# Kitumba – a new kind of copper deposit in a Zambian context

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## Zambia's copper focus

Zambia's economy has historically been based on its copper mining industry, with the Copperbelt being the main centre of production for the past 100 years or so. It is thought that mining and smelting were introduced to Zambia around AD 650, based on old smelting sites and ornaments found in burial sites (Cikin and Drysdall, 1971). Old workings based on malachite outcrops are known from the Kansanshi, Copperbelt, and Mumbwa areas in Zambia. The first European exploration activity in 1895 by the Northern Territories (BSA) Exploration Co. expedition confirmed that large copper deposits existed in Central Africa. Discoveries occurred in rapid succession in the early 1900s and by 1938, the Copperbelt was already producing 13% of the world's copper.

Following a long history of production from the central or traditional Copperbelt, significant production is now coming from the Kansanshi (First Quantum Minerals) and Lumwana (Barrick Gold Corporation) operations some 200 km to the west. Other major projects in the pipeline within the latter area include First Quantum's Trident project. Should all this production come on line, this will potentially elevate Zambia to the position of the fifth largest copper producing country in the world.

Numerous other copper occurrences are known throughout central and western Zambia, mostly as a result of prospecting in the early to mid-1900s. Much of the early exploration effort in this region was focused on the search for Copperbelt-style sediment-hosted deposits, but instead resulted in the discovery of vein- and breccia-type copper showings and deposits often associated with iron concentrations and, in some instances, gold. These types of deposits have come to be known as iron oxide copper-gold (IOCG) type deposits, with the best known example being Olympic Dam in Australia.

The locations of the Zambian Copperbelt, Kansanshi, and Lumwana operations, and the subject of this paper, the Kitumba deposit, are shown in Figure 1.


*Figure 1. Location of Kitumba relative to the Central African Copperbelt*

**Copper in the Mumbwa District, west central Zambia**

The area around Mumbwa in west central Zambia was historically a particular focus for exploration and small-scale mining and was known as the Big Concession (Figure 1). The area covered by the Big Concession lies on a plateau at an average altitude of 1 160 m above sea level (Cikin and Drysdall, 1971), and is broken by hills made up predominantly of various intrusives of the Hook Granitoid Complex as well as extensive zones of iron oxide replacement. The Kitumba Hills in the central parts of the Big Concession area represent the most elevated landscape in the region (Figure 2). These hills show a marked alignment of ridges parallel to the main north-northwest – south-southeast tectonic trend.

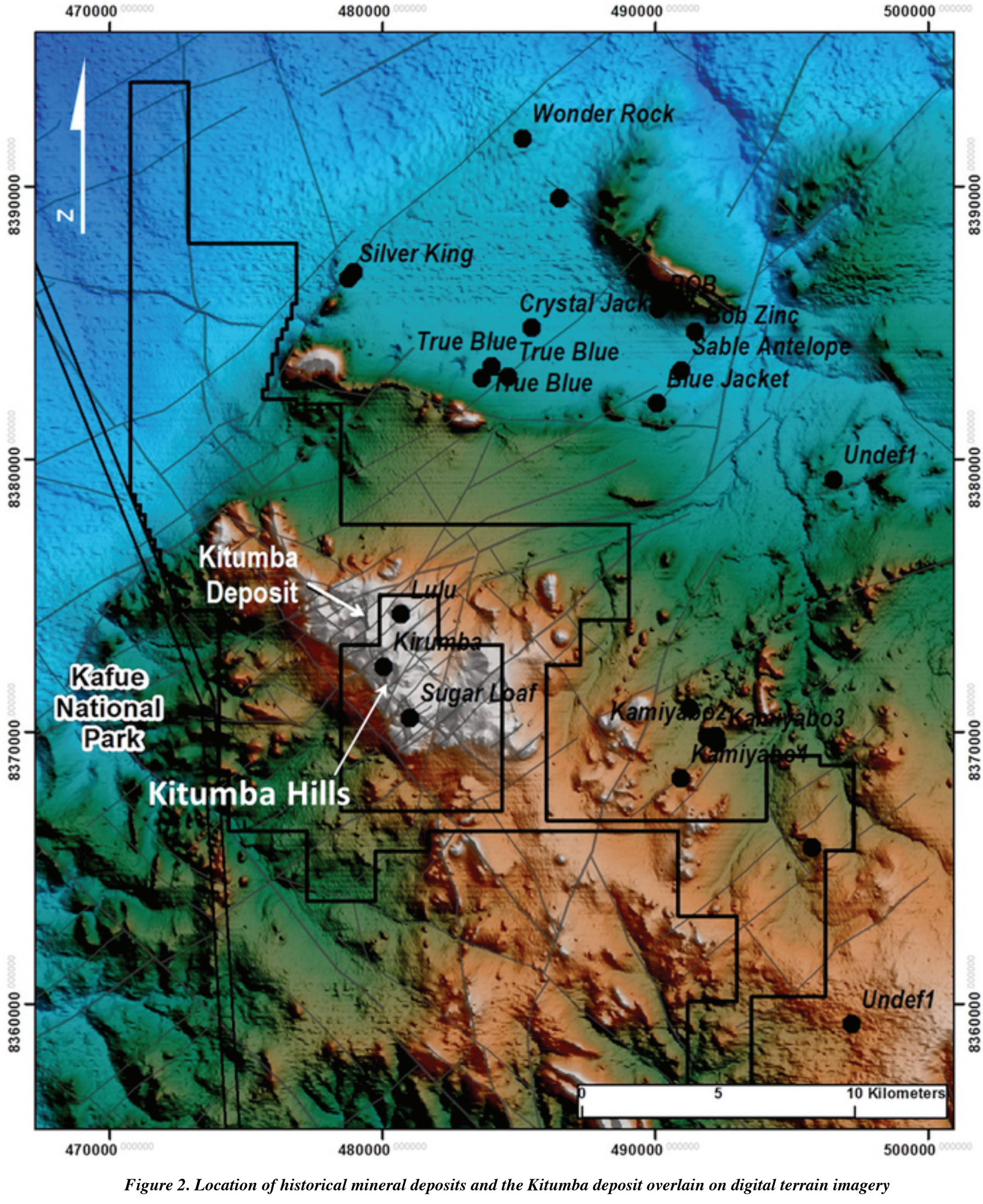



*Figure 2. Location of historical mineral deposits and the Kitumba deposit overlain on digital terrain imagery*

A summary of the exploration and mining history of the Big Concession area is shown in Table I**.** Prospecting in the area dates back to 1895 following the discovery of ancient workings (Cikin and Drysdall, 1971). Approximately 1800 km$^2$ was pegged by the Northern Copper (BSA) Co. Ltd., with subsequent ownership changes over the years. The Big Concession became known for numerous base metal showings and deposits, with a number of these operating as small-scale mines targeting shallow mineralization mainly during the period 1906 to 1923.

The principal examples are Hippo (reportedly the first copper mine in Zambia), Silver King, Crystal Jacket, Maurice Gifford, True Blue, Sable Antelope, North Star, Kamiyobo, Lou Lou, and Sugar Loaf/Copper Queen (copper deposits); Bob and Wonder Rock (lead-zinc deposits); Ninga Hill (gold-silver occurrence); coal (Hot Springs coalfield); as well as large deposits of iron oxides. The locations of these deposits are shown in Figure 2. Photographs illustrating some of the early mining activity in the region are shown in Figure 3. At the time, copper was the most important commodity, with numerous occurrences of secondary (mostly supergene enrichment) and primary copper mineralization. Iron deposits are numerous, but tend to be low grade haematite- and/or magnetite-bearing and occur as replacement, breccia, vein, and lateritic type deposits. It is interesting to note that Kitumba remained a blind and undiscovered deposit until 2006, with no surface expression of copper mineralization. The nearest historical workings to the Kitumba deposit are located at Lou Lou, 1200 m to the east of Kitumba.

