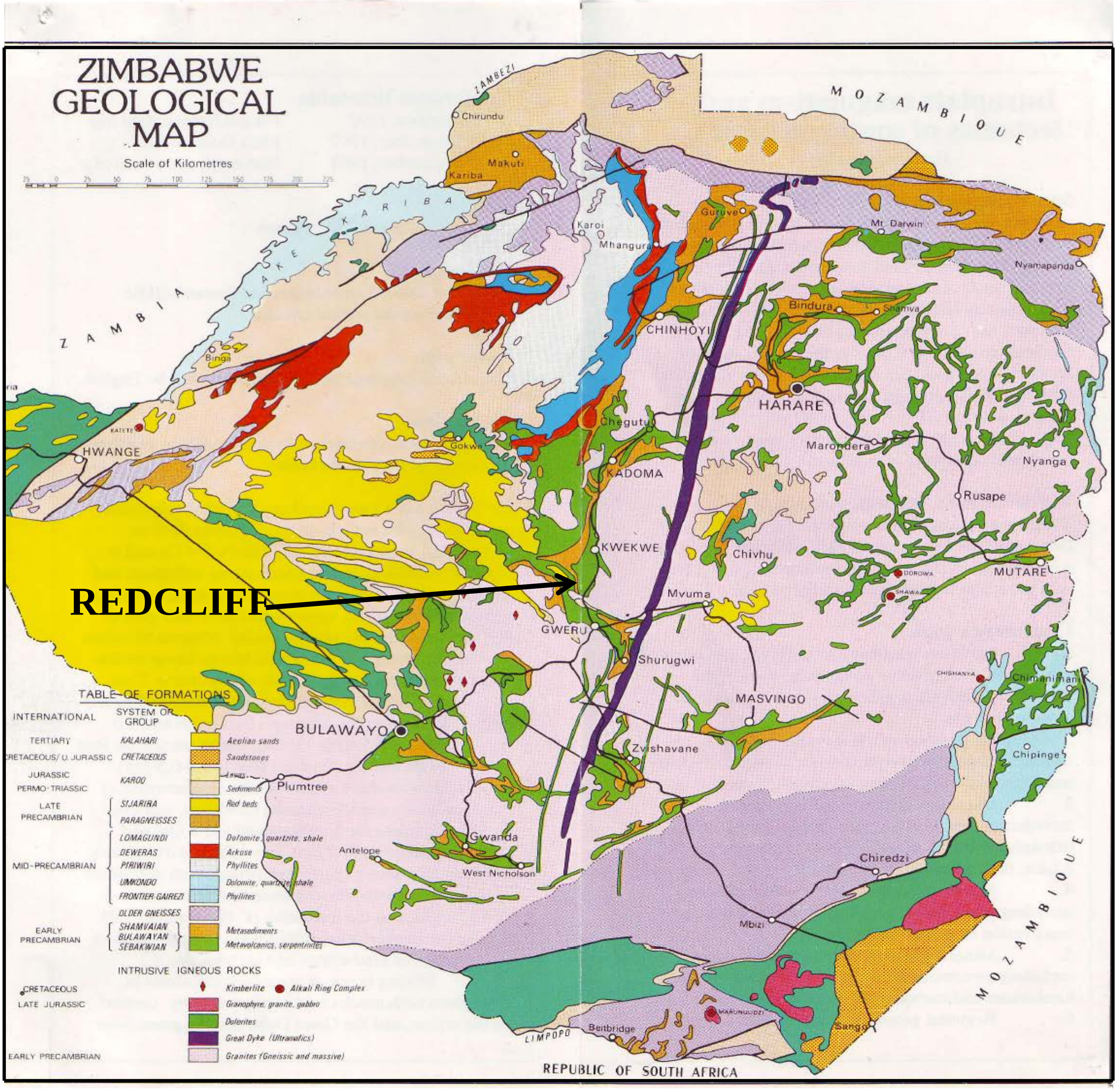
GEOLOGICAL SOCIETY OF ZIMBABWE

TOUR OF IRON ORE DEPOSITS IN THE REDCLIFF AREA

26th OCTOBER 2014

LOCATION PLAN OF REDCLIFF



1. IRON ORES

1.1 Iron-formation

Iron-formation is a chemical sediment, typically thin-bedded or laminated containing 15% or more iron of sedimentary origin, commonly but not necessarily containing layers of chert. (James, 1954). The most common type of Iron-formation is Oxide Facies (better known in the past in Zimbabwean literature as Banded Ironstone or Jaspilite). Sulphide, Carbonate and Silicate Facies of Iron-formation exist but are not that common.

