

UNIDIRECTIONAL SOLIDIFICATION TEXTURES, MIAROLITIC CAVITIES AND ORBICLES : FIELD EVIDENCE FOR THE MAGMATIC TO HYDROTHERMAL TRANSITION IN INTRUSION - RELATED MINERAL DEPOSITS



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SEEGF Conference – October 2006

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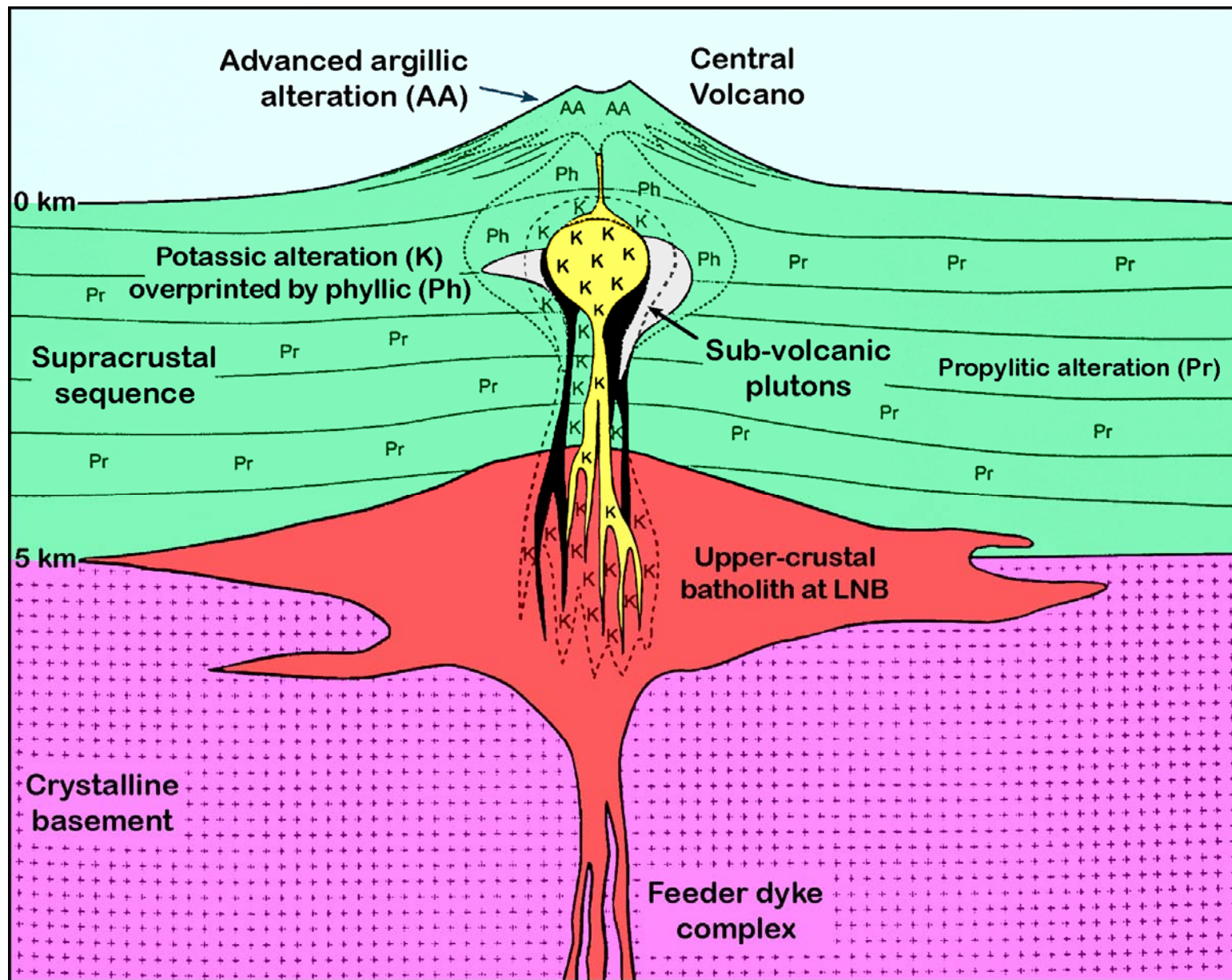
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OVERPRESSURED VOLATILES, FLUIDS AND TEXTURES IN INTRUSION - HOSTED MINERAL DEPOSITS

- Fluid – Volatiles Related Cupola Textures
(UST's, miarolitic cavities, orbicles)
- Mineralised Examples
- Potential Economic Models

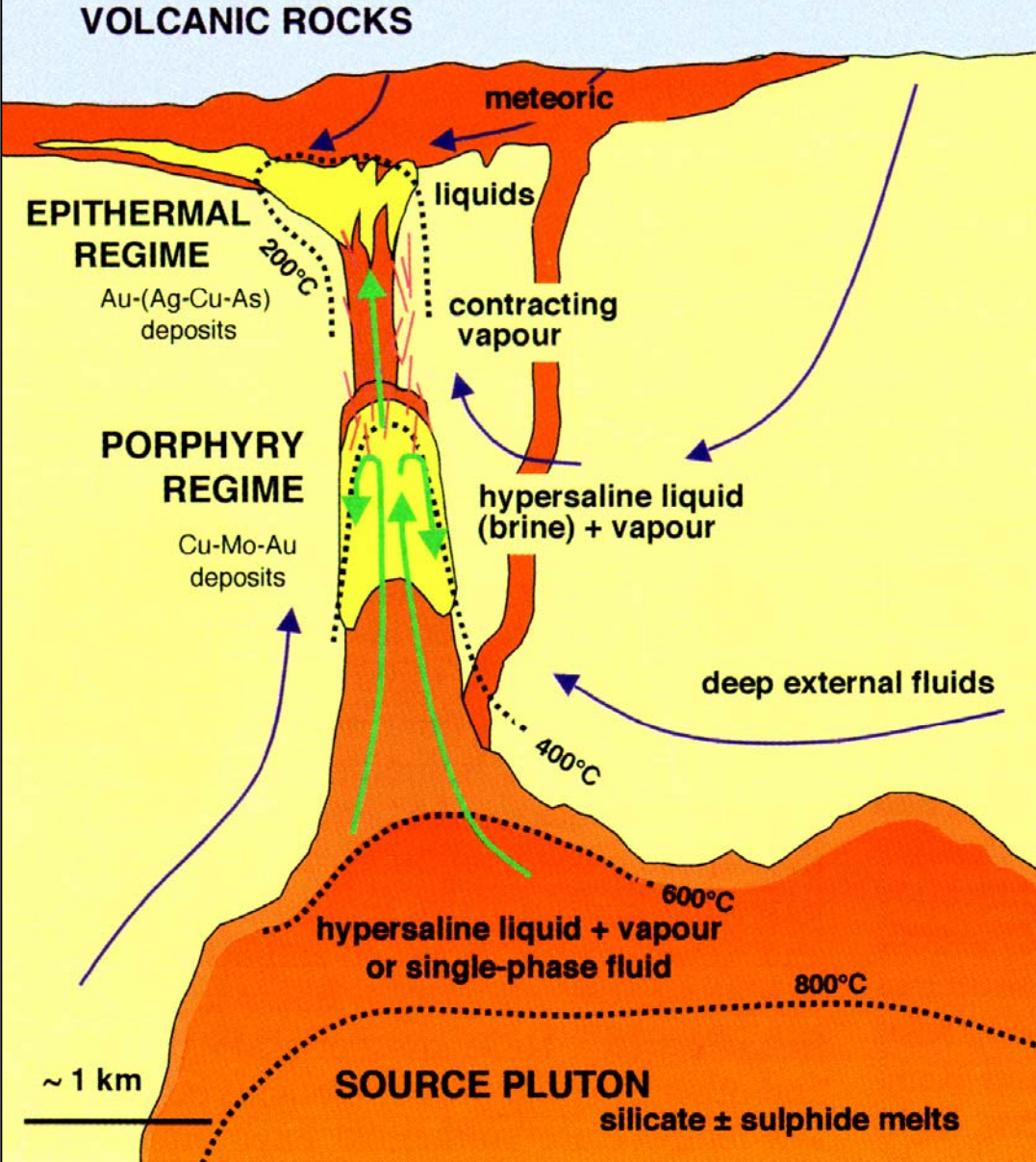


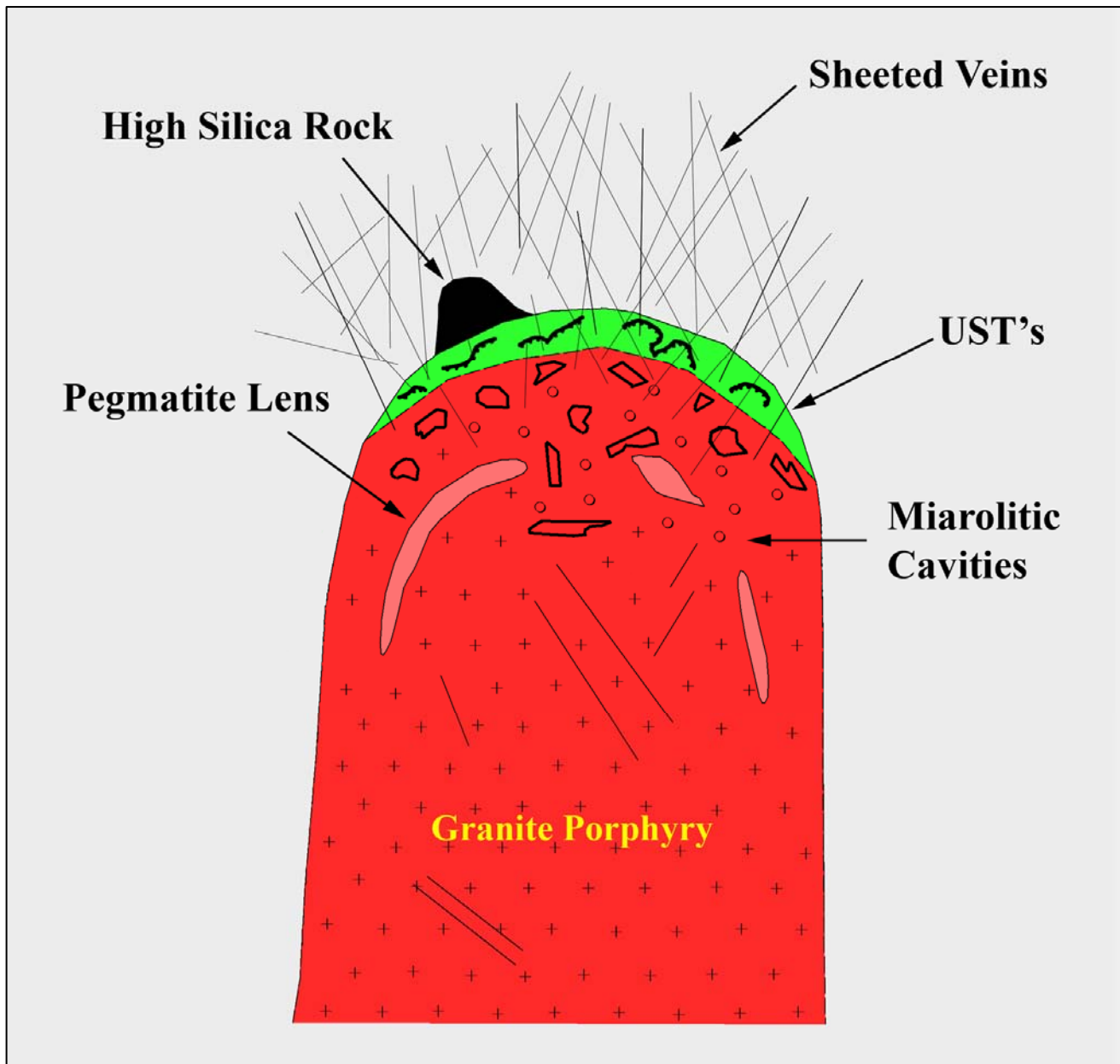


Schematic cross-section through a porphyry Cu forming volcano-plutonic system.

(Modified from Richards, 2003a)

(from Heinrich, 2005)





Schematic diagram showing distribution of various textures in aplitic apical zone of a felsic intrusion.

UST's

UNIDIRECTIONAL SOLIDIFICATION TEXTURES





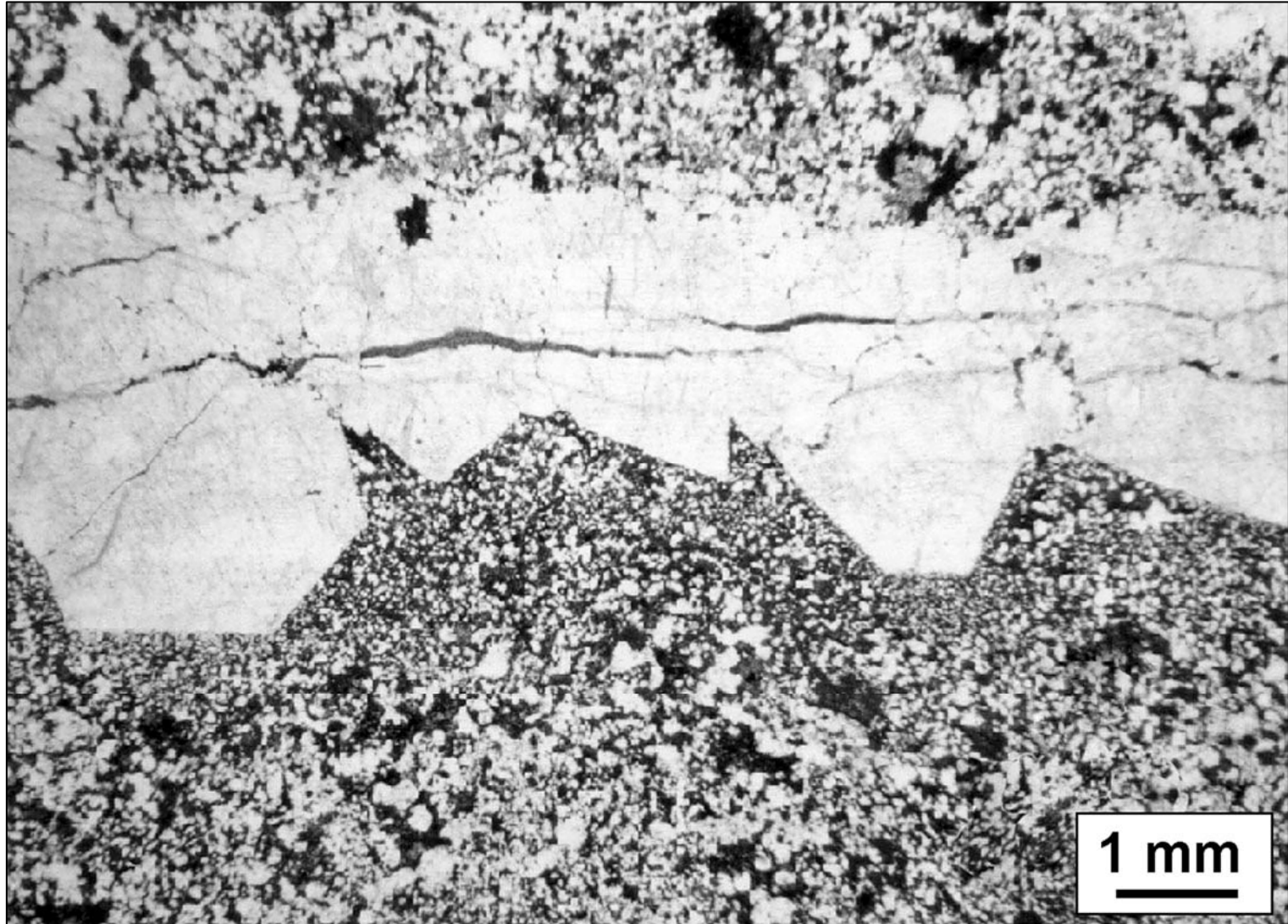
**View of cupola at Umnu Hutul (large hill in the foreground),
Western Mongolia**



