MINERALIZATION

INTRODUCTION

Between 1870 and 1927 the Gulgong Gold Field produced an estimated 1 million ounces of gold. It was the deep lead deposits that supplied most of the gold production throughout the area, but some primary deposits also made significant contributions to the total gold production. The known deep leads were quickly worked out, and as most of the leads are now under cropped land, exploration for additional alluvial deposits has been restricted. This, together with the usual technical difficulties of exploring for alluvial deposits, has been a deterrent to mineral explorers. This chapter is therefore concerned only with the primary gold deposits, which generally remain more accessible for exploration and possible mining.

A total of fourteen primary gold deposits have now been located in the Mudgee-Gulgong district. Five of these deposits were previously recorded by Matson (1973) during compilation of the Dubbo 1:250,000 metallogenic sheet. The additional ten deposits have been located through searches of unpublished material held by the Geological Survey of New South Wales and with the assistance of local property owners. The deposits all comprise abandoned workings for which there are no production records. Locations of all deposits are shown on the 1:50 000 scale geological maps (Figs. 3 and 4) together with their deposit numbers.

PRIMARY DEPOSITS

The primary gold deposits of the Mudgee-Gulgong district are hosted mostly within the Burranah Formation. These deposits contain gold ± minor base metals. Deposits are also hosted in the Dungaree Volcanics and in Early Devonian diorites but these deposits generally contain gold only (Table 4).
Table 4. Primary Gold Deposits of the Mudgee-Gulgong District

<table>
<thead>
<tr>
<th>Deposit no</th>
<th>Deposit name</th>
<th>Host formation</th>
<th>Host rock</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Salvation Hill</td>
<td>Dungaree Volcanics</td>
<td>Rhyodacite</td>
<td>Au</td>
</tr>
<tr>
<td>2</td>
<td>Red Hill</td>
<td>E. Dev. Diorite</td>
<td>Diorite</td>
<td>Au</td>
</tr>
<tr>
<td>3</td>
<td>Louisianna</td>
<td>Burranah Formation</td>
<td>Monzodiorite</td>
<td>Au, As, Zn</td>
</tr>
<tr>
<td>4</td>
<td>Gulgong</td>
<td>Burranah Formation</td>
<td>Monzodiorite</td>
<td>Au, As, Zn</td>
</tr>
<tr>
<td>5</td>
<td>Marina</td>
<td>Burranah Formation</td>
<td>Monzodiorite</td>
<td>Au, As, Zn</td>
</tr>
<tr>
<td>6</td>
<td>Lewis's</td>
<td>Burranah Formation</td>
<td>Volcanics</td>
<td>Au, Cu</td>
</tr>
<tr>
<td>7</td>
<td>Bells</td>
<td>Burranah Formation</td>
<td>Monzodiorite</td>
<td>Au, Cu, Pb, Zn, Ag, As</td>
</tr>
<tr>
<td>8</td>
<td>Divide 4</td>
<td>Burranah Formation</td>
<td>Monzodiorite</td>
<td>Au, As</td>
</tr>
<tr>
<td>9</td>
<td>Springfield</td>
<td>Burranah Formation</td>
<td>Monzodiorite</td>
<td>Au, As</td>
</tr>
<tr>
<td>10</td>
<td>Whales</td>
<td>E. Dev. Diorite</td>
<td>Diorite</td>
<td>Au, Pb, As</td>
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<tr>
<td>11</td>
<td>Orchard</td>
<td>Burranah Formation</td>
<td>Volcanics</td>
<td>Au, Cu, Pb, Zn, Ag, As</td>
</tr>
<tr>
<td>12</td>
<td>Box Hill</td>
<td>Burranah Formation</td>
<td>Latite</td>
<td>Au</td>
</tr>
<tr>
<td>13</td>
<td>Belinfante</td>
<td>E. Dev. Diorite</td>
<td>Diorite</td>
<td>Au</td>
</tr>
<tr>
<td>14</td>
<td>Royal George</td>
<td>Dungaree Volcanics</td>
<td>Rhyodacite</td>
<td>Au</td>
</tr>
</tbody>
</table>