Iron-formation is the major source of beneficiable iron-rich material in such countries as China.

1.2 Magnetite

Composition: Fe_3O_4. When pure comprises 72,4% iron

One of the main sources of commercially used magnetite is Kiruna in Sweden.

1.3 Haematite

Composition: Fe_2O_3. When pure comprises 70,0% iron.

Haematite forms the ore in the current main sources of iron ore around the world in Brazil, South Africa and Australia.

1.4 Siderite

Composition: $FeCO_3$. When pure contains 48,2% iron

Siderite used to be a common iron ore in Europe at such mines as Eisenerz in Austria

1.5 Limonite

This is an all-embracing name given to a complex group of hydrated oxides of iron with the general formula $Fe_2O_3.nH_2O$. Examples are as follows:

Turgite: $2Fe_2O_3.H_2O$
Goethite: $Fe_2O_3.H_2O$
Limonite: $2Fe_2O_3.3H_2O$
Xanthosiderite: $Fe_2O_3.2H_2O$

When pure, the most common hydrated oxide, $2Fe_2O_3.3H_2O$, contains 59,8% Fe. Limonite has been produced in relatively minor quantities at such places as satellite mines of the main haematite occurrences in Australia.

Of the four main minerals that are used around the world as iron ores only two (Haematite and Limonite) have been used in the blast furnaces at Redcliff.

The main impurities occurring in iron ores are silica, alumina, manganese, calcium, magnesium, sodium, potassium, titanium, sulphur and phosphorous; those most deleterious being sulphur, phosphorous, alumina and titanium.

In estimating the actual resources of iron ore, economic and technical considerations, as well as the iron content of the rock, determine whether the deposit is classified as an Iron Ore or an “iron-bearing material”.Hence the definition of the term ‘Iron Ore’ varies with time and place. The friability of the ore is often a major consideration as good blast furnace operation requires well sized, raw material with a high compressive strength in the range 10mm to 30mm. Material which, after crushing, is below 10 mm in diameter has to be discarded, sintered or pelletized. Addition requisites of iron ores used in blast furnaces are good low temperature breakdown characteristics, low phosphorous content(< 0,05%) a silica: alumina ratio of greater than 2,5:1, a manganese content of ± 0,8% and an iron content in excess of 60%.

2. REGIONAL GEOLOGY

The area around Redcliff is underlain by Archaean rocks of The Basement Complex. This volcano-sedimentary pile is flanked by granitic rocks of the Rhodesdale batholiths in the East and the Shangani batholiths in the west, both of which have components representing three major episodes of granitic activity. The first two phases are gneissic and vary in composition from granodiorite to tonalite and the third phase, which intrudes the two earlier ones, is adamellitic.

The stratigraphy of the Greenstone Belt in the Redcliff area originally mapped by McGregor (1937) and Tyndale-Biscoe (1949) has since been re-assessed, using lithostratigraphic units, by Cheshire (1979), but the threefold division of Sebakwean, Bulawayan and Shamvaian Groups has been retained. The sub-division of the Bulawayan into Upper and Lower Groups as in the Mberengwa-Zvishavane Greenstone Belt (Martin, 1978) has been followed in the Redcliff area mainly because of the close similarity of the respective lithologies in the Upper part of the Bulawayan succession. However, no major unconformity between the Lower and Upper Groups, such as exists at Mberengwa, was detected in the Redcliff area (Cheshire, 1979).

In spite of its great age the Bulawayan Group has suffered, in the main, comparatively little metamorphism, the grade varying from lower to middle greenschist facies.