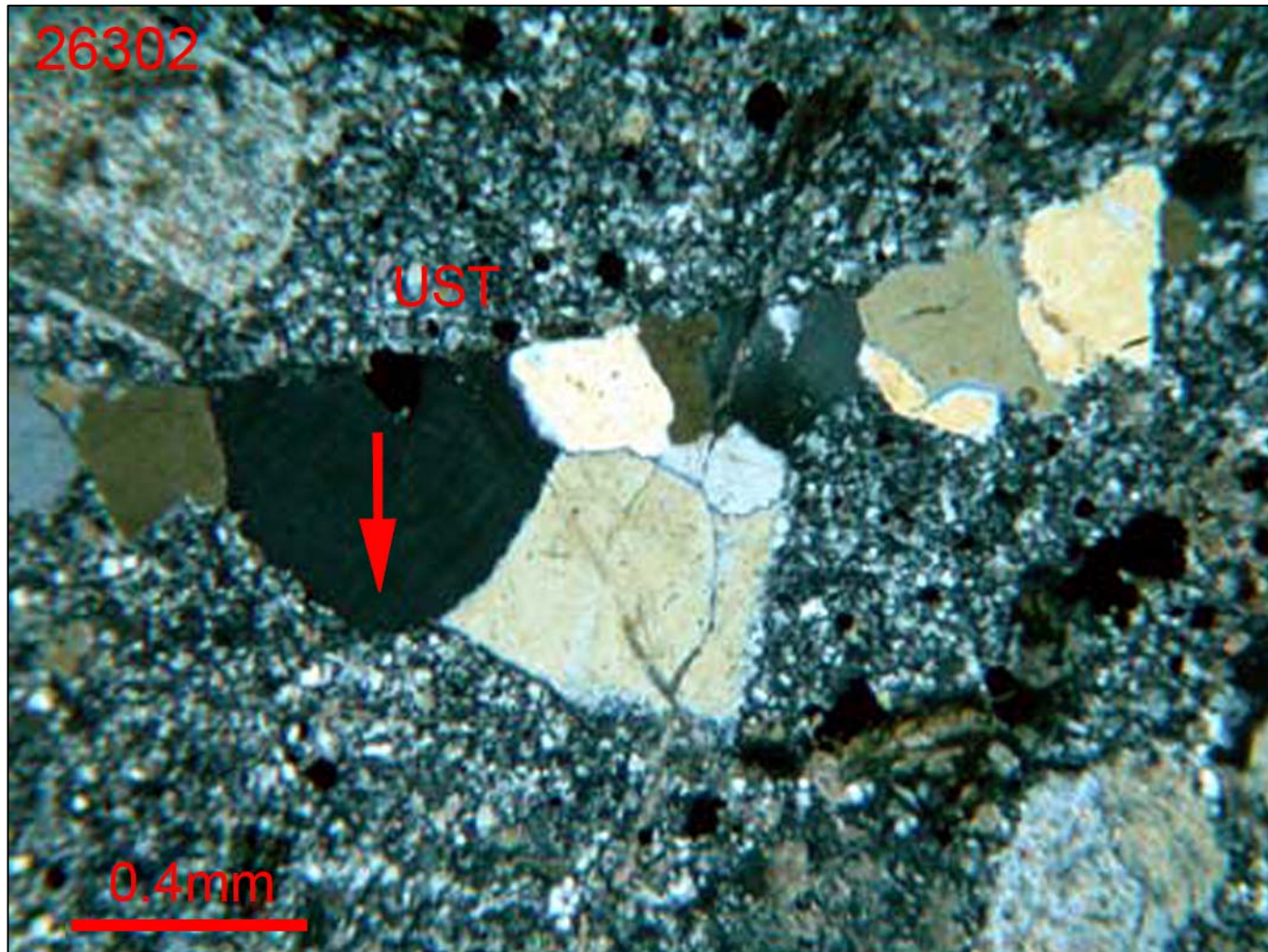
Parallel UST Bands



Contorted UST bands, Seltai, Kazakhstan

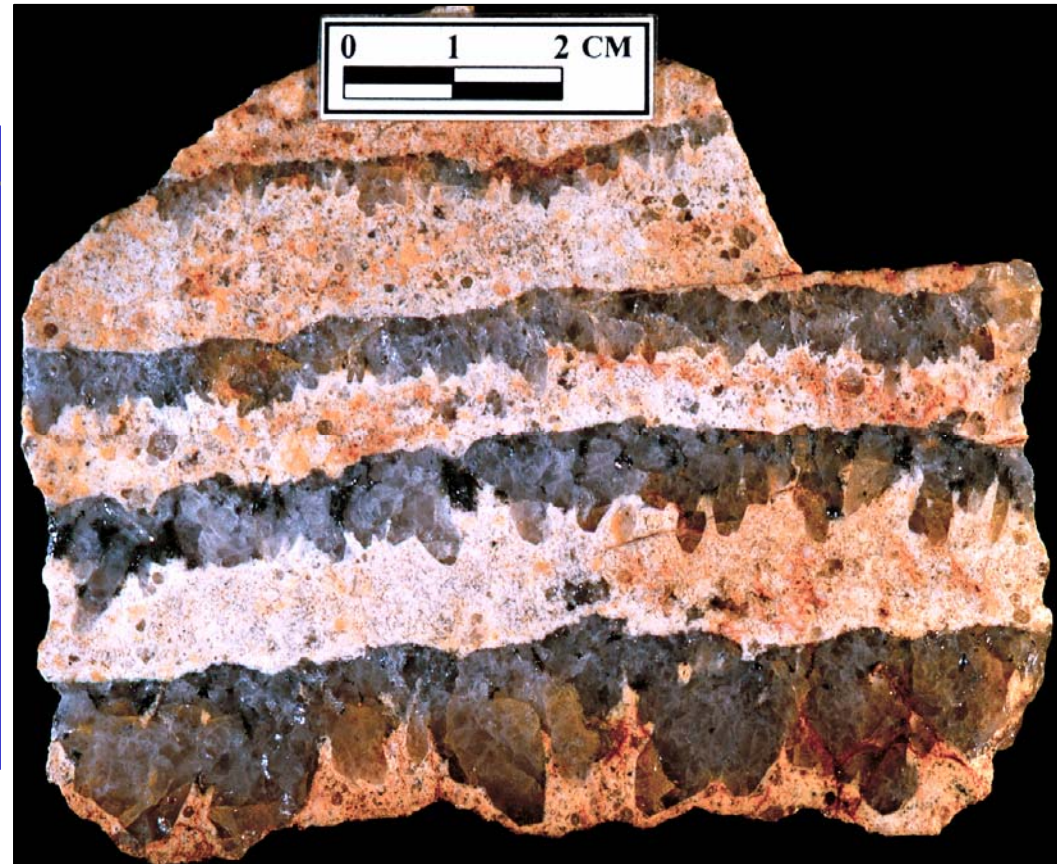
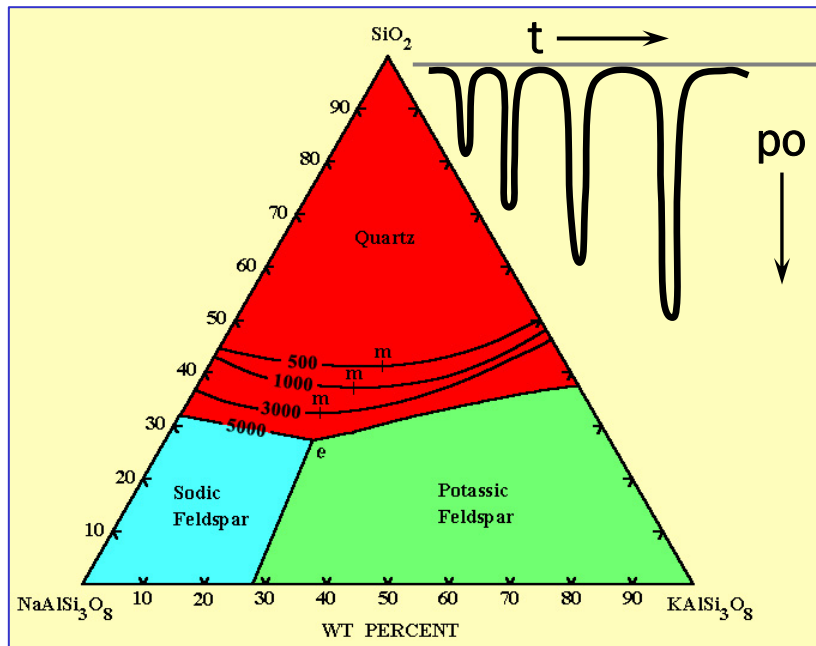


Thin section Mt Pleasant UST

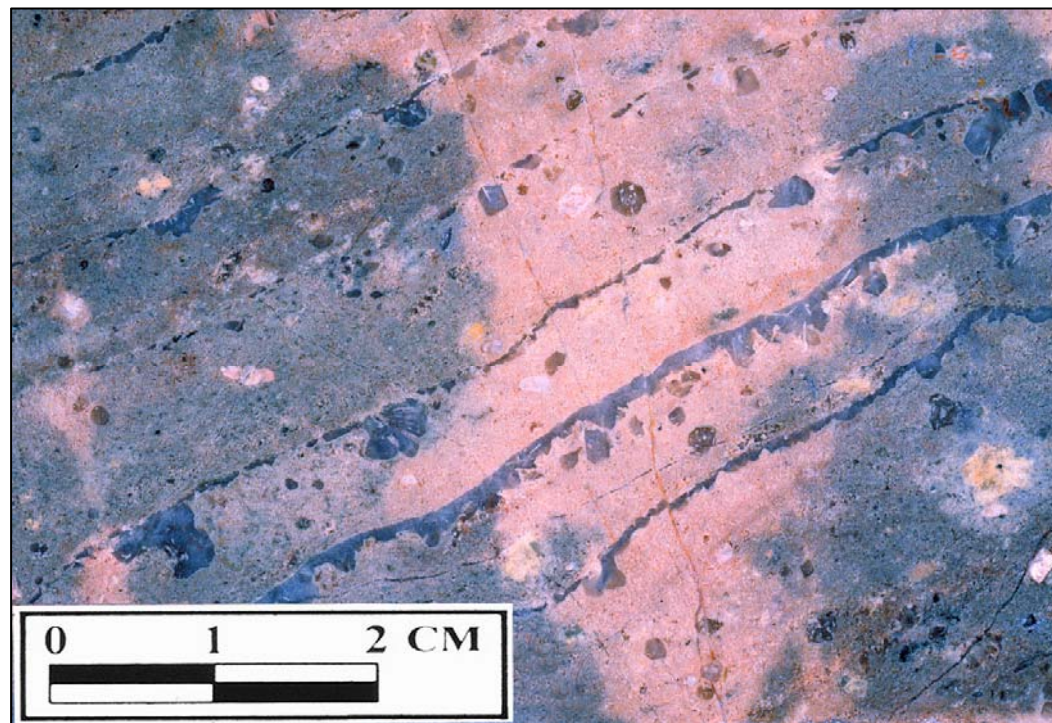
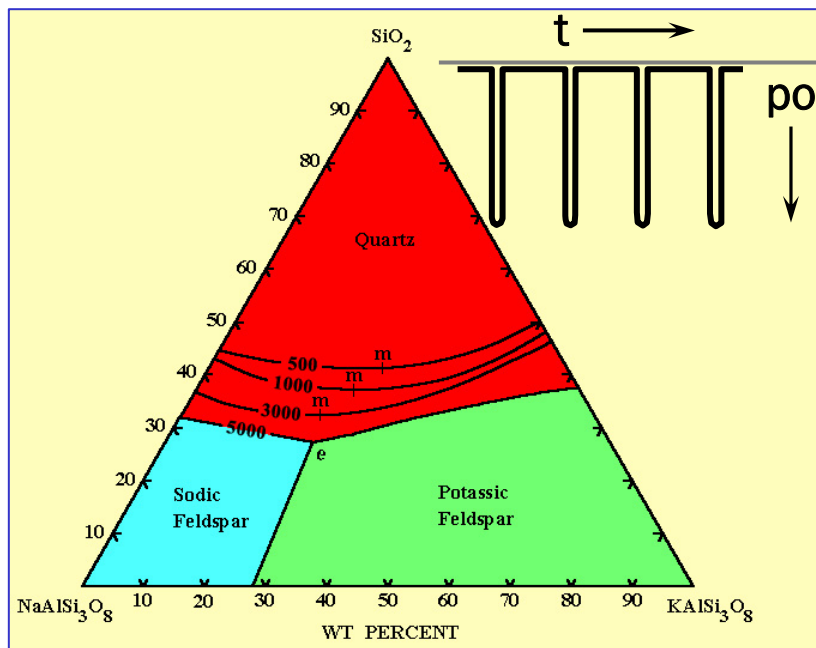


UST – Khongor, South Gobi, Mongolia

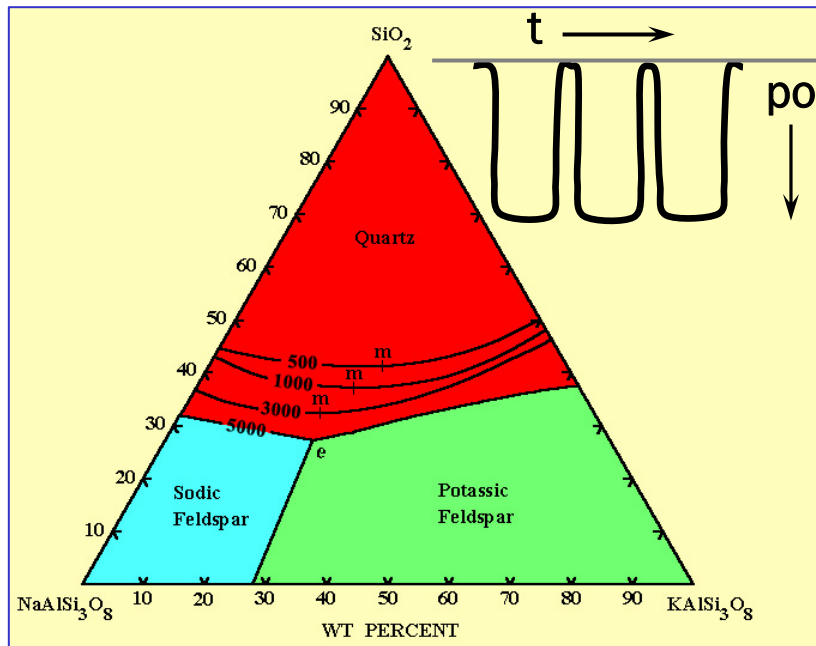
0.8 % Cu and 0.15 g/t Au



Anticlimax Mo deposit, Canada



**Red Dome porphyry Cu-Au deposit,
North Queensland, Australia**



Tsagaan Chulut, Northeast Mongolia



UST Quartz crystals – Tsagaan Chuluut district, Northeast Mongolia



View of large circle quartz layer, Zuun Mod, Southwestern Mongolia



Close-up of UST's exposure, Mongolia



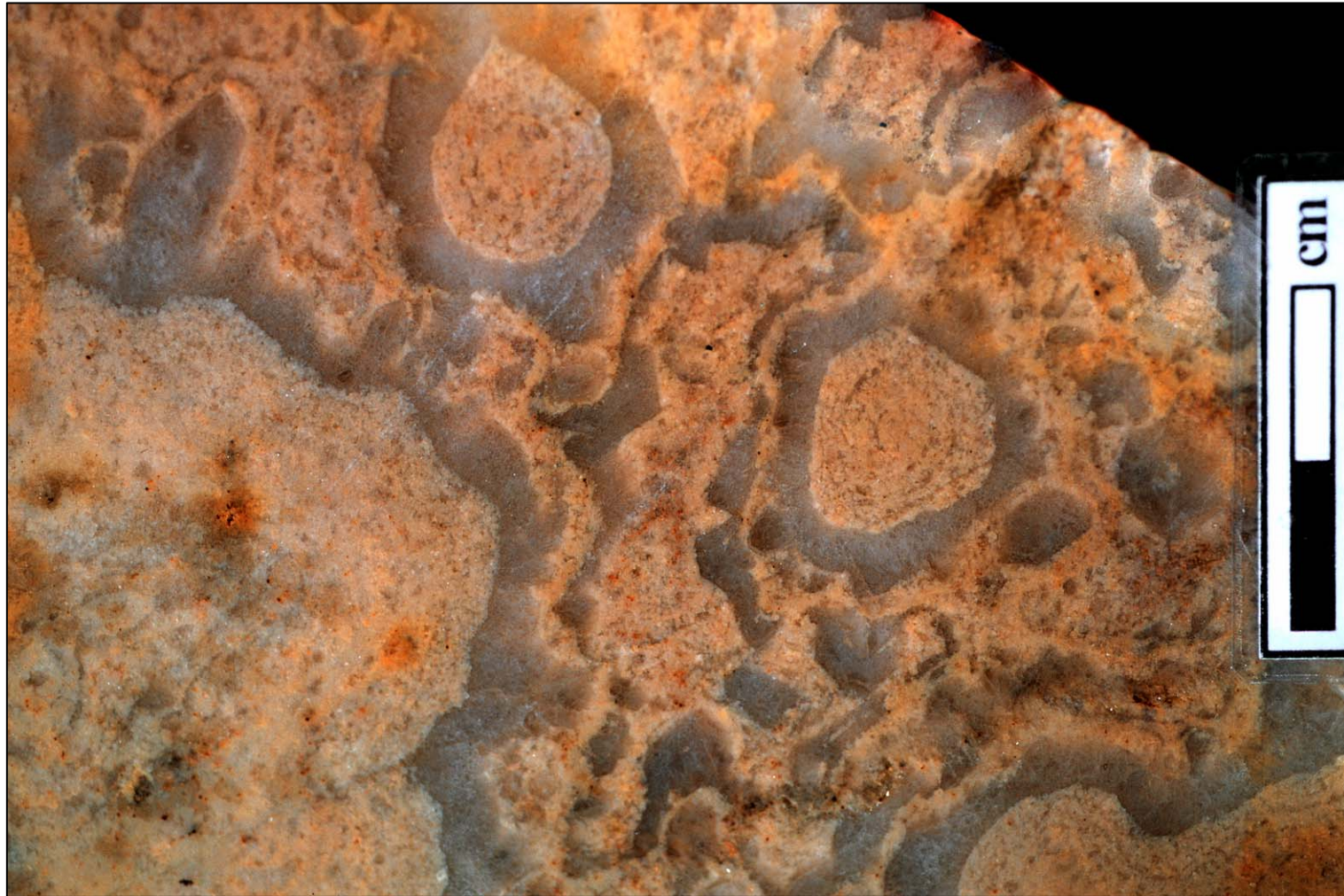
Quartz blow, Ravenswood, Northeast Queensland, Australia



*Parallel to C-axis, Logtung,
Canada*



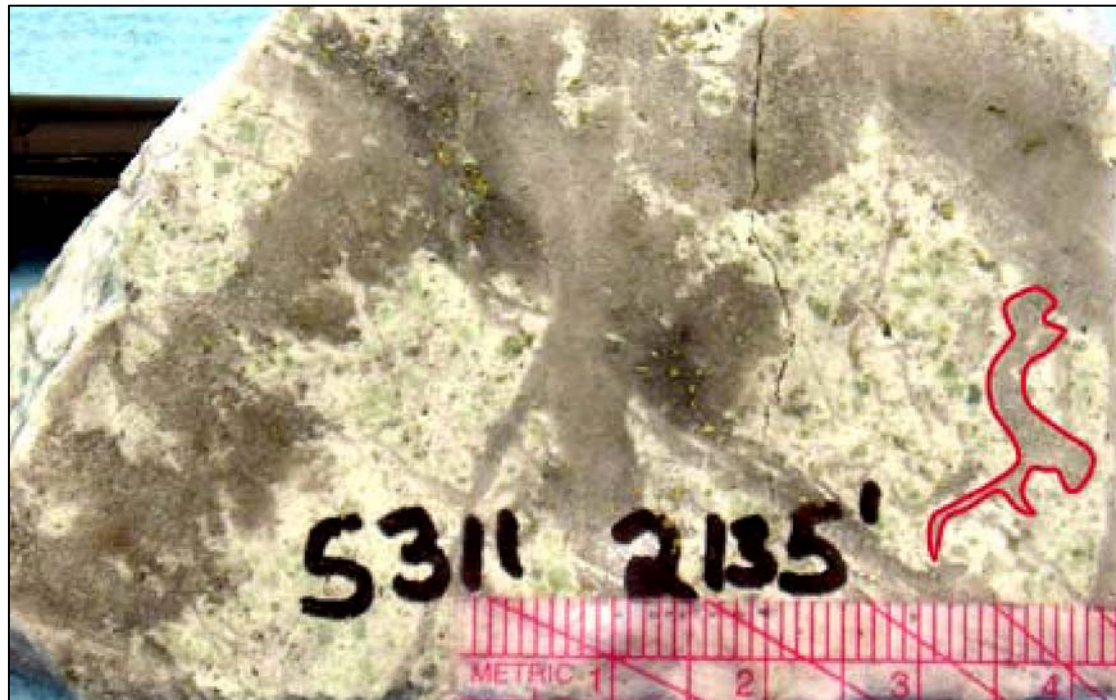
*90° to C-axis, Tate River,
North Queensland, Australia*



