BILLITON AUSTRALIA
THE METALS DIVISION OF
THE SHELL COMPANY OF AUSTRALIA LIMITED

REPORT ON WORK COMPLETED SPRING HILL JOINT VENTURE
FOR THE PERIOD 1st JANUARY, 1991 to 31st DECEMBER, 1990
AND APPLICATIONS FOR RENEWAL OF MINERAL LEASES NORTH 801 & 802

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DATE: DECEMBER, 1990
SUMMARY

Mining Leases North 801 and 802 were granted on the 1st January, 1971 and expire on the 31st December, 1990. They are located near the northern apex of the Spring Hill ridge which is located approximately 27 km north northwest (NNW) of the Pine Creek Township.

In September, 1988 MLN's 801 and 802 were purchased from Territory Resources by Ross Mining NL as part of a large tenement package covering the Spring Hill gold workings. Subsequently the Spring Hill Joint Venture Agreement was signed by Ross Mining and The Shell Company of Australia Limited with the latter being manager and operator. The joint venture took effect from 1st October, 1988.

This report details the work conducted and results gained during the period 1st January 1971 to 31st December, 1990. Details of work completed prior to the Spring Hill Joint Venture are generally poorly documented and hence much of the reporting of earlier work may lack some details and specifics.

Work completed by Territory Resources from 1985 to 1988 included gridding, mapping, costeasing, and a low altitude multispectral scanning survey. Work completed over the tenements by the Spring Hill Joint Venture partners from October, 1988 to the present time includes gridding, mapping/rockchip sampling, soil sampling, ground magnetics, induced polarisation (IP) techniques, TEM survey, reverse circulation and diamond drilling, preliminary metallurgical work, and petrological studies.

Exploration activities have detected significant potential tonnages of moderate to low grade gold mineralisation (Hong Kong sheeted veining) in MLN 801 and surrounding tenements. MLN 802 lies in a strategic position if this mineralisation is to be exploited.

Proposed work for the initial 5 years of the renewal period is likely to involve:-
(i) infill drilling on the Hong Kong sheeted veining.
(ii) metallurgical testwork and mining studies on any potential resource.
(iii) if favourable economic parameters are reached it is likely mining will take place within this five year period.
CONTENTS

SUMMARY

1.0 INTRODUCTION

2.0 LOCATION AND ACCESS

3.0 REGIONAL GEOLOGICAL SETTING & MINERALISATION

4.0 MINING HISTORY

5.0 WORK COMPLETED AND RESULTS
5.1 Territory Resources
5.2 Spring Hill Joint Venture

5.2.1 Gridding
5.2.2 Grid mapping/Rock chip Sampling - MLN 802
5.2.3 Grid mapping/Rock chip Sampling - MLN 801

5.3 Soil Sampling

6.0 ENVIRONMENTAL CONSIDERATIONS
# List of Figures

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Title</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>MCN &amp; MLN Tenements</td>
<td>1:25 000</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Summary Plan</td>
<td>1:25 000</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Grid Summary Plan</td>
<td></td>
</tr>
<tr>
<td>Figure 4</td>
<td>Geological Fact Map - MLN 802</td>
<td>1:1 000</td>
</tr>
<tr>
<td>Figure 5</td>
<td>&quot;                        &quot; - MLN 801</td>
<td>1:1 000</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Rockchip Geochemistry - MLN 802</td>
<td>1:1 000</td>
</tr>
<tr>
<td>Figure 7</td>
<td>&quot;                        &quot; - MLN 801</td>
<td>1:1 000</td>
</tr>
<tr>
<td>Figure 8</td>
<td>MCN &amp; MLN Tenements - Gridded Area</td>
<td>1:10 000</td>
</tr>
<tr>
<td>Figure 9</td>
<td>BCL Au Soil Contours</td>
<td>1:10 000</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Ground Magnetic Data (A)</td>
<td>1:1 000</td>
</tr>
<tr>
<td>Figure 11</td>
<td>&quot;                        &quot; (B)</td>
<td>1:1 000</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Apparent Resistivity</td>
<td>1:5 000</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Total Chargeability</td>
<td>1:5 000</td>
</tr>
<tr>
<td>Figure 14</td>
<td>50m Dipole Dipole IP PseudoSection (10100N)</td>
<td>1:5 000</td>
</tr>
<tr>
<td>Figure 15</td>
<td>TEM Response Profile - Line 9700N</td>
<td></td>
</tr>
<tr>
<td>Figure 16</td>
<td>&quot;                        &quot; - Line 9900N</td>
<td>1:5 000</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Composite Geophysical Plan - Line 10100N</td>
<td>1:5 000</td>
</tr>
<tr>
<td>Figure 18</td>
<td>TEM Response Profile - Line 10300N</td>
<td></td>
</tr>
<tr>
<td>Figure 19</td>
<td>&quot;                        &quot; - Line 10500N</td>
<td></td>
</tr>
<tr>
<td>Figure 20</td>
<td>Geophysics Summary Plan</td>
<td>1:5 000</td>
</tr>
<tr>
<td>Figure 21</td>
<td>Drillsection Line 9725N</td>
<td>1:500</td>
</tr>
<tr>
<td>Figure 22</td>
<td>&quot;                        &quot; 9750N</td>
<td>1:500</td>
</tr>
<tr>
<td>Figure 23</td>
<td>&quot;                        &quot; 9800N</td>
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</tr>
<tr>
<td>Figure 24</td>
<td>&quot;                        &quot; 9850N</td>
<td>1:500</td>
</tr>
<tr>
<td>Figure 25</td>
<td>&quot;                        &quot; 9900N</td>
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</tr>
<tr>
<td>Figure 26</td>
<td>&quot;                        &quot; 9925N</td>
<td>1:500</td>
</tr>
<tr>
<td>Figure 27</td>
<td>&quot;                        &quot; 10000N</td>
<td>1:500</td>
</tr>
</tbody>
</table>

# Appendices

Appendix 1: Preliminary Metallurgical Testwork Report

Appendix 2: Petrographic Notes on 21 samples from the Spring Hill Prospect.
1.0 INTRODUCTION

Mining Leases North 801 and 802 were granted on the 1st January, 1971 and expire on the 31st December, 1990.

In September 1988 these tenements were purchased from Territory Resources by Ross Mining NL as part of a large tenement package covering the Spring Hill gold workings.

Subsequently the Spring Hill Joint Venture Agreement was signed by Ross Mining and The Shell Company of Australia Limited with the latter being manager and operator. The joint venture took effect from 1st October, 1988 (Figure 1).

This report details the work conducted and results gained during the period 1st January 1971 to 31st December, 1990. Details of work completed prior to the Spring Hill Joint Venture are generally poorly documented and hence much of the reporting of earlier work may lack some details and specifics.

2.0 LOCATION AND ACCESS

Mineral Leases North (MLN's) 801 and 802 lie near the northern apex of the main Spring Hill ridge and occur just north and southwest of the main zone of abandoned gold workings. The Spring Hill ridge is a very prominent and steep topographic ridge which trends north northwest and lies approximately 27 km north northwest (NNW) of the Pine Creek township.

Access is via the Stuart Highway to the sign-posted Spring Hill Road turnoff some 20 kilometres (km) north of Pine Creek. The sign marks the Old Stuart Highway which is followed for approximately 100 metres before turning left onto the gravelled Spring Hill Road which is generally well maintained with recently constructed concrete crossings making access possible except during periods of extremely high rainfall. Spring Hill Road meets the Mt Wells Road some 11 kilometres from the Stuart Highway. Turn left onto the Mt Wells Road then left onto a four wheel drive track 2 km from the Spring Hill Road intersection. This track allows access to
the eastern flank of Spring Hill and hence to the top of the ridge via NW trending spur.

3.0 REGIONAL GEOLOGICAL SETTING & MINERALISATION

The tenements lie near the northern apex of the Pine Creek Embayment. This is a south south east trending fold belt composed of Lower Proterozoic sediments and volcanics which remain as a pendant on the intrusive Cullen Batholith. A broad, SSE zone of shear deformation - the Pine Creek Shear - extends from Pine Creek in the south and passes immediately east of the Spring Hill area. The Pine Creek Shear Zone has been a major locus for the passage of gold bearing fluids and hosts the majority of gold occurrences in the Pine Creek Geosyncline.