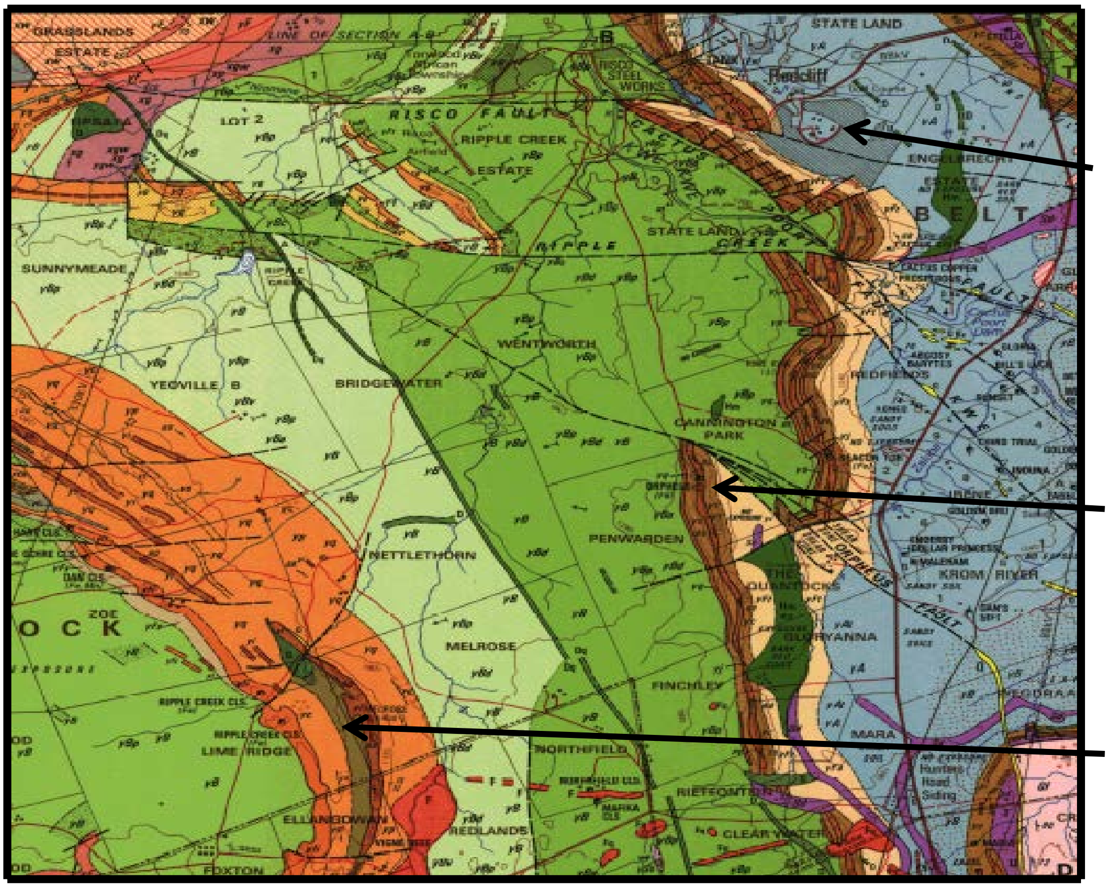
The Sebakwean Group, which is exposed some 27km to the Southwest of Redcliff, and the Shamvaian Group 10 km to the northwest, do not include any Iron-formations that bear economic iron orebodies.

The Bulawayan Group was considered by McGregor (1937) to consist of a simple syncline, the oldest members coming to the surface at the margins of the belt and the youngest being exposed in the middle. Cheshire et. al. (1979) are in dispute with this explanation and believe that both the Lower and Upper units have an antiformal development in the far East where the rocks are intruded by the Rhodesdale granites. Cross-folding causes the main trough to plunge gently both to the Northwest and Southeast. The Bulawayan Group comprises the following Formations (Cheshire et. al. 1979).

UPPER BULAWAYAN GROUP	
Sunnymeade Mafic Formation	Basaltic pillow lavas with minor doleritic greenstones. Subordinate iron-formation.
Minor Unconformity	
Lannes Sedimentary Formation	Immature to mature felsitic clastic sediments varying from argillites to conglomerates. greywackes, oxide facies and sulphide facies Iron-formation. Minor Limestone.
Minor Unconformity	
Ingwenya Mafic Formation	Massive actinolitic lavas, and doleritic greenstone. Basaltic pillow lavas. Minor andesitic and dacitic lavas and pyroclastics.
Gradational contact	
Fife Scott Formation	Basaltic and ultramafic lavas. Ultramafic intrusives.
Faulted Contact (Minor local unconformity?)	
Recliff Jaspilite Formation	Felsitic shales, grits, and minor conglomerates (re-worked pyroclastics). Iron-formation and quartzite.
Minor Unconformity	
LOWER BULAWAYAN GROUP	
Kwekwe Felsitic Formation	Felsitic tuffs and lavas. Andesitic and dacitic pyroclastics and lavas.
MAJOR UNCONFORMITY.	

