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

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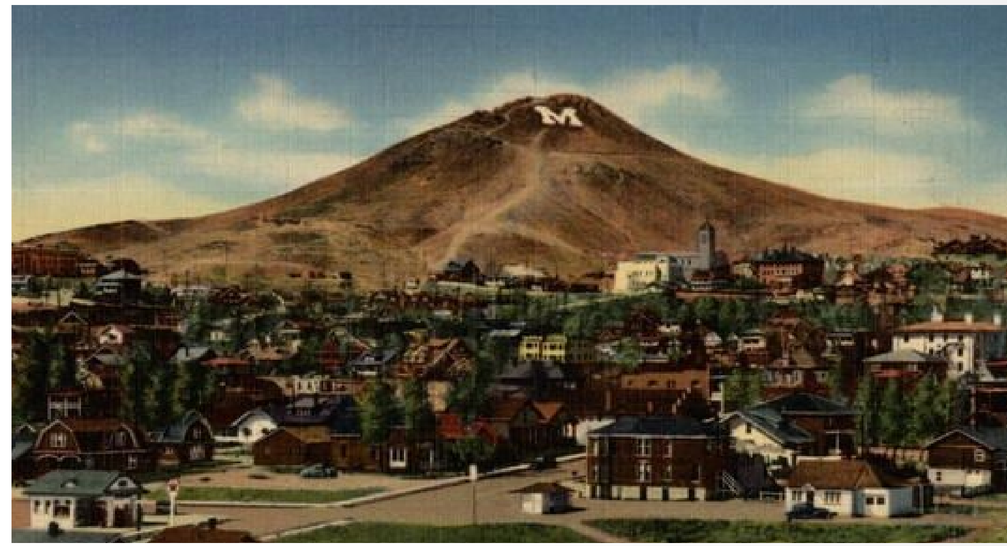

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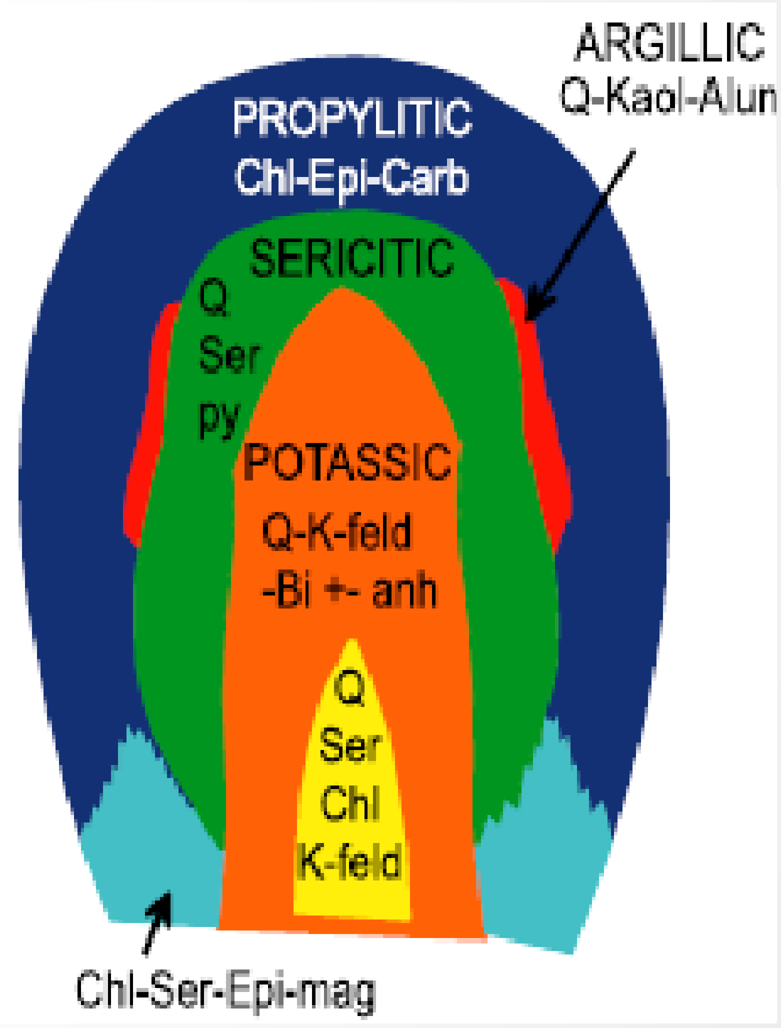
OUTLINE

- 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

PORPHYRY EXPLORATION PARADIGMS OF THE LATE 1960s – 1970s

- 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



simplified from
Lowell & Gulbert, 1970, Fig. 3

PRESENTATIONS AT SEG ANNUAL MEETINGS

INSIDE-OUT HYDROTHERMAL ALTERATION IN A PORPHYROID Cu/Mo DEPOSIT

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Minneapolis,
Nov. 1972

BATHOLITHIC ORE DEPOSITS

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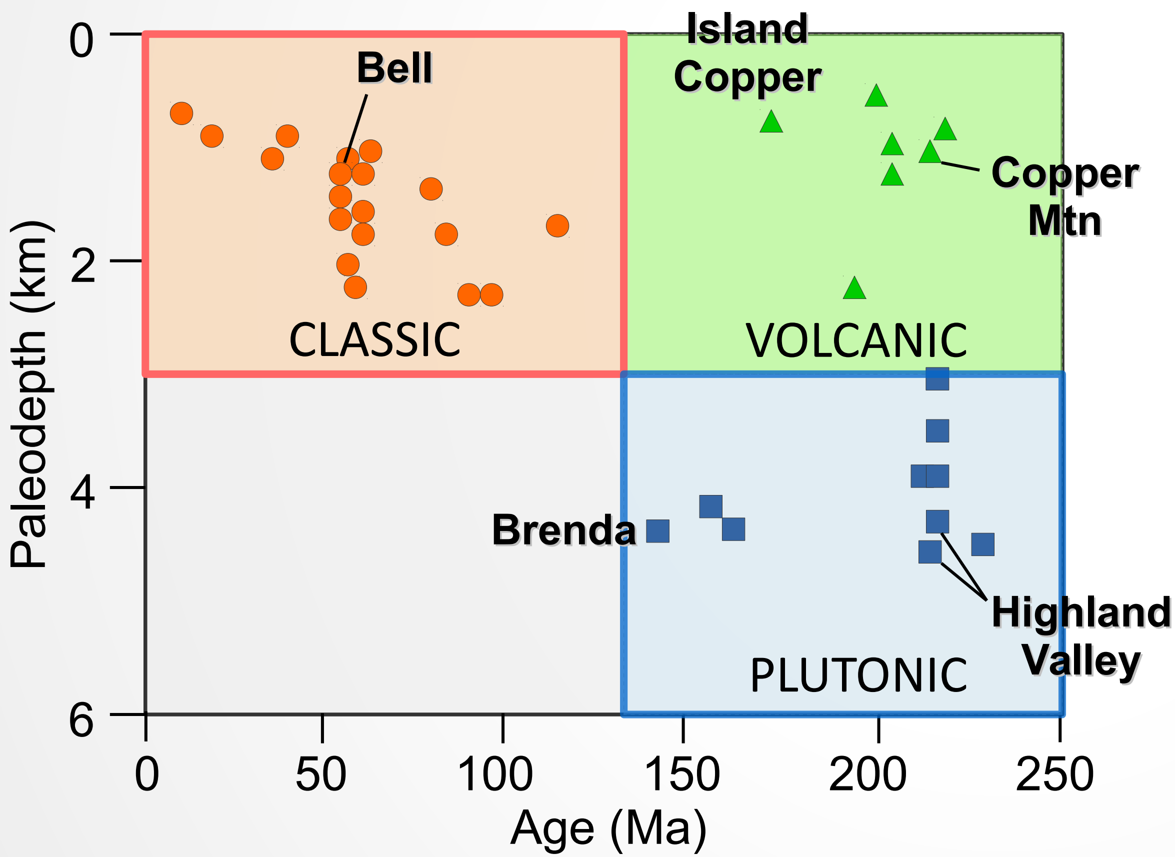
Salt Lake City,
Oct. 1975

