

# The Wyoming gold deposits: volcanic-hosted lode-type gold mineralisation in the eastern Lachlan Orogen, Australia

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**Abstract** The eastern Lachlan Orogen in southeastern Australia is noted for its major porphyry–epithermal–skarn copper–gold deposits of late Ordovician age. Whilst many small quartz vein-hosted or orogenic lode-type gold deposits are known in the region, the discovery of the Wyoming gold deposits has demonstrated the potential for significant lode-type mineralisation hosted within the same Ordovician volcanic stratigraphy. Outcrop in the Wyoming area is limited, with the Ordovician sequence largely obscured by clay-rich cover of probable Quaternary to Cretaceous age with depths up to 50 m. Regional aeromagnetic data define a north–south trending linear belt interpreted to represent the Ordovician andesitic volcanic rock sequence within probable Ordo-Silurian pelitic metasedimentary rocks. Drilling through the cover sequence in 2001 to follow up the trend of historically reported mineralisation discovered extensive alteration and gold mineralisation within an andesitic feldspar porphyry intrusion and adjacent volcanoclastic sandstones and siltstones. Subsequent detailed resource definition drilling has identified a substantial mineralised body associated with sericite–carbonate–albite–quartz–( $\pm$ chlorite  $\pm$  pyrite  $\pm$  arsenopyrite) alteration. The Wyoming deposits appear to have formed as the result of a rheological contrast between the porphyry host and the surrounding volcanoclastic rocks, with the

porphyry showing brittle fracture and the metasedimentary rocks ductile deformation. The mineralisation at Wyoming bears many petrological and structural similarities to orogenic lode-style gold deposits. Although the timing of alteration and mineralisation in the Wyoming deposits remain problematic, a relationship with possible early to middle Devonian deformation is considered likely.

**Keywords** Tomingley · Wyoming gold deposits · Lode gold · Lachlan Orogen

## Introduction

The Wyoming gold deposits are situated in the Central West Region of New South Wales near the small town of Tomingley, within the eastern sector of the Lachlan Orogen (Fig. 1). This region hosts several world-class late Ordovician porphyry gold–copper deposits such as Cadia (Holliday et al. 2002) and Northparkes (Heithersay and Walshe 1995), as well as epithermal carbonate-base metal gold deposits such as Cowal (Bywater et al. 2004). Historically, most gold production came from relatively small, high-grade quartz-vein gold deposits, which are hosted in a range of rock types ranging in age from Ordovician to Carboniferous (Suppel and Scheibner 1990).

The Peak Hill gold deposit, located 12 km to the south of Wyoming and hosted by the same Ordovician andesitic volcanic sequence, is a high-sulphidation epithermal gold–copper deposit (Masterman et al. 2002; Squire et al. 2006). The deposit was discovered in 1898, mined to 1917 and then redeveloped in 1996, with ore-mined and current resources totalling around 750,000 oz of gold. A small deposit, Myall's United, was also discovered near the town of Tomingley about the same time and mined in the period

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1895–1914. Geological knowledge of this deposit is limited but two parallel, near vertically dipping quartz veins were mined for their high-grade gold to a depth of 200 m, producing 70,000 oz of gold (Clarke and Sherwin 1990).

Recent exploration in the region around Peak Hill focussed on a potential porphyry source for the epithermal mineralisation, but success was limited by the extensive Cretaceous to Quaternary cover. Exploration was also directed at the Myall's United area, but was again limited by the extent of the transported cover, which restricted the use of traditional surface geochemical techniques (Scott et al. 2003).

Reconnaissance drilling through deep cover (>30 m) immediately to the north-northwest of the Myall's United mine located extensive areas of alteration and gold mineralisation. Subsequent reverse circulation and core drilling has identified a resource of 600,000 oz of gold to a depth of about 300 m.

The cover and total reliance on drill data have restricted the development of a three-dimensional model for and the geological history of what is a complex system of alteration and veining. This paper presents a preliminary summary of the preliminary understanding of the broader geological parameters of the gold deposits at Wyoming.

### Regional geological setting

The Wyoming gold deposits are located in the eastern zone of the early Palaeozoic Lachlan Orogen in eastern Australia. The Lachlan Orogen is composed of a complex association of early Cambrian to early Devonian sedimentary, volcanic, and intrusive rocks. These sequences developed in a setting that has been interpreted to have similarities to modern southwest Pacific oceanic island arc and back-arc basin environments (Glen et al. 1998; Gray et al. 2002; Gray and Foster 2004). Based on a structural and lithostratigraphic criteria, the Lachlan Orogen has been divided into three provinces, namely the Western, Central and the Eastern belts (Gray and Foster 2004).

