BATHOLITHIC AND EARLY HALO TYPE Cu-Mo DEPOSITS:
Cheney & Trammell (1975) revisited

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OUTLINE

- Review: Porphyry thinking in the late 1960s - 1970s
- The batholithic model of Cheney and Trammell (1975) – key elements and type example deposits
- Ahead of their time
- Early halo type vs. 'A' vein type porphyry deposits (Proffett, 2009)
- Examples of batholithic and early halo type deposits
Published models two-dimensional, emphasizing lateral alteration/sulfide zoning – focus on **symmetry** (Lowell and Guilbert, 1970; Sutherland Brown, 1976; Nielsen, 1976)

Early/mid 1970s developments:
- “Tops and bottoms” of systems (Sillitoe, 1973)
- Host rock effects (Guilbert & Lowell, 1974)
- Different magmatic compositions and metal types (Kesler et al., 1975; Hollister, 1975)

Little appreciation for the **time** dimension outside of Anaconda's Butte, El Salvador and Yerington geologic teams

*Image simplified from Lowell & Guilbert, 1970, Fig. 3*
PRESENTATIONS AT
SEG ANNUAL MEETINGS

INSIDE-OUT HYDROTHERMAL ALTERATION IN
A PORPHYROID Cu/Mo DEPOSIT
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Canex Aerial Exploration, Vancouver, British
Columbia, Canada

Minneapolis,
Nov. 1972

BATHOLITHIC ORE DEPOSITS
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Salt Lake City,
Oct. 1975
'Classic' porphyry deposit  \(\equiv\) Lowell-Guilbert (1970) model

(Sutherland Brown, 1976; McMillan and Panteleyev, 1988)

\[\begin{array}{c}
\text{CLASSIC} \\
\text{VOLCANIC} \\
\text{PLUTONIC}
\end{array}\]

modified from Sutherland Brown, 1976, Fig. 1

Lowell & Guilbert, 1970, Fig. 3
TERMINOLOGY

'Classic' porphyry deposit  ≡ Lowell-Guilbert (1970) model
(Sutherland Brown, 1976; McMillan and Panteleyev, 1988)

modified from Sutherland Brown, 1976, Fig. 1
vs. Classic porphyry deposits:

- Occur within batholiths
- Minimal or nil porphyritic rocks
- Multiple hypogene mineralizing events restricted to veins and fractures
- Biotitic alteration envelopes along veins/fractures
- Unaltered rocks outside biotitic alteration (no peripheral propylitic zones)
- Structurally controlled quartz-sericite-pyrite and chloritic alteration superimposed inside (and extending above) biotitic alteration
- Mostly low sulfide content – weak supergene enrichment
BATHOLITHIC vs. CLASSIC PORPHYRY DEPOSITS: Alteration

**Alteration modified from Cheney & Trammell, 1975, 1996**

- **BATHOLITHIC**
  - **Sericitic**
    - Qz-Ser-Py
  - **Argillitic**
    - Qz-Kao-Chl
  - **Biotitic**
    - Qz-Bio-Kspar ±Ser±Anh
  - **Phyllitic**
    - Qz-Ser-Py
  - **Chl-Ser-Qz ±Ep, Kspar, Tour, Andal

- **CLASSIC PORPHYRY**
  - **Propylitic**
    - Chl-Ep-Carb-Adul-Ab
  - **Argillitic**
    - Qz-Kao-Chl
  - **Potassic**
    - Qz-Kspar-Bio ±Ser, Anh
  - **Sericitic**
    - Qz-Ser-Py
  - **Phyllitic**
    - Qz-Ser-Py
  - **Chl-Ser-Chl-Kspar

*modified from Cheney & Trammell, 1975, 1996*
BATHOLITHIC vs. CLASSIC PORPHYRY DEPOSITS: Sulfides

fault/vein or breccia pipe

VEIN ORE
Cc-Bn-Py

PY SHELL
Py >> Cp

Mgts>Py

VEIN ORE
Py-Po-
Cp-Bn-Mo

HIGHER
GRADE
CORE

BATHOLITHIC

PROTORE

LOW
PYRITE

PERIPHERAL
Cp-Gal-Sph-Au-Ag

ORE SHELL
Cp > Py, Mo

LOW-
GRADE
CORE
Low sulf;
Cp, Py, Mo

Mgt > Py

CLASSIC PORPHYRY

modified from Cheney & Trammell, 1975, 1996
BATHOLITHIC Cu-Mo DEPOSITS

PRODUCTION + RESOURCES
(Singer et al., 2008, USGS OFR 2008-1155; Cheney & Trammell, 1996)

