ABSTRACT

The study area (Penjom Gold Deposit, Pahang, Malaysia) lies 30 km east of the major terrane boundary Bentong-Raub Suture within the central belt of Peninsular Malaysia along the NNE trending splay from the Suture line. Host rock is comprised of turbiditic sequence of Early to Late Permian ranging from well bedded siltstone, calcareous shale, carbonaceous shale, tuffaceous sandstone and conglomerate. These sequences were intruded by fine grained and porphyritic medium grained felsite intrusives (222.4 +/- 1.8 Ma). Quartz veins found here are categorized into two main types, namely shear veins and extension veins. Shear veins are ribbon to laminated veins developed only in carbonaceous units and are either thick or very thin units, parallel to bedding or shearing. This vein type is interpreted as formed during folding and thrusting events involving repeated opening of bedding and shearing planes. Associated with shear veins are several types of extensional veins including sub-vertical extensional vein arrays, hydrothermal quartz breccias and stockwork in felsite rocks. NE to NNE thrust-parallel reverse to dextral faults overprinted the earlier D2 event and generated extensional veins of similar morphology, mostly at intersections of sediment-intrusive contact or as shallowly dipping veins within the intrusive bodies. Local NNW fault controls significant mineralization at the west wall of Jalis Corridor in the form of shear vein, massive to sheeted extension vein. Several north-south trending sinistral faults, intercept at the footwall folded sequence initiated mainly after the main veining event interpreted as during D4. Normal sense of movement of the same fault crosscut and displace the vein is occurring during D5 event, are not associated with the above style of veins but locally host barren quartz calcite-veins and are in certain areas associated with the late stage galena. Common alteration minerals based on XRD analysis are fine grain muscovite, chlorite and illite, which is typically characterized the phyllic alteration. Fluid inclusions were analyzed using eleven doubly polished sections of veins including
two calcite veins and one quartz sample from hanging wall. No measurable fluid inclusions were found in calcite and hanging wall vein. Fluid inclusions fall in two populations. Population 1 is made up of H₂O-NaCl were having T<sub>f</sub> final between 145°C and 265°C while population 2 is consist of H₂O-NaCl-CO₂ fluid inclusions with higher T<sub>f</sub> final from 200°C to 375°C. Sulphides are comprised of pyrite, arsenopyrite, galena, sphalerite and chalcopyrite. Gold is commonly found with galena but also can be found together with early sulphide. Galena samples from two groups (6 from the mineralised zone and 3 from the non mineralised area) have been sampled and analyzed for trace element geochemistry and lead isotopes. The lead isotope ratios for both groups plot around the bulk crustal growth curve of the plumbotectonic model indicating Pb derived from mixed crustal and magmatic sources. Based on the Cumming and Richards (1975) growth curves, two groups of lead can be interpreted as having formed at 250 Ma and 160 Ma. The Penjom gold deposit shows many similarities with other orogenic gold deposits formed in a terrain subjected to compressional to transpresssional event. Gold and other metal could be derived from mix metamorphic-magmatic sources migrated from deeper sources and deposited at mid crustal level during the late stages of an orogenic event.
ACKNOWLEDGMENTS

I would like to express my gratitude to Assoc Prof Dr. Ng Tham Fatt, Dr. Jasmi Hafiz Abdul Aziz and Prof Dr. Teh Guan Hoe for being my supervisors and for their invaluable encouragement, support and guidance in completing this thesis. I would also like to acknowledge the supports from other lecturers and staffs at Geology Department, University Malaya. They are Dr. Iskandar Taib (XRD and Micro-XRF analysis), Prof. Wan Hasiah Abdullah (carbon analyzer), En Zamrud (thin section), En Zaharuddin (XRD analysis) and other staffs at Geology Department. I am most grateful to Head of Department Prof. Dr Azman Abdul Ghani and Prof. Dr Ismail Yusof for the support. Great thanks extended to Assoc. Prof. Zhaoshan Chang from University of James Cook, Australia for the fluid inclusion study and Dr Sebastien Meffre and Charles Makoundi from University of Tasmania, Australia for the LA ICP MS analyses.

My deepest appreciation goes to all geologists and management at Penjom Gold Mine including general managers and managers at Specific Resources Sdn. Bhd. and management at Avocet Gold (UK) and JResources, Jakarta.

I would like to extend my appreciation to my lovely wife Suziati Mustaffa for the support, patient and understanding throughout my study and also to my three lovely daughter and sons (Farah, Farhan and Fahmi) for their encouragement and inspiration.

Thank you also to my mother Khatijah Setapa and other family members for the supports and prayer for my success. Finally, to my late father Endut Bin Musa who is always in my heart and my prayers. Thank you Allah Almighty for giving me a wonderful life, opportunities and energy to complete this study and for everything.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE PAGE</td>
<td></td>
<td>i</td>
</tr>
<tr>
<td>DECLARATION</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ACKNOWLEDGMENT</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xix</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>xxxi</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td></td>
<td>xxxiii</td>
</tr>
</tbody>
</table>

## CHAPTER 1 INTRODUCTION

1.0 Introduction

1.1 Location

1.2 Objective

1.3 Scope of study

1.4 Method of mapping

1.4.1 Introduction

1.4.2 Geological mapping and methodology

1.4.2.1 Pit wall mapping

1.4.2.2 Temporary bench face mapping

1.4.2.3 Mapping during the ore excavation

1.4.2.4 Floor mapping

1.4.2.5 Mapping from blast hole sample logging

1.4.2.6 Core samples

1.5 Geological observation
CHAPTER 2 GOLD DEPOSIT CLASSIFICATION

2.1 Introduction 16

2.2 Ore forming process 18
   2.2.1 Igneous/magmatic process 18
   2.2.2 Hydrothermal process 19
   2.2.3 Sedimentary and surficial process 19

2.3 Several class of gold deposit 20
   2.3.1 Orogenic gold deposit 22
      2.3.1.1 Geology of the host terrains 22
   2.3.2 Intrusion Related Gold Deposit 23
      2.3.2.1 Geology of the host terranes 24
   2.3.3 Porphyry (copper) and gold deposit 24
      2.3.3.1 Geology of the host terranes 25
   2.3.4 Epithermal gold deposit 25
      2.3.4.1 Geology of the host terranes 25

2.4 Other subclass of gold deposit 26
   2.4.1 Disseminated sedimentary hosted/Carlin type 26
   2.4.2 Volcanogenic massive sulphide 26