The Western Belt is largely a turbiditic sequence, which hosts the major 'slate belt' type orogenic/epigenetic gold mineralisation, including the 17-million oz Bendigo goldfield. The Central Belt is also dominated by turbidites but also hosts granite-associated tin–tungsten–molybdenum deposits in its southern portion, whilst orogenic gold and base metal deposits in extensional basins around Cobar predominate in the northern part of the Central Belt, including the 2-million oz Peak gold mine (Stegman 2001). Both the Western and Central belts appear to have developed in back-arc environments, with the Eastern Belt representing the magmatic and fore arc environments (Gray and Foster 2004). This setting has

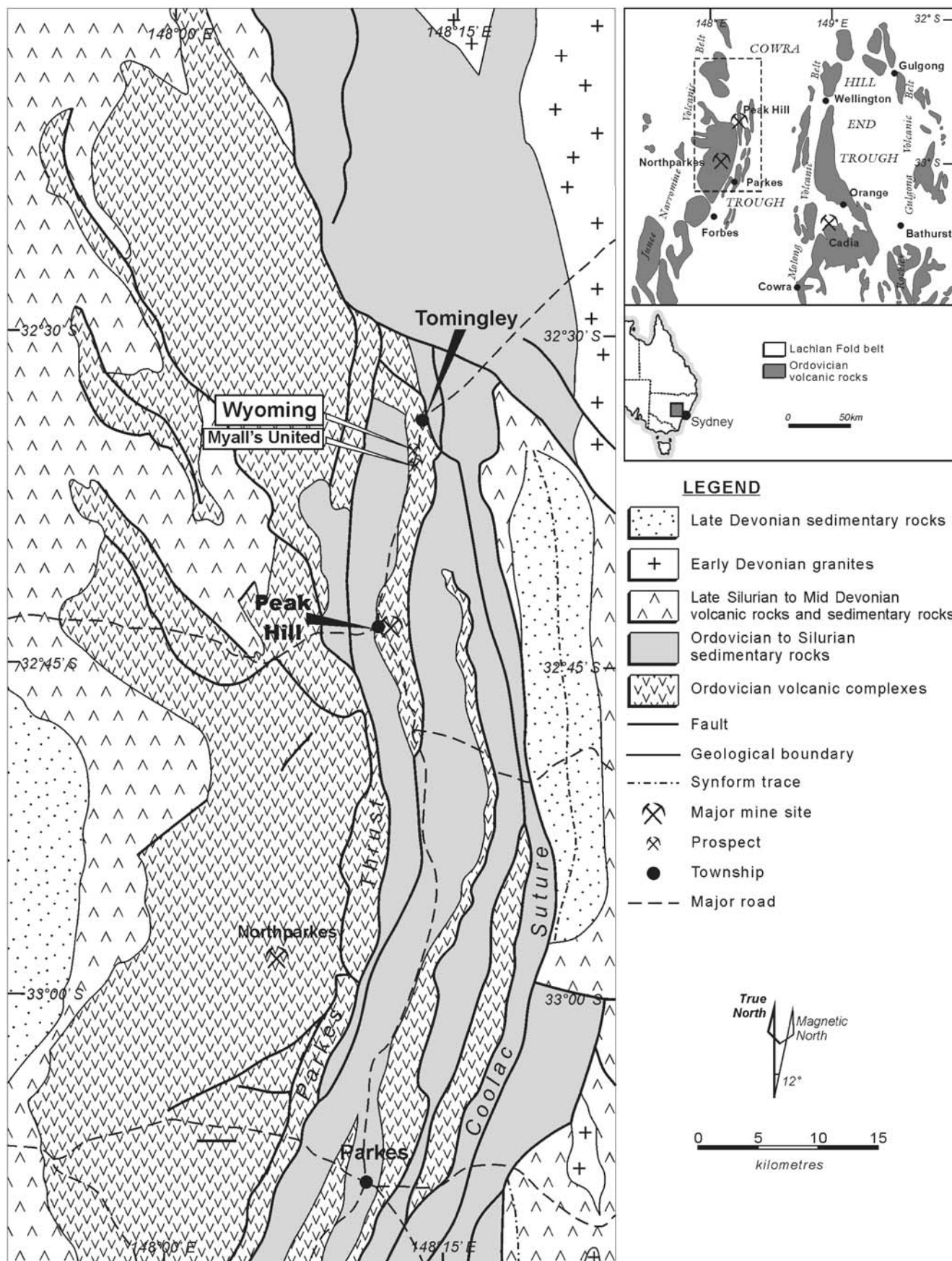
**Fig. 1** Regional geological interpretation of the Wyoming area; figure is a simplified lithostratigraphic map with the overlying cover sequences removed

been named the Macquarie Arc (Glen et al. 1998, 2004) and hosts porphyry–epithermal bodies, including the world-class 30-million oz deposits at Cadia and Ridgeway.

Within the Macquarie Arc, several individual belts of mafic to intermediate volcanic, intrusive, volcanoclastic and turbiditic rocks have been identified. These sequences are segmented by a number of generally north–south to north–northwest trending arc-parallel structures, many of which are thought to be thrust faults with either west or east vergence, or major strike-slip faults (Glen et al. 1998). Glen et al. (1998) have suggested that the Macquarie Arc initially formed as one composite oceanic island arc or volcano-sedimentary prism, which was subsequently dislocated by major thrusting and extensional rifting to form the three discrete volcanic belts (i.e. Junee–Narromine, Molong, Rockley–Gulgong volcanic belts; Fig. 1) that are observed today (Glen et al. 1998).

