# CARGO PORPHYRY Cu-Au DEPOSIT – WHERE IS THE HIGH GRADE CORE?

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**SUMMARY**

The Cargo Copper-Gold Porphyry deposit lies within the world class porphyry belt of the Ordovician Macquarie volcanic arc. It is one of several porphyry complexes in the Lachlan Orogen including Cadia Valley (42.8 MOz Au), Northparkes, Cowal and Copper Hill.

The Cargo Porphyry Intrusive Complex is a calc-alkaline suite of late Ordovician age (467 Ma) intrusives comprising quartz monzodiorite and diorite intruded by coeval andesitic and trachy-andesitic volcanics. The most prominent NW trending structural zone is characterised by areas of strong silicification, pyritisation and tectonic brecciation together with stockwork and sheeted quartz veining. It is up to 300 m wide bounded on the southern side by a major 60° SW dipping normal fault and on the Northern side by 75° SW dipping shear zones.

Mineralization and alteration is zoned from a western core of fracture controlled, potassic altered porphyry (Cu-Mo-Au) to a peripheral zone of phyllic altered gold rich quartz-sulphide veining up to 200 m wide, surrounded by an outer propylitic zinc rich halo.

The peripheral zone of Cargo contains gold rich sheeted quartz veins which hosted 14 small gold workings in the late 1800's. Two lode systems, Dalcoath and Spur, have JORC inferred resource of 4 Mt @ 1.19g/t gold for 154,000 Oz Au.

A classically zoned porphyry Cargo's geochemical footprint is comparable in size to the famous Bingham Canyon and the Bougainville Panguna deposits despite the fact that Cargo's porphyry deposits' western half has been faulted away.

**Key words:** porphyry, copper, gold, Macquarie volcanic arc, Ordovician volcanic arc, calc-alkaline suite.

## INTRODUCTION

The Cargo Copper-Gold porphyry deposit is lies within the world class porphyry belt of the Ordovician Macquarie volcanic arc. It is a low-grade porphyry system among the world class deposits such as Cadia Valley (42.8 MOz Au) Northparkes, Cowal and Copper Hill deposits.

Cargo deposit lies 15 kilometres west of the world class Cadia Valley gold-copper porphyry deposit currently being mined by Newcrest. Exploration activity at Cargo in recent years has evaluated a low grade copper mineralised core and two of approximately 19 lode systems that occur around a central porphyry that hosts low-grade copper mineralisation.

Gold resource was estimated at Spur and Dalcoath in May 2012 by H&S Consultants (ASX announcement 21 May 2012) using a range of gold cut-offs and compliant with JORC 2004 guidelines. At 0.8 g/t gold cut-off, the Inferred Resource was 4.0 Mt grading 1.19 g/t gold containing 154,000 ounces of gold. The estimation parameters excluded some intercepts of higher grade gold due to the low quality of historical drilling (GCR, 2013). These intercepts have the potential to add significantly to contained ounces once they are confirmed by further drilling.

The western half of Cargo's porphyry complex has been faulted away and a large high-grade core is missing. The eastern portion contains a small, approximately 200m diameter, potassic altered porphyry with significant drill intersections such as 108m averaging 0.52% copper, 0.22 g/t gold and in a deeper hole 546m averaging 0.11% copper, 0.07g/t gold and 58 ppm molybdenum.

The intention of this paper is to highlight the fact that there is a potentially valuable high-grade core somewhere along strike that could be discovered by modern deep looking geophysics.

## Regional geological setting

The Cargo porphyry system is hosted in the Ordovician to Early Silurian Macquarie Arc which hosts some of the world's highest-grade porphyry mineralisation at Ridgeway of 73 Mt @ 1.76 g/t Au, 0.62 % Cu for 4.1 Moz Au, 0.45 Mt Cu as part of the largest porphyry-related gold resources at Cadia Valley of 42.8 MOz Au. Economically, the most significant porphyry deposits in the Macquarie Arc are those of alkalic porphyry gold-copper deposits such as those in Cadia Valley and Northparkes districts (Figure 1). The arc also contains calc-alkalic porphyry gold-copper deposits at Copper Hill, Marsden and Cargo, skarns at Big Cadia and Browns Creek, high sulfidation gold – (copper) at Peak Hill, and quartz-pyrite-carbonate-base metal-style epithermal gold deposits at Lake Cowal.

