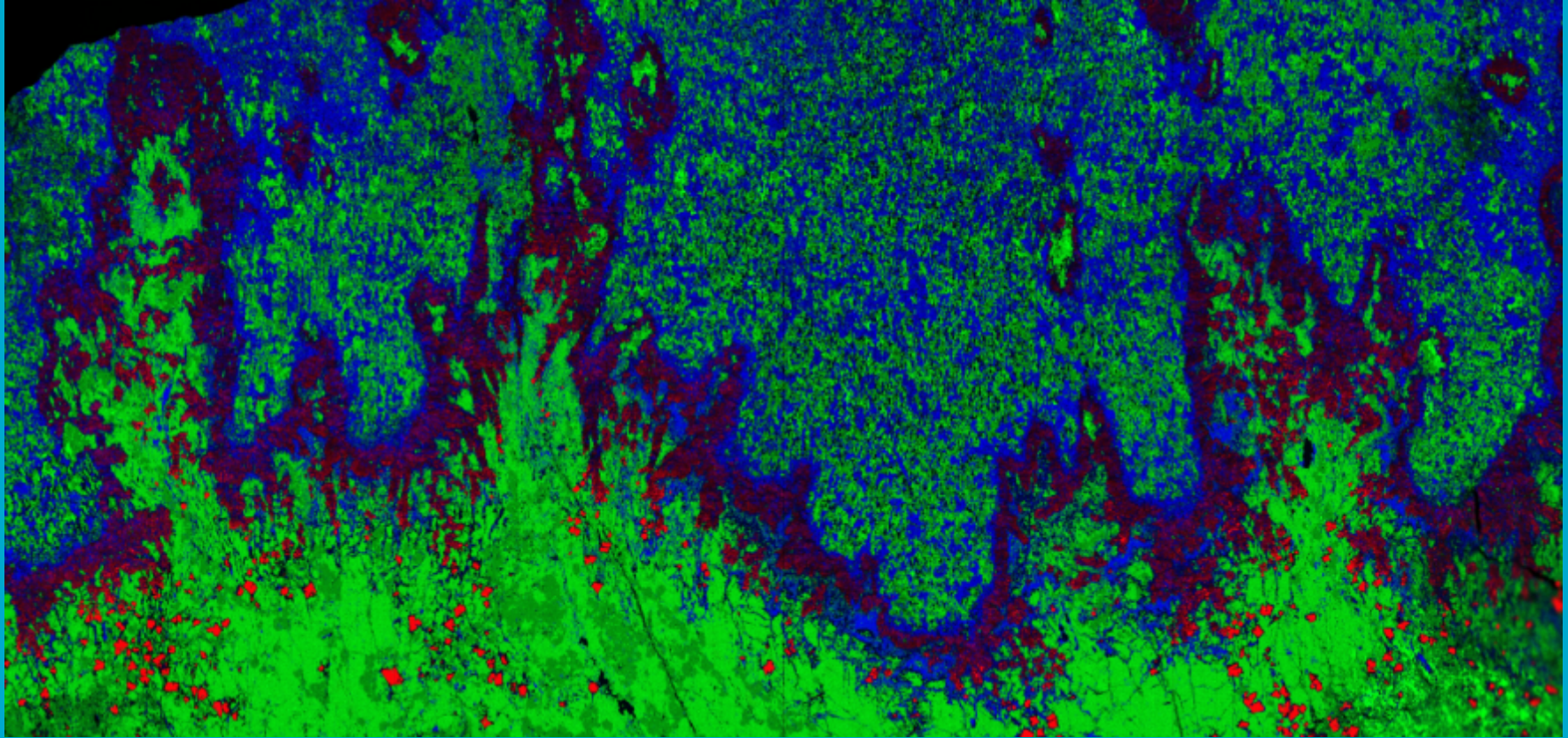


New insights into magmatic nickel sulfide ore genesis based on 2D and 3D investigations of ore textures

Downsized for printing

(or, how salad dressing and mayonnaise might help you understand your orebody)



