# Porphyry Deposits: Classification, Distribution, Geodynamic Settings and Intrusions

# 斑岩型矿床：分类、分布、动力学背景和侵入体

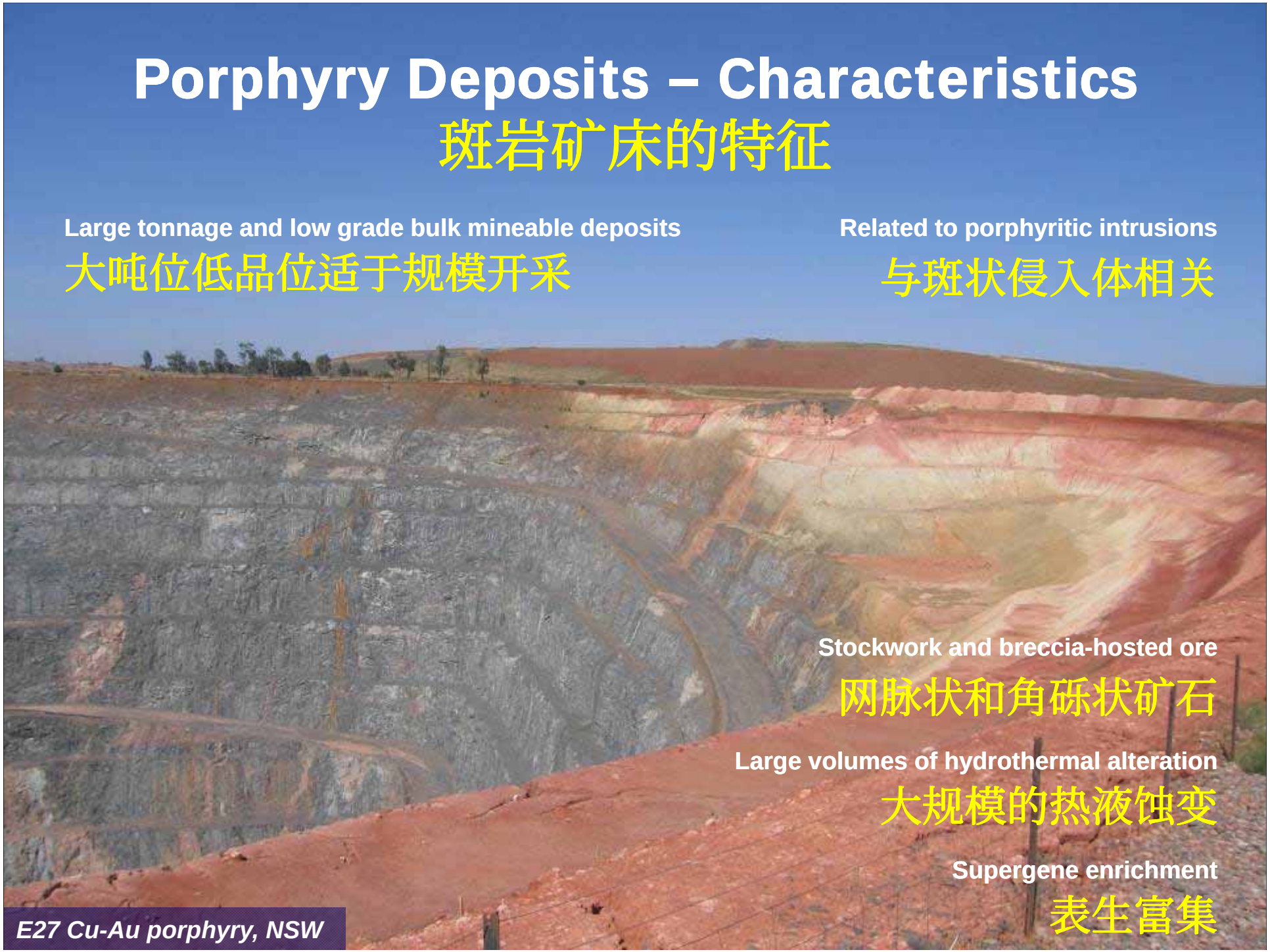


Chuquicamata, Chile

# Porphyry Deposits – Characteristics
# 斑岩矿床的特征

Large tonnage and low grade bulk mineable deposits
大吨位低品位适于规模开采

Related to porphyritic intrusions
与斑状侵入体相关



Stockwork and breccia-hosted ore
网脉状和角砾状矿石

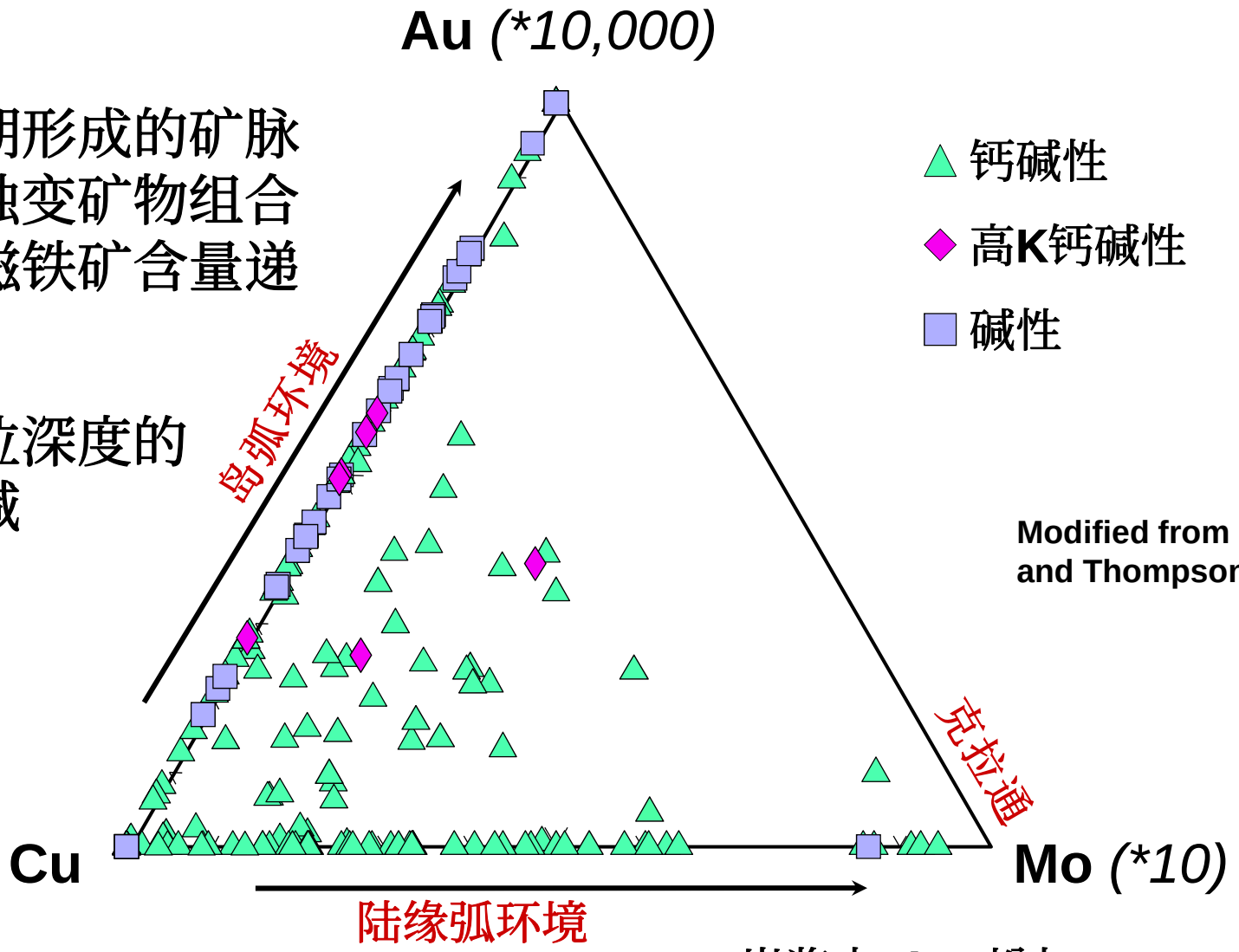
Large volumes of hydrothermal alteration
大规模的热液蚀变

Supergene enrichment
表生富集

*E27 Cu-Au porphyry, NSW*

# 根据金属含量的分类

- 早期形成的矿脉和蚀变矿物组合中磁铁矿含量递增
- 侵位深度的递减




Modified from Kesler (1973) and Thompson (1994)

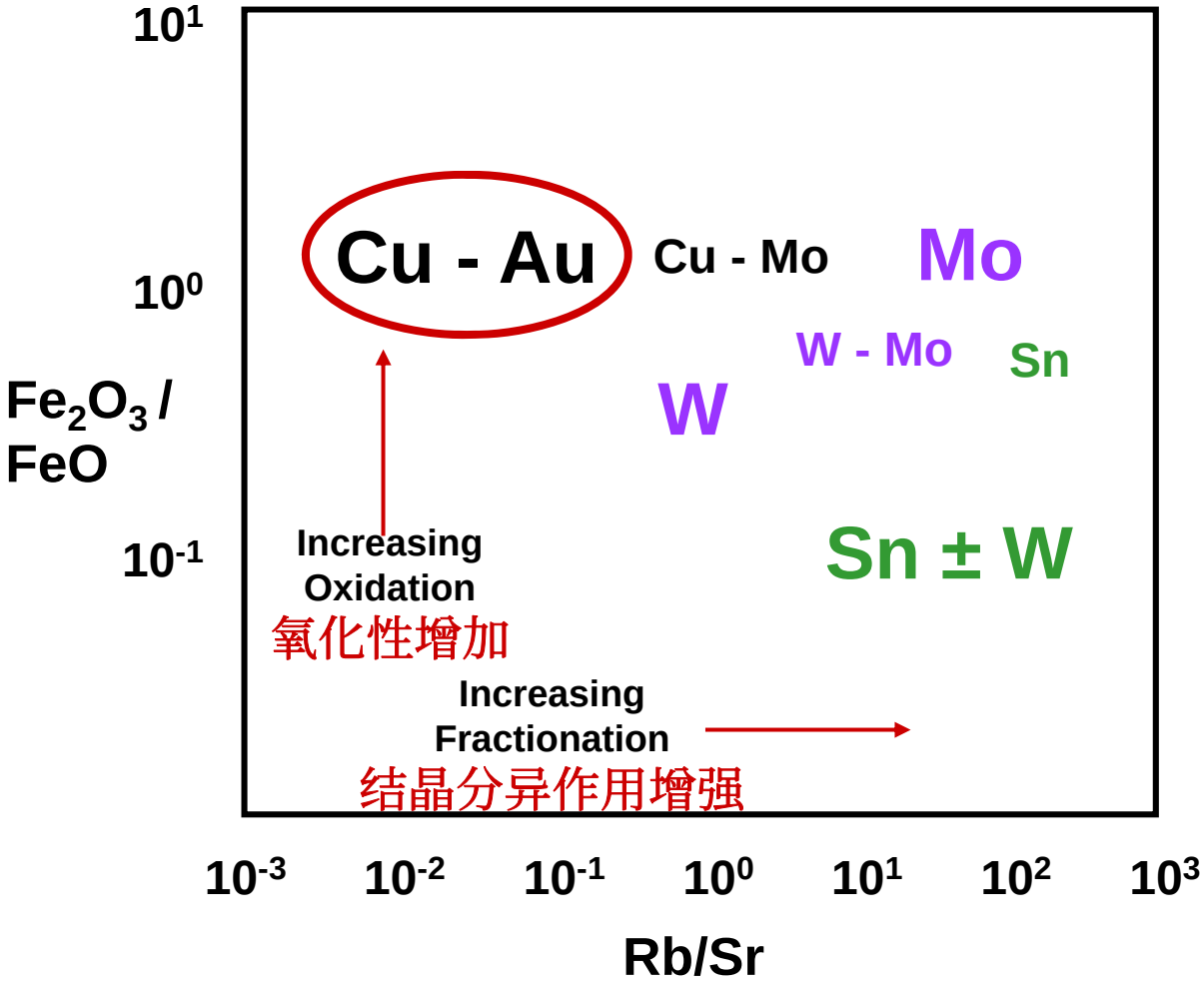
# Magma Chemistry
# 岩浆化学

**Metal endowment of intrusion-related deposits controlled by the magma's:**

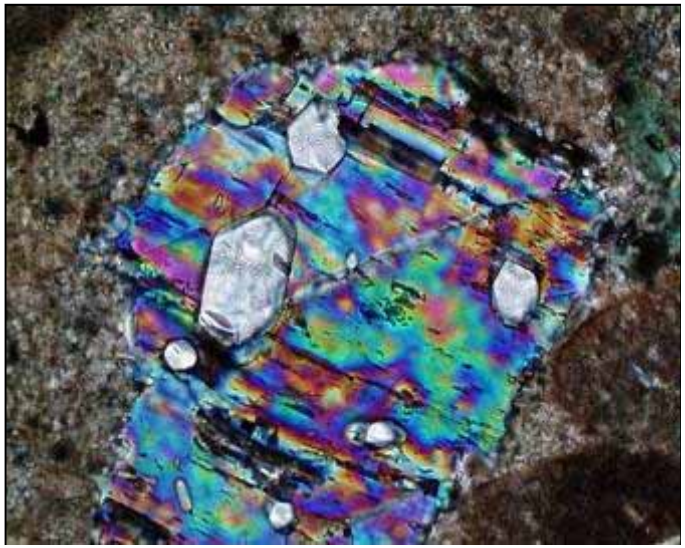
- oxidation state
- compositional evolution
- silica content