The geology of the Spring Hill area is summarised in Figure 2.

At Spring Hill there is a general younging trend to the south due to the gentle southerly plunge to a series of tight to isoclinal synclines and anticlines. The oldest rocks of the area being the shales (commonly carbonaceous) and cherts of the Koolpin Formation. These are overlain by a series of volcanoclastic sediments and tuffs known as the Gerowie Tuff which in turn underlies the Mt Bonnie Formation, a suite of generally immature siltstones and greywackes with rare tuffs and cherts. Unconformably overlying the Mt Bonnie Formation is a thick sequence of shales, siltstones with lesser greywacke and rare conglomerates known as the Burrell Creek Formation.

The Spring Hill gold workings near MLN’s 801 and 802 are hosted by siltstones and shales near the base of the Mt Bonnie Formation. Gerowie Tuff crops out some 100 metres north of the main workings within MLN 802 and defines the outline of a tight, southerly plunging anticline which can be traced for at least 8 km to the NNW where it is truncated by the Prices Creek Granite.

The gold mineralisation of the Main or Western Lode lies on the flank of a parasitic anticline within the Spring Hill anticline. The gold is associated with steep westerly dipping gossan-quartz veins within highly
cleaved shales and siltstones. The veins parallel the axial plane cleavage and cut bedding at a low angle suggesting a strong structural control on the vein directions.

The Middle Lode consists of saddle reef style quartz/sulphide mineralisation and lies near the hinge of an inferred parasitic anticline.

The Eastern Lode lies in the core of a parasitic, southerly plunging anticline some 70 metres east of the Middle Lode. The gold is associated with 2-10cm wide, discontinuous, tightly folded, lensoidal quartz-limonite veins hosted by fine grained sandstones and laminated ferruginous siltstones. All three lodes plunge to the south, paralelling the axial plunge of the anticline and do not continue into the Gerowie Tuff to the north (Figure 3).

4.0 MINING HISTORY

The Spring Hill Gold mine was one of the largest mines in the region last century. Total recorded gold production from Spring Hill amounts to 21,170 ounces (680.7 kg). Most of this was recovered between 1882 and 1885 from oxidised ores on the Main Lode which were extracted from a 109 metre shaft. From 1886 up to 1905 limited shallow mining was continued by Chinese tributers.

In 1933 Spring Hill Gold Mining Company commenced driving an adit from the eastern side of Spring Hill at a level some 120 metres below the surface exposure of the Main Lode. By 1938 funds had been exhausted and the adit had only progressed 300 metres, well short of the Main Lode. However the East and Middle Lodes were intersected at 204 metres and 290 metres respectively.

In 1948 the Northern Territory Prospecting and Development Company extended the tunnel to 427 metres and reached the Main Lode. The company carried out limited development and sampling work on the East Lode where they reported an average assay of 40.98 g/t Au over an average 0.61 metre width
in 24 metres length of drive. These results were presented in a prospectus for the float of Spring Hill Gold NL which claimed that 31,000 tonnes of ore containing in excess of one ounce (31.1g) of gold per tonne was available on the Eastern Lode above the adit level. Spring Hill Gold NL set up a ten head stamp battery and carried out limited mining of the East Lode. Ore crushings were severely limited by a lack of water. Recorded production during the period 1950-1966 was 20.2 kg of gold from ore averaging 18.6 g/t Au.

The mine was briefly re-opened in 1965-66; there has been no mining since that time.

5.0 WORK COMPLETED AND RESULTS

There is no record of exploration or mining activities within MLN 801 and 802 from the 1st January, 1971 until 1985. From this time till September 1988 exploration was conducted by Territory Resources. From the commencement of the Spring Hill Joint Venture (1st October, 1988) exploration activities have been managed by Billiton Australia, The Metals Division of The Shell Company of Australia Limited on behalf of the J.V. partners.

5.1 Territory Resources

During 1985 a literature review of the Spring Hill Gold Mine was conducted by consultant geologist Geoff Orridge. Of this work little referred to the area covered by MLN 801 and 802. It seems that little work was carried out in the past on the two tenements and this is evidenced by the few old workings that can be found. The only old workings include several small pits and trenches. The great majority of old workings at Spring Hill are confined to MLN 779 and MLN 800 which cover the Main and Middle Lodes.

Work completed by Territory resources over the two tenements from 1985-1988 including gridding, mapping and costeaming.
In 1985 Territory Resources established a detailed grid over the top of Spring Hill, mainly confined to the Eastern, Middle and Main lodes, however extending into both MLN 801 & 802. Mapping of the grid was completed in the same field season. This mapping was confined mainly to delineating the old workings, access tracks, and fold axes. Little information on the geology was recorded except for several strike and dip readings of bedding and cleavage. A number of rockchip samples were collected from old workings however these were confined mainly to the Main Lode, Middle Lode and East Lode. No rockchip samples seem to have been collected within MLN's 801 and 802.

During the 1986 field season further mapping and costeaming were completed in MLN 802. Some 200m of costeaming in 5 costeans were excavated in MLN 802. These costeans seem to have been targeted at several of bedding parallel veins within silicified mudstones of the Gerowie Tuff. It is not certain these costeans were sampled as no results have been located. Further mapping in MLN 802 was concentrated in these costeans and consisting mainly of recording a number of bedding and cleavage orientations in the attempt to more accurately locate fold axes locations (Figure 4).

During this time the emphasis of Territory Resources work at Spring Hill was at the East Lode (outside MCN's 801 & 802) in the attempt to prove up an open pittable gold resource. This work included detailed mapping, rockchip sampling, costeaming and drilling (Figure 3).

In May 1987 the Spring Hill area was covered by a low altitude multispectral scanning survey conducted by Geo-Flite Research Pty Ltd. The Geo-Flite method was aimed primarily at detecting alteration associated with mineralisation.

A number of "potentially mineralised" targets were identified in the Spring Hill area but no significant follow-up was completed. No plans from this survey have as yet been located.
5.2 Spring Hill Joint Venture

From the inception of the Spring Hill Joint Venture a very substantial exploration programme has been conducted within the J.V. area, including MLN's 801 and 802.

5.2.1 Gridding

A detailed grid using a 25 metre line spacing over MLN 801 and a 50 metre line spacing over MLN 802 was erected. This has been used as a control for detailed geological mapping, soil sampling, and ground magnetic surveying (Figures 4 & 5).

5.2.2 Grid mapping/Rockchip Sampling - MLN 802

Geological mapping in MLN 802 encountered rocks of both the Gerowie Tuff and the Mount Bonnie Formation. Rocks of the Gerowie Tuff occupy the eastern half of tenement and consist of interbedded silicified mudstone, siltstone and sandstone. These rocks typically strike at 310° and dip at 70° to the west. A strong axial plane cleavage is developed, especially in the finer grained rock types on this orientation. A thick moderately silicified unit (15m) forms the uppermost unit within the Gerowie Tuff. This sandstone commonly contains intense gash or sheeted veining. Lesser bedding parallel veining can be found throughout the rocks of the Gerowie Tuff. One of these bedding parallel veins, known as the West Lode or West Quartz Blow runs along the contact between the Gerowie Tuff and Mt Bonnie Formation and has been worked in the past (Figure 4).

Overlying the Gerowie Tuff, possibly unconformably, are the highly interbedded immature rock units of the Mt Bonnie Formation in the western half of MCN 802. These highly interbedded units consist of shale with minor chert bands, siltstone and sandstone/greywacke. These units trend in a similar orientation to those of the Gerowie Tuff i.e. strike 310° and dip 70° west.

Some sheeted veining can be found in coarser grained siltstone-sandstone beds. "Stones eggs" or ex-carbonate concretions are common to sandstone beds.
Rockchip sampling in MLN 802 has been limited. The best results obtained were grab samples of 0.24 g/t Au from some sheeted veining within a thin sandstone unit in the Mt Bonnie Formation and 0.67 g/t Au from bedding parallel buck quartz lode known as the West Quartz Blow (Figure 6).