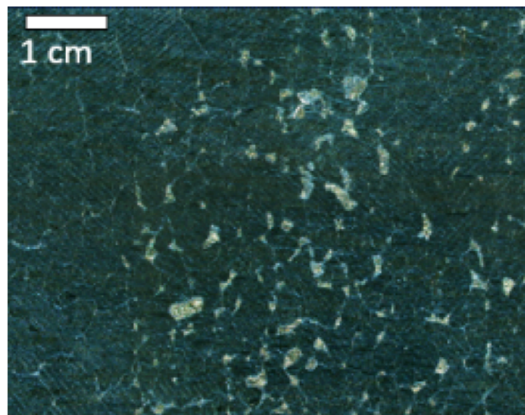
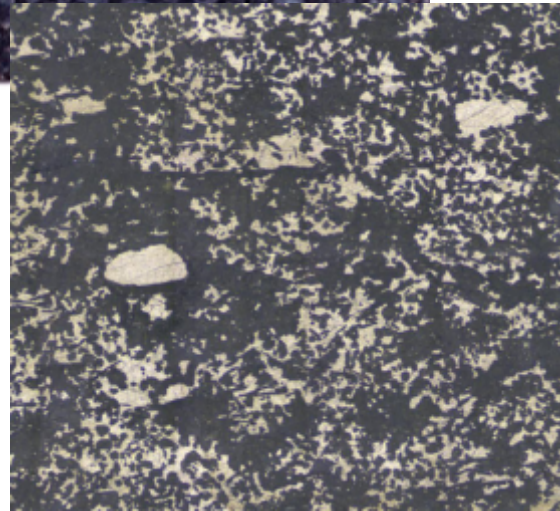
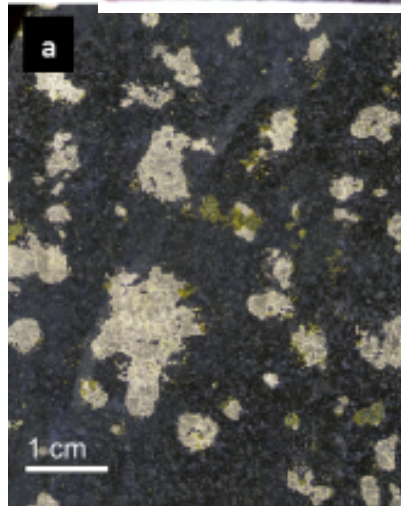
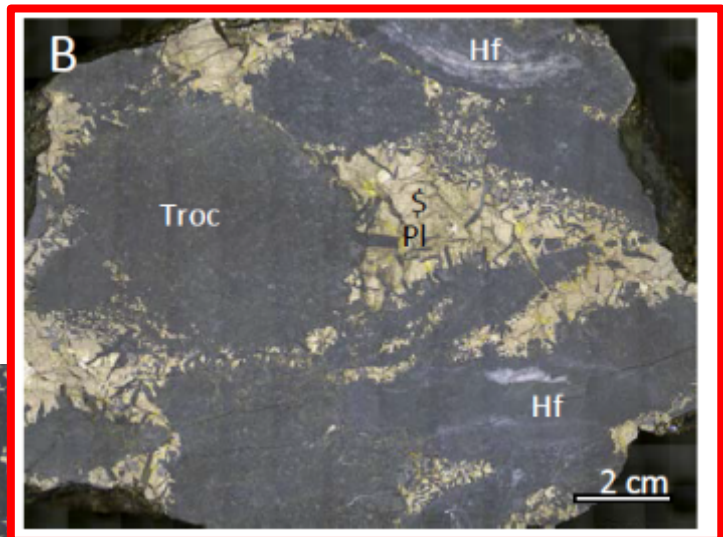
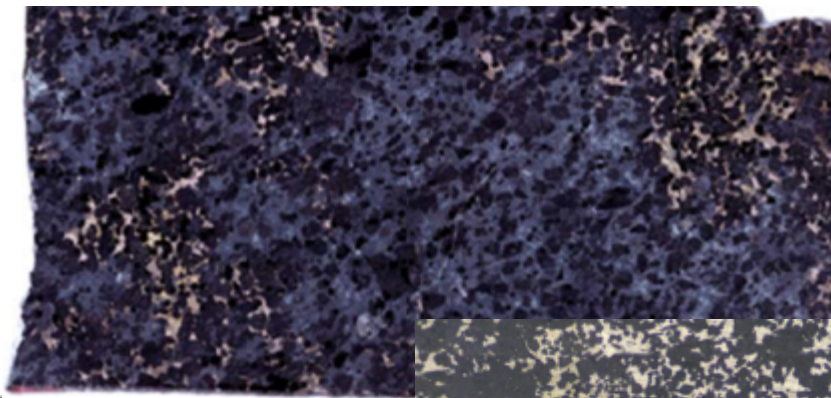
Steve Barnes