The volcanic belts comprise Ordovician to early Silurian rocks with predominantly mafic to andesitic composition and display a spectrum of rock types including lavas, breccias, volcanoclastic sandstone and siltstone, and monzonitic to dacitic intrusions associated with the porphyry copper–gold systems. The three principal volcanic belts are characterised by near-vertical, upright intrusive complexes situated within relatively undisturbed, flat-lying stratigraphy with broad open folds. By contrast, the marginal and inter-belt areas are more structurally disturbed with tight to isoclinal folding in apparent thrust-segmented slices.

The Wyoming deposits are located near the eastern margin of the Junee–Narromine volcanic belt, just east of the interpreted Parkes Thrust. This structure separates the flat-lying Goonumbla volcanic complex from a thin slice of north–south trending andesite rocks (Fig. 1). These volcanic rocks have been identified by regional aeromagnetic data and are interpreted by us to be equivalents of the Goonumbla volcanics (previously named Mingelo volcanics). The late Ordovician (Darriwilian to Bolindian) Goonumbla volcanic rocks are overlain by metasedimentary rocks thought to be equivalents of the Llandoverly (early Silurian) Cotton formation (Sherwin 1996). Although this author suggested that the Cotton formation may have been contemporaneous with deposition of the Goonumbla volcanics, Squire et al. (2006) have suggested that differences in detrital composition and biostratigraphy mean the units are distinctly different and may be part of the Silurian Forbes group. Presently, there are no data to support either argument at Wyoming, although where mapped, the metasedimentary rocks consist of well-bedded fine quartzose sandstone and laminated siltstone.



The Cotton formation is unconformably overlain by the middle Silurian Forbes group, which is dominated by sandstone and cobble conglomerate in its lower members, with overlying finer-grained mudstones and siltstones. Cotton formation and Forbes group outcrop both to the east and west of the north–south trending andesitic assemblage, suggesting that the slice of Goonumbla volcanics form an anticlinal ridge between Peak Hill and Tomingley.

The deformation history of the Lachlan Orogen is complex and reflects multiple events. Glen (2004) suggested the use of ‘cycles’ to encompass extensional, depositional and magmatic events, as well as the contractional deformation of the rock packages. Glen (2004) proposed that the Lachlan ‘Supercycle’ be divided into three cycles called Lachlan 1, 2, 3, or, alternatively, given names of their terminating deformations. Based on this subdivision, Glen (2004) defined the Benambran cycle (490–443 Ma), Tabberabberan cycle (442–380 Ma) and Kanimblan cycle (380–320 Ma).

The Ordovician rocks west of the Parkes thrust are weakly deformed, with broad open folds and sub-greenschist metamorphic assemblages (Sherwin 1996). In contrast, the Ordovician to Silurian sequences east of the fault, including the rocks hosting the Wyoming deposits, exhibit tight to isoclinal folding, strong axial planar cleavage with greenschist metamorphic assemblages. Glen (1992) suggested that the deformation of these sequences was part of the Tabberabberan and occurred towards the end of this cycle (i.e. Lachlan cycle 2) at 380 Ma (mid-Devonian). Cycle 2 also includes the Ordovician magmatic and depositional sequences in the Junee–Narromine and Molong belts that are host to major porphyry copper–gold systems.

Northwest-trending transverse structures are also evident in regional magnetic and gravity data and rarely as faults that are mappable in outcrop. These structures appear to be long-lived, crustal-scale breaks that were irregularly reactivated throughout the geological development of the Eastern Belt. The structures also show a relationship to intrusive centres and mineralisation, with these structures intersecting and occasionally offsetting arc-parallel structures (Squire and Miller 2003).

## Wyoming geology

The immediate Wyoming area is almost entirely covered by Quaternary to Cretaceous alluvial sequences of clays, sand and gravel. This cover reaches a thickness of up to 50 m in the central part of the Wyoming mineralisation, but Ordovician rocks are evident in waste dumps at the Myall’s United mine, 1.5 km to the south of the Wyoming prospect, and also crop out at the historic gold workings at Tomingley, 2 km to the north of Wyoming.

The Wyoming gold deposits are hosted within volcanoclastic rocks, rare lavas and shallow intrusive porphyritic rocks. The volcanic units are of trachy-andesite to basaltic trachy-andesite in composition, with very rare detrital quartz in the volcanoclastic rocks. These volcanoclastic rocks are dominated by well-bedded sandstones and siltstones with minor breccias, lithic conglomerates and black mudstones. The dominant sandstones and siltstones have a primary composition of plagioclase and augite, but are now largely altered to sericite, carbonate, chlorite, and albite, with rare primary quartz. The sequences that host the Wyoming gold deposits show textural and compositional affinities to rocks that host the Peak Hill high-sulphidation epithermal gold–copper deposit (Masterman et al. 2002; Squire et al. 2006).