Atoll texture, Umnu Hutul, West Mongolia



"A" veins Hall Mo-Cu porphyry, Nevada



A-Veins or UST's?; DDH 5311 Pebble porphyry Cu-Au deposit, Alaska
(Photos – Mark Rebagliati)



Quartz veins and stockwork, Escondida Cu mine, Chile



Quartz veins and UST, Escondida Cu mine, Chile

UST Mineral Park CuMo Mine, Arizona, USA

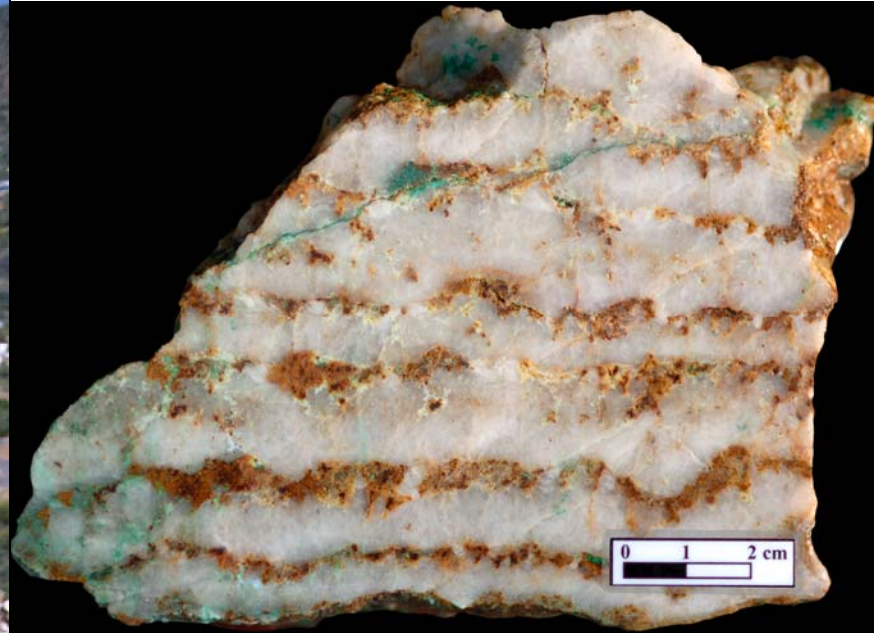


UST Mineral Park CuMo Mine, Arizona, USA





Saginaw Hill, Tucson, Arizona, USA



**UST outcrop Saginaw Hill, Tucson,
Arizona, USA**



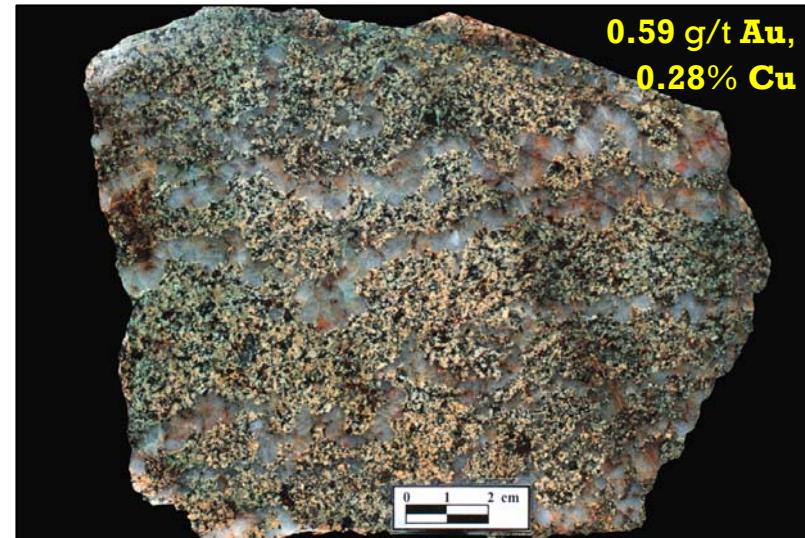
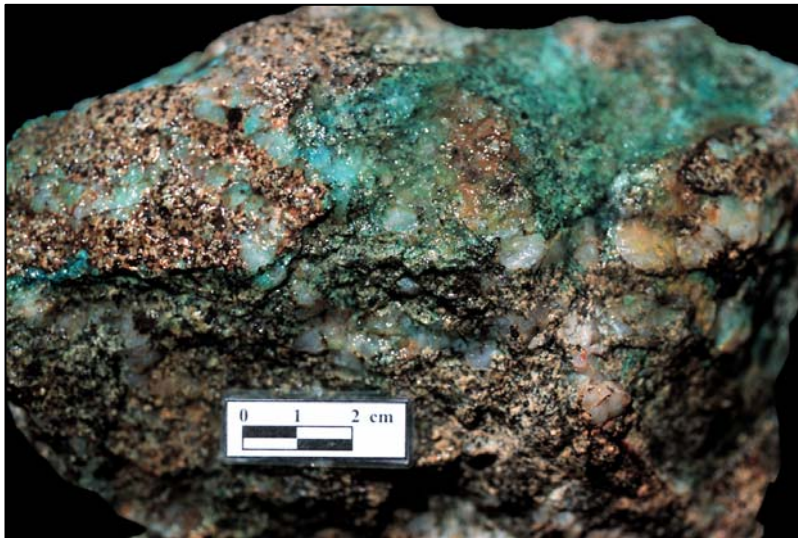
UST Ravenswood, North Queensland, Australia



Groenshoppies pegmatite, Namaqualand



Bronze Fox Au-Cu porphyry, South Gobi, Mongolia



1.05 g/t Au and 0.29% Cu



Mineralised base of UST zone

0.82 g/t Au and 1.60% Cu



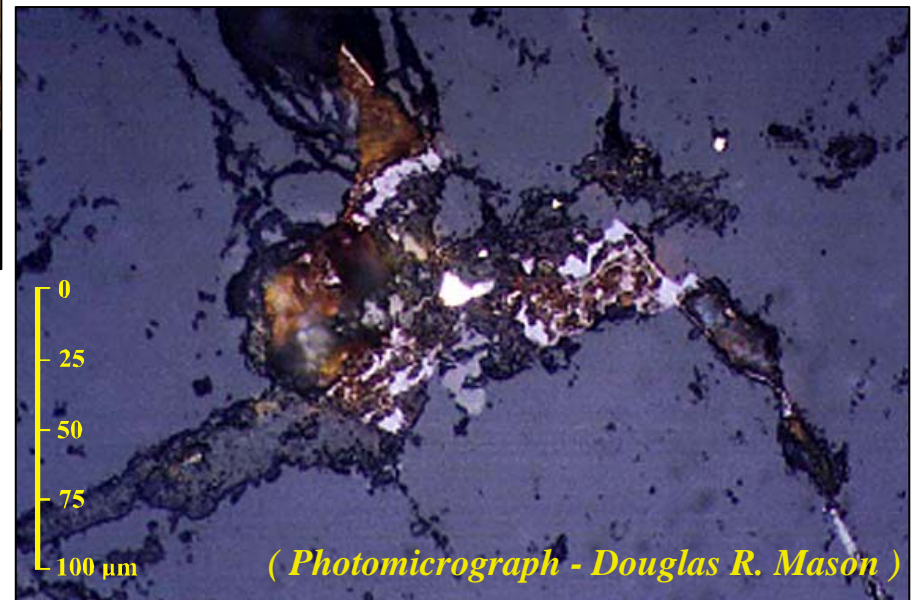
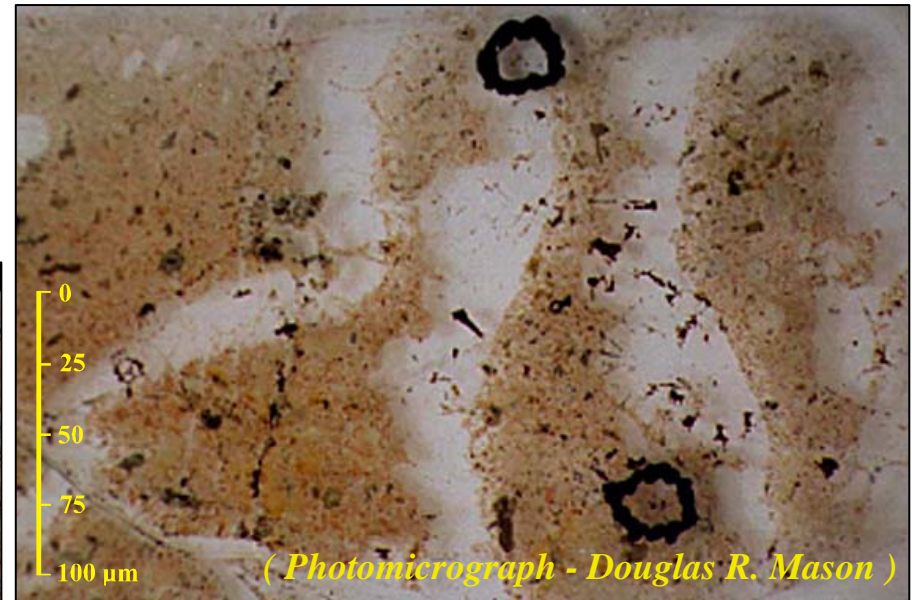
**Mineralised miarolitic cavity zone
below the UST band at Bronze Fox**

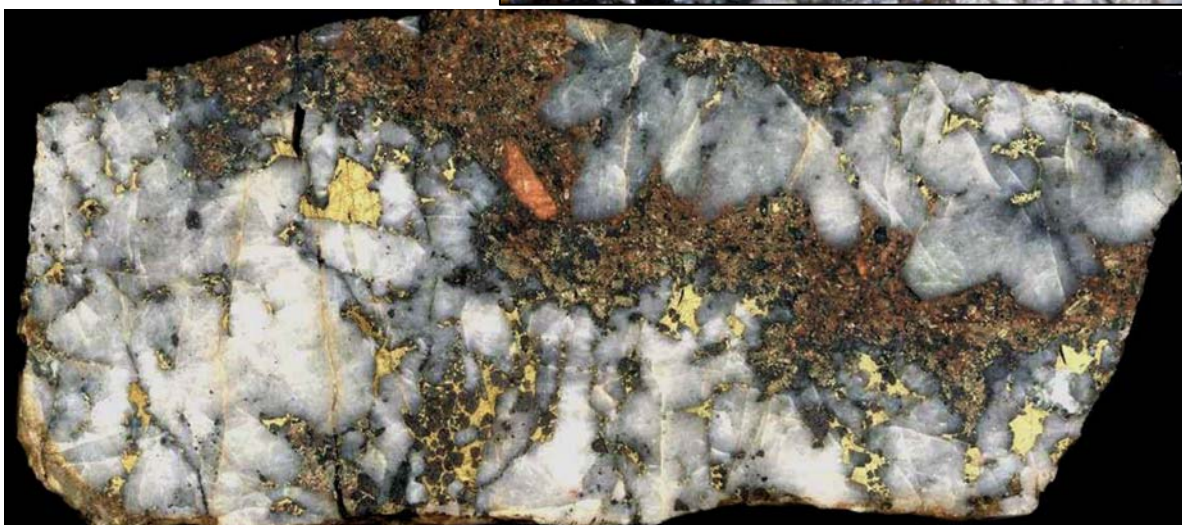
Thin section illustrating location of native gold grains in the left sample. The gold occurs with the quartz and host rock



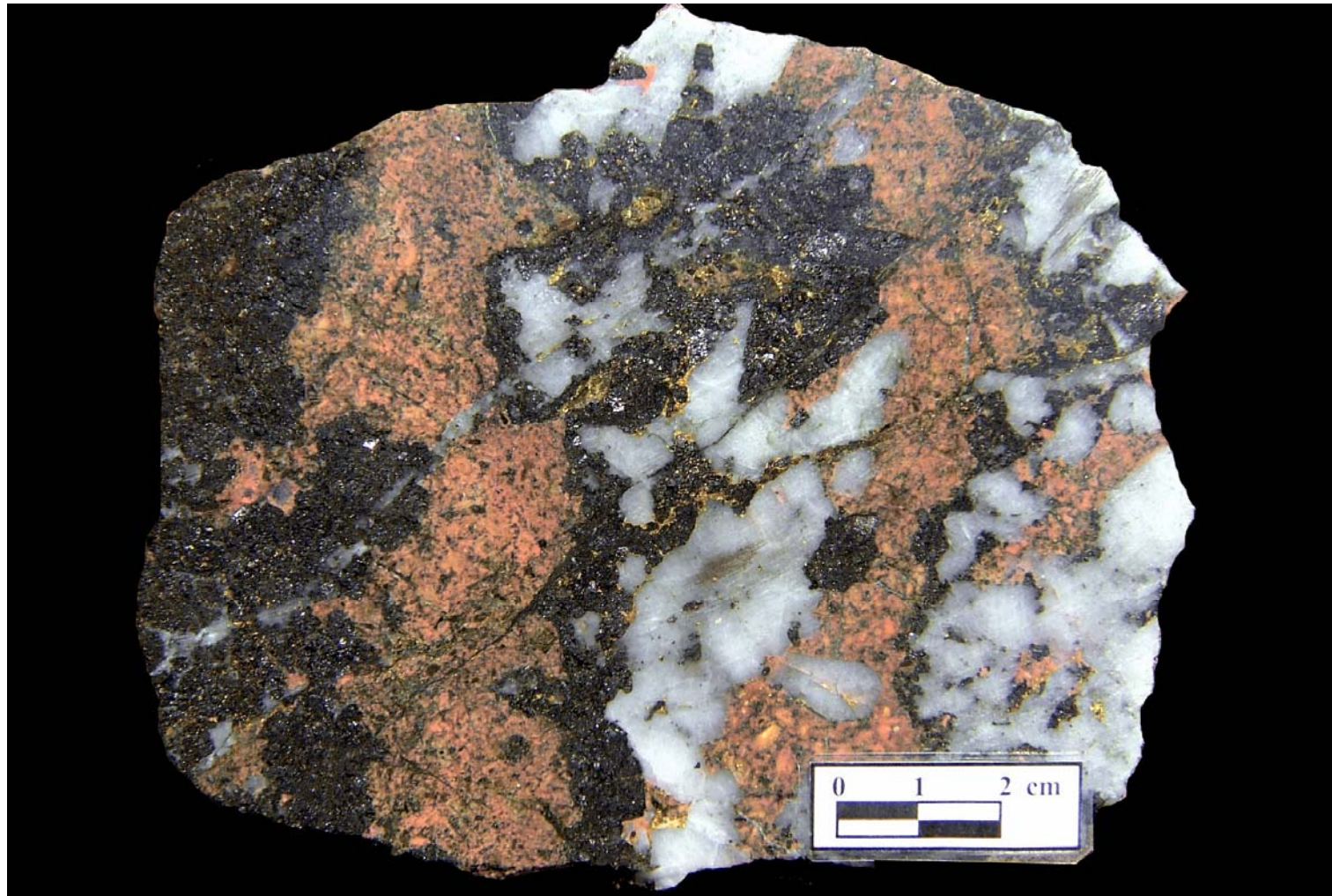
Au-Cu bearing, UST, Bayan Uul, Mongolia

Native gold in partly altered plagioclase phenocryst





**Ridgeway Au-Cu porphyry,
New South Wales, Australia**
(Courtesy of Newcrest)

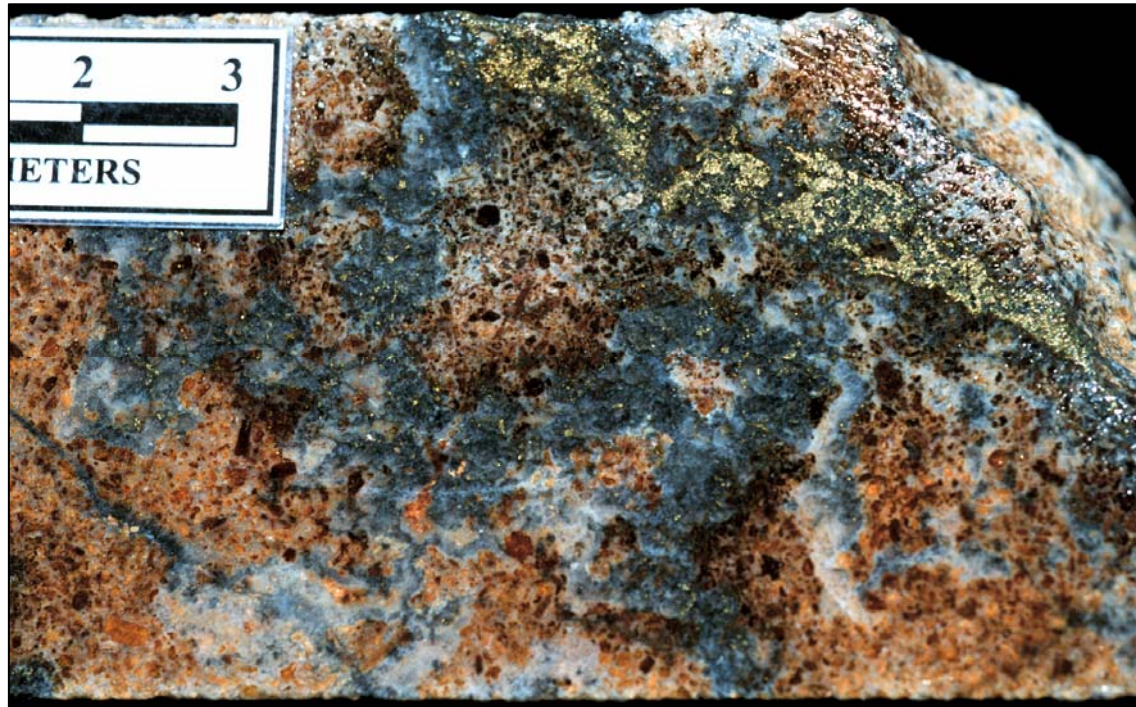
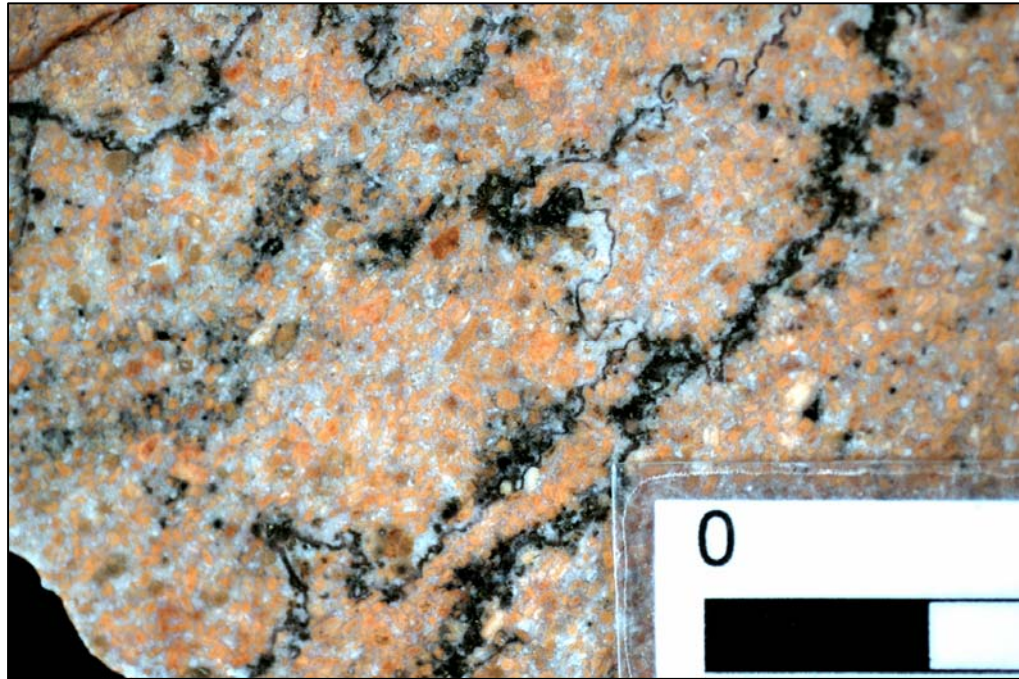