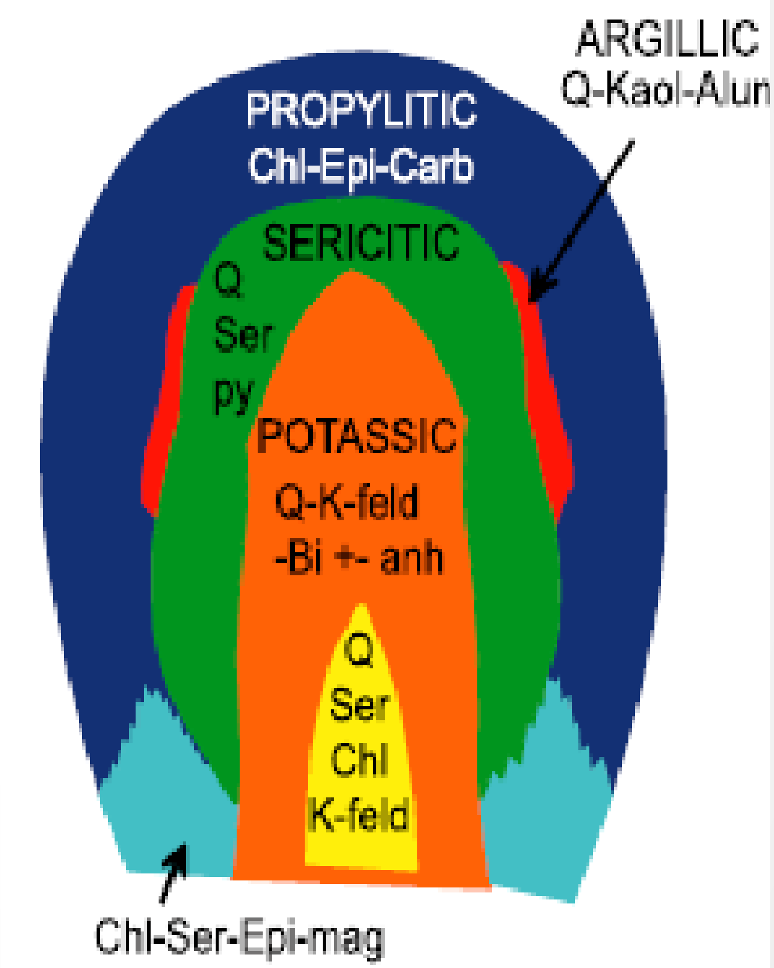
TERMINOLOGY

'Classic' porphyry deposit ≡ Lowell-Guilbert (1970) model

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



modified from Sutherland Brown, 1976, Fig. 1



Lowell & Guilbert, 1970, Fig. 3

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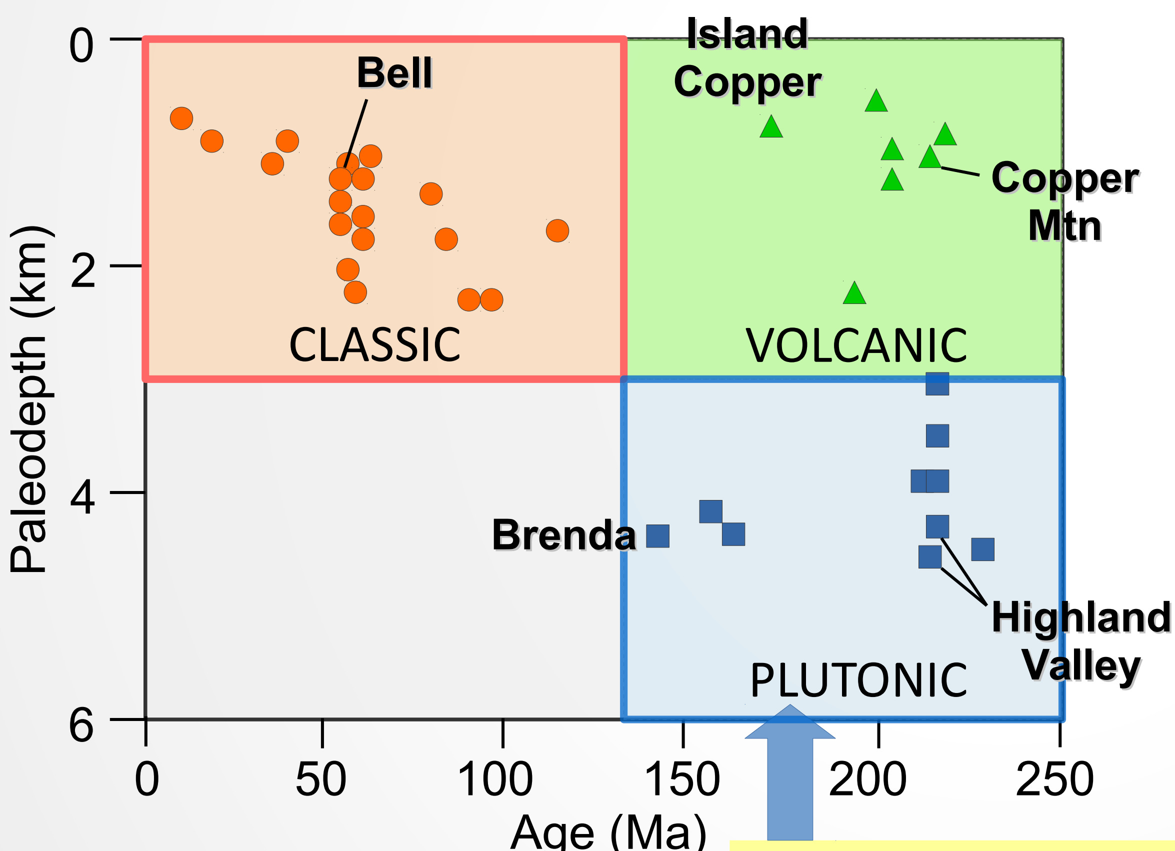
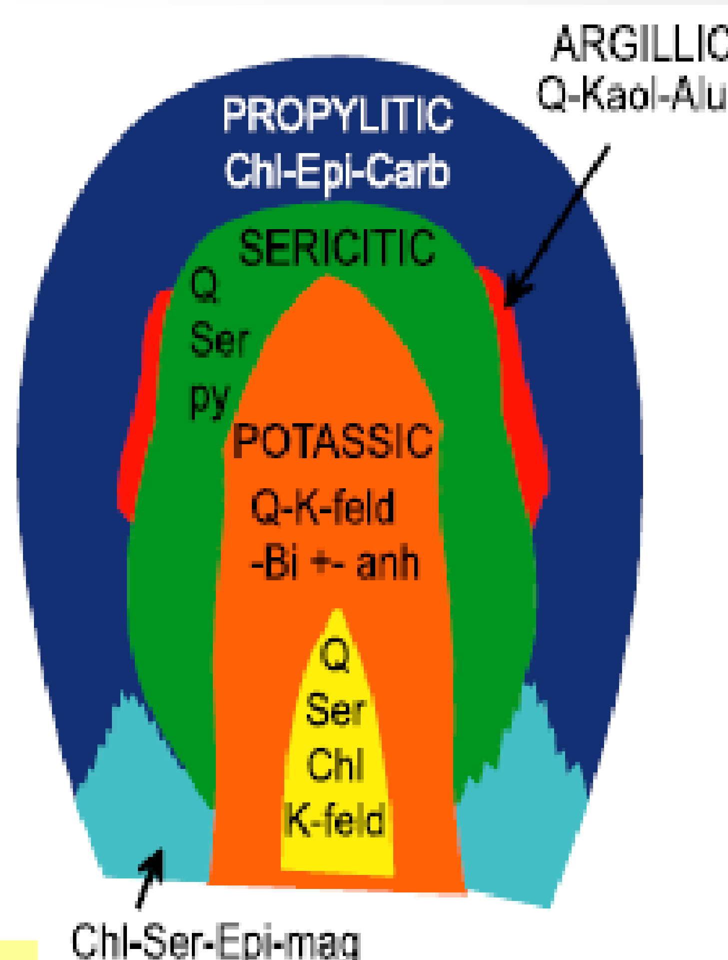


modified from Sutherland Brown, 1976, Fig. 1

broadly equivalent to Cheney & Trammell's Batholithic deposits



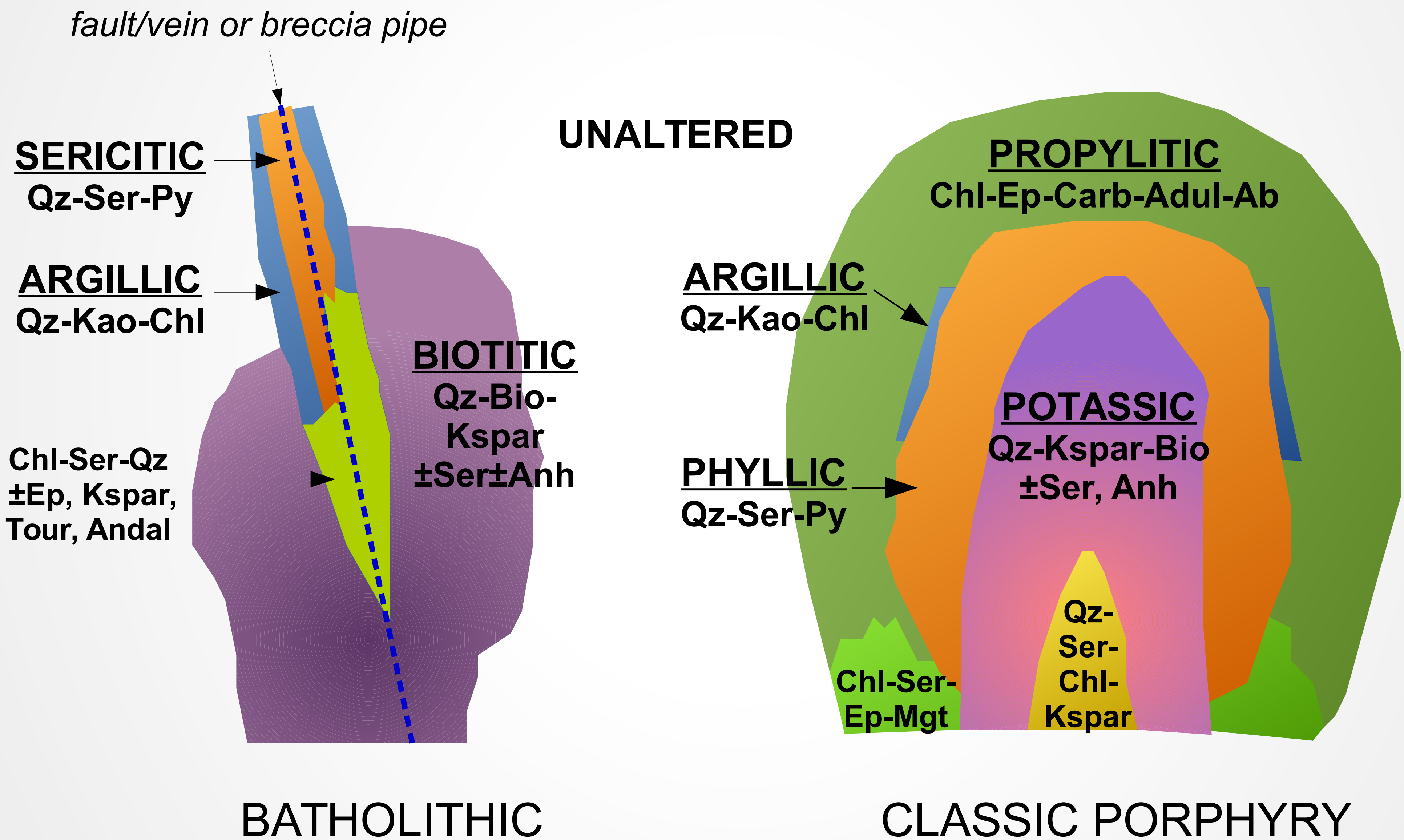
Lowell & Guilbert, 1970, Fig. 3

THE BATHOLITHIC Cu-Mo DEPOSIT MODEL OF CHENEY & TRAMMELL (1975)

vs. Classic porphyry deposits:

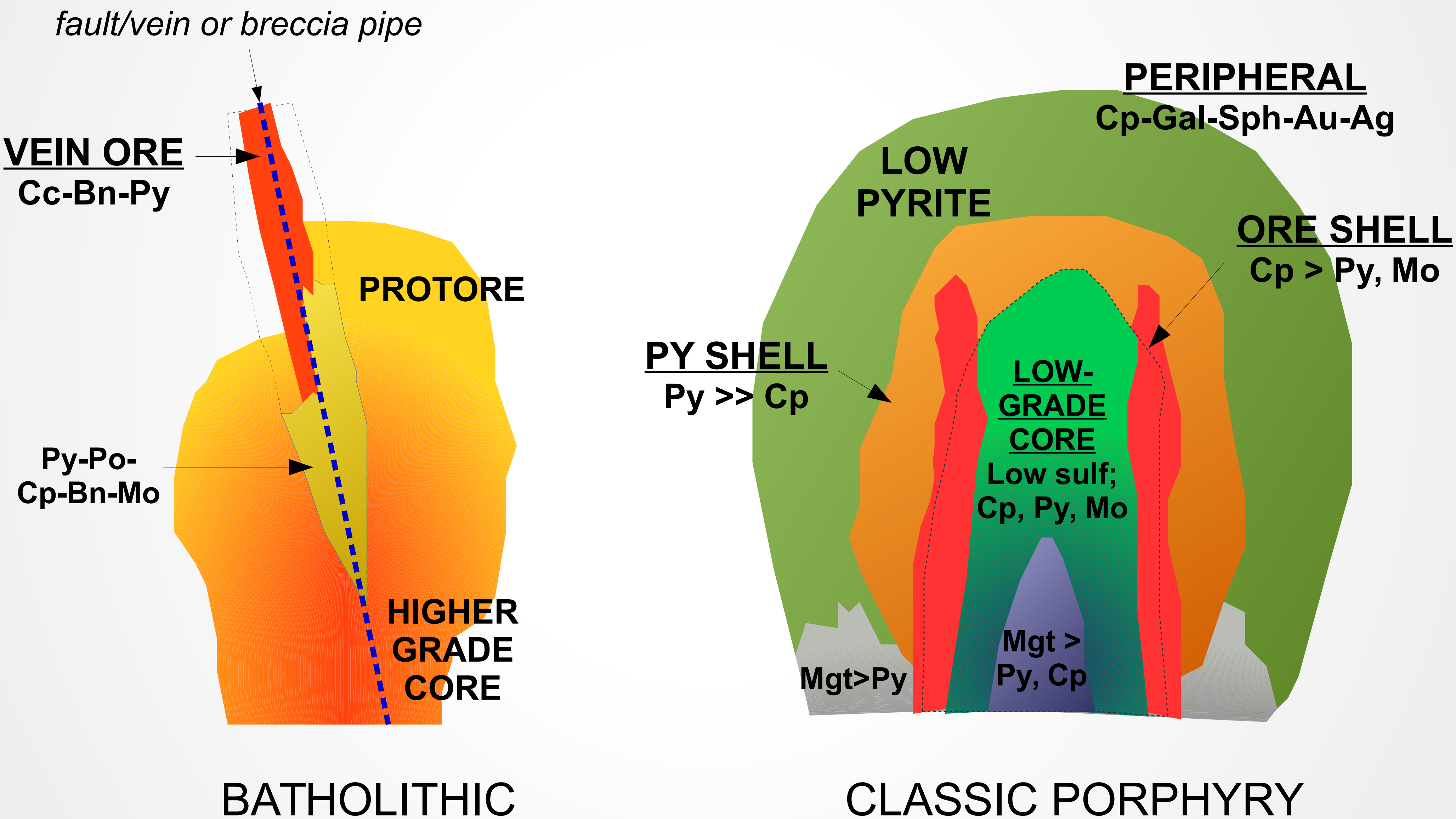
- Occur within batholiths
- Minimal or nil porphyritic rocks
- Multiple hypogene mineralizing events restricted to veins and fractures
- Biotitic alteration envelopes along veins/fractures
- Unaltered rocks outside biotitic alteration (no peripheral propylitic zones)
- Structurally controlled quartz-sericite-pyrite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