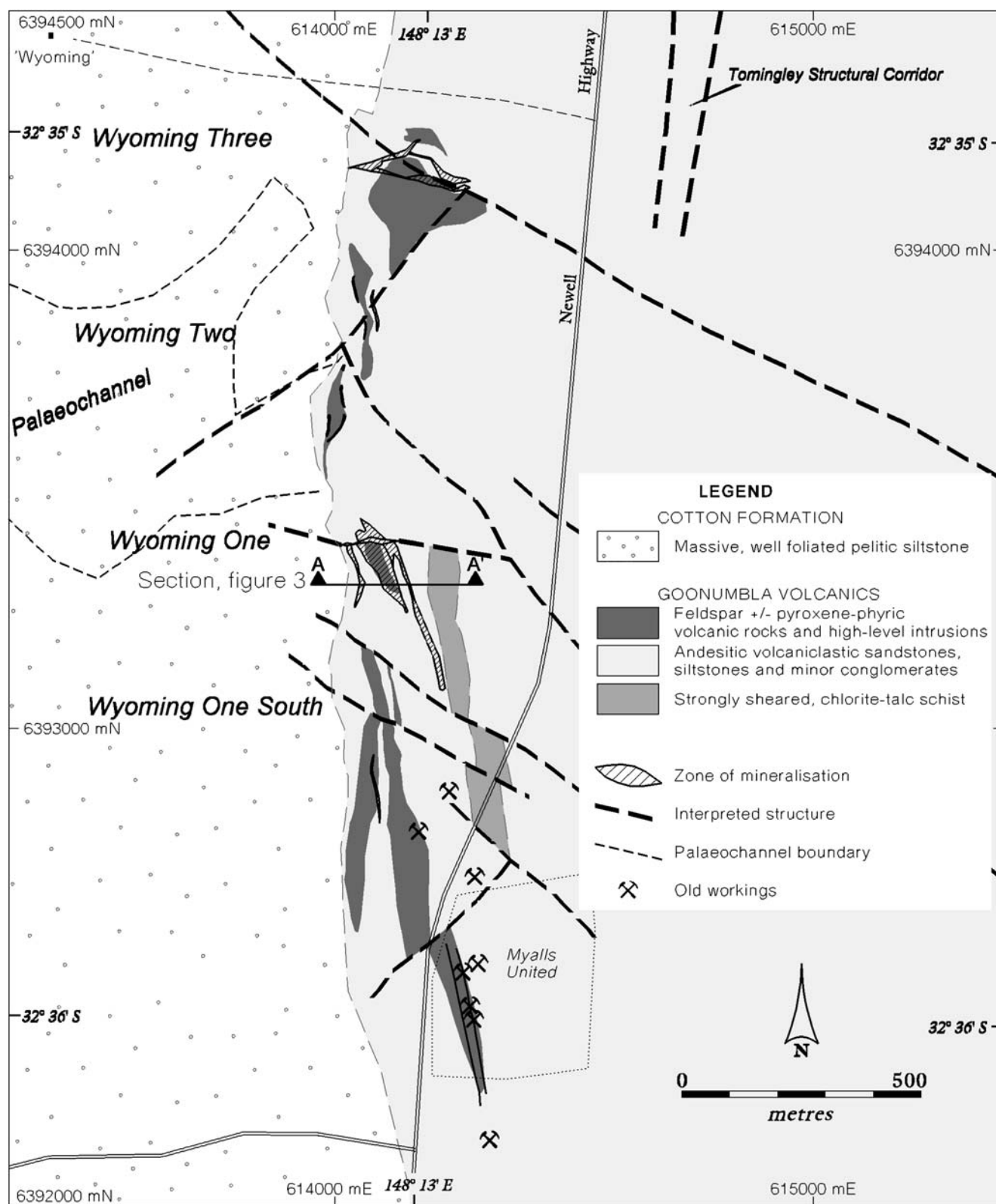
The volcanoclastic units are intruded by numerous coarse feldspar ± augite porphyritic bodies of trachy-andesitic to mafic trachy-andesite affinity. These bodies are weakly concordant to the bounding metasedimentary rocks and are interpreted as sills. The identification of rare peperitic textures suggests that the intrusions were emplaced at a relatively shallow level. Hydrothermally altered, narrow tholeiitic dolerite dykes similar to those elsewhere in the region are also present and are probably related to an Early Silurian extensional phase in the development of the Cowra Trough (A. Crawford, personal communication 2004; see Fig. 1). An up to 50-m thick unit of apparently concordant chlorite–talc schist was also located by drilling just to the east of the porphyry sills. The extent of this highly foliated unit was not determined and it may have a mafic–ultramafic precursor, similar to olivine-rich lavas (picrites), which are known from the Molong Belt (A. Crawford, personal communication, 2004).

To the west, the andesitic volcanoclastic sequence is in contact with well-foliated, fine-grained metasedimentary rocks that have been interpreted to correlate with rocks of the Ordo-Silurian Cotton formation (Sherwin 1996). The planar contact does not appear to be faulted. The eastern margin of the volcanoclastic sequence is uncertain.

A number of feldspar porphyry sills have been identified by drilling over a 2-km north–south strike length. The sills have a close spatial association with gold mineralisation and appear to have been a focus for hydrothermal alteration. From north to south, these zones of gold mineralisation have been designated Wyoming Three, Two, One, Wyoming One South, and Myall’s United (Fig. 2).