5.2.3 Grid Mapping/Rockchip sampling – MLN 801

Geological mapping in MLN 801 was completed over 25m spaced grid lines. The tenements lie totally within the Mt Bonnie Formation and rocks consist of highly interbedded immature beds of shale with minor chert, siltstone and sandstone. These beds commonly strike at 310° (magnetic) and dip 70° west (Figure 5).

A strong axial plane cleavage developed especially in the fine grained shale units. "Stones eggs" of ex-carbonate concretions that have been replaced by silica are common to the sandstone beds.

A large intense sheeted quartz/limonite vein system was discovered during the mapping. This veining is at a high angle to stratigraphy trending between 015° and 020° (magnetic) and dipping 50-60° to the east. Vein densities in these zones vary from 5 to 10 veins/metre and vein thicknesses average between 1 and 5cm. The systems are concentrated within more massive sandstone beds and commonly "die out" or "diffract" to form veins parallelising cleavage on passing into shaly units. The veins have formed as open space fillings, inferring they occur in zones of dilation. The vein system is known as the Hong Kong vein system. The system extends through the length of MLN 801 (some 240m) and is confined mainly to three adjacent sandstone units, thicknesses of which vary from 10 to 20m (Figure 5). Free gold is visible and some old reports indicate veins grading up to 30 oz/ton Au being removed from the old Hong Kong workings which mainly lie just south of MLN 857, however extend inside its southern boundary. The only other old workings in MLN 801 lie in its northeast corner and consist of an old shaft and limited scratchings on some high grade sheeted veins. Old alluvial workings can be found in the creeks which runs through the centre of the MLN.
Rockchip sampling on the sheeted veining in MLN 801 was encouraging with the best results listed below:

Channel Rockchip samples - 10m @ 7.95, 5m @ 1.05, 15m @ 0.48, 25m @ 0.48, 28m @ 0.92 and 30m @ 1.75 g/t Au.

Grab Rockchip samples - 17.5, 7.60, 16.9, 12.2, 9.5, 6.8, 5.2, 1.4, 1.02, and 1.34 g/t Au

(Figure 7).

5.3 Soil Sampling

Two phases of soil sampling have been completed at Spring Hill, the first consisting of 2 kg Bulk Cyanide Leach (BCL) samples and the second consisting of 500g bottle roll BCL samples.

MLN 802 was sampled with 2 kg BCL samples. Samples were collected over 5 metres along grid lines with 5 samples (covering a nominal width of 25 metres) composited into one 2 kg sample. Sampling was completed on 50 metre line spacings and despatched to Australian Assay Laboratories in Townsville for gold analysis using the Bulk Cyanide Leach method. Results of the soil sampling were generally low in gold. Some spiky higher results were thought to be related to contamination of soils by past mining activity. Samples were also assayed for silver, lead, zinc, copper, arsenic and tin all of which returned relatively low results (Figures 3 & 9).

MLN 801 was initially sampled with 2 kg BCL samples on 50m line spacings. Results of this sampling highlighted a zone of anomalous gold values corresponding to the Hong Kong sheeted veining. To obtain more detailed representation of the anomaly the area was then resampled with 500 g BCL samples on a 25m line spacing. Soil samples were collected every 5 metres along lines with 5 samples (covering a nominal width of 25 metres) composited into one 500g sample, which was despatched to Classic Comlabs in Darwin for gold analysis using the
bottleroll BCL method. Gold results obtained from the 500g bottleroll samples were up to one order of magnitude higher than those received from the 2kg BCL samples, particularly in highly anomalous areas.

The 500g sample results outlined a strong gold anomaly (>64 ppb Au, Figures 3 & 9) trending 020° corresponding closely to the sheeted vein systems within MLN 801. The highest result obtained in this anomalous zone was 846 ppb Au.

5.4 Geophysical Techniques
5.4.1 Magnetics
Detailed ground magnetic surveying on 50m grid lines using a 5 metre station spacing confirmed regional airborne magnetic data with a totally flat response over MLN’s 801 & 802 (Figures 10 & 11).

5.4.2 Induced Polarisation (I.P.) Techniques
Both Gradient Array and Dipole-Dipole IP techniques have been utilised at Spring Hill. Results of the work over MLN 801 & 802 were in general negative with no distinct targets being delineated. Background chargeability values of 10-20 mv/v were obtained. A high resistivity zone (granite?) was located adjacent to the Hong Kong sheeted vein system in MLN 801 (See Figures 12, 13 & 14).

5.4.3 TEM Survey
In early August 1990, a fixed loop Sirotum survey was completed at Spring Hill including the areas covered by MLN’s 801 and 802. Standard times and Z component were measured along 200 metre spaced lines.

No electromagnetic conductors were detected within MLN’s 801 and 802 (Figures 15 to 20).
5.5 Drilling

To date eleven (11) reverse circulation percussion drill holes and one (1) HQ diamond drill hole have been completed in MLN 801 (Figure 5), to test the zones of gold bearing sheeted veining. No drilling has been sited within MLN 802.

Reverse circulation holes SHRC 009, 10, 12, 13, 14, 16, 17, 18, 36 and 46 were completed during June and October, 1989 by Civil Resources using a track mounted CD350 rig with a 4.5 inch hammer. Approximately 2 kg of sample was collected (split twice through a riffle splitter) and sent to Classic Laboratories in Darwin for 50g charge fire assay. Reverse circulation hole SHRC 061 and diamond hole SHDH 001 were completed during June, 1990 by Gaden Drilling using a track mounted UDR 650 rig. The HQ diamond core was split in half using a diamond saw, one half being despatched for analysis. Samples were again sent to Classic Laboratories in Darwin for 50g charge fire assay. The remaining 75% of each reverse circulation sample and the remaining 1/2 drill core are presently stored on site at Spring Hill.

Results of this drilling are summarised in Table 1.

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<tr>
<td>SHRC 009</td>
<td>7m @ 22.1 g/t Au</td>
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<td></td>
<td>24m @ 1.8 g/t Au</td>
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<tr>
<td></td>
<td>including 4m @ 4.3 g/t Au</td>
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<tr>
<td>SHRC 010</td>
<td>13m @ 1.6 g/t Au</td>
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<tr>
<td>SHRC 012</td>
<td>No significant intercept</td>
</tr>
<tr>
<td>SHRC 013</td>
<td>22m @ 1.1 g/t Au</td>
</tr>
<tr>
<td>SHRC 014</td>
<td>16m @ 1.6 g/t Au</td>
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</tr>
<tr>
<td>-------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>SHRC 016</td>
<td>No significant intercept</td>
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<tr>
<td>SHRC 017</td>
<td>No significant intercept</td>
</tr>
<tr>
<td>SHRC 018</td>
<td>No significant intercept</td>
</tr>
<tr>
<td>SHRC 036</td>
<td>11m @ 3.3 g/t Au (2-13m) or 11m @ 2.5 g/t Au (cut to 10 g/t Au)</td>
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<tr>
<td>SHRC 046</td>
<td>5m @ 3.4 g/t Au (49-55m)</td>
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<tr>
<td>SHRC 061</td>
<td>4m @ 2.06 g/t Au (43-47m)</td>
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<tr>
<td>SHDH 001</td>
<td>30m @ 1.82 g/t Au including 7m @ 2.1 g/t Au and 10m @ 2.7 g/t Au (67-96m)</td>
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The results of the drilling suggest that the Hong Kong gold mineralisation is mainly restricted to two parallel zones of sheeted quartz-limonite veining. These zones trend from 350 to 000° (magnetic) and dip from 45° to 60° to the east. Sheeted veining within these zones consistently trends at 020° (magnetic) and dips 55° to the southeast. At present the mineralised zones have a strike extent of 250m through MLN 801 and are open to the north and south.

Gold bearing veining occurs in both shale and sandstone (greywacke) units however seems to be concentrated within sandstone.

Of the two mineralised zones the hanging wall zone or westerly most zone is wider and of higher grade. True widths range from 10 to 20m and a best intercept of 11m @ 3.3 g/t Au was received. The footwall or
easterly zone has true widths ranging from 5 to 8m and a best intercept of 7m @ 2.1 g/t Au.