DEPOSITS HOSTED IN THE BURRANAH FORMATION

Springfield Deposit (Deposit no. 9)

The Springfield deposit is located about 10 km south of Gulgong in the headwaters of the historic Springfield deep lead. The deposit was not recorded by Matson (1973) and is first mentioned in literature in a report by Endeavour Resources Limited (1981). There are no production records available for the deposit, but like most of the primary deposits in the district, production was probably small with high grades. Subsequent work on the deposit by International Mining Corporation (IMC) NL (Hawley, 1988) culminated in a gold resource estimate of 1.4 million tonnes at 1.4 g/t Au. Hawley considered the deposit to have a metasomatic origin. Additional drilling by Newmont Australia Limited (Holliday, 1990) in joint venture with IMC did not improve the
overall tenor of the deposit. Newmont viewed the deposit as an encouraging new occurrence of porphyry style mineralization in an area that historically produced large amounts of alluvial gold.

At the surface, the Springfield deposit is expressed as a series of collapsed shafts located on two north-northwesterly trending parallel quartz veins about 50m apart. The quartz veins have a thickness of about 30 cm and are located within a north-south elongate monzodiorite intrusive. The monzodiorite intrudes crystal lithic tuffs and volcaniclastic siltstones. Brecciation and shearing are locally developed along the western contact. The eastern contact of the intrusive is obscured by alluvium.

Alteration is variable throughout the deposit but is generally propylitic to phyllic and mostly confined to the monzodiorite. Common alteration minerals include chlorite, epidote, sericite and calcite. Arsenopyrite and pyrite are the dominant sulphides with minor chalcopyrite. Gold occurs as coatings on arsenopyrite which in many cases, surrounds the pyrite. Gold also occurs in solid solution or as free gold within the pyrite or arsenopyrite (Hawley, 1988). The sulphides and gold occur in stockwork veins or disseminations in the altered monzodiorite.

Drilling of the deposit by Newmont (Holliday, 1990), indicates the monzodiorite body is west dipping. Alteration in the eastern or footwall side of the intrusive is more intense than in the western or hangingwall side which is largely unaltered. The density of quartz veining also increases towards the east and becomes a stockwork system on the footwall side.

The Springfield deposit is located within a zone of higher strain between the Mount Galambine Fault and the Magpie Hill Fault. These faults define a north-south-trending zone up to 1.5 km wide that has been subject to dextral strike-slip deformation. On the regional magnetic data, the Springfield deposit is interpreted to lie on a north-northwest trending (340°) dextral fault between the Mount Galambine Fault and the Magpie Hill Fault. To the east of the deposit is a north-trending magnetic lineament. A north-east trending sinistral fault truncates the northern end of the deposit (Fig. 21).
Fig. 21 Interpretation of the first vertical derivative RTP magnetic image for the Springfield deposit area.

Fig. 22 Interpretation of the first vertical derivative RTP magnetic image for Guigong group of deposits.
The character of the mineralization at the Springfield deposit is consistent with mesothermal vein-style mineralization controlled by brittle deformation of a structurally competent body, i.e., the monzodiorite. The geometry of the fault system is similar to the theoretically predicted shear geometry derived from experimental studies by Tchalenko (1968) for isotropic materials deformed by bulk simple shear. Using the nomenclature of Tchalenko (1968) the northwest trending fault corresponds to an oblique (P) shear and the north trending lineament is a central (D) shear. Maximum dilatancy on the central (D) shear has led to increased fluid flow on the eastern side of the intrusive body and resulted in the increased veining and alteration on this side of the deposit.

The Louiisiana, Gulgong, Mariner, and Bells Deposits (Deposit no's. 3, 4, 5, 7)

The Louiisiana, Gulgong, Mariner and Bells deposits are all located in monzodiorite about 3 to 5 km southeast of Gulgong. They were the first hard rock mines to be worked in the district and grades averaged about 20 g/t Au (Matson, 1973).