与侵入岩有关矿床中金属总量受岩浆以下条件的控制

- 氧化态
- 成分演化
- $SiO_2$含量



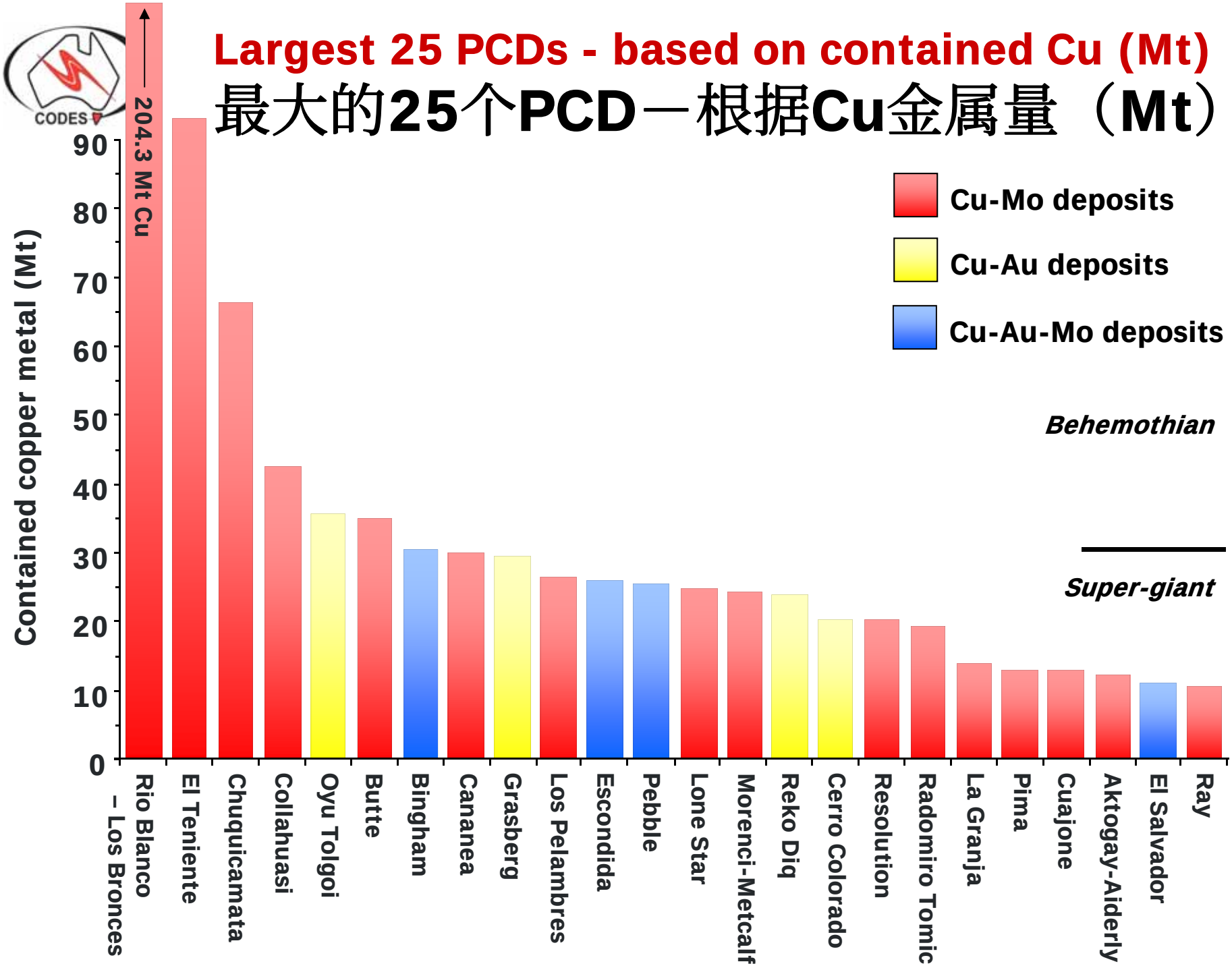

Modified from Blevin, 2003



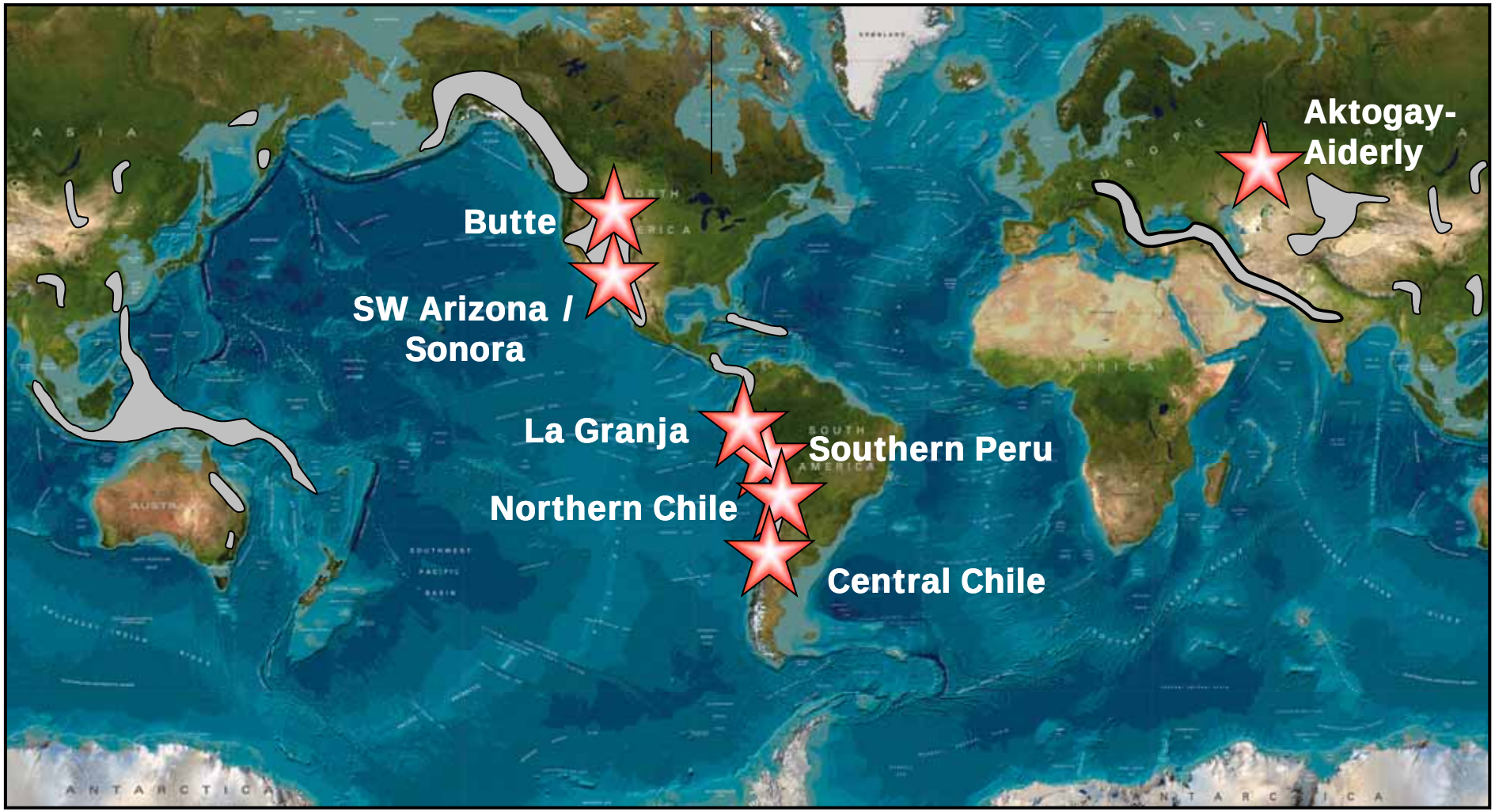
Anhydrite phenocryst with apatite inclusions, North Parkes, NSW