In the 1920s, attention shifted to the Copperbelt, and the Mumbwa region saw little further exploration activity until the early 1990s.

**Table I. Summary of the exploration and mining history of the Big Concession area, Mumbwa district**

| Period | Company | Activity | Area |
|---|---|---|---|
| 1895 - 1898 | F.R. Lewis and O. Baragwanath | Ancient workings discovered | |
| 1903 - 1930s | Northern Copper (BSA) Co. Ltd | Pegged 1800km$^2$; Prospecting and shallow mining of mostly supergene-enriched mineralisation between 1906 - 1923 | |
| | Kafue Copper Development Company Ltd | | |
| | Rhodesia Copper Company | | |
| 1955 | Geological Survey of Zambia | Mapping of the Big Concession area | |
| 1955 - 1960 | Mineral Search of Africa | Geochemical and geophysical surveys; minor drill testing | Many including Lou Lou, Sugar Loaf, Kamiyobo |
| 1957 - 1964 | Chartered Exploration Ltd | Soil and drainage geochemical sampling; minor drill tesing | 8km NW of Lou Lou; Kamiyobo, near Sugar Loaf |
| 1969 - 1972 | UNDP | Airborne magnetic and electromagnetic (INPUT) survey; soil geochemical surveys; ground geophysics; diamond drilling | Widespread with focus on Lou Lou and Sugar Loaf |
| Mid 1980s | Minex | Assessment of phospate potential; mapping, soil geochemical surveys, ground geophysics, drilling | Sugar Loaf and NE of Sugar Loaf |

***Old plant infrastructure at the Hippo Mine site, Kafue National Park***

***Old UNDP drill-hole collar, Sugar Loaf prospect***

***Old steam traction engine possibly used to transport copper matte to Broken Hill (now Kabwe)***

***Figure 3. Past mining and exploration in the Big Concession area***

The Mumbwa district represents a prospective IOCG province that is related to tectonic activity and voluminous anorogenic alkali and granitoid magmatism of the Hook Granitoid Suite that took place from 570-500 Ma along a Pan-African transform plate boundary separating the Congo and Kalahari cratons. Numerous copper-gold and iron oxide occurrences are known in the district and are noted on the Geological and Mineral Occurrence Map of Zambia. These occurrences display many of the typical characteristics of IOCG systems. This prospective IOCG province extends from south of Mumbwa at least as far as Kasempa, 150 km to the north of the Kitumba deposit. In the Kasempa areas, related diorite/syenite bodies intrude Kundulungu metasediments, with associated with iron oxide alteration and brecciation. The search for copper was focused historically on Copperbelt-type deposits, but resulted in the discovery of copper mineralization associated with haematite and/or magnetite typically in the form of veins and breccias. The significance of this style of mineralization was not appreciated at the time, in terms of a mineralization model.

The development of the IOCG mineral deposit model in the 1990s was prompted by the discovery of the giant Olympic Dam and related deposits in the 1970s. The key features of these types of deposits have been described by Lefebure (1997), Hitzman (2000), (Sillitoe (2003), and Corriveau (2007) and are summarized below.

- IOCG deposits comprise a broad range of mineralization styles, grouped together chiefly because they contain hydrothermal magnetite and/or specular haematite as major accompaniments (>20% Fe oxides) to copper sulphides. Apart from copper and by-product gold, appreciable amounts of Co, U, REE, Mo, Zn, Ag, Nb, and P may also be present
- IOCG–type deposits comprise a broad spectrum of mineralization styles from Kiruna-type monometallic (Fe ± P) to Olympic Dam type polymetallic (Fe ± Cu ± Au ± U ± REE) haematite-dominated systems to Cloncurry/Ernest Henry type magnetite-dominated systems
- Some IOCG deposits (typically haematite-rich) are characterized by breccias at various scales, with iron oxide and host rock fragments which grade from weakly fractured host rock to matrix-supported breccia (sometimes heterolithic) to zones of 100% iron oxide
- Deposits are structurally controlled by crustal-scale faults and fault splays, intersections, and dilational jogs. In addition, the vast majority of IOCG deposits are spatially and temporally related to a significant magmatic event on a regional scale. Further, many IOCG deposits are characterized by large-scale zoned hydrothermal alteration footprints.
- The morphology of IOCG mineralization varies significantly and includes breccia zones, veins, and irregular bodies that may occur as stratiform, stratabound or discordant deposits and disseminations to massive lenses, hosted by continental sediments and/or volcanics and/or intrusive rocks.

## Discovery and evaluation of the Kitumba deposit

The exploration history and discovery of the Kitumba deposit, and subsequent definition of the deposit, is summarized in Table II and in MSA (2012). In the early 1990s, Gencor identified large tracts of central, western, and northwestern Zambia as being prospective for Queensland-type Fe-Cu-Au and Olympic Dam Cu-U-Au IOCG deposits, as well as skarn-type deposits. Area selection was based on abundant oxidized post-tectonic intrusives associated with significant copper and iron occurrences.

Billiton obtained a prospecting licence in 1995 covering 8 900 km$^2$ and undertook a programme of soil geochemical sampling, ground magnetics, induced polarization (IP), and controlled-source audio magnetotelluric (CSAMT) surveys focusing on the area around the known deposits of Sugar Loaf and Lou Lou. In 1998 nine holes (4 core and 5 RC) were drilled totalling 1 867 m to test geochemical and geophysical anomalies. The holes were relatively shallow (maximum 302 m) and intersected deeply oxidized zones of haematite breccia and high altered intrusives and metasediments, carrying sub-economic grades of copper and gold. Five of these holes were located in the Kitumba Hills area, with best results of 274 m at 0.24% Cu, including 60 m at 0.6% Cu and 0. 1g/t Au in drill-hole KD3. The locations of drill-holes for each phase of work are shown in Figure 4.

The search for IOCG type deposits has been largely geophysics-driven, particularly by companies such as BHP Billiton. Following a joint venture with AIM Resources in 2004 (AIM became Blackthorn Resources in 2008), a BHP Billiton proprietary FALCON® airborne gravity, magnetic, and radiometric survey was flown over a 2000 km$^2$ area on 400 m spaced lines with 200 m infill over the Kitumba Hills area, as Phase 1 work. Detailed 3D inversion modelling of the data produced a total of 27 targets based on partially coincident gravity and magnetic anomalies with a favourable geological and structural setting, and preferably having coincident copper-in-soil geochemical anomalies. The basis for target generation was an Oympic Dam style IOCG model. The role of FALCON® airborne gravity gradiometer (AGG) in the Kitumba IOCG discovery is described in Christensen and Whiting (2013).

A total of 20 drill-holes were proposed to test 16 of these targets. Of the 20 drill-holes, 11 holes totalling 5 700 m were selected for drilling during the 2006/2007 Phase 2 work programme, only eight of which were completed as a result of challenging drilling conditions. These holes were sited over a strike length of 25 km, with five holes located in the Kitumba Hills area (Figure 4). The Kitumba Hills lie 50 km northwest of Mumbwa and represent a low-lying north-south trending range of hills dominated by haematite and magnetite replacement of metasedimentary rocks (Figure 5). This area was considered highly prospective for high-level haematite-dominant IOCG systems because of the presence of haematite breccias and pervasive sericite, kaolin, and haematite alteration, which were regarded as similar to the brittle style of deformation and alteration observed at the giant Olympic Dam deposit. In particular a north-south trending ridge of haematite breccia was considered prospective, with five holes having been drilled in the general vicinity in the late 1990s, obtaining low-grade copper intersections.