The Redcliff Jaspilite Formation bears strong lithological similarities to the Manjeri Formation which forms the base of the Upper Bulawayan Group in the Zvishavani-Mberengwa schist belt. Although Cheshire has assigned the Redcliff Jaspilite Formation to the Lower Bulawayan succession in this area he entertains the possibility that, like the Manjeri Formation, it may form the basal member of the Upper Bulawayan. The writer is of the view that Cheshire’s latter suggestion should be adopted. A definite unconformity, albeit minor, can be demonstrated at the base of the Redcliff Jaspilite Formation where there is an angular discordance of the bedding of these rocks with the foliation of the underlying volcanics of the Kwekwe Felsitic Formation.

GEOLOGICAL PLAN OF THE REDCLIFF AREA



REDCLIFF

ORPHEUS MINE

RIPPLE CREEK MINE

3. STRUCTURE

The general fold pattern is a curved Northwest to North-north-west trending synform and antiform. Major cross-folding on a West to Northwest axis has given the greenstone belt a sinuous appearance and causes the earlier folds to plunge North and South.

Renewed activity on the cross-folds gave rise to faulting along the axial plane. eg. The Orpheus Fault (Cheshire, 1979). A set of East-West compressional faults is evident in the sedimentary horizons. This faulting which causes the overlap of the Iron-formation members is probably also related to the later cross-warping of the schist belt. There is the possibility that this East-West set of faults influenced the genesis of the haematitic iron orebodies.

4. RIPPLE CREEK IRON ORE DEPOSIT

4.1 Location

The Ripple Creek iron ore deposit lies on Limeridge and Ellangowan farms 17km southwest of the Zisco (New Zim Steel) Steelworks. Access to the mine is via a dirt road directly from the Steelworks or via a narrow tar road from Hunters Road railway siding which is approximately 24km from Kwekwe on the main road to Gweru. The orebody is covered by 10 blocks of base metal claims (Ripple Creek 1 to 9 and Grasskop pegged in 1961). Narrower horizons of ore to the north are covered by Zisco’s Dan and Mel claims. The narrow southern extension is covered by the Ripple Creek South claims.