5.6 Metallurgy
In September 1989, NORMET undertook preliminary metallurgical testwork on Hong Kong RC composite samples (see Appendix 1). Duplicate bottle roll tests on "as received" material gave recoveries of 50 and 68% Au. However there was a problem in obtaining consistent assay results for the residues because of the occurrence of coarse, spotty gold in the sample. A residue size analysis gave more consistent back calculated residue grades of 0.26 and 0.27 g/t Au. Using these values together with the calculated head of the composite would give nearly 80% extraction. Cyanide consumption was low at 0.17 Kg/tonne. The samples were fairly fine, being the product of RC drilling.

In April 1990 two bulk samples of Hong Kong sheeted vein material collected by an excavator were sent to Normet in Perth for column leach testing however the head grades of the samples sent were too low upon assaying (i.e. <0.2 g/t Au) for the testwork to continue. Two samples of quarter core from SHDH 001 (Hong Kong) were collected and despatched to Amdel in Adelaide for column leach testwork in October, 1990. The results of this work are awaited.

5.7 Petrology
A selection of petrological samples from Spring Hill, including several from MLN 801 were despatched to D. England in Townsville in July 1990 for description. England offered a number of comments regarding the Spring Hill gold mineralisation, i.e.:
- the vein systems clearly post-date the cleavage(s)
- the sulphide most commonly associated with gold is arsenopyrite.
- abundance of CO₂-rich fluid inclusions in gold-quartz veins suggest general association of gold with CO₂ bearing fluids.

A copy of England's report is included as Appendix 2.
6.0 ENVIRONMENTAL CONSIDERATIONS

The Spring Hill ridge is extremely steep and hence is very susceptible to erosion and other environmental damage. To prevent unnecessary disturbance the Spring Hill Joint Venture partners have taken the following steps:

1. Utilising existing tracks where possible and encouraging staff to proceed on foot rather than drive in steep terrain.

2. A small, mobile track mounted drilling rig has been utilised to markedly decrease the access preparation/bulldozing required, particularly with regard to drilling pads, prior to each programme. For example, the CD350 rig requires a pad of only 5 metres square to operate adequately whereas conventional truck mounted rigs require pads of at least 20 x 7 metres.

3. All access tracks follow the topographic contours as closely as possible and adequate drainage is provided for run-off during the wet season.

4. All sample bags are UV resistant and have been removed to a central sample farm for safe storage.

5. All rubbish is taken from the camp and drill sites to a waste disposal site to prevent build-up of waste products.

6. All drill holes have been capped.

7. If exploration is deemed completed within a certain part of Spring Hill due to negative results rehabilitation works are initiated. This work includes ripping of drill pads/access tracks and seeding, securing of steep (easily erodible) drill pads with organimattting and seeding, and creation of adequate drainage. To date this work has been completed on some eight drill pads outside MLN's 801 and 802.

The Shell Company of Australia has a pro-active environmental policy and makes every effort to ensure damage caused to the environment by exploration activities is minimised and rehabilitated where practical.
7.0 PROPOSED FUTURE WORK

Exploration activities within the Spring Hill Joint Venture, in MLN 801 and surrounding tenements have identified significant potential tonnages of moderate to low grade gold mineralisation. Additional drilling and metallurgical testwork is currently being planned with a view to defining a viable gold resource at Spring Hill. To this end the significant gold intercepts received from the drilling within MLN 801 indicate that this mineralisation will form a significant component of any exploitable resource. MLN 802 lies on the eastern margin of this Hong Kong gold resource meaning that portions would certainly be included in any pit used for mining.

Proposed work for the initial 5 years of the renewal period is likely to involve:-

(1) infill drilling on the Hong Kong Sheeted Veining to more accurately define its extent and its depositional controls. This drilling would probably occur in both MLN 801 and MLN 802.

(2) metallurgical testwork and mining studies on any potential resource.

(3) if favourable economic parameters are reached it is likely mining will take place within this five year period.
APPENDIX 1

REPORT ON

PRELIMINARY METALLURGICAL TESTWORK

ON

ORE FROM SPRINGHILL

Complete Metallurgy Services for Miners
Mr Mike Battersby of Billiton Australia requested Normet Pty Ltd to conduct preliminary metallurgical testwork on an R.C. chip sample from Springhill. The testwork included cyanide bottle rolls and size analyses. The results are summarised as follows:

<table>
<thead>
<tr>
<th>Sample</th>
<th>NaCN kg/t</th>
<th>Lime</th>
<th>Head, Au g/t</th>
<th>Tail Au g/t</th>
<th>% Au Ext</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.16</td>
<td>1.25</td>
<td>1.80</td>
<td>2.19</td>
<td>1.09</td>
</tr>
<tr>
<td>2</td>
<td>0.17</td>
<td>1.25</td>
<td>1.80</td>
<td>1.45</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Leach feed and residue size analyses indicated that the majority of gold was leached from the finer fractions (-300 micron) and higher recoveries could be attainable by grinding the ore to a finer size. Despite this results were encouraging for the possibility of heap leaching.
TABLE OF CONTENTS

1 INTRODUCTION

2 SAMPLE

3 SAMPLE PREPARATION

4 TESTWORK PROCEDURE
   4.1 Cyanidation
   4.2 Screen Fire Assays
   4.3 Size Analyses

5 RESULTS

6 DISCUSSION
   6.1 Cyanidation
   6.2 Screen Fire Assays
   6.3 Size Analyses

TABLE 1 Sample Description
TABLE 2 Duplicate Cyanide Leach 1
TABLE 3 Duplicate Cyanide Leach 2
TABLE 4 Screen Fire Assay Results
TABLE 5 Duplicate Feed Size Analyses 1
TABLE 6 Duplicate Feed Size Analyses 2
TABLE 7 Size Analyses of Leach Residue 1
TABLE 8 Size Analyses of Leach Residue 2
TABLE 9 Size by Size Recovery for Cyanide Leach Tests
1 INTRODUCTION

Mr Mike Batterby of Billiton Australia requested Normet Pty Ltd to conduct preliminary metallurgical testwork on an R.C. chip sample from Springhill. The testwork included duplicate cyanide bottle rolls and as a result of the 'spotty' residue assays size analyses were conducted on the 'as received' material and the bottle roll residues. Also, screen fire assays were conducted on samples of 'as received' material.

2 SAMPLE

Mr Ken Hellsten of Billiton Australia submitted an ore and water sample from Springhill to Normet on 22 August 1989. A 200 L sample of site water was contained in a 44 gallon drum. The ore sample was contained in three plastic bags and had a total weight of approximately 80 kg. The ore was described as "a composite sample of mineralised drill chips from several holes, all from within a zone of weathering (max depth 70 m)". A sample description is given in Table 1.

3 SAMPLE PREPARATION

The contents of the three plastic bags were thoroughly mixed and allowed to air dry. A riffle was then used to split out several representative samples for the testwork.

4 TESTWORK PROCEDURE

4.1 Cyanidation

Two x 4 kg samples of 'as received' material were bottle rolled (in duplicate) with cyanide for 48 hours under the following conditions:

- 50% solids (in site water)
- Cyanide maintained above 0.04%
- pH maintained above 10 (using lime)
- Dissolved oxygen (DO) monitored

The pH, % cyanide and dissolved oxygen were monitored at 2, 4, 8, 24 and 48 hours. The pH was maintained above 10 using metallurgical lime (containing 63% CaO). Solution samples were also taken at the monitoring times and these were assayed for gold content.
At the completion of the tests the residues were filtered, washed, dried and a riffle split portion fire assayed to determine gold content. Due to large differences in the residue assays a second portion of each of the residues were submitted for fire assay. These results indicated that the sample was 'spotty' with respect to gold distribution and this was later confirmed by the Billiton geologists working in the Springhill region. As a result of these assays further work was conducted which included screen fire assaying and size analyses on 'as received' and leach residue samples.

4.2 Screen Fire Assays

Five representative samples of 'as received' material were subjected to screen fire assay. Each of the samples were first screened using a 106 micron screen. The size fractions were then weighed and fire assayed to determine gold content.

4.3 Size Analyses

The weights of two representative samples of 'as received' (leach feed) material and the remainder of both of the cyanide leach residues were recorded. Each of these samples were then wet screened on a 75 micron sieve. Both plus and minus 75 micron fractions were filtered and dried. The plus 75 micron fractions were dry screened using 3350, 1180, 600, 300, and 150 micron sieves. Each of the size fractions were weighed and then fire assayed for gold.