All holes were drilled vertically, except for the discovery hole S36-001, which was inclined at 70° on 090 and intersected 655 m at 0.46% Cu from 42 m depth. This was the first significant drill-hole to intersection at the Kitumba deposit. Although the deposit is overlain by anomalous copper-in-soil geochemistry and a radiometric uranium anomaly, no mineralization is observed on surface due to deep leaching. However, a prominent north-south trending topographic high has the appearance of a gossan due to massive haematite replacement, with iron and manganese having scavenged mobile metal ions. The upper 150-200 m of the deposit is strongly weathered, oxidized, and leached (leaving behind a geochemically anomalous area with copper elevated above background levels) This resulted in the deposit eluding discovery until late 2006, despite several historical holes in the immediate vicinity which produced 'smoke' intersections.

Follow-up drilling in the 2007-2008 Phase 3 programme confirmed continuity of the mineralization along strike for over 1 km through drilling of 16 holes at 100 m spacing on lines 200 m apart. This led to a maiden Inferred Mineral Resource estimate in 2009 of 87 Mt at 0.94% Cu at a cut-off of 0.5% Cu.

A high-grade core to the deposit delineated during ongoing infill drilling in Phases 5 and 6 is related to deep leaching and supergene concentration of secondary copper minerals along a north-south trending structurally controlled zone. The full extent of the high-grade core of the deposit was intersected in dril l-hole S36-038 which returned 305 m at 4.05% Cu. Ongoing drilling led to increased geological confidence and conversion of some of the Inferred resources to Indicated status (79.9 Mt at 1.3% Cu at a cut-off of 0.5% Cu) in June 2012. The latest mineral resource update in April 2013 included an Indicated Resource of 87.6 Mt at 1.17% Cu (0.5% Cu cut-off), including a higher grade core of 29.8 Mt at 2.13% Cu (1% Cu cut-off) (Blackthorn Resources, 2013). The deposit remains open to the west and northwest. Current drilling is aimed at converting some of the Indicated resources to Measured and increasing the global resource.

A plan showing the extent of drilling, surface geology, and projected 0.5% Cu and 1% Cu grade shells is shown in Figure 6. Section lines for schematic long and cross sections through the Kitumba deposit are shown in Figure 7 and Figure 8**.** A 3D rendering of the deposit is shown in Figure 9, along the same slice as the schematic long section.

The on-going exploration and evaluation of the Kitumba deposit has been managed by MSA since 2006, with all work carried out to the requirements of the JORC Code 2004.

**Table II. Discovery and evaluation of the Kitumba deposit**

| Period | Company | Phase | Activity |
|---|---|---|---|
| 1993 - 1994 | Gencore/Billiton | | Desktop studies, area selection |
| 1995 | Billiton | | Digital capture and reinterpretation of UNDP airborne geophysics, integrated interpretation, identification of 40 potential traget areas |
| 1996 | Billiton | | Soil geochemical survey and ground magnetic survey |
| 1997 | Billiton | | Induced polarisation (IP) and CSAMT follow up on geochemical anomalies |
| 1998 | Billiton | | Detailed soil geochemistry, IP, ground magnetics, 9 drillholes (4 core and 5 RC holes totalling 1,867m) to test soil, IP and CSAMT anomalies |
| 2000 - 2001 | Billiton/BHP Billiton | | Two deeper holes drilled (maximum 610m) to test mineralisation below the zone of oxidation |
| 2001 - 2004 | BHP Billiton | | Zambian operations closed down |
| 2004 | BHP Billiton/Aim Resources JV | 1 | Falcon™ gravity gradiometer, magnetic and radiometric survey over a 2,000km² area |
| 2005 - 2006 | BHP Billiton/Aim Resources JV | | Detailed 3D inversion modelling of Falcon™ data, integrated interpretation, generation of 27 targets |
| 2006 - 2007 | BHP Billiton/Aim Resources JV | 2 | Core drilling of 8 holes for 4,105m to test priority targets |
| 2007 - 2008 | BHP Billiton/Aim Resources JV | 3 | Resource definition drilling (28 holes for 14,712m) |
| 2009 - 2010 | BHP Billiton/Blackthorn Resources JV | 4 | Deep IP surveys and drill testing of a 15km long linear gravity anomaly to the north of Kitumba (26 holes for 18,670m) |
| 2011 - 2012 | Blackthorn Resources | 5 | Resource definition and step-out drilling (18 holes for 9,568m) |
| 2012 - 2013 | Blackthorn Resources | 6 | Resource definition and step-out drilling; satellite target testing (23 drillholes for 14,272m; 19 holes contributed to an updated Mineral Resource estimate) |
| 2013 - current | Blackthorn Resources | 7 | Infill drilling to upgrade Mineral Resource classification |