# Largest 25 PCDs - based on contained Cu (Mt)

# 最大的25个PCD－根据Cu金属量（Mt）



# Location: Porphyry Cu-Mo Deposits
# 位置：斑岩型Cu-Mo矿床

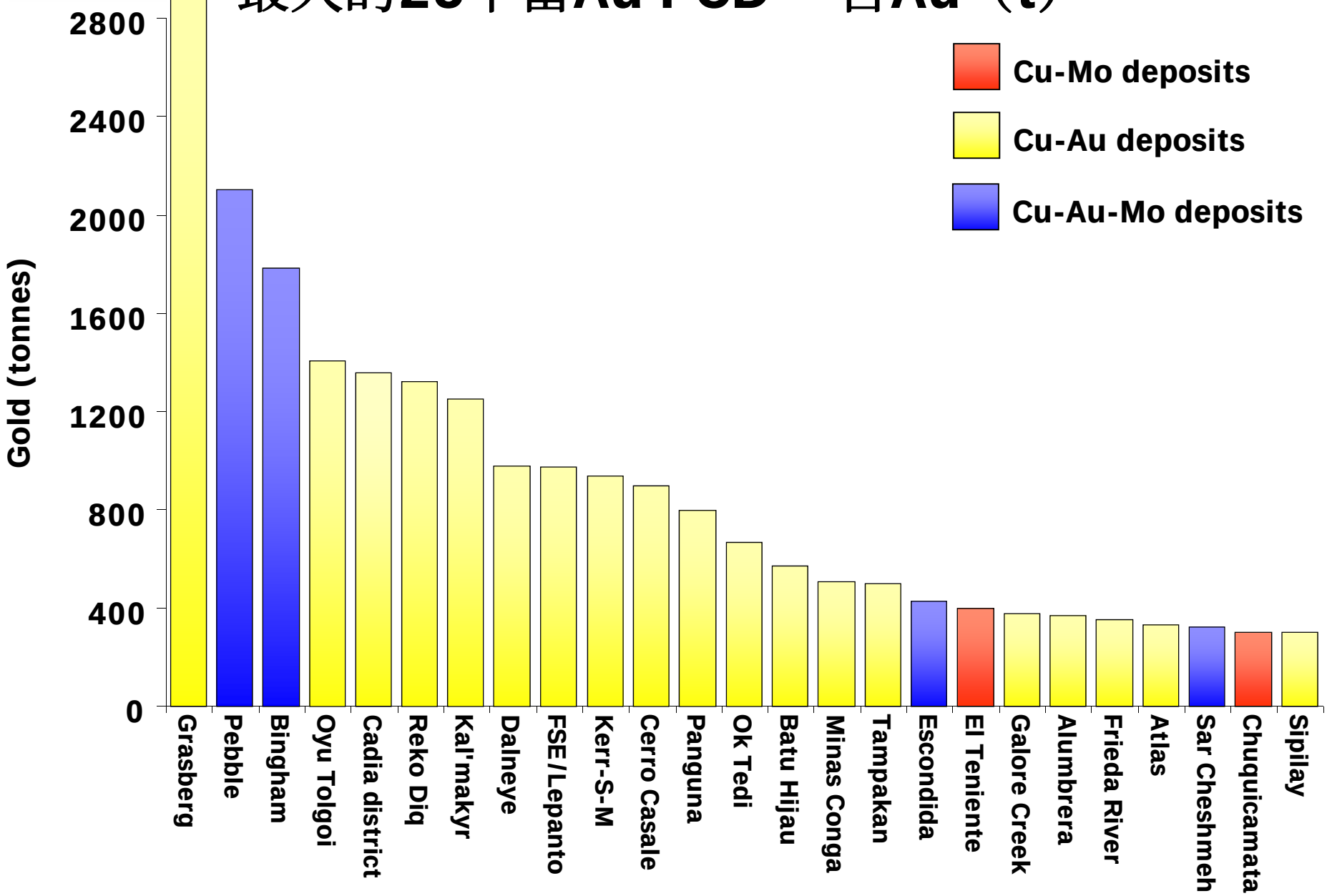



Porphyry Cu-Mo

*Map source: http://www.gebco.net*

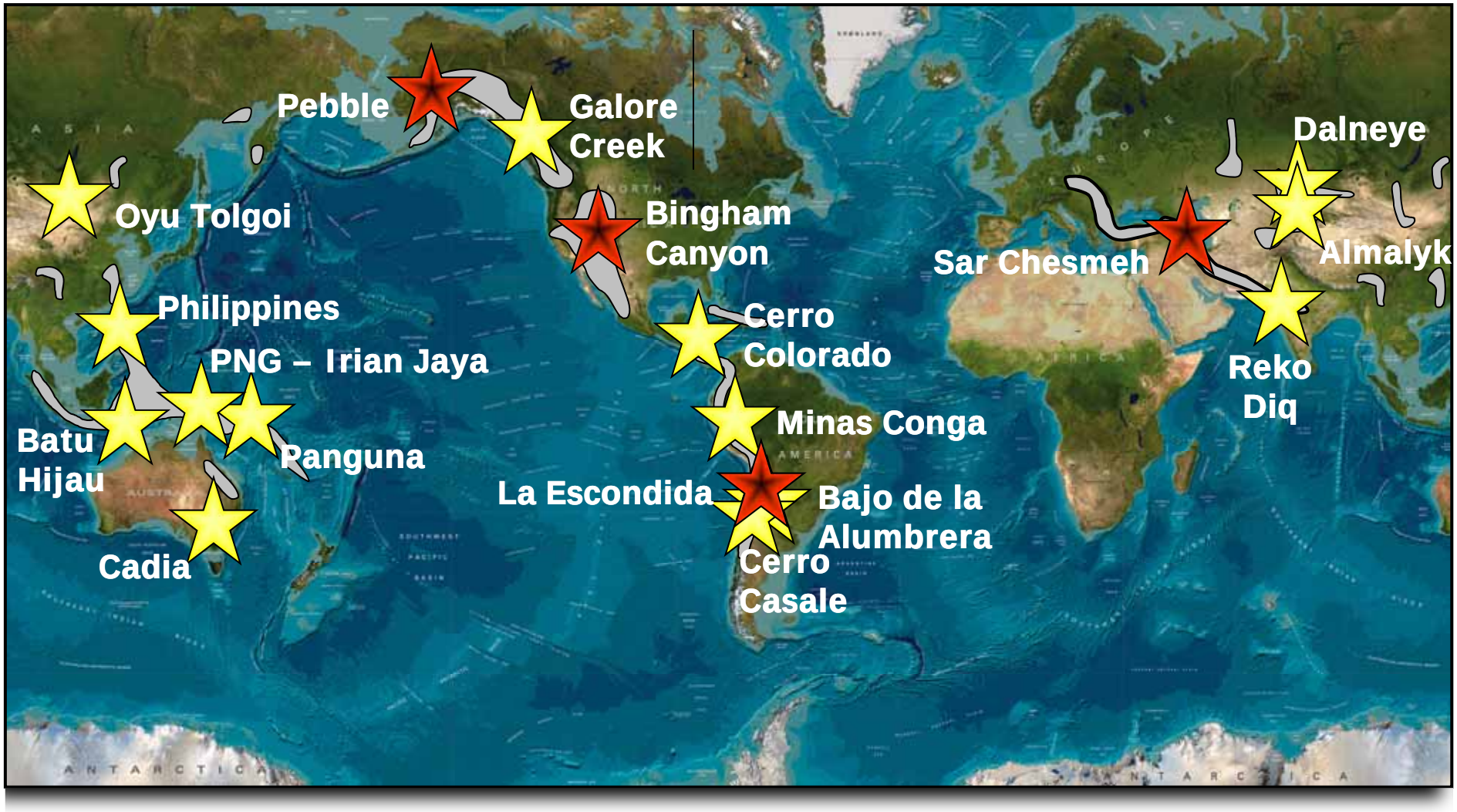
# Largest 25 Au-rich PCD - contained Au (t)