2.5 Gold deposits related to vein textures 27

2.6 Tectonic setting and gold deposit: Mainland South East Asia (SEA) 28
CHAPTER 3 HOST ROCK OF THE PENJOM GOLD DEPOSIT

3.1 Regional geology  
3.2 District geology and stratigraphy  
3.3 Stratigraphy setting of PGM  

3.3.1 Introduction  
3.3.2 Mine stratigraphy  
3.4 Detail description of sedimentary rock units  

3.4.1 Upper well-bedded laminated siltstone and shale (UMS 1)  
3.4.2 Sandstone with minor thinly bedded shale and siltstone (UMS 2)  
3.4.3 Lower well bedded laminated siltstone (UMS 3)  
3.4.4 Greenish grey tuffaceous laminated siltstone (UMS 4)  
3.4.5 Calcareous shale/siltstone (UMS 5)  
3.4.6 Carbonaceous dominant unit (MMS 1)  
3.4.7 Interbedded sandstone, carbonaceous shale and thin conglomerate (MMS 2)  

3.4.8 Greenish/reddish tuffaceous siltstone, sandstone and conglomerate (LMS 1)  
3.5 Stratigraphy Sequences  

3.5.1 Upper Mine Sequence (UMS)  
3.5.2 Middle Mine Sequence (MMS)  
3.5.3 Lower Mine Sequence (LMS)  
3.6 Stratigraphy and mineralisation  
3.7 Stratigraphy Repetition  
3.8 Stratigraphy Break  
3.9 Igneous rock  

3.9.1 Introduction  
3.9.2 Intrusive rock
3.9.2.1 Field occurrence
3.9.2.2 Petrography
3.9.3 Volcanic rock
  3.9.3.1 Field occurrence
  3.9.2.2 Petrography
3.10 Discussion and conclusion

CHAPTER 4 CARBONACEOUS ORE BODY

4.1 Introduction
4.2 Various type and origin of carbonaceous matter
  4.2.1 Sedimentary origin
  4.2.2 Carbon from metamorphic or hydrothermal origin carbon
4.3 Origin of carbonaceous material in Penjom
4.4 Carbonaceous matters and the genesis of gold mineralization
  4.4.1 Physical control
  4.4.2 Chemical control
4.5 Chemical analysis
  4.5.1 Chromatography
4.6 Field classification of carbonaceous zone
  4.6.1 Highly carbonaceous zone
  4.6.2 Moderately carbonaceous zone
  4.6.3 Low carbonaceous zone
  4.6.4 Distribution of high carbon ore in geological setting
4.7 Carbonaceous break
  4.7.1 Structural break
  4.7.2 Natural break
4.8 Remobilisation of carbon

4.9 Mineralisation break

4.9.1 Structural break

4.9.2 Natural break

4.10 Different types of carbonaceous shale and percentage of carbon.

4.11 Other organic matter (meta-anthracite)

4.12 Conclusion

CHAPTER 5 STRUCTURAL GEOLOGY AND VEINS SYSTEM

5.1 Introduction

5.2 Regional structural geology

5.3 Previous studies

5.3.1 Geological modeling 1 (1997-1999)

5.3.2 Geological modeling 2 (2000-2001)

5.3.3 This study

5.4 Folding

5.4.1 Introduction

5.4.2 Bedding

5.4.2.1 Bedding analysis

5.4.2.2 Stratigraphy correlation and style of the fold

5.4.3 Cleavage development

5.5 Fault

5.5.1 Introduction

5.5.2 Fold related fault

5.5.3 Compression fault

5.5.4 Strike slip regime
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.4.1 Dextral fault</td>
<td>105</td>
</tr>
<tr>
<td>5.5.4.2 Sinistral fault</td>
<td>105</td>
</tr>
<tr>
<td>5.5.5 Extensional regime</td>
<td>105</td>
</tr>
<tr>
<td>5.5.6 Summary of the new structural framework</td>
<td>108</td>
</tr>
<tr>
<td>5.6 Quartz-carbonate vein system</td>
<td>109</td>
</tr>
<tr>
<td>5.6.1 Introduction</td>
<td>109</td>
</tr>
<tr>
<td>5.6.2 Different style of quartz veining</td>
<td>110</td>
</tr>
<tr>
<td>5.6.3 Thrust and fold (D2) related vein</td>
<td>111</td>
</tr>
<tr>
<td>5.6.3.1 Penjom Thrust shear vein</td>
<td>112</td>
</tr>
<tr>
<td>5.6.3.2 Bedding-parallel shear veins</td>
<td>114</td>
</tr>
<tr>
<td>5.6.3.3 Sheeted extension veins</td>
<td>117</td>
</tr>
<tr>
<td>5.6.3.4 Quartz breccias</td>
<td>120</td>
</tr>
<tr>
<td>5.6.3.5 Quartz stockworks</td>
<td>120</td>
</tr>
<tr>
<td>5.6.4 Fault (D3) related vein</td>
<td>120</td>
</tr>
<tr>
<td>5.6.4.1 Sheeted extension vein</td>
<td>121</td>
</tr>
<tr>
<td>5.6.4.2 Quartz breccias</td>
<td>122</td>
</tr>
<tr>
<td>5.6.4.3 Quartz stockwork</td>
<td>124</td>
</tr>
<tr>
<td>5.6.5 Structural explanation of vein formation</td>
<td>125</td>
</tr>
<tr>
<td>5.6.5.1 Fold- and thrust-related veins (D2)</td>
<td>126</td>
</tr>
<tr>
<td>5.6.5.2 Fault-related veins (D3)</td>
<td>127</td>
</tr>
<tr>
<td>5.6.6 Role of competence contrast</td>
<td>130</td>
</tr>
<tr>
<td>5.7 Relative roles of fold and fault on quartz veining</td>
<td>132</td>
</tr>
<tr>
<td>5.8 Conclusions</td>
<td>134</td>
</tr>
</tbody>
</table>
CHAPTER 6 MINERALOGY, TEXTURE, SULPHIDE AND GOLD MINERALIZATION

6.1 Vein mineralogy 136
   6.1.1 Quartz veins 136
   6.1.2 Quartz carbonate veins 137
   6.1.3 Carbonate veins 138
   6.1.4 Late calcite veins (gold barren) 139

6.2 Veins texture 141
   6.2.1 Introduction 141
   6.2.2 Textural classification 142
     6.2.2.1 Buck texture 143
     6.2.2.2 Comb texture 143
     6.2.2.3 Lamination texture (vein septa) 145
     6.2.2.4 Ribbon texture 145
     6.2.2.5 Stylolite texture 147
     6.2.2.6 Breccias texture 147
     6.2.2.7 Minor veinlet texture 148