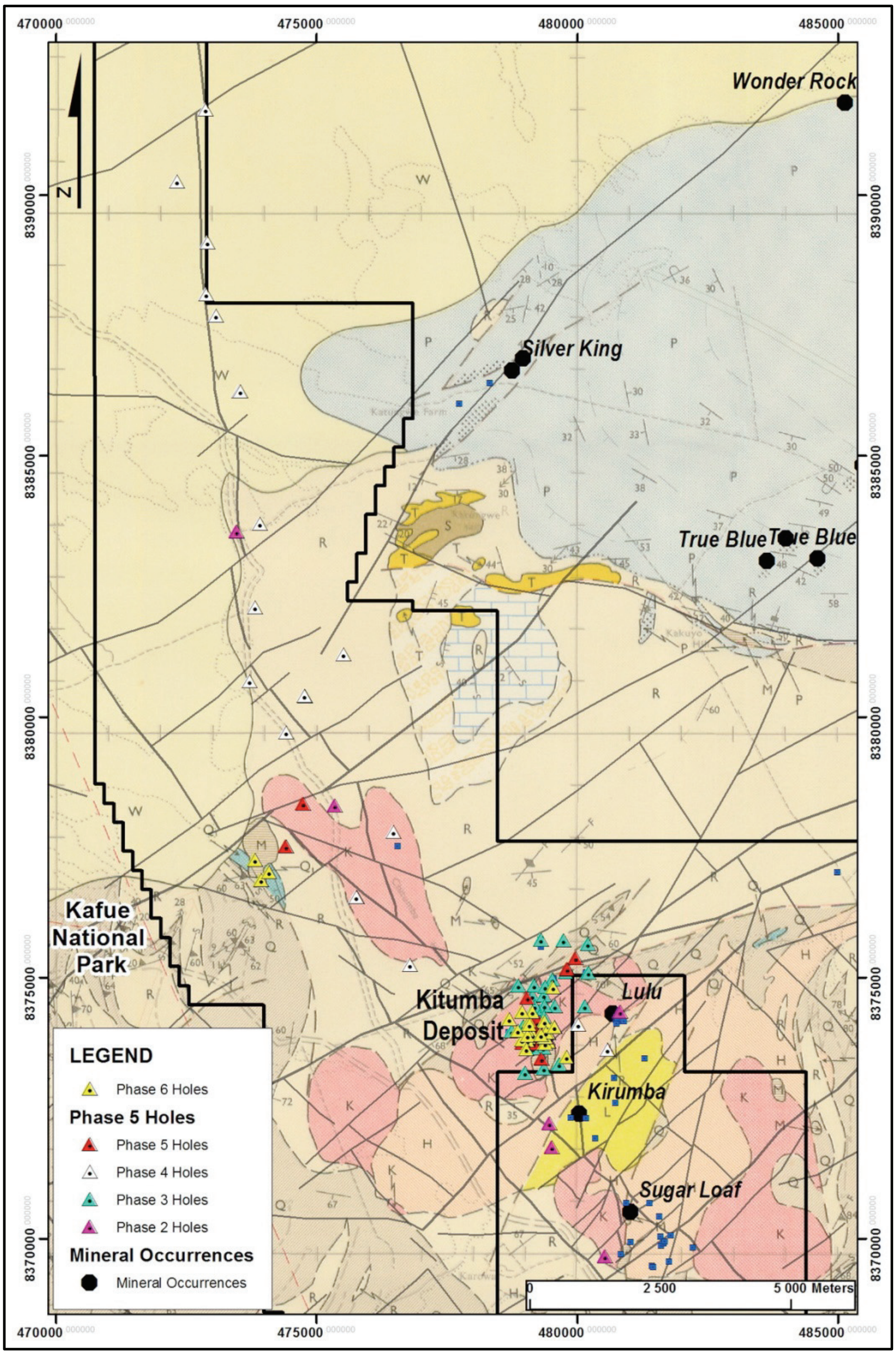



*Figure 4. Phased drilling defining the extent of the Kitumba deposit*

***Figure 5. Vista looking north from the Sugar Loaf deposit towards the Kitumba Hills***

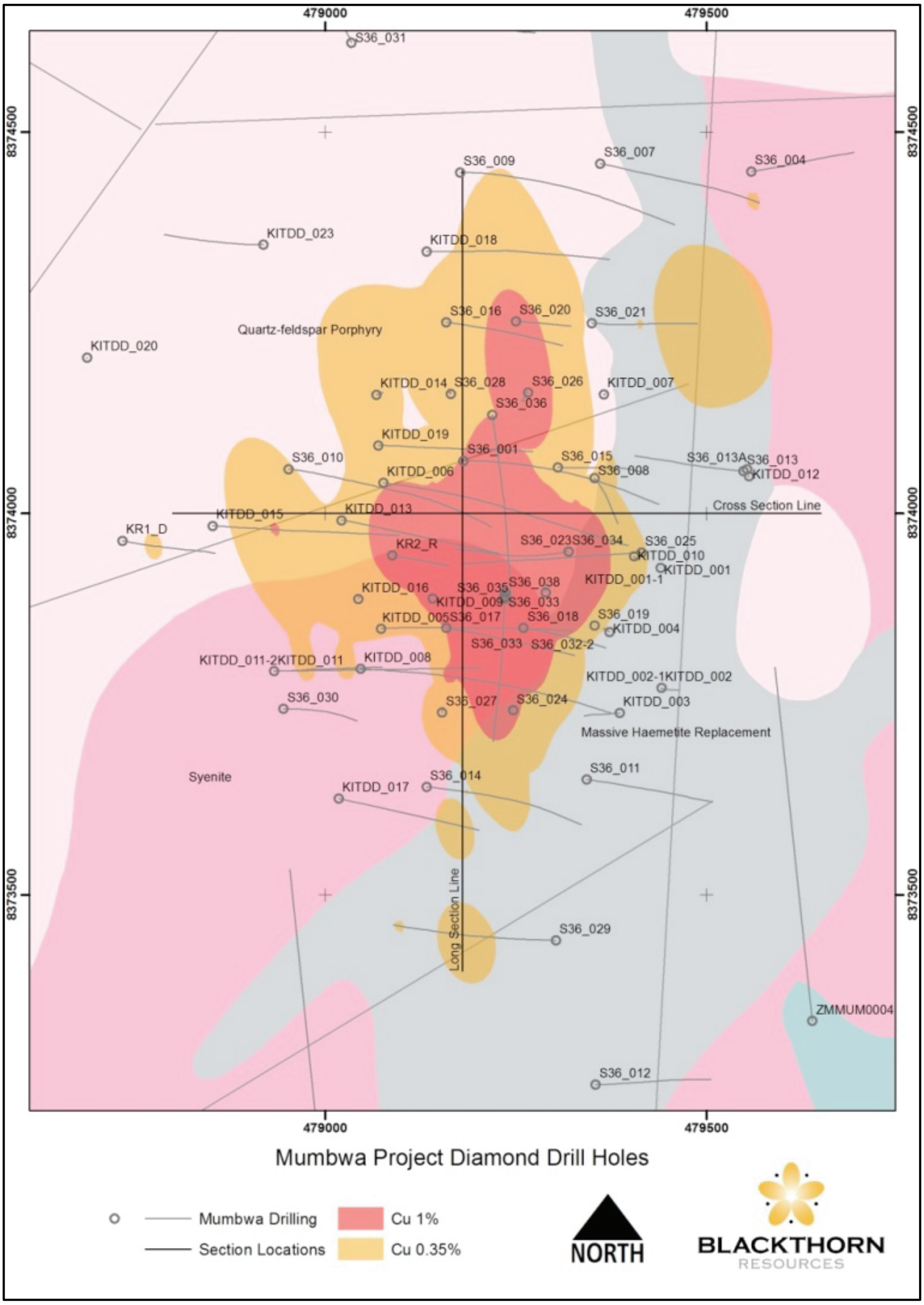



***Figure 6. Drill-hole location plan showing collar locations on surface geology and the surface projections of the 0.35% and 1% Cu shells. Also note the long and cross section location line***