Ridgeway Au-Cu porphyry, New South Wales, Australia



Mamut Au-Cu mine, Sabah, East Malaysia

**Chalcopyrite - rich UST bands,
Tampang porphyry Au-Cu,
Mamut district, Sabah, Malaysia**



The UST zone is 5m thick

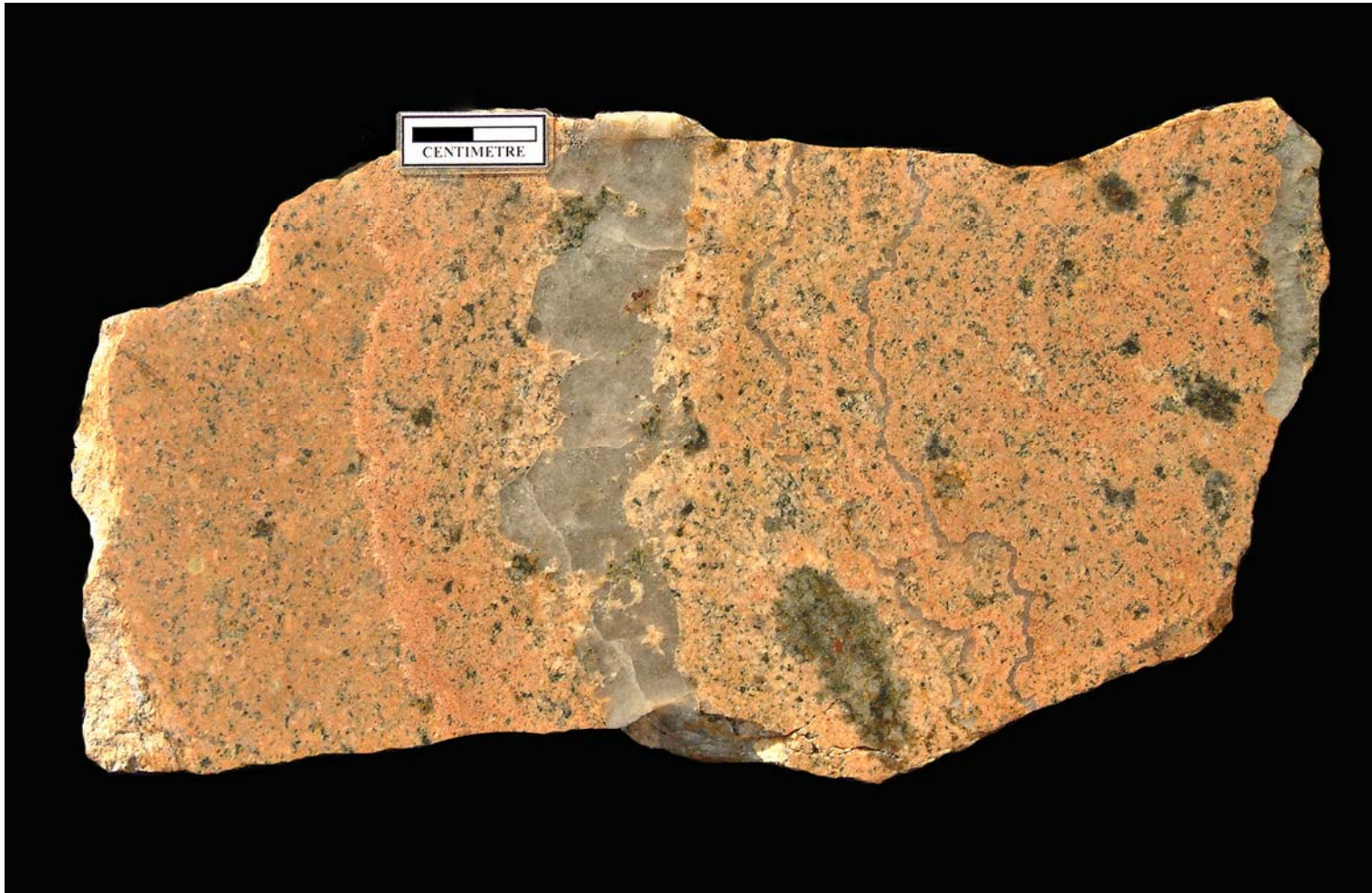


**Hada Sumu Au-Cu porphyry,
Inner Mongolia, China**





Hada Sumu Au-Cu porphyry, Inner Mongolia, China



Hada Sumu monzodiorite, Inner Mongolia, China

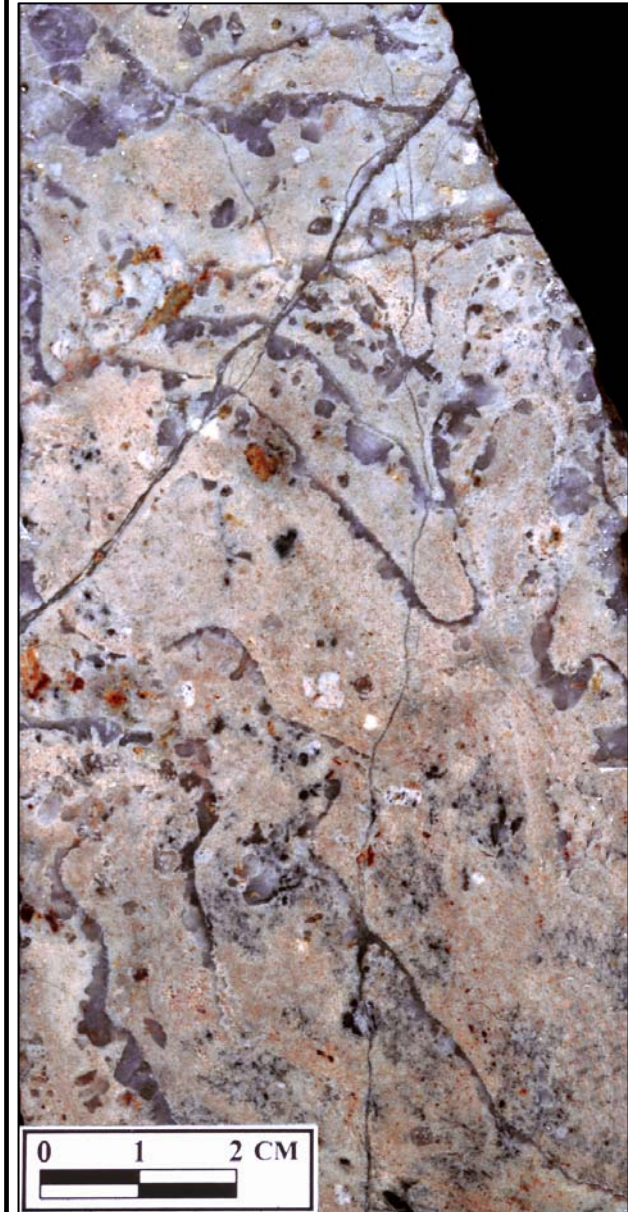
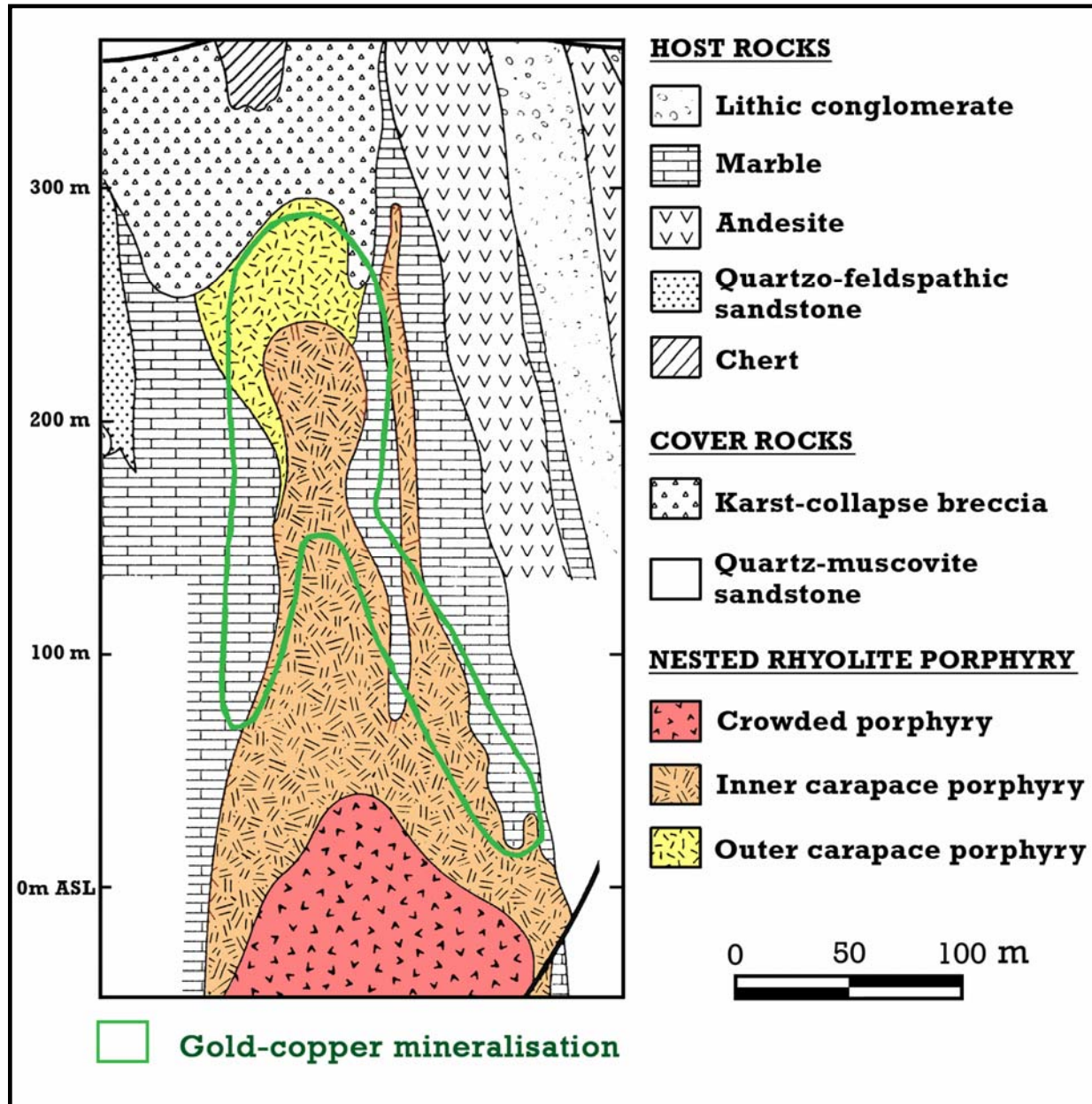
2.21 g/t Au and 103 ppm Cu



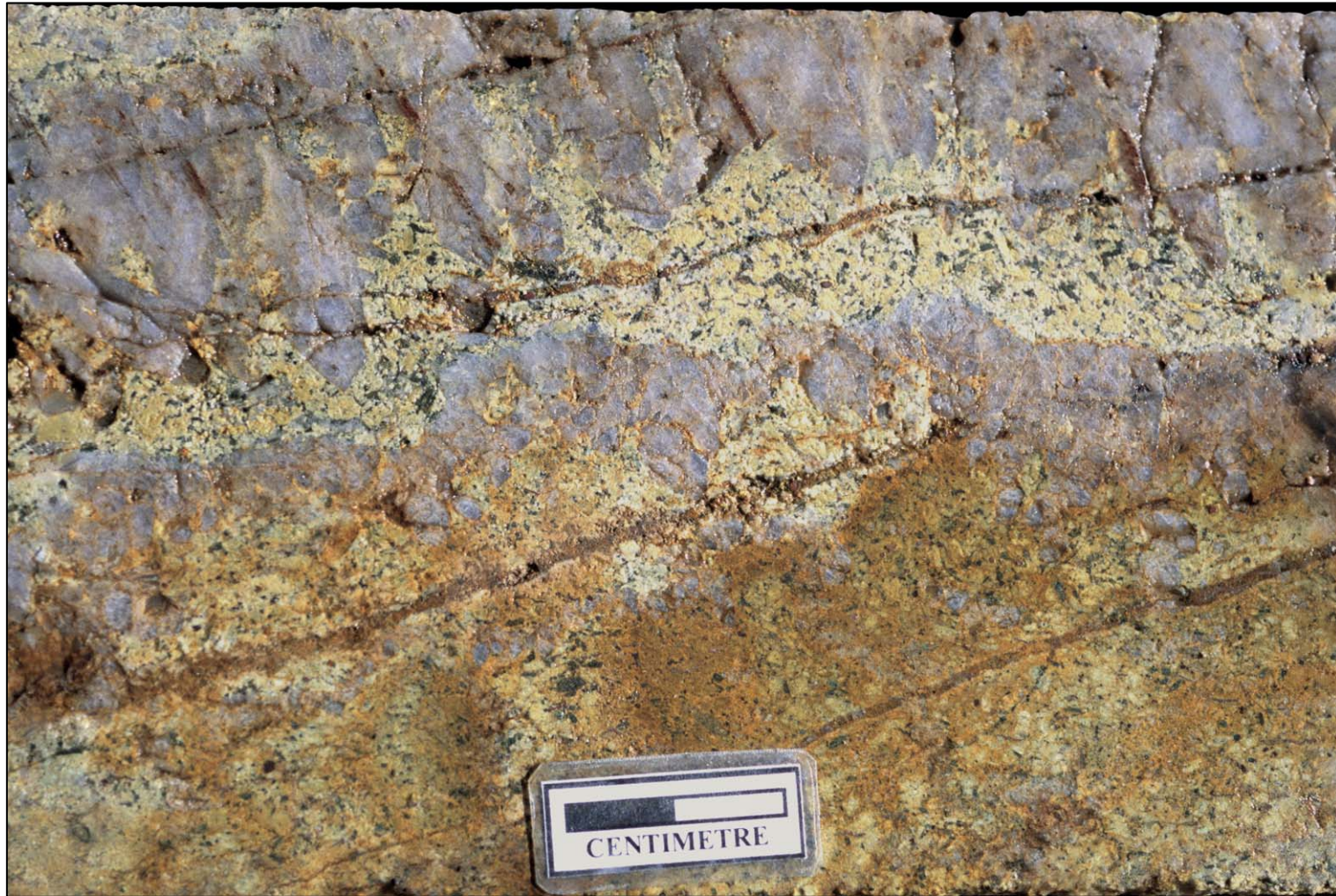
UST Magnetite, Hada Sumu district, Inner Mongolia, China