5 RESULTS

Bottle roll results are given in Tables 2 and 3.
Screen fire assay results are given in Table 4.
Size analyses results are given in Tables 5 to 8.
Size by size recovery for the leach tests is given in Table 9.
6 DISCUSSION

6.1 Cyanidation

The amount of gold extracted into solution after 48 hours of leaching was similar for both tests, the average being 1.04 g/t. This was achieved with a consumption, and more consumption; these being 0.17 kg/t and 1.25 kg/t respectively.

The gold extraction for the two leach tests varied from 50.2% to 67.6% as a result of differences in residue assays. Repeat assays still gave varying results. A full size analyses of the residues gave more consistent results and implied a back-calculated (average) residue grade of 0.27 g/t. If the latter was assumed correct then the gold extraction was 79% based on a calculated head assay of 1.31 g/t.

6.2 Screen Fire Assays

Screen fire assays confirmed the 'spotty' nature of the ore. The results indicated a significant upgrading of gold in the +106 micron fractions relative to the −106 micron fractions.

6.3 Size Analyses

Leach feed and residue size analyses indicated that the extent of autogenous degradation during the bottle roll tests was minimal. For both the feed and residues the majority of the gold was in the +300 micron size range. Size by size recoveries indicated that the majority of leaching took place in the finer (minus 300 micron) size range. It is possible that grinding to a finer size could improve gold extraction. However, despite higher residue grades in the coarser size range the back-calculated residue assays were still moderately low and encouraging for the possibility of heap leaching.
### TABLE 1

Sample Description

<table>
<thead>
<tr>
<th>Interval</th>
<th>Au g/t</th>
<th>Sample Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHRC 007</td>
<td>30 - 40 m (10 m) @ 1.4</td>
<td>141591 -&gt; 141600</td>
</tr>
<tr>
<td>SHRC 008</td>
<td>45 - 49 m (4 m) @ 3.6</td>
<td>141698 -&gt; 141702</td>
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<tr>
<td></td>
<td>65 - 74 m (9 m) @ 1.4</td>
<td>141719 -&gt; 141728</td>
</tr>
<tr>
<td>SHRC 009</td>
<td>9 - 16 m (7 m) @ 2.1</td>
<td>141766 -&gt; 141772</td>
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<tr>
<td></td>
<td>46 - 71 m (25 m) @ 1.8</td>
<td>141805 -&gt; 141830</td>
</tr>
<tr>
<td>SHRC 010</td>
<td>48 - 61 m (13 m) @ 1.6</td>
<td>141917 -&gt; 141930</td>
</tr>
<tr>
<td>SHRC 011</td>
<td>33 - 38 m (5 m) @ 2.0</td>
<td>142007 -&gt; 142011</td>
</tr>
<tr>
<td></td>
<td>56 - 63 m (7 m) @ 1.5</td>
<td>142031 -&gt; 142037</td>
</tr>
</tbody>
</table>

(Estimated grade 1.8 g/t Au, 1/4 split, 1 kg from each sample)
### TABLE 2
Duplicate Cyanide Leach 1

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>Solid (g)</th>
<th>Water (g)</th>
<th>NaCN (g)</th>
<th>Lime (g)</th>
<th>NaCN %</th>
<th>pH found</th>
<th>pH left</th>
<th>DO ppm</th>
<th>Au ppm</th>
<th>Au g/t</th>
<th>Tail g/t</th>
<th>Calc Head g/t</th>
<th>Assay Head g/t</th>
<th>Calc Het</th>
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<tbody>
<tr>
<td>0</td>
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<td>4000</td>
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<td></td>
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<td>0.27</td>
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<td></td>
<td>0.047</td>
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<td>10.3</td>
<td>7.9</td>
<td>1.10</td>
<td>1.10</td>
<td>1.09</td>
<td>2.19</td>
<td>1.80</td>
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</table>

NaCN consumption : 0.16 kg/t
Lime consumption : 1.25 kg/t

Comments : Initially DO = 6.2, pH = 5.5
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<th>Time (hrs)</th>
<th>Solid (g)</th>
<th>Water (g)</th>
<th>NaCN (g)</th>
<th>Lime (g)</th>
<th>NaCN %</th>
<th>pH found</th>
<th>pH left</th>
<th>DO ppm</th>
<th>Au ppm</th>
<th>Au g/t</th>
<th>Tail g/t</th>
<th>Calc Head g/t</th>
<th>Assay Head g/t</th>
<th>Calc Hr</th>
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<td>5.5</td>
<td>11.5</td>
<td>6.1</td>
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</tr>
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<td>0.045</td>
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<td>10.4</td>
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<td>0.98</td>
<td>0.98</td>
<td>0.47</td>
<td>1.45</td>
<td>1.80</td>
<td>67.6</td>
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</tbody>
</table>

NaCN consumption : 0.17 kg/t
Lime consumption : 1.25 kg/t

Comments : Initially DO = 6.1
           pH = 5.5
### Table 4

**Screen Fire Assay Results**

<table>
<thead>
<tr>
<th>Sample</th>
<th>+106 um</th>
<th>-106 um</th>
<th>+106 um</th>
<th>-106 um</th>
<th>Calc Head</th>
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<tr>
<td>1</td>
<td>22</td>
<td>676</td>
<td>8.63</td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>
|        |         |         |         |         | 1.05
|        |         |         |         |         | 1.03 av. |
| 2      | 52      | 478     | 1.66    |         | 0.84      |
|        |         |         |         |         | 0.87
|        |         |         |         |         | 0.86 av.  |
| 3      | 34      | 395     | 4.22    |         | 0.68      |
|        |         |         |         |         | 0.69
|        |         |         |         |         | 0.69 av.  |
| 4      | 40      | 560     | 4.26    |         | 0.95      |
|        |         |         |         |         | 1.00
|        |         |         |         |         | 0.98 av.  |
| 5      | 55      | 578     | 3.92    |         | 1.29      |
|        |         |         |         |         | 1.32
|        |         |         |         |         | 1.31 av.  |
TABLE 5
Duplicate Feed Size Analyses 1

<table>
<thead>
<tr>
<th>Screen Size microns</th>
<th>Wt g</th>
<th>Wt %</th>
<th>Assay Au ppm</th>
<th>% Au Dist</th>
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<td>0.87</td>
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<td>13.01</td>
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<td>1.27</td>
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<td><strong>TOTAL</strong></td>
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## TABLE 6
Duplicate Feed Size Analyses 2

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<th>Screen Size microns</th>
<th>Wt g</th>
<th>Wt %</th>
<th>Assay Au ppm</th>
<th>% Au Dist</th>
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<td><strong>TOTAL</strong></td>
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<td><strong>100.0</strong></td>
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TABLE 7
Size Analyses of Leach Residue 1

<table>
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<tr>
<th>Screen Size microns</th>
<th>Wt g</th>
<th>Wt %</th>
<th>Assay Au ppm</th>
<th>% Au Dist</th>
</tr>
</thead>
<tbody>
<tr>
<td>3350</td>
<td>107.1</td>
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<td>0.38</td>
<td>6.9</td>
</tr>
<tr>
<td>1180</td>
<td>254.0</td>
<td>11.8</td>
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<td>100.0</td>
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TABLE 8

Size Analysis of Leach Residue 2

<table>
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<tr>
<th>Screen Size (microns)</th>
<th>Wt. g</th>
<th>Wt. %</th>
<th>Assay Au ppm</th>
<th>% Au Dist</th>
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TABLE 9
Size by Size Recovery for Cyanide Leach Tests

<table>
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<tr>
<th>Screen Size microns</th>
<th>Feed Assay* Au, ppm</th>
<th>Residue Assay* Au, ppm</th>
<th>% Recovery</th>
</tr>
</thead>
<tbody>
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<td>69.5</td>
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</table>

* Weighted, average assays from duplicate leach feed and residue sizings.
APPENDIX 2

PETROGRAPHIC NOTES ON 21 SAMPLES FROM THE SPRING HILL PROSPECT

by

R.N. ENGLAND
M.Sc. (A.N.U)

11 Victor St.,
Cranbrook
(Townsville),
Queensland.

Prepared for Craig Mackay,
Billiton Australia Gold Pty. Ltd..