CSIRO MINERAL RESOURCES
www.csiro.au



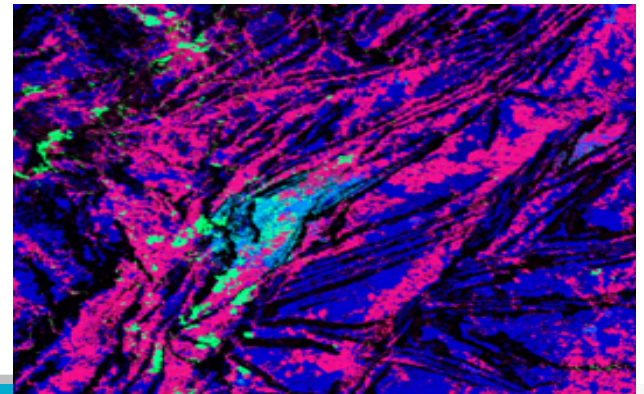
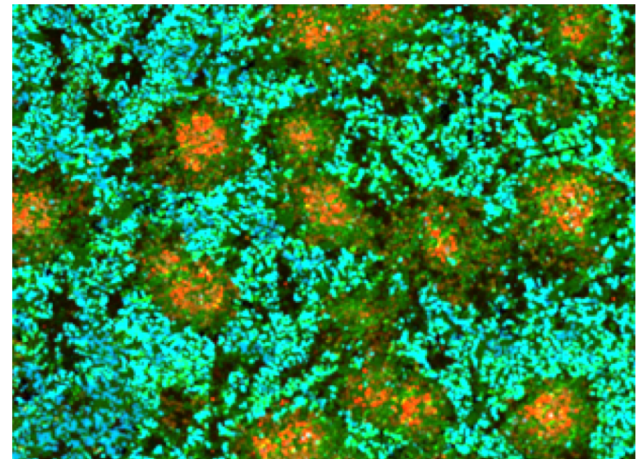
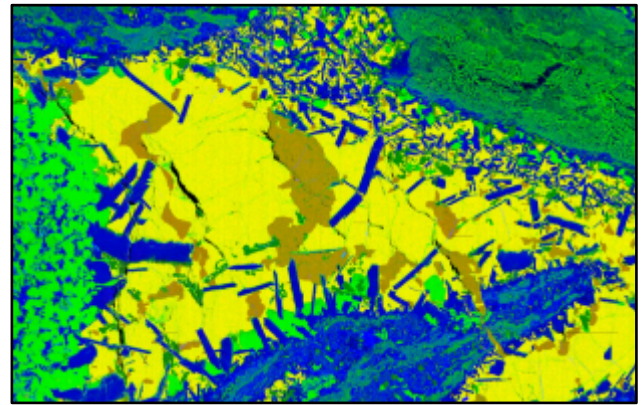
With major contributions from Margaux Le Vaillant, Belinda Godel (CSIRO), Jim Mungall (University of Toronto), Sebastian Staude (IGO)

Diversity of magmatic sulfide textures



Outline:

1. Disseminated ores (komatiites and others)
2. Net-textured (matrix) ores, the billiard ball model.
3. Sulfide-silicate wetting, migration, percolation – analogue models
4. Spinifex ores (special case of matrix ore)
5. Globular disseminated ores (Black Swan, Noril'sk, Sudbury examples)
6. Massive ores - Emulsion textures, melt-infiltration fronts (Kambalda example)
7. Sulfide-matrix ore breccias (Voisey's Bay example)
8. Synthesis, genetic models, exploration implications

