NEW CHALLENGE RESOURCES PTY LTD
ABN 23 073 911 127

EL 4/2002, Balfour

Annual Report, August 2003

Review of exploration opportunities

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LIST OF FIGURES

1. EXECUTIVE SUMMARY

2.GEOLOGY

3. GEOPHYSICS

4. GEOCHEMISTRY

5. DRILLING

5.3 a, b, c Specimen Hill, drill hole & geology plan A3x2
5.4 Specimen Hill drill hole and detailed geology plan A3

EXECUTIVE SUMMARY

Introduction and exploration rationale

Introduction: The Balfour Mining Centre is located within a 35km line of intermittent copper workings in NW Tasmania, and was mined in the 1900's. The district is one of the most mineralised in Tasmania. To the west of the copper workings are highly anomalous tin-tungsten occurrences that could readily be converted to open-pit mineable resources. Zinc and lead values are also anomalous in the Balfour area. Recently, as the result of a 2002 airborne electromagnetic survey, EM conductors been identified west of the copper mineralisation and elsewhere on EL 4/2002 (Fig 1.1, 1.10). This new EM data, that was not previously available across the EL 4/2002 area, indicates conductors of limited previous exploration with that could reflect large copper-zinc (tin and tungsten) deposits. The review herein gives main attention to copper and lead-zinc deposits and lesser attention to tin-tungsten.

EL 4/2002 was acquired by New Challenge Resources Pty Ltd (100%) over an area of 110 sq km covering the best copper workings along a strike length of 17km, from the Clump prospect in the north, to the South Balfour prospect in the south (Figs 1.1, 1.5). At the time of this Annual Report, Herald Resources Limited has entered into an option agreement to consider exploration of the Balfour area.

NCR has accessed regional aeromagnetic and EM digital data, and raster topography imagery and open-file hard copy data in Hobart. Several exploration targets are suggested for follow-up (Fig 1.2).

In recent years, the most intensive exploration was by CRA/RIO for copper because, after a review of Australian geology, Balfour was selected as having high potential for a sediment-hosted copper deposit.

Enhanced discovery potential has been revealed by a recent electromagnetic (EM) survey flown in early 2002 by the Tasmanian Government, using the Hummingbird heli-borne system. The Balfour area is flat and has only thin cover and non-saline overburden; consequently the quality of the EM data is excellent. The new data has enabled the delineation of specific drill target conductors that are located both coincident with, and just west of known geochemically anomalous mineralisation at Balfour and elsewhere (Fig 1.2). The EM anomalies are distinct and there is no doubt they reflect bedrock conductors; they are covered by button grass and gravel soils. Importantly, the conductors do not extend far south of Balfour, and do not simply follow the stratigraphy that continues to the south. The principal conductors are located adjacent to where the best-known mineralisation occurs in the area.

Discovery rationale: The Balfour basemetal and tin-tungsten deposits are located near the intersection of major crustal lineaments that, empirically, can be favourable as a focus for hydrothermal solution movement and ore deposit formation (Fig 1.3, 1.4). The triple junction at Balfour comprises:-

- a regional **NW-trend geanticline** and N-NW thrust faults and associated splays,
- a **NNE-trend synclinorium** (Smithton Trough) and an associated; major, long lived, NE-trend cross-fault, the **Roger River Fault**, and associated

parallel faults, that have been an influence along basin margins, and offset the N-NNW Balfour shear/thrust set.
- a **WNW structure** defined as the result of radiometric interpretations.

The Proterozoic Cu-Zn-Sn-W host rocks are of quartzite, shale, slate and siltstone, with prominent chlorite and silica-dolomite alteration. Granite intrusions are interpreted to underlie parts of the area. The Balfour Shear/thrust is a set of NW-trend, west-dip overthrust faults and various splays, that contain shear-related, Balfour supergene-enriched, high-grade copper deposits that probably formed from copper remobilized along an up-flow fault from an inferred major footwall copper deposit (Fig 1.7).

Conceptually, the Proterozoic geology of NW Tasmania in the Balfour area is prospective for discovery of major economic sediment-hosted copper and zinc targets (Fig 1.4). The NW Tasmanian Proterozoic is a thick, continental margin, sedimentary sequence, with copper source and copper receptive rocks. The Balfour Copper Belt's small, high grade ores are considered to be symptomatic of a large concealed copper deposit formed by the flushing of copper-bearing fluids from cupriferous basalt (known in the area) or cupriferous arenaceous units, into seal-capping units of reactive carbonaceous, evaporitic and sulphidic shales. The Balfour Shear and associated thrust and splay faults and breached domes formed the conduits for the model. The Zambian Copper Belt model appears to be especially applicable to the Balfour area, but iron-oxide Cu, and granite related models can also be considered (see Appendix). It is interesting that both the Zambian and Balfour copper deposits are anomalous in trace cobalt.

Models for tin-tungsten are of the granite-related type as mainly cassiterite-wolframite in quartz veins in sedimentary rock but tin-sulphide associated with pyrrhotite (magnetic) can also be suggested.

Although not a target model used at Balfour to date, the world class Canadian, Sullivan zinc-lead target can also be modelled, with similar Protrozoic age and associated tin-tourmaline mineralisation.

Summary and Conclusions

Copper deposits

Resources: An estimate of the copper resource at the main copper deposit on the Balfour Copper Belt, at Murrays Reward, is some *0.5 Mt. @ 0.8% Cu* (McIntyre 1973). Drilling has been sufficient to outline the deposit, to a depth of at least 200m, and indicate that the mineralisation is not viable other than as a small gouging operation. Most of the surface copper deposits have had at least one drill hole test, and further work is not warranted at most copper sites. The small deposits are IP-responsive but not significantly EM-responsive. EM anomalies are located some 500-1,000m to the west of the main copper workings at Murrays Reward.

Favourable geological setting: The host sequence of Proterozoic rocks has features indicative of a classical sedimentary copper-source and copper-depositary scenario. The Rocky Cape Group, overlying a basement of unexposed early-mid Proterozoic of sediments and granites, comprises 3km of unfossiliferous, shelf-sequence. It has a base of predominantly sandstone/quartzite, with hematite specs, passing up into an increasingly carbonaceous and chloritic siltstone. Hemipyramidal casts suggestive of diagenetic evaporite development are apparent in a shale unit of the Balfour Subgroup north of The Clump prospect. The overlying Cowrie Siltstone contains diagentic pyrite and reflects a lagoonal-stagnant mud setting, probably evaporitic and non-marine. Overlying the Rocky Cape Group is the Togari Group of rift clastics and basin sag-sediments, with dolomites, and cupriferous basalts. In the Balfour Copper Belt, a set of N to NW-thrusts has moved, from west to east, the receptive carbonaceous rocks (Rocky Cape Group, Balfour Sub-group) onto and above the stagnant lagoonal muds and dolomites and cupriferous basalts (Fig 1.7). Basic dykes, of dolerite and alkaline rocks, appear to be transgressive; diorite has been reported.

Structural control & mineralisation: The Balfour Copper Belt deposits are structurally controlled lodes in dilatation zones along the Balfour Shear, a package of N to NW thrusts and splay faults that are cross-cut and offset by NE-trend faults, and some E-W faults. The copper bearing silica-dolomite and chalcopyrite-pyrite lodes are some 10-15m thick (5-30m) and carry high copper grades over widths of 1 to 8m. In some places intersections have been 20m of >1% Cu but overall bulk-grades are low.

Primary copper ore mineralogy is simple and consistent throughout the copper belt:- chalcopyrite, pyrite, quartz, dolomite, chlorite, with trace amounts of magnetite galena, sphalerite and apatite. Pyrite occurs as early-formed (syn-sedimentary), fine grained disseminations, in carbonaceous and chloritic siltstone and slate. Later pyrite occurs as fracture filling veinlets and clasts in quartz veins in mineralised sections. Chalcopyrite does not appear to be co-genetic with pyrite or quartz in most places and is a product of later phase of the hydrothermal activity.

Alteration: The two main styles of *hydrothermal alteration* are silicification and chloritisation; both are early stage and commonly unmineralised. The silicified and chloritised rocks are cut by mineralised veins of quartz ± carbonate (dolomite, siderite, and magnesite) ± chlorite ± pyrite ± chalcopyrite. Quartz veins are the most common vein type, mostly barren, and are different generations.

Dolomite is a common hydrothermal mineral and occurs in drill core from the copper deposits. It is massive, and shows sharp, mostly faulted contacts with the host rocks. Dolomite selectively replaces the brecciated and chloritised rocks and is extensively veined by late-formed barren quartz and, to a lesser extent, by chalcopyrite and pyrite veins. Of interest is that Parkinson (1993) reported a 2km long conformable dolomitic quartzite facies in the carbonaceous shale, particularly from the Clump prospect area, and Murrays Reward; he notes this is different from dolomite alteration in veins (see Clump Prospect).

A Mt Isa model has been suggested. CRA noted some of the widest wallrock alteration and most brecciated rocks at the South Balfour prospect where arsenic values are among the most anomalous in the copper belt; this occurrence warrants further attention and is little tested.

Sn-W-B deposits

Sn-W deposits are concentrated in the same northing/latitude as the best lode copper mineralisation (Fig 1.5) and is felt that this coincidence reflects a continuum of repeated hydrothermal episodes in the Balfour area. (Past exploration data has not been exhaustively reviewed herein.)

Centred on Specimen Hill, some 500m west of the Murrays Reward copper mineralisation, is a clearly defined Sn-W anomaly and tourmaline-rich breccia. Bulldozed costeans by BHP in 1960's failed to penetrate to bedrock due to tough cemented gravels in the regolith. Subsequently, unsystematic diamond drilling by BHP and CRA showed widespread cassiterite and wolframite bearing quartz veins in the Proterozoic sediment.

The Sn-W occurrence appears to be related to a major NW-trend shear that cuts the axis of a broad south-plunge anticline; a tourmaline-rich breccia zone has been the focus of drilling. The tin-tungsten occurrences are commonly polymetallic consisting of quartz, muscovite, cassiterite, wolframite, pyrite, chalcopyrite, arsenopyrite and pyrrhotite with minor carbonates; several phases of mineralisation appear to be likely. It is possible that both sulphide- and oxide-tin is present. Wall rock alteration is of tourmalinisation, minor sericitisation and silicification with tourmalinisation being the most pervasive type in the Specimen Hill area.

Although the Sn-W deposits are most likely to be associated with the inferred underlying granite, there is some doubt on the genesis because the fluid inclusions in the tin-bearing veins are reported as being of low-salinity.

The potential for an open-pit mineable Sn-W resource resource has not been effectively assessed. Bedrock is insufficiently sampled and grade estimates in the hard rock are not possible at this time. Detailed data review and pattern RC-drilling (or wide diameter diamond drilling) is needed to test for a 100m-deep open-cut resource is warranted across the zone of anomalous Sn-W that is shedding cassiterite.

This exercise would have an exceptionally favourable "reward to cost" ratio and could immediately define hardrock open-pit Sn-W resources with a low overburden strip-ratio. (Although the copper workings have been extensively drilled, tin-tungsten assaying does not appear to have been routine even though tin is also reported from the old copper workings.)

Anomalous Zn-Pb-(B-Sn)

Anomalous Zn-Pb values in soils and rock, and some medium-grade sulphide occurrences, have been detected, again mainly in the area of Cu and Sn-W mineralisation around Specimen Hill thus emphasizing the polymetallic and repeated event focus of mineralisation on the Balfour area (Fig 1.2). One diamond drill hole CRA DDH BC4 intersected a 50m interval with several 2m zones of 0.2-0.6% Zn. One gets the impression that anomalous Zn is associated with anomalous Sn-W-B, but *neither Sn nor W were routinely assayed in recent drilling*. In CRA drill hole BC 4, mineralised shear zones are flanked by fractured and toumalinised shales. Indeed, the boron halo is considerable and indicates widespread metasomatism of the siltstone sequence. A major EM feature and fault is roughly coincident with the zinc anomaly.

General geochemistry and ore genesis

At Balfour an interesting *gross metal zoning* across strike, from west to east, of Zn-Pb to Sn-W to Cu is evident. This metal pattern is focussed on Balfour; it may be coincidental but is nonetheless intriguing and suggests that together with a complex structural evolution, major thrust structures and Proterozoic rocks (favourable as potential hosts to world-class copper deposits), that the area warrants continued exploration.

Additionally, and also with intrigue, is the widespread presence of boron metasomatism in the form of tourmaline that impregnates the rocks of the area, and in places at Specimen Hill is concentrated in breccia. This is somewhat reminiscent of the Canadian world-class Sullivan deposit with 155Mt, 9% Zn, 7% Pb in sediments with Sn and tourmaline in the footwall. Hydrothermal fluids responsible for the formation of the quartz, and associated copper deposits throughout the copper belt, were of low salinity and were probably of metamorphic origin. Somewhat surprisingly, fluid inclusions from the Specimen Hill Sn-W deposit are also of low salinity, but have higher homogenisation temperatures than those found in nearby copper deposits.

The copper mineralisation is *geochemically* simple and has low (<200 ppm) Pb, Zn, Sn, W, Bi, As and other metals, but is characteristically anomalous in Co and Ni, which show positive correlations with copper content. The tin-tungsten and zinc prospects, appear to be polymetallic, containing substantial amounts of As, Bi, Zn, Cu and Pb, but are characteristically low in Ni and Co. The geochemical data suggest that the Cu deposits vs Sn-W & Zn-Pb deposits formed from different sources and/or by different processes. Gold is not commonly reported from drilling, although some high-grade Cu intersections contain about 0.2g/t Au.

The overall features of the copper mineralisation, especially the simple mineralogy and the high concentration to massive nature of chalcopyrite, located mainly in faults and shear zones, suggest that a pre-existing low grade copper source exists at a deeper level in the Balfour area.

Geochemical exploration

The mineralised rocks in the Balfour area have been affected by near surface *chemical leaching* of sulfides and dolomites. This is demonstrated by lode-quartz exhibiting irregular cavities (sulphide leaching) and rhombohedral cavities (carbonate leaching), and formation of covellite-digenite-rich ores. The chemical leaching is considered to be extensive on EL 4/2002 and to have considerably lowered the near-surface geochemical metal values in rocks and soils. However, geochemical surveys by CRA have highlighted some metal-anomalous areas warranting further test; the anomalies around Specimen Hill appear to be significant and warrant further investigation.

Pacific Nevada undertook a *stream sediment sampling* programme in an area north of Balfour that indicated anomalous gold values (Figs 4.1, 4.2). Anomalous and visible gold is reported in a panned concentrate from *Cassiterite Creek* and also from the Frankland River area with BLEG gold values of 12-22ppb in a coherent area (Fig 4.1a) at E328800 N5436000; these warrant investigation. Visible gold found at E323100 N5430700 also warrants a check.

CRA undertook a comprehensive soil, rock and wacker sampling programme on a series of lines that detected anomalies as follows:-.

- **Cu:** Fig 4.3, Copper +2,000ppm reflects the Balfour Copper Belt trend in the prospect areas sampled, and also the Specimen Hill Sn-W-Zn area that has been little investigated for basemetals.
- **Zn:** Fig 4.3b, Zinc +1,000ppm reflects both the Murrays Reward copper shows and the +5,000ppm Specimen Hill-Peters Ridge-Skinners Flat anomalies that are inadequately explored.
- **Fe:** Iron reflects Murrays Reward, and the Clump prospects
- **As:** Arsenic has not been systematically assayed but is commonly above 500ppm in mineralised rock.
- **Mn:** Manganese hits a peak of +10,000ppm at Murrays Reward, and a few other 5-10,000ppm values at other prospects.
- **Au:** a best gold value of 3g/t Au occurs in polymetallic sulphide at Area A, south of Skinners Flat; 1.0g/t Au occurs at South Balfour Prospect, Gaffneys Creek with anomalous As, and Cu (Fig 1.9). Enhanced gold values occur spasmodically in supergene copper ores.

Geochemical reverse-circulation (or wide-diameter diamond) drilling along traverses to say a depth of 80-100m is needed to define the extent of basemetal and tin-tungsten anomalies in areas of geochemical response at Balfour.

Geophysics exploration

Electromagnetics: The 2002 frequency domain electromagnetic data (EM data), acquired by MRT during a helicopter borne Hummingbird survey on 200m line spacing, covers the entire Balfour EL 4/2002 and is of high quality (Fig 1.1). The data is unaffected by the problems of conductive and saline overburden that so commonly obscures important bedrock signals on mainland Australia. The EM data clearly defines targets that are mainly in covered areas and remain unexplained. It is interesting that the old copper workings are not particularly responsive on the new 2002-EM survey with only a weak-EM response at the Clump copper prospect, just north of a strong unexplained EM anomaly that is a new target herein.

The most interesting EM bedrock conductors are located at:-

- to the immediate west of Specimen Hill extending south to Skinners Flat and beyond to Area A and coincident with Zn anomalies
- SW of the Clump copper prospect in the northern part of EL 4/2002.
- Airfield-Nelson River Conductor
- State Forest Conductor

Other conductors are evident and are defined elsewhere in this report (Fig 1.2a).

In the Balfour area, at Specimen Hill/Skinners Flat the EM conductor is located about 1,000m west of Murrays Reward in an area of anomalous Cu-Zn (Fig 1.2b). The conductors have not been explained and they may be mineralised thrusts/shears, or formational in nature but the proximity of zinc-copper-tin-tungsten minralisation suggests that base metal and tin-tungsten mineralisation is quite likely to be associated with the conductors. They require drill-test. Other conductors are targets for further exploration.

IP surveys detected the line of copper workings but also show anomalies in the Zn-Pb and Sn-W areas in the Balfour area. The response is probably both from pyrite and pyrrhotite, and also from graphite that is reported from in the old copper prospects. The Tatlow Shaft to Peters Flat has been selected as a target for further exploration. Of importance is the observation that although IP is responsive to the known copper, EM response at Murrays Reward is flat. EM has never been used as a targetting tool at Balfour.

Aeromagnetic anomalies are enigmatic. There is a broad correlation between the Cu-Sn-W-Zn-Pb deposits along the Balfour Copper Belt (Fig 1.6) but in detail the relationship is inconsistent. In the south of EL 4/2002, the copper deposits are located directly over a magnetic anomaly but at the best copper deposit, at Murrays Reward, the anomaly is offset some 600m to the west of copper mineralisation and is coincident with the Sn-W anomaly.

The anomaly might be due to pyrrhotite or magnetite near the contact between a lower quartzite and an overlying siltstone; pyrrhotite is reported from some drill holes at Specimen Hill. But it remains puzzling because the anomaly appears to be somewhat discordant in places, conformable in others. The magnetic anomaly at Specimen Hill is located immediately east of the main EM conductor at W. Specimen Hill/ Skinners Flat and may reflect an alteration event along thrust and associated back-splay faults; it may be associated with hydrothermal mineralisation. (Magnetite has been reported in chloritic sediments to the north of the Roger River Fault, south of the Clump prospect.)

No specific test of an aeromagnetic feature is included in the recommendations herein but it is noted that magnetic anomaly at the Nelson Prospect is offset to the west from the Airfield-Nelson EM anomaly and the Roger River Fault, and may be associated.

(It is noted that magnetic and metal-bearing, Fe-oxide bodies occur in the Temma area, to the NW of EL 4/2002 and may be a deep source to the magnetic anomalies on EL 4/2002.)

Gravity: Granite at depth has been interpreted from a regional gravity-low in EL 4/2002, with an axis mainly to the west of the copper mineralisation (Fig 2.6). Unexplained local anomalies occur, offset from but adjacent to mineralisation, at sites such as the Clump prospect, where there is a coincident gravity & magnetic anomaly (Fig 1.5). One gets the impression that there are bodies of excess mass within the Proterozoic sediments that are not understood and require definition. A modern gravity survey would be ideal as a test for locations of excess mass at depth. The area is of relatively flat topography, with only thin overburden and readily accessed.

Geology and drilling

Several geology maps have been produced in varying detail; some of these can be found in the List of Figures. The Geological Survey has published the 1:25,000 Dempster and is about to publish the 1:25,000 Balfour sheets that cover most of the mineralisation areas. Studies have been made of mineralisation and isotopes that give clues to ore genesis; details are given in the report.

Drilling has been indertaken by ACI, BHP, CRA/Geopeko mainly along the line of copper workings and at Specimen Hill. There is some confusion over hole nomenclature and data retrieved by NCR are incomplete. Some better copper results are given in the table below and details are given in the report.

Murray's Reward, ACI drilling			
Hole	**From**	**Intersection**	**Copper %**
DDH 13 (Workings)		11.6m	0.7
DDH 14: (Main Shaft)	from 84.4m	21.2 m 16.5m true	0.9 4 intersec >1.7
DDH 16 (NW splay?) Supergene?	from 62.5m	**21.7 m** **incl 8.1m**	**1.4** **2.5**
DDH 19 (MR adit)		12.8m	0.5
Murrays Reward, CRA drilling			
DD97 BC9 On same section as DDH16	55.3m	**17.3m** **Incl 1.7m**	**1.1** **2.6**

Although the steep-dip, supergene enriched copper lodes at Murrays Reward are not an intial prime target for further exploration there is some indication of interesting copper in shallow, west-dip shears. This should be reassessed for potential large copper deposits down-thrust to the west.

Recommended exploration

It is recommended that the following actions be taken in order of target priority:-

TARGET 1: EM polymetallic target S, W and NW of Specimen Hill from Area A (south), Skinners Flat

Target 1 is the EM bedrock conductor immediately west of aeromagnetic anomaly, with anomalous zinc samples from shafts to the SW of Specimen Hill. Target style is of stratabound Zn-Pb-Cu in the Skinners Flat area with Zn>5,000ppm.

Action:

1. Digitise selected past exploration data and overlay digital geochemistry data.
2. Undertake ground EM traverses across the airborne EM feature in areas of anomalous geochemistry.
3. Define, model, and drill test the EM conductors using RC drilling at (E323 400, N54 29 000) Balfour Airfield (323 200, 54 30 000), (Fig 1.2a)

TARGET 2-EM polymetallic target SW of the Clump Prospect

Target 2 is the EM bedrock conductor to the SW and S of the Clump Prospect with anomalous zinc assayed from samples.

Action:

1. Digitise selected past exploration data and overlay digital geochemistry data.
2. Undertake ground EM traverses across the airborne EM feature
3. Define, model and drill test the EM conductors using RC drilling at (321 000, 54 36 700) (321 700, 54 36 300) (Fig 1.10)

TARGET 3: Peters Ridge-Tatlows Shaft basemetal anomaly
Target 3 is a 800m long, NNW-strike, geochemical anomaly, and parallel features, with Zn>5,000ppm, Cu, Sn. (E324 250, N54 29 250) No specific EM is conductor is evident but an IP response is noted. *Action:* Further review past drilling and plan fence of RC drill holes to test across IP response/geochemical trends.

TARGET 4 Tin-tungsten geochemical anomaly at Specimen Hill
Target 4 is an area shedding cassiterite from Specimen Hill and coincides with an aeromagnetic anomaly but no EM response. Systematic drilling is needed to determine resource potential for a 100m deep open pit.
Action: Further collate past Sn-W exploration data, including BHP, Geopeko, & CRA drill holes at Specimen Hill. Assess the economic potential for a 100m deep open pit to mine Sn-W at Specimen Hill and adjacent areas. Determine the ratio of Sn-W in sulphides versus Sn-W as oxide in quartz veins if possible. Assess the orientation of the main Sn-W-quartz vein sets. Design an angle RC drill programme (or large diameter diamond drill core programme) for resource delineation.
Also assess the potential for sulphide associated tin in relation to the aeromagnetic anomaly and reported pyrrhotite.

TARGET 5, EM Waratah East Conductor
Target 7 is an isolated conductor in the eastern part EL 4/2002, at E328 290 N54 25 400 along Waratah Creek, about 1km ENE of the Waratah prospect where copper sulphide has been noted. The Cowrie Sandstone is not otherwise conductive and the conductor appears to be discrete. A major NW-trend thrust fault traverses the area nearby (Balfour 1:25,000)
Action: Locate field site and inspect. Run ground EM and model to precisely locate drill target.

TARGET 6 Gap West EM conductor
Target 6 sites are selected from the broad conductor in the area at E344160 N5426605 & E324195 N5426000. At this time there is no supporting geochemistry.
Action: Inspect areain the headwaters of Cassiterite Creek just south of the Heemskirk Link Road.

TARGET 7 EM Conductor State Forest Conductor (SFC) far-east of EL 4/2002
Target 6 is an airborne EM conductor on the eastern edge of EL 4/2002 coincident with Cowrie Siltstone (pyritic and carbonaceous) and mapped faults (E325 700, N54 32 200)(Figs 1.2, 1.8, 1.10 and district geology maps). Geochemistry is unknown since the target has not been sampled before detection.
Action: Model the anomaly, check stream sediment sample geochemistry of adjacent creeks, visit site to develop basis for exploration.

OTHER TARGETS
Frankland River Gold: Steam sediment gold anomalies along the Franklin River catchment area in NE EL 4/2002 found by Pacific Nevada Mining.
Action: In-fill and inspect the stream sediment sampling in the Frankland River area to confirm and delineate further the gold anomalies
South Balfour: Old copper workings in the southern part of EL 4/2002 contain high-grade chalcopyrite veins in a 20m wide zone of structural complexity and wall rock alteration. CRA reported wide zones of alteration,

brecciation and anomalous Cu, As and Au associated with a magnetic anomaly (E325 750, N5424 200)(Fig 1.9).

Action: Investigate by field inspection and sampling to confirm potential for a wide ore zone; design a reverse-circulation drill traverse.

Nelson Prospect, found by CRA and coincident with the Nelson EM conductor and anomalous zinc; the area is undrilled (Fig 4.4a)

Nelson River to the Clump Conductor on N-trend, that may be fault related; located along E322 000, between N54 31 000 and N54 34 000).

Lindsays River: Sample the relatively inaccessible and little know copper showings in the SE part of EL 4/2002 around the Lindsay River-Doherty's Pimple area, believed to have been investigated by Mt Lyell 40 years ago (E330 000, N54 22 000)(Fig 1.2).

Murrays Reward West: Although the steep-dip, supergene-enriched, copper lodes at Murrays Reward are not an intial prime target for further exploration copper has been intersected in drilling in low-angle west-dip shears. This should be reassessed for potential large copper deposits down-thrust to the west of Murrays Reward.

Gravity: Undertake a systematic and carefully corrected gravity survey through the Balfour area to detect suspected excess mass bodies related to concealed cupriferous basalt, and/or specific Fe-oxide or sulphide mineralisation.

Diamonds: Sample the alkaline rocks reported by Everard et al (in press) to determine nature.

OTHER EXPLORATION WARRANTED

1. The data of CRA/Geopeko 1977-1985, including drilling at Specimen Hill, has been reviewed to a limited extent only; the work emphasized Sn-W exploration. Reports should be sourced from open file data, drilling and other information digitised and this report updated.
2. A priority for the project is to digitise all past drilling and other data. The surface rock and soils geochemical data has been digitised by CRA/RIO and is available for merging. The existing figures in this report could be the basis for this work combined with the Geological Survey maps and raster topographic data that is probably available as vector/spatial data that can be more readily merged.
3. Further analysis of the general EM data is warranted to rank targets for investigation, with reference to targets already defined above. This will be best attempted after digitisation of other data is complete.

