation (middle Ecça Group) are named, from the base up, as follows: Number 1 Seam (No. 1 Seam, S1); Number 2 Seam (No. 2 Seam, S2); Number 3 Seam (No. 3 Seam, S3); Number 4 Seam (No. 4 Seam, S4) and Number 5 Seam (No. 5 Seam, S5).

In certain areas of the coalfield, the No. 4 and No. 2 Seams are split by clastic partings and in those areas the Seams are called the No. 4 Upper and Lower Seams and the No. 2 Upper and Lower Seams.

The coalfield is characterised by the fact that in the northern regions, all the coal Seams, with the exception of the No. 3 Seam, attain mineable thicknesses with economic potential, while in the southern regions, only the No. 4 Seam, and in very localised areas the No. 2 Seam, attain mineable dimensions of economic importance.

The depth to the coal Seams increases in a southerly direction, e.g. the No. 4 Seam can be mined by opencast in the Kriel (northern) district, while it occurs at a depth of around 200m in the Standerton (southern) district. The coal Seams are generally flat-lying to gently undulating with a slight regional dip to the south.

Structurally, the coalfield is relatively undeformed with no prominent folding having been identified. Small-scale faulting (less than 1m) is not uncommon although large-scale faulting is. The only large-scale displacements identified are almost always associated with transgressive dolerite sills, intruded during the waning stages of the Karoo times. These intrusive dolerite sills and dykes are related to the Drakensberg Formation flood basalts. The dolerite intrusions adversely affect the coal Seams in the vicinity of the intrusions in terms of coal quality by devolatilising and burning the coal. Large areas of coal have been rendered uneconomical due to the effects of dolerite intrusions.

The most important economic coal Seams are the No. 4 Seam and the No. 2 Seam. The No. 4 Seam accounts for approximately 80% of the economically recoverable coal within the Highveld Coalfield. The No. 2 and No. 4 Seams are mined in the northern parts of the coalfield while only the No. 4 Seam is mined in the southern parts. The bulk of the coal produced is consumed in power stations and for the production of syn-fuels. A very limited quantity is exported.

- Matla Colliery

The coal deposit at Matla Colliery forms part of the Highveld Coalfield. The coal Seams are found within the Vryheid Formation of the Karoo Supergroup and date at approximately 280 million years in age. The stratigraphic sequence within the Matla area includes five coal Seams that can be easily correlated with the Seams found within the Witbank Coalfield.

The principal economic Seams currently exploited are the No. 2 and No. 4 Seams. The mining of the No. 5 Seam was terminated as a Power Station feedstock during May 1998 because of high levels of contamination that resulted in an excessively high overall abrasive content.

The Matla Colliery mining-area is characterised by two distinct dolerite types, namely the B8 (porphyritic) and B4 (olivine-rich) types, which have varying effects on Seam displacements and coal burning and devolatilisation. Floor rolls have been encountered in the No. 2 Seam workings and have created problems in the mining sections. The floor rolls strike NE-SW, vary in width from 50m – 200m, and have amplitudes up to 1.5m. Sandstone lenses encountered are generally less than 0.5m in width, but can reach up to a 1.0m in thickness. Structural information has been collected from borehole sections, horizontal drilling, aeromagnetic surveys and extrapolations from intercepted dykes in mined out areas. A dolerite sill, which has an average thickness of 10 metres, is generally found above the No. 5 Seam in the No. 2 Mine and No. 3 Mine areas, but intersects the coal Seams and underlies the No. 2 Seam at No. 1 Mine. The intrusive activity in the No. 1 Mine area caused extensive devolatilisation of the overlying No. 2 Seam, resulting in the exclusion of this Seam from the mineable reserves at No.1 Mine.