6.3 Application of quartz textures 149

6.4 Ore mineralogy 152
   6.4.1 Introduction 152
   6.4.2 Previous study 154
   6.4.3 Sulphide mineral 155
     6.4.3.1 Pyrite 155
       6.4.3.1.1 Field observation 155
       6.4.3.1.2 Microscopic study 156
     6.4.3.2 Arsenopyrite 158
6.4.3.2.1 Field observation
6.4.3.2.2 Microscopic study
6.4.3.3 Sphalerite
  6.4.3.3.1 Field observation
  6.4.3.3.2 Microscopic study
6.4.3.4 Chalcopyrite
  6.4.3.4.1 Field observation
  6.4.3.4.2 Microscopic study
6.4.3.5 Galena
  6.4.3.5.1 Field observation
  6.4.3.5.2 Microscopic study
6.4.4 Gold
  6.4.4.1 Field observation
  6.4.4.2 Microscopic study
6.5 Vein and mineral paragenesis
  6.5.1 Sulphide-gold paragenesis
    6.5.2.1 Disseminated early syn-sedimentary and diagenetic pyrite
    6.5.2.2 Quartz +/- carbonate-early sulphide gold (Fe, As, S)-Assemblage A
    6.5.2.2 Quartz carbonate-pyrite, minor arsenopyrite, base metal-gold (Fe, As, Pb, Cu, Zn)-Assemblage B
    6.5.2.3 Calcite galena vein
# CHAPTER 7 GEOCHEMISTRY OF VEIN AND ORE

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>Introduction</td>
<td>176</td>
</tr>
<tr>
<td>7.2</td>
<td>Fluid inclusion</td>
<td>176</td>
</tr>
<tr>
<td>7.2.1</td>
<td>Introduction</td>
<td>176</td>
</tr>
<tr>
<td>7.2.2</td>
<td>Previous fluid inclusion studies</td>
<td>177</td>
</tr>
<tr>
<td>7.2.3</td>
<td>Samples selection</td>
<td>177</td>
</tr>
<tr>
<td>7.2.4</td>
<td>Fluid inclusion petrography</td>
<td>179</td>
</tr>
<tr>
<td>7.2.4.1</td>
<td>SEM-CL imaging and crystal growth</td>
<td>179</td>
</tr>
<tr>
<td>7.2.4.2</td>
<td>Microscopic observation</td>
<td>180</td>
</tr>
<tr>
<td>7.2.5</td>
<td>Distribution of fluid inclusions</td>
<td>181</td>
</tr>
<tr>
<td>7.2.5.1</td>
<td>Shear vein (stage 1)</td>
<td>181</td>
</tr>
<tr>
<td>7.2.5.2</td>
<td>Extension vein (Stage 1)</td>
<td>184</td>
</tr>
<tr>
<td>7.2.5.3</td>
<td>Extension vein (Stage 2)</td>
<td>185</td>
</tr>
<tr>
<td>7.2.6</td>
<td>Thermometric measurement and results</td>
<td>185</td>
</tr>
<tr>
<td>7.2.6.1</td>
<td>Freezing and heating experiments</td>
<td>188</td>
</tr>
<tr>
<td>7.2.7</td>
<td>Discussion</td>
<td>190</td>
</tr>
<tr>
<td>7.2.7.1</td>
<td>Fluid composition</td>
<td>190</td>
</tr>
<tr>
<td>7.2.7.2</td>
<td>Temperature and pressure condition</td>
<td>192</td>
</tr>
<tr>
<td>7.3</td>
<td>Geochemistry of carbonate minerals in veins</td>
<td>194</td>
</tr>
<tr>
<td>7.3.1</td>
<td>Introduction</td>
<td>194</td>
</tr>
<tr>
<td>7.3.2</td>
<td>Quartz carbonate vein</td>
<td>194</td>
</tr>
<tr>
<td>7.3.3</td>
<td>Samples for analysis</td>
<td>195</td>
</tr>
<tr>
<td>7.4</td>
<td>Alteration of wall rocks</td>
<td>199</td>
</tr>
<tr>
<td>7.4.1</td>
<td>Introduction</td>
<td>199</td>
</tr>
<tr>
<td>7.4.2</td>
<td>Difficulties in studying alteration in Penjom</td>
<td>199</td>
</tr>
<tr>
<td>7.4.3</td>
<td>Wall rock alteration</td>
<td>200</td>
</tr>
</tbody>
</table>
### CHAPTER 7 ALTERATION AND DE-SILIHYDROXYDATION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.4.3.1</td>
<td>Pyritization</td>
</tr>
<tr>
<td>7.4.3.2</td>
<td>Arsenification</td>
</tr>
<tr>
<td>7.4.3.3</td>
<td>Phyllic alteration</td>
</tr>
<tr>
<td>7.4.3.4</td>
<td>De-silification</td>
</tr>
<tr>
<td>7.4.5</td>
<td>Discussion</td>
</tr>
<tr>
<td>7.5</td>
<td>Major, REE and trace element analysis</td>
</tr>
<tr>
<td>7.5.1</td>
<td>Introduction</td>
</tr>
<tr>
<td>7.5.2</td>
<td>Methods of study</td>
</tr>
<tr>
<td>7.5.3</td>
<td>Results</td>
</tr>
<tr>
<td>7.5.4</td>
<td>Discussion</td>
</tr>
</tbody>
</table>

### CHAPTER 8 GALENA GEOCHEMISTRY AND LEAD ISOTOPE

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0</td>
<td>Introduction</td>
</tr>
<tr>
<td>8.1</td>
<td>Methodology and purpose</td>
</tr>
<tr>
<td>8.1.1</td>
<td>Trace elements</td>
</tr>
<tr>
<td>8.1.2</td>
<td>Lead isotope</td>
</tr>
<tr>
<td>8.2</td>
<td>Results</td>
</tr>
<tr>
<td>8.2.1</td>
<td>LA ICP MS: Trace elements</td>
</tr>
<tr>
<td>8.2.2</td>
<td>Pb isotopes</td>
</tr>
<tr>
<td>8.2.2.1</td>
<td>Group 1</td>
</tr>
<tr>
<td>8.2.2.2</td>
<td>Group 2</td>
</tr>
<tr>
<td>8.3</td>
<td>Discussion</td>
</tr>
<tr>
<td>8.4</td>
<td>Conclusion</td>
</tr>
</tbody>
</table>
CHAPTER 9 DISCUSSION AND CONCLUSION