The four deposits consist of vertical to steeply dipping quartz veins up to 0.5m in thickness that generally strike 320°. Individual deposits have strike lengths of up to 300 m and were interpreted by Matson (1973) to be hosted within a single acid intrusive body thought to be related to the Gulgong Granite. Petrological and whole rock geochemical data indicate the intrusion is monzodioritic with a clear affinity with the Burranah Formation. The monzodiorite body is located between the Magpie Hill Fault and the Home Rule Fault and is relatively magnetic. The body becomes slightly less magnetic, and perhaps more altered, on its eastern side adjacent to the Magpie Hill Fault (Fig. 22).

The veins at the Louiisiana, Gulgong and Marina deposits are laminated or composite laminated and massive quartz veins with accessory sphalerite, arsenopyrite and gold. Limited sericite alteration of the wall rocks occurs within millimeters of the veins, and
arsenopyrite occurs locally as dissemination of coarse-grained euhedral crystals close to the vein. Small epidote veins are also common.

At the Bells deposit the rocks show some evidence of shearing. Malachite and azurite are present along joints and fractures, and one oxidised (limonitic) sample showed a trace of gold. A sample from a small pit at this deposit assayed 13.9% copper, 0.74% lead, 0.35% zinc, 7 ppm gold, 94 ppm silver, and 870 ppm arsenic.

Mineralization in these four deposits consists of mesothermal veins preferentially hosted in the monzodiorite intrusive in a zone of high strain between the Magpie Hill Fault and the Home Rule Fault. The veins in these deposits trend at a low angle to both faults and have developed in a P-shear (using the nomenclature of Tchalenko, 1968) during regional deformation (Fig. 22). Mineralization being preferentially controlled by the structurally more competent monzodiorite intrusive.

Orchard Deposit (Deposit no. 11)

At the Orchard deposit there are three small pits which trend north-northeasterly over a strike length of 150 m within tuffaceous sandstone. There is little evidence to suggest the deposit was worked to any considerable depth. The rocks show evidence of minor shearing and weak brecciation. Sericite and carbonate alteration are common and malachite and azurite occur along fractures and joint planes. Gossanous rocks near the pits are highly siliceous with rare inclusions of chalcopyrite. The gossan material returned assay results of 10.3% copper, 3100 ppm lead, 2400 ppm zinc, 0.4 ppm gold, 11 ppm silver and 1180 ppm arsenic.

Box Hill Deposit (Deposit no. 12)

The Box Hill Deposit consists of a 450 m long, northeast-trending zone of altered coherent volcanic rocks of latite composition. The alteration is developed over a width
of about 150 m and is confined to the steeply west dipping unit of latite. Moderate to weak carbonation, silicification, and veining are present throughout the zone with two sub parallel zones of intense alteration developed over widths of 10 m within the latite. Weak mineralization (0.4 ppm Au, 130 ppm As, 95 ppm Cu) is associated with the altered latite.

The only obvious control on mineralization at the Box Hill deposit is the host rock. Alteration and mineralization are confined to the latite unit between adjacent units of volcaniclastic sandstone.

*Lewis’s Deposit (Deposit no. 6)*

At the Lewis’s deposit there are two partly collapsed shafts approximately 25m apart and two small prospecting pits. The shafts are located on a small north-trending (345°) fault between the Mount Galambine Fault and the Magpie Hill Fault. The deposit is hosted within volcaniclastic sandstone but the magnetic data indicate the presence of intrusive monzodiorite or coherent volcanics at depth (Fig. 22). Local shearing is developed along the north-trending fault with common albite and sericite alteration. A northeast-trending fault is exposed in the pit and carries some secondary copper minerals. Malachite, azurite and chrysocolla are common minerals in joints and fractures.

Mineralization at the Lewis’s deposit is controlled by a similar set of structures to those at the Springfield deposit (deposit no. 9). The main fault controlling mineralization at Lewis’s trends at a low angle to the Mount Galambine Fault and the Magpie Hill Fault and corresponds to a P-shear (using the nomenclature of Tchalenko, 1968). At this deposit, the northeast-trending fault corresponds to an R'-type fault in the Riedel model (Tchalenko, 1968) and is also mineralized.
DEPOSITS HOSTED IN THE DUNGAREE VOLCANICS

Royal George Deposit (Deposit no. 14)

The Royal George deposit is located about 1.5 km south of Mount Galambine within the Dungaree Volcanics. It occurs about 700 m above the contact with the Burranah Formation and is confined to a 100 m thick coherent volcanic (rhyodacite) unit. The deposit was previously recorded by Matson (1973) but with incorrect host rock and vein orientation data. The deposit was worked from 1870 to 1899 and had several high-grade shoots that contained from 92 to 122 g/t Au. Average grade and total production figures are not available.