Economic No. 5 Seam is mainly expressed in the No. 2 Mine and No. 3 Mine areas, and to a limited extent, in the western limb of the Southern Reserve area. The roof consists of 0.25m to 0.70m thick sandy micaceous shale at No. 2 Mine that thickens up to 1,60m at No. 3 Mine. Above this is competent sandstone, which, in some areas, is saturated with water. Due to this, the parting between the two sequences is highly weathered. Consequently, this shale is difficult to support and is removed with the product in development sections.

The average mineable horizon, when described from bottom to top, consists of approximately 0.50m to 1.00m of mixed coal, 0.10m to 0.17m of torbanitic material and 0.35m to 0.60m of mixed coal, resulting in an average thickness of 1.50m. At No. 2 Mine, the floor is made up of competent sandstone over 80% of the area. Over the greater part of the No. 3 Mine area, the floor is generally a 0.10m to 0.25m fine-grained and micaceous sandstone. Underlying the sandstone is a 0.30m to 0.50m thick shale to sandy shale.

Economic No. 4 Seam is strongly expressed in the No. 1 Mine, No. 2 Mine and Southern Reserve areas, and to a limited extent in the No. 3 Mine area. At No. 3 Mine, the Seam splits into two thin, poor quality horizons towards the west, so it has been necessary to exclude this coal from the mineable reserves. In general terms, calorific value decreases from east to west, and from No. 1. Mine moving north toward No. 2 Mine and south toward the Southern Reserve. Thus the best quality No. 4 Seam may be found at No 1. Mine and at the eastern edges of No. 2 Mine.

Over the total mining area, it is often necessary to leave a beam of dull to shaly coal, with inter-bedded shale bands, in the roof. This is done mainly because of quality constraints. This coal in the roof has been found to form a competent beam resulting in good roof conditions.

The mineable coal horizon is restricted to the upper portion of the Seam in areas where the in-Seam parting in the lower portion exceeds 0.30m or where the sandstone band exceeds 0.10m in thickness. In such areas, the bottom part of the Seam is excluded from the reserves. The occurrence of shale bands complicates horizon and floor control.

In some areas of No. 2 Mine and No. 3 Mine, coal is left in the roof or floor due to mining height constraints. Where coal is not left in the roof, the roof consists of fine-grained sandstone or sandy, micaceous shale.

Seam thickness varies between 1.2m and 5.5m (mining height limit). The Seam generally consists of homogeneous, dull lustrous coal, interspersed with bright coal bands. In-Seam partings typically consist of discontinuous lenses of shales and siltstones less than 0.1 metres thick, but these may thicken locally to 0.3 metres. Carbonaceous limestone lenses are also prevalent within the central portion of the No. 2 Mine area.

In areas where coal has been left in the floor at No. 3 Mine, the floor is not competent and tends to disintegrate under tramming operations. The coal Seam floor generally consists of competent medium to coarse-grained sandstone.

3.3.7 Bowen Basin (Australia)

There are numerous Coalfields on the east coast of Australia of which the only Coalfield in which Kumba has an interest is the Bowen Basin in Central Queensland and specifically the western limb of the Bowen Basin. The Bowen Basin has a number of distinct coal measures of late Permian age. They range from the older Blenheim Coal measures through to the Rangal coal measures. The Bowen basin is a structurally complex compressional basin with thrusting repeating the coal sequences to the east. All the coal measures dip gently to the east with thrust faulting having a general north south trend and extensional normal faulting having a general east west trend. The Bowen Basin extends from Collinsville in the north to Emerald in the south a distance of some 250kms. Recent modeling by the CSIRO has indicated that folding can be divided into broad flexures with a 4 – 5km wavelength and that a major anticline extends from Goonyella in the north to Moranbah in the south with extensive Seam splitting occurring to the north and south of the regional anticline. In general the Moranbah coal measures, which are in the region of 320m thick, are defined by the three most correlateable coal Seams, the Goonyella Lower (Dysart) at the base. The Goonyella Middle Seam (Harrow Creek) in the centre and the Goonyella Upper Coal Seam at the top (Q upper). In general medium to low phosphorous low ash coking coal with acceptable yields can be expected from the primary coal Seams with lower quality coals occurring at the top of each of the principal Seams.