TENEMENTS AND BACKGROUND

Location

Map 1:250,000: SK55-3 BURNIE
Map 1:50/100,000: Balfour, Frankland
Map 1:25,000, Balfour 3242, Dempster 3243, Lily 3241

The area is located south of Smithton/Stanley, a town on the NW coast of Tasmania, with the nearest hamlet being Temma, a small port on the west coast (Fig 1.1). The old mining town of Balfour, with a couple of temporary prospector residents, has all-weather road access, and prospects have bush track access (Figs 1.8, 1.9). An airstrip is located 2km west of Balfour.

The country is relatively flat and open, with heath (button grass) being the main vegetation; prominent peaks of quartzite rise above the plains- Mt Frankland 447m, Mt Balfour 436m (Fig 1.9), and Mt Hazelton 669m in the Norfolk Range, in far south EL 4/2002, on the Lily Sheet (Fig 1.5). A major gravel road known as the Heemskirk Link Road, joins Balfour with the river town of Corinna, and gives access to other parts of NW Tasmania (Fig 1.1). Climate is wet temperate. All year round field-work is possible with best conditions in summer, January to March; winter is wet and cold. The Frankland River is a major Tasmanian river and, in the northern part of EL 4/2002, it is incised along a NW trend roughly 1km east of and parallel to the Balfour Copper trend (Fig 1.8).

Exploration Tenements

The mining industry in Tasmania is governed by the Mineral Resources Development Act 1995 (replacing the Mining Act 1929) (MRDA). Summary terms of Tasmanian Exploration Licences are given in the Appendix. NCR made an application on 29th January 2002 to Mineral Resources Tasmania for an area of 110sq km (excluding small mining leases). EL 4/2002 was granted on 23rd August 2002 (Minister of Infrastructure, Energy and Resources, Deputy Premier, Paul Lennon). Small mining leases are held with EL 4/2002 but none conflict with the defined exploration targets:-

- 1M/76, of 5ha (200m x 200m) held by Messrs M Laan and K Heading for copper over the site of the Murrays Reward main shaft;
- 2M/2002, of 4ha, is held for gravel by Civil Constructions Corp;
- 18M/1996 of 4ha is held by Forestry Tasmania for gravel.

The Balfour Project area is favourably located within one of Tasmania's legislated "Strategic Prospectivity Zones". These SP zones give added security to tenure and the right to mine on crown land. Most of EL 4/2002 falls within the Arthur-Pieman Protected Area and as a consequence exploration work proposals are referred to the Mineral Exploration Working Group (MEWG), an interdepartmental group consisting of representatives from Environment, Parks & Wildlife, Forestry and MRT. MRT has indicated that this should not be an impediment to exploration and mining. Members of the MEWG liaise with appropriate people within their agencies. MRT seeks advice from MEWG members prior to setting licence conditions. Licence holders are requested to provide at least two weeks notice prior to proposed dates of field activity. This allows MEWG members to visit sites and recommend site specific conditions for each activity. The Tasmanian Mineral Exploration Code of Practice (MECOP) provides the standard and acts as a guide for exploration activities.

The Tasmanian Conservation Trust, and Launceston Environmental Group discussed a number of environmental issues with NCR and MRT prior to grant in 2002. It was jointly agreed that Peter Sims, their representative, will be informed of the planned time of major exploration before major exploration activity is commenced (see Contacts). Mr Sims conducts wilderness walks (Tarkine walks) through parts of the area away from the mining sites. It was agreed also, that any new tracks constructed during exploration will be made inaccessible to the public, by using temporary barriers, to reduce 4WD recreational vehicle damage to the sensitive scrub. Concern was expressed that the spread of *phytophthora cinnamoni,* a fungus that can kill local flora, not be spread by 4WD tyres from roadside grasses of the Heemskirk link road. A management plan for the Conservation Area has now been prepared. The plan concentrates on coastal areas and includes continuation of grazing.

Copies of the management plan are available from Service Tasmania.

Details of Registered entries for the Balfour Track Forest Reserve, Sumac Rivulet and Norfolk Range Australian Heritage Commission Act, have not been checked.

History of Copper Production

Copper mineralisation was first discovered in the Balfour area, in 1901, at Tin Creek by T.C. Murray and F. H. Smith (Ward, 1911). (Tin had been discovered in the 1880's and worked at a small scale.) Mining activities started from 1906 and commenced at the main deposit at Murray's Reward in 1910; this became the only mine to produce significant quantity of copper within the area. The Central Balfour deposit, located 500m NW of Murray's Reward mine, also produced a few hundreds tonnes of ore. Ore production practically ceased in the 1920's, presumably due to the low price of copper. In 1965, Broken Hill Pty. Ltd. surveyed the area for tin.

Gross production of neither tin or copper is well documented, but the amounts were not substantial with copper production being the greater in terms of tonnage and value. Based on available Mines Department records, a total of 126 tons of metallic tin was produced between 1907 and 1942. A total of 6,380 tons of copper ore was also produced, mainly from Murray's Reward and the Central Balfour workings by 1917. In the period 1929 and 1941, some 3.8 tons of metallic copper was produced. More recently, in 1990, some 130 tonnes of ore containing 24.8% copper were mined by Martin Laan. Old reports indicate that only very rich patches of ore grading between 12 and 35% copper were mined. All ore, generally grading 12-35%Cu, was tram-freighted for treatment at Temma. The fill used in the mines graded 2-5%Cu (McKenzie, 1964).

The township of Balfour had a peak population between 1912 and 1917, when some 300 to 800 people were present, decreasing to just a few by 1942. Presently, the township of Balfour has a few part time residents and only scattered remains of some original buildings can be found.

Company Exploration and Research History

Substantial past exploration data is available in published and open file reports. In this report herein, the recent geological investigations, documented by companies in open file data since about 1970, have been accessed by NCR. Emphasis has been given to copper potential, with some notes on Pb-Zn and Sn-W. In addition, Mineral Resources Tasmania (MRT) has undertaken geological and mineralisation studies as documented in Taheri (in press) and in Everard et al (in press). Past exploration reports have been scanned by MRT and some are available "on-line". A list of company reports for the Balfour area is included in Bibliography.

Exploration was undertaken as follows:-

1900-1911 Mineralisation in the Balfour area was described by Ward (1911) and many exploration geologists.

1956: **Rio Tinto**, regional aeromagnetic survey. This indicated a series of NNW-NW trending magnetic anomalies, passing through the Specimen Hill, at Balfour. This was later confirmed by a BHP survey (1965). John Rattigan produced aerial photo interpretation geological maps for SPL's 302 & 311.

1963-1965 BHP: SPLs 392 & 410 (25 sq ml), and ML 38M/63 (320acres) held by the Balfour Mining Syndicate (Mr G Force & G Kingston) BHP tested for open-cut Sn-W potential using gravity, magnetic survey, costeaning, drilling, and geochemical sampling. A plane table survey was conducted and 170 pre-existing pits were cleaned and samples of the peat and eluvial-gravel panned before assay in Launceston or Newcastle. Attempts to costean the best assay areas largely failed because the bulldozer (Allis Chalmers HD6) was too small to be effective in cutting through partly cemented eluvial fragments to bedrock. Jackhammers were used but abandoned after only partially exposing small areas of bedrock. Only Costean 1 was sampled for 64m at 3m intervals (Chestnut, 1964). The costean started to be cleaned but a pending wall-collapse, deep weathering and unreliable samples resulted in termination of the sampling activity. (It appears that in most cases, bedrock was not exposed.) Four vertical diamond drill holes were drilled at the Specimen Hill tin-tungsten prospect in 1963-64 (Chestnut 1964). Numerous, thin quartz-tin-tungsten veins were intersected but the overall tin content was considered to be too low to justify open pit mining; veins were insufficiently thick for conventional underground mining. However, the sampling was very incomplete, unsystematic and tested only small areas. BHP also produced a geological map of the Central Mt Balfour and Murrays Reward mines.

1964 In March, at the request of BHP, Bureau of Mineral Resources flew an aeromagentic survey of Balfour using four parallel lines (Chestnut, 1964).

1966: The BMR flew a high altitude (3,000m) aeromagnetic survey.

1965- 1967: EL 12/65 Pickands Mather and Co International conducted extensive geochemical stream sampling of the Rocky Cape Group. Some discordant magnetite lodes near Temma (to the west of Balfour) were drilled (2 holes). The results indicated these are bodies 10 to 15m thick with low grade Zn, Ag, Pb and Cu.

1968-1974: ACI Ltd tested ELs 16/68, 48/70 & 49/70 in joint venture with Consolidated Goldfields, Mt Lyell and Renison for copper mineralisation in the Balfour and the Interview River areas. This "Consolidated Syndicate" commissioned Compagnie Generale de Geophysique to fly aeromagnetics. Stream sediment sampling, rock chip sampling and mapping were conducted. ACI did surface and underground sampling, costeaning, and IP surveys (along 12km of strike). The IP surveys, in 1970 by McPhar Geophysics, were initially on lines 487m apart, with more detailed line spacing down to 30m at the Blocks, 46m at the Clump, and 76m at Murrays Reward.

Some lithological contacts at the Clump and Specimen Hill were anomalous in copper. This was tested by underground workings at the mine site, two adits and a shaft to the north of the mine, as well as over thirty trenches and pits. Most of their exploration (including drilling) focussed on known deposits in the Balfour area, including The Clump (Jackaman, 1972), Murrays Reward (McIntyre, 1973) and Specimen Hill (Anon., 1972b; Davies, 1969; Davies and McIntyre, 1973; Anon., 1972a).

Thirty seven diamond drill holes (5,816.2m) were drilled on eight old prospects over a strike length of 17km in the Balfour area including:- Waratah (2), Pierpont Morgan (2), Gully(1), Development (1), Murray's Reward (16), Central Balfour (3), Balfour Blocks (3), Tin Creek (now Cassiterite Creek, 1) and the Clump (8, drilled over a strike length of 750m, poor core recovery). (Figs 5.1, 5.2, 1.8, 1.9). Quartz-dolomite-chalcopyrite zones were found to be up to 20 m wide, with an average of 0.5% Cu. The samples were not analysed for gold content, except at Murrays Reward. Core drilled by ACI, other than three holes, has been lost.

1974: Esso: Geoterrex flew Esso's large EL 2/73 with fixed-wing Barringer INPUT EM and a magnetic survey with line spacing 800m and terrain clearance of 120-180m south of the Arthur River. Many EM (INPUT) anomalies were field checked and attributed to conductive black "slates", including two on the Dempster sheet within areas now mapped as Cowrie Siltstone (Neale, 1974). Although the survey was reported from a geophysics point of view, it appears that few geochemical samples were collected in the cursory helicopter supported field follow-up that ascribed conductor/targets to graphite (Legge, 1980).

1977-1985 CRA Exploration Pty Ltd: ELs 1/77, 1/79, 12/80, 36/80, 4/83, 61/83. In 1977 CRA undertook a helicopter supported panned-concentrate and stream sediment geochemical sampling programme on EL 1/77 across much of the Rocky Cape Group seeking mainly tin deposits. Earlier stream sediment data was collated and a regional infill survey conducted (Weir, 1982).

Later, in a joint venture with Geopeko, CRA shifted the target in EL 1/77 to shale hosted lead-zinc (SEDEX) deposits, noting similarities in regional geology with the Selwyn Basin (Canada)(Legge, 1980).

Detailed exploration around Balfour by CRA and Geopeko between 1979 and 1983 was mainly for tin, and included mapping, geophysics (magnetic and IP), geochemistry and drilling (Porter, 1980a,b; Heithersay, 1982; Langsford, 1982; Dickson, 1983). Laan (1985) concluded that alluvial wash in the lower reaches of Cassiterite Creek is devoid of tin-bearing gravels. NCR has not checked this data.

At Balfour, around Specimen Hill and Peter's Ridge, CRA geologically mapped a 2.6 x 0.7km grid, drilled 5 shallow Jacro-auger holes, sampled soil and rock, undertook aeromag, ground mag with follow-up, IP, SP and Dighem EM surveys (no details seen), according to Patterson (1996).

CRA drilled 8 diamond drill holes, three at the *Specimen Hill and Murrays Reward* and one at *Hazelton (no details)*. At Specimen Hill, it was found that the tin veins are of high grade (average 0.8% Sn and 1.02% WO3), but they were considered too-thin and too-low in vein density to be economic. (Outside EL 4/2002, CRA also investigated the strong magnetic anomalies near Temma, at the *Little Eel* and *Possum Creek Prospect* and in joint venture with CRA, North Limited/Geopeko drilled two diamond drill holes. The best intersection was 3m, 2% Pb and 13 g/t Ag. NCR has not reviewed the open file reports).

1981 An Honours theses describing the Murray's Reward mine area was written:- Yaxley (1981).

1982 Geoex Pty Ltd flew fixed wing aeromagnetic survey for the Tasmanian Government in about 1982; lines were 500m apart, clearance was nominally 150m. Leaman (1982) interpreted the survey. In terms of copper potential in Tasmania, Leaman ranked the Balfour area second to the West Coast Range.

1987 Aureole Resources EL 21/87 Balfour evaluated the platinum potential along the southern margin of the Smithton Trough.

1988-1992: **Soloriens Mining Proprietary Limited** undertook on EL 53/88 & EL 52/89 Balfour

- a regional gravity survey at an approximately 1km station spacing and
- a detailed gravity survey of the Balfour and Clump prospects at 50-100m line spacing (Leaman, Oct 92 and Nov 92 in Morrisson 1993).

Studies of Pb-isotopes from both the Murrays Reward Cu, and Balfour (Specimen Hill) Sn-W deposits were commissioned to CSIRO (Carr and Dean, 1992, and Dean 1992, in Morrisson, 1991, 1992).

1993 An Honours theses describing the Murray's Reward mine area was written (Veska (1993)(not seen by NCR).

1993- Nov 1997 CRAE/RIO: EL 4/94 Balfour (25 sq km) within the larger EL18/92 (177sq km) Mt Frankland, CRA Exploration Pty Ltd surveyed the Balfour area for sediment-hosted Cu deposits after an appraisal of Australian Proterozoic potential opportunities. They looked for stratiform concentrations within favourable sedimentary units, and large, irregular stratabound silica-dolomite bodies; geophysics was used to identify possible fluid conduits and sedimentary contacts in the Rocky Cape Group favourable to redox copper deposition. These were followed up by ground geophysics and geochemistry, in particular at the Nelson prospect (near 321200mE); the Murrays Reward deposit was also re-examined (Turner, 1994b; Menpes, 1995a). Towards the end of the exploration, in 1995-97, CRA/RIO digitised much of the past geochemical exploration data.

The CRA/RIO work included:
EL 4/94
1994-96 (Menpes, 1995)

- Reviews of previous exploration, geochemistry, mineralisation styles, gravity and aeromagnetic data.
- Recompilation in profile form, and digitisation of ACI's IP survey, and previous geochemical data
- Geological mapping at 1:10,000 of the Clump and Murray's Reward mines (Nic Turner).
- 80 rock chip samples analysed for Cu, Pb, Zn, Ag, Co, Ni, Fe, Mn, Sn, W, Au from the general Balfour area and Specimen Hill, mainly by Turner
- 52 rock samples from grid lines and Heemskirk Road and Cassiterite Creek
- orientation soil and wacker sampling over the *Clump Prospect*.
- Seven grid lines, 400-800m spacing cut on the *Nelson Prospect*.
- 120 soil auger and 142 wacker samples along 5 grid lines
- Ground magnetic survey at *Nelson Prospect* along 7 grid lines (N54 20000 to 27000), and 50m dipole-dipole IP along three lines (Menpes, 1996).

1995-96 (Menpes 1996)

- CRA compiled ACI's drill data (Porter, 1996 in Menpes 1996)
- Reviewed gravity, IP and aeromagnetic data
- Reviewed Specimen Hill data
- 6 rock chip samples from Tatlow's costean

1996-1997 (Russell and Tear 1997)

- 62 rock samples from EL 4/94 and EL 18/92
- additional elements were analysed on 127 samples collected by Nic Turner
- 7 samples for thin section
- CRA drilled three diamond drill holes DD97 BC 9,10,11 (Russell and Tear, 1997)

EL 18/92

- *Airborne magnetic and radiometric survey:* High resolution, 2,705km, 100m line spacing (200m around Norfolk Range), 60m clearance, survey flown by Kevron in March 1993. The survey was predominantly E-W but an area between Balfour and Mt Frankland was flow N-S to minimised altitude variations over the Gap Prospect (Parkinson, 1993). Copy of located data was given to MRT but the data has not been included in the Government aeromagnetic data set. (It is noted that the altimeter data were not corrected for parallax and the digital positioning model has positioning errors (Raajagopalan, 1996). A vertical derivative image was generated by CRA (Tear, 1996) but this has not been sighted by NCR.
- *Detailed ground magnetics* were collected on 7 lines N54 20,000 to 27,000; the instrument malfounctioned and data is of dubious quality (Parkinson, 1993).
- 103 hand-auger soil geochemical samples, 25-50m intervals along traverse, over a *leached* pyrrhotitic siltstone along the Balfour Pyrrhotitic Siltstone yielded max 34 ppm Cu, but were mostly less than 10 ppm; Ag, As, Cu, Pb, Zn, Fe, Mn were analysed (Parkinson, 1993 (ledgers), Tear, 1996). Surface leaching is evident.
- Geochemistry compilation at 1:50,000 of previous work, with digital capture, to produce rock and soil plans of Cu, Pb, Zn, Mn, Fe, As including latest sampling of *Nelson Prospect*. Hand auger and wacker bedrock sampling.
- Tear (1996): Analysis of 135 float and outcrop samples from various localities for Ag, Au, As, Cu, Pb, Zn, Fe, Mn, Sn, W. Best values were of 2.3% Cu in "massive chloritic rock", 0.8% As, and 1.03 ppm Au in a "quartz-pyrite rock" from the South Balfour Prospect. Nic Turner 127 rock samples (Turner 1994).
- 62 rock samples. 7 thin sections by Paul Ashley (Tear and Russell, 1997)

- 177 hand auger soil samples at the Gap Prospect, along four 200m spaced lines at 25m intervals; analysed for Ag, As, Bi, Co, Cu, Mo, Ni, Pb, V, Zn, Fe, Mn (Tear 1996).
- Bedrock wacker rock sampling around the *Clump, Nelson* prospect in the *Temma* area delineated a zinc anomaly, about 1.5km long at the Nelson prospect.
- A further 100 wacker samples, on 4-lines were collected at *Nelson* by CRA (Tear and Russell, 1997)
- Tear and Russell (1997) includes large tables of geochemical sample results from the digital database.
- EL28/92 expenditure was $361,160 and EL 4/94 expenditure was $546,186 making a total of $907,346 to relinquishment.

The area covering the Balfour copper trend which cross cuts the "Savage River focal structure" was considered prospective for stratabound Cu (+/- Au) and Pb-Zn and carbonate replacement deposits.

1994 TASGO project of AGSO & MRT undertook 5 deep seismic profiles totalling 134 km onshore Tasmania. Offshore Rig Seismic recorded 1,758km of deep seismic data; wide-angle reflection and tomography experiments used onshore stations.

1996-2000 Mineral Resources Tasmania flew in-fill fixed wing aeromagnetic regional surveys across NW Tasmania (Kevron Geophysics) and stitched these into previous quality surveys by private companies; terrain clearance was a nominal 80m with line spacing 200m. The 1996 Arthur-Pieman Aeromagnetic survey was flown for the Regional Forestry Agreement by MRT and AGSO. The results are available in ER Mapper format. An extract, of preliminary quality, is given of the Balfour area as Figure 1.6. MRT has also flown helicopter borne radiometric surveys (Geo Instruments) that are available in ER Mapper format (not analysed by NCR); clearance was a nominal 80m with line spacing 200m.

1998: Pacific-Nevada Mining Proprietary Limited: EL 4/98; mainly to the NE of EL 4/2002, explored for stratiform copper, fault-related/stratabound Cu-Au, sedex Pb-Zn and carbonate replacement deposits. Exploration included- 46 sites each for stream sediment, bulk leach gold BLEG, -80#, and 39 sites of panned concentrates; 25 rock chip samples (Figs 4.1, 4.2); an airborne magnetic and EM survey covered part of NCR's EL4/2002, to the north of Balfour (Westbrook, 1999). Expenditure was $66,727.29 to July 1999.

2001 NASA's Shuttle flew high-altitude Side Look Radar in a swath 80km by 18km from the Balfour area to Renison Bell. (NCR has not been able to access this data.)

2000-02 Mineral Resources Tasmania studied prospects including the exposed lodes at Murray’s Reward, Toner River, and South Balfour. Other copper deposits including the Clump, Waratah, Balfour Blocks, Balfour Central, Tatlows, Specimen Hill are also briefly described (Taheri in press).

In early 2002, MRT commissioned Geo Instruments to fly a helicopter-borne Hummingbird **EM survey** of several areas in western Tasmania. EM digital acquisition specs are:

Line spacing: 200m, orientation 90^0true

Nominal flying height: 60m, 30m for the bird
Data output: every 0.1 seconds or less, flying speed 40m/s
Coaxial coil frequencies: 980 and 7001Hz
Coplanar coil frequencies: 875, 6,606 and 34,133Hz

EL4/2002 is entirely covered by the survey (Fig 1.1, 1.1). The Balfour Project contains large areas of fairly flat terrain so terrain variation issues should be minimal over most of the area.

MRT has published the 1:25,000 Dempster geology sheet that covers the northern part of EL 4/2002, and is close to publishing the Balfour geology sheet. A description of the geology of the Dempster, Sumac and Roger River 1:25,000 sheets is in compilation (Everard et al, in press).

REGIONAL GEOLOGY AND MINERALISATION

The geology of northwestern Tasmania has been studied by many geologists including Spry (1957,1962), Gee (1968), Gee et al (1969), Bell (1972), Lennox et al (1982), Brown (1989a), Turner (1989), Seymour and Baillie (1992), Everard et al (1996) and most recently by Everard et al (in press) from which most details of the Balfour Copper Belt geology, at least in the northern section, have been summarised herein. Nic Turner's geological map of the Balfour area is the most detailed overall coverage of EL 4/2002, and is enclosed (Fig 2.2)

King Island

On King Island, to the north of Tasmania's mainland but geologically connected, a sequence of Mid-Proterozoic shelf facies quartzarenite-pelite (1,200Ma) is overlain sequentially by diamictite, dolomite, and rift mafic volcanics and picrite (Calver & Seymour, 2001). The Wickham Orogeny (760Ma) was associated with the intrusions of granite of about 730Ma. Although there is little evidence of the Wickham Orogeny and no Proterozoic granites outcrop in mainland Tasmania, it is quite possible that rocks similar to the older quartzitic King Island sequence, and sequences older than that, underlie the Rocky Cape Group of mainland Tasmania.

NW Tasmania-Geology and Mineralisation

Basement in mainland western NW Tasmania is of Proterozoic, Rocky Cape Group bounded to the east by the Arthur Lineament, a major east-dip, NE-trend thrust, that formed in the Tyennan Orogeny c510Ma (Holm et al 2001, 2002) (equivalent of the Delamerian Orogeny) (Figure 1.4). The Arthur Lineament contains major deposits of magnetite-pyrite iron ore at the Savage River iron ore mine.

The Arthur Lineament, also called the Arthur Metamorphic Complex (AMC), separates:-

- a "Western Succession" (of the Rocky Cape Group shelf and deep water sediments) that are either of Torrensian age (750Ma) based on correlations with the Adelaide Geosyncline (Calver & Seymour 2001) or older Mesoproterozoic (Balfour Project) and

- an "Eastern Succession" (of Burnie and Oonah Formation turbidite) (perhaps 1,200 or 750Ma age)

The Balfour Project is located in the "Western Succession" of less metamorphosed sedimentary rocks in relation to the Arthur Lineament (Fig 1.4).

In a broad lithological sense, some comparison of the magnetically active Arthur Lineament might be made with elements of the Eastern Succession in Mt Isa. Magnesite, in potentially economic quantities and grades, attests to the carbonate component in the AMC. Indeed, the blue schist component of the AMC is thought to have been extruded from a west-dip subduction zone (Turner & Botrill 2001) that may now be concealed under the Rocky Cape Group of NW Tasmania. A recent seismic survey of Tasmania indicates a thickened crust for western Tasmania, consistent with a margin formed by trans-tensional strike-slip along the Tasman fracture zone (Rawlinson et al 2001).

The tectonic setting of the area in relation to major crustal lineaments is intriguing if not definitive in an ore control sense. Campbell (1989) has identified the Port Campbell-Netherby Corridor as a crustal tectonic zone that extends from Blinman in South Australia through western Victoria and down the western part of Tasmania (Fig 1.3). This feature is of uncertain origin and nature but has been identified by Campbell on the basis of magnetic, gravity, volcanic centres, drainage patterns, fault and graben trends, topography, oil and mineral occurrences. The Corridor coincides with the Balfour copper trend. It is intersected by NE-trend structures near Balfour (Fig 1.3). Additionally, a WNW fault trend is evident in the Balfour area.

Three major tectonic elements appear to have been influential on the development of the extensive Cu, and Sn-W deposits in the Balfour district. The major N to NW trend Balfour Shear/thrust that marks the displacement of the older Rocky Cape Group sequence over the Younger Rocky Cape and the even younger Togari sequence (with cupriferous basalt)(Fig 1.7), a long-lived NE-trend fault- the Roger River Fault, and an inferred intrusion of granite below the mineralised area. These elements have been used to model the area as being prospective for major Cu (and Sn-W) deposits.

The Proterozoic rocks of NW Tasmania host a number of world-class and major ore deposits that have ages of origin ranging from Proterozoic to Devonian. They include:-

- Savage River iron: 371Mt, 32% Fe in magnetite, Proterozoic
- Arthur River magnesite: 29Mt, 43% MgO, Proterozoic
- Main Creek magnesite: 43Mt, 43% MgO, Proterozoic
- Renison Bell tin: 24.5Mt, 1.1% Sn, Devonian
- Mt Bischoff: 10.5Mt, 1.1% Sn, Devonian
- King Island Scheelite: 11.5Mt, 0.7% WO_3, Devonian.

The Balfour district has indications of potential for a major copper deposit, and also has potential for economic tin and tungsten deposits. Previous explorers have recognised this potential with most district-wide work completed by RIO/CRA/Geopeko. The copper mineralisation is distributed intermittently along 35km of strike and remains a geological enigma in terms of origin and age. The geology suggest potential for Zambian sediment hosted Cu, Mt Isa Cu, Gawler Craton ironstone related Cu-U, Renison Sn, and perhaps King Island W styles, and indicate that exploration should persist in the area.

BALFOUR PROJECT GEOLOGY

Rocky Cape Group

In the Balfour area, a basal arenite-pelite package (Rocky Cape Group) is overlain by Late Proterozoic siliceous clastics, dolomite and mafic volcanics (Togari Group); the volcanics contain anomalously high copper. Major tectonic disturbance has overthrust the arenite-pelite over the clastics-dolomite-volcanic sequence and copper mineralisation has, perhaps, been redistributed at this time (Fig 1.7).

EL 4/2002 is underlain largely by the Balfour Subgroup, a sequence of interbedded laminated, cross-bedded and gutter-cast siliceous sandstone and siltstone, carbonaceous pyritic siltstone, quartzarenite and chloritic siltstone that conformably overlies the Lagoon River Quartzite and is conformably overlain by a correlate of the Cowrie Siltstone in the vicinity of Balfour (Everard et al, in press, Fig 2.1). Unit thicknesses vary dramatically along strike, particularly where units are transected by thrusts. The total thickness of the Balfour Subgroup is about 3,500m. The Balfour Subgroup and the Cowrie Siltstone are potential source rocks for copper mineralisation along the Balfour copper belt and in the Temma area.