- Butte: 5220 Mt @ 0.67% Cu, 0.03% Mo
- Brenda: 227 Mt @ 0.16% Cu, 0.04% Mo
- Quartz Creek: 0.3 Mt prod; no resource

Type Example

Butte (64-61 Ma)
Brenda (143 Ma)
Quartz Creek (~26-21 Ma)
Cheney & Trammell (1975) anticipated and/or formalized several important advances in porphyry geology:

- Ore zones within plutons (*Sutherland Brown, 1976; Sillitoe, 2010*)
- Late qz-ser-py (*Gustafson & Hunt, 1971, 1975; Carson & Jambor, 1977*)
- Inside-out alteration, with QSP internal to bio alteration; the “northern Chilean porphyry model” (*Sillitoe & Perello, 2005; Seedorff et al, 2005; Sillitoe, 2010*)
High Cu grades in porphyry Cu deposits and their relationship to emplacement depth of magmatic sources

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'A' VEIN TYPE vs. EARLY HALO TYPE PORPHYRY DEPOSITS

'A' VEIN TYPE DEPOSITS:

- Most Cu in 'A'-type granular qz-sulf veins, with Kspar and/or bio halos
- Bornite-rich with common magnetite (where not overprinted)
- Typically 5-50% qz veins
- Ore zones closely related to porphyries

EARLY HALO TYPE DEPOSITS:

- Most Cu in texture-destructive halos of mus ± bio ± Kspar with abundant chalcopyrite and/or bornite
- Magnetite absent from halos
- Typically <10% qz veins
- Domal ore zones indirectly related to small-volume porphyry dikes
- Magm-hydrothermal breccias common
YERINGTON DISTRICT, NEVADA
Jurassic cross-section

Jurassic paleosurface

Porph granite
(source of fluids)

Proffett, 2009, Fig. 1
YERINGTON DISTRICT, NEVADA
Jurassic cross-section

Jurassic paleosurface

YERINGTON MINE
'A' vein type (cupola ~4 km paleodepth)

Porph granite (source of fluids)

Proffett, 2009, Fig. 1
YERINGTON DISTRICT, NEVADA
Jurassic cross-section

Jurassic paleosurface

ANN-MASON PASS
Early-halo type
(cupola ~5 km paleodepth)

YERINGTON MINE
'A' vein type
(cupola ~4 km paleodepth)

Porph granite
(source of fluids)

1 cm

Proffett, 2009, Fig. 1
BUTTE, MONTANA
First recognized early-halo type system

Proffett, manuscript in prep; Houston & Dilles, 2013
BUTTE, MONTANA
First recognized early-halo type system

Butte Granite
(76.5 Ma, U-Pb)

Bio alt at
4200 ft level (W),
at surface (E) --
5 x 2.5 km

Proffett, manuscript in prep; Houston & Dilles, 2013
BUTTE, MONTANA
Pre-Main Stage geology: S-N section

Reed et al., 2013, Fig. 2

Quartz porph dikes
Butte granite (76 Ma)

Reed et al., 2013, Fig. 2
BUTTE, MONTANA
Pre-Main Stage geology: S-N section

- Reed et al., 2013, Fig. 2
- Seedorff et al., 2005, Fig. 7E

EARLY DARK MICACEOUS (EDM) HALOS

- Quartz porph dikes
- Butte granite (76 Ma)

Reed et al., 2013, Fig. 2
COPPER CREEK, ARIZONA
Muscovite-dominant early halos

VEIN

10 mm
COPPER CREEK, ARIZONA
Muscovite-dominant early halos

“Bowtie” textures
### MUSCOVITE-RICH EARLY HALOS vs. 'D' VEINS

<table>
<thead>
<tr>
<th>EARLY HALOS</th>
<th>'D' VEINS</th>
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<tbody>
<tr>
<td>Overlap 'A' veins in time</td>
<td>Postdate 'A' and 'B' veins</td>
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<tr>
<td>Abundant Cu sulfides</td>
<td>Abundant pyrite</td>
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<tr>
<td>Plagioclase sites obliterated</td>
<td>Plagioclase sites preserved</td>
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<tr>
<td>Bio and/or K-spar typically present</td>
<td>Bio + K-spar replaced</td>
</tr>
<tr>
<td>Muscovite gray to gray-green, typically &gt;100 μm, with radiating “bowtie” clusters</td>
<td>Muscovite white to pale gray, typically &lt;100 μm</td>
</tr>
<tr>
<td>Sericite-island textures</td>
<td>No sericite-island textures</td>
</tr>
</tbody>
</table>
MUSCOVITE-RICH EARLY HALOS vs. 'D' VEINS

