MOUNT ISA Cu and Pb-Zn-Ag DEPOSITS, NW QUEENSLAND AUSTRALIA

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LOCATION

The Mount Isa Cu and the Mount Isa, Hilton and George Fisher (formerly Hilton North) Pb-Zn-Ag deposits are located W of the Leichhardt River between 20°44' and 20°34'S at 139°29'E (Figure 1); Mount Isa (SF 54-01) 1:250 000 sheet.

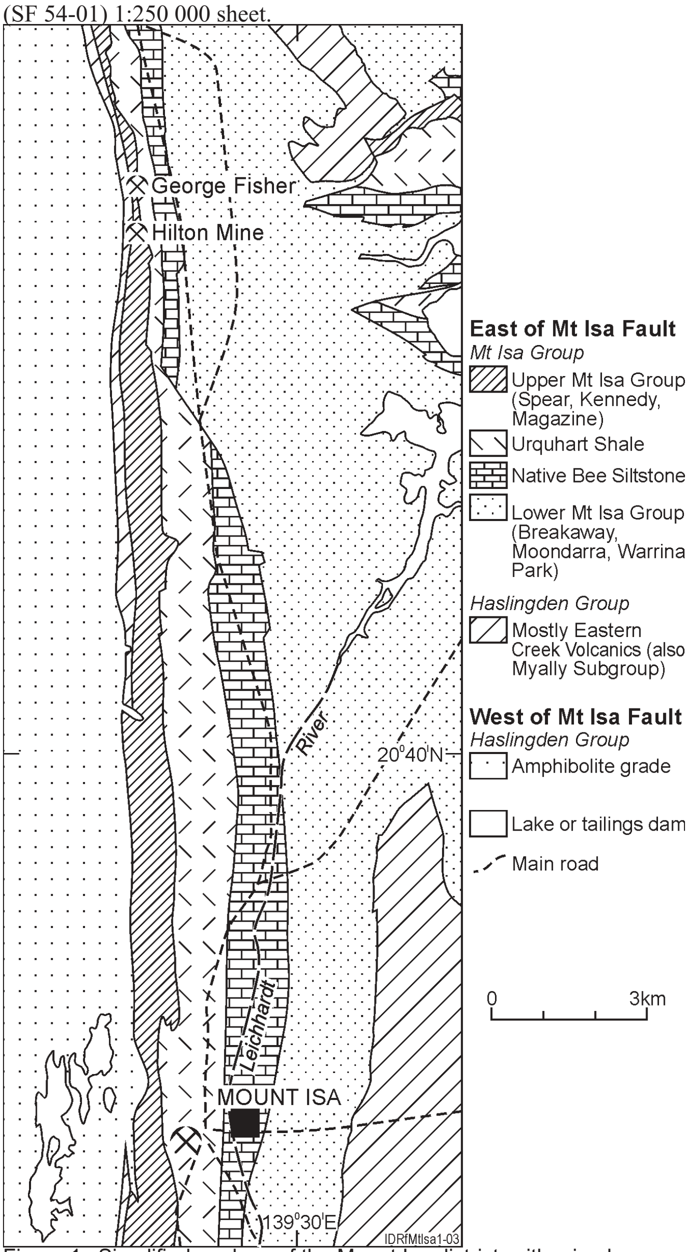

Figure 1. Simplified geology of the Mount Isa district, with mine locations, major rock units, and water bodies (after Russell and Cox, 1973).

DISCOVERY HISTORY

Lead-Ag mineralization was discovered by John Campbell Miles in 1923 when cerrusite was identified in the prominent gossanous ridges above the Mount Isa lodes. Systematic exploration began in 1927 with a 5-year, 11 000 m surface diamond drilling programme. During that time, the Black Star, Rio Grande, Black Rock Pb deposits, and the 650 and Black Rock Cu deposits were discovered.