- The Moranbah South Project occurs within the Bowen Basin

The Moranbah South coking coal project is located roughly 15km south-east of the town of Moranbah. The principal coal mining sequence in the Moranbah South area is the Moranbah Coal Measures, which are extensively mined for prime quality coking coal in the northern Bowen Basin. The Moranbah Coal Measures contains seven major coal Seams of which, only the P Seam and Harrow Creek are considered prospective underground mining targets. The P Seam, which is equivalent to the Goonyella Upper Seam, ranges from 2.13 to 3.87m thick. However, acceptable yields of +70% product can only be obtained if a product ash of 12% or higher is marketed. Thickness of the Harrow Creek Seam, including partings, ranges from 2.50m to 4.47m and averages 3.51m across the Moranbah South area. A shale band up to 50cm thick occurs in the north and west, thinning gradually to the east with a marked increase in recovery. This Seam contains high grade coking coal which can be produced at either 8.5% or 9.5% ash. The Harrow Creek (“HCK”) Seam represents the target Seam in Moranbah South. It is the equivalent of the

well-known Goonyella Middle Seam. Depth of cover to the HCK Seam, based on boreholes, ranges from 60 to 200m on the western boundary and with a dip of 1° to 5° against the eastern boundary the depth is greater than 500m. The HCK Seam does not subcrop within the controlled bounds of the property. Only in the north-west corner of the EPC (north of the Moranbah air strip) does the HCK Seam come close enough to the surface to be mined by open cut methods. The structure is partially determined due to the wide borehole spacing and is confined to the three major structures, two normal extensional faults with variable throws (Watonga and Grovenor) and a compressional thrust fault (Cherwell).

A number of igneous intrusions have been encountered in the stratigraphy above and below the HCK in a number of boreholes, indicating that the possibility of intrusions exists.

3.4 Heavy Minerals

3.4.1 KwaZulu-Natal Deposits

The heavy mineral deposits within the KwaZulu-Natal dune corridor have been interpreted to represent remnant beach deposits of a large coastal dune system that developed on the Mozambique coastal plain during the late Pliocene Era, approximately three million years ago.

Hillendale and Fairbreeze Project deposits are situated within the same geological environment, consisting of the Late Tertiary-Pleistocene dune corridor developed along the Natal coastline. The original South African coastline was generated by rifting processes involved in the fragmentation of Gondwanaland during Jurassic and Cretaceous times. By the end of the Cretaceous, the present configuration of southern African coastline was established and since that time local modifications have taken place, resulting from tectonic uplift, eustatic changes and flexuring of the sub-continent.

Tectonic events and coupled eustatic changes have resulted in the Mozambique coastal plain being subject to several marine transgression-regression cycles during Tertiary and Pleistocene times. A major Eocene transgression resulted in deposition of Eocene marine sands on the Mozambique coastal plain. Relict shoreline features occur around the southern African coastline, often at high levels (+100m) above the current sea level. Beach gravels and dunes up to 100m above mean sea level are common on the eastern seaboard of South Africa and there appear to be at least two major beach elevations at 30m above sea level and 60m above sea level. Pleistocene dune ridges are prominent along the Natal shoreline and Eastern Cape. The highest dunes are dominated by homogenous red sands of the Berea Formation that preserve many aeolian features. The red colouration of the sand is believed to be associated with weathering of heavy minerals under tropical conditions. Detailed histories of these deposits are very complex and evidence for submergence of some of the Pleistocene dunes is unequivocal. Relict submerged dunes are also present off the coast of Natal, recording periods when the sea-level was 70m lower than the present sea-level. The heavy minerals that are present within these sand units were derived from the weathering of rocks from the Natal Metamorphic Belt, the Natal Group and the Karoo Supergroup. These minerals underwent fluvial transport to the sea during protracted erosion and these minerals have subsequently been concentrated within the beach environments by near shore wave action.