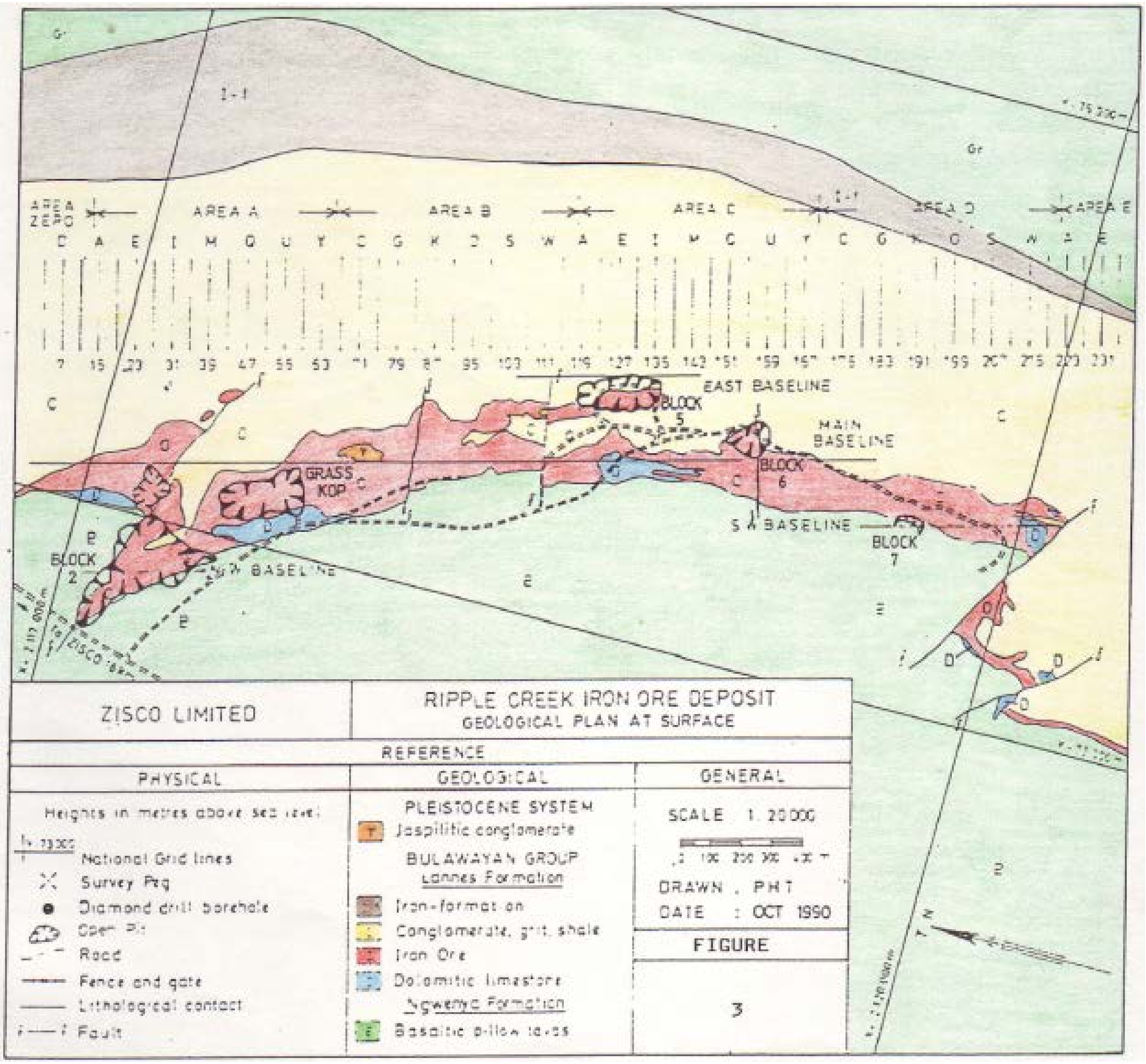
4.2 Stratigraphy

Travelling westwards from Zisco one crosses massive and pillowed lavas of the Ingwenya Mafic Formation and then basaltic lavas of the uppermost part of the Bulawayan Group, the Sunnymeade Mafic Formation. The eastern limb of the intermediate Lannes Sedimentary Formation is not exposed in this area and, due to faulting, marked by a dolerite dyke, the Sunnymeade Formation lies directly on top of the Ingwenya Formation. As one approaches Ripple Creek Mine the western limb of the Lannes Formation is crossed.

The Ripple Creek orebody lies near the base of the western limb of the Lannes Sedimentary Formation and is separated from the underlying lavas of the Ingwenya Formation only by a thin (± 5 metre) bed of felsitic shales and narrow lenticular horizons of dolomitic limestone.

4.3 Orebody Structure

The Ripple Creek iron ore deposit comprises the thickest portion of a long gossanous orebody that strikes northwest – southeast and forms a part of a 35km strike of gossanous rocks. The main deposit has a strike length of 3,5km, an average surface width of 155 metres and extends to an average depth of 150 metres. The footwall of deposit has a dip varying from 53° to 68° with an average dip of 61° to the northeast and is complicated structurally by several Northwest-Southeast and East-West striking faults. The hanging wall contact is somewhat irregular and dips either west or east but in general has a mushroom shape caused by a westward dip at surface which at depth changes to an easterly dip paralleling the footwall. It is uncertain whether this hanging wall contact is conformable with the overlying clastic sediments or whether it transgresses them.



4.4 Ore Genesis and Mineralogy

The depth of the orebody is controlled by the oxide-sulphide interface which is a reflection of the depth of weathering. The shallowest intersection of sulphides is at 115 metres below surface on the hanging wall (east) side of the body. Diamond drill holes have reached sulphides at 150 metres below surface in the middle of the orebody and iron oxides have been found to persist to 210 metres in places in the footwall of the deposit. The oxide-sulphide contact is often sharp but highly irregular. Inter-digitations of tongues of the two phases is common. Within the hydrated oxide zone the alteration process is complete and no pyrite remains. There is sometimes a narrow zone of incipient oxidation of the sulphide minerals and without doubt a supergene process controls the ore genesis.

In contrast to the enrichment of oxide facies iron-formation there is little dispersion of the silica during the supergene oxidation of the sulphide horizon. In fact, it would appear that a residual concentration of silica in the hydrated iron oxide occurs as the silica is higher in the limonitic gossan than in the underlying sulphides.

