Kempfield Silver, Barite and Base Metal (Pb-Zn) Deposit, Lachlan Orogen, Eastern Australia

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ABSTRACT

The Kempfield deposit is located in the Hill End Trough, one of several intracratonic basins developed during Silurian–Devonian time, in the eastern province of the Lachlan Orogen, Eastern Australia.

The deposit contains an oxide resource of 5.8 Mt @ 58 g/t Ag and a sulphide resource of 14.4 Mt @ 45 g/t Ag, 1.7 per cent Zn and 0.6 per cent Pb, classified and reported in compliance with the JORC Code. The deposit has been previously explored by a number of companies, including INCO, Shell, Jones Mining, Golden Cross Resources and recently Argent Minerals Ltd (Argent). Argent is currently completing a definitive feasibility study with a view to mining the deposit.

The deposit is hosted at the boundary between the Molong High to the west, comprising Ordovician sediments and volcanic rocks and the Hill End Trough to the east, interpreted as a back-arc basin containing Silurian sediments and siliceous-feldspathic volcanic rocks. The boundary between these two strato tectonic units is an imbricate thrust fault zone known as the Copperhannia Thrust.

The Kempfield deposit is hosted in felsic volcanic rocks known as the Kangaloolah Volcanics. These have been in-faulted and folded into the Middle Ordovician meta-sediments of the Coombing Formation of metasediments along the Copperhannia Thrust. The Kangaloolah Volcanics belong to the Late Silurian Mumbil Group, comprising submarine carbonate-shale facies interspersed with extensive felsic volcanic piles, which grade conformably upwards into turbiditic sandstone and siltstone sequences (interpreted to represent a deeper depositional environment). These turbiditic rocks are known as the Campbells Formation, comprising siltstone, sandstone and andesitic tuff. The rocks at Kempfield are metamorphosed to lower greenschist facies, reflected through the different type of schists.

Silver, gold, lead, zinc mineralisation is hosted in barite-rich horizons, near the boundary to quartz-phryic tuffaceous rocks in submarine, immature, reworked felsic ash tuffs. Barite appears to be hosted in greatest concentrations by the coarser grained volcanoclastic sandstones and grits, whilst intercalated siltstones are volumetrically minor and tend to return low barite and silver.

Mineralisation is hosted in stratiform and probably stratabound barite-rich horizons. A northeast-trending, steeply dipping, metamorphic cleavage (S₁) occurs throughout the project area.

INTRODUCTION

The deposit consists of three main and several small zones of generally disseminated mineralisation, with some higher grade plunging shoots, along a 3 km strike length of volcano-sedimentary sequence. These main zones are:

1. BJ Zone (Central) – a barite-silver rich zone (250 m × 100 m), interpreted as three mineralised plunging lenses.
2. The McCarron Zone (Southern) – two mineralised horizons over a strike length exceeding 800 m. These horizons consist of steep westerly-dipping mineralised zones, varying from 10 m to 25 m wide, of generally disseminated silver-lead-zinc and barite, with some narrow, more massive sulphide bands assaying up to 39 per cent combined lead-zinc.
3. Quarries Zone (Northern) – zone of high barite and silver content, centred on small barite quarries.

Remaining zones include: South Conglomerate Zone (low-grade silver-barite); Mather Zone (low-grade lead-zinc mineralisation); Hill Zone (high-grade barite and low silver) and Causeway Zone (low-grade gold-only mineralisation hosted in a silicified rhyolite).

The primary sulphide mineral assemblage comprises barite, pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, argentite, native silver and pyrrargyrite. Silver is present in galena, tetrahedrite, argentite, native silver and pyrrargyrite. The gangue is primarily barite (approximately 20 per cent of the ore mineralisation at a 40 g/t cut-off) with lesser quartz,

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The Kempfield deposit represents a classic barite-rich polymetallic volcanic hosted base metal sulfide (VHMS) deposit when consideration is given to the geotectonic setting of an intracratonic back-arc basin with host rocks of volcanic-volcanoclastic sequence, alteration and mineralogical assemblage, as well as metal zonation and cluster geometry of the deposit. Mineralisation is interpreted to have been deposited during submarine sedimentation in a subsiding basin in an area of felsic volcanic activity. The geology and mineral assemblage is consistent with a VHMS.