A tectonically stable, shallow marine, depositional environment is suggested for the formation of quartzites. In contrast, the overlying Cowrie Siltstone is mainly carbonaceous, with common diagenetic pyrite, indicating reducing depositional conditions. The Cowrie Siltstone was probably deposited in a large shallow, stagnant lagoonal environment, largely isolated from marine currents (Everard et al, in press). The presence of likely anhydrite casts in the unit is consistent with shallow water, locally evaporitic conditions. The Balfour Subgroup, however, represents a higher-energy environment with current influenced deposition than the Cowrie Siltstone.

Everard et al (in press) discuss the age and the reader is referred to this for details. The minimum age of the Rocky Cape Group is directly constrained by three minimum K-Ar ages (ranging from 584 ± 8 to 600 ± 8 Ma) of dolerite dykes intruding the Cowrie Siltstone and two K-Ar slate ages (643 ± 10 and 630 ± 10 Ma) from the Irby Siltstone, both from the north coast. There is also an approximate isotope chemostratigraphic age of 750-650Ma for the overlying Black River Dolomite. Maximum age limits of about 1,450Ma (Detention Subgroup) and probably about 1250 Ma (Jacob Quartzite) are provided by SHRIMP ages from detrital zircons.

The Rocky Cape Group comprises a thick, unfossiliferous, siliciclastic, shelf sequence, the underlying basement to which is unknown but could be similar to the Mid-Proterozoic seen on King Island, with unspecified granite.

The *Rocky Cape Group*, is the most common rock type in the Balfour area. The rocks along the Balfour track and west of Murray's Reward consist of a conformable, east facing sequence ranging from, in the west quartz arenite to grey siltstone, changing into green and grey siltstone with interbedded quartz arenite to the east, near Murray's Reward. Similar stratigraphy continues to the south and north of the Murray's Reward mine.

The most recent sub-division of the Rocky Cape Group is given by Everard et al (in press):-

- (youngest) Jacob Quartzite (Gee, 1968) (not on EL 4/2002)
- Irby Siltstone (Gee, 1968) (not on EL 4/2002)
- Detention Subgroup (Gee, 1968) (comprising the Bluff Quartzite, Port Slate and Cave Quartzite of Spry, (not on EL 4/2002)
- **Cowrie Siltstone Correlates** (Prc, Prcs) (Spry, 1957; Gee, 1968)-includes lagoonal, stagnant sedimentation
- **Balfour Subgroup**-(previously Interview Siltstone Fm) includes lagoonal, stagnant sedimentation types, carbonaceous and pyritic shale particularly from the Arthur River to 10km south of Balfour (EL 4/2002). It comprises four formations, the Skinners Flat Siltstone, the Cassiterite Creek Quartzite, the Emmetts Creek Shale and the Looneys Flat Siltstone (Everard et al, in press, see Dempster 1:25,000 for symbols)(Fig 1.7) (see below for detail). It is approximately equivalent to the "Balfour slates and sandstones" of Ward (1911) and other authors.
- **Lagoon River Quartzite** (Gee et al, 1969; Bell, 1972): massive, recrystallised, thick, magnetically noisy quartzite. EL 4/2002
- (oldest) **Pedder River Siltstone** (Bell, 1972): dark grey, poorly bedded, slump, scour/fill structures, magnetically quiet, some pyritic/graphitic, some sandstone/conglomerate) (not on EL 4/2002?)

Balfour Subgroup

- ***TOP: Looneys Flat Siltstone*** (Prbs, Prbsa, Prbsq) 1,000m thick a unit of grey to buff-coloured, micaceous, *fine-grained sandstone*, interbedded with and grading up to dominant planar laminated *green siltstone with chlorite porphyroblasts*; it is conformably overlain by a correlate of the Cowrie Siltstone (Everard et al, in press). Locally contains members of dominantly thinly bedded medium-grained sandstone (Prbsa) and thickly bedded quartzarenite (Prbsq). The Looneys Flat Siltstone (unit Prbs) can be differentiated from the Emmetts Creek Shale (Prbg) by a coarsening grainsize up-section. Micaceous and rarely pyritic fine-grained sandstone may grade stratigraphically upward into laminated chloritic siltstone. Bedding planes are typically regular and internal sedimentary structures other than grading are absent. The same porphyroblastic texture that is observed in the Emmetts Creek Shale. The most typical lithology is thin-bedded, plane-laminated, light olive-green siltstone, with prominent dark green chloritic spots ≤ 2mm in diameter, which are either selectively concentrated in certain laminae or dispersed throughout the rock.
- ***Emmetts Creek Shale*** (Prbg) 500m thick, comprises thinly laminated blue-green or green to cream siltstone with chlorite porphyroblasts, black pyritic carbonaceous shale and rare quartzarenite. Pyrite is ubiquitous (Parkinson, 1993). Conformable.It is characteristically poorly outcropping and commonly defined by a low-lying topography and dense understorey of scrubby vegetation. The Emmetts Creek Shale comprises monotonous sequences of laminated siltstone, characteristically azure to green in colour when fresh but typically weathering to alternating dull green and rusty brown colours. Individual laminae are typically less than 10 mm thick. Laminated black, pyritic, carbonaceous siltstone and shale sequences to 50

m thick also occur at irregular intervals throughout the sequence (e.g. 321900mE 5438350mN). Veska (1993) noted up to 5% pyrite in rocks from the vicinity of Balfour hamlet but also noted that some of the pyrite cuts the tectonic cleavage suggestive of a post-diagenetic origin. Consequently, the percentage of diagenetic pyrite in this unit remains uncertain. The porphyroblasts overgrow and preserve two tectonic foliations (S_1-S_2), and their formation was coincident with S_2 (See Structural Geology section.). *Parkinson (1993) reported a 2km long conformable dolomitic quartzite facies in the carbonaceous shale, particularly from the Clump prospect area, and Murrays Reward; he notes this is different from dolomite alteration in veins (see Clump Prospect).*

- ***Cassiterite Creek Quartzite*** Prbq +350m thick comprises upwardly fining cream-coloured tabular-bedded quartzarenite bands some 7m thick, laminated siltstone (can be siliceous, and ridge forming) and carbonaceous shale; abruptly and conformably overlain by the Emmetts Creek Siltstone; previously the upper member of the "Specimen Hill Siltstone" (Yaxley,1981). Unit forms clearly-defined ridges. Hemipyramidal casts suggestive of diagenetic evaporite development were also apparent in a shale unit north of The Clump (321420mE 5436475mN).Yaxley (1981) also noted a small amount of post-depositional tourmaline in rocks west of Balfour.
- ***BASE Skinners Flat Siltstone*** Prbl (base) 500m. laminated to gutter-cast and trough cross-bedded light grey, siliceous fine-grained sandstone and siltstone, and dark grey carbonaceous siltstone (the Specimen Hill siltstone of Yaxley (1981), and also called 'pyjama siltstone' (Veska, 1993). Conformable on Lagoon River Quartzite. Parkinson (1997) notes that the transition from the Lagoon River Quarzite up into siltstones of the Balfour Sub-Group is marked by a band of tourmaline-rich siltstone and shale carrying 5% pyrrhotite. This is regionally traceable. He also reports ferruginous, and carbonate-bearing units.

Cowrie Siltstone

The Cowrie Siltstone flanks the *eastern* margin of the Smithton Synclinorium, along which it extends northward, roughly along strike, to its type area on the north coast (Spry, 1957; Gee, 1968, Everard et al, in press). Only a small part lies on the Dempster Sheet (where it is mostly poorly exposed).

Cowrie Siltstone Correlates

MRT examined the area along the Franklin River upstream from Balfour by raft at E326800 N5431400 to E325300 N5431000 (Everard et al, in press)(Fig 1.8). The area is of interest because a strike persistent conductor (herein named State Forest Conductor) was detected in the area by the EM survey (Fig 1.8, 1.10). The most common lithology is a medium- to dark grey, thinly and diffusely laminated but not necessarily fissile, slightly micaceous and pyritic siltstone or very fine-grained sandstone. The lamination is usually planar; graded bedding is sometimes present and the unit generally dips and faces southwest. Sinistral mesoscopic folds, plunging at about -27°/160°, were noted on the north bank of the river at 325740mE 5430930mN. Outcrop on the surrounding hills to the north and south of the Frankland River is generally very poor.

Anastomosing carbonaceous seams are parallel to bedding in places, and adjacent mica is commonly orange-brown (oxidized?). Accessory minerals include sparse small, opaque and rounded zircons. The planar bedded rocks resemble the Cowrie Siltstone to the east of the Smithton Synclinorium but the wavy laminated varieties are atypical. The tourmaline metasomatism suggests the proximity and influence of the spine of Devonian granite, inferred to underlie the Balfour mineral field a few kilometres away (Everard et al, in press). However, the tourmaline may be reflecting mineralisation associated with the EM conductor in the area.

Togari Group

The Rocky Cape Group is overlain by the Togari Group of Late Proterozoic (700Ma) age, (previously called the Ahrberg Succession) at different stratigraphic levels in different localities around the margin of the Smithton Synclinorium (Seymour & Baillie, 1992; Everard *et al*., 1996)(Fig 1.7). This difference was previously ascribed to a compressional deformational event prior to Togari Group deposition, but it is also consistent with extensional tectonism during that time (Everard, el al 2001). Sedimentation was into rift related, intracratonic basins with initially coarse clastic sediments followed by sag-phase carbonates and volcanics. The Togari Group volcanics are a potential source of copper at Balfour from basalts, and a potential location for Sn-W in carbonates. Although the Togari Group is not widespread in outcrop on EL 4/2002, it is postulated to underlie the Balfour Copper Belt under the Balfour Thrust (Fig 1.7, 2.5a,b,c).

The Togari Group, up to 4 km thick, comprises conglomerate, dolomite and chert, siliceous and volcaniclastic sedimentary rocks and cupriferous basalt. It is divided as follows:-

Togari Group (Everard et al, in press)	
Salmon River Siltstone (youngest) ≤ 350m	
Smithton Dolomite (≤ 1500m)	Psd shallow marine dolomite and minor limestone
Kanunnah Subgroup ≤ 1400m, post sag-phase	Psvw intercalated lithicwacke, tholeiitic basalt, diamictite, lithic-arenite, hematitic ironstone, mudstone and impure carbonate, includes Smithton Volcanics and Spinks Creek Volcanics Psb, magnetically distinctive
Black River Dolomite (≤ 800m)	Pss dolomite, chert siltstone & mudstone, with pyritic carbonate and black mudstone (Brown 1989a)
Forest Conglomerate and Quartzite (oldest)(0-120m thick)	Pscb Chert breccia and conglomerate with laminated quartz arenite

In the Balfour area, a black laminated siltstone occurs at the boundary between the upper Black River Dolomite and the overlying basalt and lithicwacke (Menpes, 1965).

The Roger River Fault, to the north of Balfour, appears to have had a major influence on the deposition of the Togari Group.

Copper bearing basalt: The basalt units (Spinks Creek Volcanics) are of massive to locally pillowed, dominantly tholeiitic basalt, metamorphosed up to the prehnite-pumpellyite or, rarely, greenschist facies (Fig 1.7)(Everard, et al, in press). Copper content, commonly anomalous up to 590ppm, does not show relationships with other elements. The basalts are thought to be a possible copper source for the copper mineralisation in the Temma-Balfour area. A model of structural overthrust in the Balfour area, and associated metamorphic-leaching of buried cupriferous basalt has been proposed as a source of copper for the Balfour area.

The *Spinks Creek Volcanics* occur mainly toward the top of the Kanunnah Subgroup and are thickest east of the Roger River Fault. Together with minor associated subvolcanic intrusives, they can be subdivided into at least seven tightly defined geochemical groups on the basis of parameters such as TiO_2, Nb/Zr, MgO and REE patterns. The detailed geochemistry of tholeiitic dolerite dykes that intrude the Rocky Cape Group shows that they cannot represent feeders for the Spinks Creek Volcanics, although they may be broadly part of the same tectonomagmatic episode during Neoproterozoic rifting. (Everard et al, in press)

Proterozoic dolerite dykes, Frankland River

Two dolerite dykes have been mapped intruding correlates of the Cowrie Siltstone along faults in the eastern part of EL 4/2002 (Everard et al, in press)(Fig 1.8). The easternmost dyke, which crops out in the Frankland River at E325800 N5430900, is relatively massive and has a northwesterly trend. The other dyke about 500m further west is foliated and has a northerly trend parallel to the Balfour Shear Zone.

Chemical analyses of the westernmost of the Frankland River occurrences have a tholeiitic chemistry, indicated by relatively low total alkalis ($Na_2O + K_2O$), low P_2O_5 and low Nb/Y ratio (< 1).The Frankland River dykes (probably) are representatives of the Rocky Cape Dyke Swarm. This consists of mainly NE- to NNE-trending dolerite dykes that transect northwest Tasmania in a zone about 15km wide and 95km long, extending from the lower Pieman River to near Rocky Cape. The relatively high K_2O content is a characteristic feature of the Rocky Cape Dyke Swarm dolerites, and suggests that they are not the direct feeders for the Spinks Creek Volcanics (Everard et al, in press).

Alkalic dykes of uncertain affinities

Weathered pale grey-green to orange-coloured dykes occupy NE-trend faults along the Heemskirk Road near The Clump, at 321150mE 5436150mN, and also further south at 321900mE 5432000mN (Everard et al, in press)(Fig 1.8). The faults are syn- to post-D_3 in age and link to the NE with the regional-scale Roger River Faults. The dykes are up to 1m wide and contain angular inclusions, to 200 mm, of country rock. Despite weathering, the dykes still show an aligned porphyritic texture in hand-specimen. Thin sections reveal angular to pseudo-hexagonal and tabular phenocrysts to 3 mm in length of microcrystalline quartz after what was probably originally amphibole and feldspar, respectively.

The analysed sample is so altered that the chemical analysis needs to be considered with extreme caution. Major elements, other than SiO_2, Al_2O_3 and TiO_2, have been leached out to almost negligible levels. The high H_2O+ (10.92%) is indicative of the severity of alteration, whilst CO_2 (2.05%) may indicate analytical difficulties (possibly trapped air rather than CO_2 driven off) as there are virtually no major elements (e.g. CaO, MgO, FeO) with which it could be combined. *Cr of 760ppm may indicate an originally mafic/ultramafic/picritic/lamproitic/lamprophyric composition.*

Probably the only other potentially diagnostic elements are the relatively immobile high field strength elements such as Ti, Zr, Nb and Ce, and also perhaps Pb and Th. Their high abundance in the Clump dyke, although probably further enhanced due to mass loss of major elements during alteration, suggests strongly alkalic affinities., which are more likely to be little modified during alteration. The mainly tholeiitic dykes of the Rocky Cape Dyke Swarm, together with the bulk of the Spinks Creek Volcanics, have much lower Nb/Zr and Nb/Y and are therefore unlikely correlates. Similar considerations apply to the widespread but rare Devonian lamprophyres, which in addition are demonstrably post tectonic (Baillie and Sutherland, 1992).

Some alkalic suites, such as rare dykes on Hunter Island (Everard *et al.*, 1997), the Cooee Dolerites further east in the Rocky Cape Region, and the Group F phase of the Spinks Creek Volcanics have also considerably lower Nb/Y but higher Nb/Zr. A hornblende-phyric dyke of unknown age on Councillor Island (near King Island) also differs radically in these ratios and in Ti/Zr.

The Clump dyke has particularly high Ce/Y, Pb/Ce and Th/Ce, but some of these elements may not be completely immobile under such extreme alteration. In addition, Pb and Th are difficult to determine reliably by XRF at low concentrations. Geochemically, the most similar rocks are some Tertiary alkali basalts (e.g. sample WB17), but field evidence (mode of occurrence, foliation and possibly the severe alteration of the Clump dykes) precludes any relationship.

The dykes are foliated, faulted, and variably silicified, and were probably emplaced during the latter stages of faulting. They probably represent a previously unrecognized igneous phase of Neoproterozoic or Early Palaeozoic age.

Fresh dyke material crops out on the Temma coast (306850mE 5430850mN) in apparent extensions (from regional aeromagnetics) of the Roger River Fault splay near The Clump. This rock is massive, fractured and variably silicified in outcrop. In thin section, pseudomorphed phenocrysts up to 1.5 mm long of former euhedral hexagonal amphibole are replaced by quartz and lie in a fine-grained (to 25μm) aggregate of pale brown biotite (phlogopite). It is probably related to the dykes near the Clump, but no chemical analysis is yet available (Everard et al, in press). (Although outside the scope of this report, the presence of this rock type is intriguing given the occurrence of alluvial diamonds some 10km to the SE in the Savage River area.)

Devonian (?) granite

There are no granitic outcrops known within the Balfour-Temma area. The nearest outcrop of granite (the Pieman granite) is at Sandy Cape, some 22km southwest of

Balfour. Based on a gravity interpretation (Leaman, 1988) a NNW-trending granite spine underlies the southern to central parts of the Balfour Copper Belt, at about ~2 km depth, and deeper to the north (Fig 2.6). Most of the Sn-W prospects, as well as some nearby copper deposits (eg. Murray's Reward), occur where the interpreted granite is about 2 to 4km deep. The genetic link of the granite with Sn-W mineralisation appears evident, but less so with the copper. The Pieman Granite, exposed on the coast, appears to bear little relationship with copper mineralisation and evidence of a link between mineralisation at Balfour and the Devonian Granite intrusion is minimal. The common association of Sn-W with granite can also be questioned to some extent, and is discussed under ore genesis.

Covering rocks

Post-Proterozoic units are of siliceous gravels with interbedded quartz sand and clay of probable Tertiary age (?pre-basalt), Tertiary basalt and Quaternary talus, alluvium and swamp deposits. Tertiary basalt occurs as thin, hill-cappings, that are probably the dissected remnants of an extensive series of flows that once covered much of the region, eg Clump, Balfour town (Fig 1.8). Chemically the basalts are mostly moderately fractionated and range from basanite through alkali olivine basalt and hawaiite, to transitional olivine basalt and tholeiite (Taheri, in press).

Structure

Regional structure: The Rocky Cape Group in the Balfour area forms the eastern limb of the southerly extension of a large anticline that occurs south of Marrawah (Legge, 1980, Seymour and Baillie, 1992). To the northeast, the Smithton Trough contains Togari Group rocks in a broad syncline (Fig 1.5). To the east, the Rocky Cape group forms a large NE-trend geanticline. The Balfour area is at the conjunction of these three major structures.

ACI noted at Balfour, that the Balfour Sub-group overall has a N-NNW-strike and E-dip, mainly facing east. Broad folds plunge both north and south, with synclines evident east of the Murrays Reward-Clump area.

The important faults of the Balfour area include:-

- NE-trend, steep-dip, district-extensive, *Roger River Fault* that separates the area containing the Clump prospect area from the Balfour area (Figs 1.5, 1.8); this offsets the Rocky Cape Group (see below).
- NNW-trend *Balfour Shear*, interpreted as a thrust, of complex nature with splays that host copper mineralisation (Figs 1.5, 1.7).
- WNW-tend fault, termed the Balfour Transform, speculated by CRA, that cuts the Balfour area and influences mineralisation; no evidence for this fault has been detailed.
- NNW -trend faults, of complex nature around Mt Frankland, that form the eastern boundary to the block containing the Balfour Copper Belt.
- E-W trending fault, which separates the Balfour South prospect area from a block containing Balfour (Fig 1.9)

Based on a gravity interpretation (Leaman, 1988), the Rocky Cape Group has been overthrust onto the younger sedimentary rocks and basalts of the Togari Group.

Two phases of syndepositional extension were followed by at least four compressional phases. The first two phases of compression deformation (D1, D2) are possibly of Cambrian age whereas D3 and D4, are considered to be Devonian in age. D3 is the main deformation phase and is characterised by NW-trending folding, some cleavage development and major NE-directed low- and high-angle thrusts, one of which hosts the copper mineralisation at Murray's Reward mine along the copper belt. East of Balfour, ENE- to NE-trending strike slip faults predate late NW-trending reverse faults. One of these faults is host to vein style Sn-W mineralisation at Specimen Hill (Reed in Everard et al, 2001).

Detailed structure: The Balfour and Temma areas are structurally complex, and Everard et al (in press) have recognised at least 2 extensional and 4 compressional deformation events, summarised as follows:-.

Deformation event	Nature of deformation	Description/ location	Mineralisation
Extension	Growth faulting associated with deposition of Rocky Cape Group	Outcrop-scale growth faulting near Temma coast.	
Extension	Growth faulting associated with deposition of Togari Group.	Block rotation during extension may account for unconformity between Rocky Cape and Togari Groups.	
D1	? Tyennan Orogeny	Foliation predates chlorite porphyroblasts observed in thin sections of Rocky Cape Group rocks (eg. SE of Mt Franklin).	
D2	Tyennan Orogeny/Tabberabberan Orogeny	E-W trending folds and cleavage in Rocky Cape and Togari Groups (eg. SW of Mt Franklin).	
D3	Tabberabberan Orogeny	NW trending folds and thrusts. Reactivation of Roger River Fault.	Copper mineralisation (Murray's Reward mine) , Sn-W mineralisation (Specimen Hill)
D4	Tabberabberan Orogeny	Open upright north-trend folds (regionally developed)	

There is evidence in the stratigraphy that the Roger River Fault was an extensional, syn-depositional fault, and formed the western boundary of a half-graben into which Togari Group sedimentary and volcanic rocks were deposited. This is indicated by marked variations in the thicknesses of stratigraphic units across the Fault.

The first two compressional deformations (D_1 and D_2) are probably Cambrian (Everard, et al, in press). The S1 cleavage is commonly defined by an alignment of chlorite about E-W and dips between 20° and 45° N in weakly deformed rocks from east of Mt. Frankland. The S_2 cleavage (related to D_2 structures) is similar in form to S_1, but typically cross-cuts S_1. It is defined by preferred alignment of chlorite grains and strikes east-west and dips about 20° to 45° S.

D3 structures are seen west of the Frankland River, where a NW-trend D_3 anticline deforms Balfour Subgroup. The NE limb of the anticline is truncated by SW-dip thrusts (Figure 1.7). Reverse movement on thrusts has placed older (Rocky Cape

Group) over younger (Togari Group) rocks. The copper-mineralised thrust at 322590mE 5433760mN is intensely brecciated and silicified and separates older sandstone (Rocky Cape Group) in the hanging wall from younger chloritic siltstone (Togari Group) in the footwall (Fig 1.7). The along-strike continuation of this structure, cropping out in Cassiterite Creek, hosts the Murray's Reward copper deposit at Balfour.

Large NW-trend faults hosts the Specimen Hill Sn-W deposit at Balfour. Field observations and IP-based geophysical cross-sections show the faults dip steeply both NE and SW, with the Specimen Hill Fault dipping moderately to the SW (Menpes, 1995b).

D_4 structures in the Balfour area are open upright folds, verging towards the west. Steep, east-dip D_4 reverse faults have also been recognised along the Temma coast, overprinting D_3 structures.Both D3 and D4 structures are interpreted to be Devonian in age.

Metamorphism: Greenschist burial metamorphism is indicated by the lustrous bedding micaceous parting in pelitic rocks and by from isoclinally folded sandstone dykes. Green chlorite, commonly forming aggregates up to 1mm in diameter, is the most commonly preserved regional metamorphic mineral, but garnet has also been noted and biotite may have been retrogressed to chlorite. Grey and green siltstone in different parts of the Balfour area also show metamorphic spotting, particularly where intense cleavages have developed (Turner, 1994).

MINERALIZATION

District mineralisation styles

Mineralisation in the Balfour district can be divided into several types:

1. ***Copper lodes***, in quartz-dolomite, occurring along the 35 km long, NNW-trend, Balfour Copper Belt (Fig 1.5, 2.2). The structurally controlled lodes have depth-persistent shoots within more laterally continuous lower-grade, altered tabular zones. The Copper Belt runs roughly parallel and adjacent to a magnetic stratigraphic marker horizon of Balfour Group pyrrhotite siltstone but lodes follow a shear zone/thrust of similar NNW strike (Fig 1.7). Deposits range from Toner River (far south, outside EL 4/2002) to the Clump prospect (far north). Several styles of mineralisation are evident:-

    - Massive sulphide, covellite-chalcopyrite-pyrite and quartz lodes are tectonically brecciated and rebrecciated.
    - Brecciated quartz veins, with intermixed coarse dolomite and sulphide masses and fragments of country rock
    - Massive sulphide quartz lodes, with pyrite-marcasite, pyrrhotite, chalcopyrite, sphalerite, arsenopyrite, cassiterite eg Tatlows open cut (Porter, 1996)

2. ***Tin and tungsten vein and stockwork*** style deposits in close proximity to the copper lodes, located approximately in the middle, most intensely mineralised part, of the Balfour Copper Belt and underlain by probable Devonian granite (Figs 1.5, 2.2).

3. ***Zn-Pb anomalous geochemistry,*** reported at the Nelson Prospect (Fig 1.8), in a BHP drill hole DDH 5, and in trial workings to the SW of Balfour (Southern Shaft) with Ward (1911) reporting 7% Zn in mullock (Tear and Russell, 1997)(Fig 1.9) suggests that the Zn-Pb potential of the area remains; it has been little tested.

4. ***Cupriferous transgressive magnetite-dominated lodes*** occur in the Temma area near the coast, 18 km west of Balfour and *outside* NCR's EL4/2002. They are up to 15m thick and contain varying amounts of hematite, chalcopyrite, tetrahedrite, galena, sphalerite, pyrite, Fe-Mn-carbonates and silicates. It is possible that similar Fe-oxide occurrences, with magnetic response, could underlie, in an offset position, the Balfour Copper Belt, perhaps at depth along the Balfour Shear/thrust (Fig 1.7).

5. ***Residual:*** mineral deposits of secondary nature include alluvial tin, mostly in close proximity to tin lodes within EL 4/2002, and subeconomic coastal sand dune deposits containing cassiterite, chromite, zircon and rutile.

Overall the lithology and mineralisation, although sheared and disrupted along slightly discordant faults, and strongly discordant cross-faults, conforms to the following pattern, especially around the main workings of Specimen Hill and Murrays Reward:

Top: chloritic shale with carbonaceous siltstones, grading up into well laminated, strongly carbonaceous, pyritic siltstone; copper occurrence is best developed where the shear trend cuts carbonaceous/chloritic shale/phyllite, (Porter, 1996)(upper Rocky Cape Group)

Mid: finely laminated, contorted, slumped, cross-bedded fine sandstone and siltstone, variable carbonaceous; hosts strongly developed Sn-W and Zn-rich bands at the upper contact with overlying chloritic shales (lower Rocky Cape Group)

Lower: district extensive quartzites to the west of the Sn-W-Cu mineralisation; unmineralised (Lagoon River Quartzite)

IP anomalies closely correspond to copper mineralisation along the main trend; other untested anomalies occur to the west.

Balfour Copper Belt

Geological setting

Structural control: The Balfour Copper Belt contains about 40 copper workings, each about 2-30m (av 4m?) wide, distributed intermittently along a 35km long & 2km wide NNW-trending corridor, interpreted as a complex shear zone in the Rocky Cape Group (Figs 1.5, 1.8, 1.9). The shear zone is considered to be a thrust of Devonian Tabberabberan age (Everard et al, in press) (Fig 1.7). Chalcopyrite, as blebs and stringers, with secondary sulphides of covellite and chalcocite, occurs in a pyrite-quartz-dolomite gangue that fills fracture-controlled locations along the NNW shear and associated splay faults.