The drilling of the Ripple Creek deposit revealed that the water table within the ore zone is depressed in relation to the water table in the country rocks. It is partly due to this phenomenon that the oxidation of the pyrite has extended to depths as great 150 metres from the surface. It is believed that the water table within the orebody is low due to the relatively small inflow of water into the ore and pyrite horizon. A closed system is created by the existence of impermeable beds of argillites lying stratigraphically above and below the limonite-pyrite horizon and a hard-cap at the surface. The hard-cap is produced by upward movement of iron-bearing water during the dry season. The iron is deposited from the solution at the surface where the water evaporates. This cements and seals the cavities in the otherwise very porous ore. The upward movement of water, and its evaporation, depletes the volume that gained entry to the orebody in the wet season, and thus an artificially lowered water table is maintained. The limonite hard-cap, furthermore, ensures that the orebody has a positive relief and this results in a rapid run-off and poor permeation of meteoric water.

It is also believed that the water table was at a considerably reduced level during the Kalahari Period (3 – 4 million years ago) and also possibly during the Karroo Era thus further facilitating the depth of oxidation of the sulphides.

The ore consists predominantly of yellow to brown limonite and other subsidiary hydrated iron oxides with minor amounts of reddish-brown haematite and grey pyrolusite and is considered to be the alteration product of a massive pyrite body or a sulphide facies Iron-formation. The ore is friable, earthy and very porous and hence about 70% of it has to be sintered prior to charging into blast furnaces. The manganese tenor of the ore is variable and there is a tendency of greater concentrations to occur in the region of footwall dolomites. The iron content of the deposit is extremely inhomogeneous and varies from almost nothing in the intercalated shale bands to up to 62,8%, although most of the ore zone contains over 45% Fe. The variation in iron is caused mainly by differing amounts of clastic or pyroclastic detritus within the original massive sulphides or sulphide facies Iron-formation. This material remained in place during oxidation of the sulphides and thus dilutes the ore. A subsidiary cause of the variation in iron content is the relationship between the proportions of haematite and limonite. Unlike the hard haematite variety of ore found at Orpheus Mine and Buchwa the Ripple Creek ore is generally friable. An average coarse to fines ratio is in the region of 30: 70. Small areas of harder ore at a coarse to fines ratio, after crushing and screening at < 31,5mm > 10mm, of 50: 50 exist. This material is generally more haematitic.

4.5 Exploration

Various phases of exploration were undertaken on the Ripple Creek Deposit;

4.5.1 Between 1962 and 1964 extensive mapping, trenching and percussion drilling was carried out. Drilling was undertaken at a spacing of 30 metres x 30 metres. 1 240 holes with a total length of 24 673 metres and an average depth of ± 20 metres were drilled by contractors.

4.5.2 Between 1974 and 1975 contract Diamond Drilling at a spacing of 120 metres x 120 metres was performed. Sixteen holes with a total length of 2 118 metres were drilled.

4.5.3 Further Diamond Drilling with in-house, Buchwa Iron Mining Company (Bimco), drilling equipment took place between 1980 and 1989. This was at a spacing of 60 metres x 60 metres. 125 holes were drilled totaling 17 617 metres at an average depth of 141 metres (deepest hole: 286 metres). The drilling was extremely difficult due to the friable and broken nature of the ground and core recoveries were relatively low (< 50%).

4.5.4 In-fill percussion drilling with in-house (Bimco) track drills at a spacing of 30 metres x 15 metres took place throughout the 1980s. Generally depths of ± 35 metres were achieved.

4.6 Ore Resources

Measured, Indicated and Inferred Geological Resources of Ripple Creek and Grass Kop at 31 December 2007 amounted to 128,3 million metric tonnes at 52,2% Fe, 1,6% Mn and 9,9% SiO_2. (111 million tonnes in the Measured category). Sulphur and phosphorous contents are generally < 0,05%. Nickel, lead, copper and cobalt contents are below 100 ppm and zinc and arsenic values below 200 ppm. Selective mining has been carried out to produce ore at 53,5% Fe, 1,6% Mn and 8,0% SiO2, in order to provide a grade acceptable to the Zisco blast furnaces. The Proved Mineable Ore Reserves at this grade at December 2007 amount to 54 million tonnes giving a life, at a Zisco’s theoretical production capacity of 960 000 tonnes/annum of hot metal (liquid iron), of about 30 years.