High-grade Cu mineralization does not persist to the surface, although dark gossans amongst the mine infrastructure (Figure 2) indicate its former occurrence. Copper was first reported in 1927 in an intersection of 15 m at 17% secondary Cu from a diamond drillhole targeting Ag-Pb-Zn mineralization in the Black Rock area. Three years later, the 650 primary Cu orebody was located, again by a drillhole that targeted primary Zn and Pb, but which, instead, intersected Cu ore as chalcopyrite, including an interval of 8.8 m @ 8.5% Cu. These intersections were largely ignored until a need for Cu during World War II prompted development of primary Cu. The Black Rock Cu orebodies were drilled between 1937 and 1946. Continued drilling and underground development led to the discoveries of the nearby 500 and larger 1100 orebodies during the late 1950's. The 1100 orebody was discovered in 1954 by a drillhole intersection of 202 m at 2.2% Cu. The high-grade Enterprise Cu orebodies were discovered in the mid 1960's by deep diamond drilling above the N-dipping basement contact.

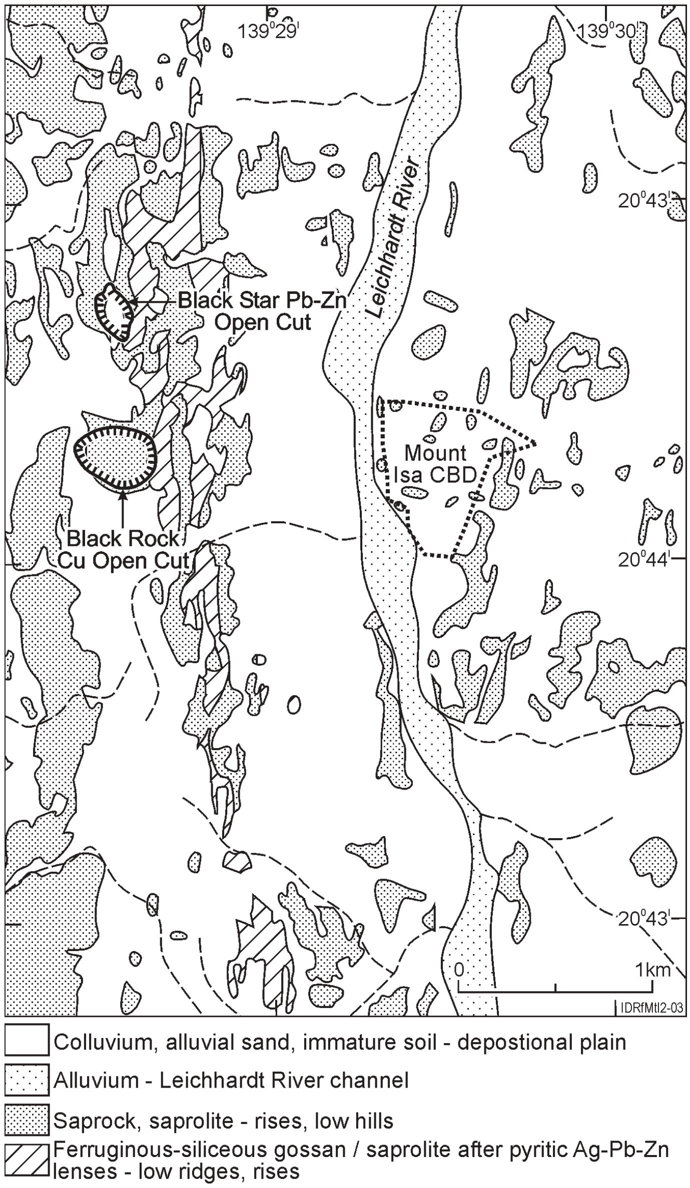

Figure 2. Simplified regolith-landform map of the Mount Isa Mine area.