The Hillendale deposit is considered to represent a paleo-spit formed at the mouth of the paleo-Mhlatuze River. It consists of dominantly Berea-type red sands but also contains discontinuous lenses of medium to coarse yellow to dark orange sands that are low in silt and clay and THM. The deposit is approximately 3.8km long, 600m wide and generally between 18m to 21m thick. THM content is between 1% and 25% with Valuable Heavy Minerals ("VHM") making up 10% to 70% of the THM suite. Grades are locally variable but as a unit Hillendale can be considered relatively homogeneous. Silt content of the sands is largely due to weathering and ranges between 15% and 25%.

The Fairbreeze Project group of deposits is considered to represent paleo-strandlines and beaches that developed adjacent to headlands. The deposits are distributed over a total strike length of approximately 10km and a width of 700m.

Fairbreeze Project deposit is divided into five separate blocks, Fairbreeze Project A, B, C Extension and D Blocks. Like Hillendale, the Fairbreeze Project deposits are hosted within Berea Formation sands, although at Fairbreeze Project, these sands are distributed above a variable bed-rock surface. In the extreme north, Vryheid Formation rocks (sandstones and shales) crop out to the southeast of the Fairbreeze Project C deposit. Between the A and B blocks Natal Group lithologies (sandstones and grits) are exposed. In this area the Berea Formation sands are generally absent and the overburden that is developed above the bedrock consists of fine-grained, silt-poor wind blown sands.

The Fairbreeze Project A and B deposits are considered to represent two sections of a set of strandline deposits. Strandlines represent tabular zones of concentrated heavy mineral accumulations that are preserved by gradual marine regression that leaves the strandline above the level of marine erosion.

Fairbreeze Project C deposit has been interpreted to be a beach deposit formed on the low energy side of an ancient headland that projected into the sea. The heavy minerals accumulated against the headland, whilst the lighter minerals were continually remobilised by wind transportation, resulting in concentration of the heavy minerals. Fairbreeze Project D deposit has been interpreted to represent a set of strandlines deposited to the east of Fairbreeze Project A, B and C deposits, during progressive sea-level regression.

The Fairbreeze Project A deposit is 18m to 63m thick with an average thickness of approximately 38m. Rapid variation in thickness is apparent with vertical differences of 15m over lateral distances of 50m. Unlike Hillendale the deposit is heterogeneous with three heavy mineral horizons dipping to the east, centred on strandlines. THM grades in the strandlines are typically between 5% and 15% with 50% to 70% of VHM.

Fairbreeze Project B constitutes an extension to Fairbreeze Project A separated by a bedrock outcrop. It is similar to Fairbreeze Project A but is characterised by lower average THM grades; silt and clay content of Fairbreeze Project B deposit exceeds that of the A deposit.

Fairbreeze Project C and C Extension are more homogeneous in nature than Fairbreeze Project A or Fairbreeze Project B and average 10% to 15% THM with a VHM fraction of 60% to 80%. Grades typically increase with depth and this deposit also has a higher zircon and rutile content than the A and B deposits.

Fairbreeze Project D is similar to Fairbreeze Project A and Fairbreeze Project B but is lower in grade and varies in thickness from 18m in the South to 34m in the North. Two strandlines are present and grades average between 5% and 8% THM in the strandlines with a VHM component accounting for approximately 50% of the THM. The Fairbreeze Project deposits contain approximately 30% silt.

Block P is located north of Hillendale and there is one significant difference between this body and both Hillendale and Fairbreeze Project; the basal unit of the deposit consists of a pebble bed that underlies a mineralised red sand unit. Granite-gneisses are present immediately below the pebble bed. With respect to the red sand orebody, Block P deposit is broadly similar to the Fairbreeze Project deposit style in that it is a strandline in nature. The Block P deposit has THM grades of around 5%. Silt and clay content is in the order of 25% for Block P.