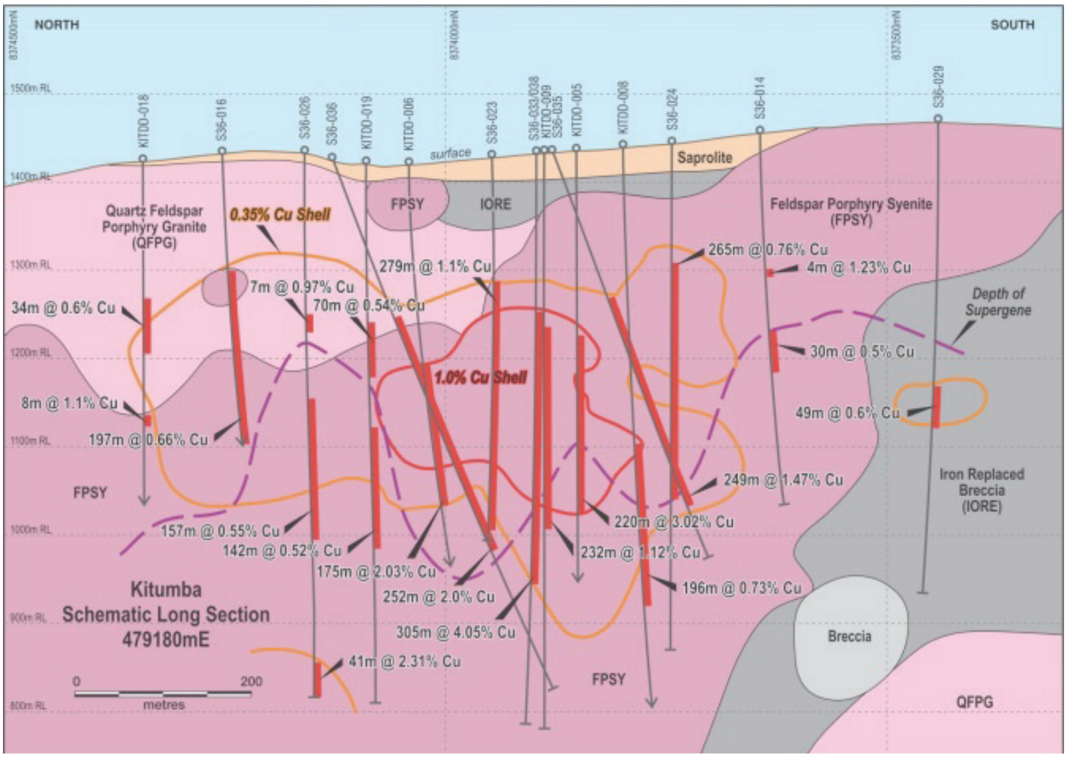



***Figure 7. Long section through the Kitumba deposit, looking east***

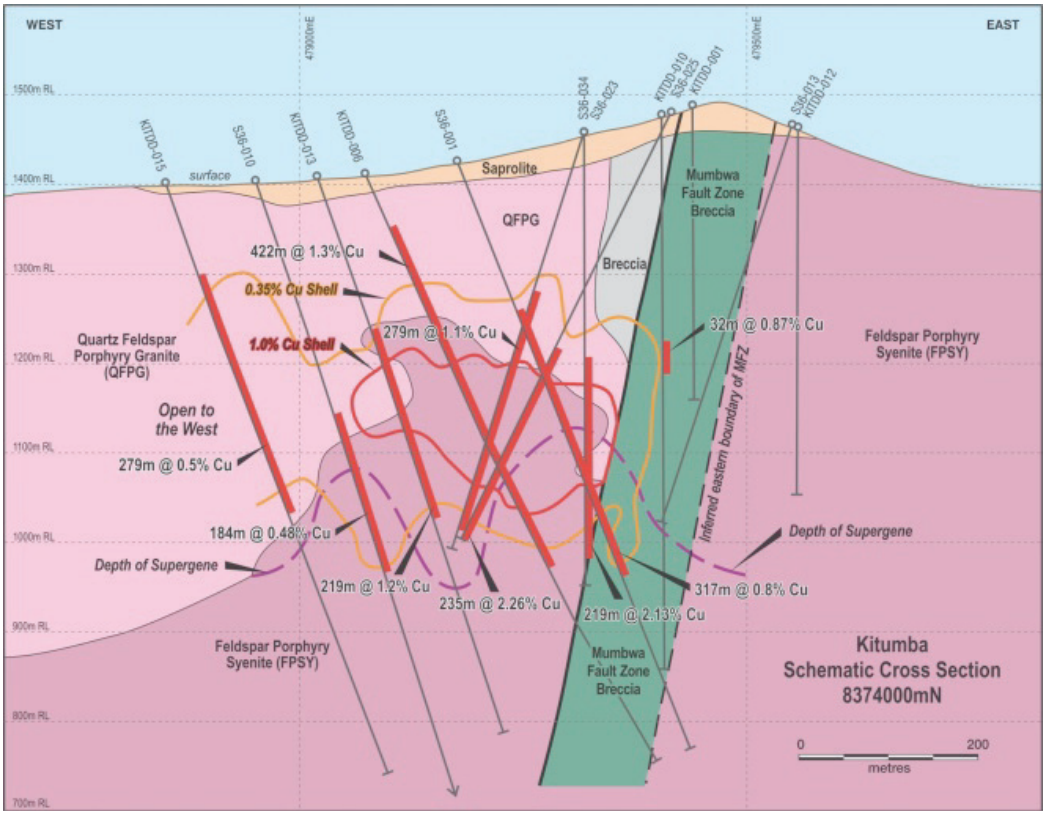



***Figure 8. Cross-section through the Kitumba deposit, looking north***

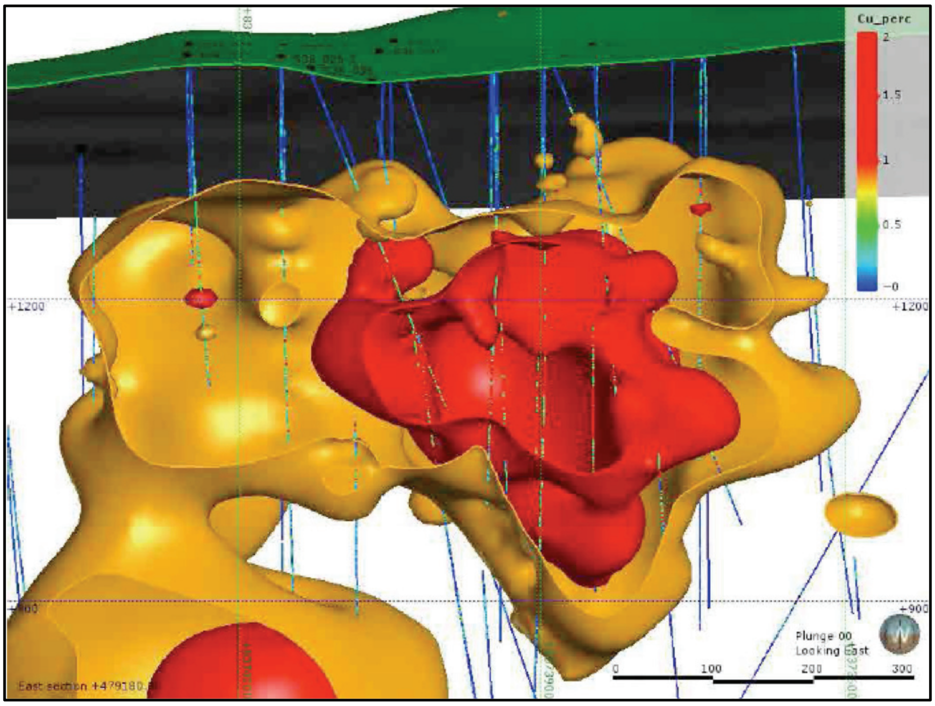



***Figure 9. Sliced 3D rendering of Kitumba deposit with drill-holes showing Cu grade (orange: 0.35%; red : 1%). The slice (479180mE) is the same as the schematic long section (Figure 7)***

**Geology, alteration, and mineralization at Kitumba**

The Kitumba deposit is located within the extreme southern portion of the Neoproterozoic Lufilian Arc. The Lufilian Arc is a large arcuate fold and thrust belt covering north-western Zambia, the southern Democratic Republic of Congo, and eastern Angola. This belt is separated from the Zambezi Belt to the south by the Mwembeshi Shear Zone (MSZ), a prominent crustal-scale east-northeast trending shear zone extending across Central Zambia. The Lufilian Arc comprises rocks of the Neoproterozoic Katanga Sequence, which in west central Zambia comprises metasedimentary rocks of the middle to lower Kundulungu Group. These comprise carbonates and calc-arenites interlayered with shales and siltstones, which are intruded by the large syn- to post-tectonic 566-533 Ma Hook Granitoid Suite and by younger post-tectonic syenites, porphyry granites, granites, diorites, and gabbros.

The Kitumba deposit is located within a giant iron oxide alteration system which is developed along a 26 km long north-northwest to south-southeast trending structural corridor referred to as the Kitumba Fault Zone (KFZ). The deposit itself is hosted within a haematite-dominated breccia system which is developed along the KFZ and which outcrops as a prominent north-south trending ridge forming part of the Kitumba Hills. Three principal rock type associations are recognised at Kitumba. Kundulungu Group calcareous siltstones and argillites are intruded by quartz-feldspar porphyry granite. These rocks are in turn extensively intruded by a feldspar porphyry diorite/syenite complex. The geometry of this system is considered to be sub-vertical and complex, arising from several phases of intrusion commonly in the form of dyke swarms (Figure 10).