9.0 Introduction 231
9.1 Gold deposit classification 231
9.2 Summary of structural deformation 232
9.3 Veins, sulphides and gold 234
9.4 Geochemistry and wall rock alteration 236
9.5 Implication for regional tectonic setting 237
9.6 Conclusion 239
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Geological map of Malaysia Peninsular and location of Penjom Gold Mine in central belt.</td>
<td>3</td>
</tr>
<tr>
<td>1.2</td>
<td>Location of Penjom Gold Mine, Kuala lipis. BRS: Bentong-Raub Suture, PS: Penjom Splay, KKL: Kelau Karak Lineament</td>
<td>4</td>
</tr>
<tr>
<td>1.3</td>
<td>Flow chart of mapping activity and compilation into geological map.</td>
<td>7</td>
</tr>
<tr>
<td>1.4</td>
<td>Example of pit wall map of southern wall across the ore zone. Scale 1:1000.</td>
<td>9</td>
</tr>
<tr>
<td>1.5</td>
<td>Geological observation during ore excavation has been plot on grade control mining plan.</td>
<td>10</td>
</tr>
<tr>
<td>2.1</td>
<td>Tectonic settings of gold-rich epigenetic mineral deposits. Vertical scale is exaggerated to allow schematic depths of formation of various deposit styles to be shown (Groves et al., 1998).</td>
<td>20</td>
</tr>
<tr>
<td>2.2</td>
<td>Idealised cross section of gold deposit in different tectonic regime (after Groves, 1999).</td>
<td>21</td>
</tr>
<tr>
<td>2.3</td>
<td>Conceptual model for styles of magmatic arc epithermal Au-Ag and porphyry Au-Cu mineralization (Corbett, 1997)</td>
<td>21</td>
</tr>
<tr>
<td>2.4</td>
<td>Gold deposit environment used by Morrison (2007) for vein texture classification</td>
<td>28</td>
</tr>
<tr>
<td>2.5</td>
<td>Location of primary gold deposit in Malaysia Peninsular (after Yeap, 1999). Gold deposit in between purple and blue line lineament in inset figure hosted within vein system.</td>
<td>30</td>
</tr>
<tr>
<td>2.6</td>
<td>Gold deposits along Central Belt (Malaysia Peninsula)-Sukhotai Fold Belt and South East Asia granite provinces (after Cobbing et al., 1986; Ng et al., 2015)</td>
<td>31</td>
</tr>
<tr>
<td>2.7</td>
<td>Hydrothermal ore deposit and its location in geological setting of magmatic bodies and major shear/ fault system (Stephens, 2004). a: Orogenic gold, b: Intrusion related, c: Porphyry gold.</td>
<td>32</td>
</tr>
<tr>
<td>3.1</td>
<td>(Left) Well bedded sandstone of upper mine sequence. (Right) Photomicrograph of sandstone with poorly sorted quartz fragment (Q) dominant and minor lithic (L) fragment with sericite and patch of carbonate (UMS2).</td>
<td>38</td>
</tr>
<tr>
<td>3.2</td>
<td>(Left) Flaser bedding at upper part of sandstone bed. (Right) Pebbles of carbonaceous mudstone occasionally found in sandstone unit.</td>
<td>38</td>
</tr>
<tr>
<td>3.3</td>
<td>(Left) Parallel lamination in lower well bedded siltstone, (Right) cross lamination in the same unit.</td>
<td>39</td>
</tr>
</tbody>
</table>
Figure 3.4: Rock samples locations for greenish grey tuffaceous siltstone UMS4 (looking south).

Figure 3.5: (Left): Photomicrograph of light grey shale (UMS4) with minor quartz grain in matrix of fine grain lithic dominant and minor quartz. Sericite and patch of carbonate (yellowish) aligned parallel to foliation ($S_0$) or bedding. (Right): Photomicrograph of calcarceous shale comprised of recrystallized calcite grain size is less than 0.2mm. Aligned dark opaque streak is carbon parallel to bedding ($S_0$).

Figure 3.6: Figure 3.6: Carbon result (%) from grade control ore block 924mRL Grey dot is 0.2 to 0.5 %C. Ore mark-out string comprised of ore grade above 0.8 g/t, red string ore block is above 6 g/t. Continuation of the high carbon ore zones along the Penjom thrust and NS corridor (western limb). High carbon content in the western limb is originated from carbonaceous shale.

Figure 3.7: Photomicrograph of sandstone in MMS comprised of dominant altered lithic (L) and quartz (Q) in sericitised matrix (location Western Limb 834mRL)

Figure 3.8: (Left) Light grey conglomerate of middle mine sequence underlying sandstone (SST) unit (location Western Limb 834mRL). (Right) Greenish grey conglomerate of lower mine sequence

Figure 3.9: Sedimentary rock of unit 8 (tuffaceous siltstone to conglomerate). A (Jalis corridor), B (Kalampong East fold axis), C (west wall). Looking to the north (photo May 2008)

Figure 3.10: Purple/reddish granule size of pebbly sandstone graded to conglomerate usually forming up to 5 to 10m thick. This unit is part of lower mine sequences.

Figure 3.11: General stratigraphy profiles for the west wall and east wall of Kalampong East pit (not to scale) and not included the west wall of Jalis. (SST-sedimentary sandstone, SSH-sedimentary shale, SSL-sedimentary siltstone, tuSSL-tuffaceous sedimentary siltstone, calSSH-calcareous sedimentary shale, cbnSSH-carbonaceous sedimentary shale, SCG-sedimentary conglomerate

Figure 3.12: Stratigraphy distribution in Kalampong pit (2007)

Figure 3.13: General stratigraphy sequences for eastern limb and western limb and the location of bedding parallel shear veins. Western limb shows stratigraphy repetition due to the E-W trending Blue Line Fault.

Figure 3.14: Looking southeast - Bottom of the pit, stratigraphy repetition as a result of displacement by Blue Line Structure (photo July 2008, bottom RL-792).

Figure 3.15: Looking south – Southwest wall of KE pit: Stratigraphy repetition indicated by lower mine sequence (LMS) comprised of massive conglomerate above carbonaceous dominance of MMS as a result of displacement by Jalish NNE reverse to dextral fault
Figure 3.16: Stratigraphy from RC samples logging shows three sequences of lithology. UMS-upper mine sequences, MMS- middle mine sequences, LMS-lower mine sequences.

Figure 3.17: Felsite cross cut the host rock sequences. Blue line represent approximate boundary between middle and upper mine sequences. Green line represent the boundary of middle and upper mine sequences.

Figure 3.18: (Left) Photomicrograph of medium grained felsites (ITN-1) with plagioclase (P) and quartz (Q) and minor alkali feldspar (F). (Right) Photomicrograph of fine grained felsite (ITN-2) comprised of quartz grain with some plagioclase. Thin section view in transmitted light.