## Structure

Due to the cover sequence at Wyoming and limited core drilling, a detailed deformational history of the Wyoming deposits cannot be determined at present. However, a

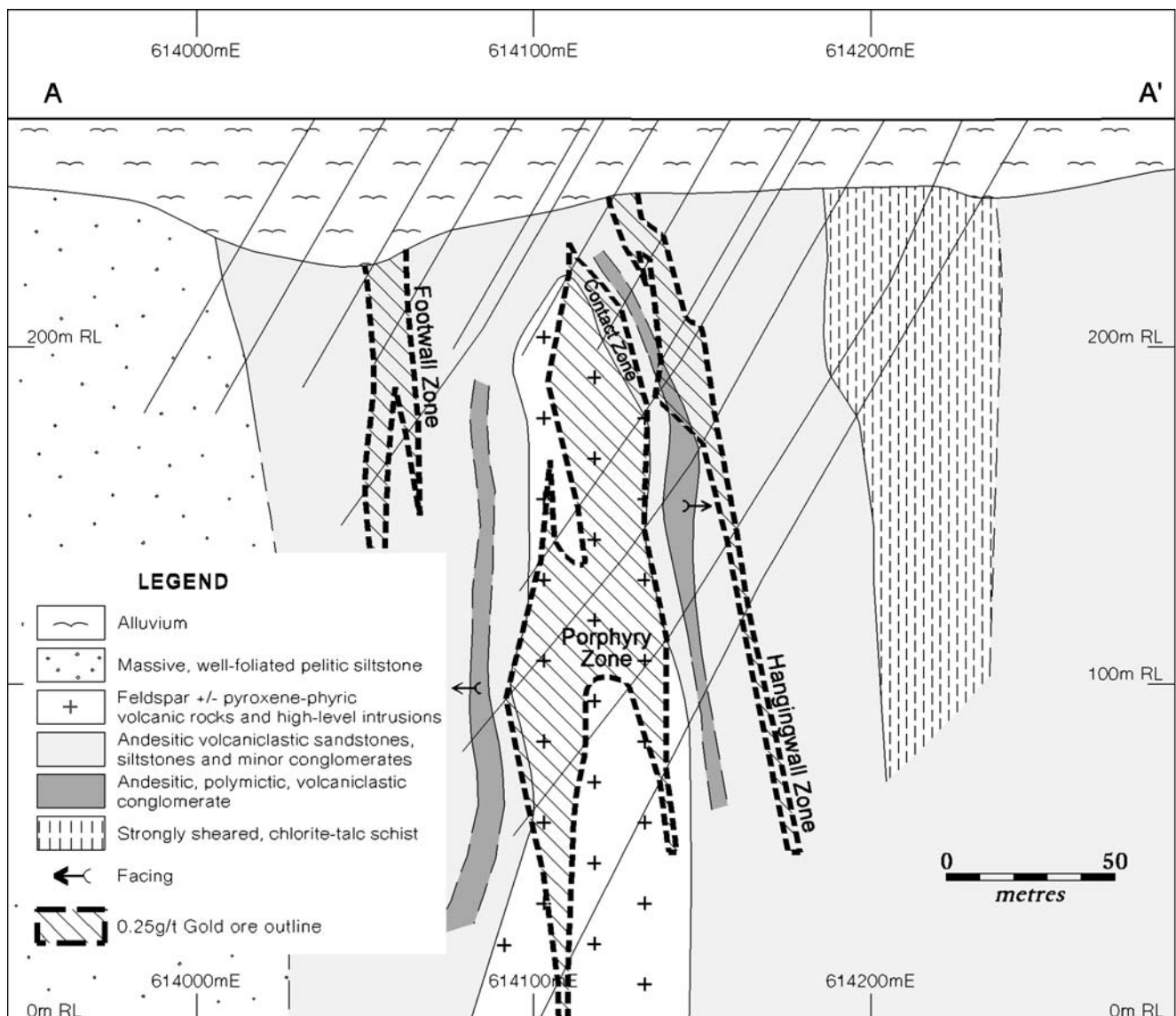


**Fig. 2** Simplified geology of the Wyoming prospect. Interpretation of the bedrock geology showing the distribution of the major rock units and gold mineralisation

number of empirical observations have been recorded from orientated drill core. The andesitic volcanoclastic sequence strikes north–northwest and dips steeply to the east. On the eastern side of the Wyoming One feldspar porphyry, the bedding also youngs to the east. There is limited evidence from west of the porphyry that the sequence there youngs to the west. This observation suggests that the structure may be a tight, easterly vergent antiform with the feldspar porphyry located near the axis of the fold (Figs. 2 and 3). The currently known boundaries of the porphyry indicate a shallow southerly plunge, but this may reflect the original geometry of the intrusion rather than a structural overprint. Foliations are largely parallel to bedding and have been interpreted to represent an axial plane cleavage.