The deposit contains of a set of three tabular parallel quartz veins up to 0.5m thick trending 060° and spaced 70 m and 120 m apart. The central vein appears to have been the most productive and has a total of five shafts sunk along its length. All veins dip to the southeast at angles between 40° to 60°. Vein material from the dumps located on the central line of workings have a laminated appearance and occasionally exhibit crystal lined vughs. Sulphides present include chalcopyrite, galena, pyrite and arsenopyrite.

The vein textures indicate they were formed as open space fillings under high fluctuating fluid pressure. Cleavage developed in volcaniclastic units to the east and west of the deposit strikes 330° and dips steeply to the west. The veins at the Royal George deposit are therefore developed perpendicular to the regional cleavage and essentially parallel to the maximum principal stress (NE-SW). Mesothermal vein-style mineralization at the Royal George deposit developed as tension veins confined to the structurally more competent rhyodacitic unit within the Dungaree Volcanics.
Salvation Hill (Deposit no. 1)

Gold mineralisation at Salvation Hill occurs in a porphyritic rhyodacite that has been fractured, brecciated, veined, hydrothermally altered and pyritised, as well as contact metamorphosed by the nearby Gulgong Granite. Hydrothermal alteration comprises sericite ± silica, chlorite, biotite and K-feldspar. Little quartz veining is evident in outcrop. The main load at Salvation Hill trends northeasterly, with a northwesterly dip. The length of mineralisation and total production has not been recorded, but the width of the lode ranges up to 12.2 m (Matson, 1973). Sulphides (pyrite and arsenopyrite) and very minor base metals are located in probable tension veins as fine-grained disseminations, clusters or veinlets.

The Salvation Hill deposit is located about 500 m to the northwest of a prominent east northeast-trending lineament that is obvious on the regional magnetic data. This lineament also comprises the southeastern margin of the Gulgong Granite. The trend of mineralization in the deposit is essentially perpendicular to the regional and local cleavage. The structural competency of the porphyritic rhyodacite may have been a factor in localising the tension veins at this deposit.

DEPOSITS HOSTED IN EARLY DEVONIAN DIORITES

Whales Deposit (Deposit no. 10)

The Whales deposit is hosted in a small, circular non-magnetic diorite that intrudes a mixed volcanic and volcaniclastic sequence of the Burranah Formation.
The deposit contains of a number of collapsed shafts that strike in a northerly direction and are associated with pervasive silica and carbonate alteration. Breccia is present on the old dumps and consists of randomly oriented fragments of chloritically altered wall rock and quartz vein fragments in a quartz matrix. Arsenopyrite, pyrite, and galena occur in narrow chloritic zones adjacent to the quartz veins. The eastern side of the diorite intrusive is transected by several northeast trending sinistral faults.

The Whales deposit is localised in a diorite intrusive located between two northwest-trending dextral faults (Fig. 23). These faults define a 1 km wide zone that has been subjected to dextral strike-slip deformation. The north-trending mineralization at this deposits is consistent with the interpretation of brittle deformation and mineralization of the structurally more competent diorite in an R-type shear in the Riedel model (Tchalenko, 1968). In this model, the northeast-trending sinistral faults that cut the eastern half of the intrusive are interpreted as R'-type faults in the Riedel model (Tchalenko, 1968).
Red Hill Deposit (Deposit no. 2)

The Red Hill Deposit is located adjacent to the Magpie Hill Fault within the town boundary of Gulgong. It was the site of the original discovery of gold in the Gulgong district. The mine site has now been rehabilitated and the only available descriptions of the workings are those given by Jones (1940).

Mineralization at the Red Hill Mine occurs in a diorite that has intruded the Burranah Formation. The diorite does not outcrop at the mine site but Jones (1940) describes 'highly altered claystones which have been intruded by dykes and masses of diorite.' Quartz veins are described as small and irregular and traversing the diorite in all directions. A 'persistent quartz reef' that varies in thickness from 10 cm to 70 cm trends north-south and dips to the east. Free gold occurs in the quartz veins and in the altered country rocks for up to 5 m from the veins (Jones, 1940).