At Balfour the shear divides two main rock types:- to the west,-dark carbonaceous siltstone with Cu-anomalous pyritic beds, and to the east,-pale carbon-poor siltstone (Turner 1994)(Fig 2.2). In the carbonaceous siltstone at Murrays Reward, copper-rich beds, with up to 652ppm Cu, also contain disseminated pyrite; they could be a source of copper but elevated tin and other metals in the ore suggest a source elsewhere (Turner, 1994). In the Murrays Reward open pit, a swarm of thin, quartz-sulphide veins bulk out as a low-grade ore-zone (Turner, 1994). Past drilling has focussed on a test of the high-grade, narrow, sulphide pods. Some intersections, 30m thick, of lower grade 0.6% Cu indicate that a sizeable mineralised system is present.

A complex history of deformation is evident including: small-scale folds, small faults, vein deformation (both of ductile and brittle nature), extensive fracturing and multiple brecciation phases.

Chemical leaching: Mineralised rocks from outcrops, dumps and old workings along the belt are generally intensively weathered and leached. Supergene alteration of chalcopyrite to covellite and digenite is evident in the Murray's Reward open cut. The leaching effect on sulphides can be seen in the quartz samples on the South Balfour and Balfour Blocks dumps where the samples consist of porous quartz with remnants of sulphides, mainly pyrite. Dolomite appears to have been completely leached, leaving cavities with a rhombohedral crystal shape.

Balfour copper ore mineralogy

The nature of mineralisation and associated hydrothermal alteration was studied by MRT on the three available drill cores from Murray's Reward prospect, together with core logs for 37 drill holes drilled along the copper belt at over 8 different prospects (Taheri, in press) (Fig 5.1 to 5.4).

The ACI core logs indicate that the hydrothermal alteration and mineralisation for the copper deposits along the belt is similar to that from the drill core at the Murray's Reward and that all the copper deposits have similar paragenetic relationships.

The mineralised sections of core are commonly intensively broken, sheared and, in places, brecciated, with common puggy zones. They vary widely in thickness, copper content, mineral assemblages and alteration intensity. The contact between the country rocks and the mineralised sections are sharp and probably fault contacts. Dark grey, carbonaceous siltstone and slates commonly host the mineralised sections (eg. Clump prospect, Murray's Reward). At Balfour Blocks, however the common rock for mineralisation is deformed chloritic siltstone (ACI core log). The mineralised zones (dolomite ± quartz ± chalcopyrite ± pyrite ± chlorite) are repeated over a 40m width, with individual mineralised zones varying in width from less than one to a few metres.

Alteration: There are basically two different pervasive alteration types observed in drill core:

chloritisation is common and formed early in the alteration, replacing the original country rocks. It is often cut and replaced by later-formed minerals such as quartz and carbonate veins. Chlorite may also occur as a later hydrothermal product associated with quartz ± carbonate veins.

silicification, replaces (brecciated?) country rocks, mainly siltstone and slate in, and on, the margins of the mineralised sections. This early silicification is commonly barren and in some places is cut by numerous thin (<2 cm) mineralised veins of quartz ± carbonate ± chlorite ± pyrite ± chalcopyrite. It may also occur in later stages replacing brecciated, chloritised slates and brecciated dolomite.

Carbonates (dolomite, siderite, magnesite) are also common in mineralised zones. Brown siderite replaces creamy-colour dolomite. Magnesite is closely associated with siderite (identified through XRD analysis) (Taheri, in press). Thin veinlets of carbonates cut early, massive dolomite. Dolomite selectively replaces the brecciated and chloritised rocks; it is extensively veined by late, barren quartz and to a lesser extent by chalcopyrite and pyrite veins.

It is important to notice that the quartz and sulfide veins postdate the early, almost barren, dolomite.

Sections of drill core have massive and weakly veined dolomite and may contain only a few hundred ppm of copper. It is likely that the carbonate sections have been formed along fractures and faults and have been repeatedly veined and partially replaced by products of later hydrothermal activity. The source of the carbonates is not known. ACI core log describes the occurrence of some thin “quartz-dolomite” bands (5-10cm wide) which have been cut by chalcopyrite-bearing veins. The bands are very likely to represent veined, early dolomite. Some dolomites zones have been suggested by ACI and CRA as being more "formational" in character than replacive.

Quartz veins, the most common vein type, are mostly barren, commonly thin (20 cm or less) and are paragenetically of multiple generations. Other vein types include pyrite ± quartz, quartz-chalcopyrite ± pyrite, and quartz-chlorite, all of which are narrow, ranging from less than 1cm to 15cm in width. The term “quartz-dolomite”, commonly used by exploration geologists, can be misleading as the quartz is a later phase cutting dolomite sections and can be barren (Taheri, in press).

Pyrite mainly occurs as an early-formed (sedimentary) disseminated, fine-grained sulphide in carbonaceous and chloritic siltstone and slate. Later (remobilised?) pyrite is seen in mineralised sections as fracture fillings, veinlets and in quartz veins. It appears (paragenetically) as an early phase relative to chalcopyrite in veins (Taheri, in press).

Chalcopyrite, is late-forming and mainly occurs as fracture fillings, irregular and discontinuous stringers along incipient fractures, dissemination and small (1 to 2 cm in diameter) patches in quartz, and as clots filling brecciated dolomite. Chalcopyrite may not be directly associated with the formation of dolomite as there are some massive dolomite sections with no visible chalcopyrite that are very low in copper content (Russell and Tear, 1998). Chalcopyrite, is formed after pyrite, which may indicate its remobilisation from dolomite and subsequent precipitation in late-forming breccias and fractures in quartz.

Traces amounts of *galena and sphalerite* and to a less extent, bornite and covellite occur in some mineralised sections (eg. Clump prospect, ACI reports).

Minor *magnetite* associated with actinolite and chalcopyrite has been reported in a mineralised dolomite-rich zone in one drill hole (DDH6) from the Clump Prospect.

A generalised paragenetic table for the hydrothermally-formed minerals along the copper belt is shown in table (Taheri, in press):-

	Paragenetic stage
Mineral	Early Late
Quartz	-----------------------------
Chlorite	---------- -----------
Dolomite Siderite Magnesite	----------------- ------------- ------------
Pyrite	----------------------
Apatite	--------------------------
Chalcopyrite	------
Sphalerite	---------------------- ?
Galena	----------------------?
Magnetite	----------------------?*
Actinolite	-------------------?

?* Minor, reported by ACI geologists (in core log)

Summary: The Balfour Copper Belt deposits are transgressive to the stratigraphy and occupy dilatational zones such as fault splays, and vein intersections. The features of mineralisation are as follows (Taheri, in press) and this report:-

- Shear controlled veins/ fracture-fillings, breccia-fillings and replacement,
- disseminated to semi-massive sulphide pods near surface,
- simple primary mineralogy, persisting over the entire belt, comprising chalcopyrite, quartz ± pyrite ± carbonates ± chlorite,
- extensive fracturing, shearing and brecciation of different generations,
- strong near surface geochemical leaching and secondary, supergene enrichment ore; leaching of bedrock elsewhere
- high sulfur isotope values indicating sedimentary-dominated sulphur derivation by hydrothermal leaching of primary mineralisation
- fluid inclusions of low salinity indicating non-granitic relationship
- lack of any correlations between the fluid inclusion homogenisation temperatures and sulfur isotopic data and the depth of underlying granite, as interpreted from gravity data and
- anomalous in Co, Ni, Sn, and to a minor extent, Au.

Copper Prospects

Balfour South prospect

Please see- South Balfour Prospect

Blocks prospect

The Blocks prospect is located about 3km NNW of Murrays Reward (E322800 N5432300) on the mineralised shear/thrust system that runs north to the Clump (Fig 1.8). ACI ran IP surveys along 8 lines at the Blocks prospect and detected anomalies along 300m strike, coincident with old copper workings.

ACI drilled DDH 5,7,8 at the Blocks prospect. Tear and Russell (1997) report high magnesium values (>20% Mg) at the Development and Blocks prospects.

Central Balfour prospect

Central Balfour is immediately to the north of Murrays Reward, drill details are also given in Murrays Reward Prospect. Some 200t of high-grade ore was mined from the Central Balfour workings (Figs 1.9, 5.2). IP surveys were run on 8 lines, 30m apart, as part of the Murrays Reward survey, and detected anomalies. A cross-fault intersects the Central Balfour ridge near the old shaft that coincides with an IP anomaly (McIntyre, 1973).

ACI drilled DDH 16,17,18, 20-22,33, 36 (1971-73) at the Central Balfour prospect and along strike as part of the Murrays Reward probable mineralised splay fault or stacked ore set (ACI lines l & M)(Fig 5.2).

ACI hole	From	Intersection m	Cu%	Note
DDH 21	42.1	13.2	0.6%	200m N of Central Balfour
DDH 16	62.5	21.7	1.4%	Towards Murrays Reward
DDH 36	195.8	25.5	1.4%	Murrays Reward, splay

*DDH 36 are results from CRA core grind

Discontinuous low-grade mineralisation occurs for about 800m. McIntyre (1973) recommended that a drill hole test the "transverse fault" in the vicinity of the Central Balfour Shaft.

Clump prospect

The Clump copper prospect (E321500 N54 37 000), located 9km NNW of Balfour, and named after heavy timber over basalt in the west, has numerous drill access tracks in button grass and peat covered plain (Figs 1.8, 2.3). A low ridge carries mineralisation, costeans and the poor rock outcrop. Mt Balfour Copper Mines NL investigated the prospect in the early 1900’s and intersected copper in adits and shafts; results were reported by Ward (1911). ACI conducted IP, ground magnetic, trenching, underground sampling and geological mapping surveys that led to diamond drilling of 8 holes, DDH 1,2,3,4,6,9,27,28, from 1970-73; gold was not analysed (Fig 1.8). Soloriens Mining conducted a gravity survey of the Clump (Leaman, 1992)(Fig 3.4).

Geology: The geology of the Clump prospect is shown on the published Dempster 1:25,000 geology sheet as Cassitterite Crek Quartzite, and also on Figs 2.3, 2.5a. Poorly exposed Proterozoic lower sandstone/shale is conformably overlain by siltstone/shale with NE-dip, and a discordant cupriferous dolomite/sandstone horizon. Minor Tertiary basalt is present (Jackaman, 1972). Shallow-N-plunge broad folds occur in the area. The Clump mineralised zone is located along a strike-persistent thrust that continues south to Balfour. The carbonaceous shale has ubiquitous pyrite, mainly near the dolomitic quartzite. Rocks include:-

- *Quartz sandstone and shale*: thicker quartz sandstone bands and thinner ferruginous/carbonate quartz sandstone bands, both 0.1m to 10m thick, form ridges. Interbedded shale averages 3m thick.
- *Siltstone/shale facies*: Laminated quartz siltstone, ferruginous siltstone, carbonaceous shale and minor ferruginous sandstone rarely outcrop. Three marker horizons are pyritic/limonitic siltstone (footwall to dolomitic quartzite), carbonaceous shale (hanging wall) and pyritic/gossan siltstone (100m in hanging wall). The shale bands are to 15m thick, averaging 0.15m. The siltstone bands average 2m, and have graded-beds, cross-beds, slump and micro intraformational faults. In drill core, the beds are of upward grading quartz siltstone to carbonaceous shale as one cycle. Composition is of rounded to sub-angular quartz, euhedral pyrite, amorphous carbon, iron oxide, carbonate, sericite, and clay. Pyrite is ubiquitous but concentrated in the coarser basal layers. Leucoxene porphyroblasts in siltstone are probably the alteration products of rutile and ilmenite.

The *dolomitic quartzite*, of 2-15m thickness, is the only rock to contain chalcopyrite, except for a few quartz veins in the hanging wall shale. Surface leaching has destroyed carbonate and sulphide, which can be seen in drill core. The dolomite quartzite was considered by Jackaman (1972) as a sedimentary rock on the basis that it formed part of the overall sequence over 2km strike anastomosed within the shale sequence but it is probably located as an alteration product along the thrusts. In costeans it is of massive quartz and quartzose fragments in a friable quartzose matrix.

Parkinson (1993) also noted a 2km long dolomite-quartzite facies within the Emmetts Creek Shale, a formation that is mapped to the east of the Clump. The dolomite is recrystallised and unstrained while the quartz is recrystallised, and strained. Pyrite content is up to 50% as coarse euhedral grains, with chalcopyrite and minor chlorite, carbonaceous material and tremolitic amphibole; both quartz and tremolite corrode the sulphides. The pyrite content of the siltstone increases towards the dolomitic quartzite.

***Geochemistry*:** ACI found that certain lithological contacts at the *Clump and Specimen Hill Prospects* are anomalous in copper. At the *Clump Prospect*, three types of outcrops were intensely prospected:

(i) the 'dolomitic quartzite formation",

(ii) a large quartz vein in the southern part of the Clump area, and

(iii) outcrops of limonitic and hematitic "gossan" developed on pyritic sedimentary rocks.

Only the "dolomitic quartzite formation" contains significant copper mineralisation (Jackaman, 1974). This was tested by underground workings at the mine site, two adits and a shaft to the north of the mine, as well as by over thirty trenches and pits. *ACI reported that at the Silver Reward shaft, immediately south of the copper workings, a vein about 0.6m wide carried 485 g/t Ag, 40% Pb, 0.6g/t Au.* The drilling showed that mineralisation at the Clump was up to 20m wide with a grade of about 0.5% Cu.

CRA conducted soil and wacker sampling over the Clump and analysed for Cu, Pb, Zn, Ag, Mn, Fe, As (Figure 4.3a,b). CRA found that wacker penetrated the ubiquitous quartz lag more effectively than hand auger. CRA demonstrated that the copper line is leached near surface with copper values less than 50ppm (Menpes, 1995). An area of elevated Cu (214ppm) and Fe (35%) in soils coincided with semi-massive pyrite and iron oxide in subcrop. The zone warrants follow-up. Disseminated Zn-Pb mineralisation has been noted in quartzite at the Clump prospect (Westbrook, 1999).

Turner (1994) sampled dump samples from a shaft and adit at the Clump, mined by Mt Balfour Mining Co and this gives a characterisation of the metals present:-

E	N	Cu %	Sn ppm	Au g/t	Co ppm	As ppm	Note
321 400	54 36 850	0.13	7	0.07	169	639	Shaft, py in qtz
321 675	54 36 925	2.5	5	0.02	60	54	Adit, cp chloritic siltstone
321 675	54 36 925	*8.8*	*38*	*0.2*	*325*	*996*	Py-cp in quartz
321 675	54 36 925	2.5	5	0.09	29	700	Py-cp in quartz

Turner (1994) noted that east of the Clump, near and above the top of the carbonaceous siltstone, chlorite/pyrite/gossan lag is anomalous in copper (sample 3757821), max 1,108ppm Cu with Pb 24, Zn 71, Au 0.03, As 39, Sn 8 ppm); it is not associated with quartz.

IP survey: IP surveys, conducted systematically by ACI in 1970 over 12km of strike comprised 14 lines, spaced at 75m, with 23m spreads. A continuous anomaly along 900m, and across a width of up to 60m, was detected. Profiles were reconstructed by CRA as profiles and show a major IP response extending the full length of the Clump grid (Menpes, 1995). Best percentage frequency responses correspond to certain lithological boundaries that are also copper anomalous (also the case in the Murrays Reward area). The anomaly is probably caused by graphite and pyrite in rocks of the mineralised zone.

A zone east of the Clump mineralisation, with coincident IP response and up to 1,100ppm Cu in rock chips and gossan, near carbonaceous siltstone has not been tested (Westbrook, 1999).

A *similar response* was obtained 4km south of the Clump at Cassiterite Creek and in Hudson Syndicate (1967) and in CRA IP data *west* of Specimen Hill. The conductor appears to correspond to lithological contacts, at the Clump-carbonaceous to chloritic siltstone; and at Cassiterite Creek/Specimen Hill to sandstone to carbonaceous siltstone (Menpes, 1965) that are copper anomalous. The conductor at Specimen Hill has not been drill tested (Menpes, 1995).

Gravity survey: Contoured gravity survey data for the Clump prospect are shown on Fig 3.4a. Leaman (Nov 1992) suggested that the NW-WNW trend positive Bouger feature coincident with mineralisation was either a ridge reflecting a deeper excess mass, or a step gradient, both of which have several local highs that may reflect mineralisation or simply spikes of the larger underlying excess mass body (Fig 3.4b). *The excess mass at the Clump appears unresolved and may indicate a mineralised body at depth or some other higher density feature.*

Underground sampling: ACI reported that sampling underground at the Clump showed a mineralised zone 18m wide, grading 0.01 to 3.5% Cu, max 0.7oz/t Ag.

Drilling*:* ACI drilled 8 drill holes in 1972-73 (DDH 1,2,3,4,9,27,28, 1,668.6m) that failed to locate a cupriferous ore zone of economic continuity but demonstated a steep W-dip lode of mineralised dolomite-quartz vein lodes. Some mineralised intersections were of encouraging grade at shallow depth; core recovery of the friable sulphides from the Cu-bearing quartz suggests understated assays (McIntyre, 1973). Chemical leaching is reported as being to 60m depth. Magnetite has been noted in the drill core from the Clump prospect but is considered to be insufficient to explain the magnetic anomaly (McIntyre, 1973). An overview of drill results is as follows:-

- **DDH 1 (139m), DDH 28 (354m), ACI Section A:** steep W-dip lode, grade has decreased at depth of about 250m to 4.5m, 0.05% Cu.
- **DDH 2, DDH 6, ACI Section B:** carbonate lode 20m mineralised about 0.15%Cu, steep W-dip; variably abundant euhedral pyrite.
- **DDH 3, ACI Section C:** max assay 0.7m, 2.3% Cu with quartz in graphitic sediments.
- **DDH 4, ACI Section D:** indicates a probable steep east-dip for the lode projection from surface with a maximum of 1.5m, 1.5%Cu, but a series of small lodes to the east are evident with 1m intervals of 0.2% Cu in pyrite-siliceous chloritic siltstone.
- **DDH 9 & DDH 27, Section E:** DDH 9 had high core loss but sludge samples indicate grades of no more than 0.3% Cu; similarly DDH 27 contained a maximum of 5.7m 0.27% Cu in a broader zone of mineralisation; lode is vertical to steep west.

DDH 27 and 28 indicate a decrease in grade with depth down dip. ACI indicated mineralisation as Cu-pyrite bearing quartz-dolomite along 750m strike in carbonaceous sediments. Turner (1995) suggested that DDHs 6 & 9 be redrilled given the likely wash-out of supergene sulphide.

Summary: The Clump prospect appears to have been drilled adequately to show the sub-economic nature of the lode-ores. However, unexplained gravity and magnetic anomalies, coincident or offset to the SW of the line of lode remain unexplained and may indicate excess mass/magnetics at depth.

Development prospect

Drives have exposed 1.5m wide lodes with chalcopyrite 9McKenzie, 1964). ACI drilled DDH 12 (98m) at the Development prospect and found trace copper in chloritic sediments (Fig 1.8, E322 400 N54 33 200) just south of the NE-trend Roger River Fault. Tear and Russell (1997) report high magnesium values (>20%) at the Development and Blocks prospects.
Comment: No action at present.

Dogherty's Pimple Line

CRA suggested that the NW-trend Dogherty's Pimple Line of trial copper workings in the SE corner of old EL4/94, be inspected where it intersected the Balfour line of copper workings; it seems the Ward (1911) did not document the workings (Russell and Tear, 1997) (Fig 1.9, E329 400, N54 20 700). The mineralisation is in a relatively inaccessible location west of the Lindsay River. Close attention to the new EM data is warranted.
Comment: Priority 3 follow-up but upgrade if airborne EM shows anomaly.

Emmetts Cu prospect

Emmetts Prospect (E324000 N5431000) is located 700m north of the Central Prospect shaft on the main Balfour Shear. It comprises a NW-trend zone of quartz and ironstone capping a ridge of deformed N-S trend sediments. ACI reconstructed old costeans and inspected an old adit (McIntyre, 1973) (Fig 1.8). It is on the continuation of the shear extending north from Murrays Reward.

The deposit is located at the gradational boundary between slaty, chloritic siltstone to the west, and finer carbonaceous sediments to the east (McIntyre,1973). Everard et al (2001, Dempster 1:25,000), show the prospect as located on a complex nested thrust block, with thrusts trending NW. The same thrust set continues to the Blocks and Development prospects.

An old adit driven west for 113m at Emmetts, was mapped by ACI (McIntyre, 1973):-

- 0-48m: fine-grained carbonaceous sediments, N-strike/E-dip, upright
- 48-113m: carbonaceous and chloritic seds sheared with discordant quartz veins, commonly pyritic, limonitic and cavernous (ex-dolomite?), with some secondary copper.

Channel samples returned <500ppm Cu, with higher values in the quartz areas. Although the channel samples have low copper, sludge from the entrance carried significant copper (McIntyre, 1973) and leaching of bedrock is evident.

ACI dug six costeans on the ridge (Fig 1.8). These returned low copper values in channel samples with a maxima of 450ppm in costean 8, 560ppm costean 10. Grab samples of ferruginous "gossan" float returned max 1,400ppm Cu. To the south, on the same shear, DDH22 cut 6.3m 923ppm Cu, with 1.8m 0.34% Cu, in brecciated siltstone (Fig 5.1, 5.2).
Comment: No action

Gap prospect

The CRA-conceptual Gap Prospect is located 2km north of the Waratah prospect, at E325 000 N54 22 000, where the magnetic response of the district-continuous pyrrhotite siltstone is weaker over a 1km stretch (Parkinson, 1993)(Fig 1.9). CRA believed that the area was favourable for copper from fluids migrating through the Lagoon River Quartzite into overlying carbonaceous siltstone where iron as pyrrhotite would be replaced by copper, and a magnetic response destroyed. Chloritic alteration was seen along the Heemskirk Road and an E-W fault inferred at N5425 700 where vuggy and breccia quartz is found (Parkinson, 1993).

The sedimentary units have a steep-east dip. Two carbonaceous siltstone units are separated by a quartzite ridge; a laminated chloritic siltstone overlies the package and is in turn bounded to the east by the Balfour line of copper workings. A siliceous sandstone is exposed in a costean over a line of copper lode.

CRA collected 177 soil samples of C-horizon along four lines spaced at 200m in an area of quiet magnetics along the Balfour pyrrhotitic siltstone; a weak copper anomaly, with As and Fe is present (Parkinson, 1993 Tear, 1996).

North	East	type	Cu, ppm	Note
N54 25 900	West end	soil	97 & 82	
N54 25 900	West end	outcrop-rock	49, & 55	Lam carb siltst+pyrite
		outcrop	62 & 54	Silic siltst-line of Cu lode
N54 25 900	324 990	Rock	111	130ppm As, 0.01g/t Au, 105 Pb, 119 Zn; pyritic sltst

Comment: No action, but soils are likely to be severely geochemically leached; review with EM data

Gulley prospect

During field work by MRT (Everard et al, in press) it was noted that a large adit had been driven into the western bank of the Frankland River near E322 770 N54 35 100, possibly to meet shafts sunk about about 200m further west near E322 550 N54 35 100 (Fig 1.8). The prospect is located on the Balfour Shear. Ward (1911, p.97) mentioned that "the intention of the owners [of Section 3955] is to drive a tunnel [from the Frankland River] to cut the lode at a depth of about 100 feet below the outcrop [in a short deep trench]….of a width of 6 feet of massive quartzose ore…..The quartz is mineralized with pyrite and chalcopyrite…Thin film of bornite and covellite are present with the copper pyrites…".

ACI drilled one diamond drill hole DDH 11 at the Gully that has not been precisely relocated. Thin quartz-dolomite occurs in carbonaceous sediments.

Comment: No action.

Jaeger's prospect

BHP (?) investigated Jaegers Prospect, on the south side of Specimen Hill. This is a high-grade Sn prospect but no details are given (Patterson 1996, in Menpes 1996)

Lindsay prospect
ACI inspected old workings between Dogherty's Pimple and the Lindsay River, some 8km SE of Mt Frankland, and described by Ward (1911) (Fig 1.9). Steep NW-trend lodes in E-dip sediments, show similarities with the main Balfour Copper Belt lodes. There are old reports of 8.5% Cu in covellite bearing lode, with strike of 2km. Stibnite is mentioned (McIntyre, 1973). See also Doghertys Pimple.

Comment: Priority 3 follow-up unless an EM conductor is indicated in the area.

Murray's Reward Mine
Murrays Reward (E324500 N5429500) was the main copper producer in the district and produced about 6,000 tons of ore in the early twentieth century, with minor production in the early 1990s (Everard et al, in press). Workings comprise four adits, an open cut (~30×15m), shafts and trenches (Figs 1.9, 2.1 geology 1:25,000, 2.2).

The high-grade sulphide and quartz-sulphide mineralisation is 15-20m wide, with 80^{o}W-dip near the surface changing to 70^{o}E-dip a depths greater than 75m. A thinner east band (0.5m wide) is separated from a west-band, 5-12m thick, by lower grade brecciated quartz, and quartz-sediment mineralisation quoted as carrying several percent copper (Porter, 1996).

BHP inspected the prospect in 1964 and produced a geological map of the surface and underground workings at Murrays Reward and Central Mt Balfour (Balfour); geology was described as being of greywacke sandstone and siltstone with carbonacoues shale (McKenzie, 1964). McKenzie noted that many of theold Cornish mines found tin below copper.

Geology: CRA's structural mapping indicates that at Murrays Reward, an ore shoot plunges steeply to the SSE and at least two main structures are present but that the intersection does not control ore shape (Russell and Tear, 1997). A NNW, steep-W-dip fault controls copper mineralisation. This is intersected by a N-S , 70^{0}W-dip fault, along a shallow 25^0-SSE plunge and can only influence matters by offset post-ore. Schistosity is parallel to the NNW fault with steep-SW-dip, but this switches to NE-dip in core and indicates a recumbent fold (Russell and Tear, 1997) or perhaps just kink variations. Over the surface area, the majority of beds are right-way-up younging to the west, but west of the open-pit the beds young to the east (Russell and Tear, 1997).

Mineralisation: ACI geologists, Veska (1993), CRA, Turner (1995), Porter (1996) and (Taheri in press) and others have described mineralisation at Murray's Reward.

The copper mineralisation in the *open cut* comprises numerous quartz-pyrite ± chalcopyrite veins associated with a shear zone that hosts some small, high grade lenses of supergene-enriched copper (mainly covellite and digenite) ore. The sheared zone is related to a NNW-trending fault contact between carbonaceous slate to the west (hanging wall) and chloritic slate and siltstone to the east (footwall).

Hydrothermal alteration associated with mineralisation includes silicification, chloritisation and sericitisation. Silica and sericite content of the footwall chloritic slate commonly increases towards the mineralisation; the carbonaceous hanging wall is chlorite enriched. The carbonaceous slate is copper-anomalous (up to 1,100 ppm, Turner, 1995) and is rich in pyrite of possibly sedimentary origin (eg. around 5429500mN, 324600mE). The mineralised zone at the Central Balfour prospect is also located at a boundary between the chloritic siltstone and slate and carbonaceous shale. Tear and Russell (1997) note that the mineralisation at Murrays Reward carries anomalous tin, with up to 276ppm Sn in high grade copper ore.

The mineralisation was probably introduced during a tensional phase and is characterised by quartz ± sulfides ± dolomite veining, extensive shearing, fracturing, and brecciation and occurring along hinges of small folds. Carbonates are rare on the surface and in shallow workings due to leaching, but is common at depth (McIntyre, 1973, Tear and Russell, 1997).

IP survey: CRA (Menpes, 1995) indicates that surveys by ACI over copper deposits gave a strong reponse (Fig 3.7).