# 最大的25个富Au PCD – 含Au（t）



# Gold-rich porphyry copper districts
# 富金斑岩铜矿地区

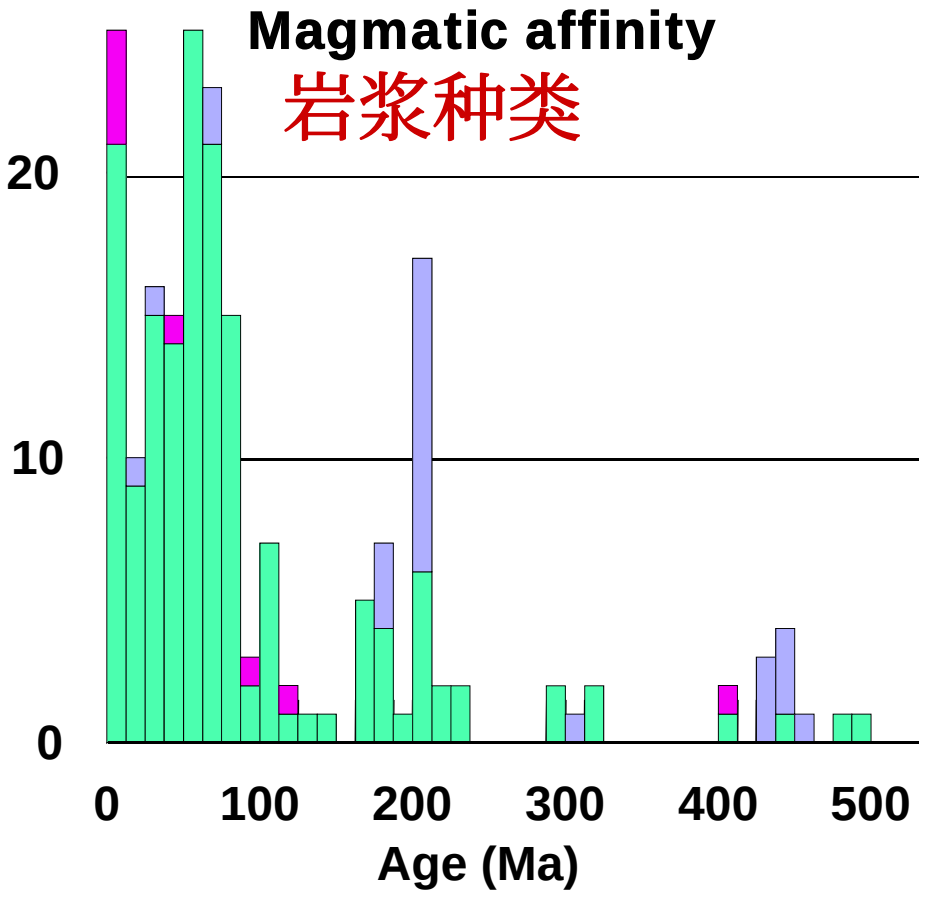
*Map source: http://www.gebco.net*

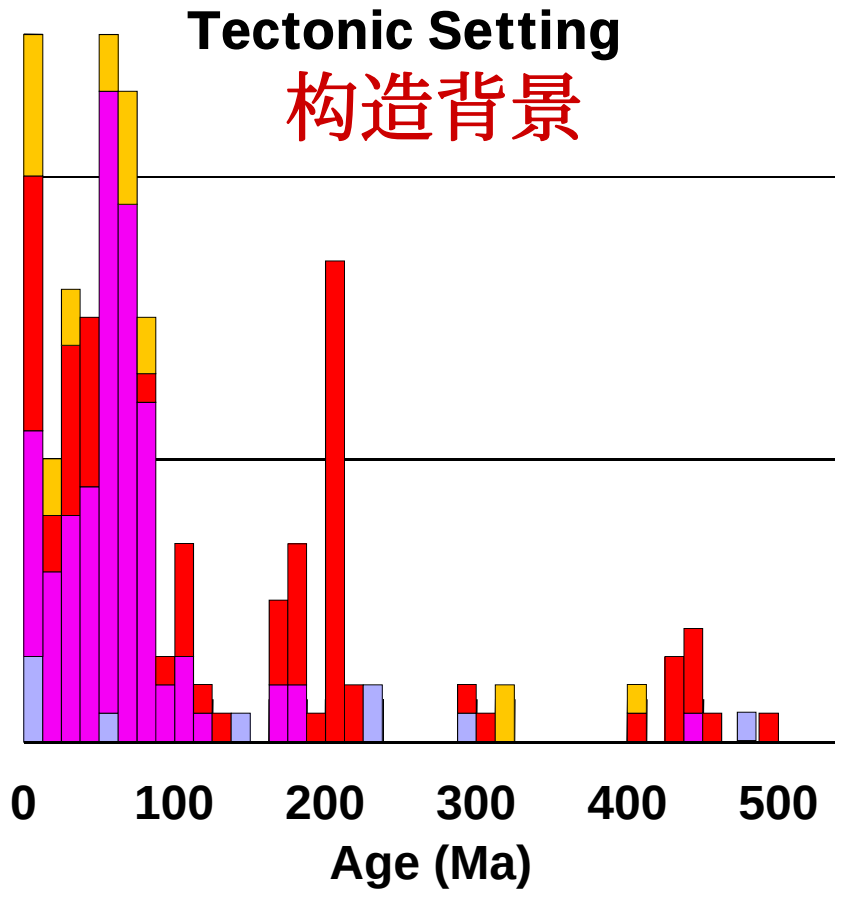



Porphyry Cu-Au
斑岩型Cu-Au 矿床

Porphyry Cu-Au-Mo
斑岩型Cu-Au-Mo矿床

# Epochs of porphyry deposit formation
# 斑岩型矿床的形成时期

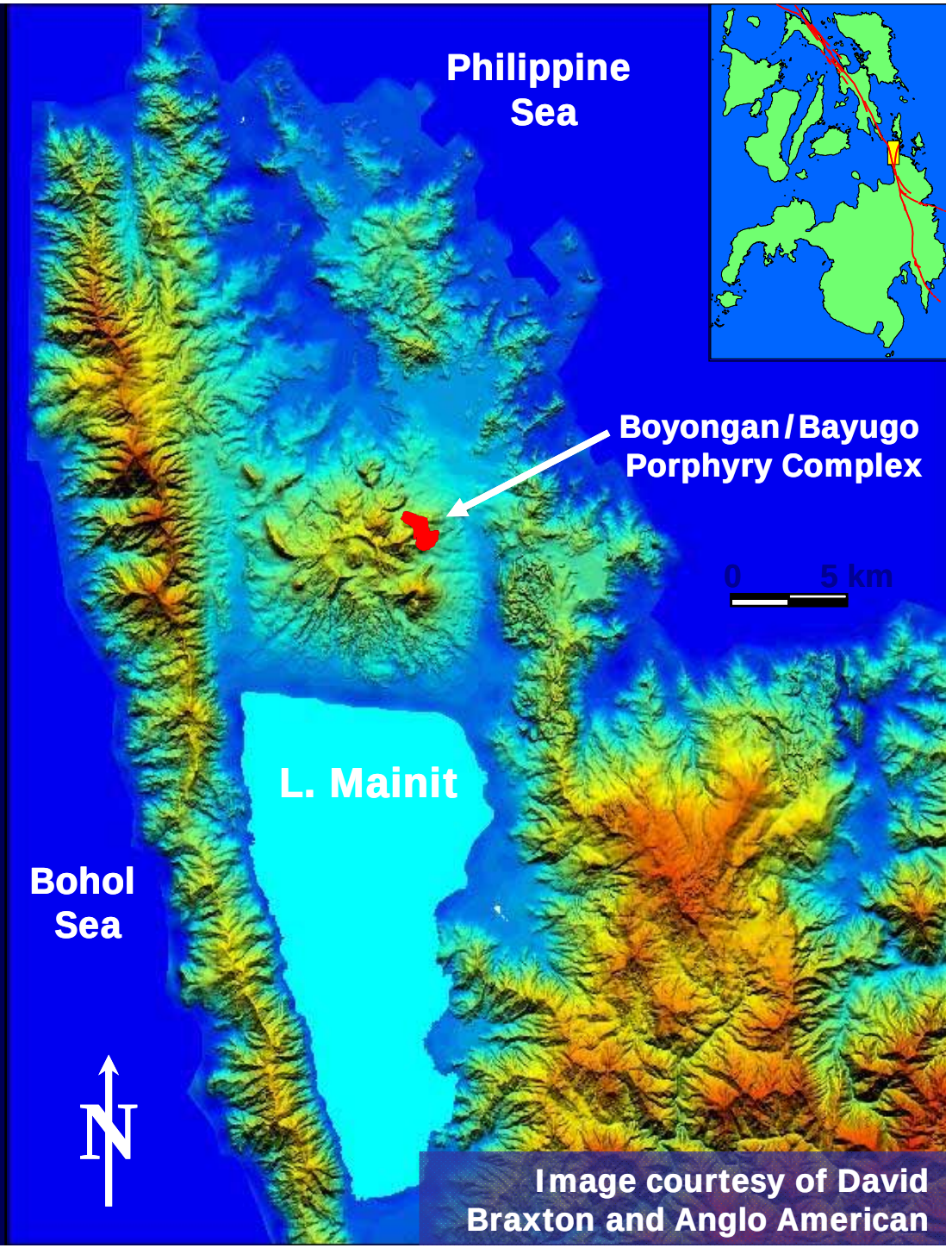


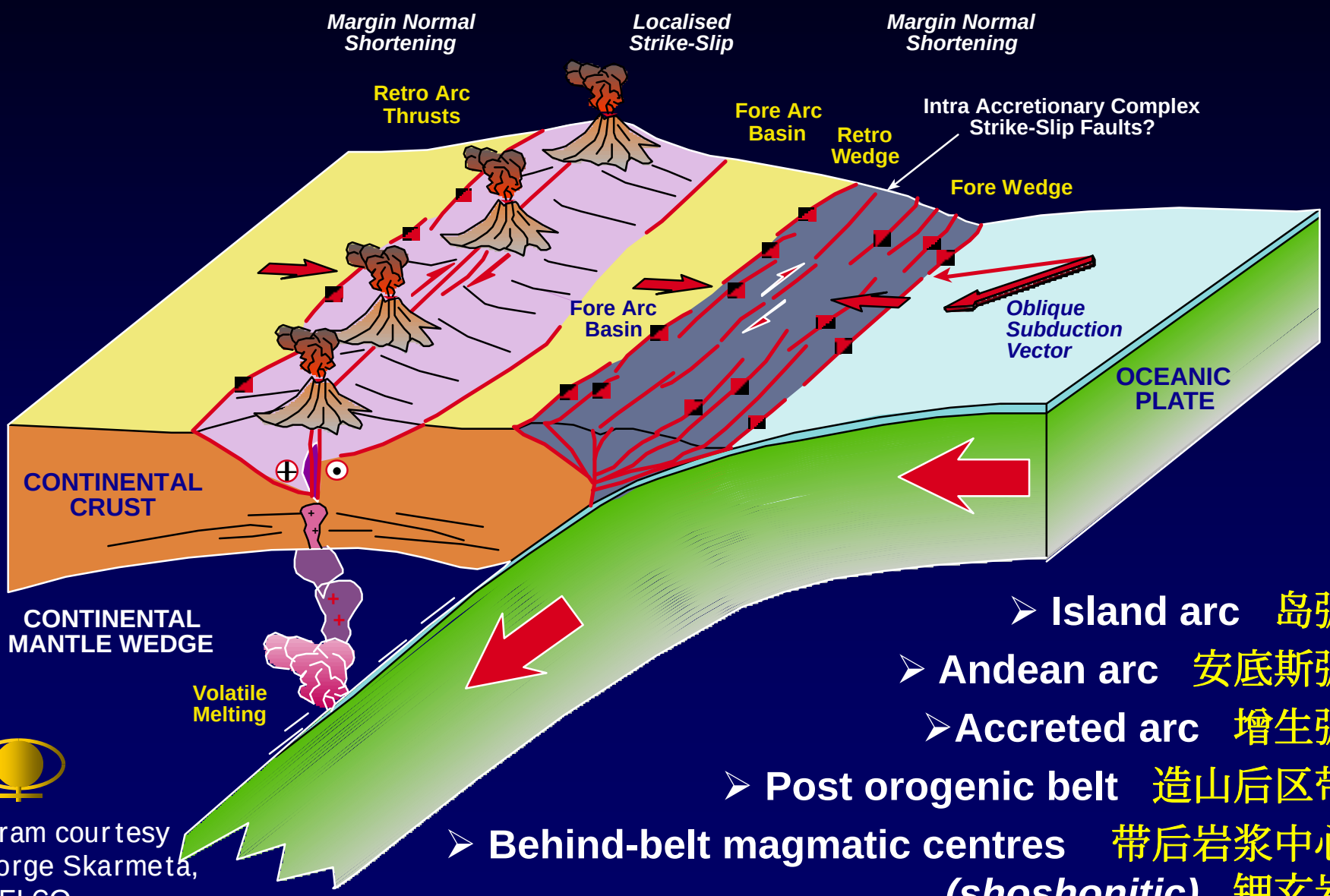

Data source: Kirkham & Dunne, 1999

# Environments of Formation

- Shallow crustal (<3 km) magmatic-hydrothermal ore deposits
- Compressional arc settings with active cross-arc and/or arc-parallel structures
- Genetically associated with skarns, HS and IS/LS epithermal deposits (telescoping)
- Rapid uplift and exhumation – *difficult to preserve supergene enrichment zones*