Order No. 8828/HJ50/CRM1

6/7/90
S1. Brecciated, quartz-veined whitemica-chlorite phyllite. Dump next to battery. Ore from collapsed adit.

This rock consists mostly of 10-50 μm flakes of white mica and subordinate chlorite, with 10-50μm interstitial quartz. Prominent <1-mm ovoid spots entirely of chlorite and quartz may replace cordierite porphyroblasts. Rutile forms very minor <50 μm clusters.

A strong foliation is defined by the preferred orientation of whitemica and chlorite; this is also evident in chlorite in the spots (which are moderately flattened parallel to it), indicating that the foliation post-dates the possible cordierite. Prominent minor 0.1-0.4 mm trains of extremely fine graphite flakes define an earlier foliation cut by the mica cleavage at about 20°. In-situ brecciation into fragments as small as 1 mm has thrown the cleavage into various orientations.

Abundant wandering 0.1-2 mm veinlets consist of 20 μm to 1-mm comb quartz. This contrasts strongly with the crack-seal texture common in most veins from the suite. The veinlets both post-date and pre-date fine graphic stylolites which separate the breccia fragments. Evidence from this sample suggests that the veining, the brecciation, and probably the mineralisation post-date both the penetrative structures.

S2. Silicified, pyritised, slate. Dump next to battery. Ore from collapsed adit.

Granoblastic quartz with a grain size of 10-30 μm forms about 98% of the rock. 10-μm to 5-mm laminations are defined by variation in the content of minor, mainly submicron graphite. Quartz is finest grained in the most graphitic laminae (where the graphite has prevented grain-boundary migration). Prominent thin-section scale folds are visible in which 0.1-0.2 mm quartz-rich (or rather graphite-poor) stringers lie parallel to axial planes. Rare 20-50 μm anhedral whitemica is disseminated through the rock.

Patchy disseminations of 2-μm to 2-mm spongy anhedral and roughly cube-shaped pyrite form about 1% of the rock. Fine-grained anhedral chalcopyrite and galena intimately associated with spongy pyrite account for a hundred or so ppm Cu and Pb. Some chalcopyrite is altered to digenite and covellite. Rare 10-20 μm chlorite is associated with pyrite.

Prominent minor wandering 0.1-0.5 mm veinlets consist of fine anhedral and comb quartz. Some of the pyrite is clearly associated with these.

S3. Gold-rich, quartz-(oxidised)sulphide vein in quartz greywacke. East side of road from SHRC014.

The host quartz greywacke consists mostly of angular clasts of 20-500 μm quartz (30%) and sericite, more rarely kaolinised feldspar (60%) in a sericitic matrix. Smaller clasts are minor chert and tabular whitemica, and rare tourmaline and leucoxenised Fe-Ti oxide. There is no obvious preferred orientation of matrix whitemica.

An 8-mm vein consists of 0.2-1 mm anhedral and <5-mm inward-growing terminated prisms of cavity-filling quartz, and abundant interstitial coarse-grained sulphide altered to colloform and boxwork goethite. The identity of the sulphide is indicated by moderately common tiny arsenopyrite grains preserved by inclusion in quartz.

1-25 μm anhedral gold grains richly disseminated through the goethite are
pretty clearly supergene. They may be breakdown products of arsenopyrite which originally contained the Au in solid solution (Cabri et al., 1989); in which case the arsenopyrite may have contained about 0.1% Au. On the other hand the rock could have been strongly enriched in Au by supergene processes.

10-20 mm of the wall rock shows heavy supergene limonite flooding of sericite.

Primary fluid inclusions following growth zones in quartz are generally small, though some large ones are present. They all appear to consist of an aqueous phase and a small vapour bubble; no liquid CO₂ can be made to form in the large ones, even when they are chilled strongly with a freezing spray. Tiny carbonate inclusions are associated with them. These fluid inclusions, which are probably of relatively low-T origin, are possibly later than the large, CO₂-rich population common elsewhere in this suite.

S4. Vein of quartz + minor oxidised sulphide. East side of road from SHRC014.

The small amount of wall rock in the section appears similar to that in S3.

The 20mm-thick vein which forms most of the sample consists largely of <5-mm anhedral quartz which is almost certainly of crack-seal origin (Ramsay, 1980). Terminations with growth-zone fluid inclusions form linings of minor <5-mm goethised-sulphide filled cavities. The identities of the sulphides are suggested by rare tiny inclusions of arsenopyrite and much less common chalcopyrite and pyrite preserved in quartz. Large aqueous fluid inclusions with a small to mid-sized vapour bubble are common in the crack-seal quartz. A small proportion of CO₂ becomes evident as a third phase which forms between the water and the mid-sized vapour bubble when the section is chilled.

S5. Strawberry Pastry; vein.

Almost the entire sample is coarse-grained (3-10mm) anhedral vein quartz. Rare prism boundaries suggest sporadic cavity filling, but most is probably of crack-seal origin. A moderate degree of strain, and the development of sutured grain boundaries are the results of deformation. Rutile forms rare clusters of a few <2-mm radiating prisms. Subhedral <0.5-mm sulphide grains (probably pyrite or arsenopyrite) formed 1-2% of the vein. These are completely altered to fine-grained haematite, sericite, kaolinite, or leached out.

Fluid inclusions in quartz are quite small. They consist mostly of an aqueous phase with a small to mid-sized vapour bubble, but a small amount of liquid CO₂ can be seen to form when the larger ones are chilled. They are best preserved in the least deformed quartz, but deformation has caused most to gather in subparallel trains.

S6. Strawberry Pastry; breccia lode.

1-5 mm angular fragments of goethite-stained whitemica phyllite (with cleavage thrown into various orientations) are cemented by 0.02-3-mm cockade quartz. The fragments are supported by much more abundant quartz, which must have replaced other material, probably smaller phyllite fragments. Minor 0.02-2 mm sulphide grains associated with the cockade quartz are either leached or altered to colloform goethite and haematite. Their shapes, and rare tiny relics preserved as inclusions in quartz, suggest that they were pyrite and arsenopy-
rite.

A 40-μm gold grain is contiguous with a small (leached sulphide?) cavity. Large fluid inclusions occur only in a few possible early relics of crack-seal quartz. These consist of an aqueous phase with a large to mid-sized vapour bubble. A small amount of liquid CO₂ forms in many of these when the section is chilled with a freezing spray. Primary fluid inclusions are very common in growth zones in the cockade quartz, but they are too small for me see any liquid CO₂.

The quartz texture is more typical of epithermal deposits than, say, Batman.

S7. SHRC030. Sheeted veins in quartz greywacke.

The host rock is quite similar to that in S3, but with some larger clasts (up to 1 mm) and a distinct cleavage defined by the preferred orientation of matrix whitemica. Small, minor rock fragments are limonitic, sericitic chert. Limonite staining in a few mm of the wall rock is clearly supergene.

A 5-mm quartz-(oxidised)sulphide vein has been emplaced along the cleavage, suggesting local structural control on mineralisation; elsewhere(e.g. S9) veins cut the cleavage obliquely. 0.1-4 mm crack-seal quartz forms about 70% of the vein. The sulphides, and possibly carbonate occurred as <5-mm masses, probably of coarse grains which may also have formed by a crack-seal mechanism. Most are leached, and nearly all the rest have been altered to colloform goethite and haematite. The few tiny grains left as inclusions in quartz are pyrite, marcasite, pyrrhotite, and arsenopyrite.

Fluid inclusions disseminated through crack-seal quartz consist of an aqueous phase and a mid-sized to large vapour bubble. Minor liquid CO₂ can be made to form on chilling.

S8. SHRC030. Sheeted veins in quartz greywacke.

The host greywacke here contains more large(<1 mm) quartz clasts than in S7. The cherty rock fragments can be quite sericitic, and limonitised; they may be very highly altered felsic volcanic material. The vein sectioned is similar to that in S7, but 10-mm wide and more quartz-rich. Minor <4-mm sulphide anhedral are completely altered to goethite and a little haematite; a few 0.1-mm ex-pyrite grains have cube-shapes. Minor <0.2-mm goethised sulphide anhedral occur in the wall rocks.