BATHOLITHIC vs. CLASSIC PORPHYRY DEPOSITS: Alteration



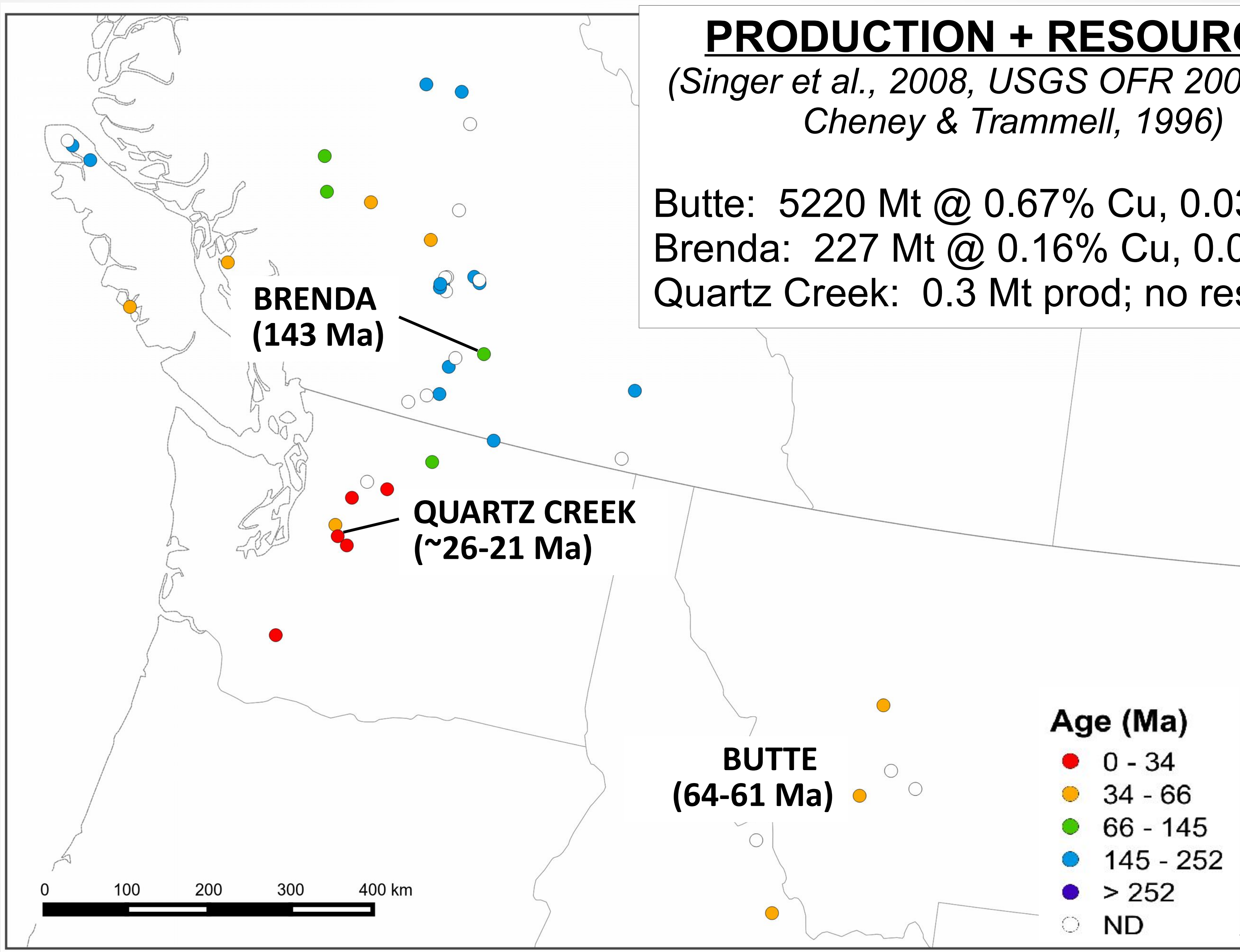
modified from Cheney & Trammell, 1975, 1996

BATHOLITHIC vs. CLASSIC PORPHYRY DEPOSITS: Sulfides



modified from Cheney & Trammell, 1975, 1996

TYPE EXAMPLE
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

AHEAD OF THEIR TIME

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)*

'A' VEIN TYPE and EARLY-HALO TYPE PORPHYRY DEPOSITS

from Geology, August 2009, v. 37, p.675-678:

High Cu grades in porphyry Cu deposits and their relationship to emplacement depth of magmatic sources

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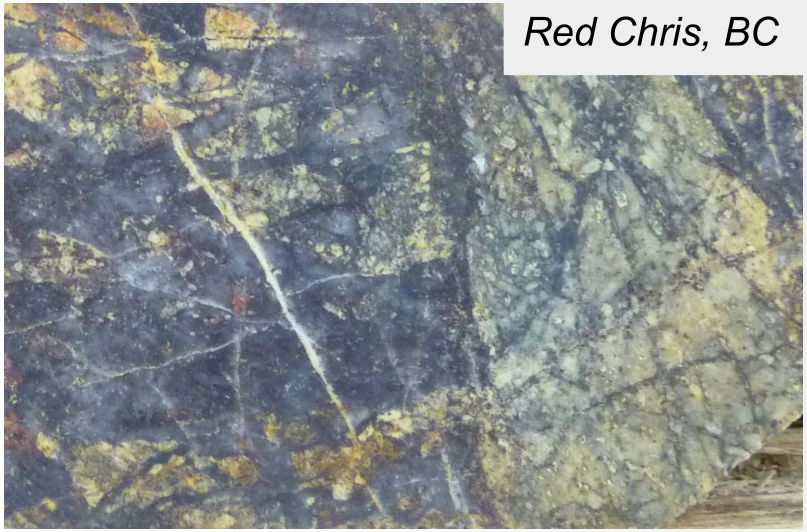
'A' VEIN TYPE vs. EARLY HALO TYPE PORPHYRY DEPOSITS

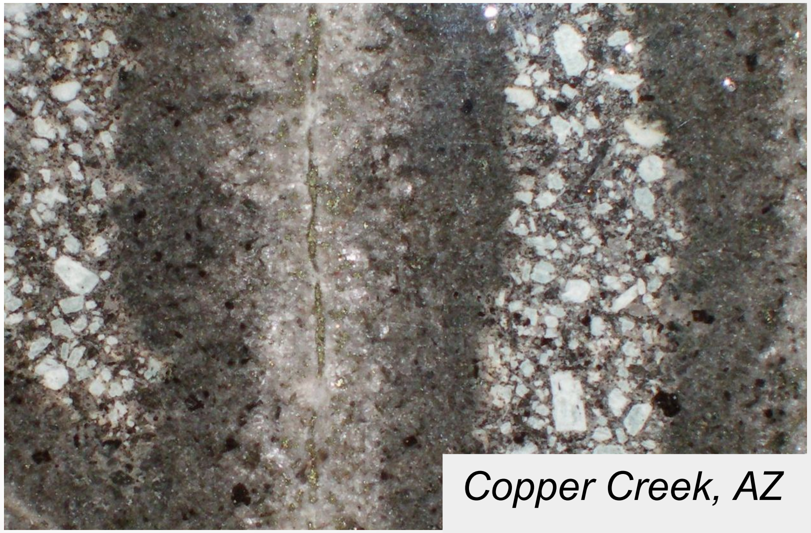
'A' VEIN TYPE DEPOSITS:

- 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:

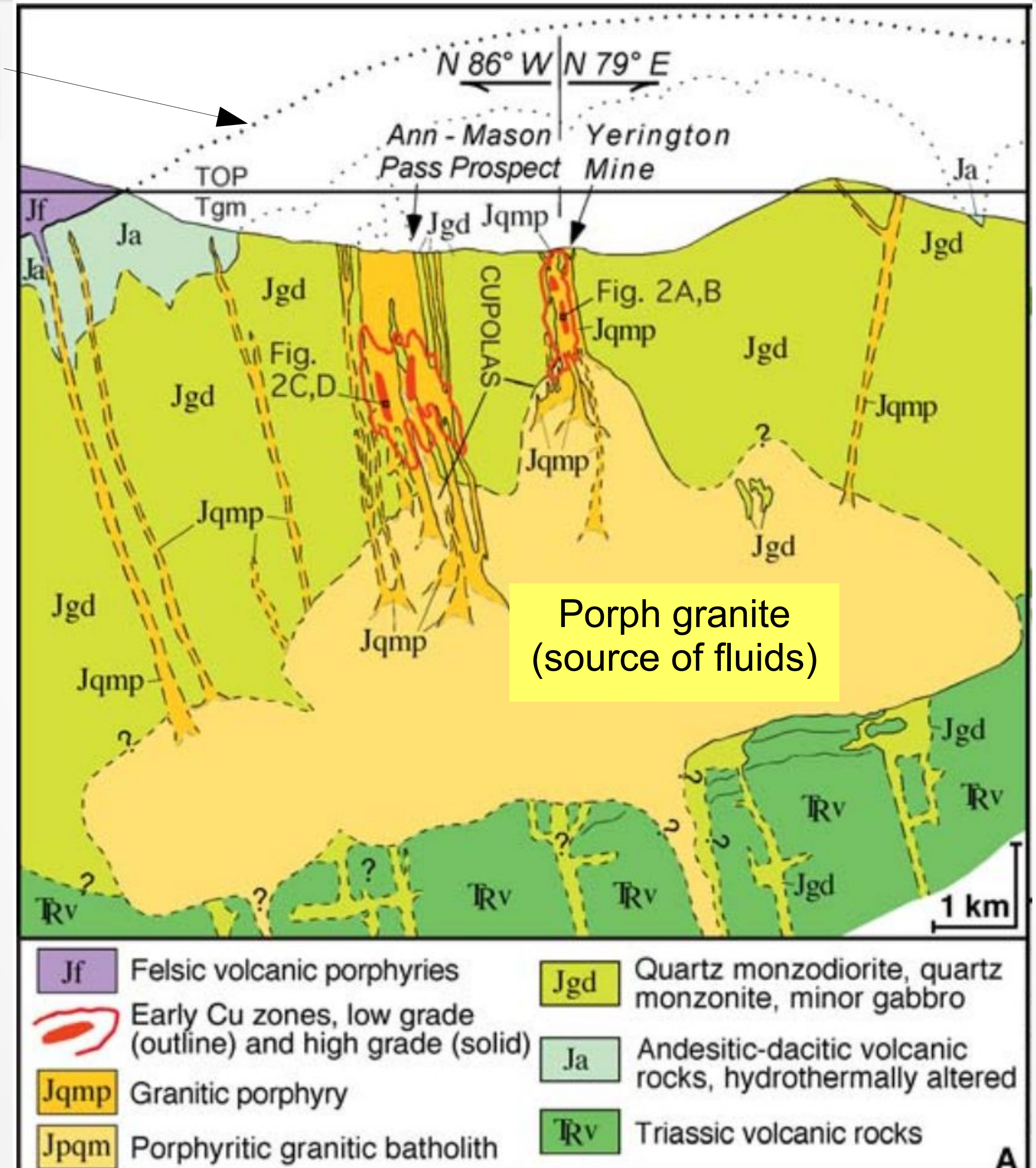
- Most Cu in texture-destructive halos of mus ± bio ± Kspar with abundant chalcopyrite and/or bornite
- Magnetite absent from halos
- Typically <10% qz veins
- Domal ore zones indirectly related to small-volume porphyry dikes
- Magm-hydrothermal breccias common