Within the massive feldspar porphyry, brittle fracture is dominant and a number of vein directions are evident. Major structures are orientated west–northwest, as exemplified by the near-vertical fault that defines the northern end of the porphyry ('376' zone) and several sub-parallel vein sets within this porphyry. A set of shallowly north-dipping veins also have a west–northwest to east–northeast strike.

The measured stress regime could indicate a fundamental east–west compression to generate the tight stratigraphic folding, whereas the distribution of alteration and the relative timing of the mineralising event(s) suggest a later, more complex fluid focussing stress field with brittle and ductile characteristics.



**Fig. 3** Vertical east–west cross section of the Wyoming One prospect showing rock units and mineralisation interpreted from drilling data

## Mineralisation

Mineralisation has been identified over a 2-km strike length, but to date, evaluation of the deposits has focussed on the Wyoming One and Three areas.

### Wyoming One

Gold mineralisation at Wyoming One is distributed both around the edges of and within a sub-vertical, south-plunging, feldspar  $\pm$  augite–phyric sill. The deposit has been separated into four distinct mineralised zones, namely the porphyry zone, contact zone, hangingwall zone, and 376 zone. A brief outline of these different zones is presented below.

#### *Porphyry zone*

The bulk of the Wyoming One deposit is hosted within the feldspar  $\pm$  augite–phyric intrusion, covers a near-surface area of about 60 by 150 m, and averages 1.5 to 2.0 g/t gold. Gold mineralisation is associated with quartz  $\pm$  carbonate  $\pm$  albite  $\pm$  pyrite  $\pm$  arsenopyrite veins within intense sericite–carbonate–albite–quartz–( $\pm$ chlorite  $\pm$  pyrite  $\pm$  arsenopyrite) alteration.

The strong porphyritic texture of the intrusion is well-preserved. Plagioclase phenocrysts are completely albitised, whereas augite phenocrysts have been altered to chlorite and carbonate minerals. The intense sericite–carbonate alteration assemblage in the groundmass gives the rock a distinct bleached khaki green appearance. Zones of broad gold mineralisation near the surface correlate well with vein intensity and pervasive groundmass alteration. However, at deeper levels (below 200 m vertical depth), intense alteration in the porphyry is restricted to quartz vein selvages, with only moderate to low alteration of the host rock. Analysis of oriented drill core indicates a relationship between vein orientation and gold grades.

#### *Contact zone*

The contact zone is characterised by high-grade gold mineralisation within volcaniclastic rocks along the immediate eastern contact of the feldspar porphyry. Within the shallow sections of the deposit, this zone is over 10 m thick, extends 100 m north–northwest and is frequently associated with grades in excess of 5 g/t Au. The style and nature of the contact mineralisation and alteration are essentially identical to that of the porphyry zone.

#### *Hangingwall zone*

The hangingwall zone (HWZ) lies approximately 30 m east of the porphyry contact and is probably stratigraphically

controlled by a fine-grained carbonaceous mudstone. This linear zone extends over a strike length of at least 300 m and widths of up to 15 m. To the north of the prospect, the HWZ appears to converge with the porphyry contact, suggesting a slight discordance of the intrusive. Unlike the porphyry and contact zones, the HWZ displays hydrothermal brecciation textures of quartz–arsenopyrite  $\pm$  sericite, in addition to quartz  $\pm$  sulphide  $\pm$  rare adularia veins, and distinctive white carbonate and green chlorite ‘spotting’. High-grade mineralisation ( $>5$  g/t Au) within the HWZ is characterised by coarse arsenopyrite and minor pyrite up to 10 mm in size.

#### *376 structure*

The northern contact of the Wyoming One porphyry is sharply terminated by a west–northwest striking, quartz-vein dominant, high-grade gold zone ( $>5$  g/t Au) termed the 376 structure. This structure ranges from 2 to 10 m in width, extends for about 100 m east–west, and contains up to 20% quartz in veins or as quartz–arsenopyrite breccia. Based on structural evidence, the 376 structure is interpreted to represent a dilated fault plane. The best grades and ore zone thickness appear to be restricted to where the structure is in contact with the porphyry. The zone is characterised by an intense sericitic selvage within the metasedimentary rocks on the northern side of the structure.

### Wyoming Three

Gold mineralisation at Wyoming Three also shows a strong spatial relationship with feldspar porphyritic rocks. In contrast to Wyoming One, however, pervasive alteration is limited to absent from mineralisation that is hosted within structurally controlled quartz  $\pm$  carbonate  $\pm$  chlorite  $\pm$  pyrite  $\pm$  arsenopyrite veins. Minor sericite alteration selvages and restricted zones of chlorite spotting can be observed.

Mineralisation is localised within three to four separate quartz-rich lodes, which strike about  $105^\circ$  and dip steeply to the north and appear to be controlled within an anastomosing shear zone about 50 m wide. This structure can be traced for several hundred metres, but is only mineralised over a length of 250 m. The lodes grade 2.0 to 2.5 g/t Au and are hosted within both the feldspar–phyric and aphyric volcanics, as well as fine-grained volcaniclastic siltstones.

## Discussion

Significant gold occurrences within the Macquarie Arc are typically of magmatic origin, such as at Northparkes, Cadia and Peak Hill (Walshe et al. 1995; Bierlein et al. 2002).