Moderate strain and sutured vein-quartz grain boundaries indicate minor deformation, but large fluid inclusions disseminated in the crack-seal quartz have survived this event; they are similar to those in S7.

S9. 9763E, 10762N. Thick quartz vein in greywacke. Lasagna; drill pad near Chinaman's grave.

The host rock is similar to that in S3, but with minor sericitic chert fragments, and a distinct whitemica foliation which the vein cuts at about 30°. The 20mm-thick vein is dominated by <12-mm crack-seal quartz which has abundant very large fluid inclusions of an aqueous phase and a small to large vapour bubble. Many have minor liquid CO₂ today(25°). Trains of tiny fluid and solid inclusions roughly parallel to the vein walls may be primary, recording individual crack-seal events.
Minor <10-mm masses of sulphide were of either crack-seal or cavity-fill origin, or perhaps both. They are leached out or completely altered to coarse botryoidal goethite which forms ∼0.5-mm prisms radiating from small nuclei of colloform haematite. No traces of fresh sulphide are preserved, and no gold is present.

S10. SHRC007. Hong Kong. Bonanza quartz vein in greywacke.

The host rock is similar to that in S3, but less evidence of sericitised feldspar. It contains about 20% of sericitic chert fragments, and has a quite strong whitemica foliation.

2–3 cm of the quartz-rich margin of the vein has been exposed over a couple of square metres. Coarse-grained gold up to a couple of mm has been picked off exposures of crack-seal quartz by a succession of visitors, but unfortunately no gold was encountered in the section. The vein cuts the foliation at about 30°, though 0.5 mm and 2 mm offshoots are emplaced along it. The central zone was probably rich in sulphide which has been weathered away.

The section is dominated by coarse-grained crack-seal quartz, with prominent minor sulphides represented by cavities or pockets of colloform goethite. Two 10-μm galena grains are preserved in quartz near a limonite-lined cavity. Minor deformation affecting the quartz has produced strain, sutured boundaries, and very weak development of granoblastic texture.

Large and especially abundant fluid inclusions quite evenly disseminated through the crack-seal quartz consist of an aqueous phase and a mid-sized to large vapour bubble (with liquid CO₂ at 20°, which disappears at about 25°). Their composition, at a guess, 20% CO₂, would be unlikely to homogenise at below 250°. They are not as vapour-rich as the otherwise similar-looking CO₂-rich fluid inclusions in the Batman crack-seal quartz.

S11. 10080E, 10200N. Pits in main lode.

This vein material consists almost entirely of very coarse-grained crack-seal quartz. Moderate strain and sutured boundaries indicate weak deformation, but the large and abundant fluid inclusions are unaffected. The only other significant mineral is cassiterite(0.5%), which forms 20-μm to 2 mm anhedral and rough prisms with brown growth zones.

Abundant fluid inclusions in quartz and in cassiterite are identical to those in the bonanza gold–quartz vein in S10. These distinctive fluid inclusions suggest that tin here and gold at Hong Kong precipitated from the same fluid at the same stage of its evolution, i.e. very nearly at the same P,T.


This rock consists almost entirely of 20–50 μm granoblastic quartz. Chlorite(<0.5%) occurs as 10–30 μm anhedral and flakes, in some places concentrated in 1-mm layers which are evidently relics of bedding, and quite commonly in c. 1 mm patches recalling the chlorite spots in S1. This suggests that the chert may be the silicification product of a very similar rock to S1.

0.3 mm pyrite cubes are extremely rare, but <2 mm cavities suggest that disseminated pyrite may have formed 0.5–1% of the rock.

The pinched-and-swollen chert layers may have developed from coalescing chert nodules such as those in S17 and S18, as silicification proceeded. Since
the nodules appear to have preceded folding (this is discussed in the section on S17). It is likely that the silicification represented here also preceded the mineralisation.

S13. Vein in Gerowie Tuff. Lasagna; near Chinaman's grave.

This sample is very much the same as S9 from the same locality, right down to the fluid inclusions, and the vein-parallel trains of inclusions in quartz.

Though it is from the Gerowie "Tuff", it looks the same as typical Mount Bonney Formation.

S14. Coarse-grained, milky vein quartz. Hong Kong; Strawberry Pastry vein set.

Anhedral crack-seal quartz (95%) has a grain size up to 20 mm. Minor deformation has produced strain, sutured boundaries, subgrains, and rare masses of granoblastic grains.

Prominent minor colloform goethite and haematite occur almost wholly as 20-μm to 3-mm veinlets, which probably replace sulphide veinlets. Rare 1-50 μm inclusions of chalcopyrite and subordinate pyrite are preserved in quartz. Chalcopyrite may have been the dominant sulphide.

Abundant, large, disseminated fluid inclusions in quartz are like those in S13.

S15. 3-mm quartz-(oxidised)sulphide vein in quartz greywacke. Hong Kong; Toothpaste.

The host rock is much like that in S3, but slightly more quartz-rich, and with moderately prominent sericitic chert and rutile-loaded <2.0mm ?ilmenite clasts.

The vein consists of 2-3mm crack-seal quartz anhedral. Subordinate <4-mm masses of sulphide have been leached or more rarely altered to colloform goethite and haematite; they tend to stretch right across the vein, suggesting that they too formed by a crack-seal mechanism. A (??later) 1mm veinlet cutting the main one at a high angle appears to have been mainly 0.2mm roughly cube-shaped pyrite.

Fluid inclusions disseminated in vein quartz are smaller than the more typical CO₂-rich ones in this suite, but liquid CO₂ can be seen when the larger ones are chilled. They are probably the typical fluid.

S16. Sheeted quartz-(oxidised)sulphide veinlets in quartz greywacke. Hong Kong; Toothpaste.

Three parallel 1-2 mm veinlets are separated by 1-2 cm of quartz greywacke.

The host rock is much like that in S15. The veins are slightly more quartz-rich but otherwise very similar.

A 20-μm gold grain occurs in the largest veinlet, included in a small crack-seal quartz grain within 30 μm of a large leached sulphide mass which extended the whole width of the vein.

Fluid inclusions in quartz tend to be small, and more vapour-rich than
usual, though liquid CO₂ can be made to form in more typical ones with chilling.

S17. Nodular slate, probably in Gerowie Tuff. Near main lode at top of hill.

The host rock is a ferruginised(?lateritised), silicified slate consisting now of 10–μm quartz and submicron goethite. 0.3–2 mm bedding laminations are defined by variation in the quartz:goethite ratio which averages about 1. Even on a fine scale the texture is nodular, with 30–200 μm slightly flattened spheroidal bodies of weakly goethitic 10–μm quartz enveloped by thin, anastomosing trains of goethite and a trace of 10–μm whitemica which define a slaty cleavage. The goethite has probably replaced original whitemica. The slaty cleavage is axial plane to minor folds in the bedding which appear to be the result of inhomogeneous strain around the large chert nodules(q.v.).

The 7–30 mm nodules consist of 10–50 μm granoblastic quartz. They form trains parallel to bedding. Spaces created by weak boudinage are filled with massive fine-grained ?Mn (hydr)oxides. They evidently predate the folding and thus predate the mineralisation. Perhaps they are diagenetic.

The extent of goethite staining, and the presence of minor <0.5 mm, in places cube-shaped, voids in both the nodules and their slate host suggest that the rock may have contained a couple of percent of disseminated pyrite.


This sample is a less nodular equivalent of S17.


This is a sandy near-equivalent of the rock which has been brecciated in S1.

20–400 μm angular to subrounded clasts of quartz and subordinate feldspar(altered to whitemica–quartz) are supported by abundant matrix of 10–50 μm whitemica flakes. Mica both in the matrix and replacing feldspar has a very strong preferred orientation; this suggests that the whitemica–alteration of feldspar preceded the mineralisation. Abundant <1-mm spheroidal voids slightly flattened parallel to the foliation strongly recall the chlorite spots in S1 (from which they may have been derived by leaching).

A streaky layering, probably a spaced cleavage, parallel to the whitemica foliation is defined by discontinuous pure slate layers a few mm wide, in places truncating clasts. Some of the streaky layers are stained with limonite. The spheroidal bodies, leached elsewhere in the sample, there consist of goethite, which is probably after pyrite.

S20. Hong Kong. Nodule("stone egg") in quartz greywacke.