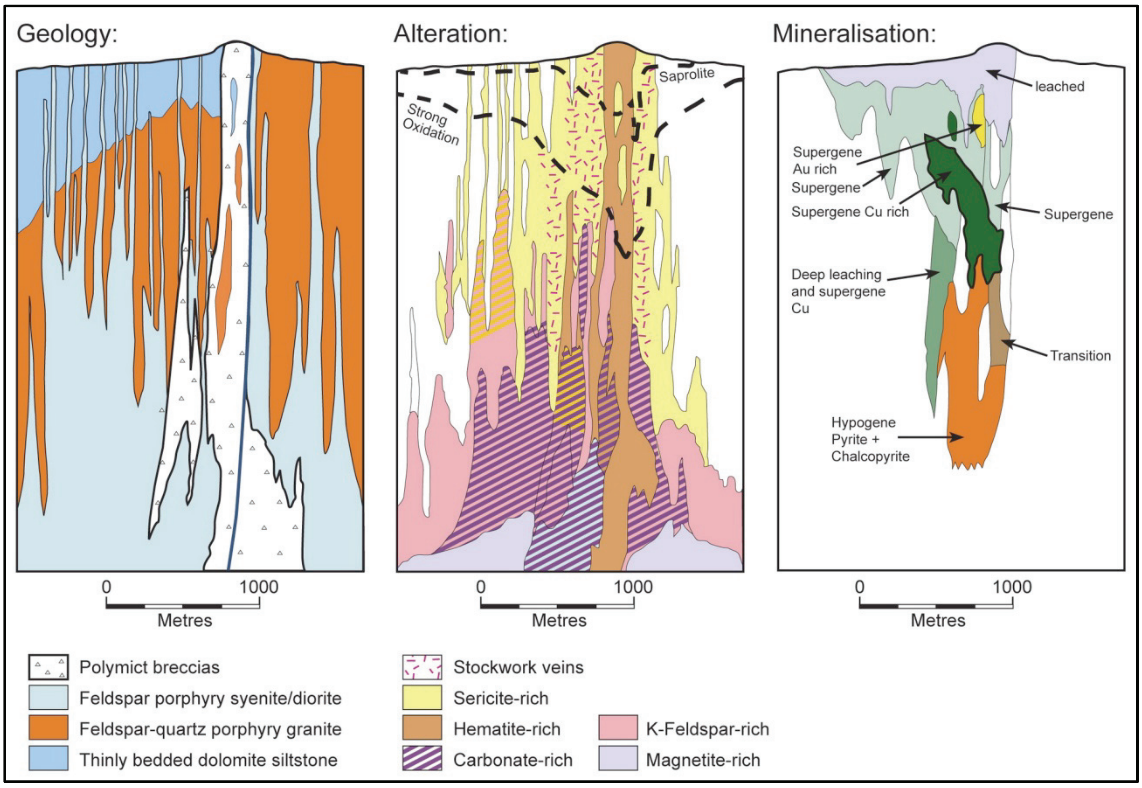



***Figure 10. Schematic section through the Kitumba deposit showing geology, alteration, and mineralization (modified after Hayward, 2008)***

Widespread brecciation is observed throughout the Kitumba area, ranging from incipient crackle breccias through jigsaw, mosaic, rubble, clast-supported, matrix-supported, disaggregation, and polyphase breccias to corrosive transported matrix- and clast-supported breccias. The central north-south trending ridge along the MFZ has been mapped as a 100 m to 400 m wide zone of brecciation and haematite replacement.

A classic IOCG-type alteration system is observed at Kitumba (Figure 10). The system is zoned from north to south, with deeper level magnetite-dominated alteration south of Kitumba to Sugar Loaf and higher level haematite dominated alteration over Kitumba itself. Potassium feldspar alteration is widespread and ranges from selective replacement of feldspar phenocrysts of porphyry granite and diorite/syenite, to clasts within earlier breccias, to pervasive replacement of all three main rock types. Sericite alteration typically overprints potassium feldspar alteration and is more prevalent in the distal parts of the system. Iron carbonate alteration is common and occurs both as pervasive siderite alteration and as crosscutting late-stage veins. A schematic section through the Kitumba deposit, showing the KFZ, alteration zoning, and the location of the high-grade supergene core of the deposit is shown in Figure 11**.**

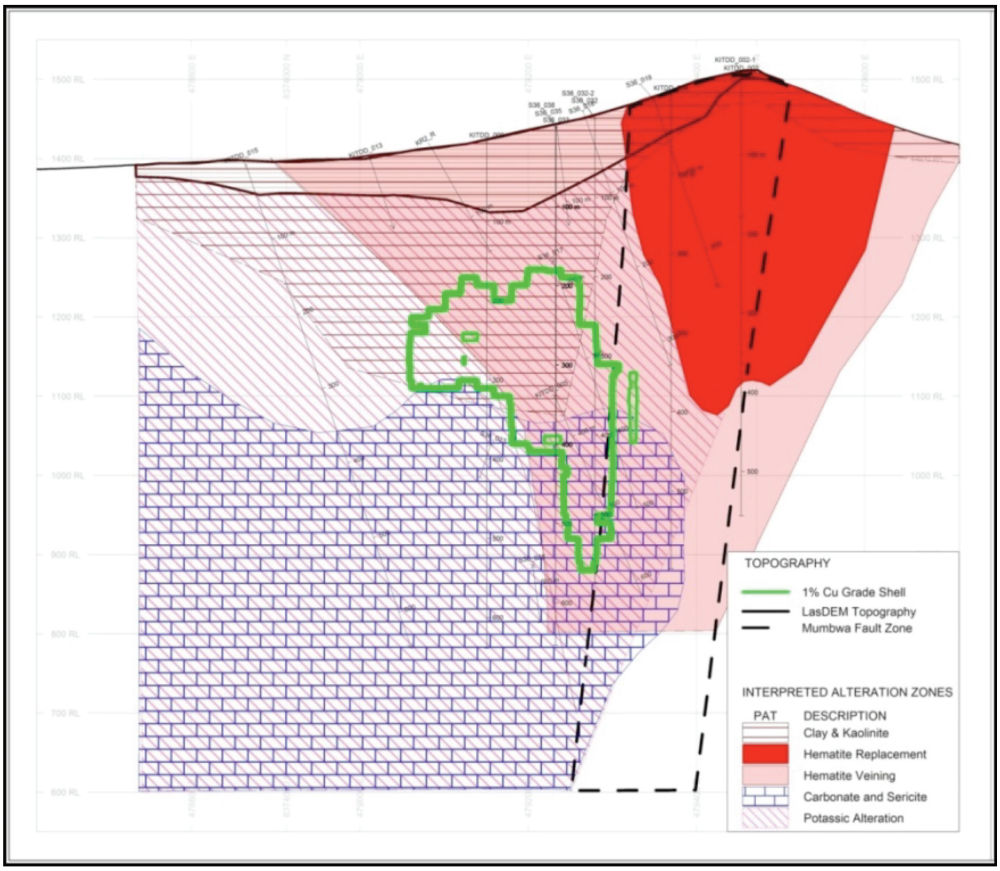



***Figure 11. Schematic section through the Kitumba deposit***

At Kitumba, a broad north-northeast trending copper-gold mineralized zone lies immediately adjacent to the western flank of a large north-south trending massive haematite replacement body, which forms part of the regional KFZ. The deposit as currently defined extends for 1.2 km along a north-south strike, has a width of 500 m, and extends to a depth of 640 m. The Phase 6 drilling campaign delineated the eastern limits of the deposit and extended the mineral resource to the west. The deposit is currently open at depth and to the northwest.