YERINGTON DISTRICT, NEVADA
Jurassic cross-section

Jurassic paleosurface

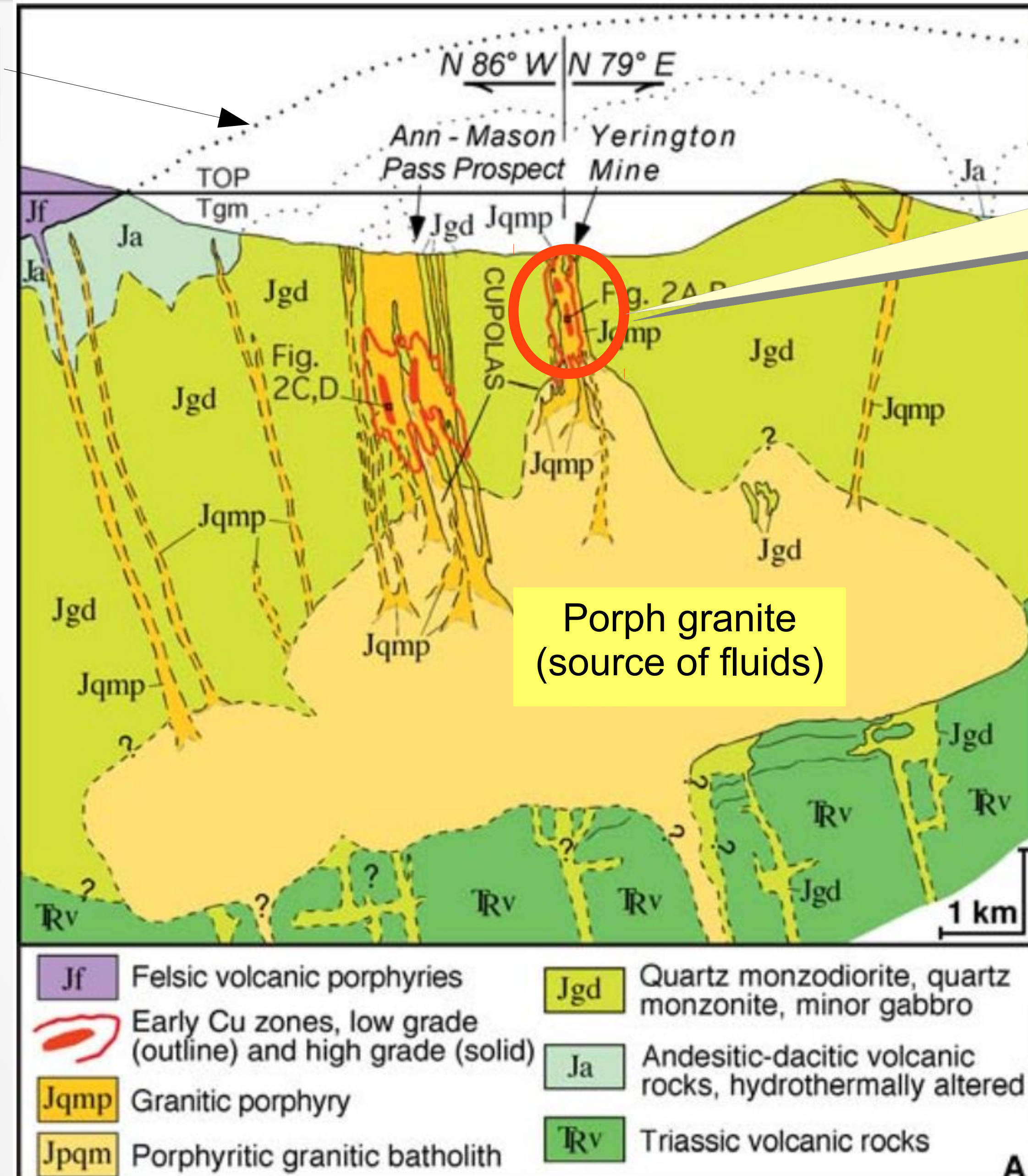


Proffett, 2009, Fig. 1

YERINGTON DISTRICT, NEVADA

Jurassic cross-section

Jurassic paleosurface



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

1 cm

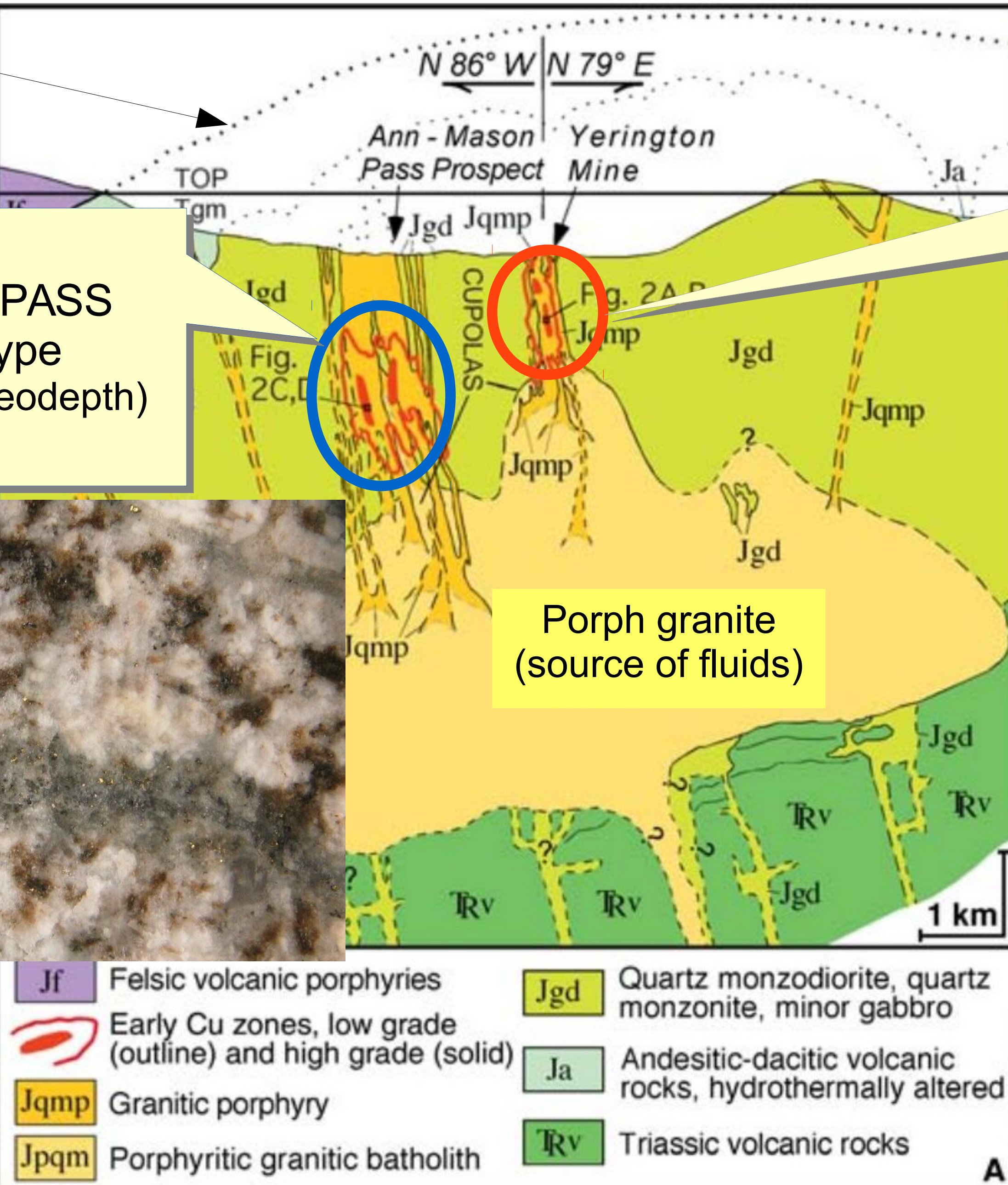
Proffett, 2009, Fig. 1

YERINGTON DISTRICT, NEVADA
Jurassic cross-section

Jurassic paleosurface

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

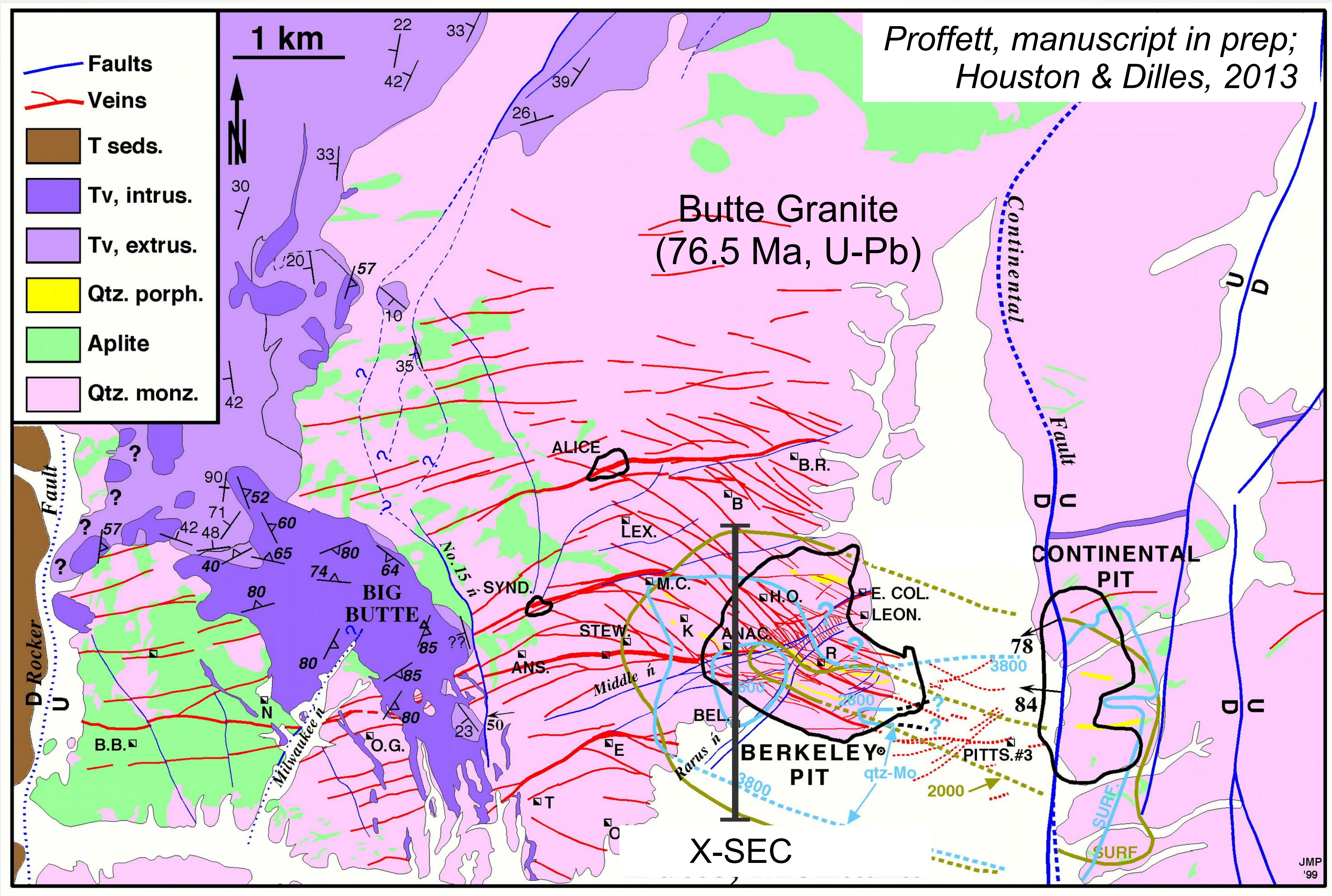
YERINGTON MINE
'A' vein type
(cupola ~4 km paleodepth)