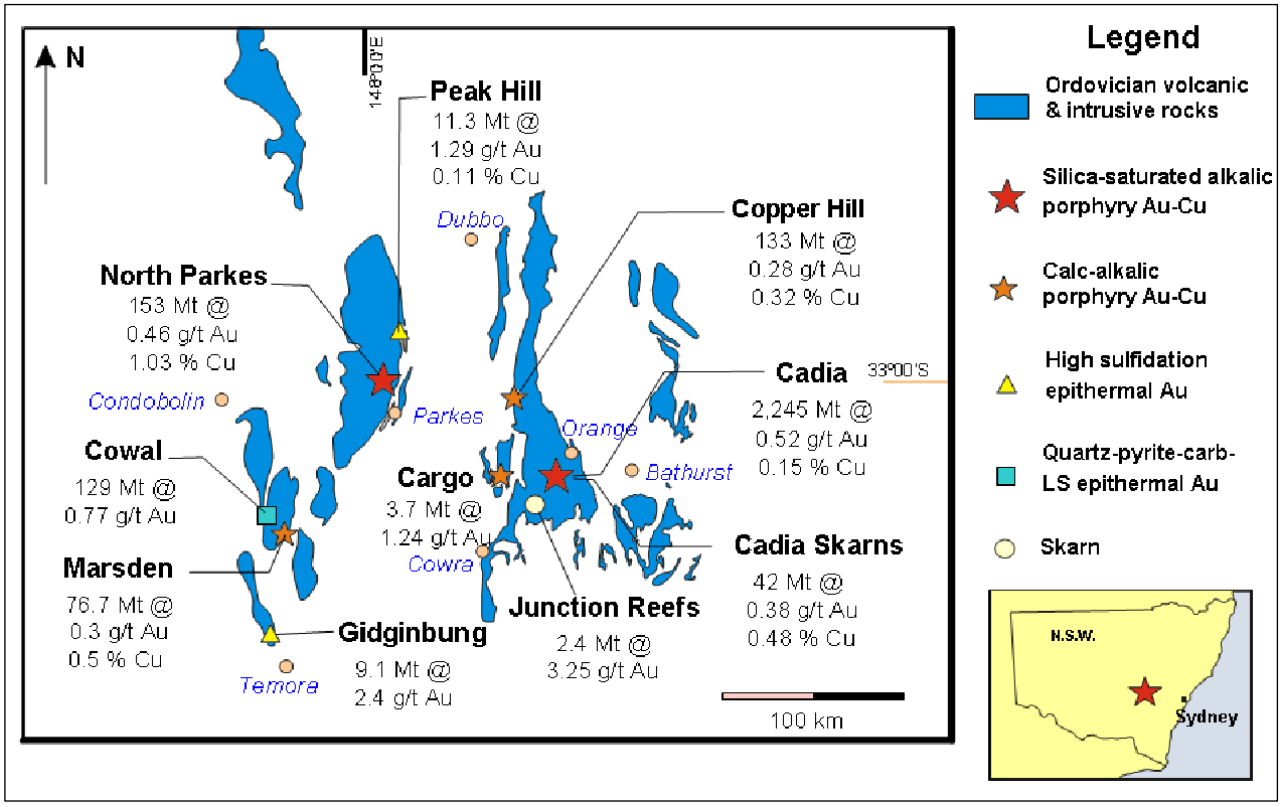


**Figure 1. Porphyry copper-gold deposits in Macquarie arc belt, after Cook et al., 2009.**

Crawford et al. (2007) and Glen et al. (2007) interpreted four phases of magmatism occurring during the evolution of the Macquarie Arc. Cook et al (2009) interpreted gold (± copper) mineralisation to be associated with these magmatic phases and group deposit according to geochemistry of intrusive suite and associated hydrothermal alteration into five groups:

1. Lake Cowal Group represent with quartz – carbonate – pyrite – base metal epithermal gold deposits;
2. Alkalic porphyry gold-copper group - Cadia and Northparkes districts;
3. Calc-alkalic porphyry copper-gold Group - Copper Hill, Cargo and Marsden;
4. High-sulphidation gold-copper deposits - Peak Hill and Gidginbung; and
5. Skarn deposits.

Quartz – carbonate – pyrite – base metal epithermal gold deposits. The Lake Cowal is the biggest and most important deposit with a pre-mining resource of 129 Mt @ 0.77 g/t gold (Figure 1). Deposit is hosted by Cowal Volcanic Complex within Junee-Narromine Belt, an early Ordovician subaqueous volcano-sedimentary succession that has been intruded by multiple sills. The intrusions range in age from ~460 to ~440 Ma. (Cook et al 2009) and alteration features point to a possible alkalic porphyry affinity, possibly implying a 440 Ma timing of ore formation (Zukowski et al., 2007). The system consists of gold-rich quartz-carbonate-pyrite-base metal sulphide veins associated with sericite-carbonate-pyrite alteration. Pyrite, sphalerite and galena are the most abundant base metal sulphide minerals. Alteration facies include potassic, calc-potassic, phyllic and propylitic mineral assemblages. Early hydrothermal alteration produced actinolite-magnetite-albite-chlorite and garnet-epidote-carbonate assemblages. Syn-mineralisation alteration facies are characterised by K-feldspar, sericite (muscovite/illite), chlorite, epidote and arsenopyrite, whereas late alteration comprises epidote-carbonate-prehnite. The hydrothermal system evolved from early high-temperature actinolite-magnetite-albite-chlorite and garnet alteration and vein facies, characteristic of an alkalic porphyry environment, to assemblages more typical of an epithermal style gold deposit (e.g. quartz, carbonate, chalcedony, adularia, gold, sphalerite, galena and illite) (Corbett and Leach

(1998). Some workers (Bywater et al., 2004) consider the Cowal gold deposits to belong to the orogenic ('mesothermal') class of ore deposits.

The Cadia and Northparkes districts are major complexes of silica-saturated alkalic porphyry gold-copper porphyries in Macquarie Arc (Figure 1). Exploration and mining at Cadia dates back more than 140 years to the discovery of copper and gold mineralisation in 1851. Modern exploration commenced in the 1950's, culminating with the discovery of the Cadia Hill by Newcrest geologists in late 1992 (Wood and Holliday, 1995). At Cadia Valley, a total of four alkalic porphyry gold-copper deposits have been identified: Ridgeway, Cadia Hill, Cadia East and Cadia Quarry/Cadia Extended) with mineralised zone ~2 km long, 600 m wide and >1500 m in vertical extent. Cadia Valley is world's sixth largest porphyry deposit with total resources of 2.3 billion tonnes at 0.44 g/t Au and 0.28 % Cu. Mineralisation and alteration was centred on monzonite pipes at Ridgeway, and dykes at Cadia East and occurs within larger monzonite plutons at Cadia Hill and Cadia Quarry in form of sheeted and stockwork of quartz – sulfide – carbonate veins associated with biotite – tourmaline – chlorite ± albite – chalcopyrite alteration (Holliday et. al., 2002).

The first porphyry-related copper-gold mineral occurrence in the Parkes district was discovered in 1976 (Jones, 1985). Subsequent exploration led to the discovery of several other mineralized intrusions in the area, which have a total combined resource of 131.7 Mt @ 1.12 % copper and 0.51 g/t gold. Hydrothermal alteration at the Northparkes porphyry copper-gold deposits is typically restricted to within ~750 m of the quartz monzonite intrusive complexes and occurs in both the intrusive and volcanic rocks. Early albite alteration was followed by widespread biotite-magnetite alteration of the volcanic wallrocks (Lickfold et al., 2003).