The Hilton and the later defined George Fisher deposits were first recognized in 1947 when S.R. Carter identified cerussite in the ironstone ridges N along strike from Mount Isa (Figure 1). In 1948, systematic drilling intersected economic mineralization, although production did not commence until 1987 at Hilton and 2000 at George Fisher.

PHYSICAL FEATURES AND ENVIRONMENT

The Mount Isa area has a semi-arid climate with an average annual rainfall of 450 mm, 45% of which falls during January and February, and an average temperature range of 17 to 32 °C. High evapo-transpiration rates result in a water deficit for most of the year. The natural vegetation is dominantly spinifex (*Trodia pungens*) and Snappy Gums (*Euca-*

lyptus brevifolia). The mines are located within the N-trending valley of the Leichhardt River at an elevation of about 355 m. Adjacent to the mines, silicified and ferruginous gossans are the surface expressions of ore lodes or pyrite lenses and form 1-5 m high strike-parallel 'ribs' along elongate, low hills that rise 5-25 m above the alluvial flats (Figure 2). Overbank sands deposited from local ephemeral creeks thinly mantle the valley floors and coalesce with equally thin (<3 m) aprons of colluvium shed from the nearby, gossanous hills. Immature, thin, sandy soil has developed on the valley flats, and skeletal, stony soil has developed to some extent on the lower reaches of colluvial aprons. Mining activities have significantly altered the landscape in some areas.

Beyond the mine areas, strike-parallel hills, generally less than 25 m high, have developed on less carbonate-rich formations of the Mount Isa Group, such as the albitic Spear-Kennedy Siltstone and the more carbonaceous Breakaway Shale (compare Figures 1 and 2). Some 1000 m W of the mine, incised plateaux in rocks of the older Myally Group rise 50-150 m above the Leichhardt River flood plain.

GEOLOGICAL SETTING

The Mount Isa, Hilton and George Fisher ore deposits are hosted by the Urquhart Shale Formation of the Mount Isa Group, a weakly-metamorphosed, 5 km thick sequence of mid-Proterozoic carbonate siltstones, mudstones and shales with sandstone and conglomerate near the base. The Urquhart Shale itself is some 1000 m thick and was deposited under periodically evaporitic conditions in a lacustrine setting (Neudert and Russell, 1981). Regional deformation produced the steeply W-dipping bedding observed throughout the district. In the hangingwall of each deposit, Mount Isa Group rocks are structurally terminated by altered metasediments and metabasites of the older Eastern Creek Volcanics Formation (Figure 1). The contact, known as the Paroo Fault, flattens out at depth to form a ramp-like basement beneath all of the major Cu orebodies at Mount Isa Mine.

At Mount Isa Mine, the Pb-Zn-Ag orebodies occur in the upper 650 m of the Urquhart Shale, in a zone extending 1.6 km along strike and 1.2 km down dip. The gross geometry of the ore lenses is one of progressive migration up-sequence to the N, although individual sulphide bands within each ore lens closely follow bedding. At their southern and down dip extremities, the Pb-Zn-Ag orebodies interfinger with lobes of 'silica-dolomite', the collective term for the bedding-replacive, vein and breccia mass of dolomite and quartz that hosts the Cu orebodies (Perkins, 1984). Economic Cu ore occurs beneath the Pb-Zn-Ag ore system, at vertical depths of 1000-1800 m towards the base of the Urquhart Shale (viz., the 3000-3500 Cu ore system), and extends more than 2 km southwards at vertical depths of 700-1200 m (viz., the 1100 Cu orebody).

At the Hilton and George Fisher Mines, individual units of the upper Mount Isa Group are noticeably thinner than at Mount Isa due to complex late faulting and possibly lower rates of subsidence during sedimentation. The orebodies also occupy a narrower interval (100-250 m) within the middle part of the Urquhart Shale.