Geochemistry: No systematic regional sampling have been undertaken to compare the overall copper content of the carbonaceous slates to those occurring in the vicinity of the copper ore deposits (that may be heavily leached). However, CRA rock chip sampled extensively and stated that the copper is restricted to the quartz-sulphide veins and does not extend into the barren host siltstone (Menpes, 1995).

ACI Drilling: ACI drilled 19 holes at the Murray's Reward mine, DDH 10, 13-19, 24-26 (1971-72), DDH 33-37 (McIntyre, 1973)(Figs 5.1, 5.2). The reader is referred to the open file reports for details of the drill logs and other information; the drilling was logged in detail with hole orientations taken. Supergene alteration along with brecciation and shearing resulted in poor core recovery in some drill holes. As a result, the actual thickness and ore grade of some mineralised sections could have been underestimated.

Selected drill data is presented to give an indication of the nature of the intersections, mainly the later drilling by ACI. Some of the better intersections are listed below.:

Murray's Reward, ACI drilling			
Hole	**From**	**Intersection**	**Copper %**
DDH 13 (Workings)		11.6m	0.7
DDH 14: (Main Shaft)	from 84.4m	21.2 m 16.5m true	0.9 4 x >1.7
DDH 16 (NW splay?) Supergene?	from 62.5m	21.7 m incl 8.1m	1.4 2.5
DDH 19 (MR adit)		12.8m	0.5
DDH 21 (CMB N-end)	from 42.5m	13.2 m	0.6
DDH 23 (MR S-end)	from 57.0m	3.1m true	2.1
DDH 33 (NW splay)	from 118.1m	5.4m true	1.3
DDH 36 (NW splay)	from 195.0m	25.5 m	0.8%

DDHs 16, 33 and 36 drilled an "off-main trend" quartz-dolomite lode 100-150m west of the main mapped Balfour copper trend (Fig 5.2). The lode appears to plunge to the NW (Menpes, 1996) perhaps towards a conductor.

The overall result was the delineation of a body of 220m x 220m x 7m, with strike 320°, dip -55° SW, (PJL note: this seems rather shallow?) with an inferred resource about 0.5 Mt. @ 0.8% Cu (McIntyre, 1973). Most of the drill core has been lost.

ACI drill holes *under the old workings at Murrays Reward* include DDH 10, 13, 14, 15, 25, 26 (Fig 5.2):

DDH 10: 179.83m, -55⁰/056⁰mag, under Main Shaft, Murrays Reward

0-120.64m, foliated, carbonaceous and graphitic siltstone with chlorite porphyroblasts, graded beds, pyritic-quartz and quartz-carbonate veins increase towards the mineralilsed zone with minor chalcopyrite. Rare breccia and slickenside faults. Max 1,338ppm Cu towards mineralised zone, 390ppm Pb, 1,000ppm Zn.

120.64-126.6m, mineralised zone, host carbonaceous and chloritic slate; quartz-carbonate chalcopyrite veins in carbonaceous and graphitic slate (1.12m 1.3% Cu, max 230ppm Pb, 1,063ppm Zn), disseminated chalcopyrite, chlorite/pyrite/quartz-carbonate in green chloritic slate (1.3m 0.35% Cu); porous, cream carbonate veins with rare disseminated chalcopyrite (0.9m, 143ppm Cu)

126.6-179.83m, chloritic slate with bands of carbonaceous and graphitic slate; quartz veins common with minor pyrite. Few quartz-carbonate veins. Max 1,713ppm Cu, 60ppm Pb, 43ppm Zn.

Overall, a broad zone of enhanced Cu occurs between 110-139m. 60 specimens were collected for thin section.

Several drill holes were drilled by ACI to the NW of the Murrays Reward shaft and *off-line of the main shear* DDH 16, 24, 33, 34, 35, 36, 37(Figs 5.1, 5.2); it seems that these holes drilled down-sedimentary dip. Thickness is about 4m, (and about 7m if the anomalous thickness in DDH 36 is included), with an average grade of 0.8% Cu. Grade and thickness decreases along strike from 8.1m 2.5% Cu (DDH 16). Overall, the mineralisation has a 320⁰ strike and -55⁰SW-dip within sediments that have a steep E-dip. The cross-fault zone controlling the mineralisation has no surface expression but IP anomalies reflect the mineralisation, either from sulphide or from pyritic and graphitic material (McIntyre, 1973). McIntyre (1973) considered that this mineralisation has been remobilised from the Murrays Reward main-trend into a cross-fault/splay fault that trends NW/dips -55⁰SW; he describes drill results as follows:-

DDH 33: 254.2m, -64.5⁰/069⁰, towards Central Mt Balfour prospect, tested splay fault as NW extension of Murrays Reward. The drill hole was extended beyond the mineralised zone in an attempt to find another copper zone below the Murrays Reward-Central Balfour Mt Prospect ridge.

0-118.1m: chloritic and carbonaceous slate, slates, some thin pyrite veinlets, minor quartz veins with chalcopyrite; grey (chlorite?) porphyroblasts elongated parallel to cleavage, and quartz-dolomite veins (20mm-150mm thick) increase towards mineralisation and contain fragments of siltstone. Also, the bedding disappears and the rock is hard and compact, suggesting some silicification.

118.1-124.4m: best mineralised zone, 5.4m true width, average 1.3% Cu. Discordant, Cu-bearing quartz dolomite, extension of zone in DDH 16 & 17. Blebs and stringers of chalcopyrite with minor chalcocite and bornite. Talc with chalcopyrite occurs at the end of the interval, as do bands of pyrite.
103.5-126.0m, 129ppm to 2.3% Cu, max 63ppm Pb, 100ppm Zn, 3dwt/ton Ag, <0.05 dwt/t Au.
124.4-254.2m, siltstone/shale, variably carbonaceous and chloritic, minor bands of quartz-dolomite with minor pyrite & chalcopyrite.

DDH 34: 173.3m, -65°/043°true, tested the NW extension of Murrays Reward mineralisation along a splay fault, and drilled NE towards Central Balfour. Thickness and grade of mineralisation decrease towards the NW as shown by DDH 34.
0-136.2m, chloritic slate, with minor 3mm pyrite-chalcopyrite-arsenopyrite-wolframite quartz veinlets, fault at 136m.
136.2-139.4m, mineralisation has 55° dip to SW, 3.0m true, 0.26% Cu, Cu-quartz-dolomite. Core recovery 88%.
117.3-144.6m, assay interval, 6 assays, 40ppm to 2,600ppm. One interval of total core loss was recovered as sludge (300ppm Cu).
144.6-173.3m, chloritic slate with minor quartz dolomite, and pyrite-quartz veins.

DDH 35: 182.9m, -65°/042°true, far north end of the NW splay fault, no mineralised interval in the chloritic slate but possibly represented by fault/brecciated carbonaceous, graphitic, chloritic siltstone at 145m and 160m with pyrite and quartz-dolomite bands and veins. Core recovery 95% except for fault zones at 145m and 160m.

DDH 36 (Fig 5.2), 237.8m, -67°/047°true. Designed to pass under DH 33 and cut deeper mineralisation.
0-189.3m, carbonaceous siltstone, with cp in quartz near mineralised zone.
189.3-221.8m, mineralised zone 32.2m true width, 0.30% Cu, (range-557ppm to 0.75% Cu). Other metals are of low values-max 100ppm Pb, 100ppm Zn, 0.3dwt/t Ag, <0.05 dwt/t Au. Duplicate assays were undertaken at ACI's laboratory. This is *one of the thickest intersections* with most copper associated with veins and thicker bands of quartz and quartz-dolomite. Several bands of massive chalcopyrite about 0.1m wide occur in the sediments where quartz and quartz-dolomite is minor (McIntyre, 1973). Bands, 0.3m, of talc occur in dark grey, carbonaceous, porphyroblastic siltstone, and appears to be shear zone gangue. *It was noted that the width of mineralisation in DDH 36 is greater than that of DDH 33, 65m above.*
221.8-225.7m, cupriferous quartz, with minor dolomite, pyrite, rare chalcopyrite.
221.8-237.8m, chloritic siltstone with common quartz veins.

DDH 37: 222.77m, -65.5°/049°true, tested between DDH 33, 34.
204.90m to 210.04m av 2,340ppm Cu, max 3,750ppm Cu. The hole confirmed the down-dip extension of the mineralised fault zone; it suggests a decrease of grade down-dip.

CRA felt that DDH 16 (Fig 5.1, 5.2), testing between Murrays Reward and Central Mt Balfour, should be redrilled and down-hole mise-la-masse indertaken; see below DD97BC 9.

There are some incomplete drill sections sections, such as Section L (Fig 5.2) where holes should have been extended to cut the Main Lode line, but it is unlikely that new intersections, that could be expected, would change the order of magnitude of mineralisation discovered to date..

CRA Drilling: CRA drilled three holes at Murrays Reward, (Russell and Tear, 1997) with DD97 BCC 9,10,11 totalling 797m. Best result was in DD97BC9 with 17.3m, 1.1% Cu at the collar site of ACI DDH 16 (Fig 5.2).

DD97 BC9 was drilled on Section L, at the site of DDH 16, and no cross section is available at present. Wallrock is of laminated (some kinked) fine-grained chloritic schist, with coarser "porphyroidal" interbands (Russell and Tear, 1997) (Fig 5.2). Younging appears to be up-core in the upper part to younging-down in the lower part. Quartz-dolomite+-pyrite veins persist to the end of hole. The eastern boundary of the copper trend appears marked by 20m of quartz and silicified chloritic schist. Conductivity measurements gave only background readings; it is noted that there is a surface IP effect.

Murrays Reward, CRA best diamond drill results, EL 4/94 (Russell and Tear, 1997)			
	from	intersection	Cu %
DD97 BC9 -55^0/050^{0}T (250.4m) E324340 N5429635	55.3m	17.3m Incl 1.7m	1.1 2.6
	64.0m	3.0m	2.1
	71.5m	0.5m	5.4
BC9 twinned ACI hole DDH16			

CRA drilling showed that there is one main ore shoot comprising disseminated to blebby chalcopyrite-pyrite in quartz-dolomite, with minor massive sulphide, with an 80^{o}W-dip and SSE plunge.

DD97 BC10, was drilled towards the NE, towards Murrays Reward shaft but, after passing minor *cassiterite in quartz-dolomite veins* at 71m, was ***abandoned at 82.1m*** in an unexpected major fault of clay-brecciated schist, located between the Sn-W of the Specimen Hill area and the Balfour Copper Belt, and did not intersect mineralisation.

DD97 BC11, a long hole of 464m, was designed to test under the Murrays Reward Shaft on Section I or J (Fig 5.2) and a gravity feature to the immediate east of the Murrrays Reward Copper trend (Fig 3.3). Cassiterite stringers occur at 38m in chloritic schist, and the main mineralised zone is of disseminated chalcopyrite with quartz-dolomite, and is similar to that in BC9 (Russell and Tear, 1997). Below the zone is laminated chloritic grey-green schist with quartz-dolomite veins and occasional pyrite, with silicification at 187-209m. The gravity anomaly vertical projection was intersected at 400m as green chloritic schist and remains unexplained by the drill hole.

Murrays Reward, CRA diamond drill results EL 4/94 (Russell and Tear, 1997)			
	from	Intersection	Cu %
DD97 BC11 -55 to 072 464.5m tested gravity anomaly E 324402 N5429412	148m	12.0m incl 0.3m	0.6 4.0 quartz dolomite, some massive sulphide cp
	170m	2.0m	1.5 breccia, chlorite schist, py, cp in massive sulphide stringers

Comment: Overall, drilling of copper deposits in the Murrays Reward area suggests that there is not an economic deposit within 200m depth. In places, the drilling has confirmed a steep dip to the mineralisation along "line of lode". However, the interpretation of lode continuity becomes less clear when the longer holes such as DDH 33 & 36, on Section M and DDH 34 & 37 on Section N are considered. On these sections the copper mineralisation appears to be in shallow W-dip zones, unrelated to the steep dip of the main lodes. Even DDH 16, located between Murrays Reward and Central Mt Balfour workings, with the highest metres x grade copper values of 6m, 3.5% Cu, has, at about 150m depth, a lode line that is in the "spur lode" or offset lode (Fig 5.2). The pattern of copper mineralisation is thefore complex and is either one of offset mineralisation, or of multiple mineralised shears of various orientations, or indeed of pitching copper shoots. One can speculate on what lies beneath. Shallow, W-dip shears dip towards the Specimen Hill aeromagnetic and Skinners Flat EM features and carry copper in places.

Mt Hazelton prospect

CRA, on EL 1/77, found that the Lagoon, Norfolk and Mt Hazelton aeromagnetic anomalies coincide with laminated siltstone, similar to that at Balfour (Fig 1.5, 1.9).

At Mt Hazelton prospect, located 10km SSE of Balfour, IP anomalies are up to 56msec (2.5x background) with low resistivity (350 ohm m) coincide with the 400nT magnetic anomaly. This IP/aeromag feature is parallel to, but offset from, the line of copper-pyrite workings. The sequence is of quartzite and finely laminated black and yellow, and black and white, siltstone. 14 soil samples across the IP anomaly gave low values of Pb 22, Zn 60, Cu 18, Ag 1, Sn 10, W 15ppm; geochemical leaching has probably depleted values. However, a gossan coincident with the IP contained 850ppm Cu. A rock sample with sulphide, collected 35m from the South Mine shaft assayed 6.5% Cu (Menpes, 1995). Apparently one diamond drill hole was completed by CRA but no details appear to be available.

Pierpont Morgan prospect

Pierpont Morgan is located on a prominent quartz-cored ridge 25m above the adjacent plain, 2.5km SSE of Murrays Reward (E324 900 N54 27 100). ACI investigated an

E-W adit/N-S drive on the east side of the ridge, with flooded shaft and trenches and drilled DDHs 31, 32 (Figure 1.9) (McIntyre, 1973). Quartz and quartz-dolomite lode slightly cupriferous, with minor magnetite and pyrite, is vertical and trends NNW in an east-dip sequence of fine-grained chloritic and carbonaceous sediments. The adit contains 9m-thick lodes with sulphides- pyrite, chalcopyrite, covellite and quartz (McIntyre, 1973; Ward, 1911).

The quartz-core in the ridge is several metres thick, Fe-stained, cavernous and gossanous in places; this perhaps marks the line of a shear/thrust. Host rocks are dominantly carbonaceous siltstone in the west grading to more chloritic in the east (McIntyre, 1973). ACI dug and sampled a 20m long costean at the southern end of the ridge with a best value of 280ppm Cu. An outcrop of pyritic black carbonaceous siltstone, 100m south of the costean contained only 75ppm Cu.

A second costean 1km to the south at E325200 N 54 26250 tested quartz veins at a sedimentary contact but all values were less than 50ppm Cu (McIntyre, 1973).

ACI drill holes were:-

> **DDH 31,** 123.42m, 103.3-111.9m, cut 5.9m true width of quartz-dolomite adjacent to a fault, in a sequence of carbonaceous slaty siltstone; max assays was 113ppm Cu.
> **DDH 32** 150.24m, 137.3-142.0m, cut 2.9m of quartz-dolomite in slaty carbonaceous and chloritic sediments with best assay 149.3 to 150.2m 0.27% Cu, in quartzose and chloritic sediments removed from the quartz-dolomite (McIntyre, 1973).

South of Pierpoint Morgan, on the Heemskirk Link Road, epidiorite, of pyroxene-hornblende microdiorite has been described in thin-section (Tear and Russell, 1997). "Diorites" dykes were identified by McIntyre (1973) as boulders from deep weathering of bedrock south of the Pierpoint Morgan prospect; they support stands of trees in the button grass plains. He considered the dykes to intrude the sediments as irregular elongate bodies, 20-120 thick and to 1.5km long; dyke trend is unreported.

Comment: Besides fine grained dolerite reported from the Clump prospect, it seems that this one of the few reported basic igneous rock in the area and is, perhaps, an intriguing potential source for copper mineralisation, so commonly associated with diorites; no indication of the magnetic or otherwise character of this rock is given in reports.

South Balfour (also known as Balfour South)

Located in the southern part of EL 4/2002 (E326700 N5424200), 8km SSE of Murrays Reward mine (Fig 1.9), are high-grade chalcopyrite veins in a 20m wide zone of structural complexity and wall rock alteration (Ward, 1911; Taheri, in press). ACI did not drill the prospect but described the prospect as being largely similar to the other prospects to the north except that it is not located on a quartz ridge (McIntyre, 1973). *South Balfour shows considerable wallrock alteration, and arsenic values are the most anomalous the copper belt; it warrants further attention* (Tear and Russell 1997). A magnetic anomaly is flanked by magnetically quiet areas; EM response indicates the area is not anomalously conductive.

CRA recorded 2.3%Cu, 0.8% As and 0.1ppm Au in quartz pyrite rock from South Balfour workings; other results are shown below (Parkinson, 1993).

South Balfour rock chip samples					
		Cu ppm	As ppm	Fe	Au g/t
326 725	54 21 490	79	<50		
326 725	54 21 490	1,583	<50		
326 725	54 21 490	8,700	1,200	7.6%	0.3
326 800	54 21 600	1,200	8,000	21%	1.05 Gaffneys Ck
326 800	54 21 600	2.3%	200	22.5%	0.08 Gaffneys Ck
Tear and Russell 1977, Turner					
326 750	54 21 460	9.6%	1,180	12.3%	0.03
326 751	54 21 461	3,840	133	15.8%	0.06 wallrock to mine

The South Balfour prospect comprises a 20m E-W adit and a shaft. The area has close folding and a fold at the adit plunges 30^o SSW and is faulted in the hinge region. The SSW-trend fault zone is about 2.5m wide, with steep SE-dip. It includes a mineralised zone, about 1m wide, on the eastern side (hanging wall). The mineralised zone is extensively brecciated, containing some pyrite "clasts" and porphyroblasts with rounded edges, up to about 20 cm. The clasts represent an early, massive sulphide formation that has been brecciated cemented by later quartz. Chalcopyrite occurs along the edges of the mineralised zone and appears to have been introduced late; it is absent in pyrite clasts. Similar structures to the one mentioned above, but at a smaller scale, are observed inside the adit. There is no evidence of quartz-dolomite in the area, but *some quartz is apatite-rich*. Apatite was not observed in any other visited prospects (Taheri, in press).

Several generations of brecciation occur in mine dumps where breccia fragments can be seen within a later-formed breccia. Quartz veins, up to 5 cm wide, have been broken and in places folded. This is different to what is observed at the Balfour Blocks, where most quartz is also porous but the cavities largely exhibit rhombohedral shapes, indicative of pre-existing carbonate, probably dolomite.

***Comment*:** The South Balfour (or Balfour South) prospect is somewhat unusual in the Copper Belt in having anomalous As & Au and apatite. It is located above a magnetic source that is not defined but continues north. Further investigation appears warranted.

Waratah copper prospect

The Waratah prospect, located 7km south of Balfour township, occurs on a 300m long quartz-lode ridge rising 25m above the plain (Fig 1.9). Quartzite ridges flank, to the east and west, the mineralised host-sequence of carbonaceous siltstone; the quartz-lode ridge is discordant to stratigraphy by about 40^0. This orientation suggests that the major fault reflected by the Specimen Hill aeromagnetic trend has some east-side-north (sinistral) movement.

ACI noted that the adit driven from the east has spoil dumps of leached quartz with pyrite and traces of chalcopyrite. The partly collapsed adit contained a friable dyke of chlorite, alpha-quartz, talc and magnesite. Six samples from dumps of the mined lode contained up to 1,250ppm Cu. Samples of limonite mud in the adit contained up to 540ppm Cu; the wall rock sediments contain <50ppm Cu. Mineralisation on the dumps is of chalcopyrite, covellite and chalcocite all of which readily washed from the quartz host (McIntyre, 1973).

ACI drilled two diamond drill holes with tricone pre-collar to up to 75m using a Longyear 38. A thin cupriferous quartz zone, vertical, trending NNW was intersected in fine-grained carbonaceous siltstone with moderate E-dip and NNE strike. (McIntyre, 1973) (Figs 1.9, 2.5c).

- **DDH 29**: 140.3 to 145.5m, 3m true, in a fault zone, pyritic quartz, <5ppm Cu.
- **DDH 30**: 135.9 to 138.96m, 1.6m true, max 36ppm Cu, thin cavernous pyritic quartz next to fault, steep-east dip. A sample with some 10% pyrite in carbonaceous sediment assayed only 36ppm Cu, same as for the quartz. Clearly the area has low copper values. No gold assays were done by ACI.

Comment: The Waratah prospect, like that at South Balfour, is located above a district continuous magnetic high that is poorly understood. EM response is close to background. No further action is warranted.

Copper prospects outside EL 4/2002

Other copper workings outside of EL 4/2002 have not been reviewed in detail. CRA sampled a workings east of the Pieman Granite, where three copper workings are aligned along 300m strike in banded siliceous siltstone; a sample of one vein 0.3m contained 15% Cu, 130ppm Zn, 32ppm Pb, 0.1g/t Au.

Toner River prospect: Toner River is located to the south of EL 4/2002 at the southern end of the Balour Copper Belt (E338300, N5408300), on the Lily 1:25,000 sheet, and is one of the few locations where primary copper mineralisation can be seen *in situ*. It is in the Balfour Subgroup, east of the Pieman Granite (Taheri, in press). The main lode, exposed in an exploration trench, strikes NNW and is about 0.5m wide with pyrite pods, and narrow chalcopyrite veins of 5 to 10 cm wide.

The mineralisation is hosted by a 3m-wide chloritised slate band, within a highly silicified zone 7m-wide. The silicification pre-dates the veining and mineralisation as shown by the occurrence of chloritic/silicified clasts within the lode. The silicified zone is not symmetrical relative to the copper lode and mainly occurs to the south. A few thin barren quartz veins adjacent to the lode show the same strike and these are cut by a late set of flat-dip, thin, barren quartz veins. The mineralogy of the ore samples in this place is similar to that observed at the other copper prospects along the belt with pyrite, chalcopyrite and quartz ± dolomite ± chlorite. The quartz on the dumps and outcrops is mostly porous, due to leaching of sulfides, mainly pyrite, from surface samples. The dump material has up to 20% chalcopyrite. The mineralisation occurs within a fault/shear zone and is strongly cleaved, brecciated and sheared.

Located about 100 m northeast of the Toner prospect are 2 to 3m wide, white, barren quartz veins, striking northwest in siltstone; there is no visible wall rock alteration.

Temma: Outside of EL 4/2002, near the small coastal port of Temma several occurrences of Cu-As-Pb-Zn mineralisation, with a transgressive magnetite lode, occur within carbonaceous siltstone. Pickands Mather and Co International, on EL 12/65 drilled two holes into the discordant magnetite lodes near Temma (to the west of Balfour EL 4/2002). The bodies are 10 to 15m thick with narrow zones of low grade Zn, Ag, Pb and Cu (Menpes, 1995). CRA/North Limited drilled two diamond drill holes into magnetic targets in quartzite and mudstone at *Little Eel and Possum Creek* Prospects. The best intersection was 3m, 2% Pb, 13g/t Ag.

Tin-tungsten deposits

This report gives emphasis to review of basemetal mineralisation but notable tin-tungsten (Sn-W) deposits occur on EL 4/2002 and are described below. The genesis of the Cu, and Sn-W deposits is generally regarded as being of two separate events but Sn occurs in the Cu areas and Cu occurs in some of the Sn areas, thus confusing thoughts on genesis. Specimen Hill and adjacent areas has potential for a small mineable Sn-W resource and potential for a large tonnage discovery (Figs 1.5, 2.2).

Historical: At least ten occurrences of cassiterite (-wolframite) are known at or near Balfour. All except one are within 2 km of the main deposit at Specimen Hill (E323900, N5429300) (Figs 1.5, 1.9, 3.5, 3.8, 5.1, 5.3, 5.4). The southern outlier is an unnamed prospect at E324900 N5426600, and the northernmost occurrence is the Premier (Old Murray Bros.) prospect at E323600 N5431200 (Fig 1.8) (Everard et al, in press). The latter, and another unnamed prospect at E323600 N5430600 (Fig 1.9), are the only known tin occurrences on the Dempster sheet. The restricted spatial extent of the tin mineralization at Balfour is in marked contrast with the more extensive copper vein mineralization.

The Balfour tin field produced at least 125 tonnes of Sn (metal) from the early 1880s to 1942, with small-scale production continuing to the early 1980s. Most production has been from alluvial deposits in Cassiterite Creek (formerly Tin Creek) and tributaries, as at E323500, N5443000, 324000,5428500 and 323000, 5429500. Alluvial tin has also been worked in Emmetts Creek (E324100, N5431000) 1.5km NW of Specimen Hill, the headwaters of which have been captured by Cassiterite Creek (Ward, 1911). This accounts for the absence of alluvial tin in the lower part of Cassiterite Creek (Laan, 1985). The peak year of production appears to have been 1914 with 30.5 long tons of concentrate. Some smelting appears tohave occurred in 1913 with 116.9lt metallic tin recorded in production (see Chestnut, 1964).

The Sn-W mineralisation occurs as quartz-tourmaline-cassiterite-wolframite vein stockworks, with associated Sn-placers. A centre of concentrated tourmaline alteration occurs with breccia (Fig 2.2). The laminated tourmaline-rich siltstone host-rock contains 100-200ppm Sn and up to 100ppm W, and has interbedded sandstone.

Specimen Hill and environs

BHP 1964-66 investigated SPL 392, 410 held by the Balfour Mining Syndicate (Mr G Force) (320 acres) and tested for Sn-W potential using a gravity and magnetic survey, costeaning, drilling, and geochemical sampling. CRA/North/Geopeko drilled, in 1981/82, DDHs- BC1 & 2 (Specimen Hill), BC4 &5 (E of Specimen Hill), BC 5 & 6 (SE of Specimen Hill), BC7 (N of Specimen Hill), BC 3 to the SW of Specimen Hill

(Figs 3.6, 3.8, 5.1, 5.2, 5.4). The holes intersected veins that average about 1 cm thick with some larger veins up to 30 cm. Best results were in DDH B5. It was found that the tin veins are of high grade (average 0.8% Sn and 1.02% WO_3).

Specimen Hill Geology: A plane table survey was used by BHP to control geological mapping and sampling (See Fig 3 in Chestnut, 1964). In 1964 BHP, using ground magnetics, and defined a magnetic anomaly trending NW, discordant to the stratigraphy (Figs 1.8, 2.2). The mineralisation is hosted by pyrrhotite-bearing siltstone, sandstone, quartzite and shale in the Specimen Hill area.

The dominant structure in the area is a broad open anticline, trending NNW and plunging south (Fig 5.3 a,b,c). A major east-dip, N/S-trend fault separates west-facing siltstone, sandstone and a black shale unit on the western flank of the Specimen Hill from the overlying east-facing siltstone units. The fault appears to have been the major conduit for hydrothermal activity and appears to coincide with the Specimen Hill aeromagnetic anomaly. The tin and tungsten mineralisation occurs on the crest and western slopes of Specimen Hill and is part of the complex and widespread mineralisation in the Balfour area.

Surface geochemistry BHP selected 170 of the numerous pre-existing numbered pits and dug/cleaned and volume-measured samples of the peat and eluvial-gravel that was panned before assay in Launceston or Newcastle; the concentrate was checked by hand magnet for iron. Results of the peat assays were expressed as "lbs of 70%Sn concentrate/cubic yard". This gave a residual cassiterite anomaly pattern with zones of anomalous tin bearing over 1.0lb/cubic yard.