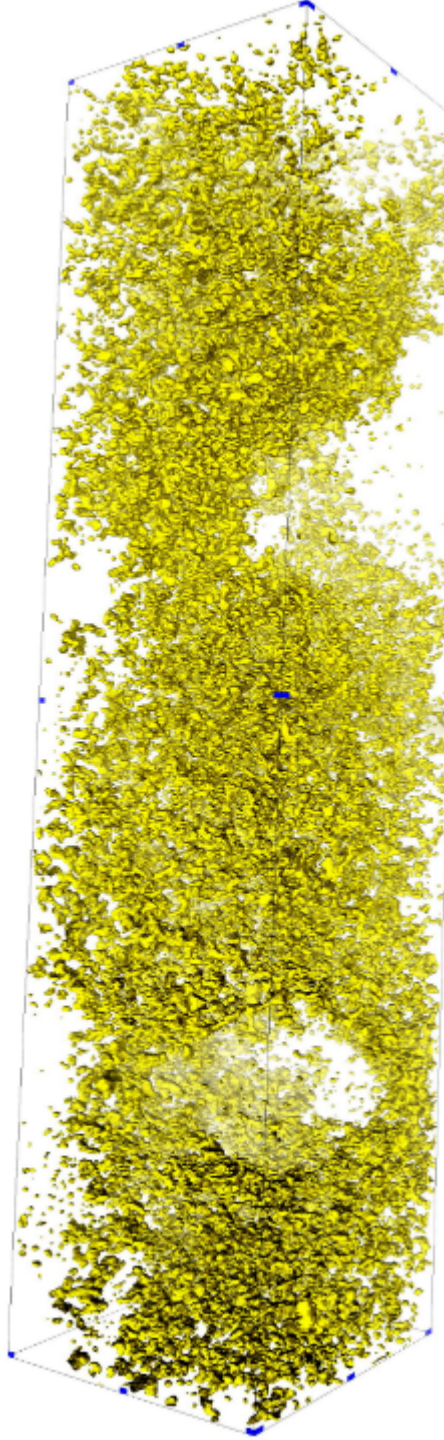


Physical properties of silicate and sulfide magmas

Melt type	Density (ρ) (kg m ⁻³)	Dynamic viscosity (μ) (Pa s)
Fe sulphide	4000	2×10^{-2}
Cu sulphide	5200	2×10^{-2}
Komatiite	2800	1
Basalt	2600	100
Dacite	2000	1×10^4

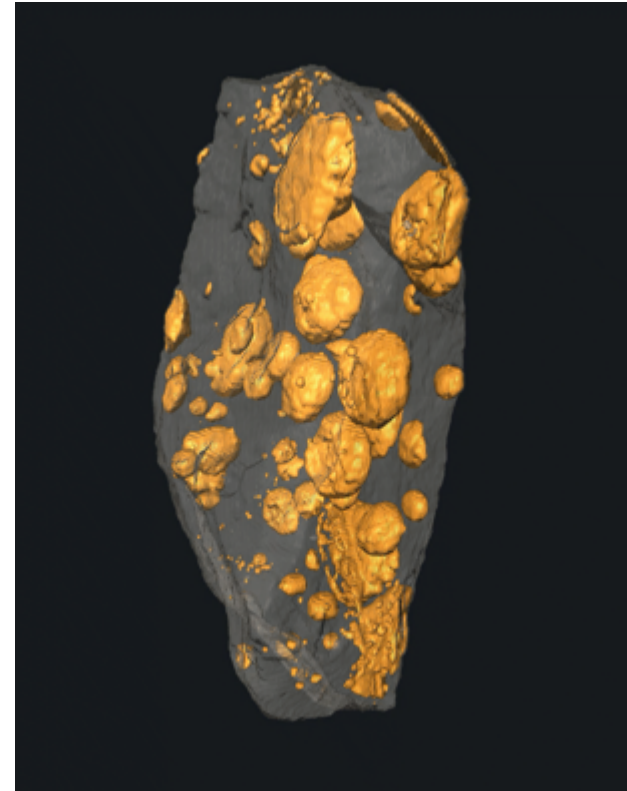
Sulfide liquids are
VERY dense
VERY runny
HIGH heat capacity
VERY efficient carriers of heat





1. Disseminated ores, matrix ores and sulfide liquid percolation, leading to...
2. Sulfide/silicate melting fronts and finally
3. “breccia ores”

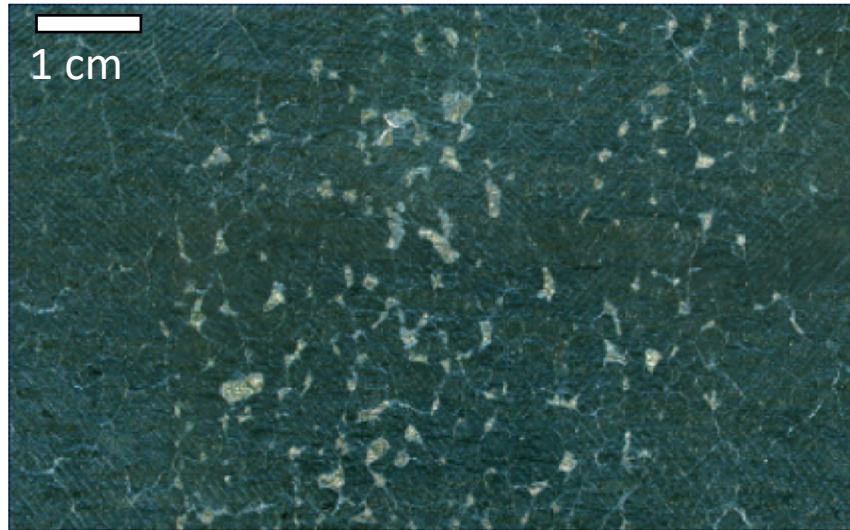
Low-resolution X-ray computed tomography at 200 micron resolution using medical scanning technology