Copper mineralization comprises a simple hypogene sulphide assemblage that is extensively overprinted by oxidation and leaching with redistribution of copper into supergene assemblages (Figure 10). Deep weathering and oxidation extends up to 200 m from surface, with the result that this zone is depleted in copper. Deep weathering is particularly pronounced in the vicinity of the KFZ and zones of high fracture intensity, where leaching of the haematite-rich breccia system has typically resulted in porous and vuggy conditions. This is likely the reason for the unusually low density of these iron-rich rocks and explains why Kitumba is not mapped as a density anomaly in the FALCON® data. Oxidation of sulphides is noted at significant depths in some holes.

Hypogene mineralization occurs mainly as disseminated pyrite and subordinate chalcopyrite hosted primarily within altered diorite, and associated with stockwork veining and brecciation. Semi-massive concentrations of pyrite and/or chalcopyrite are observed in places. Primary sulphide mineralization is largely preserved within iron carbonate (siderite) altered zones, in some instances 'perched' at relatively shallow depths, where the carbonate has largely buffered alteration by oxidizing fluids.

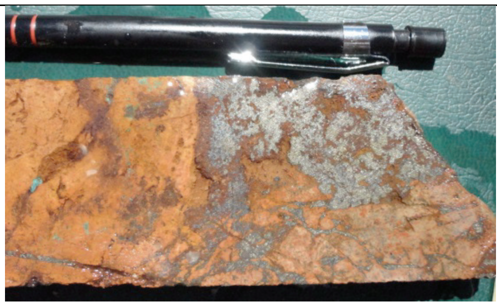
A significant proportion of the mineralization occurs in the form of secondary copper minerals formed through supergene processes within fractured and oxidized zones, where it occurs as malachite, pseudomalachite, chalcocite, cuprite, and native copper, as well as limonite after sulphides. The distribution of secondary copper minerals is related to remobilization of copper; with secondary copper minerals commonly occurring along fractures and as linings in cavities. The various styles of mineralization are illustrated in Figure 12. A zone of north-northwest to northwest trending intense faulting and fracturing in the south central part of the deposit has resulted in deep oxidation of the host rocks and remobilization and re-concentration of copper mineralization at depth. This supergene concentration has resulted in a high-grade core to the Kitumba deposit.

Gold is reasonably correlated with copper in the hypogene zones; but shows a poor correlation in oxidized zones. Gold-enriched zones appear to be controlled to a large extent by structure, notably along a narrow structural corridor to the immediate west of the haematite replacement body, east of the copper resource and at shallow levels along cross-cutting structures where gold appears to be concentrated by supergene processes.

Silver, uranium, and rare earth elements occur in anomalous concentrations and are unlikely to constitute a viable resource on their own; however these are potential credits as by-products to a copper-gold operation.

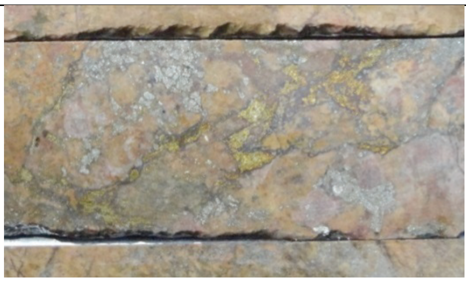
Pseudomalachite in brecciated altered diorite

Malachite, pseudomalachite and chalcocite in highly altered diorite

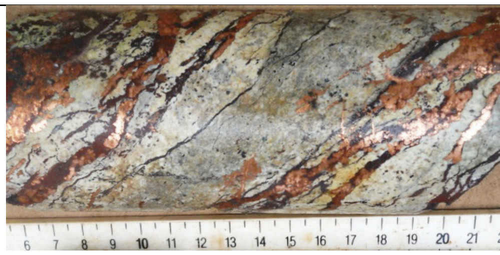


Remnant pyrite surrounded by chalcocite

Pyrite mineralised clast in altered diorite



Fracture-hosted pyrite and chalcopyrite in altered diorite



Native copper veining in altered feldspar porphyry diorite

***Figure 12. Examples of mineralisation styles in Kitumba drill core***

### Mineral Resources at Kitumba

During Phase 6, a complete review was conducted of all drill-holes within the resource area, based on an updated understanding of geology, alteration, structure, and mineralization. This included re-logging of all previous holes, revisions to the database, and improved inputs into the geological model.

Geological confidence in the deposit has been substantially improved through the discrimination of hypogene and supergene zones by means of detailed mineral zone logging, in both the historical and the new drill-holes. This information has also been fed into the prefeasibility (PFS) metallurgical studies.

Domain wireframes were created based on mineralization zone discrimination (leached, supergene, transitional, and hypogene). The leached low-grade copper zone was identified at the depth when significant copper mineralization was first observed down-hole, which generally corresponds to a grade in the region of 0.25% to 0.30% Cu. Mineralization type codes were also used to generate a surface representing the interface between supergene and hypogene mineralization.

The April 2013 Mineral Resource was estimated using a first-principles approach rather than an update to the previous estimate that was completed in June 2012. The revised geological model and resource estimate has benefited from improved geological understanding and enabled MSA to create a domained resource model incorporating supergene and hypogene ore zones.

The Mineral Resource was estimated by ordinary kriging of total copper, acid-soluble copper, cobalt, gold silver, uranium, and density into a three-dimensional block model. The estimate was guided by mineralization domains (leached/low-Cu, supergene, and hypogene) as well as a 0.25% total copper grade shell.

The Mineral Resource was classified into either the Indicated or Inferred categories in accordance with the guidelines of the 2004 edition of the JORC Code. The Mineral Resource, at a base case cut-off grade of 0.5% total Cu, is reported by class and mineralization domain as shown in Table III.

**Table III. Kitumba Mineral Resource# above a cut-off grade of 0.50% Cu, as at 8 April 2013**

| Category | Mt | Cu | Acid-soluble Cu | Co | Au | Ag | U | Density |
|---|---|---|---|---|---|---|---|---|
| | | % | % | ppm | g/t | g/t | ppm | $t/m^3$ |
| Supergene domain | | | | | | | | |
| Indicated | 58.6 | 1.22 | 0.54 | 141 | 0.04 | 0.86 | 31 | 2.58 |
| Inferred | 12.3 | 0.67 | 0.14 | 91 | 0.03 | 0.46 | 21 | 2.58 |
| Hypogene domain | | | | | | | | |
| Indicated | 28.9 | 1.05 | 0.15 | 217 | 0.03 | 0.86 | 25 | 2.87 |
| Inferred | 9.1 | 0.91 | 0.13 | 132 | 0.08 | 0.47 | 19 | 2.86 |
| **Combined domain** | | | | | | | | |
| **Indicated** | **87.6** | **1.17** | **0.41** | **166** | **0.03** | **0.86** | **29** | **2.67** |
| **Inferred** | **21.3** | **0.77** | **0.14** | **108** | **0.05** | **0.46** | **20** | **2.70** |
| **Total** | **108.9** | **1.09** | **0.36** | **155** | **0.04** | **0.78** | **27** | **2.67** |

#All tabulated data has been rounded to one decimal place for tonnage and to either no or two decimal places for grades.