Calc-alkalic copper-gold porphyry deposits Copper Hill, Cargo and Marsden were emplaced during a time of regional uplift, erosion and limestone deposition, possibly associated with an arc-reversal event (Glen et al., 2007). Copper Hill was the site of the first production of copper in NSW (1845), and is currently being explored by Golden Cross Resources Ltd. A resource of 133 Mt @ 0.28 g/t gold, 0.32 % copper has been identified. Mineralisation is associated with an adakite-like suite of medium-K calc-alkalic rocks. Copper Hill is an unusual porphyry copper-gold deposit in that palladium is enriched over intervals of tens of metres in some drill holes. Covered by 100m of clay-rich transported alluvium, the Marsden calc-alkalic porphyry copper-gold deposit was discovered in 1997 by Newcrest Mining Ltd. It contains 76.7 Mt @ 0.3 g/t gold, 0.5 % copper. Mineralisation is hosted in the Marsden intrusive complex, which is and has been truncated at depth by a low-angle thrust fault which has juxtaposed Ordovician and Devonian rocks.

High sulphidation gold-copper deposits are Peak Hill and Gidginbung (Temora) deposits hosted in in the Junee-Narromine Volcanic. These deposits comprise highly deformed zones of advanced argillic alteration, characterised by pyrophyllite, alunite and muscovite. These deposits probably have formed during phase 4 magmatism circa 440 Ma (e.g., Perkins et al., 1995), although some workers (Allibone, 1997, 1998) have advocated a younger (Devonian) syn-deformation age for high sulphidation mineralisation. Gold was first discovered on Peak Hill in 1889. By 1917, approximately 0.6 million ounces of gold was extracted from the upper 150 m of the system. More recent exploration and mining by Alkane Resource Ltd led to a further 153,000 ounces being recovered from the oxide resource with the sulphide resource (11.27 Mt @ 1.29 g/t gold and 0.11 % copper) remaining largely intact. Gold mineralisation at Peak Hill is atypical of high-sulphidation epithermal deposit, whereby ore (>5 g/t gold) is located on the margin of a core of advanced argillic alteration assemblages. The core of the deposits lacks extensive zones of residual, vuggy quartz, and is instead dominated by a pyrophyllite (± diaspore) alteration zone ~350 m wide and at least 550 m long, which grade outwards through paragonite-muscovite to kaolinite with chlorite-epidote at the margins (Squire et al., 2007).

Skarns deposits. There are several mineralised skarns known as Big Cadia and Little Cadia copper-gold-iron skarns in the Cadia District, which are intimately associated with last phase magmatism and alkalic porphyry deposit formation (Cook et al, 2009). This skarn belt also hosts the Junction Reefs and Browns Creek gold skarns, both of which were mined for gold in the past twenty years.

## Cargo geology and mineralisation

The Cargo Porphyry Intrusive Complex is a calc-alkaline suite of late Ordovician age (467Ma) intrusives comprising quartz monzodiorite and diorite to quartz diorite which intrudes coeval andesitic and trachy-andesitic volcanics.

The Middle to Lower Upper Ordovician Cargo Volcanics represents a sequence of basaltic to dacitic lavas, lava breccias and associated volcaniclastic rocks with medium-K calc-alkaline affinities has been interpreted as the subaqueous portion of a major intra-oceanic arc stratovolcano. The oldest part of the succession consists of massive to pillowed, poorly vesicular, aphyric to moderately plagioclased massive and pillowed vesicular andesite and dacite, flanked by lenses of hyaloclastite, pillow breccias and interbedded with debris-flow and turbiditic deposits of crystal-rich and pebbly volcanic sandstones, siltstone and minor conglomerate (Simpson, et al 2007). The Cargo Volcanics are interpreted to have undergone major eastward translation at this time (from an original position now buried beneath the Cowra Trough (Simpson, et al, 2007).