REGOLITH

Weathering profile

Depths and intensities of weathering vary considerably and are controlled by rock type, proximity to faults and mineralization, alteration and position in the landscape. At the mines, the base of saprolite, or the base of complete oxidation (BOCO), generally occurs at depths of 40-100 m. The pre-mining water table was about 50 m below the present day valley. Saprolite extends much deeper (to 500 m or more) along major faults that still channel meteoric water into oxidizing parts of the ore deposits (Hewett, 1968). A zone of moderate weathering, known as the transition zone, extends even deeper to the base of moderate leaching (BOML). This zone developed under more reduced conditions than saprolite but is similarly leached of carbonate. Supergene accumulations of spatially separate Zn-Ag and Cu oxide-carbonate assemblages developed above the BOCO whereas secondary Cu sulphide, particularly chalcocite, have accumulated in a transitional zone below and within about 30 m of the BOCO (Smith, 1966, and see below). Detailed investigations of the weathering profiles are in Scott and Taylor (1982), Herlihy (1994) and Yamaguchi (2001).

Beyond the mine environs, outcrops in the Mount Isa district are weakly to moderately weathered to saprock. In valleys, saprolite extends to an average depth of 30 m.

Weathering history and age of the regolith

The ferruginous and siliceous gossans are effectively the remnants of middle to upper saprolite that developed locally from the intense acid leaching of former sulphide lodes. Manganese oxide coatings, rich in Pb, Zn and Ba, from the Mount Isa Mine gossan are dated at 15-21 Ma by $^{40}Ar/^{39}Ar$ and K-Ar techniques (Vasconcelos, 1998). This range of dates fits within a wider band of Tertiary ages determined for Mn oxide minerals from other prospects and deposits in the Mount Isa region (Vasconcelos, 1998). Therefore, supergene enrichment, leaching and gossan development over the Mount Isa base metal deposits probably occurred during the same wet periods of the Miocene that contributed to the widespread silcrete and laterite, which survive today as eroded relicts on mesas and isolated Cambrian and Mesozoic plateaux. Evidently, Phanerozoic sediments had already been eroded from the vicinity of Mount Isa, allowing large quantities of meteoric water into the ore sequence by the early Tertiary.

MINERALIZATION

The pre-mining, combined Pb-Zn-Ag resources of Mount Isa, Hilton and George Fisher are estimated to have been 223 Mt at 6.2% Pb, 9.2% Zn and 118 ppm Ag. Primary Pb-Zn-Ag ore contains galena, sphalerite, pyrite, pyrrhotite and freibergite. A similar estimate for the original Cu resource at Mount Isa Mine is 248 Mt at 3.3%. The sulphide mineral assemblage in primary Cu ore consists of chalcopyrite (the only significant Cu-bearing mineral), pyrite, pyrrhotite and minor cobaltite (Table 1).

As indicated above, supergene resources are both mineralogically and spatially more complex than the primary ore. The relationships between oxide, transitional and primary zones are illustrated in Figure 3; their respective mineralogies are listed in Table 1. Above the BOCO, the Urquhart Shale is lighter but below it is invariably grey. Figure 3 illustrates this important transition at an average depth of about 70 m, but extending to much greater depths in areas of structurally enhanced permeability. The transition zone is of incipiently oxidized primary sul-