This paper represents a review of the Kempfield deposit, a silver barite-rich volcanic massive sulfide hosted in the Siluro-Devonian Hill End intra-arc basin of the Eastern Lachlan Orogen (Figure 1). The paper describes the structural and geological features and setting of the deposit and the mineralisation with alteration styles. It proposes a genetic model and compares it with other deposits in the Lachlan Orogen. In addition, resource, mining options and geomallurgy of the deposit are also discussed.

The Kempfield area was mined at the turn of the century for alluvial gold from terraces overlying and adjacent to the current silver-barite resources. Small-scale barite mining first commenced in 1918 and is still occasionally mined at up to 1500 tonnes per annum.

From 1971 to 1975, the Geological Survey of NSW undertook limited geological mapping and geochemical studies and International Nickel Australia Ltd commenced exploring for polymetallic base-metals, focussing on the drilling of a single stratigraphic horizon, which is now known as the Mather Zone.

The Shell Company of Australia Ltd explored the area for silver from 1979 to 1983 and discovered the silver rich BJ Zone. Jones Mining Ltd (1984 to 1985) undertook diamond drilling and a prefeasibility study for silver and barite on the BJ and Quarries Zones. Plutonic Operations Ltd evaluated existing data for gold in the early 1990s, as there is a low level of elevated gold within some zones.

Exploration by Golden Cross Resources between 1998 and 2007 identified a new mineralised zone (McCarron Zone) and expanded the resource in other zones by drilling in conjunction with metallurgical test work, regional and detailed geological mapping and geochemical sampling.

In recent time (2007 - 2011) Argent has undertaken a comprehensive exploration program, which has included a VTEM survey, pole-dipole IP survey and several drilling programs. Argent’s strategy resulted in an 80 per cent increase in resources and the company is now in the process of conducting a Definitive Feasibility study.

REGIONAL GEOLOGY

The Kempfield deposit is located in the eastern province of the Lachlan Orogen, which developed as part of a more than 1000 km wide orogenic system along the Pacific margin of the Australian craton during Palaeozoic time (Foster, Gray and Bucher, 1999).

The eastern province of the Lachlan Orogen is interpreted as a convergent margin terrane, dominated by mafic to felsic volcanic rocks and thick turbidite successions of Ordovician to Devonian age (Glen, 1998; Glen et al, 1995; Glen, 2002). During mid-Silurian to Middle Devonian time, a number of north-trending, back-arc rift basins formed in the eastern Lachlan Fold Belt, as a result of crustal extension (Glen, 2002). These basins include the Cobar Superbasin, Jemalong Trough, Tumut Trough, Cowra Trough and the Hill End Trough.

Depositional sequences in these back-arc basins are characterised by quartz-rich turbidites, felsic and mafic volcanic rocks, volcaniclastic rocks and black shales. The age of inversion and deformation of these back-arc basin sequences remains poorly constrained in the eastern Lachlan Fold Belt (Glen and Watkins, 1999). Middle to Late Devonian age (380 - 370 Ma) for greenschist facies regional metamorphism and cleavage development is characteristic for the Hill End Trough trough-fill and cover sequences. The Hill End Trough contains VHMS mineralisation in Late Silurian felsic volcanic and associated siliciclastic sedimentary rocks.

Within the Hill End Trough, the principal stratotectonic units hosting VHMS mineralisation include; the Campbell, Mumbil Group, Chesleigh Group and the Tannabutta Group (Figure 2) (Pogson and Watkins, 1998).

The Mumbil Group is interpreted as a shelf and slope sequence that outcrops extensively in two north-trending belts on either side of the Hill End Trough (Figure 2). On the western side of the trough, the Mumbil Group includes; the Anson Formation, Mullions Range Volcanics, Barraby Hills Shale and Gleneski Formation. The Anson Formation hosts VHMS mineralisation at the major Lewis Ponds deposit and the adjacent Mt Bulga deposit, as well as a number of small VHMS occurrences. Scott and Meankin (1998) described the Anson Formation, in the vicinity of the Lewis Ponds deposit, to include; pyritic and calcareous siltstone, limestone and rhyolitic volcanics towards the top of the sequence.