Figure 3.19: (Left) Photomicrograph of fine grained microdiorite comprised of quartz and plagioclase with carbonate vein. (Right) Hand specimen of medium (ITN-1) and fine grain felsites (ITN-2). Thin section view in transmitted light.

Figure 3.20: Photomicrograph of rhyolite to dacite porphyry comprised of quartz (Q) dominance with minor plagioclase. Thin section view in transmitted light.

Figure 3.21: Photomicrograph of volcanic rock (Andesit) made up by fine grained of plagioclase and quartz. Stringer of carbonate vein cross cut the lithology. Thin section view in transmitted light.

Figure 3.22: Lower sequences sedimentary rock is not hosted significant ore bodies based on grade control assay data. (The blue and reddish dot represents the ore grade above 0.5 g/t). Ore dominantly within the Middle sequences (example from the main KE pit).

Figure 3.23: KE geological map. Mineralised outline (>0.5 g/t) dominantly hosted in grey middle mines sequences. Some (in black circle) are hosted in felsite intrusive within the Lower Mine Sequence host rock.

Figure 4.1: Different process of sedimentary origin of carbonaceous material (after Robb, 2008 and Bierlein, 2001).

Figure 4.2: Looking north. West dipping mineralized carbonaceous unit of the western limb at contact with felsites.

Figure 4.3: Looking north view of the western limb thick carbonaceous host rock.

Figure 4.4: Close up view of the sampling in sheared carbonaceous shale and carbonaceous siltstone.

Figure 4.5: Kalampong North, Penjom Thrust reactivates along carbonaceous unit of the east limb of anticline.

Figure 4.6: Overall picture of Figure 4.5 and location Figure 4.2, 4.3 and 4.5.

Figure 4.7: Interbedded of sheared carbonaceous shale with small unit of low carbon sandstone (pen in circle as a scale) will produce a moderate carbon content during ore mining.
Figure 4.8: Overall view of photo A at south of KE, near the Penjom Thrust zone.

Figure 4.9: Cross section at 50 000 show distribution of the main highly carbonaceous unit (>1.5% C). High carbon along thrust is made up by western limb carbonaceous sequences. The ore zone along the thrust (area A) is also considered as part of western limb sequences (part of NS corridor of previous interpretation and can be correlated with area c, usually separated by fold related fault). Area A also comprised of low carbon ore. Area B is eastern limb sequences.

Figure 4.10: Distribution of the mineralized zone (>0.5 g/t) for high carbonaceous zone (green, >0.5%C) and low carbonaceous zone, <0.5%C (blue) from Kalampong East pit. Data is from 945 to 960mRL.

Figure 4.11: (A) Natural break (area N) of carbonaceous unit due to the massive tonalite, Hill 7 and Hill 2 (west wall). (B) Structural break of carbonaceous and mineralization (east wall) due to fault displacement.

Figure 4.12: (A) Close up view of area Y (east wall), carbonaceous and mineralization break by the structure, (B) Overview of area X and Y, Penjom fault (dash line) responsible for area X and Hill 6 NS fault (dot line) reactivate/diffract along main fault responsible for area Y.

Figure 4.13: The main structural event affected the carbonaceous unit.

Figure 4.14: Grade control ore block (above 0.8g/t). NS corridor (Jewel Box/Area C) is also high carbon content.

Figure 4.15: Various types of carbonaceous shale. See explanations in text.

Figure 4.16: Reflectance scale of 4.5 to 5 indicates organic carbon is meta-anthracite.

Figure 4.17: (Left) Anthracite cemented by quartz vein infilled dominantly parallel to rock fabric in silicified carbonaceous shale. (Right) Polish section image of meta-anthracite (A) in carbonaceous shale and framboidal pyrite under reflected light.

Figure 4.18: (Left). The occurrence of framboidal pyrite (FP) (bright reflectance) associated with anthracite under reflected light. (Right). Meta-anthracite is observed with vesicles indicative of thermally altered. Framboidal pyrite can also be observed.

Figure 5.1: Tectonic-magmatic event involving the collision of Sibumasu-Indochina terrane (Metcalfe, 2013).

Figure 5.2: Geological map of Kalampong pit (2008), inset photo shows bird eye view of Kalampong and Manik pit.
Figure 5.3: North wall as current pit slope (2009). Area for bedding analysis plotted in stereonet. Bedding at area 1, 2 and 3 are dipping east and area 4 is dipping west.

Figure 5.4: North wall before cutback shows the same style of folding.

Figure 5.5: South wall during third cutback. Hill 6 NS fault intercepted along the eastern limb

Figure 5.6: South wall of Kalampong pit before 2009 cutback shows recumbent fold of tight inclined fold

Figure 5.7: Hanging wall, Area 1 - Hill 6: Mean Orientation = 44/126 (Dip/dip direction). Area 2 – Hill 5: Mean Orientation = 46/147 (Dip/dip direction). Foot wall, area 3 (zone B) - Eastern Limb near fold axis: Mean Orientation = 38/157. Area 4 (zone C) – West wall North: Mean Orientation = 64/277

Figure 5.8: Jalis-Manik corridor. Stereonet plot of bedding at Jalis west wall shows mild cross fold of the east dipping bedding: Mean Orientation = 30/094

Figure 5.9: Cross-section at 49700.

Figure 5.10: Cross-section at 49 900.

Figure 5.11: Cross-section at 50 100.

Figure 5.12: Cross-section at 50200.

Figure 5.13: The stereonet plot of fault orientation in several zones. Number of data in bracket

Figure 5.14: (Left) Undeformed shear vein with fracture cleavage S1 below the vein (western limb). (Right) S2 fold axis cleavage also affected the shear vein (refolded western limb)

Figure 5.15: (Left) Shearing at contact of felsites intrusive as indicate by shear vein V1, intrusive is undeformed. (Right) Shearing as a result of reactivation of the fold at contact with intrusive produced parallel fracture in narrow sill (refolded of the western limb)

Figure 5.16: (Left) S12develop in refolded fold below incline fold. (Right) Close up view of northerly strike parallel fracture cleavage. Dash line is bedding outline.

Figure 5.17: Structural classification for Kalampong East (KE) Pit shows three main structural events.

Figure 5.18: (Left) R1F and R2F displace felsite body, looking south (852mRL). (Right) R1F as expose on the wall
Figure 5.19: (Left) R4F (NNE fault) displace felsite rock in incline fold zone, base level 834mRL (looking south) after cutback. (Right) Close up view, intense quartz below R4F at contact with felsites intrusive.