The matrix in the "stone egg" is enriched in 10–50 μm quartz, and shows less goethite staining. These bodies are therefore zones of slight silicification, which has made them harder, and less permeable to goethite-staining meteoric fluids than the surrounding rock. They are probably equivalent to the chert nodules in the slates.

Much of the rock is 5–20 μm flakes of whitemica, stained with minor 1–10 μm flakes of goethite and rare 20-μm rutile clusters. Very minor limonite occurs in 0.2mm lenses parallel to the cleavage(q.v.). A 5mm bed contains c. 20% of 5–30 μm anhedral quartz, some of which is clastic. Part of this bed contains quite abundant disseminated <100-μm goethised sulphide(?)pyrite, ?arsenopyrite) or possibly rhombohedral Fe carbonate.

A very strong slaty cleavage cuts the bedding at about 10°.

GENERAL COMMENTS ON THE SPRING HILL GOLD MINERALISATION

The vein system pretty clearly post-dates the cleavage(s), though some veins show evidence of minor deformation. Most veins consist mainly of crack-seal quartz, though some cavity-filling, terminated prismatic quartz, suggesting lower P is dominant in some samples, especially ones containing gold (q.v.).

The sulphide most commonly associated with gold is arsenopyrite.

The most significant feature of the veins is the general abundance of CO₂-bearing fluid inclusions in crack-seal quartz. Rechecking all the CO₂-rich fluid inclusions at the same temperature(22°) reveals what may be a widespread population with about 70% water, 20% liquid CO₂, and 10% vapour. This applies for S4, S6(in rare relics surrounded by cockade quartz), S7, S9, S10, S11, S13, S14, and probably S15 and S16.

The abundance of CO₂-rich fluid inclusions at Spring Hill has already been noted by Burlinson(1984). He recognised a general association of gold and CO₂-bearing fluids in the Pine Creek area (and I have corroborated this at Ralston). Burlinson is probably still based in Darwin: his decrepitiometry may be a useful exploration tool. Wygralak & Ahmed(1990) also recognised CO₂-rich fluid inclusions in gold-quartz veins from the Pine Creek Geosyncline.

Paradoxically, the most gold-rich of these samples (S3) appears to have formed from fluid showing no evidence of CO₂. It shows only cavity-filling quartz textures, though this may be because it was very sulphide-rich (cavity-fill textures are common where quartz abuts sulphides). Another sample with gold, S6, is also dominated by cavity-fill quartz with only a few crack-seal relics. Only one sample (S16) has predominantly crack-seal quartz. However, the bonanza vein sample, S10 had typical crack-seal quartz with spectacularly abundant CO₂-rich fluid inclusions. There was no gold in my section, and we are not completely sure of its relationship with the crack-seal quartz. Perhaps there are two periods of gold deposition, one (with Sn) from CO₂-rich fluids associated with crack-seal quartz formation, and a later one, of Au remobilised in more water-rich fluids at lower P.T. Cavity filling is likely to take place at lower fluid pressure, even with the same amount of rock overburden, since it implies open fissures; these could permit direct access to the surface, and associated adiabatic cooling.
ADDITIONAL SAMPLE

80686. Quartz-cemented breccia of light grey, devitrified opaline silica fragments.

Highly angular <10-mm fragments of very finely devitrified opaline silica lie, partly self-supporting, in a cement of 20-μm to 2-mm anhedral quartz. The fragments have a very finely porous texture in which 5-30 μm highly irregular grains in several slightly different optical orientations are intergrown. This texture is probably inherited from the original opal structure.

Most of the cement appears to be of crack-seal origin, and fibre texture is well developed in many places.

Aqueous fluid inclusions in the crack-seal quartz have mid-sized vapour bubbles which do not liquate CO₂ when chilled. Their fairly low density suggests a formation temperature above 150⁰.

A second brecciation, developed only locally, has produced >20-μm fragments of the above-described material, and these have been cemented by extremely fine-grained chert.

The fluid inclusions clearly indicate that the first cement crystallised under hydrothermal conditions from a superheated aqueous phase. It is very likely that the original opaline material formed by rapid deposition due to falling fluid (P,T), probably near the surface, i.e. in an epithermal regime. The brecciation and crack-seal quartz may be the result of shrinkage of the original opal as it devitrified and became dehydrated.

REFERENCES


NOTES:
1. MCN & MLN locations are approximate.

- Old workings
- Road
- Railway
- Excluded areas

0 1000 metres
BASIC LEVEL : 47350 ft

PLOT SCALE : 50
LOGARITHMIC CONTOURS ohm-m

INSTRUMENTATION USED
Rx TYPE : Huntec Mk IV 9/s
Tx TYPE : Huntec Mk IV 7.5 kW
SURVEY : IP & RESISTIVITY
METHOD : Dipole, Dipole Array Lt 50

Time sequence : 2 sec on, 2 sec off
Integration time recorded : Channels 0
Integration time plotted : Channels 0
Delay time, TD : 50 msec. after cut off
Linear channel width : 150 msec

LOCATION MAP

BILLITON AUSTRALIA
The Western Division of the Anglo-Australian Metals Group

SYDNEY OFFICE: 11th Floor, 177 Pitt St, Sydney 2000
OSCAR OFFICE: 4th Floor, 136 Chalmers St, South Brisbane 4101
STAFF OFFICE: 2nd Floor, 200 Pacific Hwy, West Gosford 2250

SPRING HILL J.V. EL 4793 & 4873
NORTHERN TERRITORY

ERTH GRADIENT ARRAY SURVEY
APPARENT RESISTIVITY
QHM/M

Author: [Name]
Date: [Date]
Survey No.: [Survey No.]

12.
INSTRUMENTATION USED
Rx TYPE: Huntec Mk IV s/n
Tx TYPE: Huntec Mk IV 7.5 kW
SURVEY: I.P. & RESISTIVITY
METHOD: Dipole, Dipole Array L=50

Time sequence: 2 sec on, 2 sec off
Integration time recorded: Channels 0
Integration time plotted: Channels 0
Delay time, TD: 50 msec. after cut off
Linear channel width: 150 msec
**INSTRUMENTATION USED**

- **Rx TYPE**: Huntex Mk IV s/m
- **Tx TYPE**: Huntex Mk IV 7.5 kW
- **SURVEY**: IP & RESISTIVITY
- **METHOD**: Dipole, Dipole Array L = 50

**LOCATION MAP**

- **AZIMUTH**: 0°

**APPARENT RESISTIVITY (ohm m)**

- Logarithmic contour interval 5 ohm m

**APPARENT CHARGEABILITY (msec)**

- Contour interval 5 msec

**LOCATION MAP**

- NORTHERN TERRITORY

**SPLITTON AUSTRALA**

**SPRING HILL J.V.**

**NORTHERN TERRITORY**

50m DIPOLE DIPOLE

IP PSEUDO SECTION

10100N
TEM Response Profile
SPRINGHILL LINE=9700N FIXED LOOP SIROTEM by SEARCH EXPLORATION SERVICES PTY.
Fixed Loop TX, Roving Surface RX Z Component
(10500N, 9500N/9600E, 9200E)
Field Data Only

Response (μV/A)

Distance Along Profile

Fig. 15.
TEM Response Profile

SPRINGHILL LINE9900N FIXED LOOP SIROTEM by SEARCH EXPLORATION SERVICES PTY.

Fixed Loop TX, Roving Surface RX  Z Component
(10500N, 9500N/9600E, 9200E)

Field Data Only

Response (μV/A)

Distance Along Profile
TEM Response Profile
SPRINGHILL LINE10300 N  FIXED LOOP SIROTEM by SEARCH EXPLORATION SERVICES PTY.
Fixed Loop TX, Roving Surface RX  Z Component
(10500N, 9500N/9600E, 9200E)

Field Data Only

Response (uV/A)

Distance Along Profile
TEM Response Profile
SPRINGHILL: LINE 10500N  FIXED LOOP: SIROTEM by SEARCH EXPLORATION SERVICES PTY.

Fixed Loop TX, Roving Surface RX  Z Component
(10500N, 9500N/9600E, 9200E)

Field Data Only

Response (uV/A)

Distance along profile

'LASAGNA' 40.41