The overlying Mullions Range Volcanics, comprising volcaniclastic sandstone with minor trachytic and rhyolitic lavas, tuffaceous siltstone and volcanic breccia (Scott and Meankin, 1998), hosts the nearby Calula deposit. Further north, the siltstone and quartz crystal tuff of the Gleneski Formation is host to VHMS deposits in the Commonwealth mine area as a number of small VHMS and copper–zinc...
occurrences. On the eastern side of the Hill End Trough, the Bells Creek Volcanics (Mumbil Group) host a number of small VHMS and copper-zinc occurrences.

Undifferentiated sedimentary rocks of the Middle to Upper Silurian Campbells Group dominate the southern part of the Hill End Trough. This group comprises the Kangaloolah Volcanics, which comprise rhyolitic and dacitic volcanic rocks with feldspathic sandstone and siltstone (Raymond et al., 1998) and host barite-base metal mineralisation at Kempfield. Further south, in the Peelwood area, a number of base metal deposits (John Fardy, Peelwood and Cordillera, Elsinora) occur at the contact between the undifferentiated feldspathic sandstone, siltstone and slate of the Campbells Group and the felsic volcaniclastic rocks of the Kangaloolah Volcanics.

The Tannabutta Group, to the southeast of Mudgee, contains several base metal occurrences, including the Accost prospect (Figure 2). The mineralisation is associated with the Dungeree Volcanics, which comprise rhyolite to dacite lava, fine- to coarse-grained volcaniclastic rocks, conglomerate and limestone (Colquhoun et al., 1997).

Towards the eastern margin of the Hill End Trough, the felsic volcaniclastic rocks of the upper Chesleigh Group - Piambong Formation (Colquhoun et al., 1996) host massive

![Diagram](image-url)

**FIG 2** - Location of Kempfield and other volcanic hosted massive sulfides (VHMS) deposits and the distribution of Late Silurian felsic volcanic and related sedimentary units within and adjacent to the Hill End Trough, Eastern Lachlan Fold Belt. Geology adapted from the Bathurst (Raymond et al., 1998) and Dubbo (Morgane et al., 1999) 1:250 000 and Crookwell (Johnson et al., 2000) 1:100 000 map sheets.
sulfide mineralisation at Sunny Corner and the Belara deposit in the north of the region.

Critical to the development of VHMS mineralisation, the eastern Lachlan Fold Belt was subjected to prolonged crustal extension, in response to slab rollback at the leading edge of the palaeo-Pacific oceanic plate and a retreating subduction boundary (Collins, 2002).

**LOCAL GEOLOGY**

The Kempfield silver-barite VHMS deposit occurs within the Hill End Trough, on the east flank of the Molong High. The trough is a Siluro-Devonian back-arc basin (extensional trough) of clastic sediments and siliceous-feldspathic volcanics. The trough sequence is folded and faulted into the Ordovician basement of the Molong High along the Copperhania Thrust Zone. The Molong High to the west consists of Ordovician flysch (metasediments) and calc-alkaline to alkaline volcanics (Pogson and Watkins, 1998).

In the Kempfield area, the oldest (Ordovician) rocks belong to the Coombing Formation, which comprise tremolite schists, biotite hornfels, a porphyritic andesite and black carbonaceous slate (Figure 3).

Overlying these rocks are the Kangaloolah Volcanics, a felsic volcanic-derived sequence of sediments and minor volcanics which can be subdivided into three units:

1. A sequence of fine-grained and quartz-phyric tuffaceous rocks, in faulted contact with.
2. Volcanoclastic sedimentary rocks, which host silver-barite and lead-zinc mineralisation. The upper part of the sequence contains minor allochthonous crinoidal limestone/dolomite and massive barite and grades up into.
3. Unaltered barren siltstone.

The mineralised volcanoclastic sedimentary unit comprises poorly sorted, graded sandstones and grits with subangular to angular grains, locally with well-rounded pebble
conglomerates as well as primary tuffs. The unit is interpreted to represent submarine, immature, reworked felsic ash tuffs, probably located proximal to their source. Textures characteristic of submarine debris flows are common. The determination of protolith is, in places, obscured by later metamorphic and shear induced recrystallisation of barite.

