KILLARA COPPER PSEUDOGOSSAN, WESTERN AUSTRALIA

C.R.M. Butt

CRC LEME, CSIRO Exploration and Mining, PO Box 1130, Bentley, Western Australia 6102 Charles.Butt@csiro.au

LOCATION

The Killara prospect is 3 km NE of Killara Homestead and about 56 km NE of Meekatharra, Western Australia, at 118°58'39"E, 26°18'34"S; Glengarry 1:250 000 map sheet, SG50-12 (Figure 1).



Figure 1. Location and regional geology, Killara (mapping by R.C. Horwitz, CSIRO).

DISCOVERY HISTORY

Ironstone sampling was carried out as part of a gossan search by R.C. Horwitz, CSIRO Division of Mineralogy, in 1976, during a regional geological mapping program. Evidence of volcanicity and tectonism during sedimentation suggested that the region was favourable for base metal mineralization. Several ironstones had elevated, seemingly anomalous, base metal contents. Prioritization of possible drill targets was important, particularly as it was recognized that many such enrichments were not related to significant mineralization. The Killara ironstones had the highest Cu content and were drill tested in 1977 by CSIRO. The Cu enrichment was found to be a product of weathering and the subsequent detailed study was undertaken to assist in the recognition of other false anomalies (Butt, 1979).

PHYSICAL ENVIRONMENT

Killara is close to the main continental divide on the interior plateau of southern Western Australia, at an elevation of approximately 580 m. The present landscape is gently undulating, with strong relief restricted to hills underlain by quartzites (to the S) and gabbros (to the N). The ironstones are on the erosional pediment of a low hill capped by lateritic residuum (Figure 2). The climate is semi-arid, with a mean annual rainfall of about 230 mm, falling mainly during January to July, with mean minimum and maximum temperatures being 23-38°C (January) and 6.8-19.7°C (July). Vegetation is an open woodland dominated by mulga (*Acacia aneura*), with *Eremophila* spp. and sparse, tussocky grasses forming the understorey.

GEOLOGICAL SETTING

Killara is in a shore-line environment of the Lower Proterozoic, southern Glengarry Sub-basin (Figure 1). The deepest unit has pillowed, massive or fragmental mafic volcanic rocks overlain by sandstones, carbonaceous shales and ribbon and stromatolitic carbonates. The sequence above the volcanic rocks overlaps the Archaean Yilgarn



Figure 2. Outcrop geology, soils and topography, Killara. A: Outcrop geology. B: Topographic section.

Craton to the S. All rocks are intruded by dolerites. At the prospect site, exposure is very poor, but the sequence consists of S-dipping siltstones, shales and dolomites. Drilling shows that the ironstone itself overlies a complex sequence of black carbonaceous shales, mudstones and fine siltstones intruded by quartz dolerite. The shales are appreciably hardened within 2-3 m of the dolerite which, in turn, has a pronounced chilled margin. The ironstones are developed over a structurally-complex zone, trending ENE, and some delineate steeply-plunging dragfolds. The rocks have been metamorphosed to lower greenschist facies and are composed predominantly of quartz, albite and chlorite, with muscovite in sedimentary rocks; leucoxene is a common accessory.

REGOLITH

The hill E of the outcropping ironstones is capped by about 3 m of pisolitic lateritic gravel and duricrust (Figure 2). Some pisoliths contain fragments of ferruginized fossil wood. The lateritic duricrust overlies an upper zone of silicified, goethite-mottled kaolinite- and quartz-rich saprolite, 15 m thick, which is carbonate-rich between 5 and 12 m. This, in turn, overlies soft, strongly ferruginous clay-rich saprolite. Below the water-table at about 30 m, the saprolite is harder and passes to fresh rock at 35-45 m. The pediment has outcrops of ironstones, chert and weathered shales, and residual lithosols and red earths. Outcrop decreases down slope and passes to shallow colluvium and alluvium, with some red-brown hardpan.

MINERALIZATION

There is no primary mineralization. The highest Cu contents of 185-190 ppm (one metre interval) were in fresh shale and dolerite. Trace quantities of sulphides, mainly primary pyrite, secondary pyrite after pyrrhotite and chalcopyrite, were visible in some polished sections, and a few grains of sphalerite, galena, chalcocite and cobaltite were tentatively identified by SEM.