However, a magmatic origin for the Wyoming deposits is considered unlikely due to the absence of significant base metals (copper, lead and zinc), as well as other magmatic indicators such as molybdenum and bismuth. Although the Wyoming deposits are largely associated with an intrusive lithology (i.e. porphyry sills), there is a notable absence of iron-oxide alteration (magnetite and haematite), which is ubiquitous within porphyry–magmatic gold–copper mineralisation in the Lachlan Orogen in New South Wales (Heithersay and Walshe 1995; Holliday et al. 2002). Likewise, the Wyoming deposits lack the extensive advanced argillic alteration of the host volcanic/volcaniclastic sequence characteristic of, for example, mineralisation at Peak Hill (Degeling et al. 1995; Masterman et al. 2002; Squire et al. 2006).

Groves et al. (2003) proposed a broad classification for gold deposits found within metamorphic belts and documented the characteristics that define the orogenic lode type. These deposits form within accretionary prisms that are integral parts of the evolution of subduction-related accretionary or collisional terranes. However, several issues regarding the genesis of orogenic gold deposits remain problematic, such as the source of fluids and metals, the architecture of the hydrothermal systems (particularly the relationship between first- and lower-order structures), and the specific depositional mechanisms.

The majority of the turbidite-hosted orogenic lode gold deposits of the western Lachlan Orogen formed synchronously with regional metamorphism and thrusting between 455 and 440 Ma, with remobilisation and secondary phases of mineralisation occurring between 420 and 400 Ma (Bierlein et al. 2002). The porphyry copper–gold deposits and associated skarn and epithermal systems of the Macquarie Arc in the eastern Lachlan Orogen formed during magmatic activity between 440 and 420 Ma (Perkins et al. 1995; Bierlein et al. 2002).

The structurally controlled London-Victoria gold deposits near Parkes (Lyons et al. 2000), located 60 km to the south of Wyoming, are the closest (spatial) analogy to the Wyoming deposits in terms of host rocks and alteration mineralogy. However, the shear-hosted vein deposits at London-Victoria are situated near the contact of the andesitic volcanic sequence and finer-grained metasedimentary rocks (Cotton formation?). Clarke and Sherwin (1990) proposed that the competency contrast between the volcanic and metasedimentary rocks focussed fluid into dilatant sites, with gold mineralisation being introduced late in the deformational history. These authors proposed that the London-Victoria mineralisation was post-Silurian and that the gold was sourced from late Ordovician shoshonitic volcanic rocks. By contrast, Carr et al. (1995) argued that although the London-Victoria mineralisation is hosted by late Ordovician volcanic rocks, the lead isotope signature of

the deposit indicated that lead was sourced from both the Ordovician mantle-derived shoshonites and younger sedimentary rocks. On the basis of that data, Carr et al. (1995) suggested an early Devonian age (400 Ma) for the mineralising event.

Without definitive data, it seems probable that the Wyoming deposits formed towards the end of the Tabberabberan (Lachlan cycle 2) between 400 and 380 Ma as a result of regional deformation.

## Conclusions

Gold mineralisation at Wyoming has few documented affinities with the typical Ordovician, magmatically derived Cu–Au deposits identified elsewhere in the Lachlan Orogen in New South Wales. Instead, the style of mineralisation and associated sericite–carbonate–albite–quartz alteration assemblage are more typical of orogenic lode style gold deposits.

Within the Wyoming One deposit, the mineralised fluids are interpreted to have been focussed by differential strain in and around feldspar porphyry sills as a result of the rheological competency contrast between the sills and the bounding volcanic rocks. The distribution of elevated gold grades ( $\geq 5$  g/t Au) appears to be correlated with increases in the competency gradient (i.e. contact zone) and the occurrence of internal cross structures that are sub-parallel to the ore zones within the feldspar porphyry body (i.e. 376 zone).

Whilst the timing of hydrothermal alteration and gold mineralisation, source(s) of the fluids and metals, and the distribution of the local stress regime at Wyoming remain unresolved, the deposits can be classified as lode-type gold mineralisation on the basis of their geological, petrological and structural characteristics. Although the deposits are hosted in Ordovician andesitic volcanic rocks and a magmatic input to the mineralising event cannot be discounted, gold mineralisation at Wyoming possibly occurred not until regional deformation and metamorphism related to the Tabberabberan in the early to middle Devonian.