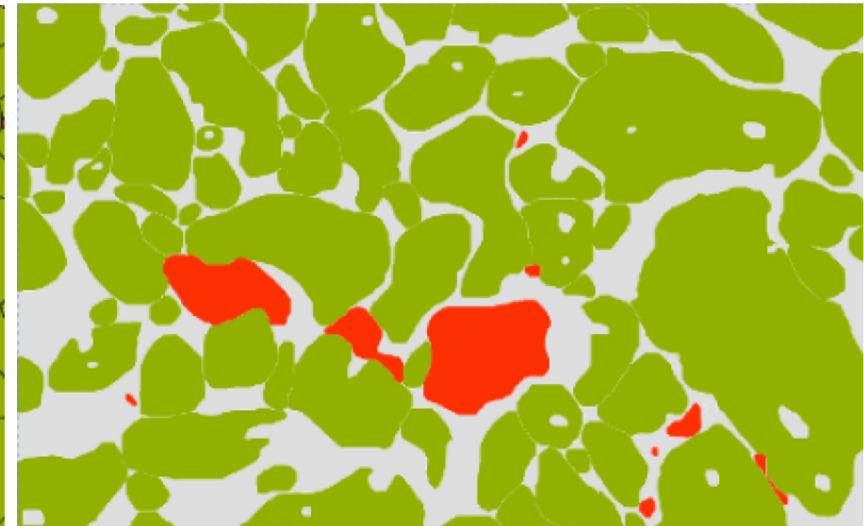
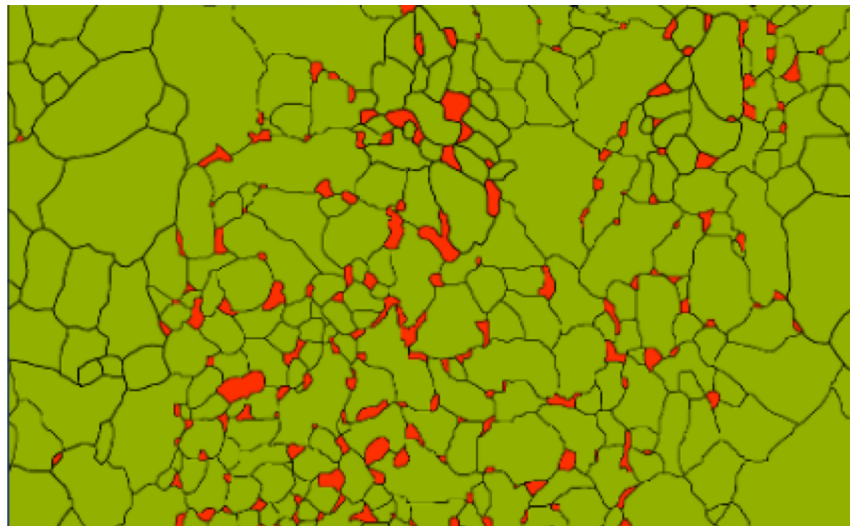
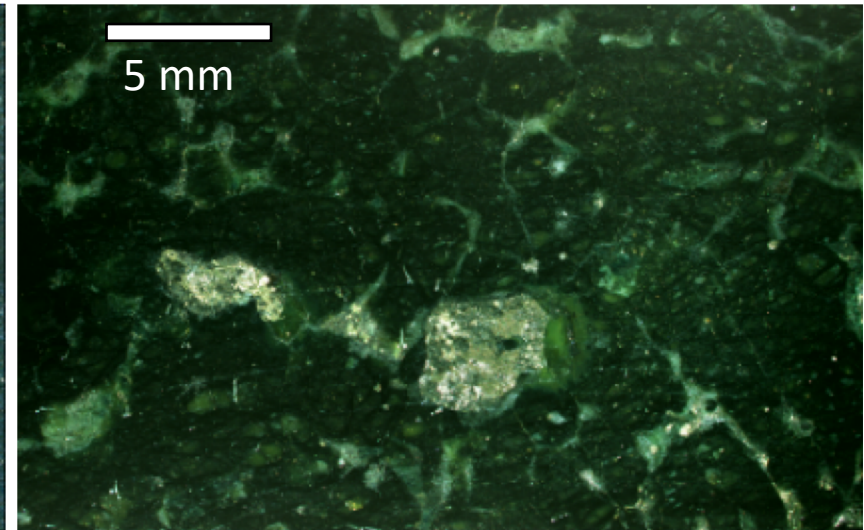
Globular sulfide ores