Mineralisation is hosted in stratabound barite-rich horizons, which are interpreted to have been folded and reverse faulted within rocks now metamorphosed to middle greenschist facies. The apparent repetitions of horizons may be due to deformation and/or the presence of multiple mineralised layers within the original sequence. A northeast-trending, steeply dipping, penetrative, metamorphic cleavage (S1) occurs throughout the region, whilst, an east-dipping, consistently orientated S2 surface occurs as a fine crenulation with a consistent eastward vergence. An array of northwest-trending faults offset the mineralised sequences.

The mineralised barite-rich horizons occur near the boundary of the volcanoclastic sedimentary rocks and unaltered siltstone and can be traced over three kilometres of strike length (Figure 4).

Deformation occurred subsequently, with the development of a moderate to strong sericite/muscovite-defined foliation (representing S2 fabric) that wraps around the altered fragments.

**MINERALISATION**

Mineralisation at the Kempfield deposit can be separated into two geometallurgical domains; oxide (silver-barite) mineralisation and primary (sulfide) mineralisation.

Slight supergene oxidation effects were imposed on the oxide mineralisation, leading to the local development of goethite and jarosite. In the oxide zone chlorargyrite, native silver and argentite have been identified (Ashley, 2009). In addition, it is likely that anomalous silver and lead enrichment is associated with jarosite (Figure 5a). If there is a significant amount of supergene-affected rock, containing potentially ore grade silver values, then it is critical to ascertain the mineralogical location of the silver; that is, it could occur in metallic form (native silver), in jarosite (eg argentojarosite) and in silver halides (chlorargyrite - silver-chloride). The gangue is primarily barite with lesser quartz and sericite.

The primary (sulfide) mineral assemblage comprises pyrite, sphalerite, galena, chalcopyrite, argentite, tetrahedrite, native silver and pyrrargyrite. Pyrite is the main sulfide mineral, with traces of iron-poor sphalerite, silver sulfosalts (tetrahedrite, proustite-pyrrargyrite), galena and chalcopyrite. The galena mass also contains included pearceite-polybasite (Figure 5b and c). Iron-poor sphalerite and pyrite are commonly disseminated and locally form composite aggregates in places, with traces of galena and silver minerals, including pearceite- polybasite, proustite-pyrrargyrite and tetrahedrite (Figure 5d). Silver is present as native silver, argentite/acanthite and in galena. The gangue is primarily barite with lesser quartz and sericite. The mineralisation is dominated by disseminated grains and small aggregates of pyrite, though there is a little associated iron-poor sphalerite and traces of galena, tetrahedrite, argentite/acanthite and a ruby silver phase (eg proustite-pyrrargyrite), (Ashley, 2009).

Significant lead-zinc intercepts have been encountered at the McCarron Zone, along with low level gold and at depth in the BJ Zone. No significant copper has been identified as yet. Barite is abundant gangue in all zones, forming another part of the resource.

**Sulfur isotopes**

Sulfur isotope ratios assist in determination of the possible sources of sulfur in sulfides and sulfates. Burns and Smith (1976) reported δ34S ranges of 3 - 6 ‰ for galena, 4 - 8 ‰ for sphalerite, 8 - 10 ‰ for pyrite and for barite 29 ‰. Dowes and Seccombe (2004) found that the δ34S values range from 12.6 ‰ to 29.0 ‰ for barite and 2.0 – 17.4 ‰ for pyrite. Single analyses of arsenopyrite and galena gave δ34S compositions of 5.8 ‰ and 9.6 ‰, respectively (Figure 6).

Measured sulfur isotope signatures for sulfide mineralisation from the Kempfield deposit have general average δ34S values ranging from 5.4 ‰ to 8.1 ‰, similar to the Commonwealth, Cordillera, Peelwood and Sunny Corner deposits. These deposits appear to have formed from ore fluids that were more oxidising than deposits such as Lewis Ponds. The isotopic signature is considered consistent with a mixed contribution of sulfur derived from partial reduction of seawater sulfate in addition to sulfur from other sources (Dowes and Seccombe, 2004).

The 834S analysis of barite at the Kempfield deposit (eg Commonwealth) indicates a clear contribution from sulfate of...
seawater origin and Late Silurian age, with a $\delta^{34}$S composition commonly in the range of 23 - 31‰. Sulfate-sulfide isotope geothermometry indicates depositional temperatures near 350ºC for some barite-bearing deposits, although these results need to be treated with caution.