JORC Code-compliant Mineral Resources are stated for Kitumba down to a elevation of 800 m, which is approximately 630 m below surface. No Mineral Resources occur above the stated 0.5% Cu cut-off-grade within 100 m of surface. At a cut-off-grade of 0.5% Cu, the total Mineral Resource is 108.9 Mt at a total copper grade of 1.09%. This equates to 1.2 Mt of contained copper *in-situ*.

In order to illustrate the sensitivity to cut-off grade, the Mineral Resource is presented at a variety of cut-off grades in Table IV and Table V for the Indicated and Inferred categories respectively.

**Table IV. Kitumba Indicated Mineral Resource# by cut-off grade, as at 8 April 2013**

| Cut-off grade | Mt | Cu | Acid-soluble Cu | Co | Au | Ag | U | Density |
|---|---|---|---|---|---|---|---|---|
| (Cu%) | | % | % | ppm | g/t | g/t | ppm | $t/m^3$ |
| 0.20 | 258.2 | 0.60 | 0.19 | 131 | 0.04 | 0.80 | 34 | 2.68 |
| 0.35 | 146.9 | 0.87 | 0.29 | 153 | 0.03 | 0.77 | 28 | 2.68 |
| **0.50** | **87.6** | **1.17** | **0.41** | **166** | **0.03** | **0.86** | **29** | **2.67** |
| 1.00 | 29.8 | 2.13 | 0.83 | 203 | 0.03 | 1.03 | 27 | 2.67 |
| 1.40 | 21.7 | 2.49 | 0.98 | 208 | 0.03 | 1.04 | 28 | 2.65 |

#All tabulated data has been rounded to one decimal place for tonnage and to either no or two decimal places for grades.

**Table V. Kitumba Inferred Mineral Resource# by cut-off grade, as at 8 April 2013**

| Cut-off grade (Cu%) | Mt | Cu % | Acid-soluble Cu % | Co ppm | Au g/t | Ag g/t | U ppm | Density t/m$^3$ |
|---|---|---|---|---|---|---|---|---|
| 0.20 | 146.6 | 0.36 | 0.06 | 92 | 0.04 | 0.58 | 28 | 2.74 |
| 0.35 | 43.9 | 0.59 | 0.12 | 108 | 0.05 | 0.49 | 22 | 2.69 |
| **0.50** | **21.3** | **0.77** | **0.14** | **108** | **0.05** | **0.46** | **20** | **2.70** |
| 1.00 | 3.5 | 1.39 | 0.12 | 148 | 0.04 | 0.37 | 21 | 2.95 |
| 1.40 | 2.0 | 1.55 | 0.09 | 152 | 0.04 | 0.37 | 20 | 2.96 |

#All tabulated data has been rounded to one decimal place for tonnage and to either no or two decimal places for grades.

In terms of benchmarking of the Kitumba deposit, a comparison is made in Table VI with the Prominent Hill deposit in Australia, another haematite-dominated IOCG hydrothermal breccia deposit.

**Table VI. Comparative analysis of the Kitumba Indicated Mineral Resource with Prominent Hill. This comparison only takes into account copper Mineral Resources**

| Deposit | Category | Cut-off grade Cu (%) | Tons (Mt) | Cu (%) | Contained Cu (kt) |
|---|---|---|---|---|---|
| Kitumba | Indicated | 0.5 | 87.6 | 1.17 | 1 025 |
| Prominent Hill [1] | Indicated | 0.3 (open pit) and 0.5 (underground) | 76.4 | 1.40 | 1 068 |
| | Measured | | 21.3 | 1.62 | 347 |

[1] Source: OZ Minerals Ltd (www.ozminerals.com) – 30 June 2012

Drilling to the east of the previously defined resource area has clearly defined the limits of mineralization to the east; however modelling of the Mineral Resource indicates that the deposit is open to the west and northwest. Extension of mineralization to the west was confirmed through Phase 6 drill testing of selected Orion 3D chargeability anomalies to the west of the previous resource limits. In addition, potential for additional hypogene mineralization at depth has been demonstrated by deepening hole S36_032 during the course of Phase 6.

The current Phase 7 infill drill programme in the high-grade core of the deposit is aimed at increasing the geological confidence and converting some of the Indicated Resources to Measured Resources and thereby de-risking the project.

With respect to regional potential, the Kitumba deposit is part of a much larger IOCG system that is potentially mineralized elsewhere along its 25 km north-south strike length. Evidence for this is observed in the satellite Kakozhi 5 km to the northwest of Kitumba. In addition, significant exploration potential exists for the discovery of further IOCG-type mineralization to the north along the offset continuation of the KFZ, particularly at the intersections of northeast-trending faults, where soil geochemical anomalies have been defined in previous work.

Detailed alteration logging in combination with modelling of multi-element geochemistry, has defined an alteration zoning pattern, which will assist in vectoring towards potential targets elsewhere in the Mumbwa project area.

## High-level processing and mining considerations

In the Phase 6 drilling programme, specific holes within the resource area were identified as metallurgical test holes. These holes were drilled at HQ size (63.5 mm diameter) to provide material for metallurgical test work. The testing is designed to determine the best method of copper extraction over the four mineralization zones (leached, supergene, transitional, and hypogene). For holes where metallurgical test work was performed, quarter HQ core was sent to the laboratory for routine assay. This left half core to be available for selection for metallurgical testing and quarter core remaining on site.

In order to prevent oxidation of the samples it was necessary to remove all the air from the samples by vacuum-sealing them in bags as soon as possible. One-metre sample intervals were vacuum-sealed based on Niton XRF logs; these samples were grouped into the four zones based on the mineralogy. The samples then awaited the return of the laboratory assay results, and the final samples that were selected for test work were based on these results. The vacuum-sealed core not chosen for metallurgical test work was returned to the core tray from which it was taken.

A prefeasibility study is currently in progress and due for completion by end July 2013, comparing the advantages and disadvantages of open pit and underground mining methods, and taking account of increased pre-strip costs evident from the revised resource model. The underground scenarios being considered are sub-level block caving and sub-level open stoping. The latter case involves mining the high-grade core of the deposit (Indicated Resource of 29 Mt at 2.1% Cu using 1% cut-off) delivering a higher head grade than large-scale open pit mining. A smaller scale underground mine has the potential to provide a better return on investment when compared with a larger scale open pit with a significant pre-strip.

Following encouraging early flotation results, subsequent testing has shown that while good bulk flotation recoveries can be achieved, marketable concentrate grades cannot be achieved by flotation alone. Test work has shown that best results can be achieved with a plant design that involves a combination of flotation, leaching, and solvent extraction and electrowinning (SX/EW) processes. A number of alternative flow sheets based on these unit operations are being evaluated. In all cases, the majority of the metal by volume is produced in the form of cathode. The final process design will take account of capital and operating costs as well as metal production volumes.

SX/EW plants have the advantage of greatly reducing downstream logistic costs, offsetting increased site power and processing cost requirements. Producing cathode also has marketing advantages. In addition to the PFS metallurgical testing, samples are being collected in the current phase of drilling for further test work in future feasibility phases, the focus of which will be the high-grade core.

An environmental impact study is well advanced and is scheduled to be completed in the timeframe of the PFS.

## Conclusions

The discovery of the Kitumba deposit by Blackthorn Resources in 2006 has resulted in a new style of copper deposit being recognized in Zambia. Kitumba is regarded as an IOCG type deposit, with significant potential for the discovery of additional deposits within the region. This has sparked exploration interest by a number of companies who are now operating in the region.

Deep leaching of the deposit, together with high-grade supergene concentrations of copper at depth, and the presence of hypogene sulphide mineralization at depth, has resulted in comprehensive metallurgical test work and mining studies, as part of a PFS currently under way.

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