Disseminated sulfides in komatiitic olivine cumulates

ADCUMULATES (Mt Keith, Goliath)

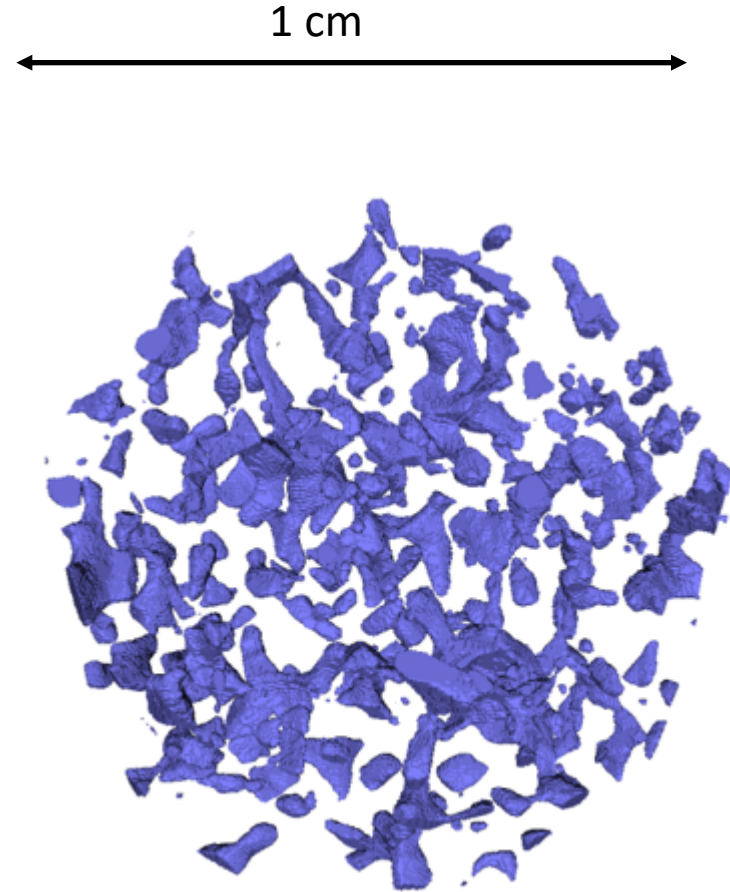
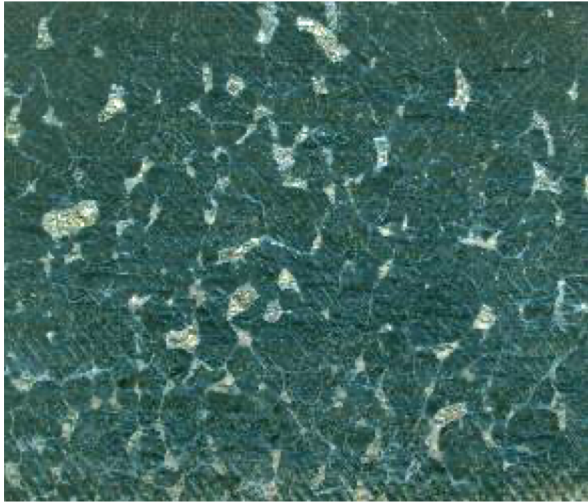


ORTHOCUMULATES (Black Swan)