Lead isotopes
Three samples of galena minerals from the Kempfield deposits were collected for lead isotope studies (Dean, 1994). The median lead isotope ratios are: $^{206}$Pb/$^{204}$Pb = 18.037 (in range 18.037 to 18.044), $^{207}$Pb/$^{204}$Pb = 15.609 (in range 15.610 to 15.618) and $^{208}$Pb/$^{204}$Pb = 38.100 (in range 38.082 to 38.126). The lead isotopic ratios are given in Table 1 and plotted in Figure 7. The analysed galena samples show homogeneous lead isotope ratios which plot within the Currawang 95 per cent confidence ellipse and close to the galena samples from Burraga and some of the sulfide data from Lens 1 at John Fardy (Dean, 1994). A model age of $440 \pm 15$ Ma is calculated.

**FIG 5** - (A) Drill hole AKM01 at 24.4 m depth. Aggregates of goethite-stained, finely granular jarosite (orange-brown, with green and red speckles), hosted in barite (grey and white), with adjacent dark brown goethite mass (left). Transmitted light, crossed polars, field of view 1 mm across. Jarosite and goethite are potential hosts for silver and lead in supergene oxidised samples. (B) Drill hole AKM01 at 42.0 m depth. Portion of a small sulfide aggregate with subhedral pyrite grains (pale creamy) adjacent to sphalerite (mid grey) and proustite-pyargyrite (pale blue-grey with faint reddish internal reflections). Dark grey gangue includes barite and quartz. Plane polarised reflected light, field of view 0.2 mm across. (C) Drill hole AKM01 at 47.2 m depth. Grains of tetrahedrite (pale grey), one with chalcopyrite (yellow) inclusions and hosted in quartz and microcline (darker grey). Plane polarised reflected light, field of view 1 mm across. (D) Drill hole AKM04 at 26.0 m depth. Composite sulfide aggregate, hosted in barite and quartz (darker grey). Sulfides include host sphalerite (mid grey), galena (silvery) and silver sulfosalts (centre), including pearceite-polybasite (pale olive grey) and associated proustite-pyargyrite (faintly bluish-grey). Plane polarised reflected light, field of view 0.4 mm across.

**FIG 6** - Distribution of sulfur isotope values from the Kempfield deposit. Data reinterpreted from Burns and Smith (1976) and Downes and Seccombe (2004).
for the data based on the Lachlan Fold Belt plumbotectonics model presented by Carr et al. (1995).

The Kempfield lead isotope ratios are within the range of ratios determined for many examples of VHMS mineralisation within the Lachlan Orogen of NSW. Specifically, they plot at the low $\text{206Pb}/\text{204Pb}$ end of the range and have crustal $\text{207Pb}/\text{204Pb}$ and $\text{208Pb}/\text{204Pb}$ value. The lead isotopic signatures do not show evidence of any incorporation of mantle derived lead from shoshinitic units evidenced by lower $\text{207Pb}/\text{204Pb}$ and $\text{208Pb}/\text{204Pb}$ ratio, associated with the Cacula and Mt Bulga deposits (Carr et al., 1995). Consequently, based on the lead isotope signature, mineralisation forming the Kempfield deposit is most likely related to Silurian volcanism (Dean, 1994).

**DEPOSIT DESCRIPTION**

At Kempfield, seven zones of mineralisation have been identified along a 3 km strike length of mapped barite.

**TABLE 1**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>$\text{206Pb}/\text{204Pb}$</th>
<th>$\text{207Pb}/\text{204Pb}$</th>
<th>$\text{208Pb}/\text{204Pb}$</th>
<th>$\text{206Pb}/\text{204Pb}$</th>
<th>$\text{208Pb}/\text{204Pb}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kempfield 1</td>
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<td>0.8654</td>
<td>18.037</td>
<td>15.610</td>
<td>38.092</td>
</tr>
<tr>
<td>Kempfield 2</td>
<td>2.119</td>
<td>0.8653</td>
<td>18.032</td>
<td>15.604</td>
<td>38.082</td>
</tr>
<tr>
<td>Kempfield 2</td>
<td>2.129</td>
<td>0.8655</td>
<td>18.044</td>
<td>15.618</td>
<td>38.126</td>
</tr>
</tbody>
</table>