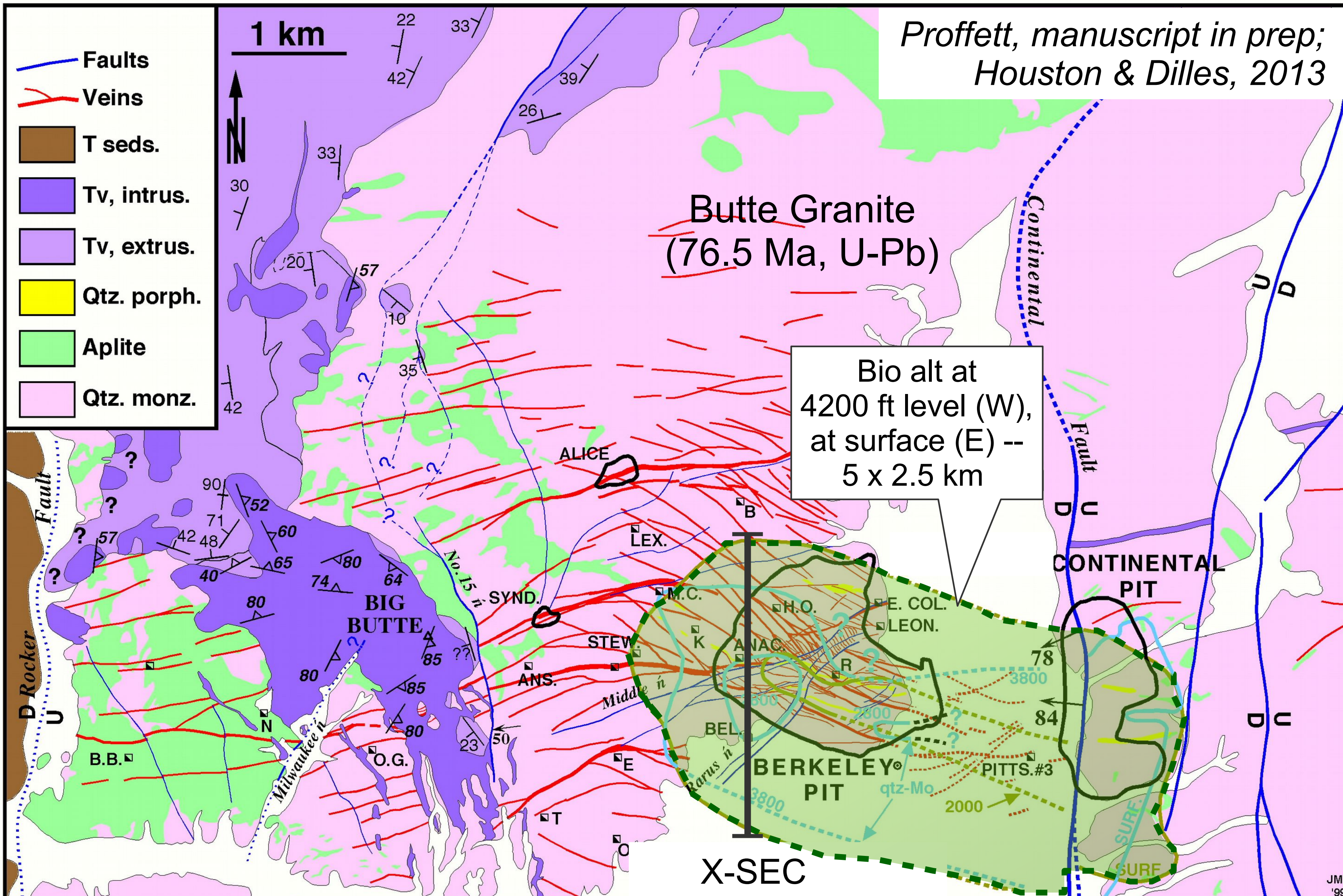
1 cm

Proffett, 2009, Fig. 1

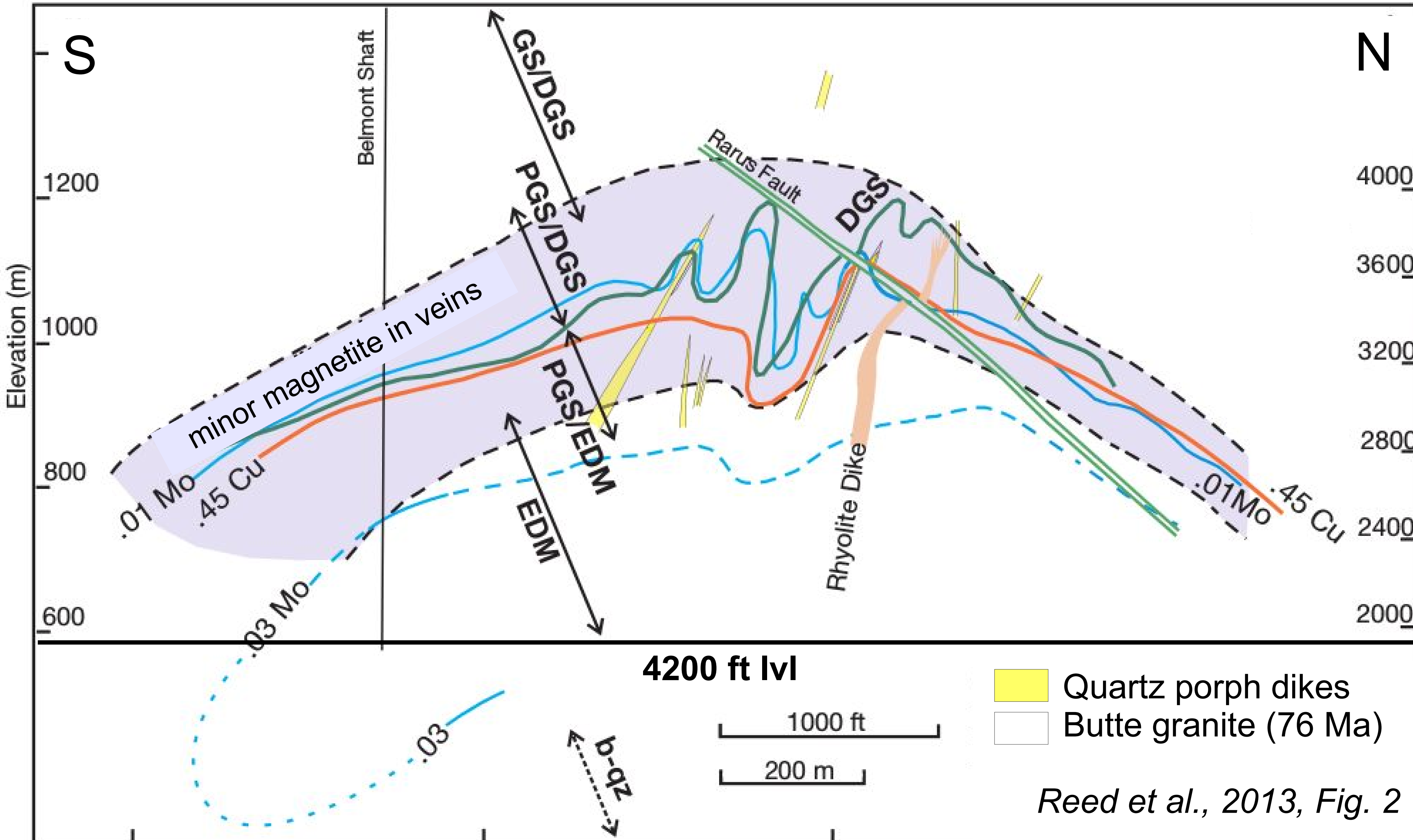
BUTTE, MONTANA
First recognized early-halo type system