REGOLITH EXPRESSION

Ironstone and rock chip survey

Most ironstones are intensely ferruginized saprolite, in detail composed



Figure 3. Ironstone and soil geochemistry, Killara. A, B: Copper and zinc distributions, ironstones. C,D: Copper and zinc distributions, soil >2000 μ m. E: Copper distribution, all soil fractions <420 μ m. F: Drill hole locations and plan projections. Drillholes all have a prefix of KPH (not shown).

of botryoidal and reniform goethite around an Fe oxide-rich lithic matrix. There is a pronounced NE-striking Cu anomaly, shown by small outcrops over a width of 10 m, defined by the 550 ppm contour (Figure 3). The most Cu rich ironstones (1100-1850 ppm) occur on the pediment slope in 'gossanous' samples, some apparently having boxwork textures. No other element has a similar distribution; some ironstones are enriched in Zn (maximum 660 ppm) but these are rarely Cu-rich. Multi-element analyses of selected ironstones indicated that none of the potential pathfinder elements (e.g., Ag, As, Bi, Cd, In, Mo, Sb, Sn, W) is present in detectable or significant amounts, nor is there any evidence for scavenging of Cu or Zn by Mn oxides. The lateritic duricrusts are depleted in mobile elements such as Mn, Cu, Ni and Zn, and enriched in Ti, V and Cr.

Soil survey

The highest Cu (and As, Cr, Fe, V, Zn, Pb) contents in soils from 0-20 cm depth are in the coarse fractions (>2000 µm, and 420-2000 µm) whether anomalous or not. The Cu distribution shown by both fractions follows the NE trend of the ironstones, with contents >400 ppm in the >2000 µm fraction delineating the outcrop of the Cu-rich ironstones (Figure 3). Traverses across the anomaly show that the widest lateral spread and greatest contrast is also shown by the $>2000 \ \mu m$ fraction compared to the 420-2000 µm fraction. There is no significant variation in finer fractions. The anomalies are terminated in the NE by lateritic duricrust and in the SW by the increasingly transported nature of the overburden. Fractions finer than 420 µm do not show this Cu distribution; no other element, in any size fraction, has a distribution similar to that of Cu in the coarse fractions. The Zn distribution shown by the coarser fractions is unrelated to those of either Cu or Zn in the ironstones, although some higher values (>100 ppm Zn) continue the anomalous trend to the SW. The Cu anomaly in the coarse fractions of the surface soils is the result of the clastic dispersion by sheetwash of Cu-rich fragments from the ironstones and has resulted in some downslope (westward) displacement of the anomaly, e.g., about 100 m for the 140 ppm contour.

Saprolite and bedrock

No fresh or weathered rocks intersected by percussion drilling could be



Figure 4: Geology and weathering profiles from percussion drilling, Killara. Copper and Mn data are maximum values (in ppm) averaged over intervals indicated. Locations of holes indicated in Figure 3F. A: Drill section on pediment. B: Drill section through lateritic residuum.

considered as discrete sources of Cu. Within the regolith, Cu, Fe, Mn, Ni and Zn contents are generally higher in the saprolite than in either fresh rock or the overlying mottled clays and lateritic residuum. There is little correlation between the distributions of Cu and other elements, but the highest concentrations of Cu (200-800 ppm), Mn, Co and, in part, Ni and Zn in the regolith occur at, or close to, many of the lithological contacts (Figure 4; Table 1). However, the Cu, Ni and Zn maxima are not always coincident with those of Mn and Co. Where the contacts occur in the calcareous saprolite, only Cu is enriched. The highest Cu content of any 1 m drill interval is 800 ppm Cu, 11-12 m immediately below the most Cu-rich ironstone. The Cu enrichment is probably continuous through the regolith, but the structural complexity does not allow a single contact to be followed. Although the maximum Cu contents of the ironstones (1100-1800 ppm) are 2-5 times greater than those at contacts, they are not necessarily more strongly enriched; the ironstones were chip-sampled from outcrops mostly 0.2-0.4 m across, whereas the contacts are drill composites over 1 m intervals. There are no equivalent enrichments in fresh rock and it is concluded that these enrichments are the product of leaching of Cu and other elements from either or both host lithologies, with precipitation along

the contact.

Copper host minerals

Host minerals for Cu, determined by electron microprobe, are:

Fresh to slightly weathered rocks: chalcopyrite and secondary pyrite

0.1-0.35% Cu
0.1-1.1% Cu (plus Ba, Co, Ni)
<0.08% Cu
<0.8% Cu
0.2-0.6% Cu
<0.08% Cu

Origin of Cu enrichment

Copper enrichment at lithological contacts might be due to stringer mineralization or leakage from sulphides at depth. However, no such sources have been intersected, and indeed some contacts in the primary zone appear depleted. It is concluded that the enrichments are products of weathering and related to the juxtaposition of two lithologies, carbonaceous shale and dolerite. Fresh shales and dolerites with similar sulphide contents (0.1-0.3% S) have contrasting pH of 4.2-4.4 and 7.3-7.5, respectively (pH in the regolith ranges from 5.5 to 9.0, with no contrast between lithologies). The contact provides an oxidizing environment, acts as a channel-way for percolating groundwater and is an interface between rocks with contrasting pH. It appears that these factors result in redox conditions ideal for the precipitation of Fe and Mn oxides and the coprecipitation of Cu, Co, Ni and Zn, all derived from the rocks adjacent to the contact, and/or leached from above. Contacts in the more leached upper horizons have been depleted in Mn, Co, Ni and Zn. Copper is only present in Fe oxides. Similarly, further reworking at the surface has concentrated Fe oxides, with Cu hosted principally in botryoidal goethite.