**FIG 7** - Conventional $\text{206Pb}/\text{204Pb}$ versus $\text{208Pb}/\text{204Pb}$ and $\text{207Pb}/\text{204Pb}$ versus $\text{206Pb}/\text{204Pb}$ isotope ratio plots comparing data from Kempfield (plotted as numbers) and ratios of VHMS mineralisation from the Hill End Trough (Carr et al., 1995). Ninety-five per cent confidence ellipses for Currawang and Woodlawn are shown. Dashed lines are the Lachlan Orogen model crustal curve defined by Carr et al. (1995) with age markers at 50 Ma intervals, with analytical precision shown in the upper left-hand corner of each plot.
horizons contained within the volcano-sedimentary sequence (Figure 8). Recent exploration activity has focused attention on three of these zones.

**McCarron Zone (Southern)**
The McCarron zone includes two or more mineralised zones over a strike length exceeding 800 m; McCarron West and McCarron East. The westerly steeply-dipping mineralised volcanoclastics horizon contains up to 25 m wide intervals of massive sulfides, locally with up to 15 per cent combined lead and zinc over narrow intervals in drill holes (Figure 8). This zone also exhibits elevated gold and copper values, which can be correlated with elevated copper values. The overall resource gold grades are averages 0.15 g/t Au. The mineralisation in this zone in general has a moderate (45°) plunge to the north, where it is transacted by a west-northwest trending subvertical fault. At the southern end of the deposit, mineralisation is transacted by a west-northwest trending subvertical fault (Figure 8).

**FIG 8 - Simplified geology of the Kempfield deposit.**
The McCarron zone contains 35 per cent of the tonnes, 27 per cent of the contained silver and 57 per cent of the contained lead and zinc estimated to occur within the Kempfield deposit.

**BJ Zone (Central)**
The BJ zone contains broadly developed, stratiform, silver-barite-rich mineralisation covering an area of 250 m × 100 m. The zone is interpreted to occur within the steeply west-dipping Kangaloolah Volcanics, containing three lenses which can be correlate barite horizons (Figure 9).

The BJ zone has returned intersections of 22 m at 195 g/t Ag and 0.21 g/t Au and 36 m at 2.3 per cent Pb and 2.0 per cent Zn including a 10 m zone of 150 g/t Ag, 1.83 per cent Pb, 4.06 per cent Zn and 0.44 g/t Au. High-grade lead and zinc mineralisation within the BJ Zone primarily occurs as fine-grained disseminations and poorly defined bands in altered phlogopite-Mg chlorite volcanoclastic rock. Silver occurs in sericitic altered, barite-rich volcanoclastic that locally may include thin allochthonous crinoidal limestone bands, above which follow baritic volcanoclastic, matrix-poor grits. Silver exhibits a moderate correlation with barite, at a >60 g/t cut-off Ag is largely enveloped by the >10 per cent Ba contour.

The BJ zone contains 42 per cent of the tonnes, 50 per cent of the contained silver and 23 per cent of the contained lead and zinc.

**Quarries Zone (Northern)**
The Quarries Zone represents the northern extension of the Kempfield deposit (Figure 8), characterised by high barite and silver grades in westerly steeply dipping lenses centred around small barite quarries. This zone extends in a north-easterly strike over 600 m with a width of 250 m, containing multiple barite (silver rich) lenses; Quarry South Zone, Quarry Zone, Bean Quarry Zone, Coopers Zone and Coopers North Zone. The Quarry South Zone is intruded by a rhyolite dome characterised by intense silicification and elevated gold grades. Overall, the structural style is reverse faulting along the NE trending westerly steeply-dipping faults of tight isoclinal folds axes (Figure 10).

The Quarries zone contains 23 per cent of the tonnes, 23 per cent of the contained silver and 20 per cent of the contained lead and zinc estimated to occur within the Kempfield deposit.

