Ordovician igneous rocks of the central Lachlan Fold Belt:
Geochemical signatures of ore-related magmas

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ABSTRACT

The majority of economic gold deposits in NSW are associated with Ordovician-aged igneous rocks and are examples of the Cu-Au porphyry-skarn-epithermal association commonly developed in convergent margin to orogenic settings. They are among the oldest porphyry Cu-Au deposits in the Pacific Rim region. They are similar to younger deposits in terms of tectonic setting and structure, but the largest are chemically distinct, being associated with shoshonite magmas (Cadia, Ridgeway and Northparkes). The Lachlan Fold Belt (LFB) porphyries are subdivided into four sub-groups based mainly on their age relative to development of the Lachlan Transverse Zone (LTZ) structure. Two subgroups pre-date the LTZ, one group is syn–LTZ and one group post-dates the LTZ. No mineralisation has been found or reported among pre-LTZ porphyries, but it is common in post-LTZ porphyries.

Petrographic analysis and microprobe results establish a wide range of primary and secondary features within the Ordovician rocks examined in this study. Calcalkaline to shoshonitic affinities are supported by the variable abundance of primary K-feldspars. Primary mineral phases such as pyroxenes and igneous magnetite provide an indication of fractioning mineral assemblages responsible for igneous trends in magma chemistry. The hydrothermal mineral assemblages documented in these LFB study areas are characteristic of younger Cu-Au Porphyry style mineralisation. As expected, the most pervasive alteration is associated with highly mineralised shoshonitic Ordovician rocks at Ridgeway and Cadia. The less strongly mineralised calc alkaline Ordovician rocks at Cargo, Copper Hill and Fairholme, are correspondingly less strongly altered overall, although secondary mineral assemblages are locally abundant. Many varieties of oxides and carbonates are observed at the different study localities.

Most of the studied samples conform to igneous chemical trends because they are weakly altered, although post magmatic processes, such as veining, are detectable in certain trends. The K$_2$O enrichment of the studied samples is consistent with subduction-modified mantle wedge sources. A few effects, such as the high Fe$_2$O$_3$ contents of some Ridgeway samples, probably reflect porphyry-style hydrothermal alteration processes. Host rocks at the Cadia and Ridgeway are entirely alkalic on the K$_2$O versus SiO$_2$ plot and shoshonitic on the Total Alkalies versus SiO$_2$ plot. Igneous rocks at the other deposits display a range of compositions between low K tholeiites to shoshonites that in some cases reflects multiple igneous suites.

The LREE and LILE enrichments, and HFSE depletions (Nb, Ta and Ti) of the magmas associated with these deposits are characteristics of a subduction-related tectonic setting. They all fall in the volcanic-arc granite and syn-collisional granite field of the Nb-Y tectonic discrimination diagram. Several magma types are identified by differences in the HFSE and REE trends. Differences in the extent and style of magma fractionation are evident in the trace element data. The Ridgeway samples define a wider range of trace element concentrations than the Cadia samples that may indicate a greater extent of fractionation during emplacement of the Ridgeway magmas. Fairholme samples display a high Nb and Zr trends that are distinct from the main fields on Zr variation diagrams.

Compositional differences between larger Cu-Au deposits, Cadia-Ridgeway and smaller deposits, Copper Hill, Cargo and Fairholme are evident in terms of Nb-Ta depletion and variation. The smaller deposits show constant Nb/Ta or negative Nb/Ta trends that extend to high Nb. The larger deposits display positive Nb/Ta trends that do not extend to high Nb. This distinction reflects a difference of preferential incorporation of Nb in a mineral phase (magnetite). Comparisons between Cadia-Ridgeway and other shoshonite (altered samples of Bajo de la Alumbrera, Argentina), calc alkaline magmas
from New Zealand and rocks from other areas indicate that Nb/Ta is not directly correlated with the shoshonitic classification, K₂O vs. SiO₂, and that the Cadia-Ridgeway Nb and Ta variation is not the result of alteration. The fact that the weakly altered LFB Capertee shoshonites exhibit a narrow range of Nb and low Nb/Ta suggest the shoshonite trend for the LFB as a whole is a steep one on the Nb/Ta versus Nb plot. The results of this study could provide important information for exploration within the LFB. Only the Cadia and Ridgeway deposits display a wide range of Nb/Ta values and lack the near-horizontal trend seen for other localities associated with smaller deposits.