The Cargo Volcanics are intruded by Cu–Au mineralised, plagioclase+hornblende+quartz-phyric dacites with medium-K calc-alkaline affinities. These dacites are compositionally similar to Late Ordovician to Early Silurian (453 – 441 Ma) dacites at Copper Hill (Simpson, et al 2007).

The dacites at Cargo are intruded by small, apparently unmineralised monzonite intrusions with shoshonitic affinities of porphyritic granodiorite and syenite-quartz monzonite porphyry (Figure 2). Simpson et al (2007) described Cargo in detail subdividing them into

four main suites of intrusions: (i) dacite; (ii) a monzonite suite; (iii) medium- to coarse-grained dolerite dykes; and (iv) fine-grained basaltic dykes.

The largest structure is the Cargo Fault which truncates the mineralised system. The Cargo Fault can be traced for a strike-length of over 15 km. Contacts between lithological units in the area are interpreted to be faults. A strong downdip lineation, indicating east – west-directed dip - slip displacement, is locally developed on steeply dipping foliation surfaces within a > 20 m wide, north-trending shear zone between the lowermost basaltic andesite pillow lava and younger volcaniclastic rocks. Field relationships suggest displacements of at least a few tens of metres to perhaps a few hundred metres on the larger faults in the Cargo area (Simpson et al, 2007), and probably could give an answer as to where the Western mineralised portion might have ended up.

Folds in the Cargo Volcanics are generally trending from NNE to NNW, open to tight, and commonly trend parallel to the strike of adjacent larger faults. Bedding in the Cargo Volcanics has moderate dips (20° – 40°), but particularly adjacent to the larger faults, bedding dips much more steeply (60° to 80°).