The resources are based on a cut-off of > 40% Fe and < 12% $SiO_{2.}$

4.7 Mining

Ore extraction at the mine is by conventional open pit methods of drilling, blasting, loading and off-highway dump-truck or ADT haulage with a capacity to produce 160 000 tonnes/month at a stripping ratio of 1:1,5. Mining generally took place at several faces simultaneously to achieve an even blend of the very inhomogeneous ore.

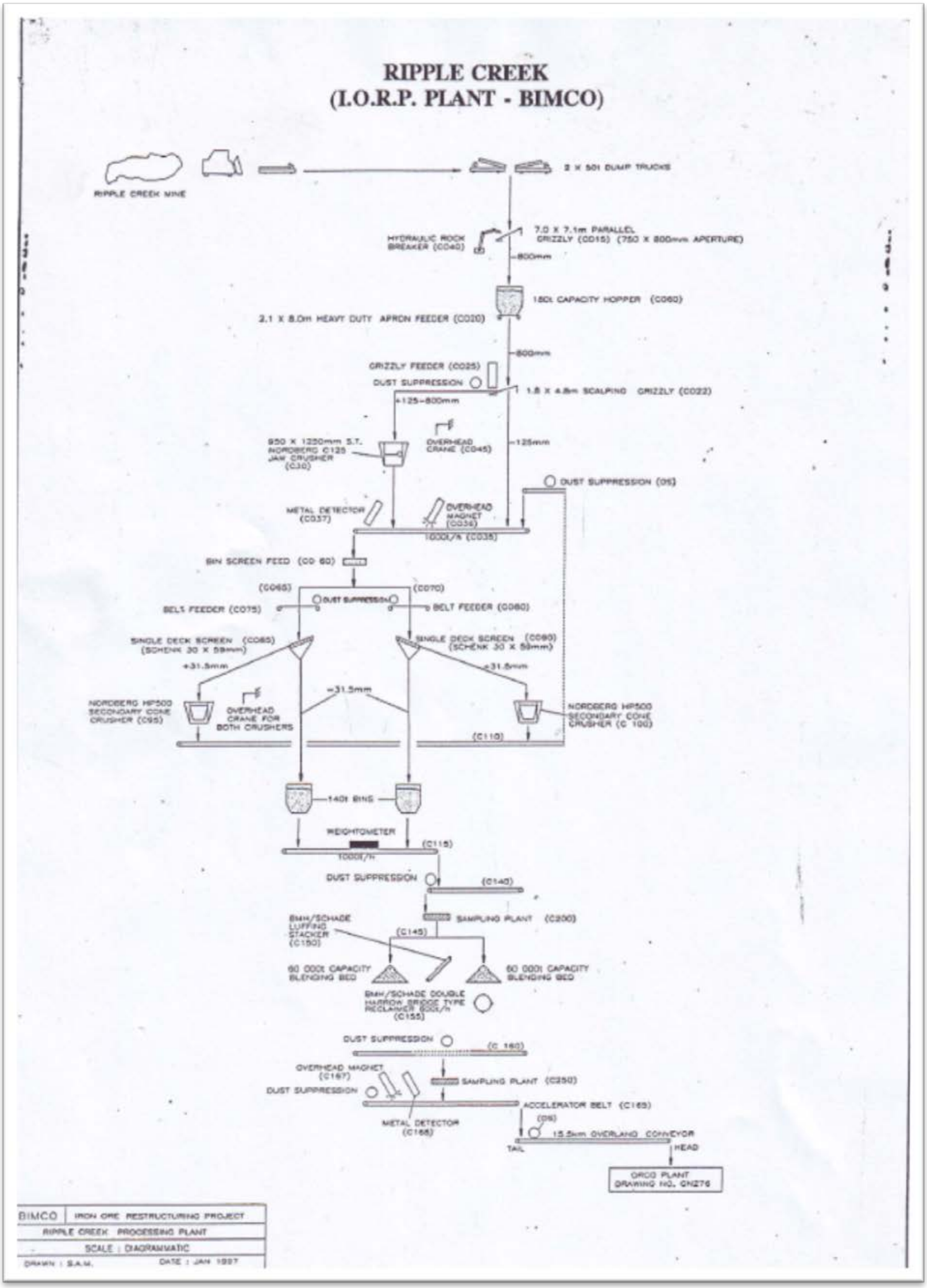
4.8 Ore Processing

Ore processing at the mine includes primary jaw crushing, secondary gyratory crushing, stacking, blending and reclaiming. The secondary crushers are in closed circuit with “banana” screens so as to ensure that all the ore is reduced to < 31,5mm. The banana screens are specially designed to deal with the ore which is very “sticky” in the rainy season. The plant has a metal detector, a tramp iron electro-magnet, a sophisticated automatic sampler and a dust suppression system. The plant is capable of treating 1 000 tonnes/hour. The < 31,5mm product from the two 60 000 tonne blending beds is transported to the Zisco Steelworks by means of a 500 tonne/hour 15,5km single flight steel-cord conveyor – one of the largest of its kind in the world. The 755mm wide conveyor belt travels at 4,25 metres/second and is powered by four 250kW electric motors. At the steelworks ore & coal handling plant (ORCO) the ore is screened into two fractions (> 10mm and < 10 mm). The < 10mm material is fed to a sinter plant and the > 10mm goes to the blast furnaces. There is a tertiary crushing system and the > 10mm fraction can be reduced to sinter feed if desired. The ore can be mixed with material from other sources such as Buchwa and is also re-blended at the ORCO plant to improve its homogeneity. The plant was commissioned in 1997 but has remained idle since March 2008 when the Steelworks ceased to function.

4.9 Production

Production commenced at Ripple Creek in 1965 when there was an output of 5 114 tonnes which was hauled by road to the steelworks.

Up to the end of 2006 a total of 8 557 674 tonnes of ore has been produced. The maximum annual delivery to Zisco was in 1988 (595 728 tonnes). Mining was carried out by contracting companies such as Richard Costain (with Squirrel and Popplewell doing the blasting), Boart Drilling & Contracting and finally Gullivers until 1992 when it was taken over entirely by Buchwa Iron Mining Company. Deliveries to the steelworks were by road until 1997 since when it was transported by the 15,5km overland conveyor.