The tectonic evolution of the LFB is a major factor contributing to occurrence of large porphyry Cu-Au deposits. The sequence of important events, however, commences with sub-crustal generation of oxidised magma and finishes with efficient Cu-Au accumulation by hydrothermal processes at favourable structural sites. The increase in Au-Cu deposit size from small (Copper Hill-Cargo) to world class (Cadia-Ridgeway) indicates the importance of magma composition during this process. The most obvious differences between the Cadia-Ridgeway and New Zealand rocks is that the latter are volcanic in origin and associated with an arc-back arc system. Therefore, they did not form in a tectonic regime suitable for the evolution of porphyries and the focussed movement of hydrothermal fluids during dilatant episodes. As a result, they are not linked to mineralisation despite having Nb-Ta and Nb/Ta variations that are typical of the high oxidation states in Au-prospective magmas of the LFB.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>I</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>III</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>VII</td>
</tr>
<tr>
<td><strong>CHAPTER 1: THE GEOLOGY OF GOLD MINERALISATION IN NEW SOUTH WALES</strong></td>
<td></td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Research objectives</td>
<td>1</td>
</tr>
<tr>
<td>1.3 Gold in NSW</td>
<td>2</td>
</tr>
<tr>
<td>1.4 The Lachlan Fold Belt in Central NSW</td>
<td>3</td>
</tr>
<tr>
<td>1.5 Gold mineralisation in the LFB of NSW</td>
<td>5</td>
</tr>
<tr>
<td>Cobar gold field</td>
<td>6</td>
</tr>
<tr>
<td>Mineral Hill area</td>
<td>7</td>
</tr>
<tr>
<td>Parkes area</td>
<td>8</td>
</tr>
<tr>
<td>Orange area</td>
<td>9</td>
</tr>
<tr>
<td>Blayney area</td>
<td>10</td>
</tr>
<tr>
<td>1.6 Tectonic setting</td>
<td>11</td>
</tr>
<tr>
<td>1.7 Common features of Cu-Au porphyry deposits</td>
<td>13</td>
</tr>
<tr>
<td>1.8 Research methodology</td>
<td>18</td>
</tr>
<tr>
<td><strong>CHAPTER 2: STUDY LOCALITIES AND SAMPLE PETROGRAPHY</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>19</td>
</tr>
<tr>
<td>2.2 Localities and sample descriptions</td>
<td>19</td>
</tr>
<tr>
<td>Ridgeway deposit</td>
<td>19</td>
</tr>
<tr>
<td>Cargo deposit</td>
<td>24</td>
</tr>
<tr>
<td>Copper Hill deposit</td>
<td>27</td>
</tr>
<tr>
<td>Fairholme deposit</td>
<td>29</td>
</tr>
<tr>
<td>Nasdaq deposit</td>
<td>33</td>
</tr>
<tr>
<td>2.3 Summary</td>
<td>35</td>
</tr>
<tr>
<td><strong>CHAPTER 3: MAJOR ELEMENT CHEMISTRY</strong></td>
<td></td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>36</td>
</tr>
</tbody>
</table>
3.2 Variation diagrams
   3.2.1 Compatible major element variation diagrams
   3.2.2 Incompatible major element variation diagrams

3.3 Chemical classification
   3.3.1 $K_2O$ versus $SiO_2$ classification
   3.3.2 TAS classification

3.4 Summary

CHAPTER 4: TRACE ELEMENT CHEMISTRY

4.1 Introduction
4.2 Trace element variation diagrams
   4.2.1 Compatible variation diagrams
4.3 Incompatible trace elements
   4.3.1 Large ion lithophile elements (LILE)
   4.3.2 High field strength elements (HFSE)
4.4 Rare earth elements (REE)
4.5 Multi-element primitive mantle normalised plots
4.6 Distinctive geochemical features of the Cadia-Ridgeway deposits

4.7 Summary

CHAPTER 5: DISCUSSION - TECTONICS AND MAGMA CHEMISTRY

5.1 Introduction
5.2 Tectonic setting of the Pacific Rim Cu-Au porphyries
5.3 LFB porphyries versus the Pacific Rim: tectonic and petro-chemistry
5.4 Porphyry subgroups versus tectonics of the LFB
5.5 A comparison of Nb/Ta variations in LFB and other magmas
5.6 Factors contributing to large porphyry deposits in the LFB
5.7 Summary

CHAPTER 6: CONCLUSIONS

REFERENCES

Appendices
FIGURES AND TABLES

Figure 1.1 Major geological provinces of NSW 4
Figure 1.2 Distribution of Ordovician igneous rocks 13
Figure 1.3 Simplified model of the Kalamazoo – San Manuel porphyry 14
Figure 1.4 Schematic time-depth relations of principal alteration types 15
Figure 1.5 A simplified cross-section of the Cadia Hill deposit 17
Figure 2.1 Simplified geological map of the Cadia area 20
Figure 2.2 Cross-section of the Ridgeway deposit 21
Figure 2.3 Photomicrographs of silicate minerals 23
Figure 2.4 Simplified geology of the Cargo deposit 24
Figure 2.5 Photomicrographs of alteration-related silicate and carbonate minerals 25
Figure 2.6 Simplified geology of the Copper Hill deposit 28
Figure 2.7 Simplified geology of the Fairholme deposit 30
Figure 2.8 Photomicrographs of primary and alteration-related opaque minerals 32
Figure 2.9 Simplified geology of the Nasdaq prospect 34
Figure 3.1 Variation diagrams for compatible major elements 38
Figure 3.2 Variation diagrams for incompatible major elements 40
Figure 3.3 A K₂O versus Si₂O classification plot 41
Figure 3.4 A total alkali (Na₂O + K₂O) versus Silica diagram (TAS) 42
Figure 4.1 Compatible element variation diagrams 47
Figure 4.2 LILE variation diagrams 48
Figure 4.3 HFSE variation diagrams 50
Figure 4.4 A Nb versus Y tectonic discrimination plot 51
Figure 4.5 Rare Earth Element ratio variation diagrams 53
Figure 4.6 Chondrite-normalised rare earth element plots 55
Figure 4.7 Primitive mantle-normalised plots 56
Figure 4.8 Th contents plotted against major elements 58
Figure 4.9 Variation diagrams for magnetite-associated elements 59
Figure 5.1 PNG transfer structures and Cu-Au deposits 64
Figure 5.2 Variation of Nb/Ta with iron oxides contents of LFB igneous suites 68
Figure 5.3 Variations in Nb/Ta versus Nb for mineralised LFB igneous suites 69

Figure 5.4 A comparison of variations in Nb/Ta versus Nb for Cadia-Ridgeway and others 70

Figure 5.5 A comparison of Nb/Ta versus Nb for Cadia-Ridgeway and other shoshonites 72

Table 1.1 Typical Porphyry Deposit Alteration Mineral Assemblages 15

Table 2.1 Copper Hill mineral resources 27

Table 5.1 LFB Ordovician porphyry groups based on age and structural setting 66
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