3.4.2 Toliara Sands Project

The Toliara Sands Project comprises two heavy mineral deposits that were discovered in 1999 by MRNL near the town of Toliara in southwest Madagascar. The Ranobe deposit is located 35km north of Toliara and has been the subject of detailed exploration by MRNL and Exxaro; the Manombo – Morombe area located north of Ranobe has undergone superficial exploration by MRNL and follow up drilling by Exxaro.

The Ranobe deposit has a strike of approximately 12km and consists of a dune complex between 1km and 2km wide, with a thickness that varies between 2m and 50m. This dune complex is situated to the west of a prominent limestone cliff feature and has been sub-divided into three geological units:

- The Upper Sand Unit consists of clean, well-sorted sand with low slimes content (3% – 5%). The thickness of this unit may reach 30m. This unit hosts the Mineral Resources that have been delineated within the Ranobe deposit and has been interpreted to represent a dune body.
- The Intermediate Clay Sand Unit underlies the Upper Sand Unit and comprises a clay-rich sand layer that does not extend above 100m above mean sea-level. This unit is interpreted to represent a tidal flat or lagoonal deposit.
- A Lower Sand Unit is present beneath the Intermediate Clay Sand Unit. The Upper Sand Unit where present, overlies limestone basement or the Intermediate Unit. The Intermediate Unit, where present, overlies limestone basement or the Lower Unit. All Units contain significant THM mineralisation, but Mineral Resource estimates have only been prepared for the Upper Sand Unit.

3.4.3 Limpopo Province – Gravelotte

The Limpopo Province assets of Kumba are located approximately 8km north of the town of Gravelotte, in southwestern South Africa and comprise both alluvial and hard rock ilmenite deposits. The principal resource consists of alluvial sand deposits containing ilmenite liberated from the weathering of Archaean magnetite rich rocks of the Rooiwater Complex, developed along the northern flank of the easterly-trending Murchison Greenstone Belt.

The Rooiwater Igneous Complex consists of the Novengilla Gabbro, the Quaqua Quartz-Amphibolite and the Free State Hornblende Granite. The Novengilla Gabbro hosts the magnetite rich bands that are the source of the ilmenite within the Gravelotte deposits. During metamorphism of the Rooiwater Igneous Complex the ilmenite, which is typically present as exsolution lamellae within magnetite, has recrystallised as discrete crystals of ilmenite. The weathering of this material has largely disaggregated the magnetite and ilmenite making it possible to segregate the ilmenite from magnetite. The residual sand and soil derived from weathering is accumulated above a pebble layer that overlies the bedrock.

Mineral Resources estimates have been developed for the sand unit, as well as the pebble layer and the underlying hard rock bodies. The sand layer is on average 0.9m thick and the pebble layer is on average 0.3m thick; the sand resource is present within an area with a strike length of approximately 24km and a width of 2.5km, over the farms Begin 765LT, FreeState 763 LT, Mon Desir 782LT, Gravelotte 783LT, Quagga 759LT, Malati 764LT, Rubbervale 784LT and Solomons Mine 76LT.

3.4.4 Tiwest JV

The Perth Basin of Western Australia has historically provided a significant proportion of the world's ilmenite, rutile and zircon. These detrital heavy minerals originate from igneous and metamorphic rocks in the Achaean shield in the interior of Western Australia, but have been concentrated through multiple phases of weathering, erosion and deposition. Economic accumulations of heavy minerals are mostly found in high energy Cainozoic shoreline deposits, although significant accumulations also occur in older Cretaceous fluvial sediments.