The diorite body at the Red Hill deposit is reasonably magnetic and well defined by the airborne magnetic data. The diorite becomes less magnetic, perhaps due to alteration, along its eastern margin adjacent to the Magpie Hill Fault. Outcrops of the diorite have been located to the west and southwest of the town. Whole rock geochemical data indicate that the diorite is distinctive from the intrusives of the Burranah Formation. This data, together with the observations of Jones (1940), supports the interpretation that the intrusive is one of the younger, probably Early Devonian suite.

The Red Hill Deposit is localised on the eastern side of the diorite body adjacent to the Magpie Hill Fault (Fig. 4). Dextral movement on this fault has been interpreted to the south of this area and may have also been responsible for brittle deformation of the more competent diorite adjacent to the fault. The fractured and brecciated diorite has provided a fluid pathways for the development of the stockwork and sheeted vein system.
Belinfante Deposit (Deposit no. 13)

The Belinfante Deposit is located about 1.5 km west of Mount Galambine within a west-dipping sequence of the Dungaree Volcanics and in the footwall of the Mudgee Fault (Fig. 4). The prospect occurs within an elongate north-south diorite intrusive that is concordant with the host volcanics. The central area of the intrusive is covered with alluvium leaving northern and southern areas of outcrop. Numerous old workings are located within the diorite body, clustered toward the southern end of the northern outcrop area.

The diorite body is essentially non-magnetic but its extent is well defined by the more magnetic hornfelsed volcaniclastics. The magnetic data indicate the diorite may be folded into a synform with a faulted eastern limb (Fig. 4).

Alteration at the Belinfante deposit corresponds closely to the outcrop of the diorite intrusive. The alteration zone is characterised by pervasive carbonate alteration with lesser silicification and disseminated pyrite. The most intense alteration occurs on the western side of the diorite in the area of the old workings and is accompanied by quartz-carbonate-pyrite stockworks.

At the Belinfante Deposit, the diorite intrusive has been the preferred lithology for alteration and mineralization. A strong competency contrast exists between the diorite and the enclosing volcaniclastic lithologies of the Dungaree Volcanics. The location of the stockwork veining is consistent with brittle deformation of the diorite, and fluid movement into this area during D2 movement on the Mudgee Fault and the formation of the footwall syncline.
LEAD ISOTOPE DATA

The use of lead isotopes as a discriminator in mineral exploration is based on a detailed understanding of the relationships between isotopic signatures and the age and nature of all mineralizing events in a particular tectonic domain. Carr et al., (1995) present an objective method of relating mineral occurrences to tectonic events in the Lachlan Fold Belt based on a study of over 100 deposits. In this study, isotope data was integrated with geochronological data and detailed geology to define a plumbotectonic framework that can be used to predict the likely metallogenic association, and thus potential economic significance, of sulphide mineralization.

Carr et al., (1995) published a lead isotope ratio value for the Springfield deposit (deposit no. 9) but attempted to interpret the value in the context of the Early Devonian age previously assigned to the Burranah Formation.

To supplement the reinterpretation of this data, a sample of galena from quartz vein material from the Orchard deposit was analysed at the CSIRO (North Ryde) for its lead isotopic compositions. The results of the analysis together with the published data of Carr et al., (1995) are shown in Table 5.