Red Dome Cu-Au mine, Chillagoe, North Queensland, Australia



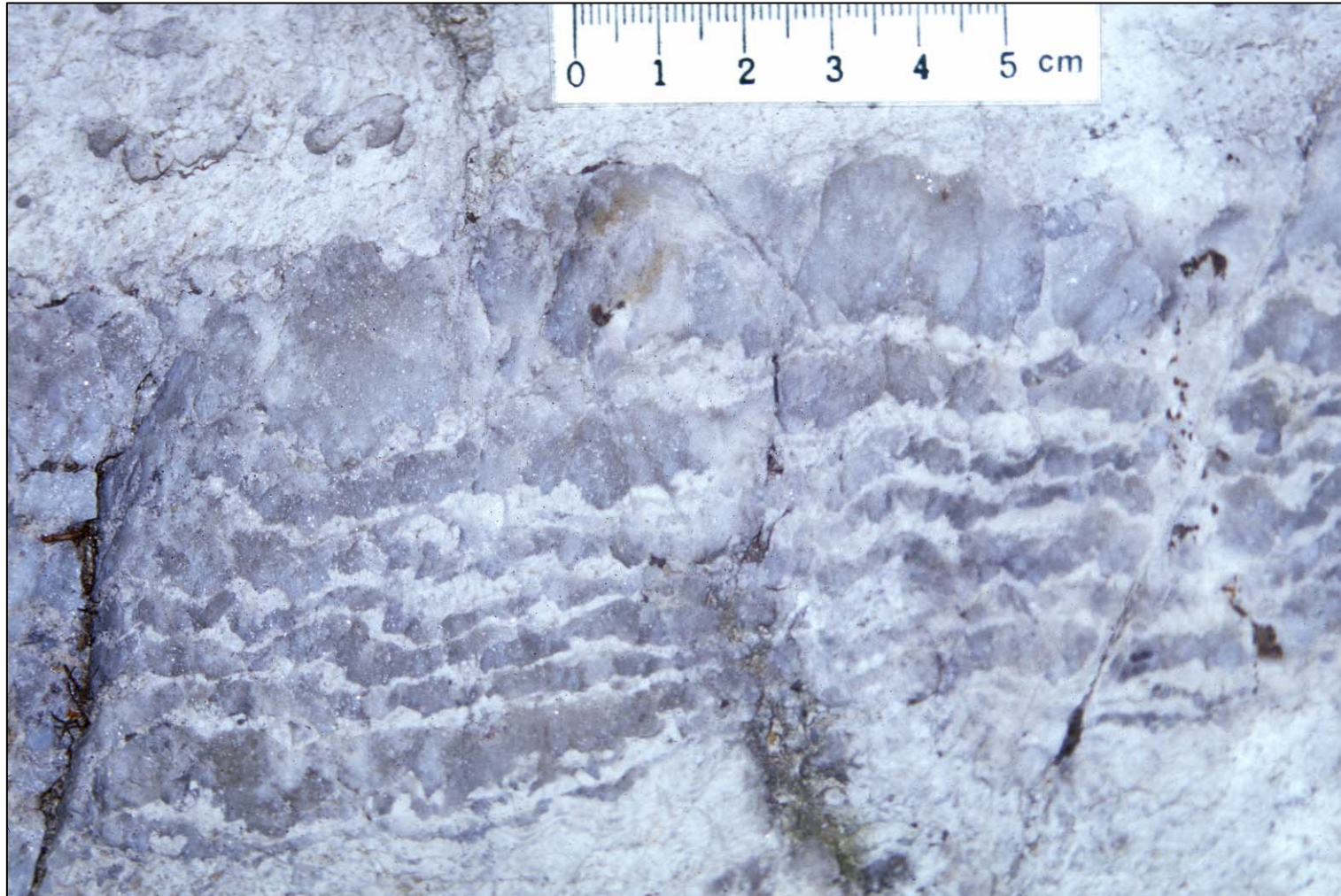
Geological cross-section of the Red Dome deposit. (Torrey *et al.*, 1988)



UST STD-18, 203m, Boyongan, Philippines



Orivesi, Finland



UST Orivesi Au mine, Southwest Finland

MIAROLITIC CAVITIES



Gifu, Japan



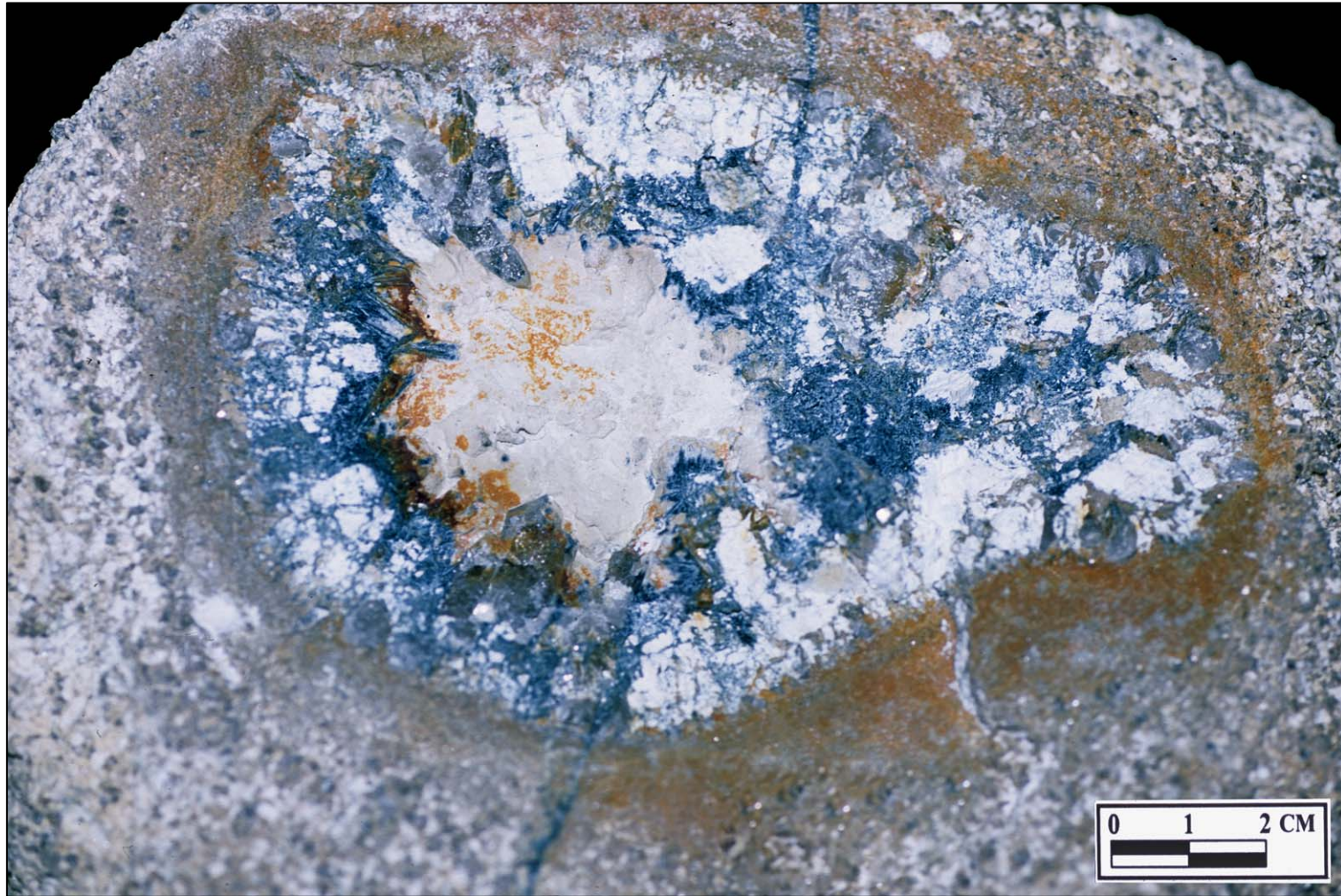
Miarolitic cavities, Gorkhi, Mongolia



Miarolitic cavities, Gorkhi, Mongolia



Miarolitic cavities, Black Pearl WO_3 mine, Arizona, USA

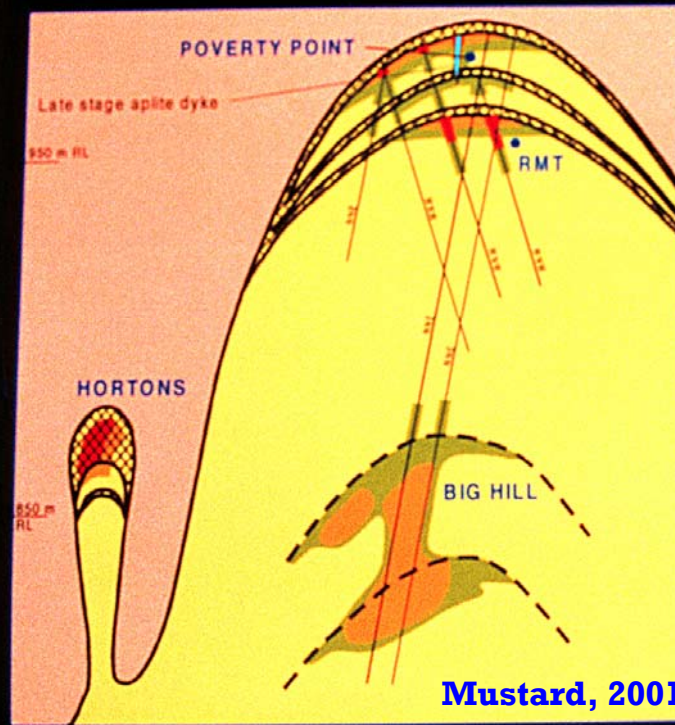


Miarolitic pipes, Goonbarrow, Cornwall, UK

Timbarra Mineralisation Model



ROSS
MINING N.L.



Mustard, 2001

TIMBARRA PROJECT

GEOLOGICAL MODEL

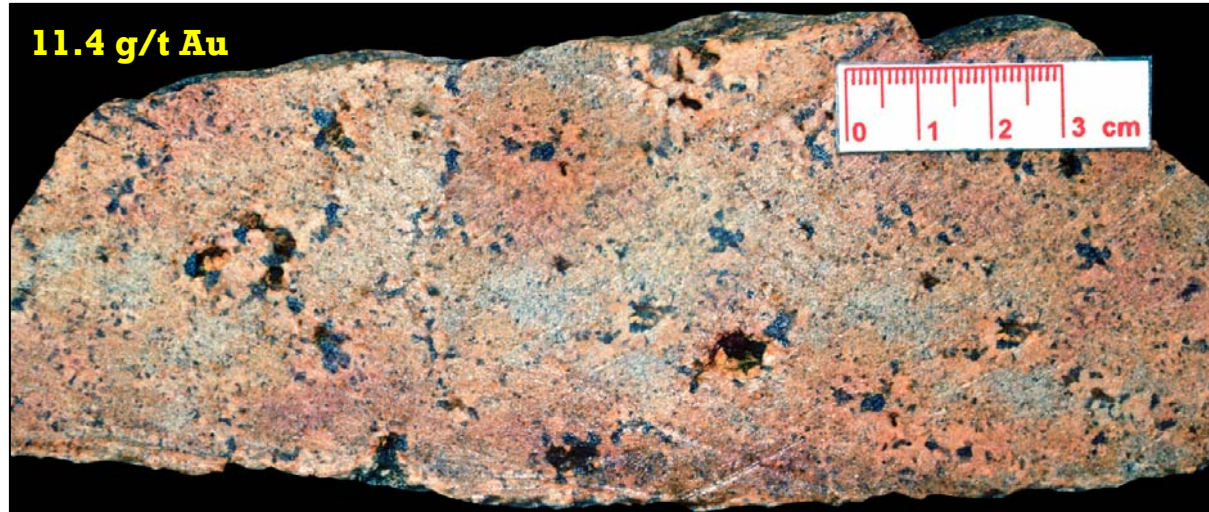
MINERALISATION

- Moderate sericite-chlorite and albite alteration
- Moderate grade gold mineralisation (0.5 to 3.0 g/t Au)
- High grade gold mineralisation (>3 g/t Au)

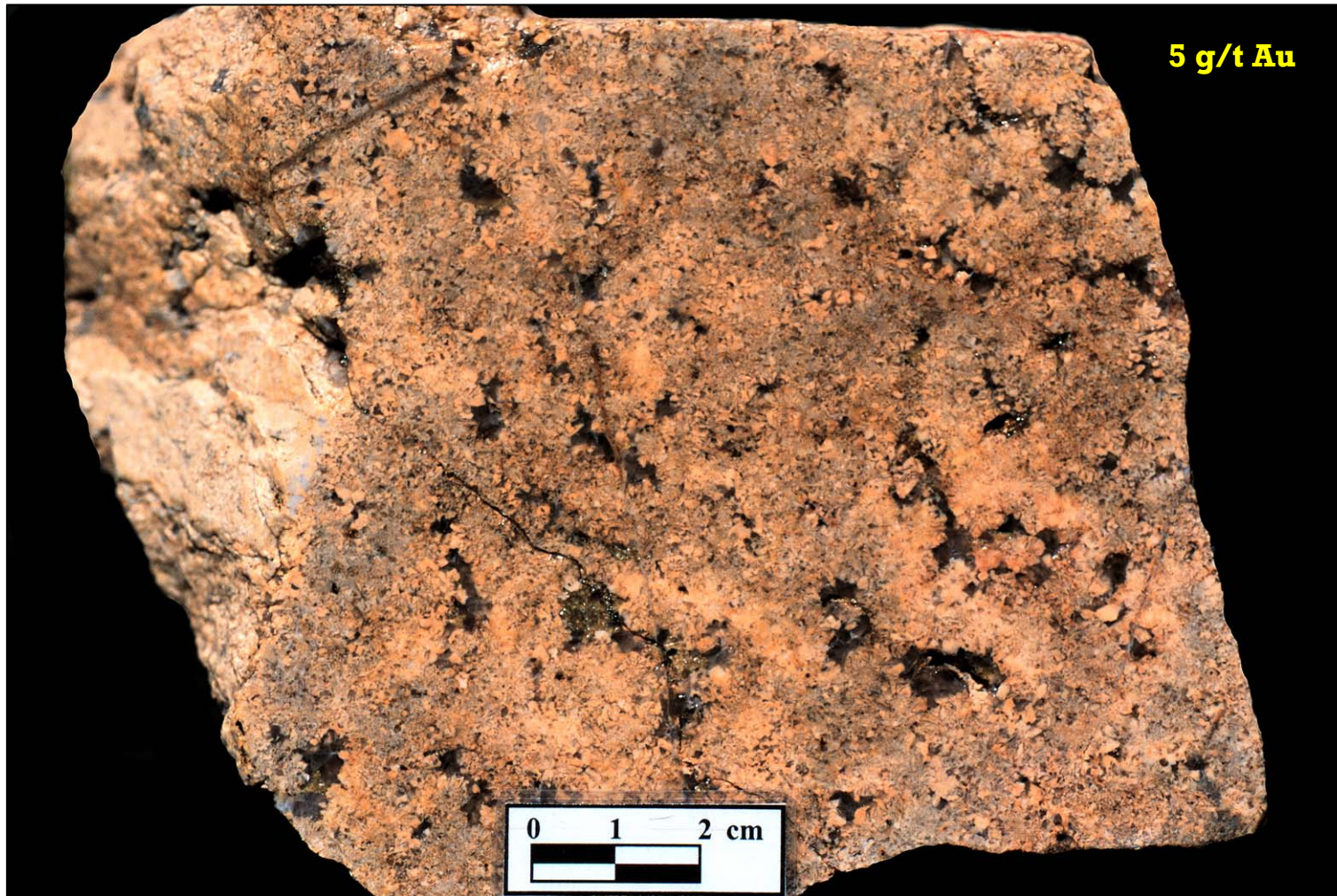
LITHOLOGY

- Late stage aplite dyke
- Microgranite
- Microgranite layer
- Equigranular granite
- MONTY'S GRANITE
- Porphyritic granite

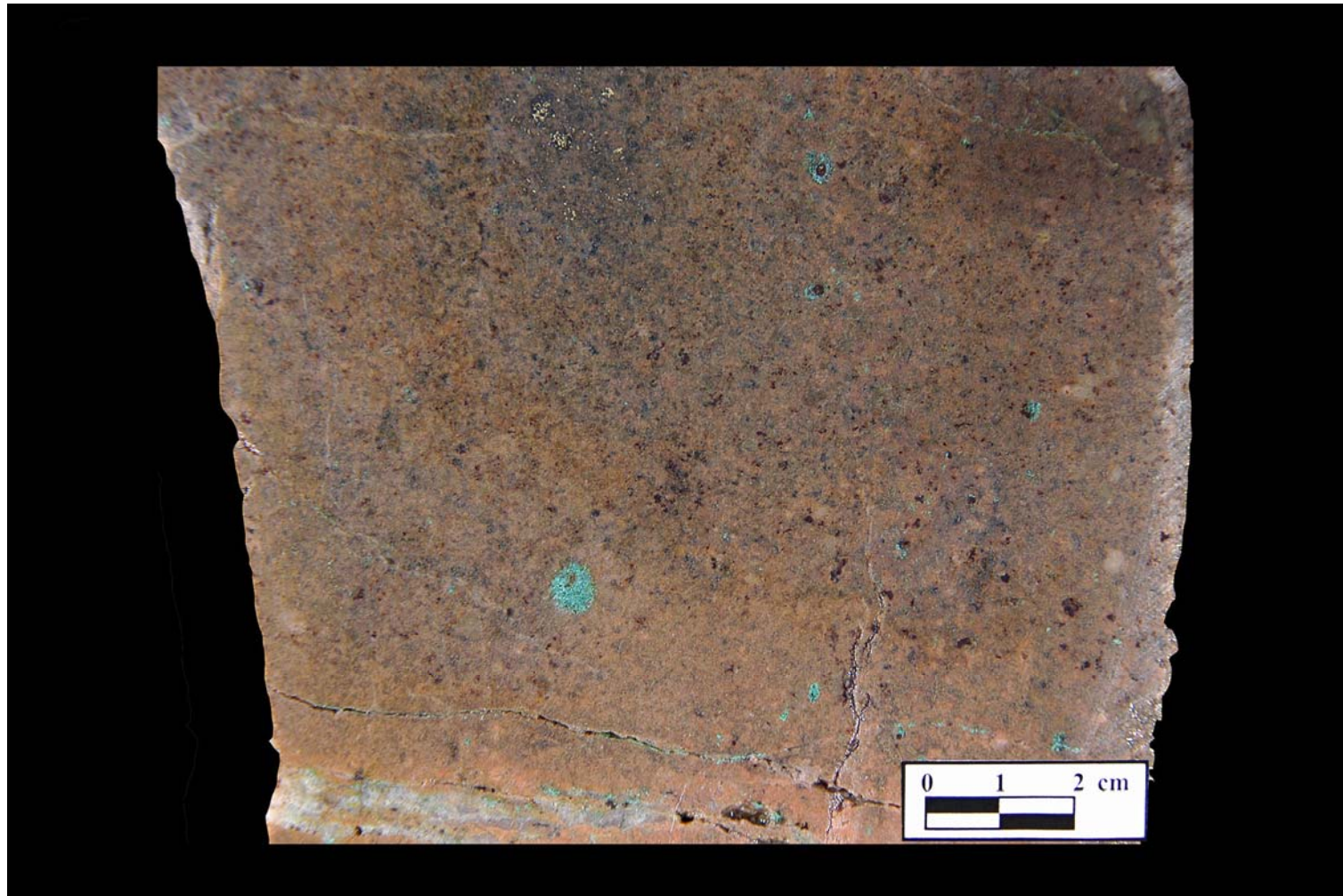
11.4 g/t Au







Miarolitic cavities in monzonite cupola, 80 kms west of Kharmagtai, South Gobi, Mongolia