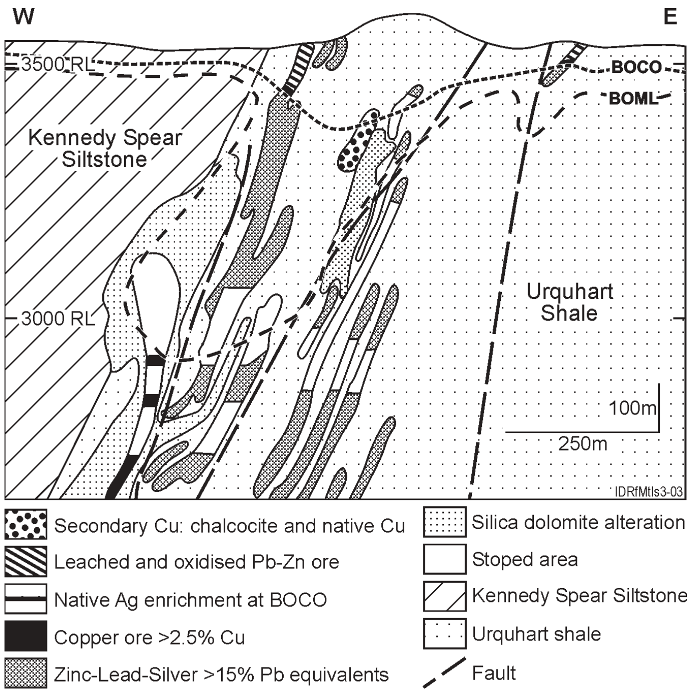

Figure 3. Geological cross-section through the northern area of the Mount Isa Mine (mine grid 36 550mN) displaying simplified relationships between mineralization, structure, weathering and alteration.

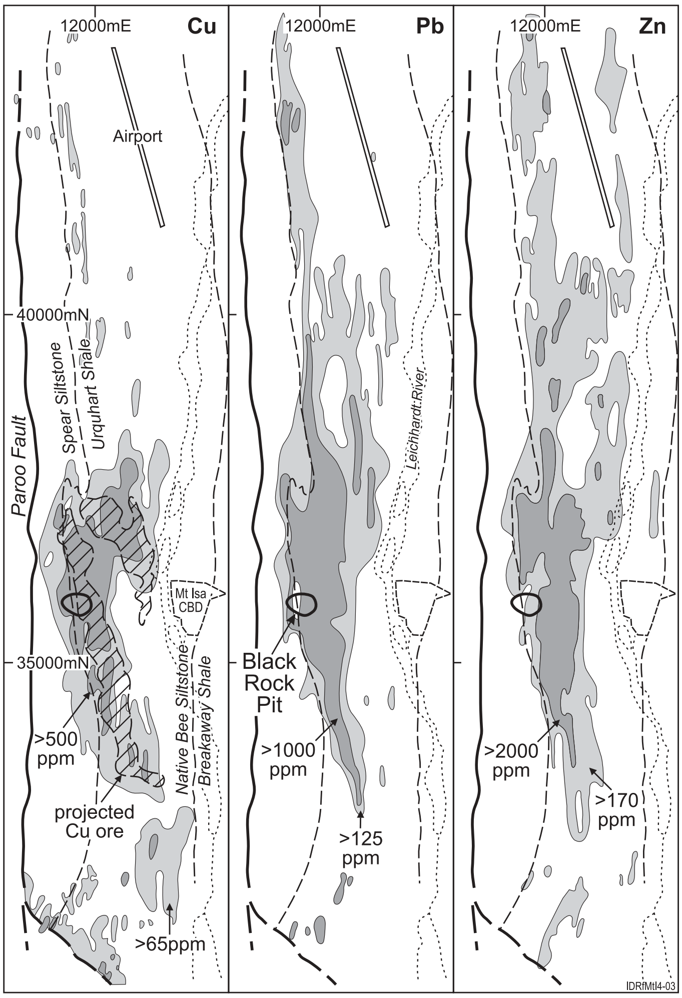

Figure 4. Distributions of Cu, Pb and Zn in weathered bedrock above the Mount Isa Cu and Pb-Zn orebodies and environs (derived from Brodie, 1994). Samples were collected from RAB and diamond drill holes to avoid contamination at the surface. Abundance contours are interpolated in areas of mine infrastructure and incomplete sample coverage (dashed lines). The Cu orebody polygons are projected up-dip to the surface.

phide, secondary enrichment and locally, water-soluble salts.