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Sample</th>
<th>$^{206}$Pb</th>
<th>$^{207}$Pb</th>
<th>$^{208}$Pb/</th>
<th>LFB Model age (Ma)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Springfield</td>
<td>D9</td>
<td>18.30</td>
<td>15.52</td>
<td>38.00</td>
<td>365</td>
<td>Carr et al., (1995)</td>
</tr>
<tr>
<td>Orchard</td>
<td>GUJW6</td>
<td>18.25</td>
<td>15.55</td>
<td>38.05</td>
<td>370</td>
<td>This study</td>
</tr>
</tbody>
</table>
The lead isotope data has been plotted with data from Carr et al. (1995) for deposits from other Ordovician shoshonitic volcanics in the Parkes-Narromine belt in the Lachlan Fold Belt (Fig. 24). On this figure the Peak Hill, Lake Cowal, and Endeavour group of deposits all plot on the mantle mixing line. The data from the Springfield and the Orchard deposits have slightly higher $^{207}\text{Pb}/^{204}\text{Pb}$ ratios and plot with the London-Victoria, Dayspring, Mt Morgan and Ben Nevis group of deposits. This group of deposits deviates from the mantle mixing line and show lead isotope compositions that are intermediate between crustal and mantle sources. The London-Victoria, Dayspring, Mt Morgan and Ben Nevis deposits are all structurally controlled vein gold deposits with hydrothermal activity regarded as syn- or postdeformational (Clark et al., 1990). The smaller deposits in this group, such as the Ben Nevis and Day Spring show the most crustal contamination while the larger deposits such as London Victoria have the least contamination.

The small, though significant, crustal component of lead in the Springfield and Orchard deposits, and their LFB model ages is consistent with mixing in response to hydrothermal events (metamorphic) rather than Ordovician processes. The mantle lead was probably derived from leaching of the Ordovician intrusives within the middle to upper crust rather than being directly plumbed from the mantle. This was mixed with higher $^{207}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ ratio crustal lead derived from the volcaniclastic dominated wall rocks.

The lead isotopic signatures of sulphide mineralization from the major porphyry and epithermal copper ± gold deposits hosted within Ordovician shoshonites (eg, the Endeavour group of deposits) all plot on the mantle mixing line. Carr et al., (1995) postulated that the position of each deposit along this line is an indication of the timing of metallogenesis within the Ordovician magmatic cycle, and possibly also the degree of mixing of melts from a more primitive asthenosphere and a more enriched lithosphere, potentially fertile for copper and gold. Samples which plot on the mantle mixing line and have high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios are considered to have the best chance of representing a large metallogenic event. The mixed mantle and crustal signature of the lead in the Springfield and Orchard deposits suggests that these deposits, and perhaps
the Burranah Formation in general, may have limited tonnage potential.

Fig. 24 Lead isotope ratio plots of sulphide mineralization from deposits hosted in the Burranah Formation. Figure modified from Carr et al., (1995).
SULPHUR ISOTOPE GEOCHEMISTRY

The sulphide minerals arsenopyrite and pyrite are ubiquitously associated with gold in many of the deposits hosted in the Burranah Formation. The sulphur isotopic compositions of these minerals therefore provide a means to evaluate possible sources of sulphur and assist the overall genetic interpretation of these deposits.

In the Springfield deposit, arsenopyrite occurs as large euhedral crystals. Eight arsenopyrite samples were hand drilled from altered monzodiorite from this deposit and the powders collected for analyses on the stable isotope mass spectrometer at the University of Tasmania. The $\delta^{34}S$ percentage values obtained from the samples are shown in Table 6.

Table 6. Sulphur Isotope Data from the Springfield Deposit

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Alteration</th>
<th>Mineral</th>
<th>$\delta^{34}S$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUJW0027a</td>
<td>Quartz/sericite</td>
<td>Arsenopyrite</td>
<td>15.6</td>
</tr>
<tr>
<td>GUJW0027b</td>
<td>Quartz/sericite</td>
<td>Arsenopyrite</td>
<td>15.6</td>
</tr>
<tr>
<td>GUJW0027c</td>
<td>Quartz/sericite</td>
<td>Arsenopyrite</td>
<td>16.0</td>
</tr>
<tr>
<td>GUJW0027d</td>
<td>Quartz/sericite</td>
<td>Arsenopyrite</td>
<td>15.8</td>
</tr>
<tr>
<td>GUJW0027e</td>
<td>Quartz/sericite</td>
<td>Arsenopyrite</td>
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<td>GUJW0027g</td>
<td>Quartz/sericite</td>
<td>Arsenopyrite</td>
<td>15.9</td>
</tr>
<tr>
<td>GUJW0027h</td>
<td>Quartz/sericite</td>
<td>Arsenopyrite</td>
<td>15.7</td>
</tr>
</tbody>
</table>