BUTTE, MONTANA
First recognized early-halo type system

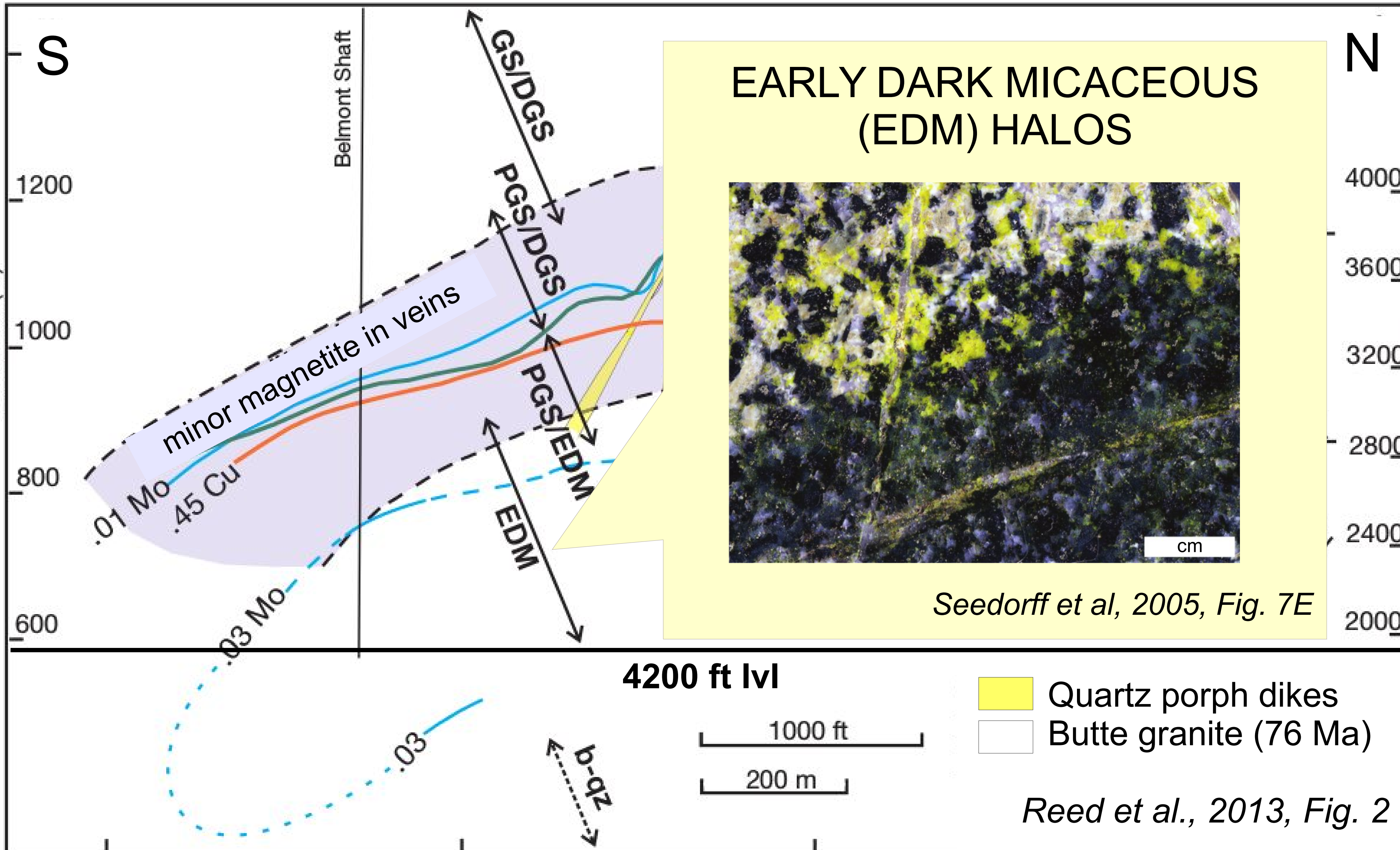


BUTTE, MONTANA
Pre-Main Stage geology: S-N section



Reed et al., 2013, Fig. 2

BUTTE, MONTANA
Pre-Main Stage geology: S-N section



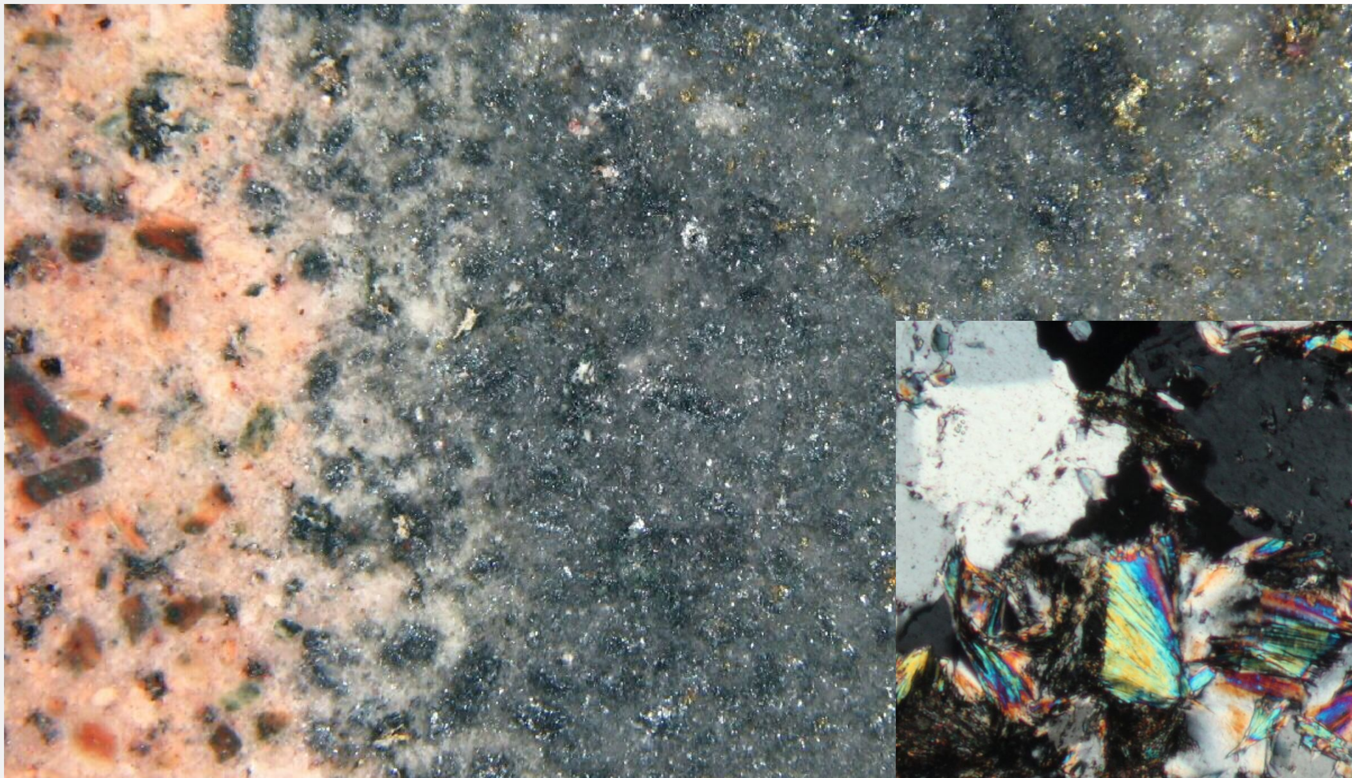
Reed et al., 2013, Fig. 2

COPPER CREEK, ARIZONA
Muscovite-dominant early halos

VEIN

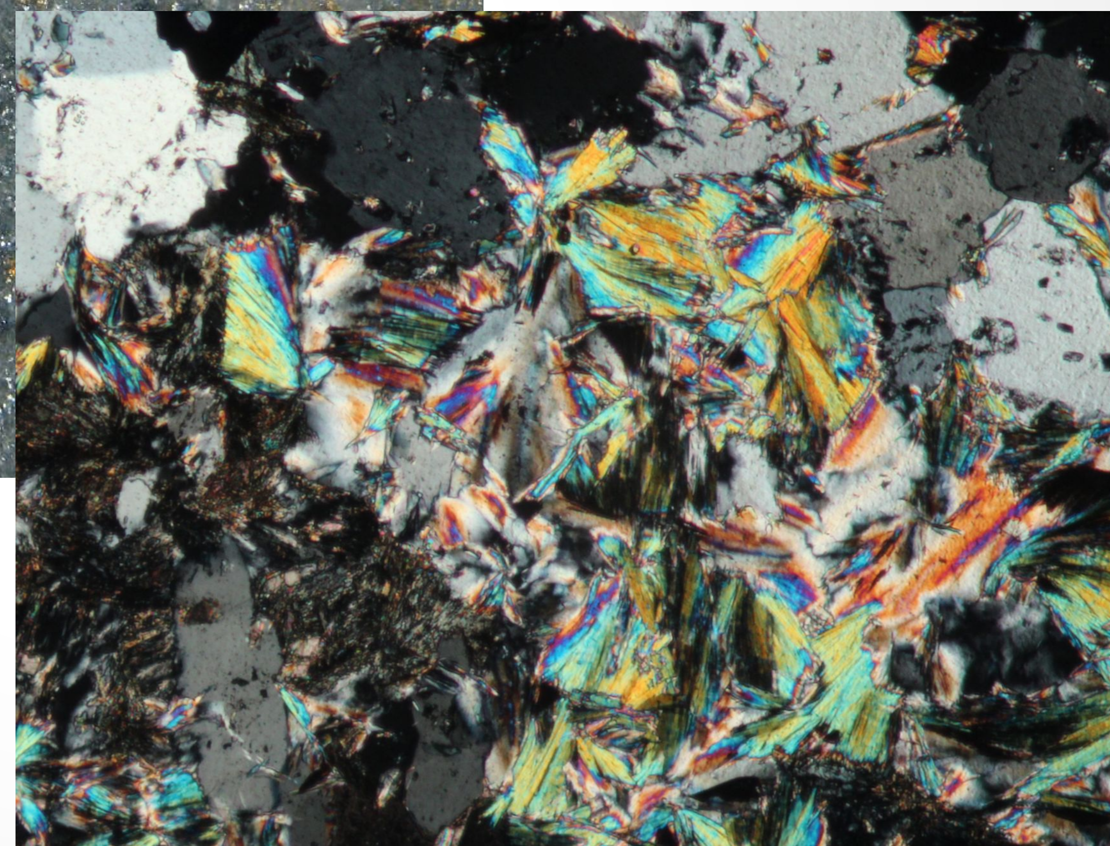
10 mm

COPPER CREEK, ARIZONA
Muscovite-dominant early halos



10 mm

“Bowtie” textures

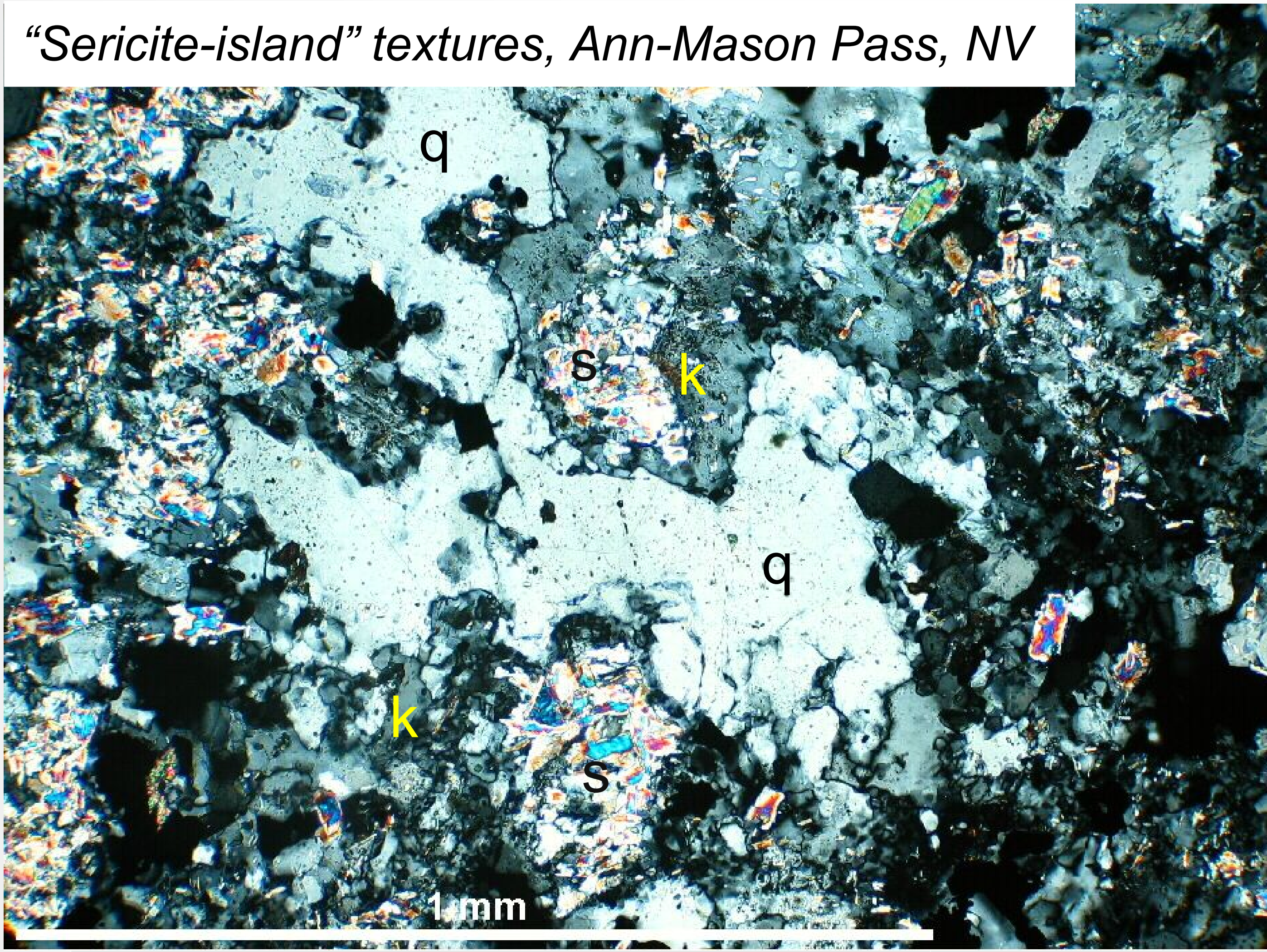


0.5 mm

MUSCOVITE-RICH EARLY HALOS vs. 'D' VEINS

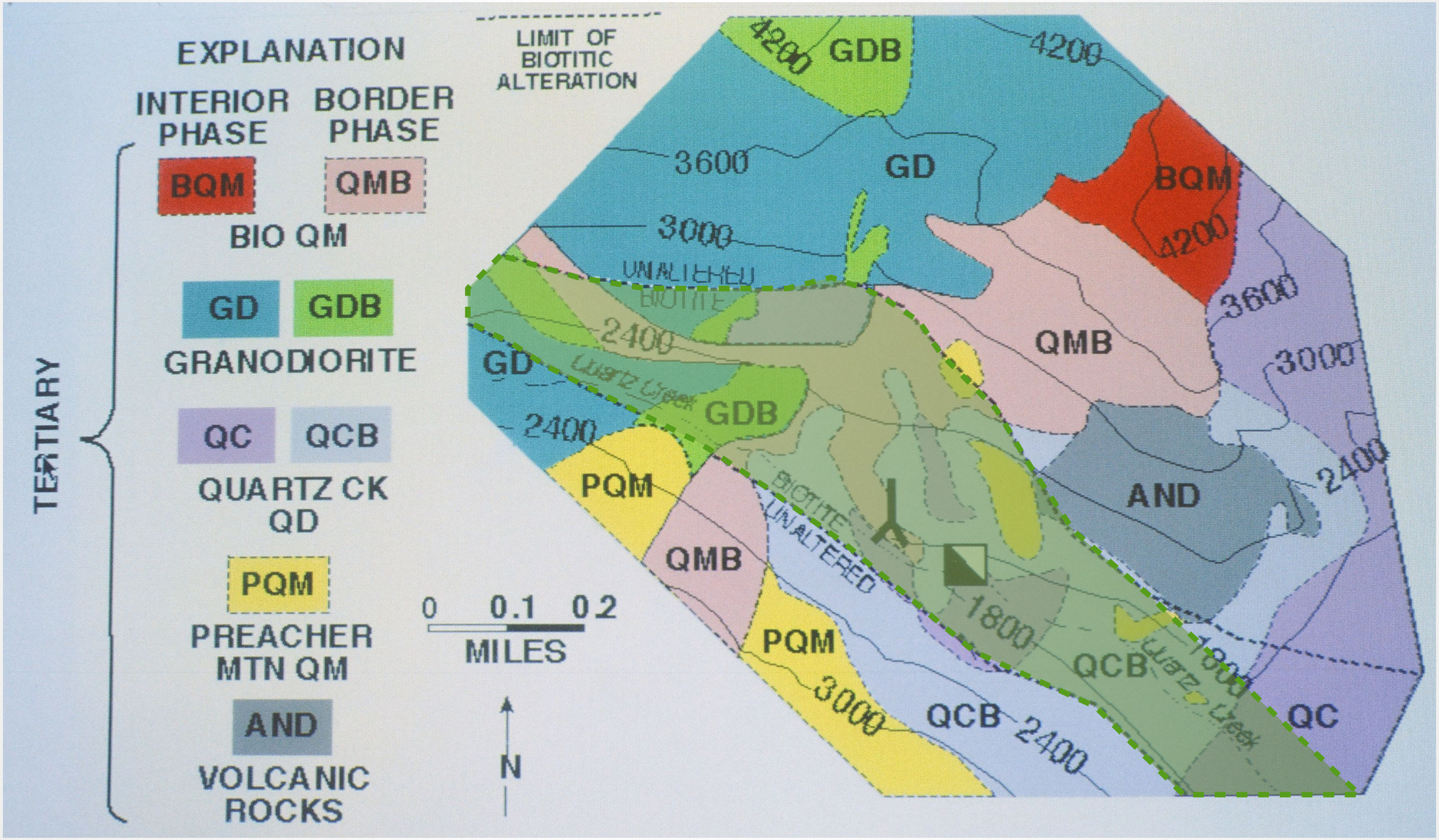
EARLY HALOS	'D' VEINS
Overlap 'A' veins in time	Postdate 'A' and 'B' veins
Abundant Cu sulfides	Abundant pyrite
Plagioclase sites obliterated	Plagioclase sites preserved
Bio and/or K-spar typically present	Bio + K-spar replaced
Muscovite gray to gray-green, typically >100 μm, with radiating “bowtie” clusters	Muscovite white to pale gray, typically <100 μm
Sericite-island textures	No sericite-island textures