The Perth Basin is a narrow, north-south trending longitudinal trough bounded to the east by the Darling Fault and to the west by the continental shelf (Cockbain, 1990). The basin is approximately 1,000km long, and up to 15km deep. The basin has undergone two major stages of evolution, as represented by the sedimentary fill:

1. An early phase extending from the Silurian to the early Cretaceous consisting of thick sequences of continental siliciclastic sediments and minor shallow marine sediments. During this period the basin was probably bounded by continental crust to the east and the west.
2. From the early Cretaceous to the present, the basin sediments are typical of a marginal sag basin with generally thin sequences of shallow marine sediments. Eustatic sea level changes over this period, and possibly some tectonic movement, have caused near-shore sediments to be deposited over much of the east-west extent of the basin, especially over the coastal plain regions.

Many of the high grade heavy mineral deposits in the Perth Basin lie within shoreline deposits sitting unconformably against Mesozoic sediments or weathered Precambrian basement. The extensive deposits against the Darling Scarp and the Whicher Scarp in the South Perth Basin (Yoganup, Boyanup, Waroona), and the Gingin Scarp in the North Perth Basin (Gingin, Cooljarloo, Eneabba) belong to this group. Despite the near-shore origins of these sediments, a lack of fossils has made them difficult to date. They are correlated together as the Yoganup Formation on the basis of similar lithology and geomorphological position (shoreline deposits between 26 – 115m ASL). This formation has been correlated with the fossiliferous Ascot Beds, of likely Pliocene age (Cockbain, 1990).

A younger series of shorelines is found to the west of these deposits, within Quaternary sediments. These shorelines have been economically significant in the South Perth Basin near Capel, but have not been as significant in the north. The younger strandlines are known to exist in the North Perth Basin (Dongara, Jurien and possibly Eneabba West), but a large limestone ridge covers most of the prospective areas. The younger strandlines typically contain higher garnet concentrations and less altered ilmenite than the older strands.

The Capel and Eneabba districts have been the most significant mineral sand producing areas in Western Australia. The various deposits within these districts are situated in what were northward facing embayments (sometimes called J-shaped bays). Heavy minerals were probably accumulated with a combination of longshore drift and wave action. Mineralisation is also partly controlled by the location of paleodrainages and sediment sources.

The mineralisation at Cooljarloo comprises the valuable detrital heavy minerals ilmenite, rutile, leucoxene, and zircon with subordinate monazite and trash aluminosilicates kyanite, staurolite, andalusite and tourmaline. These minerals were concentrated in near-shore sediments deposited during transgressive, interglacial peaks, probably in the Late Pliocene or Early Pleistocene. The deposits form a swathe of about 15 north-westerly trending sub-parallel strands over a three-kilometre wide belt. These have been described by Baxer (1977) as the Munbinea shorelines and can be followed from Cataby to Badgingarra over a 40-kilometre section of the Gingin Scarp.

The shallow marine and near-shore sediments that host the mineralisation are between 20m and 50m thick and unconformably cover the fluvial sands and silts of the Upper Jurassic Yarragadee Formation. At Cooljarloo, some of the high grade mineralisation abuts the Gingin Scarp, which marks the eastern extent of the Cainozoic marine transgressions. However, a significant proportion of the mineralisation lies in a fan of strandline deposits that lie west of the scarp. The mineralised sands near Cooljarloo were deposited in at least three sequences of marine transgression and regression.

First Transgression and Regression (“33000 Layer”): The locally named 33,000 layer unconformably overlies the Yarragadee Formation as a sheet over much of the north-eastern area at Cooljarloo. It is a variable layer of silty, weakly carbonaceous, poorly sorted sand that is often grey-green in colour, or yellow-brown (possibly an oxidised version of the grey-green material). The layer is typically 5m to 7m thick and contains moderate levels of heavy minerals.

The heavy mineral in the 33,000 layer has been well-studied and is considerably finer than the overlying strandline mineralisation (D50 of 0.12mm compared with 0.18 for the overlying HM. It has a significantly higher level of monazite (1.3% versus 0.4%) and the ilmenite is less altered (TiO₂ of 56% versus 62% in the overlying strandlines). All of these properties make the 33,000 layer less attractive for mining than other areas.