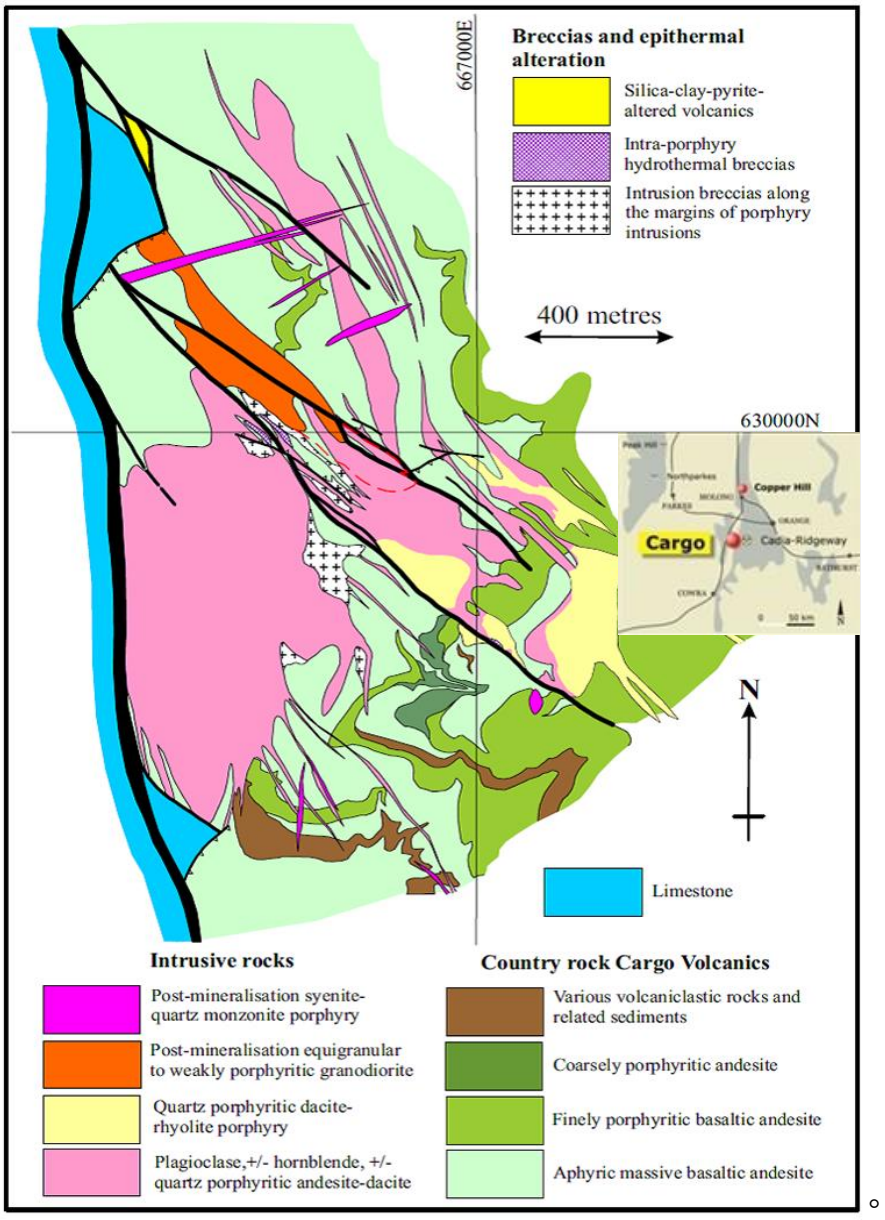


**Figure 2. Cargo mineralised porphyry system – geology (GCR archive).**

The most prominent NW trending structural zone is characterised by dacite porphyries, alkalic intrusives and areas of strong silicification, pyritisation and tectonic brecciation together with stockwork and sheeted quartz veining. Mineralisation and alteration is zoned from a western core of fracture controlled, potassic altered porphyry Cu-Mo-Au to a peripheral zone of phyllic altered gold

rich quartz-sulphide veining up to 200 m wide, surrounded by an outer propylitic zinc rich halo (Figure 3). Torrey and White (1998) recognised four distinct paragenetic stages:

- Stage 1 - magmatic alteration characterised with albitite, biotite, magnetite and secondary K-feldspar during potassic alteration.
- Stage II - magmatic hydrothermal alteration characterised by stockwork and sheeted quartz veins containing K-feldspar. In addition, biotite and magnetite alteration also occurs during this stage.
- Stage III - hydrothermal alteration and mineralisation, distinguished by intense development of chlorite and sericite associated with pyrite. Chalcopyrite and gold are deposited late in this stage and molybdenite locally overgrows these minerals. Strong silicification occurs proximal to major structures.
- Stage IV is the post mineral weathering along open fractures and includes weathering minerals smectite, kaolinite, jarosite, minor covellite and gypsum.

Gold mineralisation occurs peripheral to this, as radiating sulphide lodes within the surrounding andesite (Figure 3). The peripheral zone contains 14 gold rich sheeted quartz vein systems which hosted small gold workings in the late 1800's and have not all been systematically drilled. Two of the lode systems, Dalcoath and Spur, have been sufficiently drilled to support a JORC based inferred resource of 4 million tonnes grading 1.19g/t gold at a 0.8g/t cut-off containing 154,000 ounces of gold to a depth of 180 metres (Figure 3) (GCR, 2013).