Figure 5.20: Slickenline striation on Hill 6 NS fault plane shows slightly oblique normal fault.

Figure 5.21: At the southern most part of the Kalampong pit, a steeply dipping N-S normal fault (DMF) (right side of the picture) cuts the gently dipping NNE-SSW reverse fault and high carbon zone. Other normal fault (NS Jalis) at left side reactivates along Penjom Thrust.

Figure 5.22: NNW fault developed as a Riedel fault in between NS indicating normal sense of movement.

Figure 5.23: Fault striation indicates normal sense of small scale NS fault cross cut quartz-carbonate shear vein.

Figure 5.24: (Left) Normal north-south fault displace flat dipping high grade laminated vein (looking south, 834mRL). (Right) Close up view of normal NS fault displace bedding parallel vein.

Figure 5.25: (a) Penjom Thrust ore zone trending NNE and subparallel to bedding. (b) Close up of area ‘A’ shows laminated to ribbon quartz. (c) Another bedding parallel vein below the thrust ore zone (after further digging of area ‘B’ in photo ‘a’). (d) Ore zone comprised of shear veins (black line), cross cutting through intrusive rock (ITN). (e) Q2W shear veins as shown by slivers of host rock in sheared intrusive. Blocky intrusive on the right side lack quartz veining.

Figure 5.26: Looking mine north (35° from true north), cross section at 50100 at the center of Kalampong Pit, shows structural framework of shear veins (Q1W, Q2W and Q3W) in the fold setting of the Kalampong Anticline. Inset figure is an evolution of the folding.

Figure 5.27: (a) Roughly laminated veins in carbonaceous shale unit with more planar laminations inside the veins. This shear vein type 2 in Table 1 was formed through shear induced lamination. (b) E-W extension vein array type 2 or planar sheeted vein developed at θ equals to 90° below the main shear vein (red dash line), looking south and at level 840mRL. (c) A series of E-W striking sheeted veins (extension vein array type 2) exposed after the excavation of the main shear veins (looking east, at level 834mRL). (d) Equal area, lower-hemisphere stereographic projection showing the average dip and dip-direction and pole to vein.

Figure 5.28: (a) Dominant low angle extension veins Type 3 in felsites dyke perpendicular to contact, bedding and fault. Location: north of KE pit; Spacing: from 5 to 50cm; Thickness: from 1 to10cm. (b) Dominant vertical E-W extension veins Type 1 across the bedding and felsite intrusive at Jalis West Wall. Spacing: from 5 to 50cm; Thickness: from 1 to 20cm. Vein intensity increases in intrusive. (c) Dash line represent west dipping shear plane across felsite. 1-vein stockwork near shear plane (D2 deformation), 2-vein infilling parallel fracture resulted to low angle vein array, 3-less vein away from the shearing. (d) Vein across the lithology contact.
Figure 5.29: (a) Stockwork (ST) veins (extension vein Type 4) in intrusive rock below North-South trending West dipping shear veins (red line) and hydrothermal breccias (HB) in between two shear veins in intrusive and siltstone. (b) Fractures cleavage (S3) locally developed below NNE D3 fault affected the D2 shear vein. (c) Normal D5 fault (green line) displaces flat dipping along synform axis D2 shear vein.

Figure 5.30: (a) Lower hemisphere equal-area of sheeted vein orientation (poles plot of dip direction and dip) shows dominant steeply north dipping extension veins discordant to bedding from three areas. (b) Overall lower hemisphere equal-area of bedding orientation (poles plot of dip direction and dip, n = 1187), (c) Vein (poles plot of dip direction and dip, n = 797), 0.5% interval.

Figure 5.31: (Left) Stress field diagram shows relationship of extensional fractures perpendicular to maximum compressive stress. (Right) Dominance E-W sheeted extension vein Type 2 in felsite unit at fault intercept. Looking east at east wall.

Figure 5.32: (a) Crenulated extension veins as a result of ongoing deformation that also produced the cleavage at high angle to veins. (b) Late vein stringers across gold network within brecciated calcite vein. (c) Ribbon quartz from side view with gold along vein margin. (d) Laminated veins with sign of fault striations affecting the gold itself on the vein margin.

Figure 5.33: Location of Jalis NNW Fault Zone sub-parallel to carbonaceous shale (looking north). Red line is outline of the shear vein within and outside the fault zone. Economic mineralization (ore body) localised at intercept with dominant felsic host rock.

Figure 6.1: (Left) Late stage of white quartz infill along lamination but also cross cut lamination of gray quartz and carbonate vein (CO3). (Right) Milky quartz and micro-fault truncated stylolite, a band of grey quartz and carbonate (CO3) veins.

Figure 6.2: Intergrowth of prismatic carbonate (calcite dominance based on XRD analysis) and quartz in quartz carbonate veins. (Left) Ribbon to laminated vein comprised of carbonate (calcite) at the bottom and quartz on top. (Right) E-W sheeted carbonate veins cross cut the brecciated quartz within the vein but not continuous outside the brecciated quartz vein body.

Figure 6.3: (Left) Ankerite appears as red after expose to oxidation for certain period. (Right) Calcite extension vein parallel to the bedding with fibrous of veins growth perpendicular to vein wall

Figure 6.4: Quartz-carbonate veins, ribbon quartz on top and carbonate bottom

Figure 6.5: (Left) Ankerite appears as red after expose to oxidation for a certain period. (Right) Calcite extension vein parallel to the bedding with fibrous of the veins growth perpendicular to veins wall
Figure 6.6: Late calcite veins at different phase with sheeted quartz carbonate vein. Reverse sense of movement were evidence in both photo.

Figure 6.7: A. Ribbon quartz and massive inside the vein. B. Coarse grains quartz inside the vein made up the passive grain. C. Fine grain along the laminated veins represents the active plane. D. Anhedral to euhedral quartz grain close to carbonate veins along ribbon.

Figure 6.8: Medium comb with crystal growth perpendicular to vein margin, (Right) Coarse comb but the with a more random crystal growth texture.

Figure 6.9: Parallel veins in siltstone with multiple veins to form lamination or septa. Vein crystals align parallel to the wall and with no fibre or comb quartz are indicative of veins forming in the confined space.

Figure 6.10: (Left) Reactivated shear on ribbon (in box) which produced the cataclasite quartz grain and massive anhedral buck below the ribbon. (Right) Photomicrograph of fine abrasive quartz represents the mill grain and anhedral buck quartz below the shear.

Figure 6.11: (Left): Bedding parallel shear vein with parallel wavy style stylolite. (Right) Shear vein with fractured fill stylolite or infill breccias texture.