Miarolitic monzonite 1.3 g/t Au *and* 0.6% Cu, Oyut Ulaan, South Gobi, Mongolia



Zaaiplats Sn mine, Rooiberg, South Africa



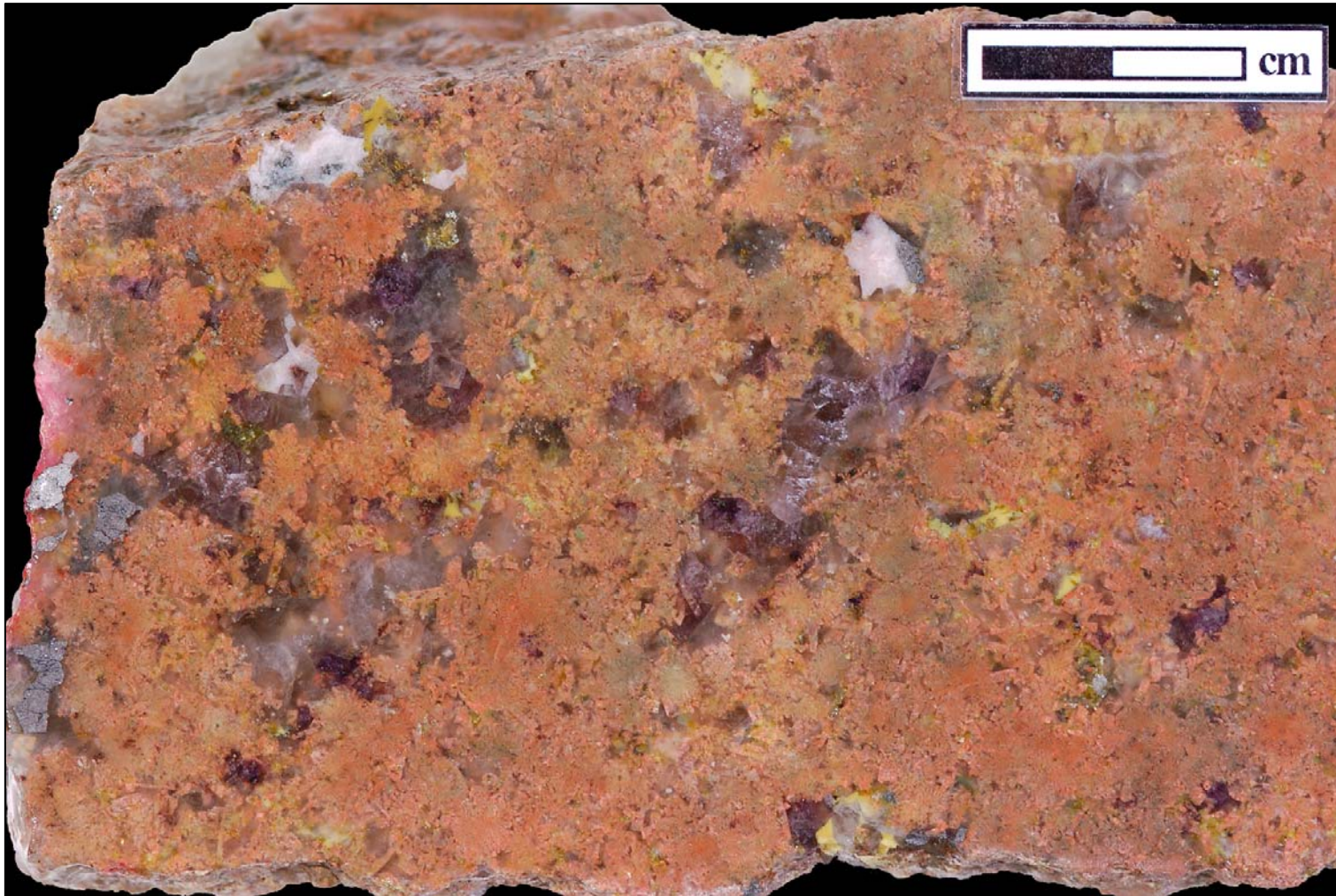
Tourmaline miarolitic cavities, Zaaiplats Sn mine, Rooiberg, South Africa



Tourmaline-bearing miarolitic cavity, Zaaiplats



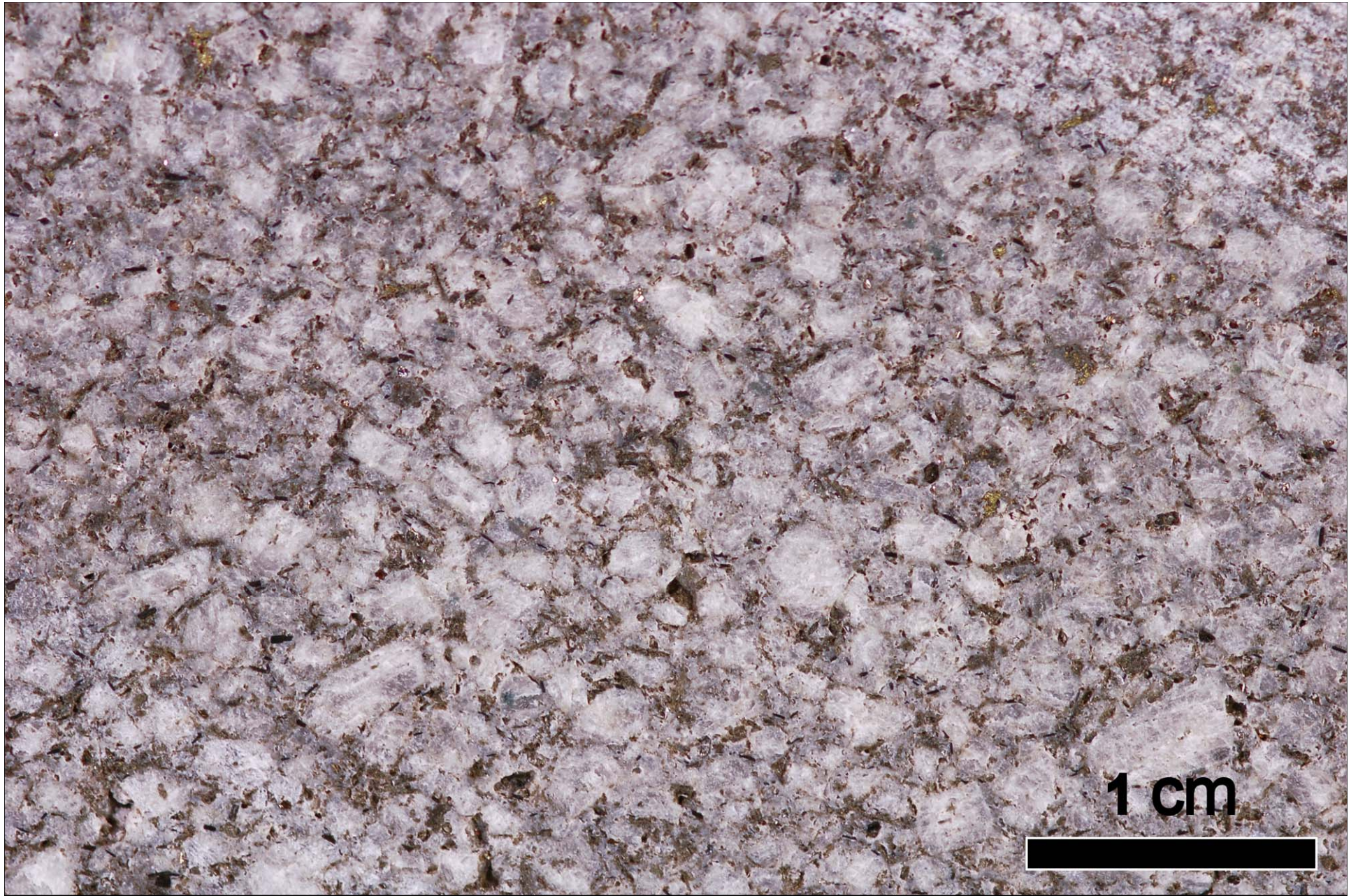
Ore pipes, Zaaiplats



Disseminated Sn ore, Zaaiplats



King King porphyry Cu-Au deposit, looking north, Mindanao, Philippines



Miarolitic cavities and disseminated chalcopyrite-bornite, King King



Spitzkoppe granite, Namibia



Plumose feldspar, Spitzkoppe, Namibia



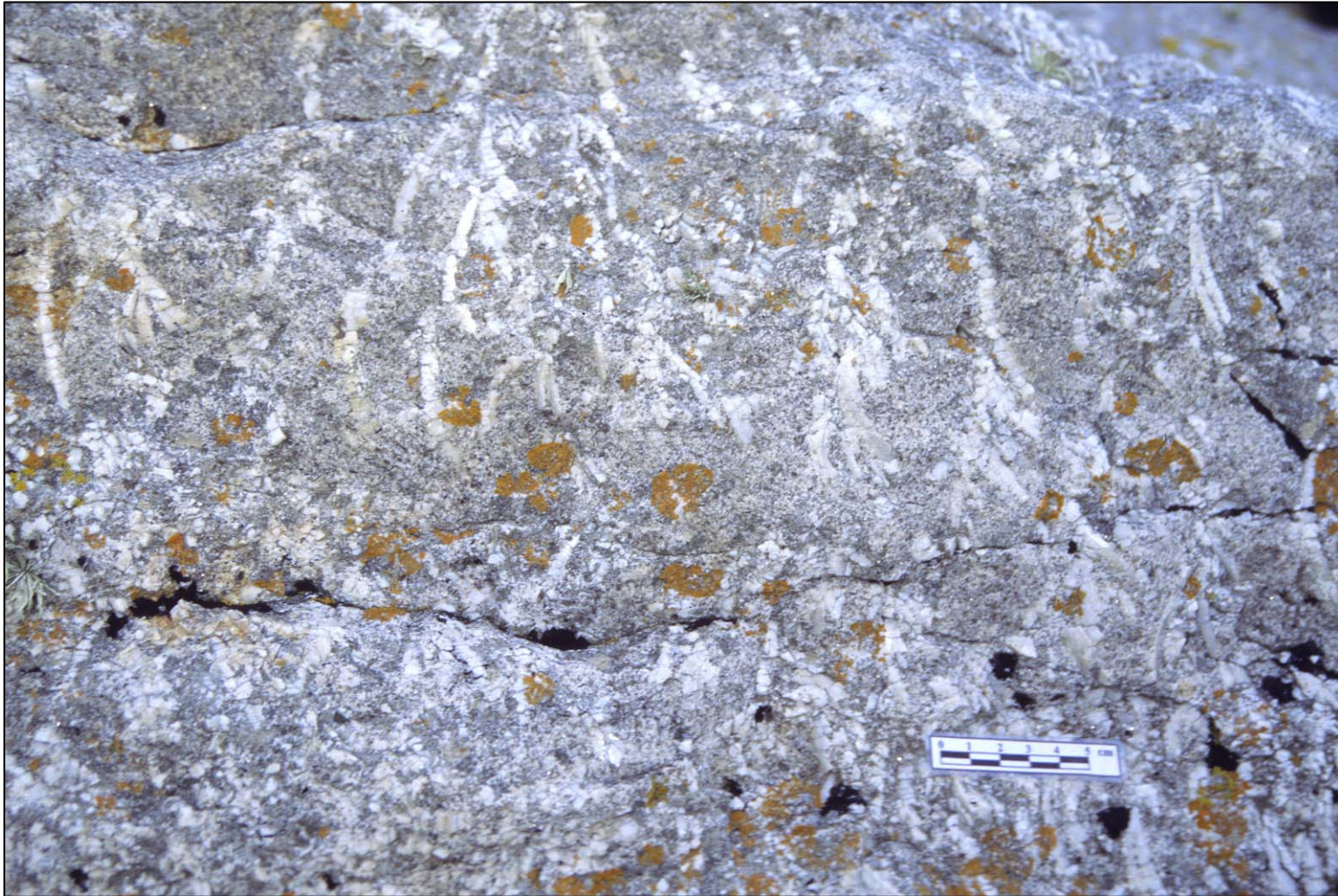
Plumose feldspars, Goonbarrow, Cornwall, UK



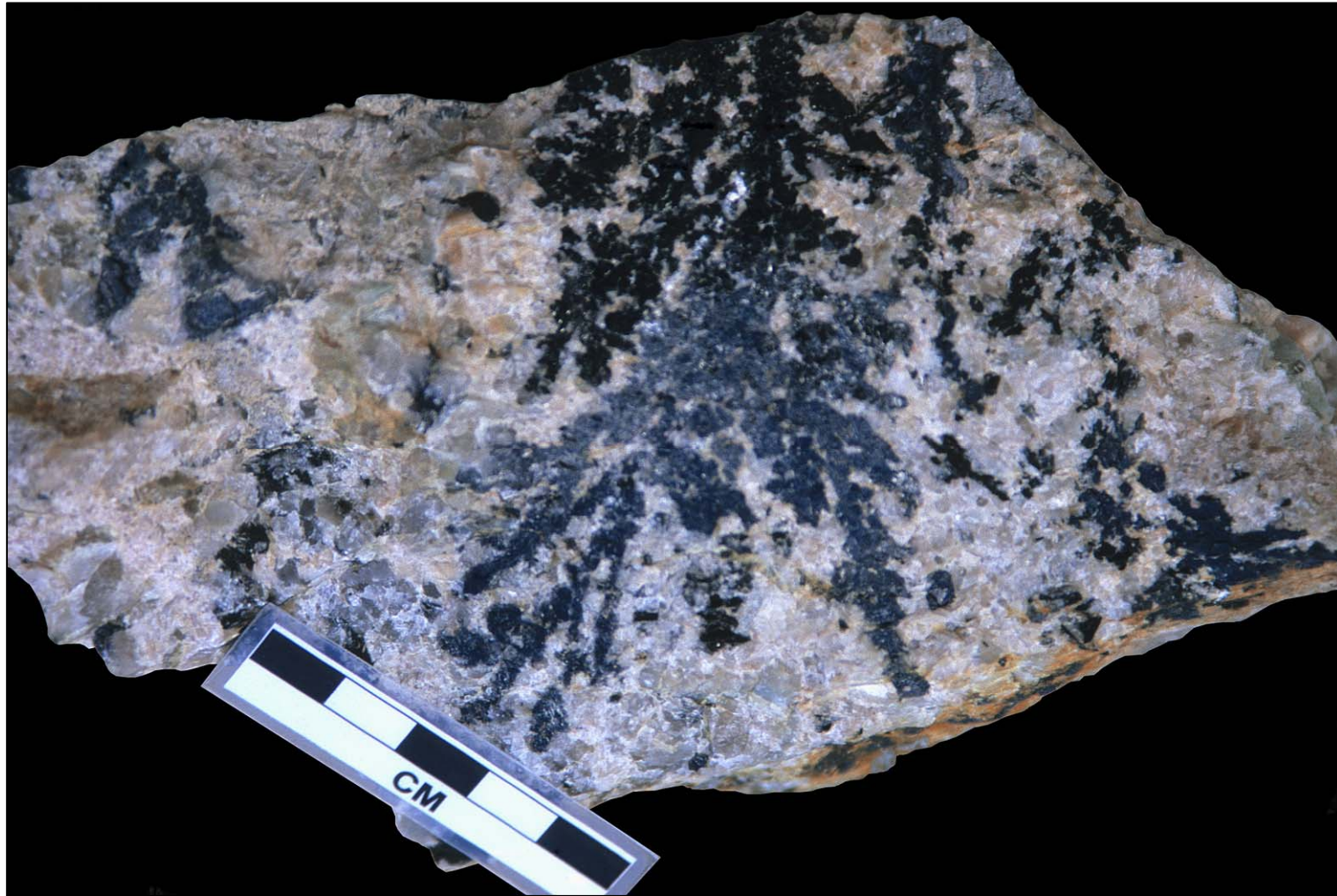
Plumose feldspars, Goonbarrow, Cornwall, UK