# Favourable Geodynamic Settings
# 有利的地球动力学环境




- Island arc 岛弧
- Andean arc 安底斯弧
- Accreted arc 增生弧
- Post orogenic belt 造山后区带
- Behind-belt magmatic centres 带后岩浆中心 *(shoshonitic)* 钾玄岩

Diagram courtesy of Jorge Skarmeta, CODELCO

# Porphyry Provinces
# 斑岩省

- **Porphyry deposits emplaced within a narrow time interval**

  斑岩型铜矿就位于一个很短的时间区间

- **Similar magma suites in each event**

  在每期事件中呈现相近的岩浆组合

- **Similar metal suite in each event**

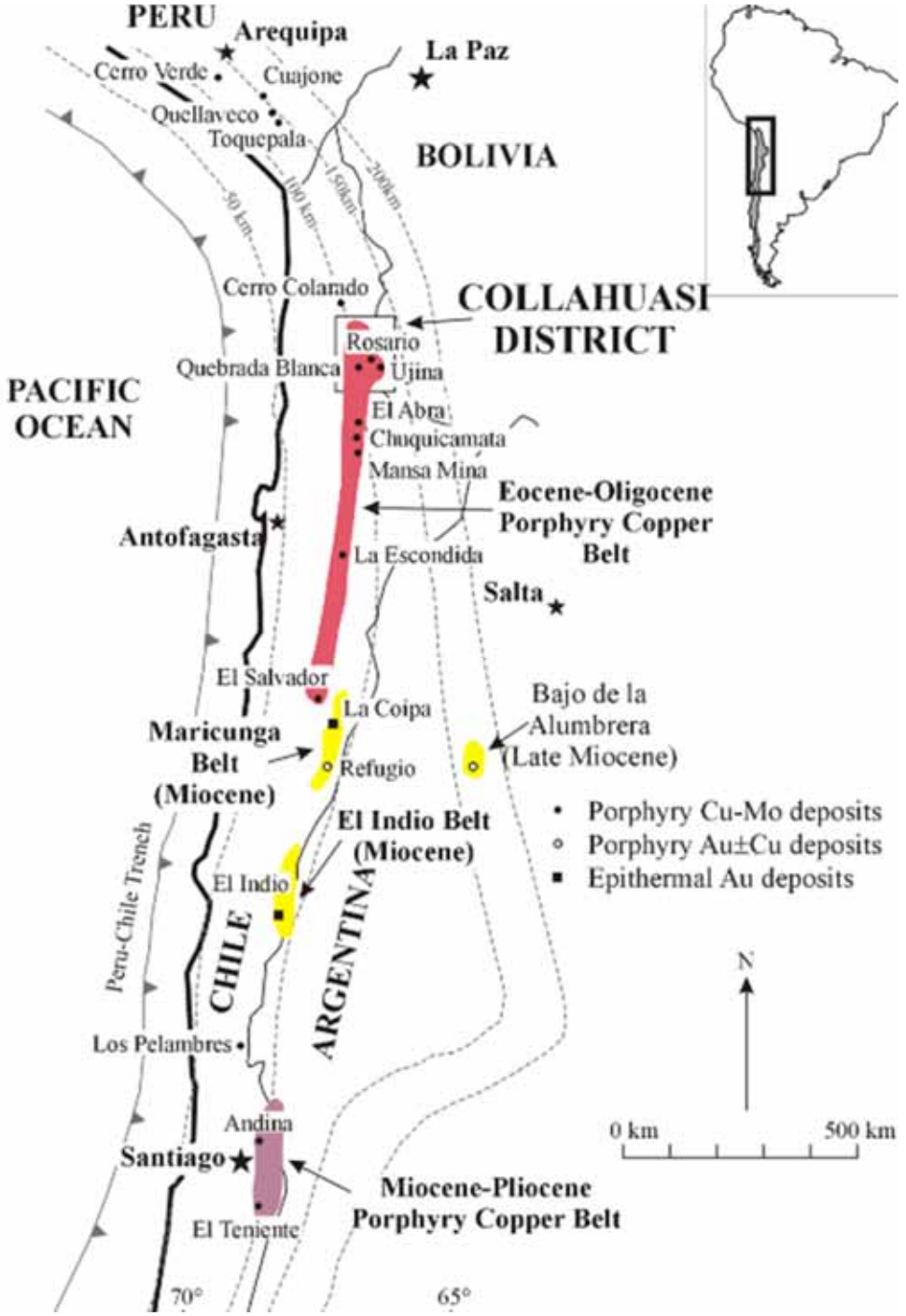
  在每期事件中具有相似的金属组合

- **General relationship to subduction environment**

  通常与俯冲环境有联系

- ***Specific relationship to tectonic change***

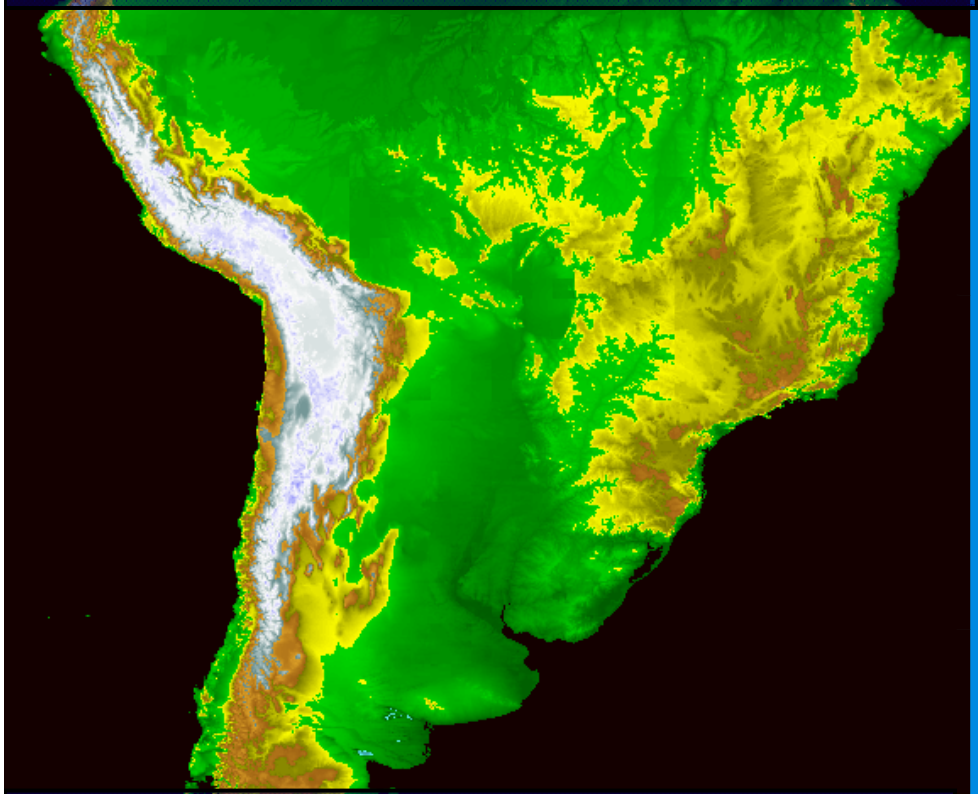
  *与构造环境转变具有特定关系*



# Ridge Subduction 海岭俯冲

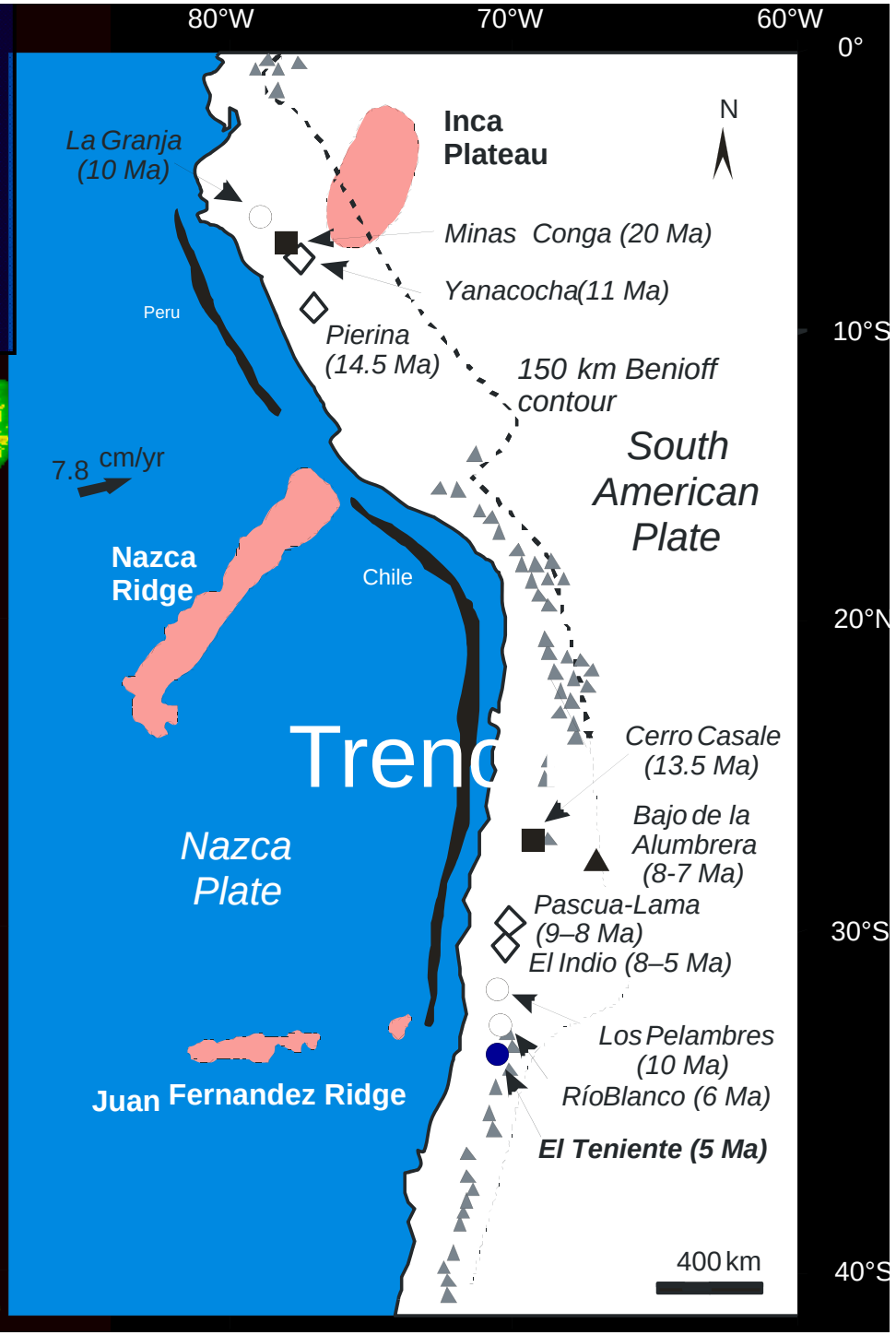
**Triggered Miocene porphyry & HS mineralisation - central & northern Peru**