Figure 6.12: (Left) Fractured stylolite or infill breccias texture. (Right) Superimposes features of aggregate breccias in shear vein can be originated from recrystallized fractured stylolite or infilled texture (sample half core HQ).

Figure 6.13: Quartz carbonate vein near to fold axis and Penjom Thrust has a network of thin veinlets overprint the earlier ribbon texture.

Figure 6.14: Gold infilling the local breccias texture in reactivated shear vein as in circle 1, 5, 6 and along stylolite in circle 2 and 4. Discordant vein (black line 7) as a late stage veins cross cut the massive brecciated veins and gold.

Figure 6.15: Discordant quartz veinlet as a late stage event cross cut the stylolite and gold. Stylolite made up of soluble carbon and sulphide.

Figure 6.16: Pyrite py1 hosted along the host rock remnants in vein and along mineralogy boundary. (Right) Pyrite Py1 is more randomly distributed in carbonate (CO3) vein.

Figure 6.17: (left) Deformed pyrite as indicated by shining yellowish surface as a result of fault (KE, Q2W shear vein). (Right) Late stage quartz vein (v1b) cross cut lamination and pyrite pyl aggregate.

Figure 6.18: Mild refolded of shear vein (V1) (Q3W shear vein) hosts to pyrite (Py1) and galena (ga1b), Calcite crystal growth (V2b) on the shear plain during the later stage not associated with any sulphide mineral.
Figure 6.19: (Left) Extension vein-Gold (Au) and galena (Ga) infilling fracture in pyrite (sample q3w879- Q3W near to fold axis). (Right) Sample q3wb gold and chalcopyrite infilling crack and fracture in pyrite.

Figure 6.20: (Left) Disseminated subhedral to anhedral arsenopyrite around thin network of quartz veinlet in tuffaceous shale. (Right) Thinly bedding parallel veins has been buckled-up as a result of ongoing deformation (sample FQ1) and also affects sulphide mineral.

Figure 6.21: (Left) Aggregates of arsenopyrite in extension vein. (Right) Band of cataclasite arsenopyrite at lower contact of shear vein along slivers of carbonaceous shale (sample MNQ2A).

Figure 6.22: (Left). Photomicrograph of gold occurs as inclusion in arsenopyrite. (Right) Photomicrograph of the shear vein FQ1-Arsenopyrite intergrowth with pyrite and also in corroded pyrite. Reflected light.

Figure 6.23: Photomicrograph of sample MNQ2A in Manik (left) and FQ1 (right) in eastern limb of the fold (KE) shows cataclastic features of arsenopyrite along the active shear plane. Reflected light.

Figure 6.24: Photomicrograph of Q3WA shows galena (ga) at a margin and infilling fractured arsenopyrite (apy) in Q3W quartz carbonate-early sulphide and base metal. Reflected light.

Figure 6.25: (Left) Laminated vein Q3W shear vein with galena (black) and sphalerite (honey red) occupy along the lamination. (Right) Visible gold (yellow), sphalerite and galena along the lamination.

Figure 6.26: (Left) Small pieces of sphalerite in quartz carbonate vein in circle have been prepared for the polish sample. (Right) Photomicrograph of chalcopyrite diseases occur in sphalerite as a fine bleb. Fine particles of galena surrounding the fracture sphalerite. Reflected light.

Figure 6.27: (Left) Occurrence of galena and chalcopyrite in extensional veins within intrusive rock. No association with carbonate vein. (Right) Spot of pyrite and chalcopyrite in fill the fracture in quartz.

Figure 6.28: (Left) Band of dendritic galena infilling local breccias in a milky quartz vein. (Right) Coarse grain galena associated with calcite but not associated with gold.

Figure 6.29: Left. Photomicrograph of galena (ga1b) in Janik area near the fold hinge is observed as fractured (reflected light). (Right) Sample Q3WL: Galena in thicker segment of vein and absent in ribbon quartz.

Figure 6.30: (Left) Photomicrograph of gold and galena infilling fractures in arsenopyrite. (Right) Photomicrograph of gold and galena infilling pyrite.

Figure 6.31: (Left) Gold in quartz carbonate shear vein forming a layer parallel to vein margin. (Right) Gold infilling fractures in vein which part of shear vein.
Figure 6.32: (Left) Gold along the lamination has faulted/sheared effect indicating gold synchronously deposited during repeated opening and shearing of the bedding. (Right) Gold associated with pyrite within wall rock inclusion and late quartz cross cutting the early quartz.

Figure 6.33: Summary of several phase of structure, veins and sulphides mineral paragenesis. Py-pyrite, Apy-arsenopyrite, Ga-galena, Sph-sphalerite, Cpy-chalcopyrite.

Figure 7.1: Fractures zone in shear vein shown by low angle string outline and overlapped with zone of trail inclusion. Vertical fractures are less coincided with zones of trail. (A) SEM CL image. (B) Under reflected light.

Figure 7.2: (A) Sample (Z2N), extension vein-Stage 1: Several trails (T) of inclusion and cluster (CL) within the grain. Trail mainly L-V of Type 1 inclusion and cluster made up of L-V of Type 1, 2 and 4. (B) Extension vein, stage 1: Occurrence of both Type 1 L-V and Type 2 L-V inclusion along trail. (C) Similar sample: Type 1, L-V homogenized at 189oC and Type 2, L-V still preserve the inclusion. (D) Shear vein, stage 1: Cluster of Type 2 and Type 3 L-V inclusion. (E) Close up view of photo D: Coexistence of Type 3 L-V with double-bubble of CO2 inclusion and Type 2 L-V with dark rim. (F) Shear vein, Stage 1: Overall view of photo G and H containing inclusion forming as a cluster. (G) Close up of photo F. Top two inclusions are vapor rich of Type 5 and bottom two are Type 3 V-L. (H) Inclusion at 15oC showing the formation of CO2 liquid and vapor in all inclusions.

Figure 7.3: Thermometric experiment is using LINKAM MDS600C with Olympus camera attached.

Figure 7.4: Temperatures of final homogenization (T_h) obtained from all samples (85 data).

Figure 7.5: Final melting temperatures of Ice and Clath (T_m) plotted against temperatures of final homogenization (T_h) (85 data).

Figure 7.6: Final homogenization temperatures (T_h) plotted against salinity.