St. Michaels Mt., Cornwall, UK





Plumose feldspars, St. Michaels Mt., Cornwall, UK

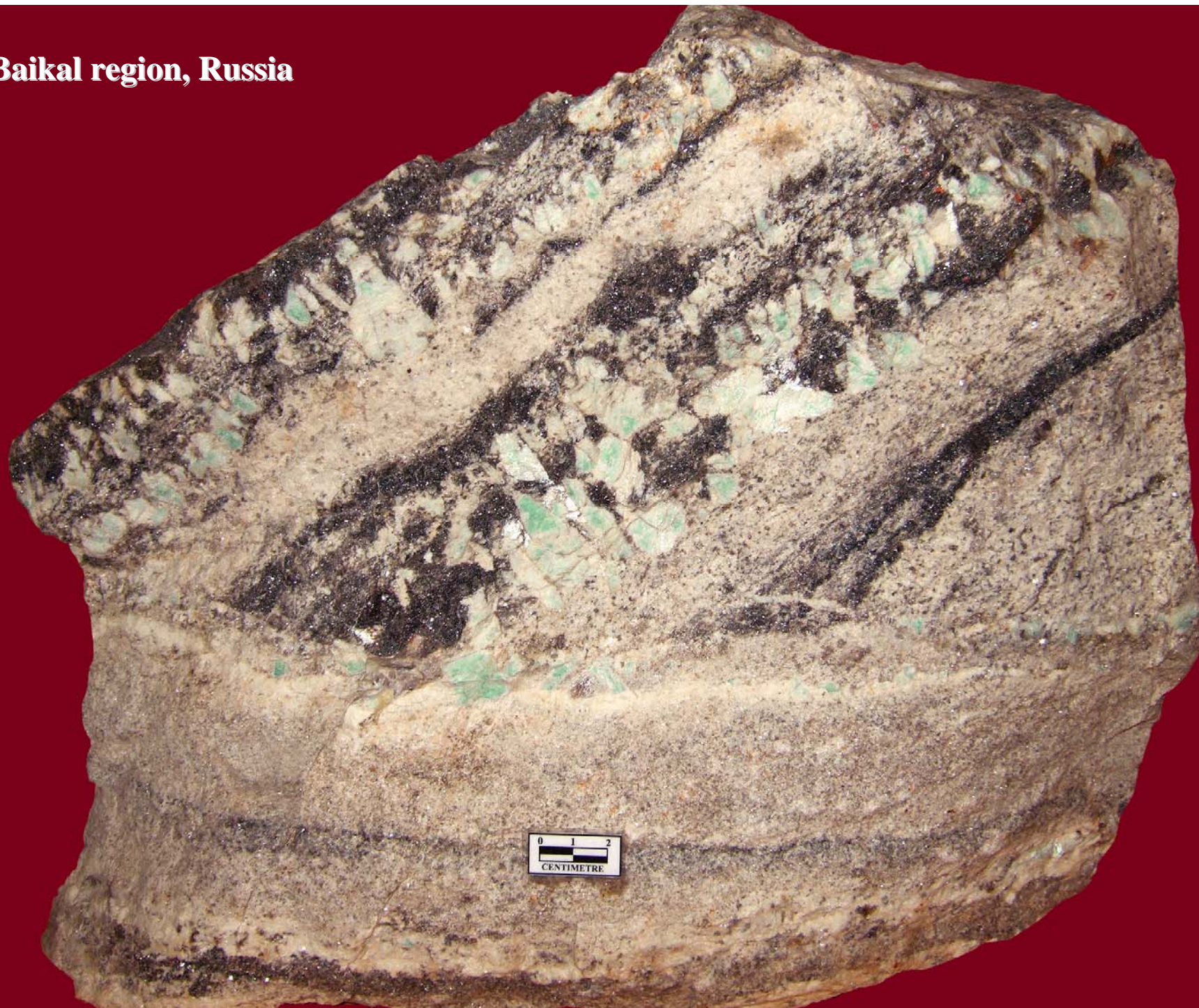


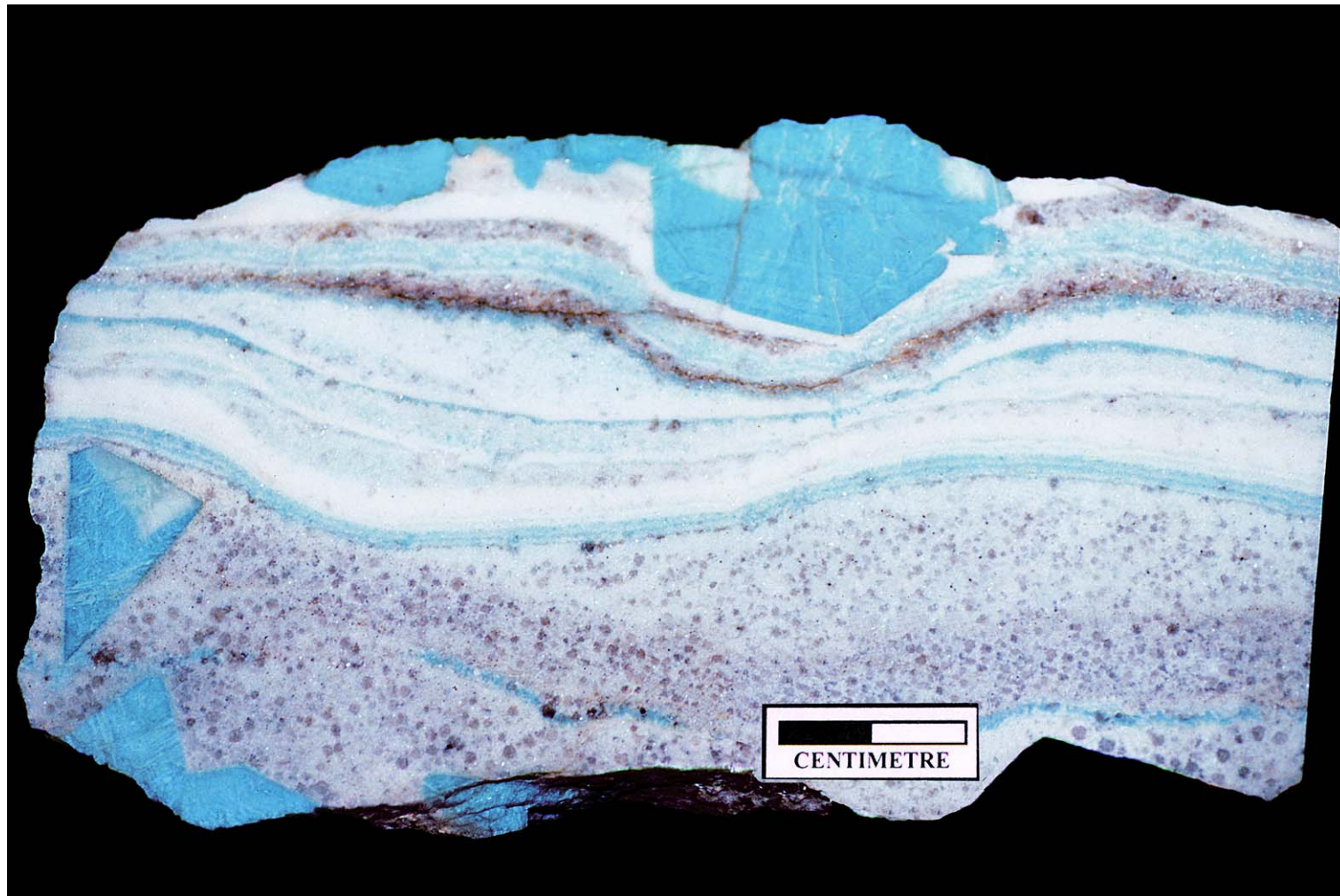
Plumose biotite contact zone, Wiborg Batholith, Southeast Finland

**Hopunvaara, South Karelia,
Russia**



Baikal region, Russia





Amazonite UST, Etyka Siberia, Russia (*Reimar Seltsmann specimen*)



Cupola outcrop, West margin of the Khanbogd



Arfvedsonite-albite line rock



Plumose arfvedsonite zone

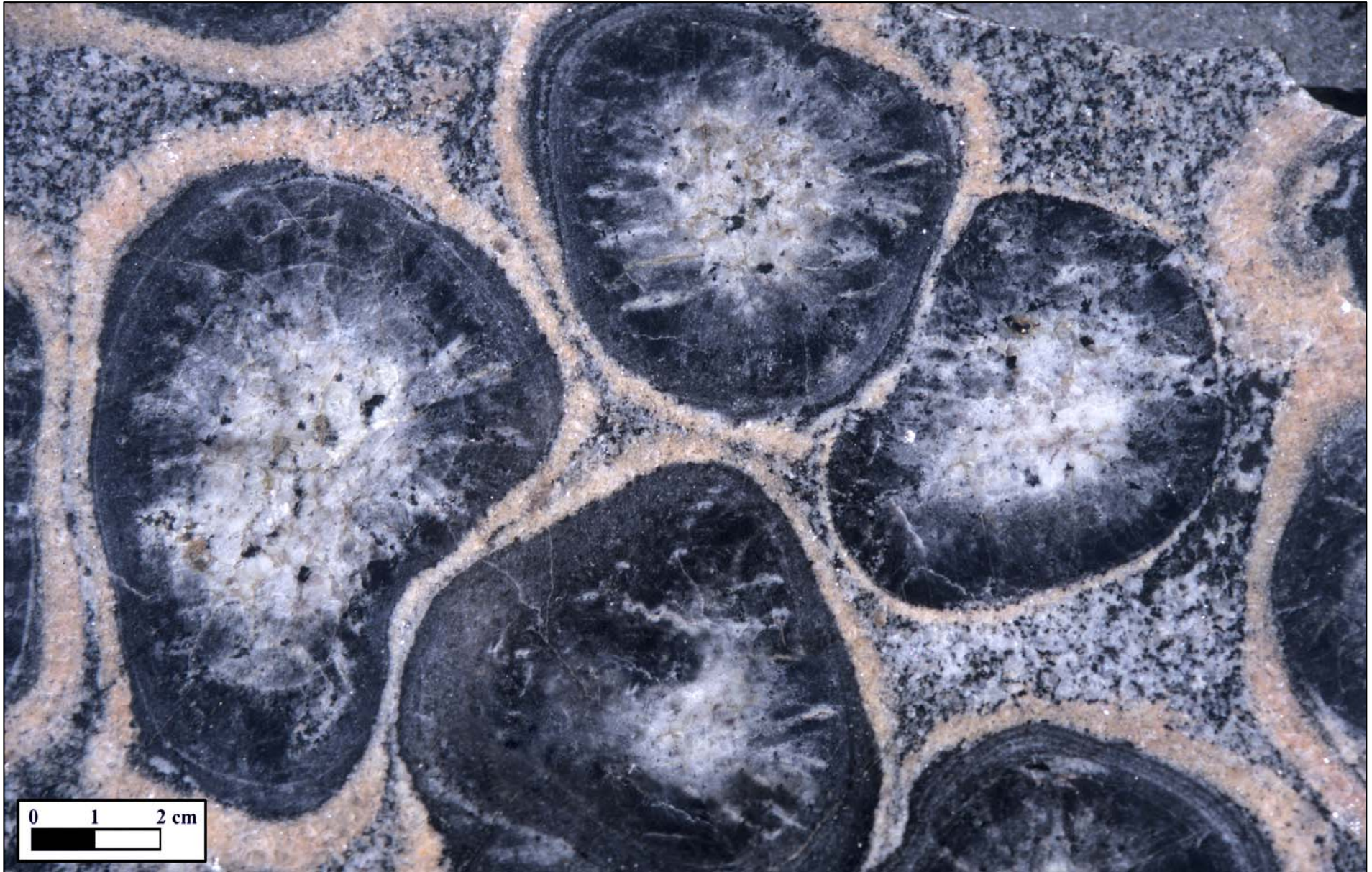


UST Tourmaline, Mogok, Myanmar



Topaz zinwaldite, Altenberg, Erzgebirge, Germany

ORBICULES



Kuru, Finland



**Orbicular Koperburg diorite
from Orbicle Koppe,
Concordia, Okiep district**



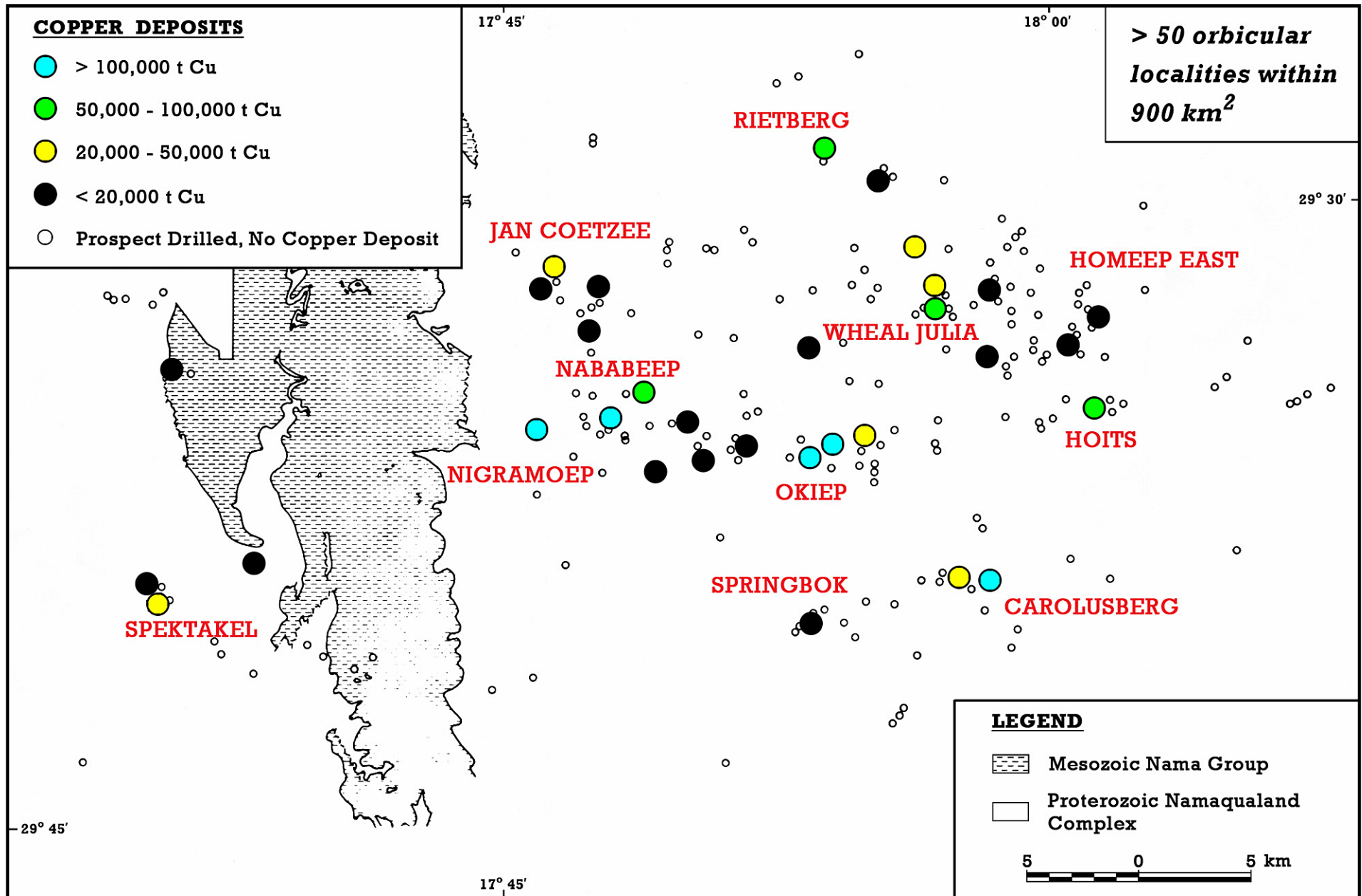
Orbicular, Koperburg diorite, Okiep, South Africa



Orbicular, Koperburg diorite, Okiep, South Africa



NababEEP, Smelter, Okiep, South Africa

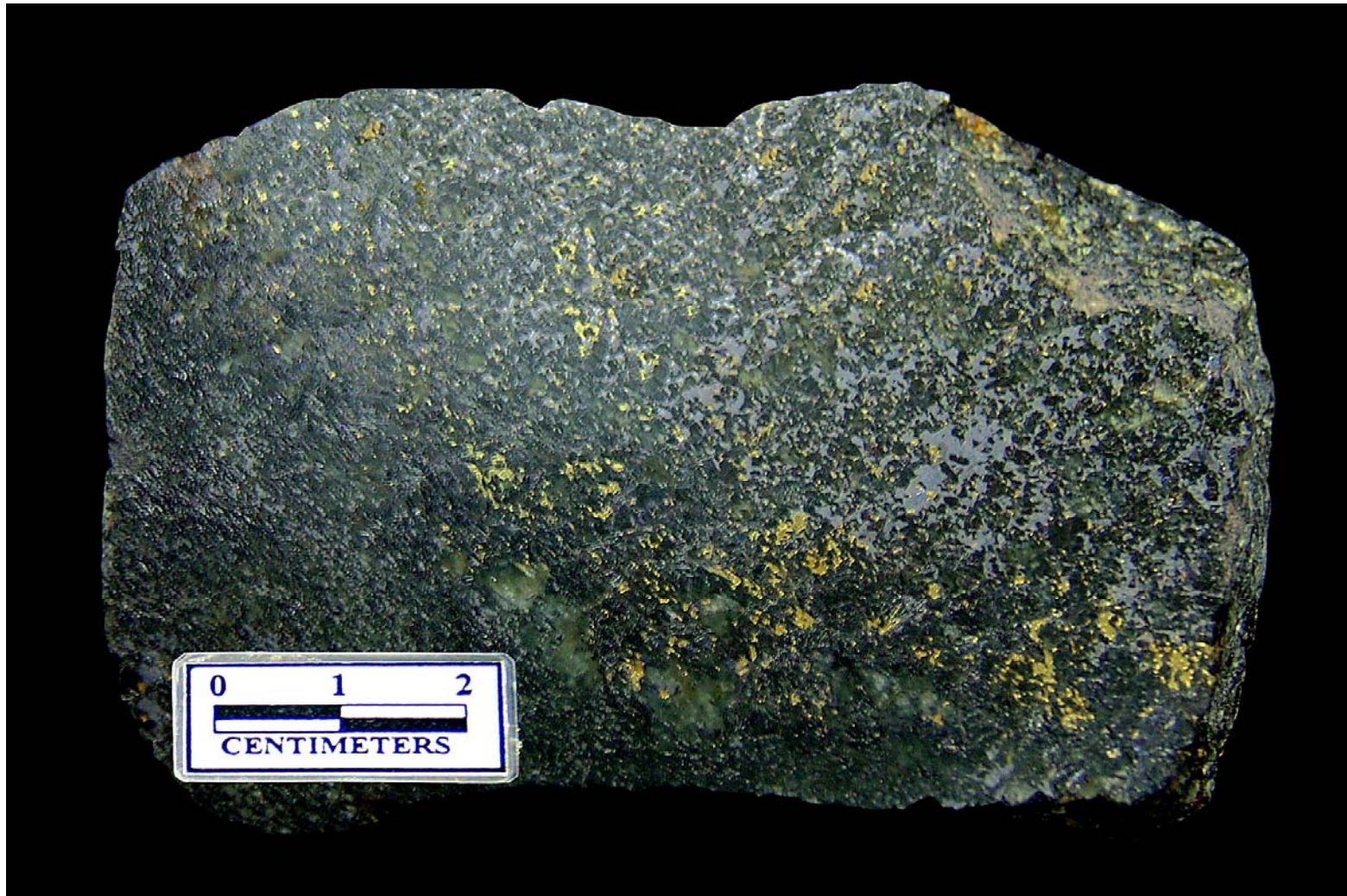


Copper deposits of the Okiep district (Lombard, 1986)