**触发了中新世的斑岩和HS矿化 — 秘鲁中北部**



**Triggered Late Miocene – Pliocene porphyry & HS mineralisation - Central Chile**

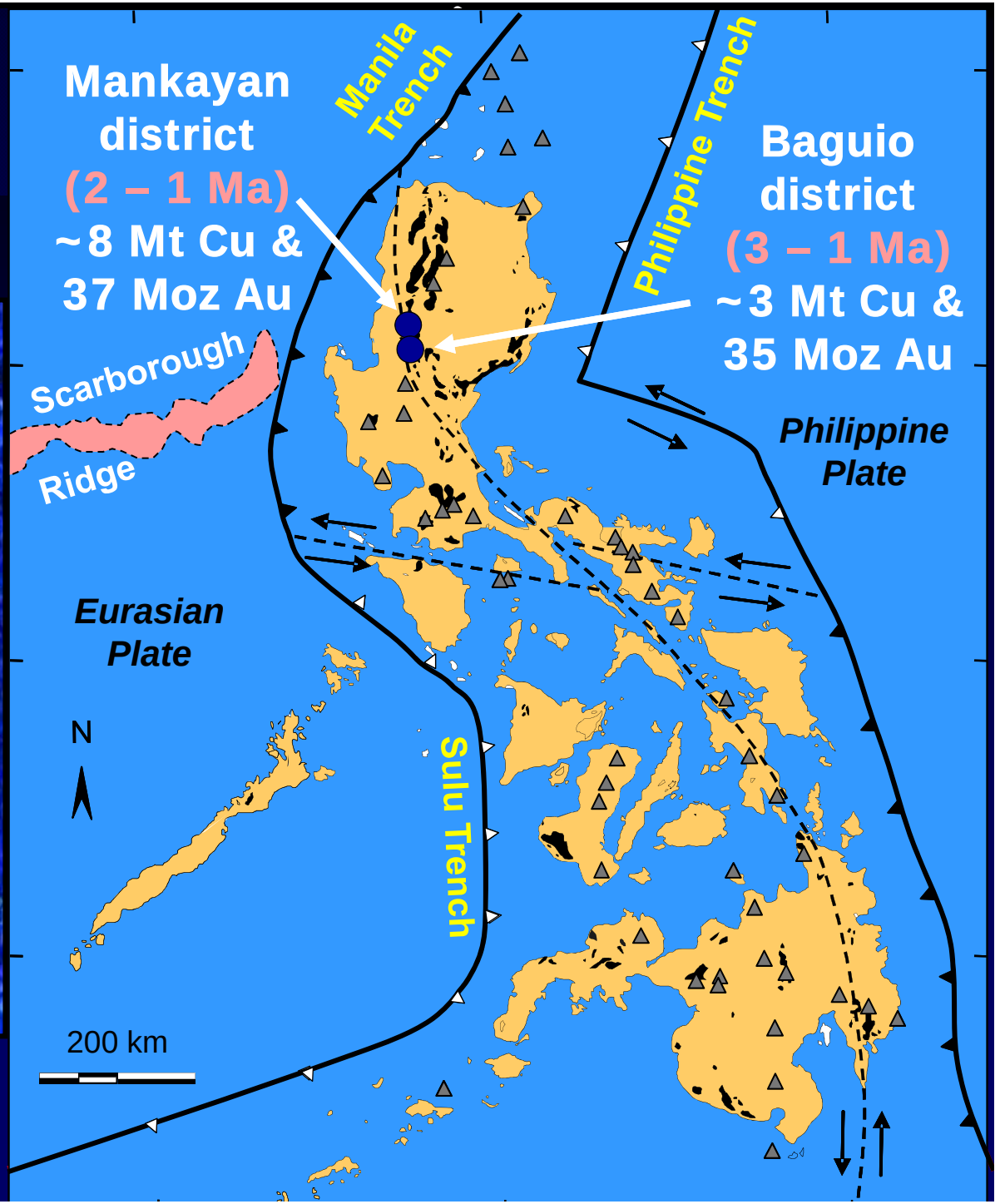
**触发了晚中新世—上新世的斑岩和HS矿化—智利中部**



# 菲律宾
# Philippines



*Source:*
*http://www.ngdc.noaa.gov/mgg/image/2minrelief.html*

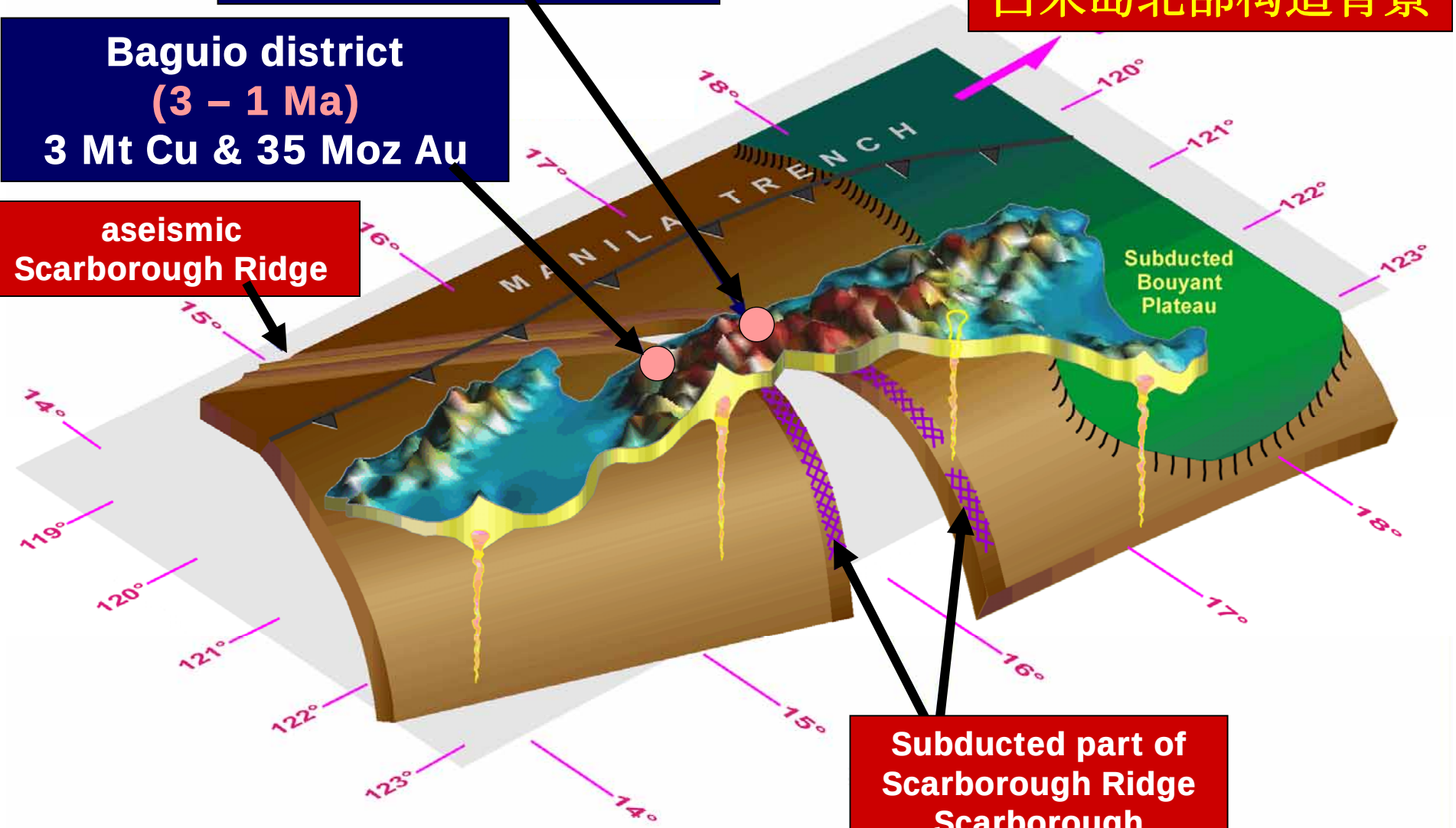


# Northern Luzon Tectonic Setting
# 吕宋岛北部构造背景

**Mankayan district**
**(2 – 1 Ma)**
**8 Mt Cu & 37 Moz Au**

**Baguio district**
**(3 – 1 Ma)**
**3 Mt Cu & 35 Moz Au**

**aseismic Scarborough Ridge**




**Subducted part of Scarborough Ridge Scarborough**
**山岭的俯冲部分**

*Image courtesy of Paddy Waters, AngloAmerican (Philippines)*

CODES

## Ridge Subduction - Side Effects?

# 海岭俯冲的副作用？

- **Shallowing subduction angle**

  使俯冲角度变小

- **Cessation of voluminous andesitic volcanism**

  使大规模安山质火山作用停止

- **Thrust stacking & crustal thickening**

  逆冲堆叠和地壳加厚

- **Giant earthquakes and propogation of deformation fronts**

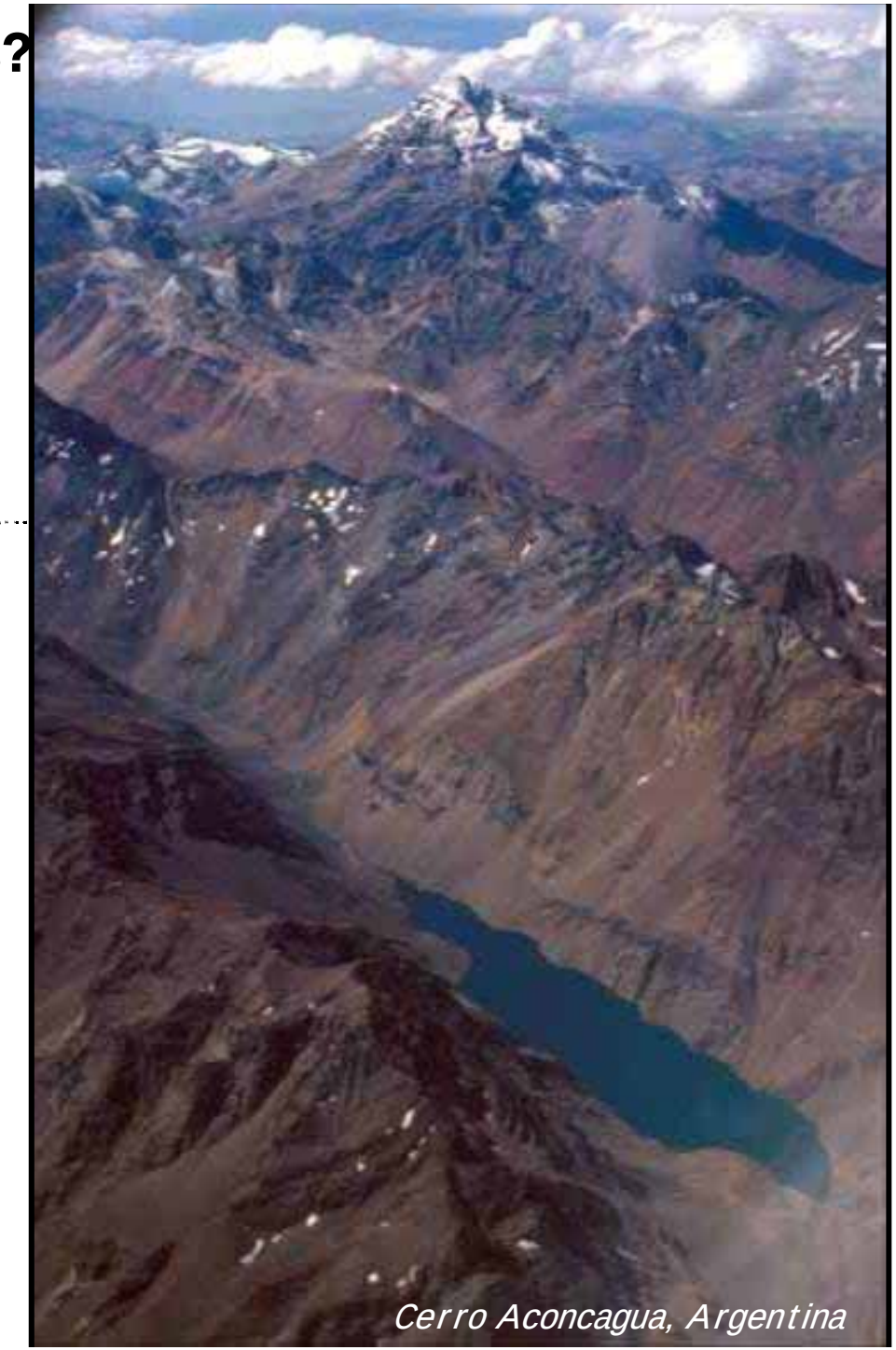
  强烈地震和变形前缘扩展

- **Formation of porphyry and epithermal deposits**

  斑岩和浅成热液矿床的形成

- **Rapid uplift & exhumation**

  快速隆升和剥蚀

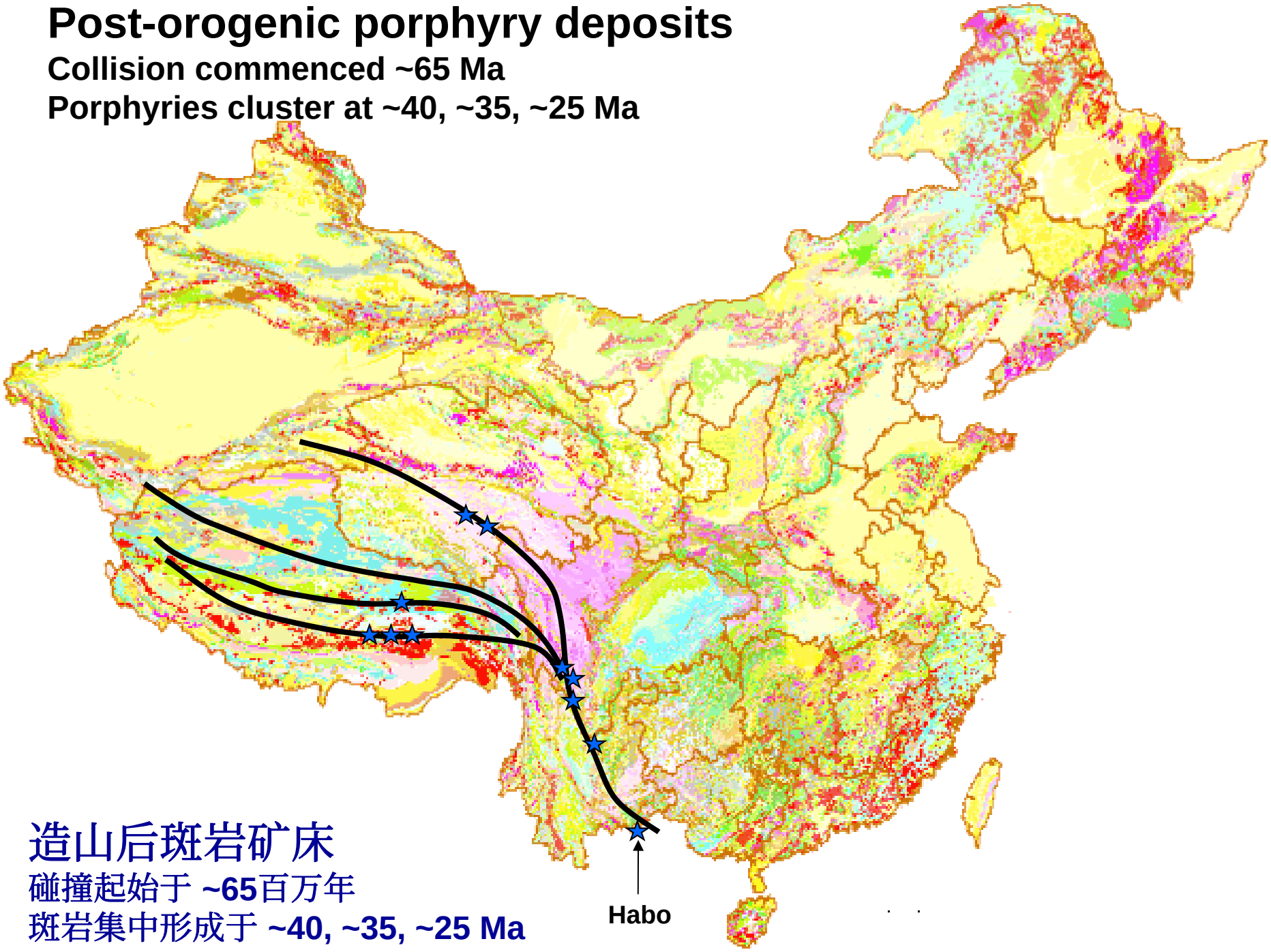


*Cerro Aconcagua, Argentina*

# Post-orogenic porphyry deposits

**Collision commenced ~65 Ma**

**Porphyries cluster at ~40, ~35, ~25 Ma**




## 造山后斑岩矿床

**碰撞起始于 ~65百万年**

**斑岩集中形成于 ~40, ~35, ~25 Ma**

# Intrusions
# 侵入岩



# Intrusion Geometries
# 侵入体形态





*QMP pipe, E27 Cu-Au PCD, North Parkes, NSW*

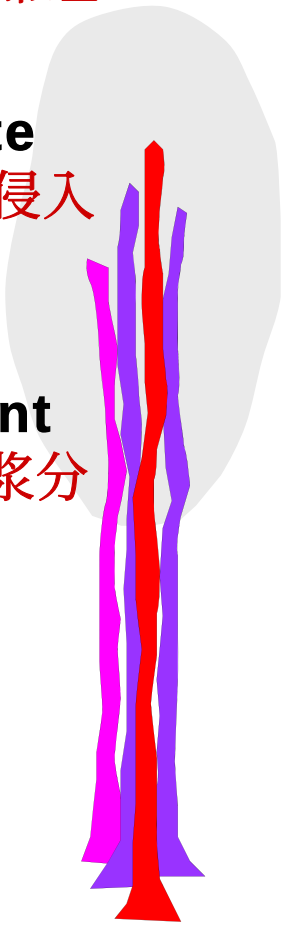
# Intrusion Geometries
# 侵入体形态





# Multi-phase intrusions 多相侵入体

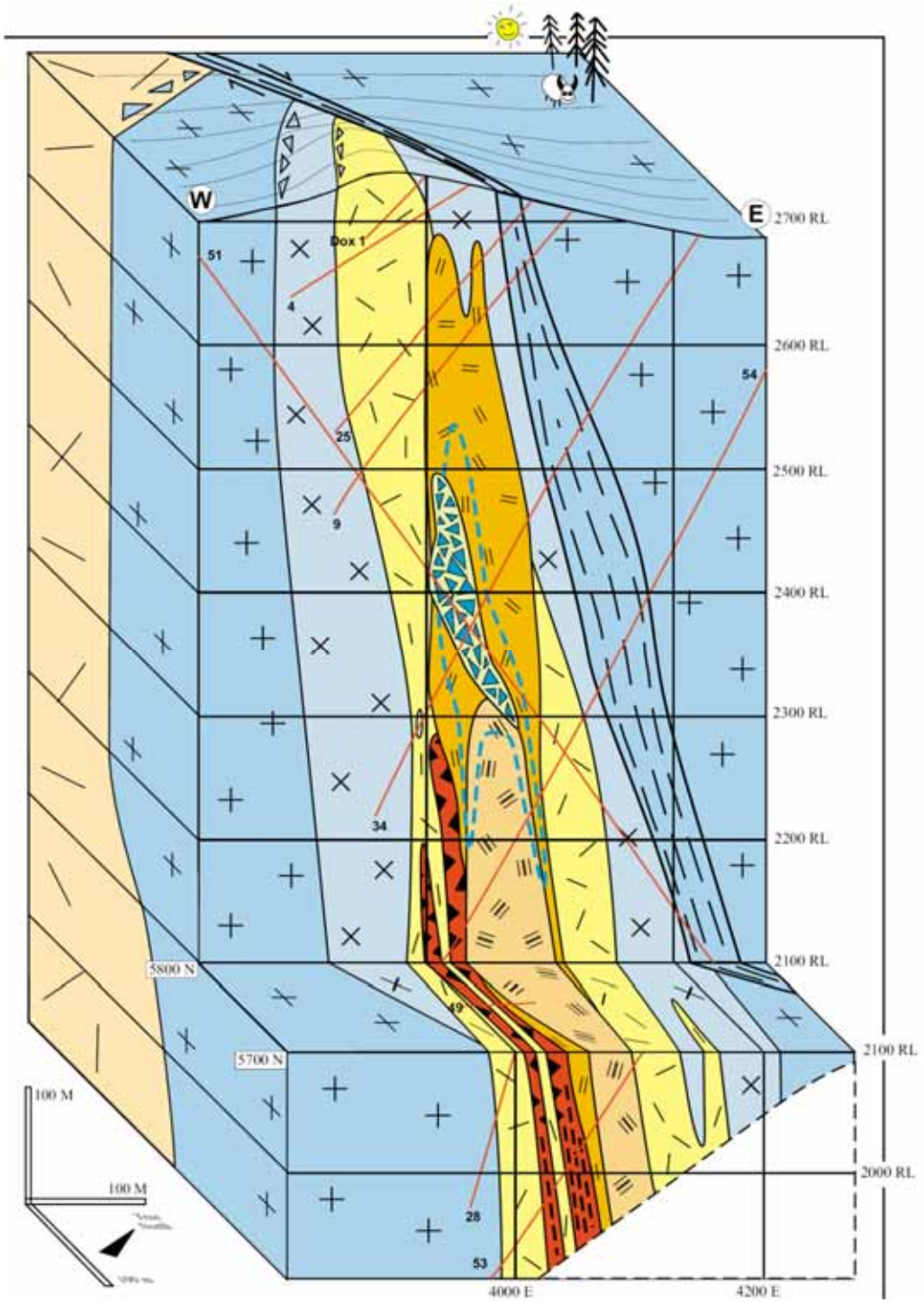
- **Multiple pipes, dykes or sills typically comprise mineralised intrusive complexes** 矿化侵入杂岩体通常由多个岩筒、岩墙或岩席组成
- **Only one or two intrusive phases create significant mineralisation** 只有一到两个侵入相产生重要矿化
- **A number of factors may affect an intrusion's capacity to exsolve abundant volatiles and metals, including:** 影响岩浆分出挥发份和金属能力的因素包括：
  - ***depth of emplacement*** *侵位深度*
  - ***volatile content*** *挥发份含量*
  - ***crystallisation history*** *结晶史*
  - ***seismic activity*** *地震活动*



**Early, high grade quartz monzonite porphyry cut by later, lower grade crystal-rich Quartz monzonite porphyry, North Parkes porphyry Cu-Au deposit, NSW**