Second Transgression and Regression (Mid-level Deposits): The mid-level deposits were emplaced in three episodes between R.L. 44m and 64m. Drill core shows thin lamellar, mineral sands, small cross-set beds and massive disseminated mineral sands. The low energy conditions and shallow marine environment are evident. These conditions were periodically interrupted by storm events that reworked up to five metres of sand and destroyed any previous structure. The sands are grey to white, medium-grained, well-rounded and well-sorted mature sediments. They differ from units in other transgressions by the absence or low content of feldspar. The sands are generally very clean with less than 5% clays. These are the sequence currently mined at Cooljarloo, together with the overlying third transgression minerals.

Third Transgression and Regression (Near-surface Deposits): The third and final transgression must have been quite rapid, as much of the previous regressive sands were undisturbed. The sands in this regression are coarser and more angular than the second transgression and contain more feldspar. These facts all support the theory that the sands are less mature than the older lithologies. The valuable minerals are generally coarser and contain less rutile and zircon than the older, more mature mineral suits. There are also more alumino-silicates in the heavy mineral assemblage. The near-surface strands were deposited in seven or eight events over a three-kilometre wide coastal strip.

3.5 Base Metals

3.5.1 Rosh Pinah

The Rosh Pinah Zinc-lead deposit is hosted by the Rosh Pinah Formation of the Late Proterozoic Gariep Belt, which is an arcuate north trending tectonic unit some 400km long by 80km wide. This belt consists of sediments deposited in association with late pre-Cambrian continental rifting, which resulted in the formation of sedimentary basins. These basins are commonly sites for sedimentary exhalative (“SEDEX”) base metal mineralisation, which involves hot, metal-rich brines from depth rising along the extensional faults before emerging from the sea floor and interacting with the cold seawater. This results in the deposition of metal sulphides into topographic lows along with other sediments. Compressive tectonic processes resulted in the obliteration of the extensional features, folding of the strata and the development of thrust faulting.

The current geological interpretation of the Rosh Pinah deposit is that it represents a single layer of SEDEX sulphide mineralisation subsequently deformed by tectonic processes. The original strata have undergone varying degrees of deformation ranging from broad folding in the northern extremity of the deposit to isoclinal folding with associated faulting to the south. Ductile deformation has resulted in the attenuation of the mineralised zone along the limbs of the folds with general thickening in the fold hinges. Shearing along fault planes sub-parallel to fold axes has enhanced thinning of some of the mineralised zones. The result of this has been the development of a series of discrete, sub-linear orebodies resident primarily on the crests and troughs of folds, but which typically extend into one or both of the fold limbs. These individual orebodies range in size from several tens of metres to as much as 200m in length along the axes, with thicknesses of the order of less than 1m to as much as 60m. The degree of geometric variability in section is substantial over distances of only 10m to 15m, with changes to the ore thickness of 50% or more commonly encountered within these distances.

Rosh Pinah has operated continuously for over 30 years with no more than seven years of Mineral Reserves identified ahead of production. The extension of the Mineral Reserves has been through the discovery of new orebodies within the same lithological units, in additionally drilled fold hinges. The mine is currently closing out the south eastern most of the orebodies and drilling along the less well-drilled fold limbs between the existing orebodies. In addition, the mine is exploring in the area of possible extension of the mineralised horizon.

The complex structures which control the development of the discrete orebodies makes the discovery of new orebodies uncertain, but any new discoveries usually extend the life of the mine by a couple of years. The regional exploration has been halted at present in favour of exploration close to the current orebodies. However, the geological environment responsible for mineralisation is regional in nature with a high degree of probability for similar deposits having been formed in association with other metallic brine outlets.