**Nigramoep Cu mine,
Okiep, South Africa**

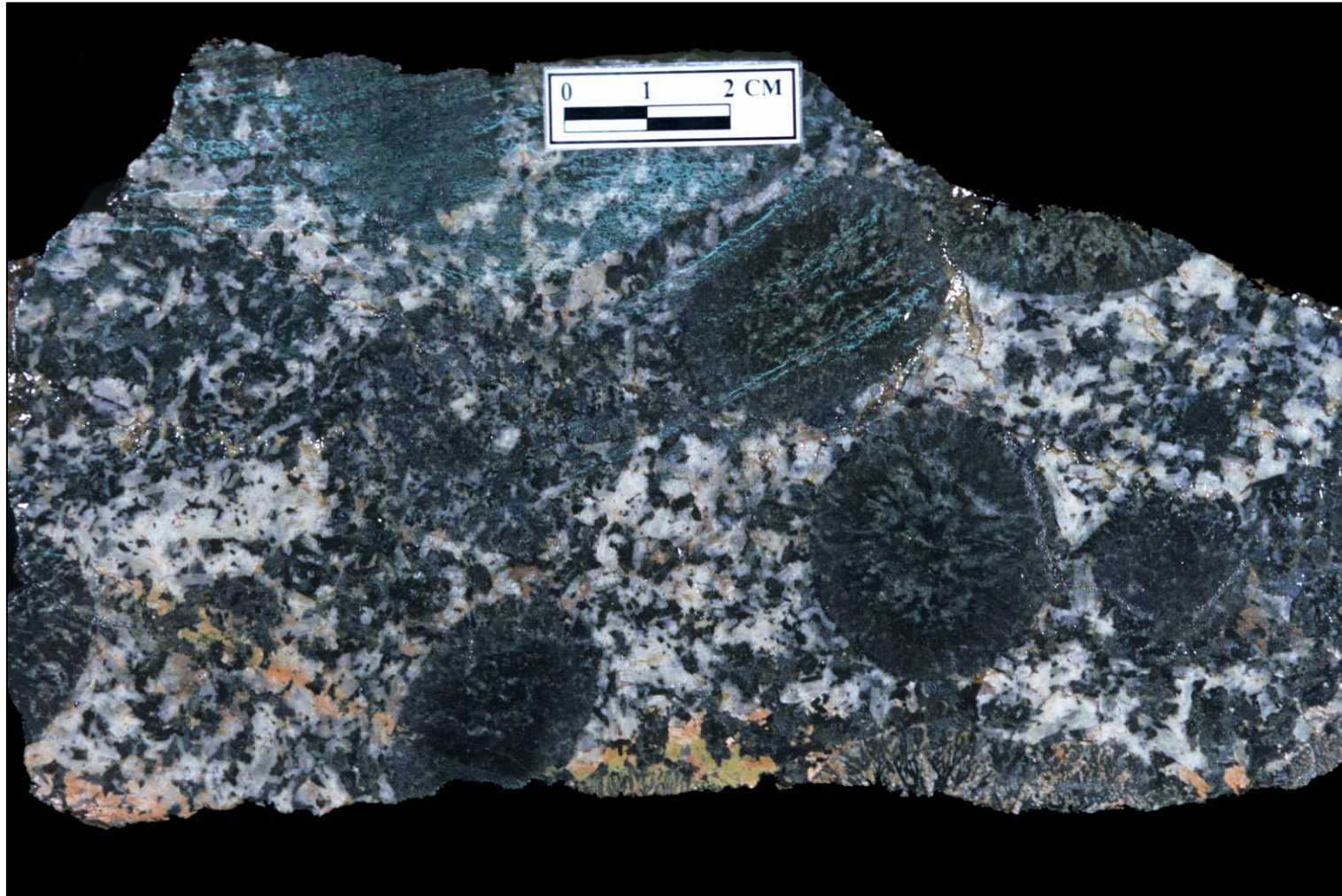




Copper-bearing diorite, Okiep, South Africa

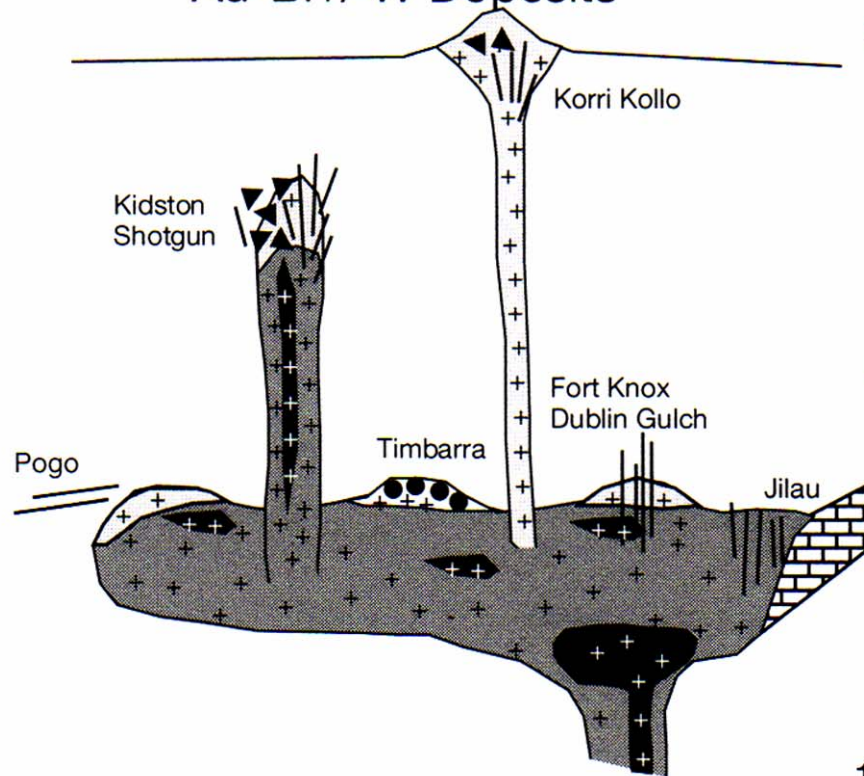


Orbicular granite outcrop, Berger Nuur, West Mongolia



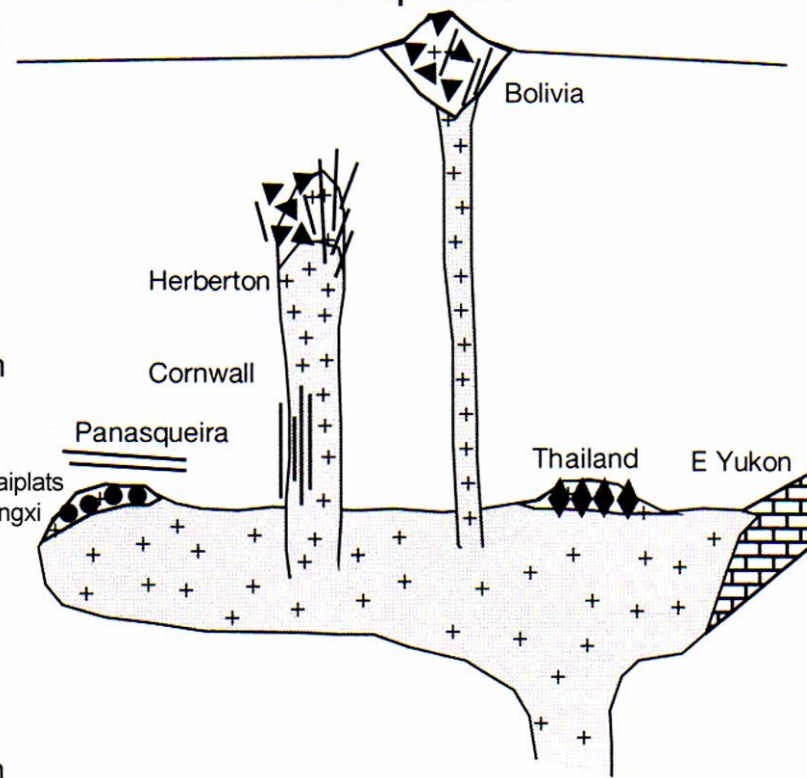
Orbicular granite, Berger Nuur, West Mongolia

Au-Bi+/-W Deposits



Granites associated with Au-Bi+/-W
 Rb/Sr 0.1 to 1.0
 Fe_2O_3/FeO 0.1 to 0.6
 Metaluminous to peraluminous
 I-type

Sn-W Deposits



Granites associated with W+/-Sn
 Rb/Sr 0.1 to 10
 Fe_2O_3/FeO 0.1 to 2.0
 Peraluminous to locally metaluminous
 I-type and S-type

Granites associated with Sn+/-W
 Rb/Sr 1 to 100
 Fe_2O_3/FeO 0.01 to 0.5
 Peraluminous
 I-type and S-type

Granite types



Diorite



Granodiorite



Granite



Highly Fractionated Granite

Deposit styles



Pegmatite



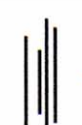
Disseminated Greisen



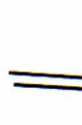
Breccia



Skarn



Sheeted



Flat



Stockwork

Veins

(Baker et al., SEG Newsletter, April 2005)

UST EXAMPLES

- ◎ Climax - type molybdenum systems
Henderson, Colorado – Questa, New Mexico – Kung Hu Tung, Inner Mongolia – Max, British Columbia
- ◎ Tungsten - bearing systems
Logtung, Canada – Seltai, Kazakhstan – Yuguzer, Mongolia
- ◎ Tin - bearing systems
Zaaiplats, South Africa – Tate River, Queensland
- ◎ Intrusion - related gold - copper systems
Ravenswood, Queensland – Hada Sumu, Inner Mongolia – Bayan Uul, Mongolia
- ◎ Intrusion - related gold systems
Timbarra, New South Wales – Ad Duwayhi, Saudi Arabia
- ◎ Breccia - intrusion related gold systems
Kidston, Queensland – Shot Gun, Alaska – Orivesi, Finland

UST EXAMPLES

◎ Porphyry copper - molybdenum systems

Yerrington, Nevada – Mission, Arizona – Tsagaan Survaga, Mongolia

◎ Porphyry molybdenum - copper systems

Hall, Nevada – Mineral Park, Arizona – Zuun Mod, Mongolia

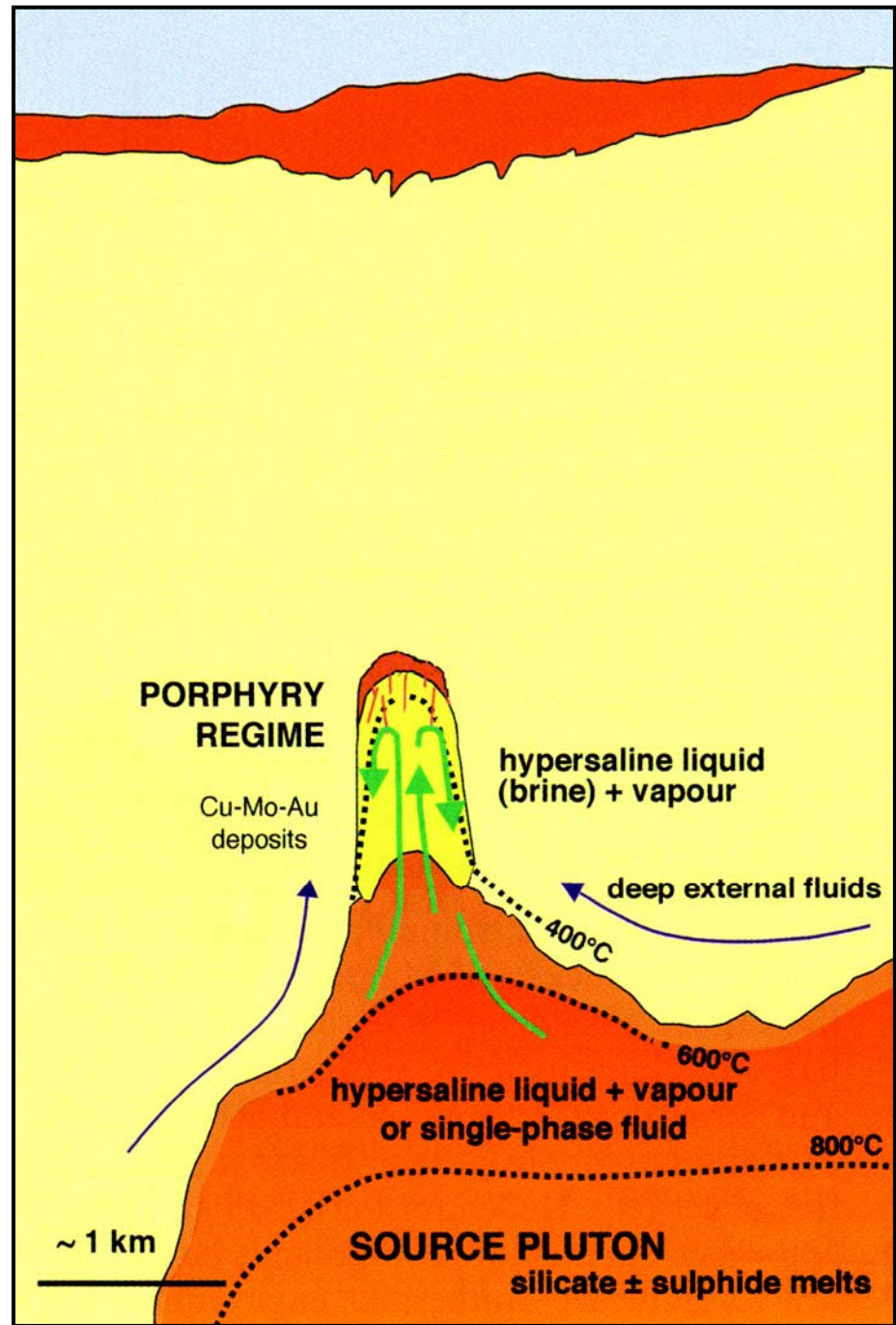
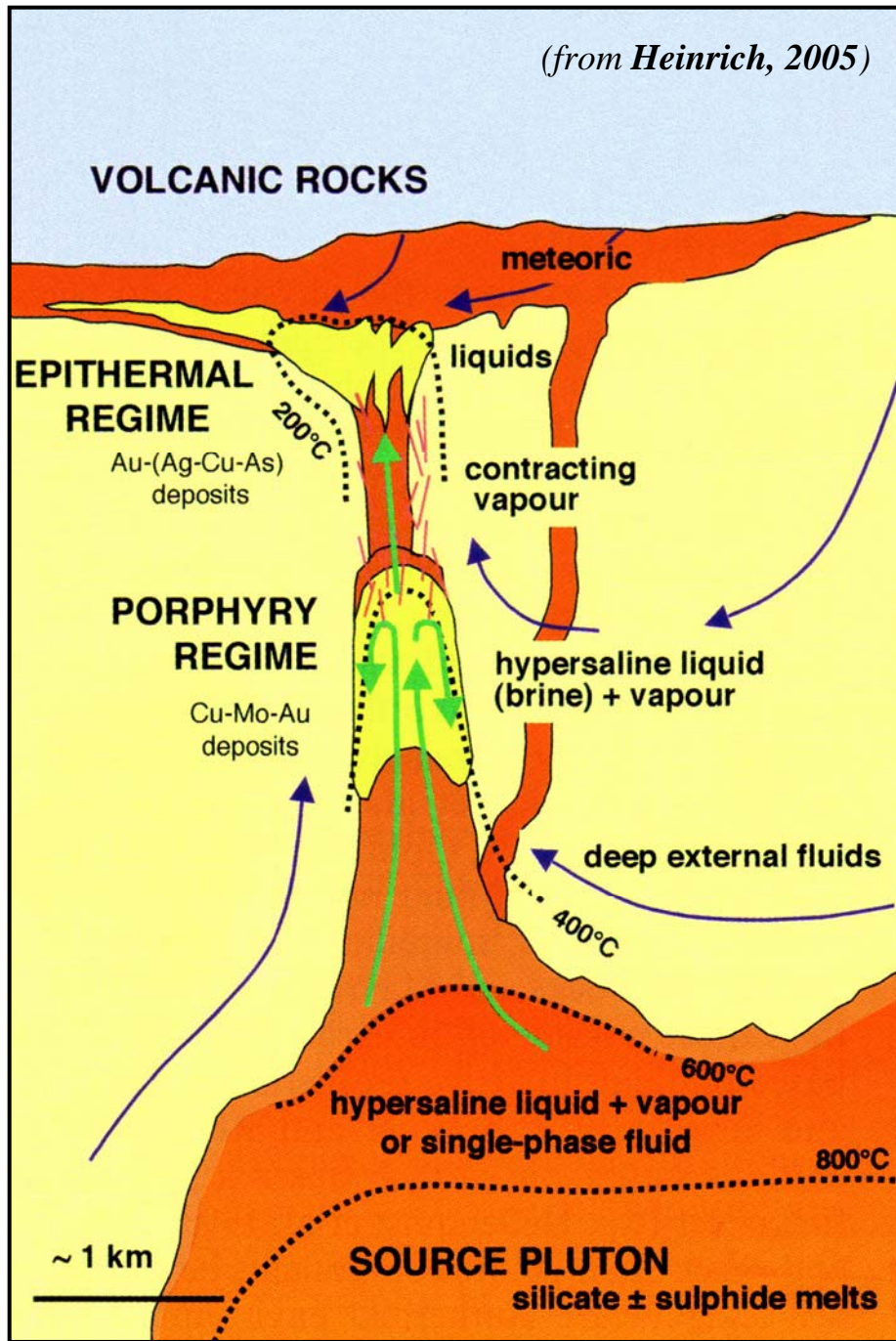
◎ Porphyry copper - gold systems

Bajo de Alumbrera, Argentina – Red Dome, Queensland –
North Parkes, New South Wales

◎ Porphyry gold - copper systems

Ridgeway, New South Wales – South West Oyu, Mongolia –
Kharmagtai, Mongolia – Boyongan, Philippines

(from Heinrich, 2005)



WHAT IF THE FLUIDS AND VOLATILES ARE CONFINED WITHIN THE CUPOLA ?

TRAP

1. Excess lithostatic load pressure
2. Hornfelsed wallrock shell
3. Reactive wallrocks

TEXTURES

1. Mineralised UST zone
2. Mineralised miarolitic cavity zone
3. ± Overprinting sheeted veins within the intrusion
4. Lack of significant breccia pipes

POTENTIAL ORE BODY?

1. Crescent shaped morphology at top of cupola
2. Lower tonnage and higher grade than an average typical porphyry system

ie. 50-200 MT @ 2-3 g/t Au & 0.5-1.0% Cu ?





THANK YOU