# Multi-phase Intrusions

# 多相侵入体




*Didipio Igneous Complex* 侵入杂岩

Diorite 闪长岩

Monzodiorite 二长闪长岩

Surong Monzonite 二长岩

*Dinkidi Stock* **Dinkidi** 岩珠

Tunja Monzonite 二长岩

Balut Dyke 脉岩

Quan Porphyry **Quan** 斑岩

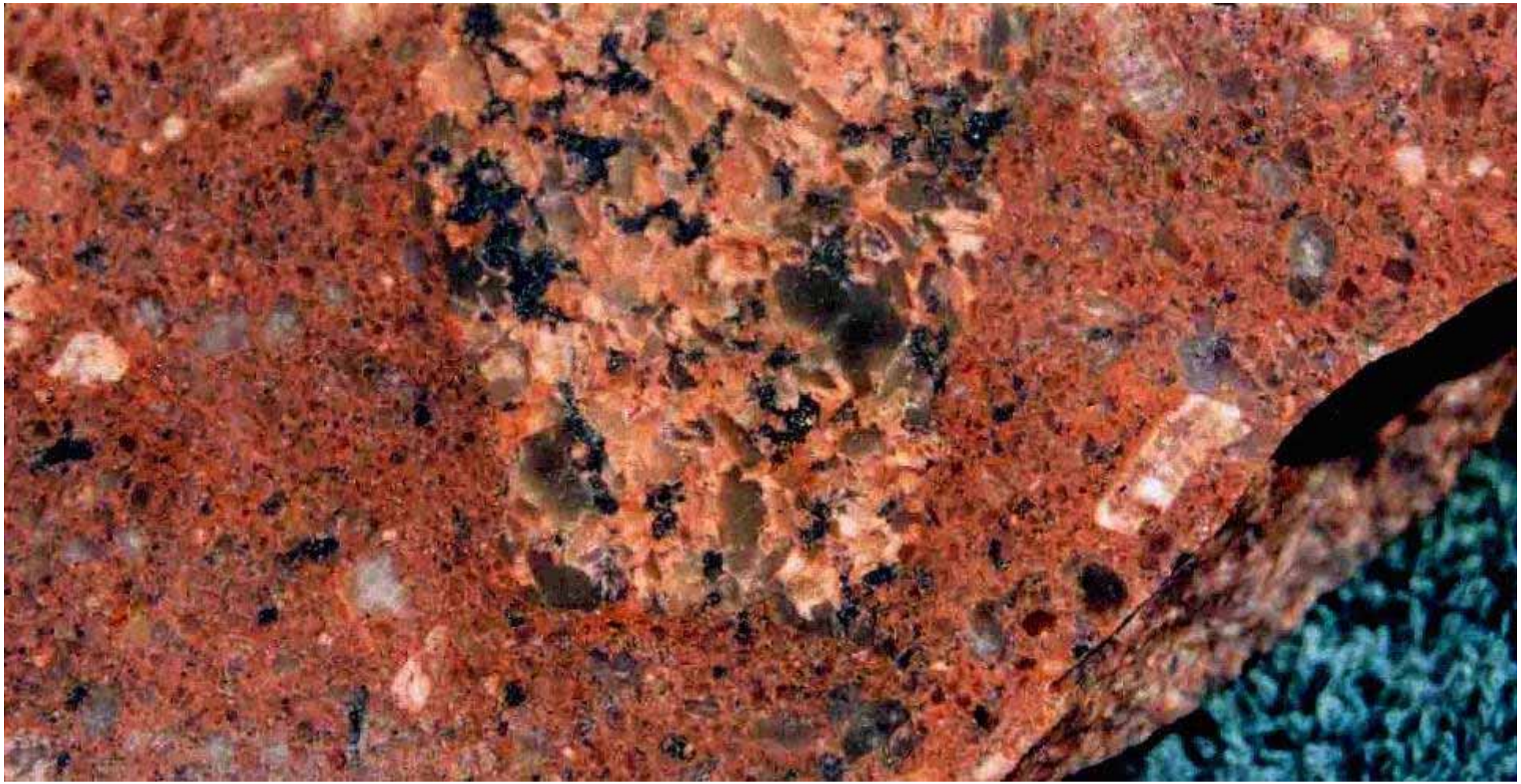
Bufu Syenite 正长岩

Approx. extent of Bugoy 'pegmatite' dykes

Quartz fragment breccia 石英碎屑角砾岩

***3-D geology block model Dinkidi Stock (Wolfe, 2001)***

# Multi-phase intrusions
# 多相侵入体



**Biotite quartz monzonite xenolith in quartz monzonite porphyry, NorthParkes, NSW**

**石英二长斑岩中的黑云母石英二长岩捕虏体 NorthParkes, NSW**

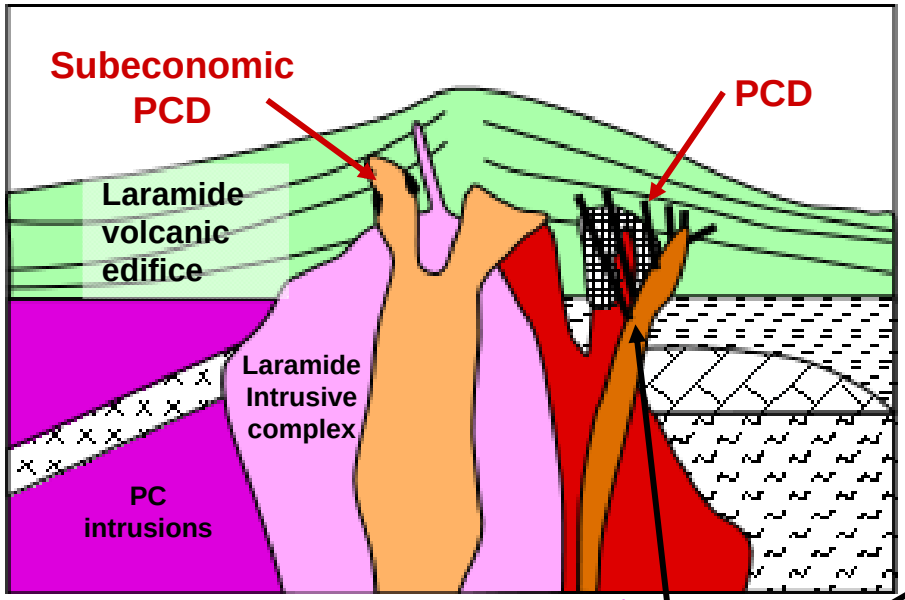
# Truncated Veins
# 被截断的矿脉



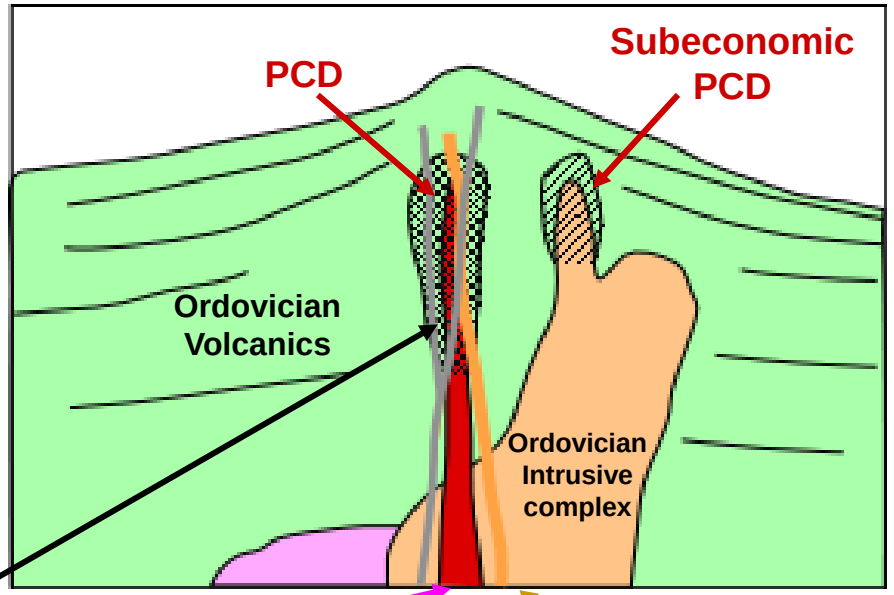
黑云母蚀变粗面安山岩中的石英黄铜矿脉，被QMP侵入体截断

# Intrusion Geometries
# 侵入体形态

## Arizona Cu-Mo PCDs




## North Parkes Cu-Au PCDs




- **Dykes (shallow)** 岩墙 ***Late***
- **Pipes** 岩筒
- **Stocks** 岩株
- **Plutons (deep)** 岩体 ***Early***

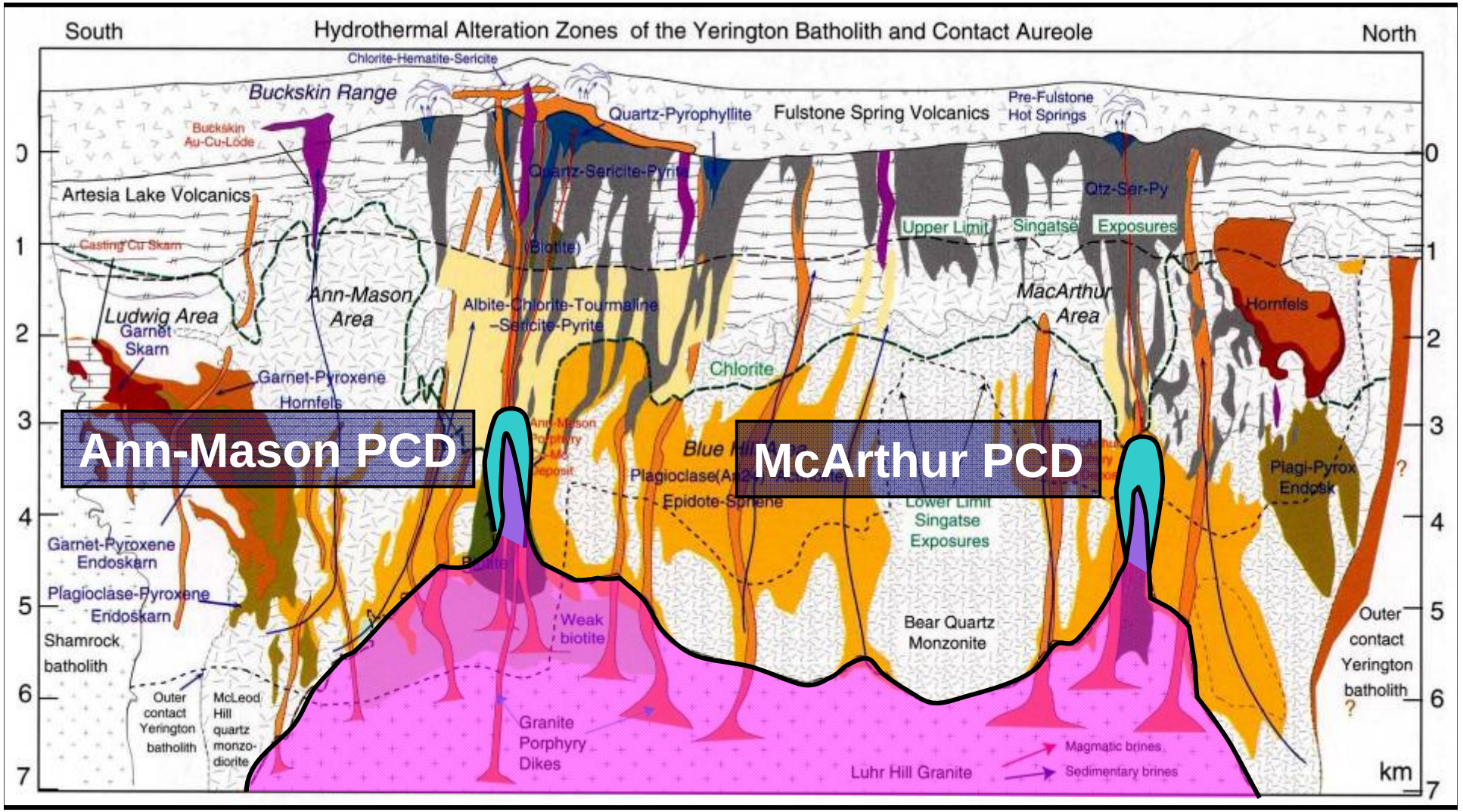
*Sections from Lang and Titley (1998) and Lickfold et al. (2003)*