Eluvial gravels were dried, crushed and a 3-5lb sample sent for assay to 0.01%Sn precision; results confirmed the soil distributions with most anomalous values being >0.1%Sn (Fig 5, Chestnut, 1964). The NW area of Specimen Hill is consistently anomalous in tin.

The best assay areas were then attempted to be costeaned (lineal 2,316m) using a bulldozer. The bulldozer (Allis Chalmers HD6) was too small to effectively cut through cemented eluvial fragments and failed to dig to bedrock; on some costeans jackhammers were attempted but the costean were abandoned after partially exposing some bedrock. Potential wall-collapse, increased depth of weathering and unreliability of samples, resulted in termination of the programme. Only Costean 1 was sampled for 64m at 3m intervals (Fig 6 cross-section, Chestnut, 1964). (It appears that in most cases, bedrock was not exposed.)

The soil/peat concentrate mineralogy was described by S Whitehead (in Chestnut, 1964):-

Quartz-abundant
Cassiterite-angular 0.5mm crystals and aggregates, rare twins, variable colour.
Zircon-minor, well rounded, derived from sedimentary rock
Tourmaline-very rare, prismatic
Ilmenite, recrystallised leucoxene and one chalcopyrite grain.

Mineralisation noted by BHP: The peaty soils were found to be 0.5m thick overlying a partially cemented angular gravel and sand mix up to 1.8m thick. The major quartz veins had shallow dips, whereas the other veins were of no fixed orientation; an anticlinal flexure on a regional anticline was proposed as the controlling structure. Loaming of soils and gravels from pits showed maximum cassiterite on the NW flank of Specimen Hill (Chestnut, 1964). Langsford (1982) described mineralisation at Specimen Hill as a swarm of quartz-tourmaline-cassiterite-wolframite-(muscovite) veins, up to 0.5m wide, with up to 10% Sn-W and 20% sulphides, within a breccia zone. Tin appears to have formed later than the copper and is possibly associated with minor cross-cutting felsic intrusions and a second phase of regional deformation. Limited S-isotope and fluid inclusion data suggests that the Sn mineralisation is unrelated to the copper, but Pb-isotopes interestingly indicate a similar Pb-source.

Quartz veins in outcrop are porous, indicating the leaching of sulfides and/or carbonates. In drill core cassiterite and wolframite are associated with pyrite, chalcopyrite, arsenopyrite and pyrrhotite and minor carbonates. The proportions of minerals vary between deposits and drill holes within a deposit. Ward (1911) reported mineralised samples containing quartz, pyrite, siderite, galena, sphalerite and chalcopyrite and assaying about 7.5% Zn, 2.7 %Pb, 0.23 %Cu, 4 g/t Au and 80 g/t Ag from a shaft to the south of Specimen Hill.

Wall rock alteration is of tourmalinisation, minor sericitisation and silicification with tourmalinisation being the most pervasive type. They are erratic both in terms of tin and tungsten content, widths and directions.

Drilling: BHP, in 1963-64, drilled four diamond drill holes (DDH B1-4) which tested quartz veins and the associated magnetic anomaly at Specimen Hill (Chestnut 1964). Subsequently, two holes (DDH B5 & B6) tested magnetic anomalies to the north and south (Fig 3.6, 3.8, 5.3, 5.4); sludge samples were collected and found comparable with rock assays (Chestnut, 1964). (Details have not been completely researched herein). The southern anomaly contains pyrrhotite with tin, and also Sn-Zn-Ag in pyritic shale. BHP drill results (Chestnut 1964) are:-

DDH B1: 88.6m, vertical, Specimen Hill, cut steep-dip quartzite, shales and baded siltstone with sulphide blebs and veinlets. Best assay from 48.7m, 1.92m 0.54% Sn (This contained a quartz vein 10cm thick assaying 10% Sn)

From	**To**	**Interval m**	**%Sn**	**note**
36.6	50	13.4	0.12	
41.5	50	0.6	0.17	
44.5	50	5.5	0.23	
48.1	50	1.9	0.54	
From	**To**	**Interval m**	**%W**	**note**
72.5	72.98	0.44	4.1	
72.2	74	1.8	1.0	

DDH B2: 73.15m, vertical, Specimen Hill, assays said to be poor
Sequence was similar to DDH B1(Chestnut,1964). The highest grade vein was

From	To	Interval m	Sn %	W%	Cu%	As%
44.47	44.74	0.27	0.57	0.4	2.0	9.9

DDH B3: 30.6m, vertical, NW Specimen Hill, targetted 20cm vein that outcropped on the west side of Specimen Hill. Vein cut 26cm assayed 1.4% Sn. Thought to be same vein in DDH B1 and 60m up-dip from B3.

From	To	Interval m	Sn %	W%	Cu%	As%
17.90	18.17	0.26	1.4	1.2	1.3	12.6

DDH B4: 167.49m, south end Specimen Hill, vertical, deeper hole, banded siltstone, some shale, quartzite. Major fault at 9m to 43m; minor fault 51m to 52m. Vein-

From	To	Interval	Sn %	W%	Cu%	As%
137.7	138.2	0.5		yes	yes	

Several other veins were intersected. Petrography on core from 160m was described (Whitehead and Apthorpe, in McKenzie 1965) as sericite quartzite with secondary carbonate and sulphides, mainly pyrrhotite with trace sphalerite and chalcopyrite.

The drilling indicated quartz veins with cassiterite and silicification; pyrite, and arsenopyrite are abundant with lesser cassiterite, wolframite, chalcopyrite, siderite, mica and pyrrhotite in both the veins and the silicification. Chestnut (1964) noted that the cassiterite mineralisation is on vein selvages and weathers-out near surface. In a second round of drilling BHP drilled DDH B5 & 6 (Chestnut, 1965).

DDH B5: 300m, vertical, tested the southern end of magnetic anomaly, near an old adit, and towards Matrix Creek. Intersected steep-dip, banded light/dark grey siltstone with dispersed blebs of sulphide. DDH B5 failed to intersect a magnetic source as modelled by BHP; Chestnut (1965) suggested that the target body is located to the west of the vertical drillhole. Some Specimen Hill type quartz-sulphide veins were cut. Resampling of the DD B5 drill core by CRA ***yielded 25m, 0.3% Sn, 0.7%Zn, 10 g/t Ag*** in pyritic shale with quartz, including 0.3% Sn, 3.0% Zn, 70g/t Ag, 0.2% Pb in a quartz vein (Fig 5.3b). A narrow zone of 0.3m, at about 116m depth, carried 1.1% Sn associated with a sulphide lode in banded quartzite (Dickson, 1982).

DDH B6: 183m, -55°/236magW, in the NW sector of Specimen Hill, targetted a 3m zone on surface of massive leached quartz vein. The zone was cut between 128.7m and 136.3m as silicified and chlorised siltstone with sulphide 5-10% that was magnetic. It was assumed to be pyrrhotite with pyrite, and minor chalcopyrite, galena and sphalerite. There was no *visible* cassiterite but a section of silicified siltstone 126.7m to 130m assayed 0.2% Sn. The pyrrhotite occurs as blebs in laminae of the tourmaline bearing siltstone.

Numerous, thin quartz-tin-tungsten veins were intersected but the overall tin content was considered to be too low to justify open pit mining; veins were insufficiently thick for conventional underground mining. However, the sampling was very incomplete, unsystematic and only a small area has been assessed.

The exploration by CRA for Sn-W in the 1970's-1980's has not been reviewed in detail and warrants futher documentation. Holes drilled included (Fig 5.3a):-

- DDH81 BC1 (to west, TD 116m) veined tourmaline breccia, with up to 0.1% W, 500ppm Sn;
- BC2 (to NW, TD220m) veined tourmaline breccia, with up to 4.1%W, 0.1% Sn;
- BC4 (210m) with up to 0.7% W, 0.3% Sn;
- BC6 (to east?, TD 274m) with up to 0.6% W, 1.0% Sn

in various quartzite and siltstone with zones of quartz veining (Dickson, 1982).

Economic viability: A review was done by CRA (Patterson 1996, in Menpes 1996). Patterson noted that three of the BHP drill holes were directed at the area of brecciation and tourmalinisation at Specimen Hill where geological mapping had shown a south-plunge anticline. CRA drill hole DD82-BC8 (Fig 3.6) was sited to intersect an IP target, and intersected 33 quartz veins around the Specimen Hill Fault, cut at 293m. Past CRA/North/Geopeko work was included in Patterson's review. Patterson (1996) found that:-

- BHP's drilling showed concentrations of cassiterite from 1-10% in massive quartz veins but *volumetrically most tin occurs in laminated shale wallrock with 100-1,100ppm Sn.* Disseminated pyrrhotite in drill core seemed to explain the magnetic anomaly.
- BHP's 1964 costeans largely failed to penetrate cemented gravels and failed to reach bedrock.
- CRA channel samples of 15kg may have been insufficiently large to assess grade given the coarse nature of the cassiterite.
- CRA's NQ core drilling is unlikely to have reflected true grade given the erratic veining and coarse cassiterite.
- Some 42% of quartz veins are mineralised.
- Ore sorting separation techniques probably would be inefficient given the white quartzite versus white vein-quartz separation problems.
- Geological mapping was limited by inaccuracy of the tape and compass grid.

Patterson (1996) estimated that 10Mt (to 100m depth) at 0.6% Sn is needed for an economic operation at tin prices of US$6,300/t (equivalent to 1Moz Au at 3g/t)(CRA did not specify exchange rate; Sn price is now US$4,000/t $A1=US$0.64). Specimen Hill has an estimated quartz vein content of 0.66% with average grades of 0.8%Sn and 1.0%W. The potential size of the mineralised tourmaline breccia zone at

Specimen Hill has been estimated by Langsford (1982, in Patterson 1996) at 50,000m^3, using SG 2.5, to 200m, a total of possibly 25Mt. Patterson (1996) restimated a surface area of 44,000 m^3, SG 2.2, 100m depth at 10Mt. He considered grade to be insufficient for an economic operation but further work was recommended by Patterson to increase tonnage, including at Peter's Hill and Tatlows.

Comment: NCR suggests that a test of Sn-W resources to 100m depth at Specimen Hill, and adjacent areas such as Tatlows, can be achieved rapidly by pattern drilling using inclined reverse-circulation, wide diameter drill holes. Sampling should be of large samples processed to produce a split-sample bulk assay and also a concentrate sample. The deposit remains a good-quality exploration target for a low-medium grade, open pit Sn-W operation of low strip-ratio, with probable recoverable (gravity) Sn and W concentrates of high quality. The possibility of tin-in-pyrrhotite and other sulphides is unknown and may complicate recoveries but a high-proportion is expected to be cassiterite or wolframite easily separated. Tin associated with EM-conductors remains a target for exploration.

Tatlow's, Robbies & Southern Shaft

Tatlows shaft (E324500 N5429300), Tatlows costean and Robbies workings (E324400 N5428700), about 600m SE of Specimen Hill, small high grade tin lodes are exposed (Langsford 1982) (Figs 1.9, 5.2). Massive to semi-massive sulfides (pyrite, sphalerite, arsenopyrite, pyrrhotite) with quartz, cassiterite and wolframite are accompanied by sulphide-free, quartz-cassiterite veins containing up to 70% cassiterite (Langsford, 1977). According to Patterson (1996), Langsford (1982) noted that BHP drill hole DDH B14, sited west of Tatlow's shaft, drilled east below workings without intersecting mineralisation; it should have been sited south of the shaft and drilled to the north. Samples of lode quartz with pyrite-cassiterite were analysed by CRA (EL 4/94) (Turner, 1994, Menpes, 1995):-

Sample	**E**	**N**	**Sn %**	**W %**	**Cu %**	**Pb %**	**Zn %**	**Ag ppm**	**Au ppm**	**Location**
3757880	324400	542920	0.2	0.0	***0.6***	0.0	***0.3***	37	0.0	Tatlows costean, py qtz, **As 1.4%**
3757881	324400	542920	0.1	0.3	***0.7***	0.0	***0.2***	17	0.0	Tatlows costean, cp, siderite, sp? **As 1.8%**
3757882	324400	5429200	***0.9***	0.1	***1.6***	0.2	***9.9***	135	0.0	Tatlows costean, cp,qtz, **As 3.3%**
3757883	324075	5428900	0.2	0.0	0.1	0.0	0.0	10	0.0	South Shaft, qv,py As 0.7%
3992208	323800	5428500	***1.6***	0.3	0.0	0.0	0.0	79	0.0	Shaft/costean, qtz-mica, greisen/granite
3757885	324075	5428900	***8.6***	***8.2***	0.2	0.0	0.0	37	0.0	Southern Shaft, qv, sp,py?, **As 4.3%**
4142268			***0.3***	***0.2***	***1.1***	0.01	***0.4***	>50	0.03	

The samples show the variability of metal typewith high Sn-W-Cu-Zn-As in samples that appear to be mainly of sulphidic quartz veins. Although cassiterite has been noted, some of the tin may be in sulphide. These occurrences are quite likely to be of mineralised quartz veins with a cross-strike orientation, and are likely to be discontinuous. They may represent mobilisation of anomalous metals in deep bedrock, of a lower-grade, but potentially economic, target that has not been tested.

CRA drill hole BC 5 was drilled in green chloritic siltstone towards Tatlows Shaft (Figs 5.2). This hole does not appear to have intersected significant mineralisation with Cu, Pb <100ppm, but there is 1m of 0.2% Zn; it is suspected that the Tatlows target-vein mineralisation is likely to be somewhat parallel to hole direction. CRA diamond drill hole BC11 a long hole (Fig 5.2), designed to test under the Murrays Reward Shaft and a gravity feature intersected cassiterite stringers at 38m in chloritic schist, and the main mineralised zone is of disseminated chalcopyrite with quartz-dolomite (Russell and Tear, 1997).

At *Robbies workings*, about 300 m south of Tatlow's, thin quartz-cassiterite veins occur in shallow workings (Fig 5.3b); quartz-cassiterite veins with minor chalcopyrite are also exposed in sluiced areas. The vein appears to be oriented WSW.

The *Southern Shaft,* 500m SSW of Specimen Hill (sample 3757885 in table above) contains high grade Sn-W (Fig 1.9). The value of 0.8% W is in a quartz vein, presumably from dump material with scheelite, and is the highest W assay in the area (that I have seen) and was collected by CRA (in Russell and Tear, 1997).

Peters Flat and Peters Ridge

Located to the east of Specimen Hill E324100 N5429500, towards Murrays Reward, poorly-exposed tin-bearing quartz veins occur in an area of 400m x 100m (Langsford in Patterson 1995). This area could also contribute ore to open pit mining.
(Turner 1994) collected samples from Peters Ridge, unnamed shaft and costean:-

Sample	E	N	Sn %	W %	Cu %	Pb %	Zn %	Ag ppm	Au ppm	Location
3992207	323800	5428500	0.0	0.0	0.0	***1.5***	0.0	14	0.0	Qv sp, py
3992208	323800	5428500	***1.6***	0.3	0.0	0.0	0.0	79	0.0	Shaft/costean, qtz-mica, greisen/granite, ***As 11.8%***
3992209	324075	5429050	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Qv with gossan

Untested coincident IP and zinc anomalies are evident in the area (see below).

Other

Cassiterite was also recorded as finely disseminated (<0.5 mm) grains in altered, laminated shale in the Specimen Hill area (Langsford, 1977), but was not observed by MRT (Taheri, in press). Tin has been recorded in massive sulphide from Murrays Reward dumps where a composite chip sample by CRA returned 350ppm Sn in a sample with 4.5% Cu (Langsford, 1982).

Zinc-Lead-Copper prospects

Nelson Pb-Zn-Cu Prospect

CRA was keen on a low-moderate value zinc anomaly in soil and wacker samples at the Nelson Prospect located along the Nelson Bay River headwaters, some 3.5km WNW of Balfour (Tear and Russell, 1997) (Figs 1.8, 4.4). The anomaly is in the area of the major NE-trend Roger River Fault (Dempster 1:25,000) and the Nelson-Airfield EM conductors.

CRA investigated prospect, with 8 grid lines on 400-800m spacing, ground magnetics, outcrop sampling (52 samples), geology, hand auger soil (120) and wacker (142) sampling along 5 grid lines at 25m spacing, and 3 lines of dipole-dipole 50m IP but did not target drill the area (Menpes, 1995). The 3km long geochemical anomaly is located at the contact of quartzite and overlying siltstone. Best values are at the south end around E 321 300 N54 30 800 and these appear to be at the site of a weak EM conductor (Fig 1.10). Diamond drilling was recommended but not undertaken.

Rock samples, taken from the northern area of the Nelson-Airfield EM conductor are only weakly anomalous and may be "leached":-

Nelson Prospect CRA rock chip samples				
		Cu ppm	Pb ppm	Zn ppm
322 320	54 31 765	29	**255**	18
322 290	54 31 840	21	**336**	35
322 530	54 33 675	13	8	**243**

An initial 43 *rock chip* samples were collected and one sample, in Cassiterite Creek (E322220, N5433160) of graphitic shale with trace pyrite, contained 0.2g/t Au, 22ppm As, 88ppm Cu.

Nearby samples were also weakly anomalous in Zn 116ppm and As 39ppm. A further 9 samples were collected around the anomaly but all results were <0.005ppm Au. Values were max Cu 88, Pb 336, Zn 243, Ag <1, Fe 19.5%, Mn 2,352, Co 35, Ni 21, As 5038 ppm. Anomalous Pb values of 255 and 336ppm are near each other.

146 hand auger soil and 142 wacker bedrock samples were collected more systematically at 25m spacings on grid lines with anomalies as follows (Fig 4.4):

Nelson Prospect CRA Hand soil auger and wacker samples							
		Hand or Wacker	Cu ppm	Pb Ppm	Zn ppm	Fe	
321 575	54 32 800	W	**108**	92	**104**	1.3%	Mag anom
321 500	54 31 200	W	61	**113**	36	4%	mag
321 175	54 31 200	W	20	17	**148**	1.3%	mag
321 350	54 32 800	W	16	**276**	106	1.8%	
321 025	54 31 200	W	5	15	**452**	0.8%	mag
321 025	54 32 800	W	18	39	**237**	1.8%	mag
321 550	54 33 600	W	34	70	**318**	3.3%	

Tear (1996) and Tear and Russell (1997) followed up the anomaly and collected an additional 100 wacker samples on 4 lines, and obtained best values of Zn 664ppm, Pb 156ppm. This work delineated three parallel zinc-anomalous zones, the longest of which runs NNW for 1.5km, coincident with a dark grey siltstone, part of the Wavy Laminar unit.

The best results from a total of 353 wacker samples are:-

Nelson Prospect, Wacker Samples (Menpes, 1995 Tear, 1996) all ppm						
			Ag	**Cu**	**Pb**	**Zn**

321 250	54 30 400		2	23	**1,788**	**1,845**
321 225	54 30 400		-1	24	105	1,100
321 150	54 30 400		-1	10	62	1,058
321 275	54 30 800		-1	44	12	1,450

Although the results are, in absolute terms, relatively low in view of the degree of chemical leaching, they may reflect mineralisation of interest.

Ground magnetic values were collected at *Nelson Prospect* along 7 grid lines (N54 20000 to 27000), and IP along three lines (Menpes, 1996). Ground magnetic high and lows trend NNW through the Nelson Prospect. One of these coincides with the main zinc anomaly and with siltstones and shales (Menpes, 1965, Tear and Russell, 1997).

Dipole-dipole IP survey, by Zonge Engineering in 1995, with 50m spacing, on 3 lines (9.1km) shows an anomaly 150m wide along 400m of strike, open N-S (54 31 600, 54 32 000, 54 33 600). The aeromagnetic low, to the immediate east of the Nelson prospect, coincides with carbonaceous shales and an IP anomaly (Tear 1996). Areas of poor-quality IP response coincide with quartzite; ground conditions were very wet and non-optimal readings were obtained (Tear, 1996). The Nelson-Airfield EM anomaly is located just to the east of the CRA centred Zn-Pb, magnetic anomaly target.

The area remains undrilled and is of lower priority interest.

Peters Ridge to Tatlows Shaft, East of Specimen Hill, Zn-Sn-B

A line of anomalous soil and bedrock zinc values of +5,000ppm Zn occurs 250m west of the Balfour Shear and the Murrays Reward copper deposit; it coincides with an IP feature along some 750m of strike (Fig 5.2). The IP and geochemical anomaly occurs in E-dip sediments at the contact between underlying quartz-arenite and overlying green siltstone. Tatlows Shaft plots where the anomaly extends south. The anomaly may have high-tin but only the zinc geochemistry is held by NCR; no tin geochemistry appears to be available but should be checked in CRA/RIO digital geochemistry data base (CD).

Previous drilling collars along the anomaly are:-

- BC5 (near Tatlows Shaft, 95.5m, weakly anomalous zinc, Fig 5.2),
- 25 (ACI targetted Murrays Reward, upper 30m RAB (and not sampled?), other carbonaceous and green shales intersected may have not been sampled, before the copper mineralised intervals at the end of hole at 250m (Fig 5.2),
- BC10 (CRA, abandoned after 82m in clay shear) may have tested parts of the anomaly but were targetting the copper lodes.

This area is a recommended target herein.

Skinners Flat, south of Specimen Hill, to Area A

CRA's plot of soil and bedrock zinc values shows a strong anomaly around Skinners Flat, to the immediate S-SW of Specimen Hill with values to 5,000ppm Zn that is continuous on a N to NNW trend for 1km. (Figs 1.9). The Southern Shaft (Sn-Zn-Pb) is nearby but the anomaly does not appear contamination. The Skinners Flat EM anomaly is approximately coincident with the geochemical anomaly or located to the immediate west (down-thrust?). A major W-dip, NW-trend, thrust fault is mapped to the immediate east; this breaches the Specimen Hill anticline (Balfour 1:25,000, Figs 5.3a,b). The anomalies appear to be roughly along/overlapping the contact between the Lagoon River Quartzite and the Skinners Flat siltstone (see Balfour Geology 1:25,000).

Only one specific drill test appears to have been undertaken, with a CRA diamond drill hole:-

- **BC 4** (approx E324 250 N54 29 450, 211.4m), drilling west on Section Line J (Fig 5.2) intersected some of the anomalous zone at a depth of about 120m. Zinc sections have 1.5m, 0.6%, & 2m 0.2% Zn; Cu<150ppm , Pb < 150ppm, no Sn-W assays given. The core log describes a fractured host siltstone sequence with intensely brecciated carbonaceous shale with scheelite noted and very tourmalinitic siliceous siltstone just prior to the mineralised interval of chloritic silicified slates.

Southern extension: ACI investigated an old shaft and adit 0.5km south of Skinners Flat at *Area A* (E323900, N5428300) (Fig 1.9). The area is located at the north end of a N-trend EM anomaly, extending along E324 100, that is offset to the west and continues north as the Skinners Flat EM feature. The Area A is in Skinners Flat Siltstone and is on the west flank of the southern extension of the Specimen Hill aeromagnetic anomaly (Fig 1.9).

At *Area A*, McIntyre (1973) reports a poorly-defined ridge with scattered ferruginous and quartzose float in fine-grained carbonaceous sediments with an E-dip. Ward reported a shaft to 15.2m, that cut a SW-dip lode, *4.3m thick, assaying 7.5% Zn, 2.7% Pb, 0.2% Cu, with 3g/t Au (2dwt 16 grains) and 2oz/t Ag (2oz, 13dwt, 14gr) in picked samples.* ACI sampled two costeans with maxima of 280ppm Cu, 900ppm Pb, 100ppm Zn in the north, and 400ppm Cu in the south costean. Two drill holes of uncertain origin DDH 5 & C3 tested the area but no details have been seen (Fig 1.9).

Northern extension: One hole by CRA/Geopeko DDH 10 (approx E323 370 N54 29 670), tested a target NW of Specimen Hill, near the Balfour track, and cut from 24m to 39m (EOH) weakly anomalous zinc (max 300ppm) (Porter, 1980)(Figs 1.9, 5.1). At the same horizon, 1.4km to the south CRA/Geopeko DDH 3 tested the best Pb-Zn anomaly west of Specimen Hill but the hole did not explain surface data (Heithersay, 1982). This drill data has not been researched by NCR.

Target: The Skinners Flat EM-Zn anomaly, and its offset extensions to the south, and continuations to the north, to the Airfield, is a prime target for further investigation for stratabound Zn-Pb-Cu-Ag deposits. Systematic drilling is warranted.

(ACI also investigated *Area B* (324200, 5428300.At *Area B* a collapsed adit had been driven into a ridge with quartz float in sediments. ACI sampled the north costean max 150ppm Cu and south costean max 380ppm Cu.)

Clump Zn-Cu

A lead-zinc anomaly was found in rock chip samples, 1km south of The Clump prospect, near the Clump basalt occurrence shown on the 1:25,000 topo map (Fig 1.8)(Turner, 1995). A quartz sandstone (sample number 757835 at E321 475, N54 35

775) in a cutting on the Heemskirk Link Road contains patches of pyrite and sphalerite and assayed 800ppm Pb, 750ppm Zn, 1ppm Ag. It appears to be coincident with parts of the Clump EM conductive feature. This was considered to be a possible stratabound Pb-Zn anomaly but was not followed up (Menpes, 1965). This area, given the deep chemical leaching, warrants follow-up and is a scheduled target herein.

BROAD EXPLORATION SURVEYS, BALFOUR REGION

Geochemistry

Surface Leaching: McIntyre (1973) noted the friable nature of the quartz-dolomite-pyrite mineralisation at surface and in drill-core loss throughout the district, particularly at Murrays reward and the Clump prospects. Drilling, indicated that supergene alteration extends to depths greater than 150m. CRA also noted that the surface soils are very leached and in some cases carry possibly exotic gravels in button-grass plains. Even costean samples are probably within the zone of deep leaching. This is to be expected because:-

- the button grass area would continually generate strong humic acid
- the bedrock mineralisation contains carbonate that would decompose under the near-surface acid conditions
- pyrite is reported as being widespread, especially in the carbonaceous and chloritic siltstone and would oxidise to contribute more acid
- the quartzites contain hematite, presumably derived from matrix pyrite and hence have probably generated acid

On this basis, it is quite likely that surface soil, wacker, costean and rock sample surveys, undertaken mainly by ACI and CRA, have been an inconsistent screen of basemetal potential in the Balfour area. Furthermore, the flat areas between quartzite ridges are very poorly exposed; these may contain more extensive aeas of dolomite alteration that would be recessive, and yet be ore targets. This being said, it is noted that the soils/wacker samples around Specimen Hill/Murrays Reward are of high values.

Reverse circulation drilling has not been used anywhere in the area but would be well suited to testing below near surface leaching and able to handle the commonly wet conditions found in western Tasmania and high water flows in shallow drill holes.

Stream sediment sampling: CRA undertook a helicopter supported panned-concentrate and stream sediment geochemical sampling programme on EL 1/77 across much of the Rocky Cape Group seeking mainly tin deposits. Earlier stream sediment data was collated and a regional infill survey conducted (Weir, 1982). Most Sn and W anomalies were isolated and outside EL 4/2002, but some in the Blackwater Rivulet area (outside EL 4/2002) were attributed to detrital minerals derived from Tertiary gravels.

Later, in a joint venture with Geopeko, CRA shifted the target in EL1/77 to shale hosted lead-zinc (SEDEX) deposits, noting similarities in regional geology with the Selwyn Basin (Canada)(Legge, 1980). Stream sediment lead-zinc anomalies are all to the far eat of EL 4/2002. A similar programme of stream sediment, soil and rock sampling and mapping was undertaken in EL12/80, which included the southeast of the Dempster sheet and areas to the south (Weir, 1983a; Dickson, 1985). CRA concluded that black shales at the eastern margin of the Smithton Synclinorium were too thin to have generated brines sufficiently metal-rich to produce a sedex-style of mineralisation. Any metals deposited in carbonate were considered likely to have been leached out during subsequent silicification (Weir, 1983b).