Ohmoto and Rye (1979), stress that it is difficult to characterize the sulphur isotopic values of all potential reservoirs, because small changes in temperature, pH, and oxygen activity can induce profound changes in the sulphur isotopic values of indigenous or derived sulphur-bearing species. Significant fractionations can potentially occur at the fluid and sulphur source, during fluid migration and transport, and at the site of precipitation during rock fluid interaction. Given the specific environment of
the Springfield mineralization however, the most likely sources of sulphur, in terms of size and availability of reservoirs, include direct derivation from mantle fluids, leaching of primary and secondary sulphide minerals, and seawater sulphate.

The δ³⁴S value of Late Ordovician seawater sulphate is about 28% (Claypool et al., 1980). Fractionation values for bacterial reduction of seawater vary from as high as 40% in open systems to very low values in a closed system such as a deep marine environment. In the latter case, sulphate reduction would cause the δ³⁴S values of reduced sulphur to remain close to that of the contemporaneous seawater sulphate. Syngenetic sulphides with large positive values would be incorporated into volcaniclastic and volcanogenic deposits of the Burranah Formation in such a closed system.

Primary sulphides of the Burranah Formation volcanics and intrusives would have a δ³⁴S value close to that of magmatic sulphur. Hydrothermal fluids that obtained sulphur by decomposition of sulphides in igneous rocks would have δ³⁴S values close to those of the magmatic fluids (Ohmoto and Rye, 1979).

The δ³⁴S values of the hydrothermal arsenopyrites from Springfield define a single population with a narrow range between 15.6 and 16.1%. These values are inconsistent with a direct magmatic contribution but possible sources for the sulphur include the following:

1. Seawater sulphate reduced in a partial closed system with a ΔS ≈ -12%
2. Mixing during metamorphism and deformation of magmatic sulphur in the coherent volcanics and intrusives with seawater sulphate in the volcaniclastics and volcanoclastics.

Option (2) is the preferred option and is consistent with the interpretation of the lead isotopic data that also indicates that mixing, in response to hydrothermal events (metamorphic) was important.
DEPOSITIONAL MODEL

Host Rocks

Primary gold mineralization is hosted in rocks which range in age from Late Ordovician (Burranah Formation) to Early Devonian (diorites). Within these units, the structurally more competent lithologies are preferentially mineralized. These include diorites and monzodiorite intrusives and coherent volcanic rocks.

The host rocks have been metamorphosed to lower greenschist facies grade during regional deformation. Hydrothermal alteration associated with mineralization generally comprises a propylitic to phyllic assemblage of carbonate, chlorite, sericite, and quartz. These alteration assemblages suggest mesothermal temperatures of emplacement for the mineralization of about 200°C to 250°C. In many cases, hydrothermal alteration has been magnetite destructive and produced magnetic lows in areas of mineralization.

Structural Setting

Mineralization is mostly confined to a zone of higher regional strain between the Mudgee Fault and the Home Rule Fault. Within this zone gold mineralization occurs primarily in dilational and shear type extension veins. As such, the deposits are structurally controlled and directly related to fault systems. The distribution of gold mineralization is a function of the variably rheology of the host rock succession. The development of extension veins requires that the rock deform in a brittle manner.

The orientation of the faults, shear zones and veins within the district are consistent with those predicted by a dominantly dextral Reidel shear model.
Fluid Sources

The lead and sulphur isotope data are consistent with the interpretation that the ore-forming fluids are of metamorphic origin and are derived, along with the gold, from the host rock sequence.

Timing of Mineralization.

Similar styles of structurally controlled gold deposits are present in host rocks of the Late Ordovician Burranah Formation, the Late Silurian Dungaree Volcanics and the Early Devonian diorites. The ubiquitous and systematic association of the mineralization with faults and shear zones, and evidence regarding the timing and formation of mineralisation from lead isotope studies, suggests that orebodies are syndeformational, metahydrothermal in origin. The style and nature of the deformation within the area are consistent with the regional Early Carboniferous deformation responsible for the majority of folding, thrusting and cleavage formation in the northeastern Lachlan fold Belt. The age of the mineralization is regarded as Early Carboniferous.