MUSCOVITE-RICH EARLY HALOS vs. 'D' VEINS



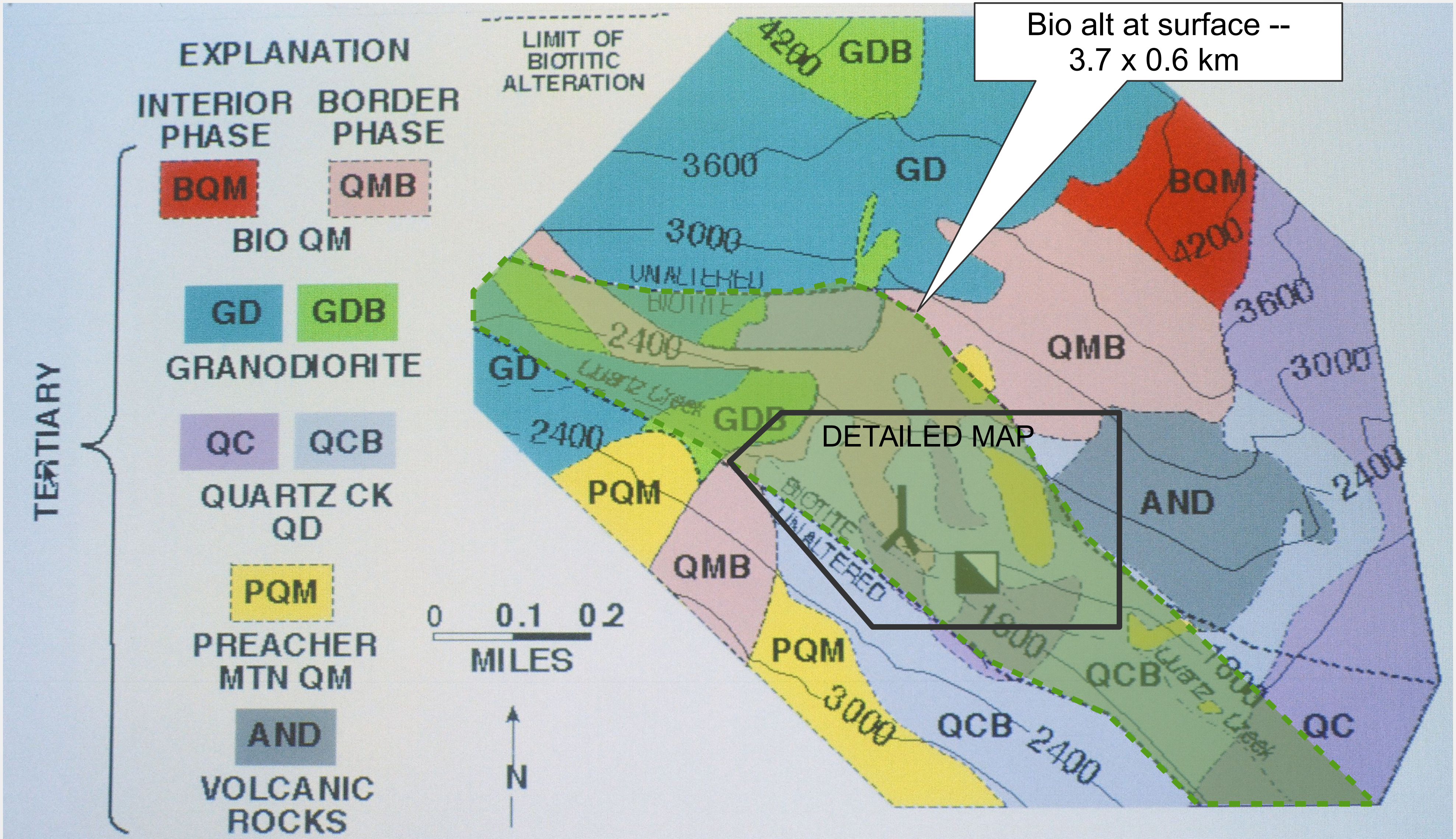
	' VEINS
	and 'B' veins
	rite
	sites preserved
	replaced
	hite to pale gray, 0 µm
Sericite-island textures	No sericite-island textures

QUARTZ CREEK, WASHINGTON



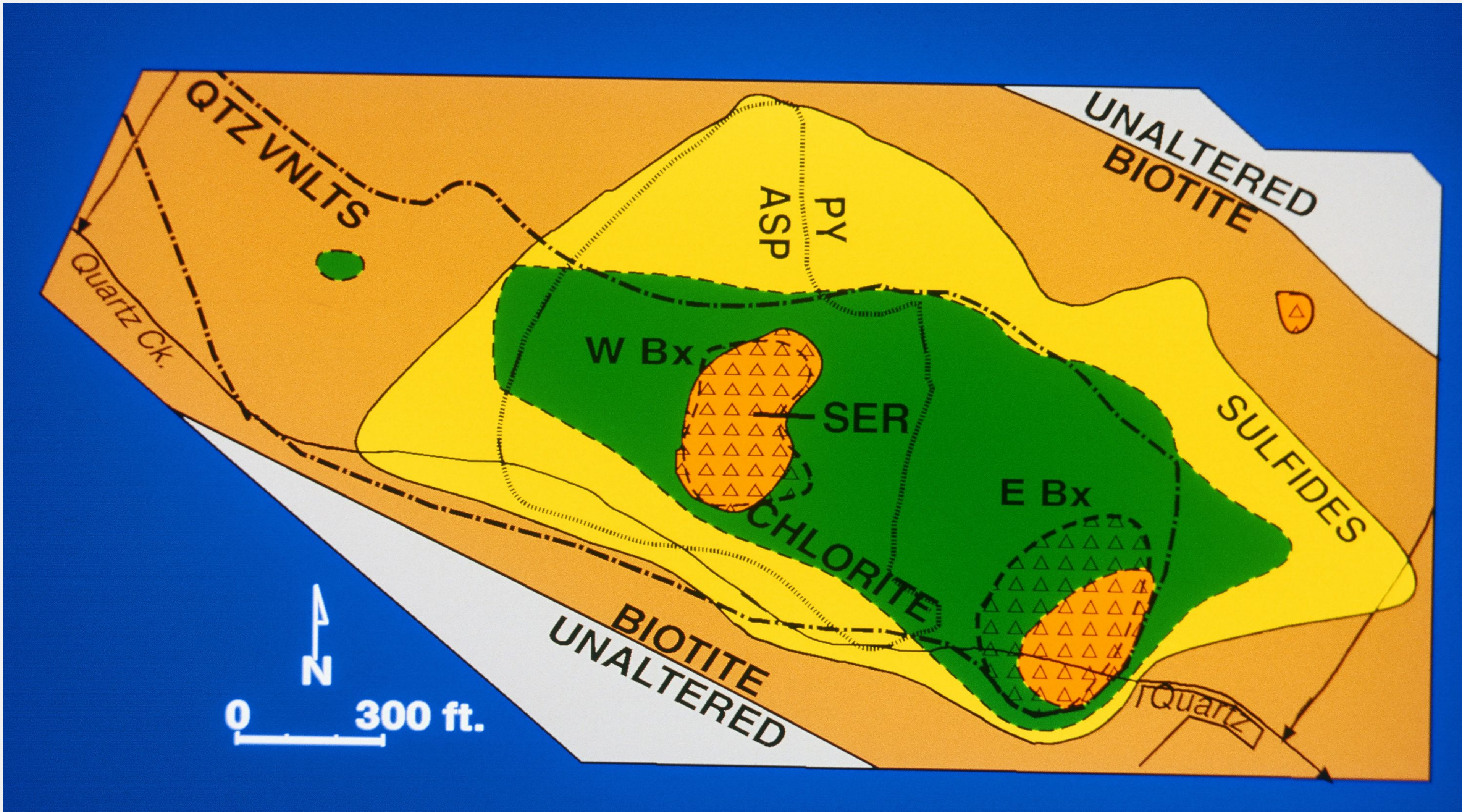
Cheney & Trammell, 1996, Fig. 5

QUARTZ CREEK, WASHINGTON



Cheney & Trammell, 1996, Fig. 5

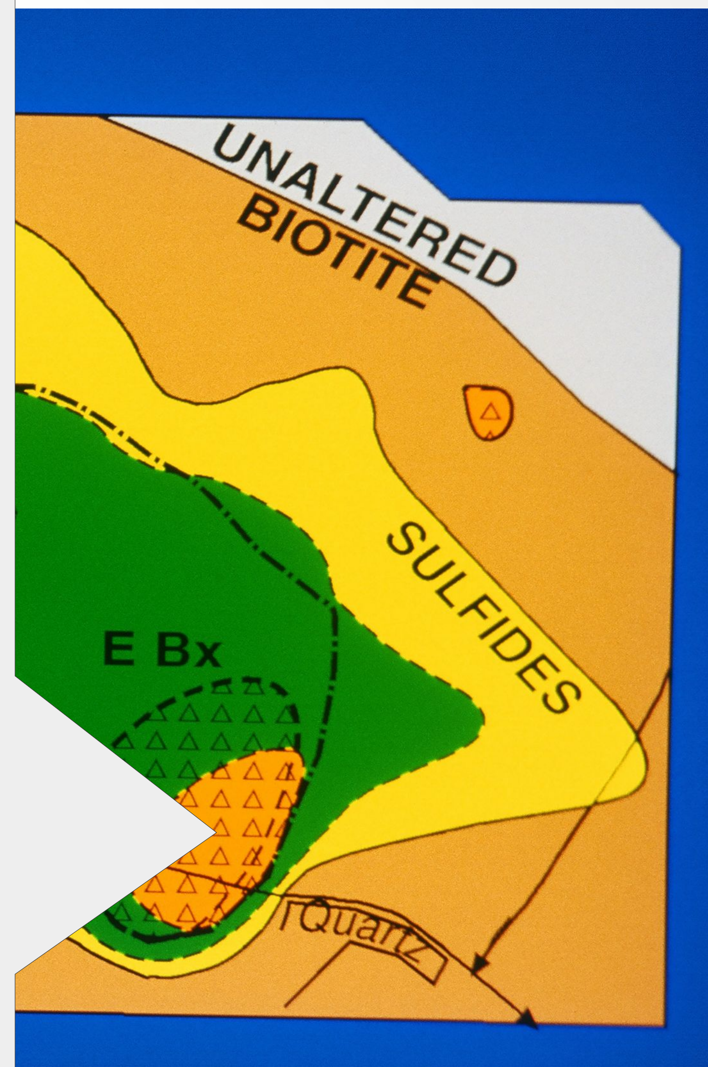
QUARTZ CREEK, WASHINGTON
'Inside-out' alteration