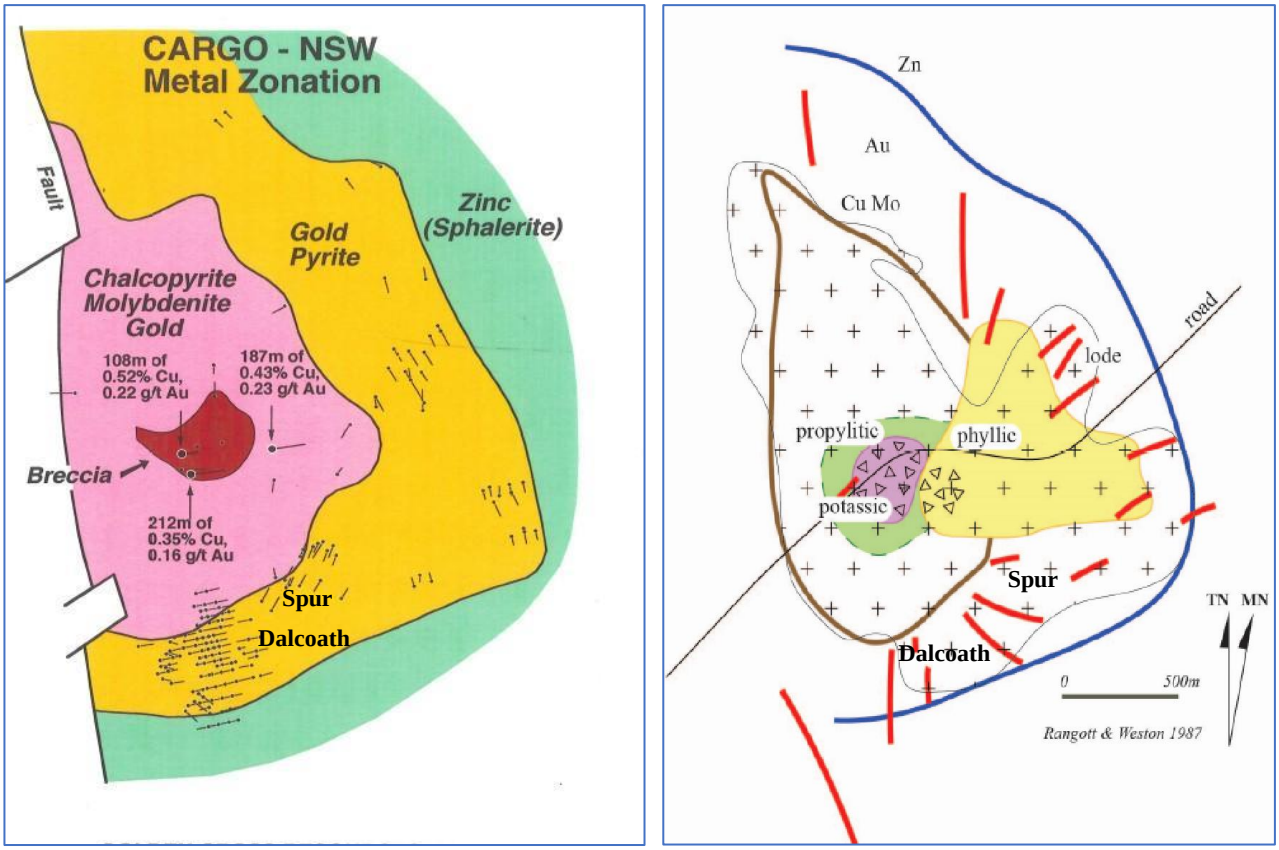


**Figure 3. Cargo mineralised porphyry system metal and alteration zonation adapted from GCR..**

Preliminary metallurgical tests indicate gravity recovery of between 21 and 34% of the gold, combined with flotation recovery varying from 42 to 96% for a total recovery of gold between 59% and 85%. More tests are required to improve the recoveries to exceed the desired 90%.

Individual miners have been extracting auriferous pyrite from two mining leases accessed by a shaft on top of the hill West of Cargo village, and producing a gravity concentrate. The immediate development potential appears to lie in drilling out all of the fourteen peripheral gold lode systems with old mines and workings before the inevitable next gold boom when the world returns to the gold standard.