REGOLITH EXPRESSION

The distributions of bedrock Cu, Pb and Zn in near surface drill hole samples from the vicinity of Mount Isa Mine are summarized in Figure 4. Most of the samples were collected during the 1980s from saprolite or saprock at depths of 3-10 m to avoid the effects of more than 30 years of contamination from ore and concentrate stockpiles and smelting operations. Although the contours are locally schematic and extrapolated across areas of significant infrastructure, they are based on sufficient data to demonstrate the extent of primary base metal dispersion above the ore deposits, well beyond the high level ore lodes that are now expressed as gossan (compare Figures 2 and 4). A soil survey over the Hilton-George Fisher deposits in 1967 clearly defined a 3 km x 250 m anomaly, centred on N-trending gossan ridges, at the thresholds for Pb and Zn listed in Table 2 (Shalley and Lord, 1967). In this case, the surface anomaly is locally widened by up to 300 m or more by downslope runoff and mechanical dispersion from the gossans.

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TABLE 1

MINERAL AND GANGUE ASSEMBLAGES - OPEN PIT MT ISA -

Weathering Zone	Cu minerals	Pb minerals	Zn minerals	Ag minerals	Fe minerals	Other gangue minerals	Metal enrichment / depletion
oxide BOCO ~50 m	chalcocite azurite malachite chrysocolla tenorite cuprite chalcotrichite azurite native Cu chalcanthite	cerrusite pyromorphite hydrocerrusite leadhillite (anglesite)	smithsonite	tenorite cerargyrite native Ag	hematite goethite lepidocrocite	hollandite group supergene silica barite alunite-jarosite family kaolinite smectite	Zn strongly depleted Ag strongly depleted Pb moderately depleted Cu locally re-mobilized and re-precipitated, moderate depletion elsewhere Ag moderately enriched at base of BOCO, and strongly depleted elsewhere
transitional BOML ~70 m	cuprite native Cu chalcocite covellite digenite djurleite antlerite brochantite chalcanthite chalcopyrite	anglesite galena	smithsonite	pyrargyrite ceragyrite (pyrousite) (polybasite)	copiapite	Mg aluminocopiatite ferroan dolomite ankerite greenockite alunite-jarosite siderite	Zn strongly depleted Cu moderately enriched towards top of transition zone, generally depleted elsewhere Pb locally enriched towards base of transition zone and depleted elsewhere Ag depleted
primary	chalcopyrite	galena	sphalerite	friebergite tetrahedrite argentite acanthite	pyrite pyrrhotite	cobaltite silica dolomite	

TABLE 2

SAMPLE MEDIA SUMMARY

Sample Medium	Element	Detection Limit (ppm)	Background (ppm)	Threshold (ppm)	Significant Maxima (ppm)
Fresh Urquhart Shale (outcrop and RAB samples)	Cu	2	30	65	250
	Pb	5	25	55	1000
	Zn	5	45	100	2000
	Ag	0.1	0.5	1	2
	Tl	0.5	0.6	1.5	10
	As	5	30	46	100
	Bi	0.1	0.11	0.39	0.6
	Mo	1	1.1	2.5	4.5
	Cd	1	1	4	6
Soil, <32 mesh (0.5mm) (Hilton Mine area)	Cu	2		(65)	250
	Pb	5		100	2000-10000
	Zn	5		150	1000-5000
Saprock and saprolite Mount Isa Mine (mostly from RAB drill assays)	Cu	2		65	up to 5000
	Pb	5		200	up to 10000
	Zn	5		350	1000-5000
	Ag	1			5-50
	Tl	0.5			20-50

Analysis by AAS and ICP after $HClO_4/HCl/HNO_3$ digestion

The data for fresh Urquhart Shale in the table above are derived from the assays of visibly unmineralized samples of diamond core drilled between Mount Isa and George Fisher. The backgrounds and thresholds were determined statistically. The maxima provide an indication of the levels at which metal abundances are considered to be potentially significant, and not simply due to high levels of contained pyrite. Thus, the soil and RAB drillhole maxima were obtained largely from areas of gossan.