**Remaining mineralised zones**
The remaining mineralised zones are less significant contributors to the mineral resource and include (Figure 8):
- **The South Conglomerate Zone**, a narrow zone of low-grade silver-barite mineralisation extending southeast from the BJ zone for approximately 400 m.
- **The Causeway Zone**, where gold-only mineralisation is developed within a silicified rhyolite over a strike length of 300 m extending southwest from the Quarries Zone. One drill hole intersection in this zone 52 m at 0.37 g/t Au.
- **The Mather Zone** was the horizon originally tested by Inco Ltd, who encountered lead-zinc mineralisation over a strike length of 250 m west of the McCarron Zone. This zone is characterised with higher lead-zinc values (32 m at 3.5 per cent Zn, 0.57 per cent Pb and 22 g/t Ag).
- **The Hill Zone** contains high-grade barite and weak to moderate silver mineralisation over a strike length of 450 m on the south-eastern margin of the Kempfield deposit. One drill hole returned a 10 m intersection of 76.5 per cent barite.

**RESOURCE ESTIMATE**
A resource estimate of the silver-lead-zinc-barite resource at the Kempfield property has been undertaken by consulting
FIG 10 - Geology plan of the Quarries Zone.
geologists Hellman and Schofield Pty Ltd. Grades were estimated using Ordinary Kriging. The estimates for each zone are constrained by a specific geological model based on detailed logging of drill core and RC chips by Argent geologists, or by previous explorers data reviewed and verified by Argent geologists. Resource evaluation holes have generally been drilled on 25 m cross-sections and typically spaced 30 m apart on section lines. Grades were estimated using 3 m down hole composites into 5 m × 12.5 m (or 10 m) × 10 m blocks in easting, northing and elevation directions respectively.

This resource estimate is summarised in Table 2, which indicates that there is:

- 31.6 million ounces of contained silver, equivalent to 718 000 ozs of gold at a silver/gold ratio of 44 to 1;
- plus 30 000 ozs of contained gold;
- plus 175 000 tonnes of contained zinc as sulphide; and
- plus 86 000 tonnes of contained lead as sulphide.

Approximately 72 per cent of the sulphide resource are classified as Measured or Indicated. Approximately 88 per cent is classified as Measured or Indicated. The oxide and transitional resources, have lower average silver grades but contain 2.5 per cent combined lead/zinc. The much larger sulphide resources, lying below the oxide and transitional resources, have lower average silver grades (61.6 g/t) but contain 2.5 per cent combined lead/zinc.

MINING AND PROCESSING

The Kempfield operation would involve mining ore from the BJ, McCarron and Quarries zones with a combined tonnage waste to ore ratio of 1.4 to 1. The BJ and McCarron pits are the largest at 2.9 and 2.5 million tonnes respectively and are situated between 500 m and 600 m from the proposed plant site. The Quarries Zone would be mined using a number of smaller pits and is located about 1300 m from the plant site. The Quarries Zone is situated between 500 m and 600 m from the proposed plant site.

The scoping study envisages contract mining and is based on drill and blast for all ore and waste and grade control drilling on the ore. The cost of contract mining, at $11.34 per tonne of ore, is based on indicative prices supplied by a medium sized contractor.

The processing route for the oxide and transitional ore envisages crushing, grinding and agitated leaching, followed by silver/gold precipitation in a Merrill Crowe unit and the production of silver with gold credits dore bars, which would be sent off-site for refining and sale. The ore has a low work index of 7.0 and a relatively low abrasion index of 0.06. Metallurgical test work has indicated average silver and gold recoveries of 83 per cent and 85 per cent respectively for the oxide and transitional ores.

The processing route for the primary ore includes the leaching/Merrill Crowe/silver-gold dore process, followed by processing the leached tail through a flotation circuit to produce zinc and silver-rich lead concentrates (Figure 12). Bottle roll tests indicate that 63 per cent of the silver in the primary ore appears to be recoverable via agitated leaching. Flotation test work and both Quemscan and Microprobe analysis on the BJ primary ore indicates that approximately 80 per cent of the silver remaining in the leach tail could be recoverable to either lead or zinc concentrates, giving an overall recovery of the silver in that ore of approximately 93 per cent. Gold recoveries to the agitated leach circuit are estimated at 85 per cent.