# Deposit Clusters
# 矿床群

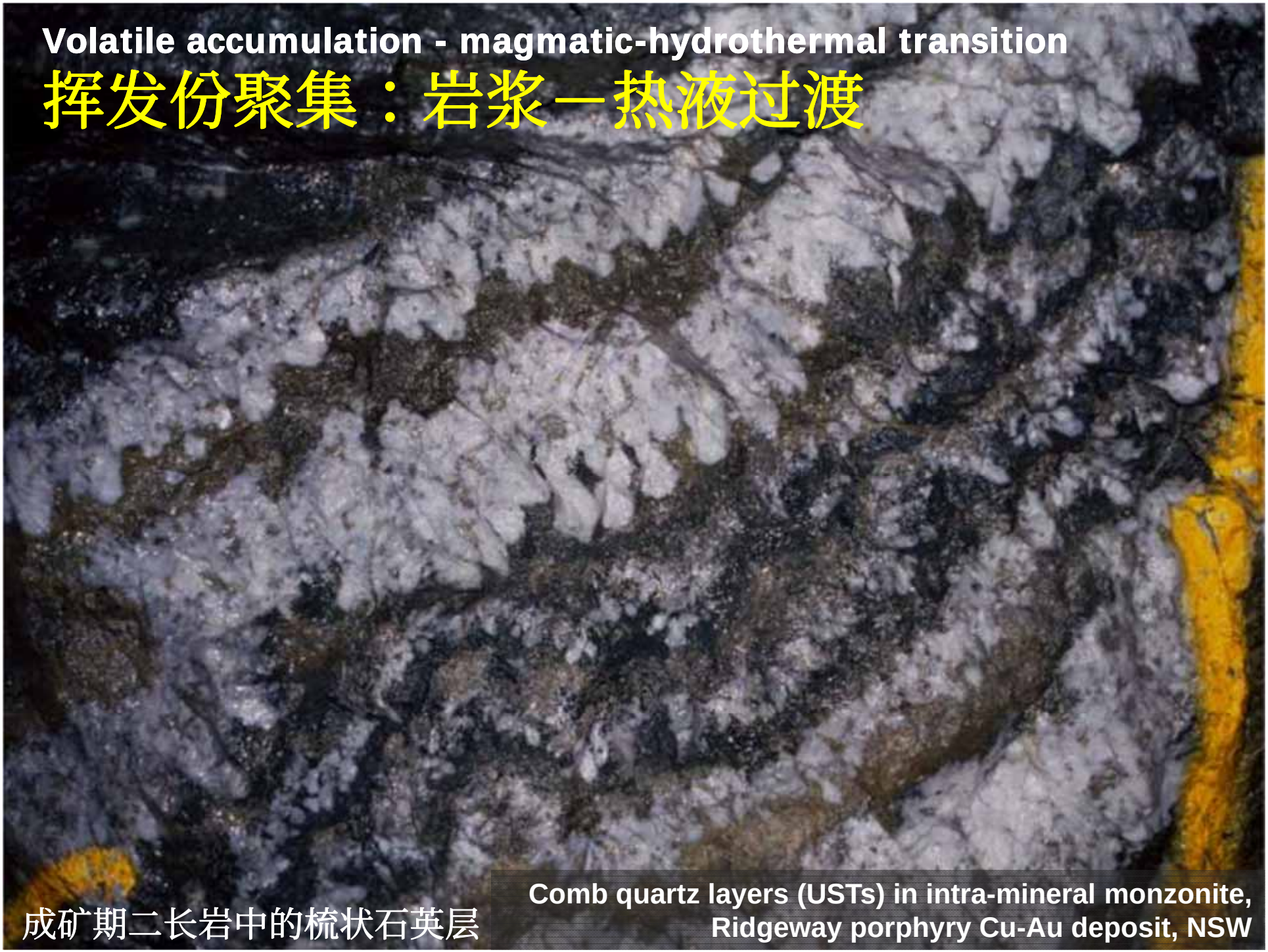



*Endeavour porphyry Cu-Au deposits, North Parkes, NSW*

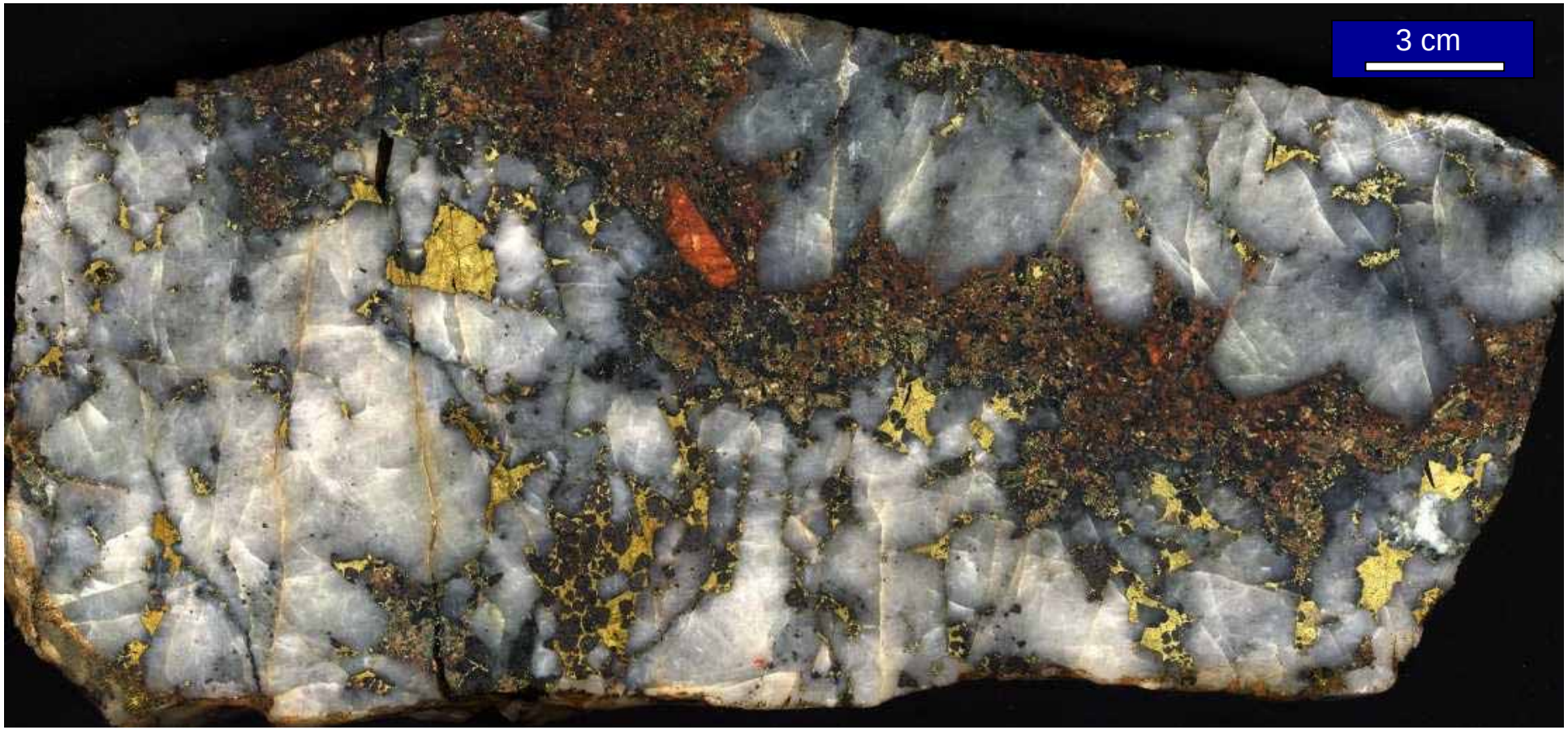
# Batholithic Roots - Yerington, Nevada
# 根部岩基




Yerington cross-section from Dilles et al. (2000)


Volatile accumulation - magmatic-hydrothermal transition
挥发份聚集：岩浆—热液过渡
成矿期二长岩中的梳状石英层
Comb quartz layers (USTs) in intra-mineral monzonite,
Ridgeway porphyry Cu-Au deposit, NSW

# Magmatic-Hydrothermal Transition
# 岩浆—热液过渡



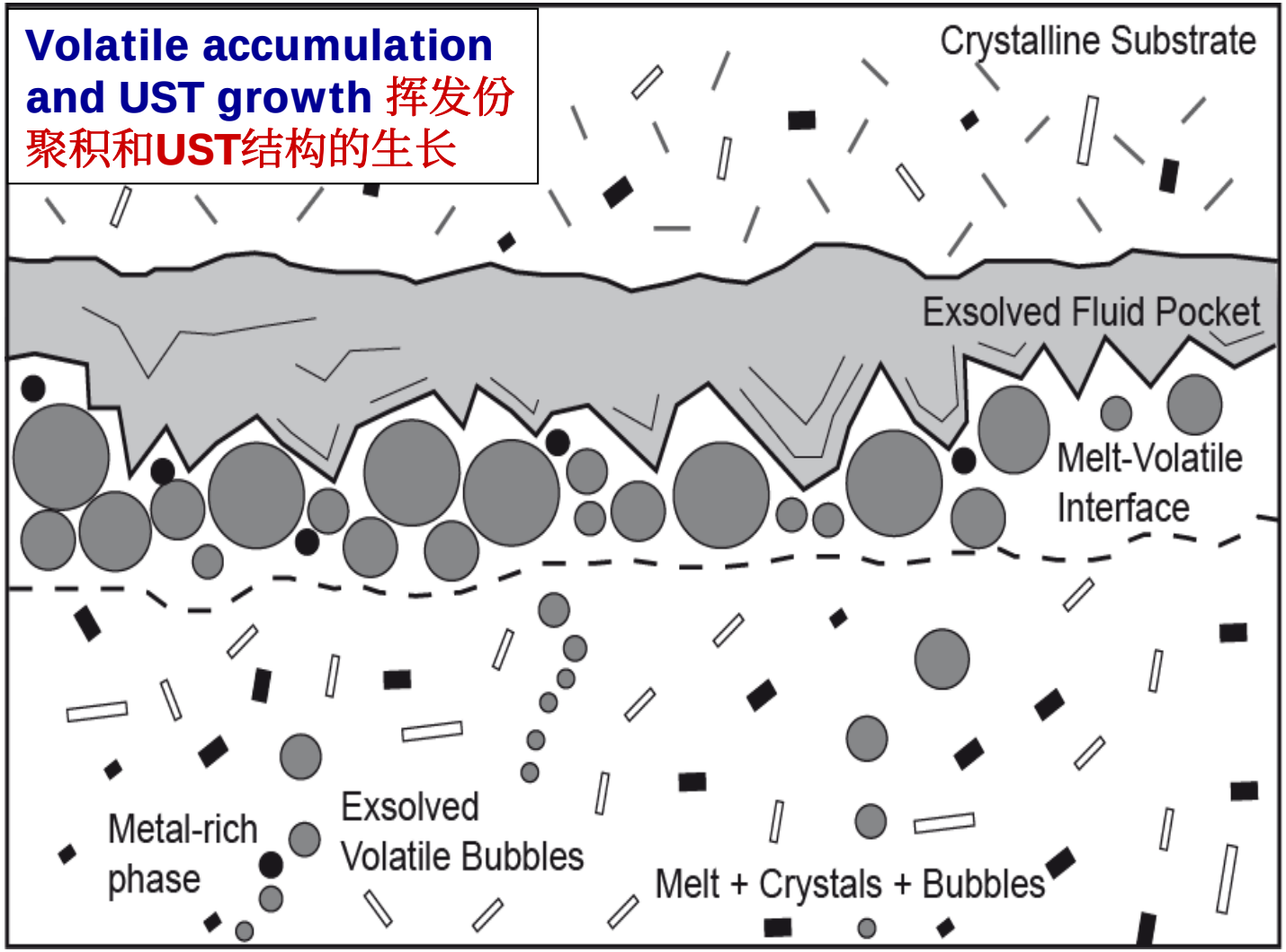

**Unidirectional solidification textures (USTs)**

单向固结结构（**USTs**）

二长岩中的梳状石英层

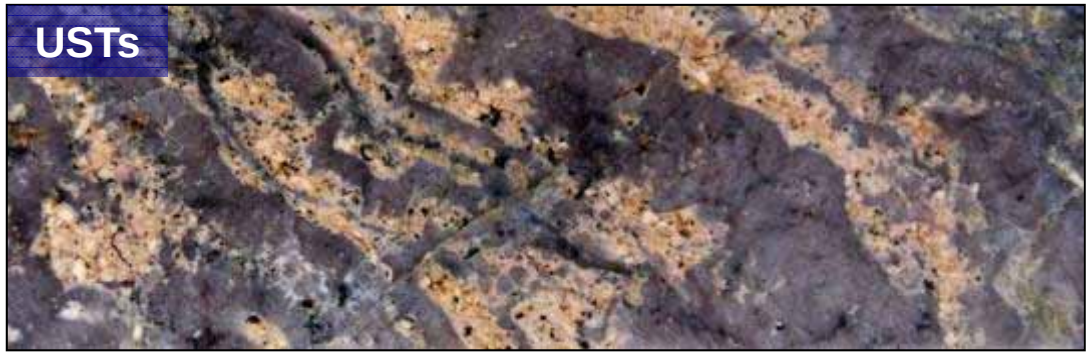


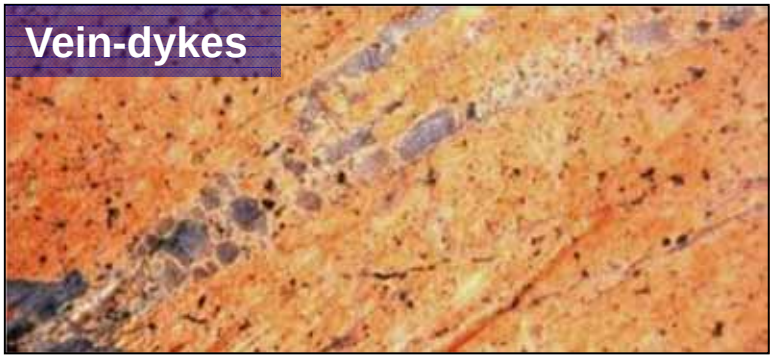

## Volatile accumulation and UST growth 挥发份聚积和UST结构的生长



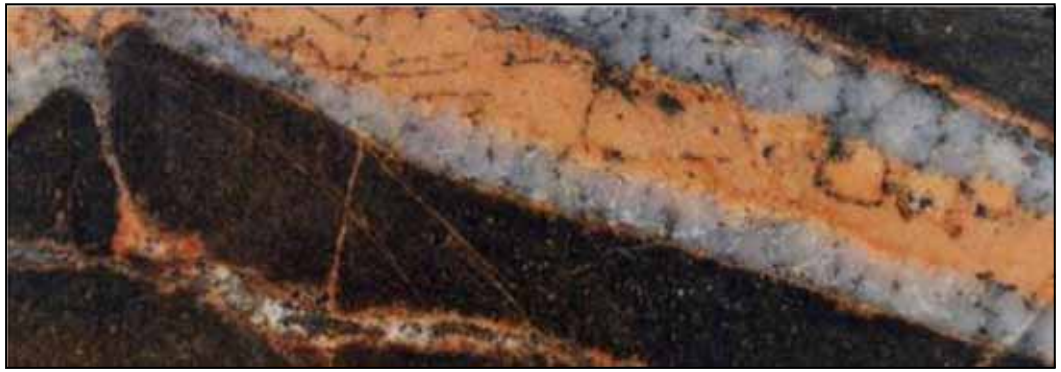

- **Buoyant hydrothermal fluid migrates upwards through the melt and accumulates in the roof of the inwardly-crystallizing magma** 热液流体向上运移，穿过熔体，聚集在向内结晶的岩浆房的顶部
- **Bands of distinctly prismatic crystals (e.g., qz, mt) grow downwards from the roof of the volatile pocket** 柱状晶体（如石英、磁铁矿）从挥发份囊的顶部向下生长；多批次形成多个带

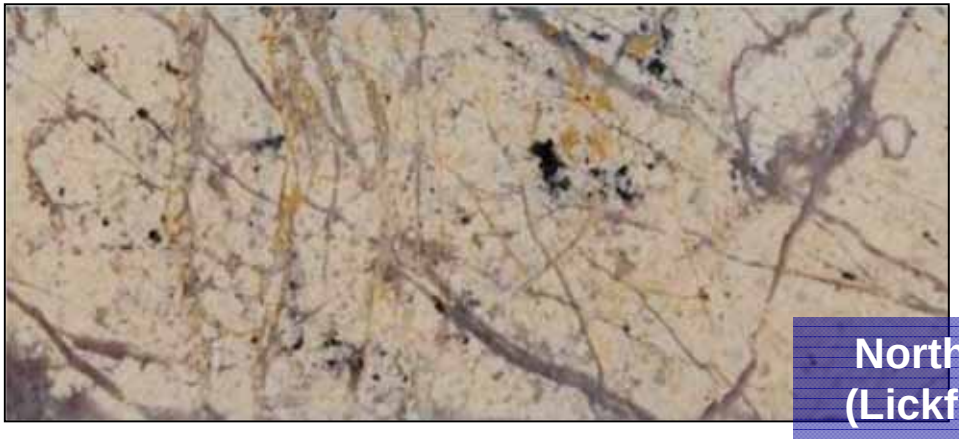
# Magmatic-Hydrothermal Transition
# 岩浆—热液过渡









North Parkes, NSW
(Lickfold et al. 2003)

# Porphyry ore genesis 斑岩矿床成因

- **Tectonic trigger (e.g., ridge subduction)** 大地构造引发
- **Incompatible behaviour of metals and volatiles allows magmatic transport of metals and sulfur** 金属和挥发份的不兼容性使得岩浆能搬运金属和硫
- **Multiple phases of intrusive activity – one or more of which efficiently concentrates and releases metals** 多相侵入活动 – 其中的一或多期有效聚集和释放金属
- **Fluid exsolution may be triggered by mafic magma underplating of felsic magma chamber** 流体分离可以由长英质岩浆房下的镁铁质岩浆垫托诱发
- **Cycles of volatile accumulation and release at the apex of the mineralizing intrusion (multiple seismic events)** 多周期挥发份聚积和释放发生在成矿岩体的顶部(多次地震)