**EARLY HALOS**
- Overlap 'A' veins in time
- Postdate 'A' and 'B' veins
- Abundant Cu sulfides
- Abundant pyrite
- Plagioclase sites obliterated
- Bio and/or K-spar typically present

**'D' VEINS**
- Sericite-island textures, Ann-Mason Pass, NV
- Sericite
- Sites preserved
- Bio replaced
- White to pale gray, typically <100 μm

**Sericite-island textures**

**No sericite-island textures**
QUARTZ CREEK, WASHINGTON

Cheney & Trammell, 1996, Fig. 5
QUARTZ CREEK, WASHINGTON

EXPLANATION

INTERIOR BORDER PHASE

BQM

BIO QM

GD

GDB

GRANODIORITE

QC

QCB

QUARTZ CK QD

PQM

PQMB

PREACHER MTN QM

AND

VOLCANIC ROCKS

LIMIT OF BIOTITIC ALTERATION

4200 GDB

3600 GD

3000 GD

2400 GD

1800 GD

1200 GD

600 GD

Bio alt at surface -- 3.7 x 0.6 km

DETAILED MAP

Cheney & Trammell, 1996, Fig. 5
QUARTZ CREEK, WASHINGTON
'Inside-out' alteration

Cheney & Trammell, 1996, Fig. 6
QUARTZ CREEK, WASHINGTON
'Inside-out' alteration

Sericite overprinting bio alteration
Rainy mine, E breccia pipe
Early halo with bio-ser replacing hb; cp + py

Preacher monzongranite; background bio alt'n

mgt-qtz centerlines

QUARTZ CREEK, WASHINGTON
Early potassic (EDM?) halos
BRENDA, BC
Geology

modified from Soregaroli & Whitford, 1976, Fig. 2

Triassic volcanic rocks

BRENDA PLUTON (~176 Ma)
- granodiorite porphyry phase
- qz diorite (-tonalite) border phase

Bio replacements = early halos?

0.5 km
BRENDA, BC
Stage 2 (potassic) veins

Stage 2A
qz-Kspar-cp

Stage 2B
qz-cp vein with thin bio halo

5060 bench

BRENDA PLUTON (~176 Ma)

qz diorite (-tonalite) border phase

granodiorite porphyry phase

Bio replacements = early halos?
### EXAMPLES: Batholith and Early halo type deposits

<table>
<thead>
<tr>
<th>Batholith (BATHOL)</th>
<th>Porphyry (PORPH)</th>
<th>Early Halo</th>
<th>A Vein Type</th>
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</thead>
<tbody>
<tr>
<td>Quartz Creek, WA, USA</td>
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<tr>
<td>Brenda, BC, Canada</td>
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<td>Butte, MT, USA</td>
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<td>Lomas Bayas, Chile</td>
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<td>Valley, Highland Valley, BC, Canada</td>
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<td>Los Pelambres, Chile</td>
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<td>Copper Creek, AZ, USA</td>
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<td>Ann-Mason Pass, NV, USA</td>
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<td>Escondida Este, Chile</td>
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CONCLUSIONS

- **Batholithic deposits are substantially different from Classic porphyry systems;** Cheney & Trammell were among the first to recognize these differences.

- **All Batholithic deposits are Early-halo type systems;** likely formed above cupolas emplaced at >4-5 km depths. EHT systems range from end-member Batholithic to transitional Classic.

- **Characteristics considered typical of Batholithic systems in 1970s now also recognized in some (reversed zoning) or all (crosscutting qz-ser) Classic systems.**

- **EHT systems more common than recognized.** Musc-dominant early halos widely mismapped as qz-ser or 'D' veins. Can be correctly identified based on crosscutting relationships, textures, and mineralogy.
“Exploration programs and Federal land withdrawals based on models of porphyry ore deposits may not recognize batholithic deposits.”

- final sentence of abstract, Cheney & Trammell, 1975
QUESTIONS?

REFERENCES:

For a list of citations, email 'kbriedell@shaw.ca'