Preliminary metallurgical test work on the BJ ore showed high mineral liberation and indicated that it should be possible to produce a silver-rich lead concentrate and a high-grade zinc concentrate by selective flotation.

| Table 2 | Summary of Kempfield resources. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Tonnes** | **Silver** | **Gold** | **Lead** | **Zinc** |
| **Grade** | **Contained Metal** | **Grade** | **Contained Metal** | **Grade** | **Contained Metal** | **Grade** | **Contained Metal** |
| **Million** | **g/t** | **M ozs** | **g/t** | **000 ozs** | **%** | **000 t** | **%** | **000 t** |
| **Oxide/Mixed cut-off grade 25 g/t Ag** | 5.8 | 58 | 10.8 | 0.1 | 19 | N/A | N/A | N/A |
| **Primary cut-off grade 50 g/t Ag Eq** | 14.4 | 45 | 20.8 | 0.1 | 46 | 0.6 | 86 | 1.2 | 175 |
| **Total** | 20.2 | 49 | 31.6 | 0.1 | 65 | N/A | 86 | N/A | 175 |
| **Table 3** | Kempfield resources – measured and indicated categories. |
| **Tonnes** | **Grade (g/t)** | **Grade (%)** |
| **Oxide and mixed** | **Million** | **Silver** | **Gold** | **Lead** | **Zinc** |
| Measured | 2.1 | 70.3 | 0.1 | - | - |
| Indicated | 2.7 | 52.4 | 0.1 | - | - |
| Inferred | 1.0 | 45.5 | 0.1 | - | - |
| **Primary** | **Measured** | 2.1 | 60.2 | 0.1 | 0.64 | 1.08 |
| Indicated | 7.5 | 45.7 | 0.1 | 0.59 | 1.21 |
| Inferred | 4.8 | 38.5 | 0.1 | 0.60 | 1.31 |

* Approximately 83 per cent of these resources are Measured or Indicated.
** Approximately 64 per cent of these resources are Measured or Indicated.
Leaching-plus-flotation tests on the BJ primary ore indicated 94.7 per cent total silver recovery from a head grade of 88 g/t Ag, 55 per cent lead recovery from a low head grade of 0.2 per cent Pb and 96.1 per cent zinc recovery from a head grade of 0.8 per cent Zn. These figures represent first-pass recoveries to a rougher concentrate. Ultimate lead and zinc recoveries and concentrate grades are yet to be confirmed by selective flotation test work. Consequently, the estimates used in the study and which underpin the viability of the project, ie that 88 per cent of the zinc would be recovered to a zinc concentrate grading 57 per cent zinc and that 51 per cent of the lead would be recovered to a lead concentrate grading 46 per cent lead, are best approximations available based upon the flotation test work conducted to date.

The leaching and flotation characteristics revealed by the tests on the BJ ores have been assumed to apply to ores from the McCarron and Quarries Zones. An important and early part of the definitive feasibility study work will be additional and extensive test work to confirm the scoping study’s leaching and flotation parameters. This will include leaching and precipitation tests on all ore types in each zone, as well as locked step flotation tests on the sulfide ores in each zone. An agitated leach/flotation plant may be capable of successfully treating a wider range of ores than a heap leach project, including gold ores sourced from the Kempfield area, or from the surrounding region.

Barite concentrates can also be produced with the addition of further float cells. The in-pit mining inventory at Kempfield...
is estimated to contain over 1 million tonnes of barite, though in the absence of a firm market for the product, the Scoping Study does not envisage or assign value to barite production. If a market for Kempfield barite was developed in the future, it could provide a valuable income stream for the project.

Previous metallurgical test work has shown that barite floats readily to produce an A grade product. However a market could not be developed without having access to a significant tonnage at a guaranteed grade. With the addition of extra float cells, a barite market could be developed to replace the barite presently sourced from overseas and thereby add a potentially valuable income stream for the Kempfield project.

CONCLUSION

The Kempfield deposit is a silver barite-rich polymetallic hosted base metal sulfide (VHMS) deposit, where the mineralisation is interpreted to have been deposited during submarine sedimentation in a subsiding basin in an area of felsic volcanic activity. The geology and mineral assemblage is consistent with a VHMS.

A definitive feasibility study is presently underway to confirm the robust results indicated by the recent Scoping Study. A large program of drilling has started to confirm and expand the resource and detailed metallurgical studies of the individual zones are being undertaken. Concurrent with these programs will be the work required to obtain all the necessary approvals leading to the opening of a new mine at Kempfield.

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REFERENCES


Dean, A J, 1994. A metallogenic Assessment of Mineralisation at the Kempfield Prospect, near Turnkey NSW, based on the Pb Isotopic Composition of Galena, Exploration and Mining report 33C.