Cheney & Trammell, 1996, Fig. 6

QUARTZ CREEK, WASHINGTON
'Inside-out' alteration

Sericite overprinting bio alteration
Rainy mine, E breccia pipe

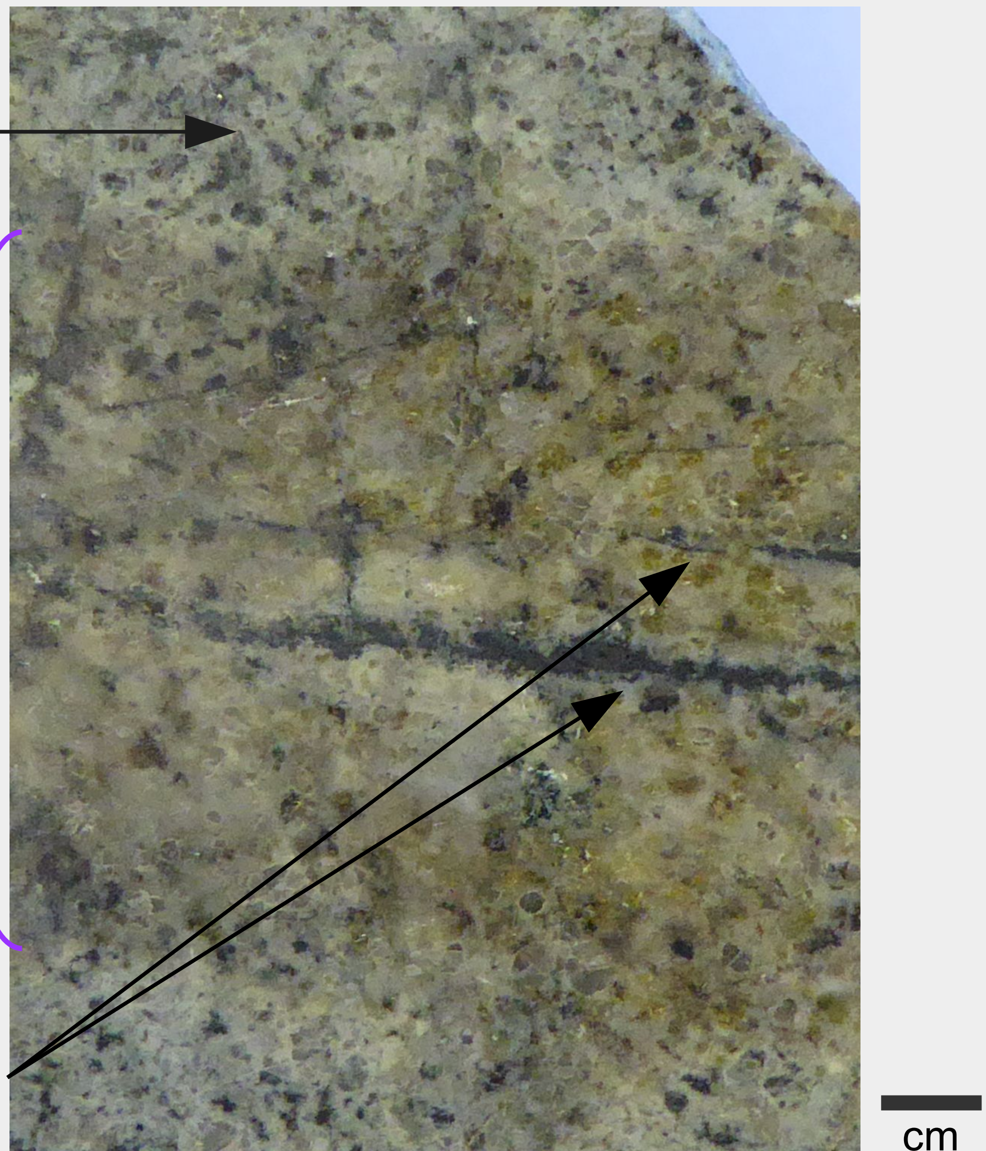


QUARTZ CREEK, WASHINGTON
Early potassic (EDM?) halos

Preacher monzongranite; background bio alt'n

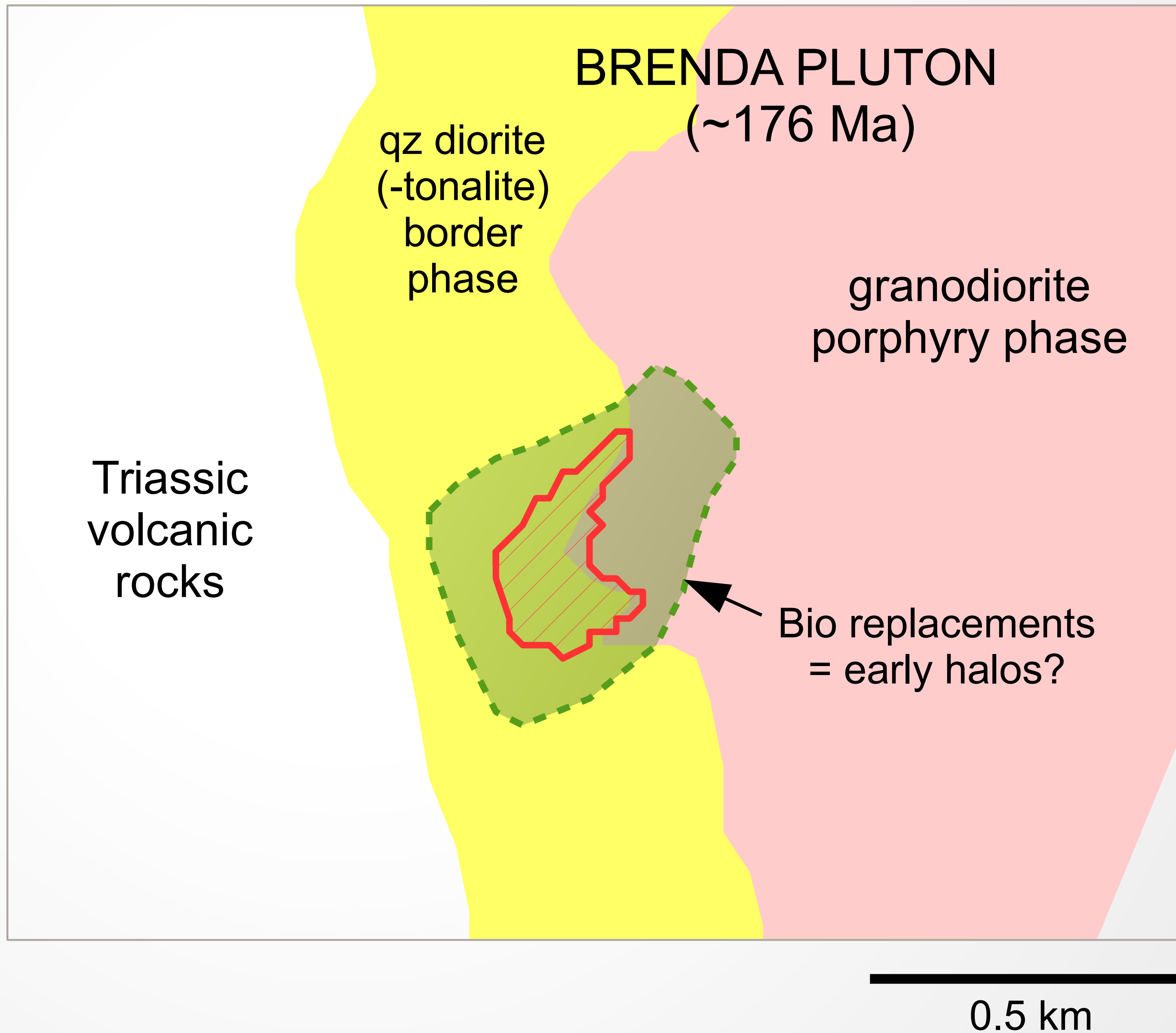
Early halo with bio-ser replacing hb; cp + py

mgt-qtz centerlines

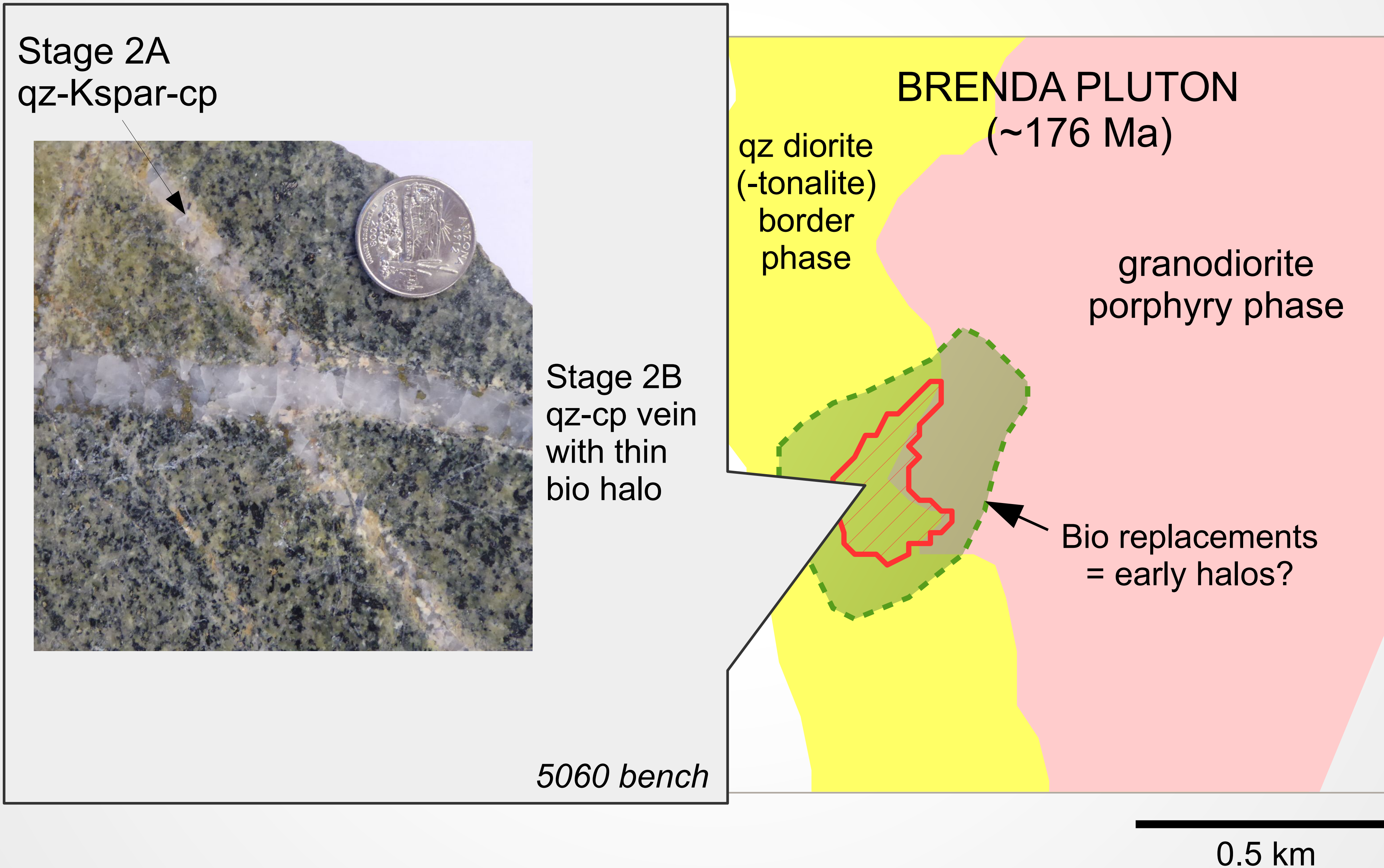


BRENDA, BC
Geology

modified from Soregaroli & Whitford, 1976, Fig. 2



BRENDA, BC
Stage 2 (potassic) veins

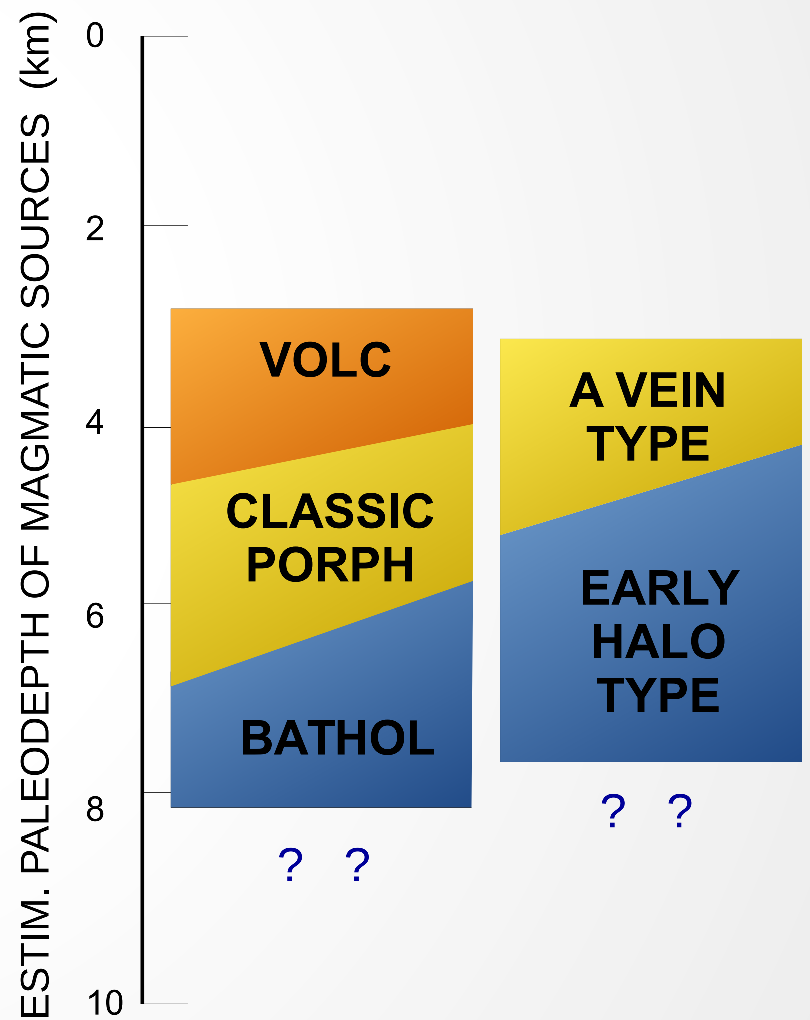


EXAMPLES: Batholithic and Early halo type deposits

- Quartz Creek, WA, USA
- Brenda, BC, Canada
- Butte, MT, USA
- Lomas Bayas, Chile
- Valley, Highland Valley, BC, Can
- Chuquicamata, Chile
- Los Pelambres, Chile
- Copper Creek, AZ, USA
- Haquira, Peru
- Ann-Mason Pass, NV, USA
- Escondida Este, Chile

CONCLUSIONS

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



A FINAL WORD

"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

biotite crackles, Continental area, Butte, MT, 1973

QUESTIONS?

REFERENCES:

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