Figure 7.7: Calcite vein with gold. Gold infilling brecciated portion of the vein (sample Q1jn)

Figure 7.8: XRD analysis of sample Q1jn with higher calcite peak

Figure 7.9: Extension quartz carbonate vein with reddish color after exposure to oxidation at the edge of the vein (inset photo) confirmed from XRD analysis as ankerite. Sericite alteration detected as indicated by occurrence of muscovite.
Figure 7.10: Deformed shear vein from Penjom Thrust zone at Janik hosted in high carbon zone have quartz carbonate vein of ankerite and calcite.

Figure 7.11: (A) Sulphides in vein comprised of mainly pyrite and a black shining galena and disseminated pyrite in altered wall rock zone. B: Altered wall rock and disseminated pyrite

Figure 7.12: Disseminated pyrite in felsite intrusive within the bleached altered host rock around the vein.

Figure 7.13: XRD analysis of samples along Penjom Thrust hosted vein comprised of quartz, calcite and illite.

Figure 7.14: XRD analysis of Penjom Thrust wall rock comprised of quartz, muscovite, pyrite and calcite.

Figure 7.15: XRD analysis of altered wall rock at southern pit extension vein comprised of quartz, muscovite and chlorite.

Figure 7.16: Location of samples for XRF analysis. Hanging wall samples are HW-R and HW-NSF

Figure 7.17: Plot of Au, As and Pb in the ore (11 samples, refer to Table 7.6), hanging wall rock (HW-R and HW-NSF) and waste rock outside the mine site (KLGM and KLB).

Figure 8.1: Location of galena sample for geochemistry study

Figure 8.2: Galena samples for the analysis. A. Close up view of sample Q3WA, B. Sample ZNNW, C. JNNE: Galena infilling brecciated calcite along fault plane, D. Hanging wall galena (HW S2). Broad correlation of all elements in galena (in log scale) except Cd, Se, Ag, Te and Bi which is very low in hanging wall galena.

Figure 8.3: Broad correlation of all element in galena (in log scale) except Cd, Se, Ag, Te and Bi, which is very low in hanging wall galena. Refer to Table 8.1 for galena stages.

Figure 8.4: Plot of trace element in galena hosted in bedding parallel shear vein (sample Q2WL), dendritic galena (Q2WA) and galena along lamination. All show broad correlation especially the first two samples.

Figure 8.5: Plot of Cd, Te, Se, Ag, Bi of galena in Penjom, Tanah Merah (near Ulu Sokor) and other places (MI-Mount Isa, BH-Broken Hill, MM-Mt Murchison, BM-Baja Mare, TY-Tynagh, OD-Olimpic Dam).

Figure 8.6: Summary plot of lead-isotope ratio 206Pb/204Pb vs207Pb/204Pb. SRABCG- Subduction-related and bulk crustal growth, SK-Stacey and Kramers (1975), CR- Cumming and Richards (1975).

Figure 8.7: Summary plot of lead-isotope ratio 206Pb/204Pb vs208Pb/204Pb. SRABCG- Subduction-related and bulk crustal growth, SK-Stacey and Kramers

Figure 9.1: Summary of the geological elements studied and a possible correlation with a deformation event.

Figure 9.2: Cross section at Bukit Koman (Raub) underground gold mine showing vein parallel to compression fault and bedding.
Tables 1.1: The main geological aspects focused in this study include rock unit, vein, geological structures and sulphide minerals

Tables 1.2: Previous geological study conducted by geologists in Penjom mainly for resources estimation

Tables 2.1: Summary of the Lindgren gold classification (after Lindgren, 1922)

Tables 2.2: Summary of gold deposit classification based on fluid source and crustal depth. Depth is only relative in two groups and superimposes may occur due to the uplift and reactivation.

Tables 2.3: Several type of gold deposit in mainland of South East Asia

Tables 3.1: Group of rock units in stratigraphy sequences

Tables 4.1: Different types of carbonaceous preg-robbing ore


Tables 4.3: Carbon contains in different fold related shear vein ore zone.

Tables 4.4: Various type of carbonaceous shale and result of carbon content and sulfur (as analyzed at Penjom Lab)

Tables 5.1: Summary of deformation events in Peninsula Malaysia (Shuib, 2009)

Tables 5.2: Summary of structural event in PGM indicates two main structural events. D2 to D3 involving compression to transpressional and D4-5 extensional period.

Tables 5.3: Classification of vein type, host rock and superimposed reactivation by later fault

Tables 6.1: Quartz texture types for different deposits environment (Dowling and Morrison, 1989). Blank-absent, 1-rare, 2-present, 3-common, 4-abundant, 5-predominant.

Tables 6.2: List of the polish section samples.

Tables 6.3: Structural phases, description of veins, gold content of ore zones and the occurrence of sulphides. Ore grade – low: 0.5 to 1 g/t; medium: 1 to 3 g/t; high: 3 to 6 g/t; very high: >6 g/t). Py: pyrite; Apy: arsenopyrite
Table 7.1: Sample for fluid inclusion represents different vein type and sulphide assemblage. Stage 1 vein is controlled by D2 deformation, Stage 2 vein by D3 deformation. Vein type based on Table 5.03. Sulphide assemblage as described in Chapter 6.5. Py-pyrite, Apy-arsenopyrite, Ga-galena, Sph-sphalerite.

Tables 7.2: Summary of micro-thermometry results

Tables 7.3: Results from XRD analysis. Some of the vein samples are the same with Table 7.2.

Tables 7.4: Total carbon percentage in vein sample reflected the inorganic carbon from quartz carbonate vein in various ore zone (analysis at Penjom Lab).

Tables 7.5: Summary of XRD analysis of vein and wall rock alteration mineral of several main ore bodies which is typical of phyllic alteration.

Tables 7.6: Geochemical results of trace elements analysis in three types of rock. Fe, Mn, Cr, in %: Au in ppb, others in ppm

Tables 8.1: List of galena samples (n=9) from Penjom from several stages.

Tables 8.2: Results (in ppm) of the trace elements in galena for samples (Q2WL, Q2WA, JL2, ZX3, JNNE, ZNNW, HW-S2, G1a HW-S, HW-E. Three analyses were undertaken for each sample. Other samples are from University of Tasmania collection: MT Isa-Mount Isa, B Hill-Broken Hill, MT M-Mount Murchison, B Mare-Baja Mare, Tynagh, SW-Sweet Water and O Dam-Olympic Dam.

Tables 8.3: Lead isotope ratio of various stages of galena in Penjom.

Tables 9.1: Tectonic setting, structural episodes and timing of veins formation for several major gold deposits and comparison to Penjom gold deposit.
LIST OF PUBLICATION AND PAPER PRESENTED

LIST OF APPENDICES

Appendix A: Fluid inclusion data
Appendix B: XRF geochemistry data