DISTINGUISHING BETWEEN GOSSANS AND OTHER **IRONSTONES**

Many ironstones contain elevated abundances of one or more orerelated elements. Anecdotal evidence suggests that contact ironstones, especially between shale and dolerite, as at Killara, are commonly Cu-rich. Distinguishing between true gossans, i.e., ironstones derived from massive or matrix sulphides, and pseudogossans (false gossans), i.e., ironstones with no sulphide precursor, can be difficult, yet is important for prioritizing drill targets. Bearing in mind that the Cu in these ironstones is probably derived mainly from chalcopyrite, no truly diagnostic criteria may exist, but the following characteristics are important:

1: The ironstones have low Pb and Zn contents and are barren of pathfinder elements such as Ag, As, Bi, In, Mo, Sn and W. The latter are diagnostic of VMS deposits (see Taylor and Thornber, 1992).

2. There is a dispersion halo only in the coarse fraction of surface soils, derived from the erosion of the ironstones. Soils adjacent to many true gossans have anomalies in all fractions, including <75 µm (see other case histories, e.g., Freddie Well, Nifty/Rainbow - this volume). The processes of formation of a pseudogossan is one of concentration of Fe and base metals from a dispersed source, whereas that of a gossan is the opposite, namely hydromorphic leaching from a discrete source into wall-rocks that may already have a primary alteration halo; weathering of the wall-rocks contributes to the fine fraction of soils.

3. Lead isotope data. The ironstones have very low Pb contents, hence the isotope ratios are not diagnostic. However, the data are consistent with Killara being a barren prospect (Gulson, 1986).

REFERENCES

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TABLE 1 SAMPLE MEDIA - SUMMARY

Ranges and mean compositions of selected elements. (N=number of samples)

	Ν	Cu ppm	Pb ppm	Zn ppm	Fe%	Mn ppm	Co ppm	Ni ppm
Cu-rich ironstones	4	1250-1810	15-20	180-210	42.5-57.6	145-330	35-65	25-50
		1660	16	195	52.8	205	90	30
Other Cu ironstones	6	580-895	<10-25	25-540	31.5-57.2	50-960	75-115	20-120
		650	20	330	47.9	465	90	55
Zn-rich ironstones	3	50-170	15-24	410-660	48.9-56.4	195-350	85-120	120-170
		95	20	570	52.3	270	110	140
Lateritic rubble	2	280-270	13-17	60-150	39.4-41.5	10-90	60-65	<10-65

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Contacts: Samples adjacent to lithological contacts having >180 ppm Cu, and zones in which contacts (occur

	Ν	Cu ppm	Pb ppm	Zn ppm	Fe%	Mn ppm	Co ppm	Ni ppm
Calcareous mottled clay	8	180-800 280	<10-50 20	40-95 60	7.2-11.9 9.6	95-450 230	<10-45 23	20-50 30
Mottled and Fe clay saprolite	20	180-480 295	<10-30 15	130-450 210	7.9-17.0 11.5	980-9060 3540	40-350 150	45-460 180
Saprolite	3	190-210 210	<10-25 16	160-190 180	11.2-11.9 11.5	1410-1770 1600	40-175 68	110-140 130
Fresh rock	17	25-95 50	11-35 25	65-140 115	4.9-8.3 6.8	570-2020 1130	20-50 30	40-120 85

Saprointe and tresh rock									
	Ν	Cu ppm	Pb ppm	Zn ppm	Fe%	Mn ppm	Co ppm	Ni ppm	
Mottled clay	54	13-190	11-75	130-340	6.0-12.2	300-2980	16-110	55-280	
saprolite. Shale		85	30	210	8.4	1410	50	150	
Fe clay saprolite	63	45-350	<10-40	20-240	6.4-17.6	60-5030	<10-295	<10-245	
Dolerite		140	13	45	10.6	700	27	40	
Saprolite; dolerite	41	70-260	<10-65	120-240	8.4-12.3	970-3080	40-95	55-160	
		140	14	160	10.2	2080	60	100	
Fresh shale	73	21-185	11-60	60-240	3.5-8.4	95-870	<10-55	25-135	
		65	30	145	5.8	430	30	75	
Fresh fine dolerite	7	50-120	13-55	100-150	7.0-11.6	1100-2620	35-70	70-120	
		65	25	130	8.2	1510	50	90	
Fresh dolerite	29	45-190	<10-45	50-150	6.9-14.0	840-3590	35-75	40-100	
		125	17	120	9.7	1970	50	65	

Ag, As, Bi, Cd, In, Mo, Sb, Sn, W: below detection limits of XRF and emission spectrograph