Pacific Nevada undertook a geochemical sampling programme along the Frankland River, in an area north of Balfour (Westbrook, 1999)(Figs 4.1, 4.2). Gold and base metal values are generally low, and this was partly attributed to the effects of leaching, quartz lag cover and a weakly incised drainage system. *However, anomalous and visible gold was present in a panned concentrate from Cassiterite Creek*. The anomalous gold results have not been pursued and warrant investigation although specific locations are not specified. Sample results are:-

Pacific Nevada, Best geochem results, Westbrook 1999 (EL 04/98)						
Sample	Type	East	North	Metal	Note	Action
7711059	Pan Con	323140	5430670	4660µg Au	Visible gold	***In EL 4/02***
7720996	BLEG	322720	5436260	22ppb Au		***In EL 4/02***
7720998	BLEG	322710	5436980	12ppb Au		***In EL 4/02***
6521034	BLEG	324720	5436660	7ppb Au		outside
7730978	-80#	324500	5431550	824ppm Cu	Pb19, Zn11,	***In EL 4/02***
7741874	Rock	322880	5433620	179ppm Zn,	81Pb	***In EL4/02***
7740747	Rock	324420	5435780	113ppm Zn, 2370Ba		***In EL4/02***
7720995	BLEG	322720	5435940	15ppm Zn	anomalous	***In El 4/02***

The BLEG gold values of 12-22ppb are in a coherent area (Fig 4.1a) at E328800 N5436000 and warrant investigation. Visible gold found at E323100 N5430700 also warrants a check.

Taheri (in press) analysed sixty mineralised samples from different prospects in the Balfour-Temma area for base metals, nickel, cobalt, tin, tungsten, bismuth and gold The copper mineralisation is geochemically simple with low (<200 ppm) lead, zinc, bismuth, arsenic and other metals. Co and Ni concentrations show positive correlations with copper. This may either suggest that the copper has been remobilised from basic rocks (eg. Spinks Creek Volcanics), rich in copper, nickel and cobalt, or it has been remobilised from a pre-existing copper deposit enriched in these elements.

Based on drill core geochemistry, tin-tungsten prospects are characteristically polymetallic, containing substantial amounts of Fe, As, Bi, Zn, Cu and Pb (Russell and Tear, 1998). The Sn-W deposits also are low in Ni and Co (Russell and Tear, 1998).

Soil and wacker surveys: CRA conducted surveys on several lines and these are discussed under the prospect areas. CRA digitised all available geochemical data (Russell and Tear, 1997). A summary of the geochemical results is shown on Figs 4.3, 4.4. The soil and wacker surveys have not been undertaken through the area on a systematic basis but are restricted to the cut-lines as shown on the figures.

Metal discrimination: CRA found that the metals contents could discriminate the Cu (Murrays Reward/Clump), being more uniformly Cu-As-(Pb-Zn-Au-(Co-Sn)) and with simple mineralogy, from the more arealy restricted and variable metal content Sn-Cu mineralisation (Specimen Hill)(Turner, 1994). This difference of regionally extensive copper but focussed tin mineralisation suggests that the copper has tapped a more regional fluid system versus the local (?granite) for the tin (Turner, 1994). Overall, although the copper mineralisation is associated with elevated As, Ag, Co, Ni, multielement study has not demonstrated a distinct signature for the copper mineralisation (Russell and Tear, 1997).

- Bi and As are anomalous in the Sn-W prospects. Tatlows is especially high with a maximum value of 800ppm Bi observed in one sample.

- Au is low in mineralised zones, commonly less than 0.05 ppm but values up to 0.1ppm have been reported (Russell and Tear, 1998)

- Sn contents of mineralised rocks from the copper prospects are generally low with the exception of a few samples from the Murray’s Reward where values of up to 250 ppm Sn occur

The geochemical data clearly show that the copper deposits are formed from different sources and/ or by different processes than the Sn-W deposits. This is despite the fact that the main Sn-W deposits are less than 2 km from some copper deposits along the belt (eg. Murray’s Reward).

Comment:

- Geochemical leaching appears to be significant but unquantifiable.
- The copper deposits appear to contain elevated Co & Ni, whereas the Sn-W deposits contain elevated Bi & As.
- Limited stream sediment survey of the Frankland River suggests that a gold anomaly warrants follow-up in the far-east of EL 4/2002.
- Other geochemical targets are described in the "prospects" sections.

The geochemical data continue to be interpreted in conjunction with the 2002 digital geophysics. Digitisation of drilling and overlay onto other digital data will be undertaken.

Magnetics

The recent aeromagnetic surveys supercede older surveys but a note is made of the older surveys. The best mineralisation associated with an aeromagnetic anomaly appears to be the Sn-W at Specimen Hill. Some anomalies probably represent underlying, shallow, magnetic bodies of unknown nature. (The Temma deposits, to the NW of EL 4/2002, are associated with magnetite-rich ironstones.)

Magnetic Surveys

Ground magnetics: In 1964 & 1965, BHP surveyed the Balfour area using an Askania Torsion magnetometer on 150m spaced traverses using tape and compass. BHP geophysicist reported that none of the rocks from Specimen Hill could explain the ground magnetic anomaly and suggested a massive sulphide source at depth. A target was modelled as 210m wide, at 100m depth, striking 350^{o}mag, dip -70E. A hole DDH B5 was proposed south of DDH 4 (Taylor, 1965). Leaman (Oct 1992, in Morrisson) reviewed ground magnetic surveys around Specimen Hill by BHP and CRA (Chestnut, 1994 & 95; CRA 1979) but old “difficult to locate" grids limit their use.

Aeromagnetic surveys: Earliest surveys, by Riotinto were of a regional analogue type. Leaman (Oct 1992, in Morrisson) reviewed the two relatively-poor resolution older data sets - CRA 1979 (200m lines, 75m clearance), and BMR (AGSO/GA) in 1986 (500m spaced lines, 150m clearance, Leaman 1988). A small area was flown over EL 18/92 & EL 4/94 for aeromagnetic & radiometric data by CRA in 1993 using a more detailed 100m line spacing, 200m in the south; this survey's digital data has not been sourced by NCR.

In 1996 a more detailed survey with 200m line spacing and 90m terrain clearance was flown over an area, including EL4/2002 and elsewhere, by MRT and AGSO for the Regional Forest Agreement; an image is given as Figure 1.6. (The CRA 1993 survey was not incorporated into the MRT data set; pers comm Bob Richardson). The MRT 2002 EM survey also included digital aeromagnetic data.

Aeromagnetic interpretation

Several anomalies and trends are evident in the aeromagnetics and are discussed from north to south in EL 4/2002 (Fig 1.6). The magnetic anomalies occur in a range of rock formations.

Far north EL 4/2002: A NW-trend broad aeromagnetic anomlay, cut by the Blackwater Road roughly coincides with the boundary between the upper Emmetts Creek Shale (Prbg) nd the lower Looneys Road Siltstone (Prbs). No specific mineralisation is associated and the source is unkown.

Clump aeromagnetic anomaly: Near the Clump Tertiary basalt exposure (that has no significant magnetic response), a weak magnetic response is located just NE. Host rocks are of Cassiterite Creek Quartzite (Prbq). This magnetic anomaly is offset to the NE of Clump EM response and is of uncertain origin. It is parallel with but not especially coincident with the Clump mineralisation and appears to be coincident with a gravity anomaly of interest.

Spinks Creek Volcanics: A zone of intense short wavelength anomalies is located immediately east of the Roger River Fault and is both with and outside of EL4/2002 (Figs 1.5, 1.6). The linear north-south trending zone north of Balfour (E324400 E5437000 to E324900 N5431600) and the Lindsay River exposure (329700mE 5430000mN) reflects Neoproterozoic basalt (Spinks Creek Volcanics, Psb) with a magnetic susceptibility an order of magnitude higher than other major units. The anomaly was gridded and sampled by CRA but no follow-up work undertaken (Porter, 1980a)(Fig 1.9)(no details seen).

Nelson Prospect: 4km NW of Balfour, centred on E321000 N5431500, is the Nelson magnetic anomaly that coincides with Cassiterite Creek Quartzite (Prbq). This anomaly occurs immediately west of the Nelson-Airfield EM anomaly and is in an area considered prospective for stratabound basemetals. The anomaly appears to be truncated in the SE by the Roger River Fault.

Copper mineralisation: CRA interpreted a range of magnetic images and noted that Murrays Reward, South Balfour, and Development copper prospects are located in breaks of the magnetics, or lie east of a pyrrhotite-bearing siltstone in bland magnetics (Parkinson, 1993). Magnetic highs associated with basalt (Tertiary?) plugs are present, eg Balfour township. He suggested that targets exist where the pyrrhotitic siltstone is disrupted by faults and has low magnetic response at the end of high-zones.

Specimen Hill and extensions to the south: The linear magnetic anomaly that passes through Specimen Hill, 700m west of Balfour. The anomaly transgresses stratigraphic boundaries and appears to be somewhat structurally related to the major fault that cuts the Specimen Hill anticline (Fig 3.5, Balfour 1:25,000). In CRA drill hole DD82BC7, at the north end of Specimen Hill, pyrrhotite was intersected (Turner, 1994) but it remains uncertain that this fully explains the magnetic anomaly. BHP postulated a concealed massive sulphide source. This anomaly with associated Sn-W bearing quartz veins warrants continued investigation of near surface open-pit resources. Magnetic highs may reflect higher concentrations of pyrrhotite and possibly higher Sn-W.

The magnetic anomaly extends further south and is mapped as a thrust fault between Looneys Flat Siltstone (east) and the Skinners Flat Siltstone (west)(Balfour 1:25,000).

Southern EL 4/2002*:* In the southern part of the Balfour Copper Belt, on EL 4/2002 the copper workings appear to be coincident with an aeromagnetic high of 50-200nT and a topographic low, in sheared slate between prominent quartzite ridges (Fig 1.9).

Figure 1.6 shows a number of isolated magnetic highs (unexplained) and cross trends due to basic dykes occupying WNW cross faults or dilational zones.

Overall, the Specimen Hill magnetic anomaly can be traced to the south through most of EL 4/2002 and can be regarded as the most dominant semi-continuous feature on the tenement. It has been mapped as a major thrust fault and may be an influencing structure on major mineralisation in the district.

Radiometrics

AGSO/MRT have digital radiometric data available. CRA flew detailed radiometrics in 1993 and examined processed images; they divided the area into domains West & Central- coincident with the Rocky Cape Group, and the NE domain- over the Cambrian Smithton Trough (Parkinson, 1993). In general, the sandier units of the Balfour Subgroup are less radioactive than the silty units and there appears to be a tenuous correlation between the copper trend and high total, K and Th count; this may relate to the presence of sericite (Rajagopalan, 1996, in Menpes, 1996). Some weak K and Th response coincide with gravel pits, costeans/workings and tracks indicating the bedrock response is supressed by soil/lag gravels, and vegetation. However, Murrays Reward Cu, the Clump prospect, and Specimen Hill do not show anomalous radiometrics (Parkinson, 1993).

Specific radiometric targets identified by CRA (Parkinson, 1993) are:-

- NW EL 18/92 (no coordinate given), presumably to the NW of NCR's EL4/2002, elevated K, Th, cuts across magnetic stratigraphy, max response associated with the Frankland River may be reflecting a major alteration zone
- North of Balfour, a NNW line of Th-(K) anomalies and coincident magnetics, displaced 2.5km along Roger River Fault
- Development prospect, 1km halo of weak radiometric response surrounding a central elevated core (E322 700, N54 32 500) coincident with cut lines.
- Clump Prospect has elevated response
- Smith Creek, 9.5km SSE of Balfour, has headwaters with K-Th-(U) response that cuts across topography near a land slide.

These targets do not appear to have been further investigated.

MRT reviewed the radiometrics on the Dempster-(Sumac-Roger River) sheets (Everard et al in press). The total count image predominantly reflects rock type, but physiographic, vegetation and cultural effects are also present. The unit most consistently associated with areas of high total counts is the Cowrie Siltstone (Prc), reflecting its pelitic character (high K and presumably Th and U).

North and NW of Balfour, the Balfour Subgroup has a locally strong but very variable radiometric signature. A radiometric high near 331100mE 5435700mN (Dempster sheet) suggests an inlier of Rocky Cape Group, but no field evidence for this was found in this area of poor exposure and low dense vegetation.

Siliceous units such as the Lagoon River Quartzite (Dempster sheet) also give low to very low total counts. Tracts of Neoproterozoic basalt (Spinks Creek Volcanics) also have low values, although slightly higher than the Black River Dolomite.

The large area of Tertiary basalt on the Dempster sheet is characterized by intermediate to low total counts, slightly but appreciably higher than Neoproterozoic basalt, reflecting its more alkalic and potassic character.

Tertiary siliceous gravels (unit Tsgs), where developed on Smithton Dolomite and other Togari Group lithologies, give very low total counts (e.g. Salmon River area). Where they rest on the Cowrie Siltstone, notably in the southwest of the Sumac sheet, their radiometric signature is very variable, suggesting the presence of a locally derived pelitic component.

The signature of Quaternary alluvium (Qha) is also very variable. Alluvial flats along the Arthur River have areas of high total counts, suggesting the dominance of pelitic Rocky Cape Group derived material.

Gravity

Gravity coverage in most of the area is regional, with 5 to 8 km station spacing with more detailed (about 1km station spacing) in the west, extreme south and parts of the east of Dempster sheet, mainly in areas of road access and/or open country. Regional gravity data (about 1 km station spacing) was completed by Soloriens Mining. In addition, Soloriens Mining Pty Ltd, commissioned MRT to survey the Balfour and Clump Prospects on 50-100m spaced lines (Bob Richardson MRT operations report) with data corrected and interpreted by Leaman (1992,in Morrisson 1993). Contoured Bouger data is included herein (Figs 3.3, 3.4). This data has been included in the Tasmanian State Gravity database (Bob Richardson pers comm).

The western Tasmanian crust is thickened (Rawlinson et al 2001) and may contain further underlying Mid-Proterozoic sequences and Proterozoic granites.

BHP's Specimen Hill ground gravity survey, in 1994, using a Canadian Gravity Meter 141; gravity readings were corrected for free-air, Bouger, latitude, drift and terrain effects (but terrain corrections were uncertain); no significant conclusions were drawn (Taylor, 1964). This showed an E-W break near N54 29 700, that corresponds with a break in the magnetics (Leaman, 1992). At the Murrays Reward/Balfour survey (Figure 3.3) E-W “faults” were noted at N54 29 500, and N54 29 760, and a NW-trend through E324 500 N54 29 750.

A small positive Bouger anomaly (1m gal), was located near the southern workings, at E324 600, N5429 500, on the east side of a magnetic anomaly, near the intersection of ENE, NW and N-S structural trends (Leaman, Nov 1992)(Fig 3.3). The anomaly straddles the boundary with ML 1M/76, Laan and Langsford. The anomaly on line 4, 100m east of Murrays Reward, was reviewed by CRA for potential to reflect a discrete mineralised body but CRA decided that it was an "odd" high-frequency affect perhaps due to levelling/elevation errors of +-1m expected from lack of base station barometric control (Rajagopalan, 1996 in Menpes, 1996). However, this is clearly only surmise and the anomaly remains a valid target for further investigation; CRA specified a gravity follow-up programme. A high was noted over Specimen Hill where Sn-W has been drilled.

To the north of Balfour, north of the Roger River Fault and west of the Balfour Fault, a gravity anomaly was highlighted by Pacific Nevada near of the intersection of the Roger River Fault and the Balfour Shear; it occurs over basalt and volcaniclastics, (Newnham, 1998, Westbrook, 1999)(The data source and location of this is not known to NCR).

MRT reviewed the gravity data (Everard et al in press). The Smithton Synclinorium (Trough) is clearly evident on the coloured image as a region of positive residual Bouguer anomaly, corresponding to the relatively dense carbonate and mafic rocks of the Togari Group (Fig 1.5). The southwest margin of this positive area runs parallel to and slightly west of the Frankland River on the Dempster sheet. *This is well to the* *west of the limit of outcropping Togari Group rocks, but consistent with their presence at depth, overthrust by the Rocky Cape Group (see cross-section Fig 1.7).*

The area of slight negative residual Bouguer anomaly near the southern margin of Dempster sheet extends southwest to Sandy Cape and southward to the lower Pieman River. There is some suggestion of a narrow NNW-trending trough, roughly coincident with the "Balfour Copper Trend", and which has been attributed to a spine of Devonian granite (Leaman, 1988; Leaman & Richardson, 1992). The gravity survey by Soloriens Mining suggested a probable northerly extension of the Pieman Granite, at a depth of less than 1km, to the Balfour area. Known copper mineralization was thought to lie at the intersections of magnetic and air photo linears in a NNW- to NW-trending corridor, and to be probably associated with gravity highs.

Comment: Gravity surveys have been spasmodically undertaken in the Balfour district and several anomalies are ineffectively explained. A systematic, preferably airborne survey of EL4/2002, would test the potential for a concealed excess mass body at depth. A more in-depth review is warranted.

Electrical IP geophysical surveys

Leaman (1992) reviewed small surveys at the Clump, Murrays Reward, and the Block as reported by Bell and Hallof (1967) McIntyre (1971), CRA (1979), Flis & McKay (1980), and Dickson (1983).

IP surveys were conducted systematically by ACI (McPhar Geophysics, 1970) over 12km of strike. CRA-reconstructed profiles to show *a major conductor* extending the full length of the Clump grid (Menpes, 1995). A *similar response* was obtained 4km south of the Clump at Cassiterite Creek and in Hudson Syndicate (1967) and CRA IP data west of Specimen Hill (Fig 3.6, 3.8). A strong IP response is coincident with Murrays Reward mineralisation and a weak to strong response south of the main mineralisation reflects the extension south of the Specimen Hill response (Fig 3.7). The IP response appears to correspond to lithological contacts, at the Clump- carbonaceous to chloritic siltstone; and at Cassiterite Creek/Specimen Hill to sandstone to carbonaceous siltstone (Menpes, 1965) that are copper anomalous.

Conductivity measurements were below background from DD97BC9 on the Murrays Rewards splay fault (Fig 5.2), even in the most mineralised zones. Nevertheless, the mineralisation at Murrays' Reward closely follows the trend of the main I.P. anomaly (Russell and Tear, 1997).

The western conductor at Specimen Hill has not been drill tested (Menpes, 1995). Induced polarization (IP) anomalies were considered by CRA to coincide with Sn-Zn anomalies near the contact between quartzite and green chloritic shale (Flis and Mackay, 1980).

Comment: IP surveys of variable quality, commonly affected by wet weather conditions, show significant response over the Balfour Copper lodes. Other IP responses occur coincident with anomalous geochemistry, especially at Peters Ridge SE of Specimen Hill. These areas have been little drilled and warrant more work.

EM surveys

MRT completed a major EM survey of the Balfour area in 2002 that covered the entire area of EL4/2002. Prior to this, CRA reported flying a small DIGHEM survey at Balfour, but neither specifications, data nor maps have been sighted. CRA has plotted DIGHEM conductors to the immediate west of the Specimen Hill that do not appear to have been tested by drilling (Fig 1.2, 3.6, 3.8) and it is apparent that this conductor has been detected by the MRT 2002 survey and is herein called the Skinners Flat EM conductor.

Prior to the MRT 2002 survey, Pacific Nevada undertook an airborne magnetic and EM survey over the Roger River area (Westbrook, 1999) and this survey covered the NE part of NCR's EL4/2002. The survey did not extend south onto the Balfour Sheet; the digital data is not available to NCR and has been superceded by the MRT survey.

NCR purchased a licensed digital copy of the MRT airborne 2002 EM-magnetic data and used ER mapper and Mapinfo to review images generated for various EM filter frequencies. Files delivered on CD ROM for the Balfour survey are as follows (cp-coplanar, cx-coaxial):-

Dtm, 7,800kb, DTM.ers 8kb
Tmi, 7,800kb, TMI.ers, 8kb
Log_cp34k_AResistINV, 3,780kb; Log_cp34k_AResistINV.ers
Log_cp6k_AResistINV, 3,780kb
Log_cp880_AResistINV, 3,780kb
Log_cx7k_AResistINV
Log_cx980_AResistINV

An image of the apparent conductivity data, generated by NCR, using the low frequency 880 co-planar set, is shown as Figure 1.10. BHP-Billiton kindly processed considerable data and generated a hardcopy set of A4 colour pseudo-cross sections gridded by depth layers for many of the flight lines. These are not included with this report and are being assessed. The University of Tasmania commenced in the summer of 2003 local moving loop ground EM surveys at several sites on EL 4/2002; data has not been reported to NCR.

The regional EM survey has highlighted the presence of the most intense EM conductors being somewhat restricted to the northern part of EL 4/2002, mainly north of N54 26 000 and east of E324 000. This makes the Balfour Subgroup "special" in the area extending from Balfour to the Clump prospect. ***This is also where most mineralisation occurs on EL 4/2002 and where it is considered most likely that a major Cu-Zn-Pb deposit will be discovered.***

The challenge, of course, is to identify within the strike-extensive conductive response, specific conductors that correlate with geochemical anomalies and known mineralisation and might, in turn reflect, economic copper or zinc mineralisation. The carbonaceous and often pyritic nature of certain packages of the sedimentary rocks is known. Such "reduced" sequences are commonly good host rocks to some of the world's major stratabound zinc-lead-copper deposits. An initial screen of the data has enabled a selection of responses that warrant further investigation, and these are noted below and in the body of the report. More analysis of the EM data is planned.

(As a passing note, it is somewhat puzzling that the copper deposits with known graphite are apparently not EM responsive eg at Murrays Reward and indeed most of the small copper occurrences appear to associated with airborne EM resistive response.)

In a regional context, the EM survey has shown conductivity of significance in only a few main areas across the entire survey. Three of these occur in EL 4/2002:-

- EL 4/2002 is traversed in the northern sector by a NW-trend belt of conductive response that runs roughly parallel to the NW-trend of the Balfour Copper Belt but is offset roughly 1km to the west (Fig 1.10). The conductive trend, while broadly parallel to regional lithology trends, are quite discordant in detail. The trend appears to be largely confined to the Balfour Sub-group rocks, in particular quartzitic formations. The potentially important Skinners Flat EM conductor is within this trend.
- The Clump conductor, that is located to the immediate south of the old Clump copper prospect (that itself has a weak EM conductive response)
- EL 4/2002 is impinged by the NW extremity of the Frankland River-Mt Frankland regional EM anomaly (see below).
- The NW trend of the old Balfour copper workings is largely coincident with an EM response reflecting relatively resisitive rocks, except at the Clump prospect.

In an unpublished table provided to NCR in 2003, Dr Hungerford, of Hungerford Geophysical Consultants, Melbourne defined several conductor targets in the MRT EM data. The selected targets are as follows:-

EM FLIGHT LINE	Name	easting	northing	EM	Mag	Comments	Intensity (PJ Legge)
10170	Clump copper prospect	321547	5437000	buried	shallow	Cu prospect	weak
10211	Clump EM target	321700	5436200	shallow	deep	1km S of the Clump copper prospect	strong
10431	Nelson Bay R-Cassiterite Ck EM target	322140	5431800	shallow		E-edge of the Nelson EM anomaly. Cassiterite Ck Quatzite	very strong
10481	NNW Specimen Hill EM	322700	5430800	shallow			Moderate
10541	Airfield EM anomaly, south end	322580	5429600	shallow		On Heemskirk Link road, Lagoon Quartzite	Very strong
10621	Area A EM feature	324020	5428000	shallow	buried 220m?	Old shafts with high grade basemetals	strong
10691	EM	324160	5426605	shallow	adjacent to trend	Far NW of CRA Gap Prospect	Very strong
10723	EM	324195	5426000	shallow	shallow	Far W of CRA Gap prospect	strong
10751	Waratah EM	328290	5425400	shallow	shallow	About 1km east of Waratah copper sulphide	Strong, isolated
10551	State Forest EM	326515	5429400	shallow		Mt Frankland-Frankland River, State Forest	Very strong

These targets represent specific selections within larger EM conductive zones, and are not an exhaustive list. The locations of EM conductors in relation to other exploration data are discussed throughout the report and other targets can be generated form the data.

Specific EM features discussed in the report herein are as follows:-

Skinners Flat-Area A EM target: see Zinc-Lead-Copper prospects in this report.

Clump EM target: see Zinc-Lead-Copper prospects in this report

Waratah east EM target: This EM response is an isolated conductor in the eastern part EL 4/2002, at E328290 N5425400 along Waratah Creek, about 1km ENE of the an undocumented? Prospect, further up Waratah Creek, where copper sulphide has been noted. The Cowrie Sandstone is not otherwise conductive and the conductor appears to be discrete. A major NW-trend thrust fault traverses the area nearby (Balfour 1:25,000).

Gap West EM targets: The southern extension of the Skinners Flat-Area A EM-anomaly contains two EM targets about 1.5km SE of the topographic feature Mt Balfour (436m). These target EM features are of high intensity. CRA ran preliminary exploration at their Gap Prospect, mailny to the east of the EM, over a break in the aeromagnetics trend. The Gap West EM target has not been previously explored and there is no known supporting geochemistry. However, 1km to the south gossans occur on old ML 302, in pits/shafts.

Nelson-Airfield EM target: see Zinc-Lead-Copper prospects in this report. The northern part of the Nelson-Airfield EM feature coincides with the Roger River Fault, complexly faulted Balfour Sub-group rocks and also alkaline dykes (Dempster 1:25,000). The most prominent anomalies are over quartzite, mainly the Cassiterite Ck Quartzite (Prbq) but also the Lagoon Quartzite (Prl), along the Roger River and adjacent complex faults. The association of conductors with quartzite either reflects carbonaceous horizons or ore-mineral conductors or both.

NNW Specimen Hill Conductor: A somewhat isolated conductor, and moderate strength, occurs at just to the east of the Balfour airfield, flanking the western side of a strong magnetic anomaly (on the southern border of the Dempster Sheet) (Fig 1.2, 1.8, 3.6). This untested anomaly requires investigation. CRA drill hole DDH BC7 (also called C7) tested the magnetic anomaly lying parallel to the east. Hence the hole was collared, and drilled, to the east of the target EM feature (Fig 3.6a). This EM feature probably continues south to become the stronger EM anomaly flanking the western side of the Specimen Hill magnetic anomaly, known herein as the Skinners Flat EM anomaly.

State Forest Conductor: A strike extensive conductor occurs in the far east of EL 4/2002 at E325 700 N54 32 200. The anomaly within EL 4/2002 occurs at the NW extremity of the large, NW-trend, Frankland River-Mt Frankland EM anomaly located just east of the E 326 000 EL boundary (Figs 1.2, 1.8, 1.10); there is no associated magnetic anomaly. The Frankland River has been mapped (using a raft) across the anomaly and MRT reports what is fairly typical laminated carbonaceous sediments, of the Cowrie Siltstone Correlate, in an area of subdued relief (Everard et al, in press)(Dempster 1:25,000). It can be speculated that the cause is formational but the anomaly should not be dismissed and may follow a mineralised thrust in the area; it remains unexplained. It is a target specific herein.