Should the life of mine be extended by the discovery of a new orebody in close proximity to the mine, the regional exploration would again be continued. None of the regional targets drilled to date have however yielded any significant orebodies.

The mineralisation consists of sphalerite and galena with pyrite and minor chalcopyrite along with a suite of other minor accessory minerals. Sphalerite and galena are the economically important minerals with gold, silver and copper providing minor contributions to value. The upper contacts of the orebodies as defined by mineralisation are very sharp with little or no mineralisation beyond the hangingwall. The lower horizons show varying degrees of mineralisation, largely in the form of fracture-filling sulphides between breccia clasts and in fractures developed in late-stage brittle deformation. The grades developed in this "footwall" are generally less than 2% zinc equivalent and so are not currently of economic interest.

3.6 Industrial Minerals

3.6.1 Glen Douglas

Glen Douglas Mine exploits two of the three dolomitic formations of the Malmani Subgroup of the pre-Cambrian Transvaal Sequence, namely the Lyttelton and Monte Christo Formations. The Monte Christo Formation represents a widely deposited oolitic carbonate 300m to 500m thick, which is overlain by the Lyttelton Formation. The Lyttelton Formation consists of a dark, chert-poor, fine-grained dolomiticrite 100m to 200m thick. The contact of the Lyttelton Formation with the overlying Eccles Formation is transitional and indistinctly marked by the increased presence of chert bands.

The Eccles, Lyttelton and Monte Christo Formations subcrop beneath soil within the Glen Douglas Mine lease area. Sedimentary bedding in the area dips to the west-northwest at approximately 70° resulting in subcropping of these three formations beneath the soil cover as broad northeast trending bands. The uppermost Eccles Formation exists only in the northwest portion of the property beneath the process plant facility and is not encountered in the LoM pit designs. The Lyttelton Formation subcrops in a broad 800m to 1,000m exposure within which the current and planned pits lie. The Monte Christo Formation subcrops over the remaining area of the property to the east and is encountered only at depth in the pits. Over most of the property bedrock is overlain by a varying thickness of soil (up to 30m) containing a combination of scattered and stacked dolomite boulders representing eroded remnants of karst towers, and matrix-supported dolomite cobbles and chert rubble. In the north of the property the Lyttelton Formation is intruded by a syenodiorite sill which has a similar dip as the sedimentary strata but a strike that is slightly more to the east. The sill gradually transgresses upwards to the south where it eventually forms the hangingwall of the Lyttelton Formation in the southwest of the property.

Also present are diabase dykes that are deleterious in the metallurgical grade material and are classified as waste along with any dolomite significantly contaminated by them. Due to weathering, alteration and mineralogy the dyke material is also unacceptable for aggregate use. The southwest area of the mine is transected by an east-west striking graben structure, which effectively sterilises the dolomite for an additional bench over a width of some 100m due to the increased depth of weathering. Initial recovery of the metallurgical dolomite is affected by the presence of "mud pockets". These are small depressions and voids in the dolomite produced by deep weathering into which groundwater has introduced an influx of mud, soil and clay contaminants. These pockets are often small enough to be missed by the blasthole drilling and so can be difficult to predict. The only significant potential at Glen Douglas Mine to add to the current LoM metallurgical-grade reserves lies beneath the process plant and workshops. In addition to the metallurgical-grade dolomite, there is a substantial volume of aggregate-grade material currently demonstrated by the mine's management to be uneconomic if mined independently. The Lyttelton Formation is a dark, homogeneous, finely crystalline and massive dolomiticrite with an average SiO₂ content of 1.15%, Al₂O₃ content of 0.20% and K₂O content of 0.05%. The lower layers of the Lyttelton Formation near the contact with the Monte Christo Formation show an increase in chert partings and siliceous detritus, which raise the SiO₂ content above acceptable limits for metallurgical uses. This higher-silica material, along with the upper layers of the Monte Christo Formation, is mined for construction aggregate.