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## References

- Bywater A, Williams S, McInnes P, Dijkmans V (2004) Developments at the Cowal gold project. In: Bierlein FP, Hough, MA (eds)

- Tectonics to mineral discovery—deconstructing the Lachlan Orogen. Proceedings Volume and Field Guide, MORE-SGEG Conference, Geological Society of Australia Abstracts No. 74, Orange, NSW, 6–8 July, 2004, pp 77–82
- Bierlein FP, Gray DR, Foster DA (2002) Metallogenic relationships to tectonic evolution—the Lachlan Orogen, Australia. *Earth Planet Sci Lett* 202:1–13
- Carr GR, Dean JA, Suppel DW, Heithersay PS (1995) Precise lead isotope fingerprinting of hydrothermal activity associated with Ordovician to Carboniferous metallogenic events in the Lachlan fold belt of New South Wales. *Econ Geol* 90:1467–1505
- Clarke I, Sherwin L (eds) (1990) Geological setting of gold and copper deposits in the Parkes area, New South Wales. Geological Survey of New South Wales Records 23, Sydney
- Degeling PR, Corbett GJ, Leach TM (1995) The Peak Hill high sulphidation gold deposit NSW. In: Mauk JL, St-George JD (eds) Proceedings of the 1995 PACRIM congress; Exploring the rim. Australasian Institute of Mining and Metallurgy, pp 175–180
- Glen RA (1992) Thrust, extensional and strike-slip tectonics in an evolving Palaeozoic orogen; a structural synthesis of the Lachlan Orogen of southeastern Australia. *Tectonophysics* 214:341–380
- Glen RA (2004) Plate tectonics of the Lachlan Orogen: a framework for understanding its metallogenesis. In: Bierlein FP, Hough MA (eds) Tectonics to mineral discovery—deconstructing the Lachlan Orogen. Proceedings volume and field guide, MORE-SGEG conference, Geological Society of Australia Abstracts No. 74 Orange, NSW, 6–8 July, 2004, pp 33–36
- Glen RA, Walshe JL, Barron LM, Watkins JJ (1998) Ordovician convergent-margin volcanism and tectonism in the Lachlan Sector of east Gondwana. *Geology* 26:751–754
- Glen RA, Crawford AJ, Cooke DR, Percival IG, Meffre S, Scott RJ, Squire R, Barron LM (2004) The Macquarie Arc: a key component of the Ordovician and earliest Silurian tectonics of the Lachlan Orogen. Geological Society of Australia Abstracts No. 73, p 162
- Gray DR, Foster DA (2004) Tectonic evolution of the Lachlan Orogen, southeast Australia: historical review, data synthesis and modern perspectives. *Aust J Earth Sci* 51:773–817
- Gray DR, Foster DA, Bierlein FP (2002) Geodynamics and metallogeny of the Lachlan Fold Belt. *Aust J Earth Sci* 49:1041–1056
- Groves DI, Goldfarb RJ, Robert F, Hart CJR (2003) Gold deposits in metamorphic belts: Overview of current understanding, outstanding problems, future research, and exploration significance. *Econ Geol* 98:1–29
- Heithersay PS, Walshe JL (1995) Endeavour 26 North: a porphyry copper–gold deposit in the Late Ordovician, shoshonitic Goonumbla Volcanic Complex, New South Wales, Australia. *Econ Geol* 90:1506–1532
- Holliday JR, Wilson AJ, Blevin PL, Tedder IJ, Dunham PD, Pfitzner M (2002) Porphyry gold–copper mineralisation in the Cadia District, eastern Lachlan fold belt, New South Wales, and its relationship to shoshonitic magmatism. *Miner Depos* 37:100–116
- Lyons P, Raymond OL, Duggan MB (eds) (2000) Forbes 1:250,000 geological sheet SI55-7, 2nd edn. Explanatory Notes. Australian Government Survey Organisation Record 2000/20
- Masterman GJ, White NC, Wilson CJL, Pape D (2002) High-sulphidation gold deposits in ancient volcanic terranes: insights from the mid-Palaeozoic Peak Hill deposit, NSW. *Soc Econ Geol Newsl* 51:9–16
- Perkins C, Walshe JL, Morrison G (1995) Metallogenic episodes of the Tasman Fold Belt System, eastern Australia. *Econ Geol* 90:1443–1466
- Scott KM, Chalmers DI, Ransted T, Kairaitis R (2003) Wyoming gold deposit, Central Western NSW. In: Butt CRM, Cornelius M, Scott KM, Robertson IDM (eds) *Regolith expressions of Australian Ore Systems*, CRC LEME, Perth. Available at <http://www.crcleme.org.au/RegExpOre>
- Sherwin L (1996) Narramine 1:250 000 Geological Sheet SI/55-6: explanatory notes. Geological Survey of New South Wales, Sydney
- Squire RJ, Miller JML (2003) Synchronous compression and extension in East Gondwana; tectonic controls on world-class gold deposits at 440 Ma. *Geology* 31:1073–1076
- Squire RJ, Herrmann H, Pape D, Chalmers DI (2006) Evolution of the peak hill high-sulphidation epithermal Au–Cu deposit, eastern Australia. *Miner Depos* (in press)
- Stegman C (2001) Cobar deposits: still defying classification. *Soc Econ Geol Newsl* 44(1):15–26
- Suppel DW, Scheibner E (1990) Lachlan Fold belt in New South Wales—regional geology and mineral deposits. In: Hughes FE (ed) *Mineral deposits of Australia and Papua New Guinea*. The Australasian Institute of Mining and Metallurgy, Melbourne, pp 1321–1327
- Walshe JL, Heithersay PS, Morrison GW (1995) Toward an understanding of the metallogeny of the Tasman fold Belt system. *Econ Geol* 90:1382–1401