ORE GENESIS

Fluid Inclusions

A fluid inclusion study was undertaken by MRT on quartz from nine prospects- Waratah, Balfour South, Murray's Reward, Premier, Balfour Block, Clump, Couta, Specimen Hill, Strickland, and along the tin-copper belt and in the Temma area. Also, two quartz samples from barren quartz veins from Temma Farm and south west of the Clump prospect were assessed **(**Taheri, in press**)**.

Only a few samples contain workable fluid inclusions and only rare, smaller fluid inclusions (<5 μm), particularly those occurring immediately adjacent to small patches of sulfides, have been protected from the effects of tectonic deformation. In general, fluid inclusions in quartz from both the copper prospects along the Balfour belt and the Temma area are dominantly two phase (liquid H_2O and vapour) inclusions, and rarely contained CO_2+ CH_4 in addition to water.

This fluid inclusion study, has shown:-

- hydrothermal fluids responsible for the formation of quartz, in the copper deposits throughout the copper belt, appear to be of low salinity and are possibly of metamorphic origin.
- CO_2 + CH_4 bearing fluid inclusions are rare and were only observed in quartz from the Specimen Hill tin-tungsten prospect.
- Homogenisation temperatures vary considerably within different deposits.
- Temperatures and fluid compositions obtained from fluid inclusions do not show any correlations with the estimated depths of the interpreted underlying granite. *Therefore the fluid inclusions and geophysical data are inconsistent with a granitic origin for the fluids responsible for copper mineralisation along the Copper Belt and in the Temma area.* For example, at Balfour South and Waratah prospects, the granite surface is at depth of only about 1 to 2km and yet the primary-looking fluid inclusions in quartz show very low homogenisation temperatures of around 200°C. The Clump is, however, positioned nearly 9 km above the surface of the underlying granite, but the fluid inclusions have high homogenisation temperatures of up to 400°C. Similar high temperature fluid inclusions are found in the Temma area (Strickland and Couta prospects) where the top of the granite is inferred to lie at depths of more than 9 km (Leaman, 1988).
- There is a general increase in the homogenisation temperatures of the fluid inclusions from south to north along the Copper Belt.
- A pulse(s) of hydrothermal fluid of low salinity, during deformation, at higher temperature than the original temperature of formation of the quartz, is indicated by secondary fluid inclusions with homogenisation temperatures exceeding primary inclusions (eg. Clump prospect).
- Fluid inclusions found in quartz from the Specimen Hill Sn-W deposit are larger and have much higher homogenisation temperatures than those found in nearby copper deposits (eg. Murray's Reward). The quartz is also less deformed in the Specimen Hill area. The quartz-cassiterite and/ or wolframite veins used for the fluid inclusion study, contain quartz and tin-tungsten minerals paragenetically belonging to the same stage of formation. Taheri (in press) notes that at *Specimen*

Hill, the fluid inclusions are of high temperatures, and of low salinity. This is in contrast to fluid inclusions found in most other Sn-W deposits in Tasmania, which are characterised by high temperature, and high salinity fluid (eg. Patterson, et al, 1981, Taheri, 1986, Halley, 1982, Collins, 1981). Despite the limited data, the distribution of fluid inclusions, and their behaviour upon heating, Specimen Hill samples may be explained by fluid immiscibility in the CO_2-H_2O system . The criteria used for this interpretation are:

(a) Variability in vapour-liquid ratios and possibly water-CO_2 ratios.
(b) Co-existence of CO_2- free (or poor) and CO_2-rich fluid inclusions in the same grain,
(c) Homogenisation of fluid inclusions to liquid or vapour

If this is the case, then no fluid inclusions were found that could be related to the parent (magmatic) fluids from which the CO_2-H_2O immiscible fluid has been derived. However, in some Eastern Australian deposits, tin mineralisation has been shown to be associated with the low salinity fluid exsolved from a more saline parent magmatic fluid. In Tasmania, this is also the case at the Lakeside deposit (Taheri and Green, 1990).

- Fluid inclusions from barren quartz veins are of low temperatures and low salinities. They are similar to fluid inclusions found in quartz veins along the copper belt and in the Temma area.

Oxygen Isotopes

Twelve quartz samples from copper and tin-tungsten prospects and one from a barren quartz vein located southwest of the Clump prospect were analysed for oxygen isotope by MRT (Taheri, in press). In general, the oxygen isotope values exhibit a narrow range of 12.3 to 14.5‰.

Although the oxygen isotopes of the *quartz* are similar for most of the deposits along the copper belt, the calculated isotopic compositions of *water* in equilibrium with quartz are vastly different for different prospects varying from –0.1 to 8.1‰. This is mainly due to the wide variations observed in the homogenisation temperatures of the fluid inclusions in quartz samples from different prospects. If the minimum and maximum temperatures are considered for each sample, then the oxygen isotope composition of water could vary up to 11‰ between different prospects.

A magmatic-dominated source is indicated from the oxygen isotope compositions of water in equilibrium with quartz from Specimen Hill (Taylor, 1979). This is expected, considering the hydrothermal alteration mineralogy (see mineralisation section for details) and the geophysically-predicted occurrence of an underlying granite at shallow depth (Leaman, 1988) in the area (Fig 2.6).

Oxygen isotope compositions of water in equilibrium with quartz along the copper belt are low and similar to each other in the southern half of the belt, but they are mostly higher in the northern half of the belt. This resulted from the general increase in the formation temperatures of quartz associated with copper mineralisation towards the northern half of the belt. The oxygen isotope values of water in equilibrium with quartz from the Blocks prospect are, surprisingly, very similar to those obtained from the granite-related Specimen Hill prospect even though there is no evidence of granite-related mineralisation or alteration assemblages. Also, based on the gravity interpretation of Leaman (1988) the underlying granite surface is at a depth of around 9km in this area.

Oxygen isotope data, along with the ore mineralogy, the compositions and temperature of ore-bearing fluids and also the available gravity data strongly suggest various metamorphic fluids of different temperatures and probably different compositions are responsible for the formation of copper deposits along the belt. The deposits have probably formed from sporadic introduction of different ore-bearing fluids into long active pre-existing fluid conduits (faults, thrusts and shear zones) during various stages of deformation/ tectonic activity. The data is also consistent with involvement of isotopically shifted meteoric water.

Sulfur Isotopes

MRT collected twenty-three sulfide samples including pyrite, chalcopyrite, arsenopyrite and galena for sulfur isotope analysis from 12 prospects along the copper belt covering some 35 km **(**Taheri in press) (Fig 2.6). A few sulphides were also analysed from the Temma area. Yaxley (1981) and Veska (1993) also analysed some sulfide samples from the Specimen Hill (Sn, W) and Murray's Reward (Cu) prospects.

In general, the sulfur isotope values are fairly uniform throughout the copper belt over 35 km. The sulfides from the Sn-W deposits have lower sulfur isotope values than those from Cu areas. The few sulfur isotope results from the Temma area also indicate a marked similarity with those obtained along the copper belt. The sulfur isotope values in sulfides from Sn-W deposits range from 7.4 to 15.2‰ with majority between 12 to 15‰, whereas those from the Cu prospects have values between 20 to 23‰. The exceptions are two relatively low values from the Clump and Toner River of 13.7 and 14.8‰ respectively. Veska (1993) has also reported an unusually low value of 1.5‰ from the Clump prospect.

The tin-tungsten deposits and associated quartz + sulfides ± muscovite ± tourmaline in the Specimen Hill area are indicative of a genetic link to underlying granite. A NNW-trending granite spine, as part of the Pieman Granite, shallowly underlies (~2 km) the southern to central parts of the copper belt (Leaman, 1988, Leaman and Richarson, 1992). Most of the Sn-W prospects occur where the granite surface is inferred to be deeper (~ 4 to 6 km). Murray's Reward and other nearby copper prospects occur in a similar position relative to the depth of the granite surface. There are also some copper deposits to the south, including the Balfour South, where the granite ridge is only 2 km below the surface. To the north, copper prospects lie more than 9 km above the granite surface.

In summary, the positions of the copper deposits relative to the underlying granite vary from less than 2km to the south to greater 9km to the north. The sulfur isotope values from the sulfides along the belt, however, are relatively consistent and distinctly different from those of the Sn-W deposits. The high and consistent sulfur isotope values of pyrite from the copper deposits (up to 23.4‰) may represent the original (or very close to) sulfur isotope compositions of sedimentary pyrite from which the sulfur isotope compositions of chalcopyrite has been derived.

The sulfur isotope values from the Sn-W deposits are in general high for granitic fluids. ($\delta^{34}S$ igneous sulfur = 0 ± 5‰, Omoto, 1986). The high values may indicate partial leaching and/or remobilisation of heavy sedimentary sulfides in the formation of sulfides in the Sn-W deposits. High sulfur isotope values up to 15‰, have also been reported by Taheri (1986) from Sweeney's mine, Western Tasmania. The Devonian Heemskirk Granite hosts the Sweeney's tin mine and the high sulfur isotope values were interpreted to have been derived by the circulation of hydrothermal fluids through Pre-Cambrian rocks overlying the granite with high sulfur isotope values.

Comment: The very high sulfur isotope values from the copper deposits strongly indicate that igneous sulfur has had very little input in the sulfur isotope composition of the sulphide along the copper belt and in the Temma area. This, along with the fact that they are isotopically heavier than those from the tin-tungsten deposits supports the possible derivation of sulfides in the copper deposits and the Temma area from a pre-existing stratiform deposit at depth.

Pb-isotopes (CSIRO)

In the absence of galena-rich samples, 7 covellite/pyrite-rich quartz samples from ***Murrays Reward*** were used by CSIRO (Carr and Dean, Jun 91, in Morrisson, 1992) to study lead isotopes. Results indicate that the lead in pyrite and galena have a common source for both the copper and tin-tungsten deposits. The likely radiogenic contribution was determined from U and Th analyses (U 0.2-1.2%, Th 0.4-5.67%, U/Th 2.6-5.0%). It was considered that the *source* rocks were enriched in thorium, because 208Pb is enriched in the samples, and, normally, is derived from the decay of Th.

CSIRO also studied the ***Balfour*** Prospect (probably the Sn-W, Specimen Hill prospect?) (Dean, 1992 in Morrisson). Six samples were used to extract galena and pyrite; Pb is considered to be high. Although the proximity and typical metal association suggesting a genetic link with the underlying and supposed Devonian granite, and samples were expected to yield unequivocal Devonian results (206Pb/204Pb>18.4), the 208Pb/204Pb ratios are high, in turn suggesting high Th/U ratios in the source rocks. This is considered to be reflecting metamorphosed Proterozoic crust.

Isotope ratio age conclusions were indefinite because of the uniqueness of the results relative to other Tasmanian data:-

- Most likely: Cambrian, similar ratios of 206Pb/204Pb to Mt Read Volcanic, Cambrian VHMS deposits for both Murrays Reward and Balfour (Specimen Hill).
- Intermediate likelihood: Proterozoic, little evidence of U-enrichment, ratios represent initial ratios.
- Least likely: Devonian, no direct evidence from Pb isotopes (Carr and Dean Oct 92). Geological and geophysical evidence and the high thorium content for both types of the mineralisation are considered, then a possible source is a Devonian granite carrying lead remobilised from older (Precambrian) rocks (Veska, 1993), all of which point to local remobilisation from a Proterozoic original ore source.

In a surprising finding, CSIRO felt that both the mineralisation from Murrays Reward, and Balfour (Specimen Hill) were probably derived from the same hydrothermal event. The Pb was probably derived from metamorphosed basement with high Th/U and probably low U/Pb. It is possible that the Devonian Pieman Granite is an immediate source of the Pb. If true then the K-feldspar in the granite should have a similar Pb-isotope signature to the Murrays Reward/Specimen Hill mineralisation and this can be tested (Dean, 1992).

The Pb isotope composition of pyrite from the Murrays Reward copper deposit at Balfour was initially thought to be most consistent with a Cambrian age for this mineralization (Carr and Dean, in Morrison, 1991b). Later, similar work on pyrite and galena from Sn-W mineralisation at the nearby Tatlows prospect (E324400 N5429300), presumably related to Devonian granite, showed lower and less variable $^{206}Pb/^{204}Pb$ ratios (Dean, in Morrison, 1992). However this data plots on the same linear trends as for the copper mineralisation, suggesting that both types of mineralization were produced by the same, presumably Devonian, hydrothermal event. Both have higher $^{208}Pb/^{204}/Pb$ and lower $^{207}Pb/^{204}Pb$ than typical Cambrian mineralization in western Tasmania, suggesting high Th/U lower crustal high-grade metamorphic rocks were the ultimate source of the lead. However, $^{206}Pb/^{204}Pb$ is lower than in typical western Tasmanian Devonian mineralization (e.g. at Queen Hill). It was suggested that this Pb isotope signature should also be present in the Interview Granite (Dean, ibid).

Mineralisation models

Copper

The possible origins suggested for the mineralisation vary from stratabound redox, metamorphic to granite-related models. In general, the modelled, underlying and concealed granite, assumed to be an extension of the Devonian Pieman Granite, has been taken to be a principal factor in the formation of Sn-W and/or perhaps remobilisation of the Cu deposits along the belt but doubt remains.

The copper deposits show the following features (Taheri, in press):-

- mineralogy is simple (pyrite, chalcopyrite ± quartz ± carbonate ± chlorite), and lacks the typical low pH, low fO_2 magmatic hydrothermal mineral assemblages associated with tin-tungsten deposits (eg. tourmaline, muscovite, topaz, arsenopyrite).

- copper mineral assemblages are consistent throughout the 35 km long copper belt. despite the fact that the depth of the underlying granite can vary from around one kilometre (eg. South Balfour area) to greater than nine kilometres (eg. Toner River, The Clump).

- presence of early pyrite (clasts) with high (sedimentary) sulfur isotope values in cupriferous zones.

- sulfur isotope values of sulfides throughout the copper belt are similar but are characteristically higher than those observed from the tin-tungsten deposits within the area.

- fluid inclusions in quartz from the Specimen Hill Sn-W prospect have higher temperatures (up to 400° C) than those are found in nearby copper deposits such as the Murray's Reward and Waratah (homogenisation temperatures of around 200° C).

- copper mineralisation along the belt is characterised by concentrations of Cu and Fe, with traces of Ni and Co; the elevated content of cobalt and nickel is also a characteristic feature of the stratiform copper deposits (eg. Zambian Copper Belt). The Balfour Copper Belt deposits are generally low in other metals such as As, Zn, Pb, Sn and W. This is distinctly different to the tin-tungsten deposits where the mineralised sections are high in As, Zn, Pb, Fe, Cu, Sn, and W with traces of Bi being common, but is characteristically free from Co and Ni.

Models considered by explorers include:-

***Synsedimentary copper**:* ACI Limited (Jackaman, 1974, McIntyre, 1974) suggested that the pyrite and chalcopyrite were formed by diagenetic and microbiochemical sulfidation of syngenetic, syn-sedimentary iron hydroxides and oxides and cupriferous material. Later tectonism mobilised and concentrated some of the disseminated chalcopyrite along the shear zones as quartz-carbonate-sulfide veinlets.

CRA (Parkinson, 1994; Menpes, 1995) considered the Balfour Copper Belt to be prospective for concealed stratiform/stratabound copper deposits and identified specific lithological contacts prospective for sediment-hosted copper deposits. Some sedimentological and structural features (e.g. redox fronts, growth faults) of the Proterozoic sequences suggest that there is potential for larger tonnage, lower grade stratiform/Mt Isa style copper and/or Sedex-style Pb-Zn deposits. A model of copper solutions migrating from the Lagoon River Quartzite into the overlying Balfour Sub-group pyrrhotite-bearing siltstone and replacing iron to leave chlorite/hematite and low magnetic character was theorised by CRA.

The sediment-hosted copper model was intensively explored by CRA. They suggested that major structures such as an inferred WNW-trending faults in the Murray's Reward area (Balfour Transform), and the NNE-trending Roger River fault were controls on ore focus. Evidence for the Balfour Transform seems to be equivocal although some WNW dykes occupy cross-faults.

CRA (Parkinson, 1994, Tear, 1996) identified two sedimentary boundaries between oxidising and reducing sedimentary rocks, that could be favourable for the formation of stratiform copper deposits.

Stratiform target 1: The first contact is between the Lagoon River Quartzite and the overlying carbonaceous siltstone of the Balfour Subgroup. The contact is marked by a strongly magnetic siltstone unit extending some 60km.

Stratiform target 2: The second contact occurs between the carbonaceous and pyritic siltstone and chloritic siltstone, with a strike length of 8 km, between Murray's Reward and The Clump. East of The Clump prospect are pyrite-rich, chloritic rocks with anomalous Cu-Au values, to 1,100 ppm Cu and 0.034 ppm Au (E322 700 N54 35 900) as reported by Turner (1995).

Hypothermal: CRA/Rio Tinto (Tear and Russell, 1997) proposed that the combination of basalt-derived copper, and granite-driven hydrothermal fluids, was capable of producing a large-scale bulk-mineable copper orebody at the intersection of the NNW Balfour Shear and cross-faults such as the CRA Balfour Transform. Steep shoots, as at Murrays Reward were envisaged to be sourced from reservoir bodies that constituted potential world class targets, but exploration was stopped during a time of corporate rationalisation.

***Balfour subgroup as Cu, Fe source rocks*:** Copper-anomalous, sedimentary pyrite-rich, carbonaceous slate and siltstone, within the Balfour Subgroup, may represent a low-grade, stratiform copper deposit; parts of this sequence have pyrrhotite and are magnetic. This represents a possible source of sulfur and copper for the fault-related copper deposits along the belt.

Spinks Basalt-thrust target: A potentially important source of copper is the Spinks Creek Volcanics, of the Togari Group which are generally anomalous in copper, with up to 600 ppm (Everard et al., in press). The volcanics are younger than the Cowrie Siltstone and the Balfour Subgroup (Rocky Cape Group) which host the mineralisation. Geological and geophysical evidence (Everard, et al, in press), suggest the Rocky Cape Group has been thrust over the younger sedimentary rocks and basalts of the Togari Group (Fig 1.7). If, during thrusting, the cupiferous basalts were metamorphosed and hydrothermally leached, solutions could rise along the thrust and associated back-thrust faults and concentrate copper at receptive chemical and structural sites. Such an origin appears to be consistent with the metamorphic nature of the copper deposits.

Magnetic target for ironstone related copper: The Temma district about 20 km to the west also contains some copper deposits, mostly distinct to those at Balfour. Studies (geological, geochemistry, mineralogy, fluid inclusions and stable isotopes) show some similarities (oxygen and sulfur isotopes, and fluid inclusion results) between these deposits and the copper deposits occurring along the Balfour Copper Belt. A related origin for the formation of these deposits is suggested.

The broad spatial association between some linear magnetic trends and copper deposits in the Balfour area may indicate that cupriferous magnetite-bearing bodies underlie and may have been the main sources for the Balfour copper deposits. These may represent large, mineralised (magnetite and/or pyrrhotite-rich) sedimentary or epigenetic deposits from which later, structurally-controlled copper deposits have been derived through remobilisation of the original copper and fluid focusing into active dilatant structures.

World class models: Sediment-hosted copper deposits are the second most important sources of copper worldwide after porphyry copper deposits. They are characterised by lateral continuity and consistent grades; these make them very attractive exploration targets.

Sediment-hosted copper deposits are represented by deposits of giant sizes such as the Late Proterozoic copper belt of Central Africa, White Pine in America, and Permian Kupferschiefer in north-central Europe. The pre-mining reserves and resources for the Central African Belt have been estimated to be around 4.9×10^9 t at 3.4% copper (Freeman, 1986). The sediment-hosted copper deposits may contain Co of economic significance (occurs in the Balfour copper deposits) and also they may also contain minor quantities of gold, uranium, platinum-group and rare earth elements (Kucha, 1982).

A post-sedimentary (diagenetic) genetic model for the formation of sediment-hosted deposits is widely accepted (e.g. Brown). The host rocks do not have to be related to a single favourable sedimentary environment, because the introduction of copper postdates the formation of host rocks. They must, however, be able to precipitate the introduced copper and other metals by having a reductant, typically carbonaceous matter and having pre-ore stage pyrite, or sulfate such as gypsum and anhydrite that can be reduced and form sulfide, possibly by reaction with brine fluids (Brown, 1997). In this model, reduced rocks become mineralised by ascending aqueous brines leaching copper while passing through the redbed and reaching the redox horizon (carbonaceous, pyritic strata) where the brine can precipitate metals mainly in the form of sulfides. At the White Pine sediment-hosted copper deposit, however, there is also a later, economically significant copper mineralisation which is structurally controlled (Mauk, 1993).

The associated sequences are commonly redbed sedimentary rocks and sometimes volcanics. The carbonaceous (reduced) host rocks overly oxidised (redbed) sedimentary rocks, a situation identical with that found in the Rocky Cape Group of Balfour. Carbonaceous and pyritic shales are common within the Cowrie Siltstone and parts of the Balfour Subgroup of the Rocky Cape Group and also within the Black River Dolomite of the Togari Group. Evaporitic environments are indicated by the presence of some possible anhydrite casts, formed during the deposition of the Cowrie Siltstone (J. Everard, pers. comm.). Although the redbeds are considered to be the main immediate sources of copper for most sediment-hosted copper deposits, other sources of copper such as deep metamorphic fluids or magmatic fluids have been suggested (eg. Annels, 1984).

Tin & tungsten

There are probably direct links between the formation of the Balfour tin and tungsten deposits and a shallowly underlying granite (2-4 km, Leaman, 1988). Evidence includes

(i) the occurrence of greisens in the Tatlows prospect (Yaxley, 1981),

(ii) the close association of cassiterite and wolframite with possibly granite-related hydrothermal minerals such as tourmaline, muscovite, pyrrhotite, and arsenopyrite, and

(iii) anomalous bismuth and arsenic. Similar hydrothermal alteration and mineral assemblages are also associated with other Devonian granite-related tin-tungsten deposits in Tasmania (Taheri, 1985; eg. Collins, 1981; Patterson, 1979).

Potential for Renison-style tin, and King Island style tungsten, exists in the Togari Group, related to an inferred underlying Devonian granite and sulphidic sediments, but this idea has not been explored.

It is noted elsewhere, that in the 1980's a drill hole west of Renison intersected two zones of Cu-W-Sn skarns. The upper skarn had a low sulphide content while the lower skarn contained pyrrhotite and chalcopyrite in veins, disseminations, stringers and semi-massive bands with tin-bearing granite at depth. It is possible that this is a Devonian W-Sn overprint of a stratabound copper mineralisation zone and may have similarities with the Balfour area. This model for exploration has not been applied before to the Balfour area.

Conclusions: The above observations strongly suggest that the copper deposits have been formed under different conditions to the tin-tungsten deposits.

The overall features of the copper mineralisation, especially the simple mineralogy and the high concentration of chalcopyrite, located mainly in faults and shear zones, suggest that the copper deposits have been derived from pre-existing low grade copper deposits at a deeper level. A regionally extensive hydrothermal system where the ore-bearing fluids, of possibly metamorphic driven origin, has remobilised copper from a prexisting copper deposit.

In contrast, the granite-related tin-tungsten deposits are mainly restricted to the Specimen Hill area. The contrast between the two types of deposits, despite close proximity in the Balfour area, suggests that they are the products of different but repeated hydrothermal mineralising events, Such repeated mineralising events is likely to have enhanced the probability of a world class deposit forming in the area

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APPENDIX

Ore Deposit Descriptions and Models

Savage River Iron Ore

Resource: about 150Mt, 46% Fe_2O_3, strike length 3km, depth at least 100m below pit base, thickness of sub-vertical sheet is about 100m. Magnetite-silicate-sulphide ores are associated with greenschist-metamorphosed mafic, serpentinite, and carbonate near the eastern boundary of the upper part of the Western Succession. Ore are of rhythmically layered magnetite and pyrite, minor chalcopyrite and trace sphalerite, ilmenite and rutile in a gangue of tremolite, actinolite, dolomite, quartz, antigorite and chlorite.

King Island Scheelite

The basement Proterozoic sequence comprises a +6,000m thick western sequence of quartzite, and quartz mica schist, overlain by a +7,000m thick eastern sequence of predominantly pelitic rocks. The Cape Wickham Granite is dated as 727+-23Ma. Samples from SW King Island, outside of the metamorphic aureole of the Cape Wickham granite are dated at 1,224-1,258Ma (Holm et al, 2001). The Proterozoic sequences are overlain by the Late Proterozoic Grassy Group +-200m thick, of dolomitic siltstone, shale and tillite. This sequence is intruded by Devonian granites and hosts the world class King Island Scheelite deposit, last mined by North Limited prior to closure and flooding in the early 1990s'. The overall resource at the deposit, mined and remaining, is some 11Mt, 0.7% WO_3.

Central African Copper Belt

In Zambia, the copper deposits are hosted by late Proterozoic Lower Roan Group sediments, a shelf sequence that laps-onto the basement. Many of the deposits are in "ore-shale", the first dolomitic argillite above basal clastics (similar to the Balfour Copper Belt). The underlying sandstone is a shore facies whereas the siltstones are more off-shore with algal bioherms on local palaeo-highs. At Nchanga the deposits are developed over 150m of stratigraphy in a range of rock types. At Mufilira, 21 mineralised beds of feldspathic quartzite and carbonaceous rocks extend over 70m of stratigraphy. The main ores are bornite, chalcopyrite, and carrollite. Locally, the deposits also yield Pb, Zn, Bi, Mo, Se, Re, U, Au PGM.

Size is large:-

Zambian deposit	Mt	Cu %	Other
Nchanga	800	2.8	Co, Ag
Nkana	560	2.6	Co, Ag
Konkola	525	3.2	Ag
Mufilira	335	3.3	Ag

The deposits are not restricted to one rock type and are discordant on map scale. The mineralisation is disseminated, and replaces pyrite, evaporite, organic material etc. This is potentially similar to Balfour. The source of copper is seen as first cycle red-beds with 40ppm Cu or mafic volcanics with 100ppm Cu. Early alteration releases copper, leaches silicates, converts magnetite to amorphous ferric oxide (to give the red colour).

The Western Tasmania Minerals Programme

The Western Tasmanian Minerals Province represents one of the most mineral rich areas of the Australian continent. The adjacent Bass and Sorell Basins are prospective for oil and gas. The Commonwealth Government established the Regional Minerals Program to facilitate regional development in mining and minerals processing. The Western Tasmanian Regional Minerals Program forms part of this program and is a tripartite agreement between the Commonwealth and Tasmanian Governments and the Minerals Industry. The program covers the areas of western and northern

Tasmania as far east as the River Tamar including the offshore Bass and Sorell Basins. The aims of the Western Tasmanian Regional Minerals Program are to: propose a regional development plan for up to 15 years, to identify the infrastructure needed to support an expanded industrial base in Tasmania; make existing mining and mineral processing operations more cost effective by recommending solutions to common problems such as infrastructure and energy limitations; to lower development cost of new projects; to determine what remote sensing and ground data is needed to facilitate exploration for minerals, oil and gas; and to recommend actions and priorities to industry and governments to implement the plan, including a broad timetable.

The project was coordinated by Mineral Resources Tasmania (MRT) in conjunction with a Management Committee consisting of representatives from the mineral industry in Tasmania, Tasmanian Minerals Council, Mineral Resources Tasmania and the Commonwealth Department of Industry Science and Resources. The project team has prepared two reports, the Regional Development Plan and the Guide for Industry Development. These reports summarize the current status of infrastructure development in the region (current to October 1999), recommends a series of actions to set the Minerals Industry on a strong footing for the next 15 years, and presents contact information from whom the prospective developer can obtain further information. The reports will be particularly useful tools for international and interstate developers who are unfamiliar with Tasmania and its infrastructure, data availability and the current approval process for new developments.