RIPPLE CREEK
(I.O.R.P. PLANT - BIMCO)

5. ORPHEUS MINE

Orpheus Mine lies on Penwarden Farm approximately 8 kilometres by dirt road due south of Ziscosteel.

Geologically the deposit lies in the Iron-formation of the western limb of the Redcliff Jaspilite Formation. The ore is a hard, dense, grey haematite enclosed by, and derived from, a finely banded grey and red Iron-formation. It is believed that the ore is of hypogene origin although supergene processes have not been ruled out. The ore has formed by the leaching of silica-rich bands and possible infilling of iron. Faulting of the Iron-formation and associated clastic sediments has taken place and separates the orebody from the nearby Beacon Tor deposit. The faulting could have played a role in the ore genesis.

It is believed that the claims were pegged in the late 1940s possibly when Zisco commenced operations in the area in 1947. The ore, which was of high grade (± 65% Fe and < 5% SiO_2 , was mined to "sweeten" the ore from the North Hill, Central Hill and South Hill deposits adjacent to the steelworks which were the main source of ore for iron and steel-making from the time it opened to 1975. Records are not available to indicate what quantity was mined from Orpheus and Orpheus South but it was possibly in the region of one million tonnes. Current Resources are as follows:

Orpheus: 224 000 tonnes at 62,0% Fe, 0,25 Mn and 6,0% SiO_2

Orpheus South: 367 000 tonnes.

Total: 591 000 tonnes.

In addition to haematite ore for steelmaking Orpheus Mine is the source of Red Ochre. The ochre, which is a soft, iron stained talcose material, has been mined and pulverized by Bimco and sold as a colouring agent to various industrial users.

1. REFERENCES

A.M. Macgregor
Geological Survey Bulletin No. 31
The Geology of the Country around Hunters Road, Gwelo District.
Salisbury 1937

P.E. Cheshire, A. Leach and S.A. Milner
Zimbabwe Geological Survey Bulletin No. 86
The Geology of the Country between Gwelo and Redcliff.
Salisbury 1980

C.G.A. Castelin
Bimco Internal Confidential Reports
Redcliff 1970 to 2008

CCLT/C:, ExtHD/Geological Society/GSZ visit to Redcliff\Tour of Redcliff Iron Ore Deposits 2014-10-26 (MSW – 2007)-
Prepared by Charles Castelin October 2014