## CONCLUSIONS

The isolated porphyry systems of Cargo and Copper Hill are characterized by copper with gold mineralization in quartz-rich suites (Torrey & White, 1998, Blevin, 2002). Insufficient published data exists to evaluate the K-enrichment of the other districts and the Macquarie arc as a whole, however it is likely that the intrusive chemistry and degree of enrichment could prove to be one of the most reliable discriminators of productive districts. Cargo's mineralised system is characterized by two mineralization styles:

1. Disseminated copper gold ore body reserves of 27 million tonnes of 0.2% Cu (Richardson et al., 1983). Central zone of elevated Cu, Mo. Concentric, porphyry style potassic, phyllic, propylitic alteration; NW-zone of sheeted quartz veins stockwork of barren qtz veinlets.
2. Peripheral gold halo, and outer zinc-rich zone contains late radial qtz-carbonate-Au veins with two lodes Dalcoath and Spur yielding a JORC compliant Inferred Resource of 4.0Mt grading 1.19 g/t gold containing 154,000 ounces of gold. (GCR, 2013). Additionally, small gold placer deposits are also present.

Historical production 1870 to 1904 was 318 kg Au and 10 t Cu. Radial veins with 30 to 102 g/t Au; alluvial placers at 6 to 40 g/t Au.

Mineral assemblages and host lithologies are believed to represent the upper levels of a porphyry copper system. Mineralization is mainly epigenetic, having formed from late stage hydrothermal fluid s permeating the base of a dacite volcano.

The porphyry, epithermal and skarn deposits of the Macquarie Arc are comparable to the ore deposits that form in modern oceanic island arc settings probably the best comparison in metal zonation and alteration assemblage is with Bingham Porphyry (USA) and Panguna Porphyry (Bogainville), Figure 4.

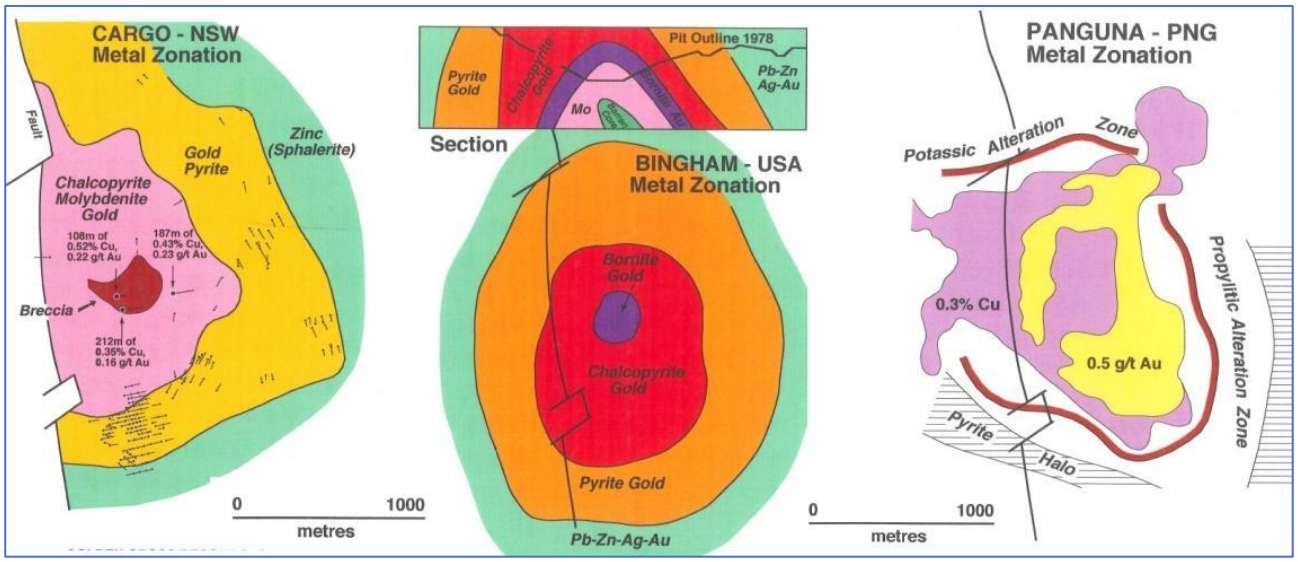


**Figure 4. Porphyry system comparison – Cargo vs Bingham and Cargo vs Panguna (data from GCR archives).**

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