■ Olivine ■ Sulfide □ Trapped melt

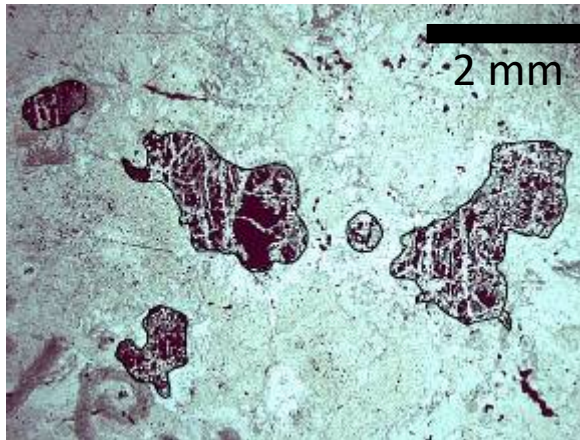
CT visualisation of magmatic Ni sulfides - Type 2 nickel sulfide ore, Mt Keith



Sample is “adcumulate” =
100% olivine + ~ 3.5% sulfide liquid –
no interstitial silicate magma

Barnes et al Geology 2008

CT visualisation of magmatic Ni sulfides – Sulphides in orthocumulate, Black Swan



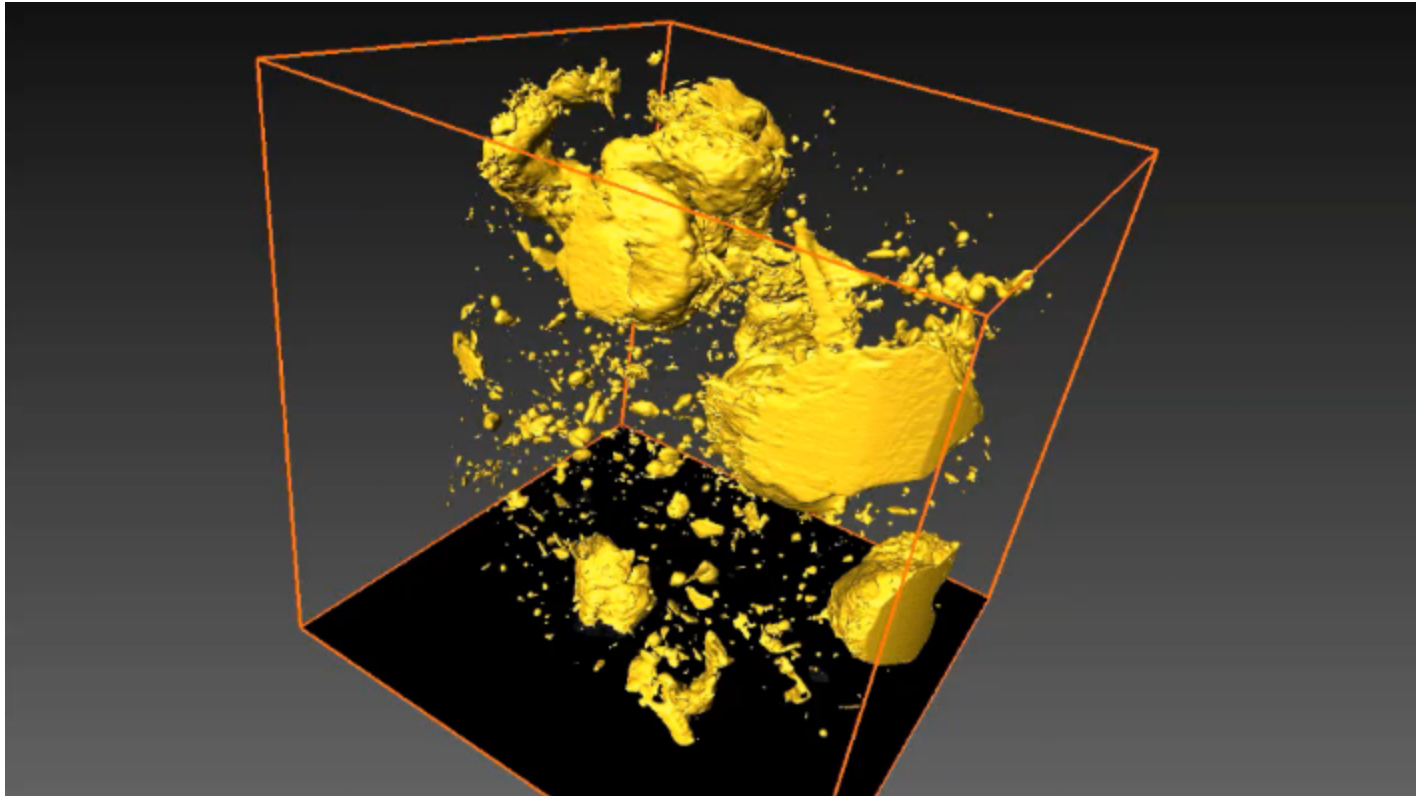
Transmitted light

“orthocumulate =
olivine + sulfide liquid + ~40%
interstitial silicate magma

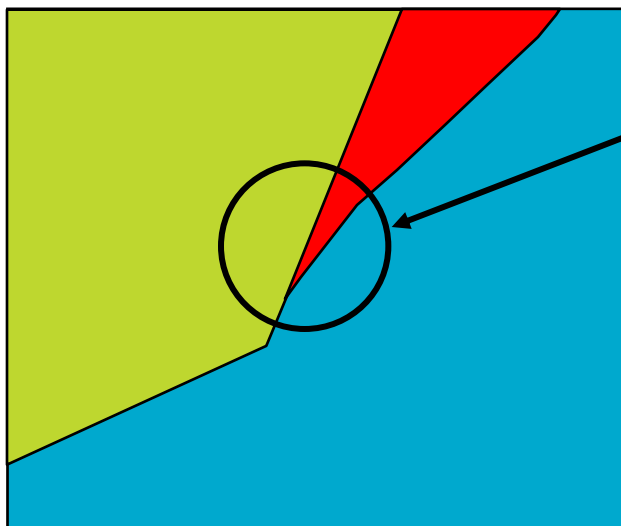
1 cm



(movie)



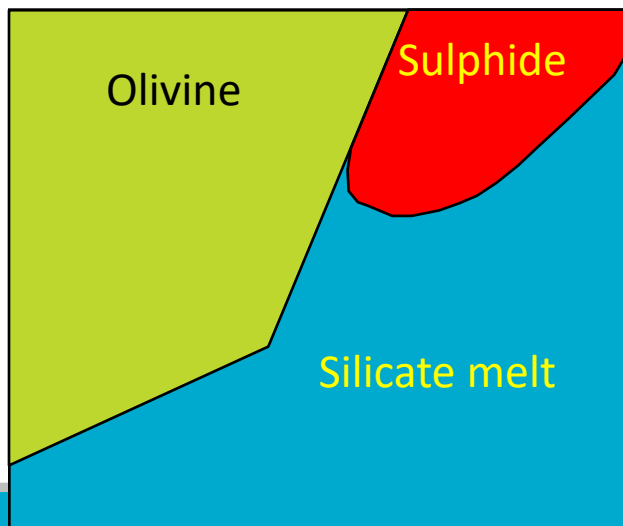
Wetting angle and sulfide textures



Wetting angle θ

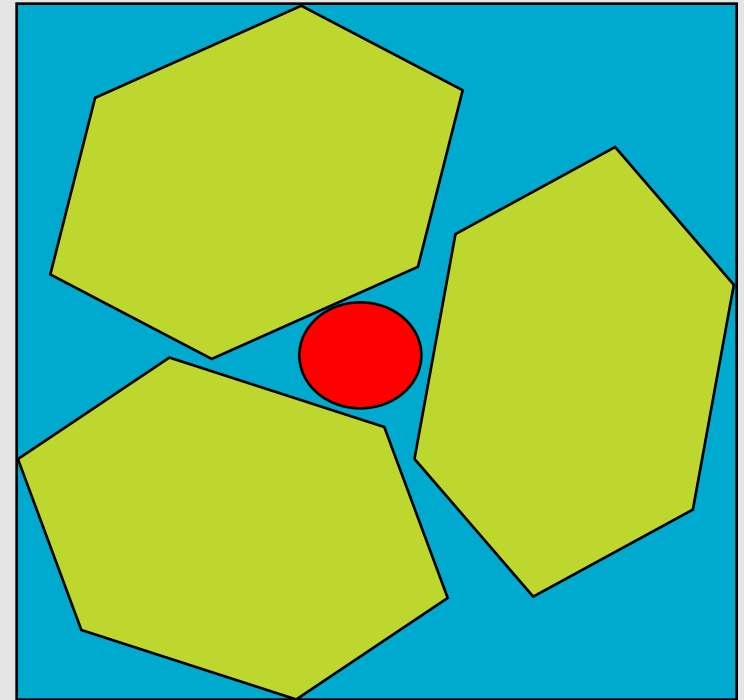
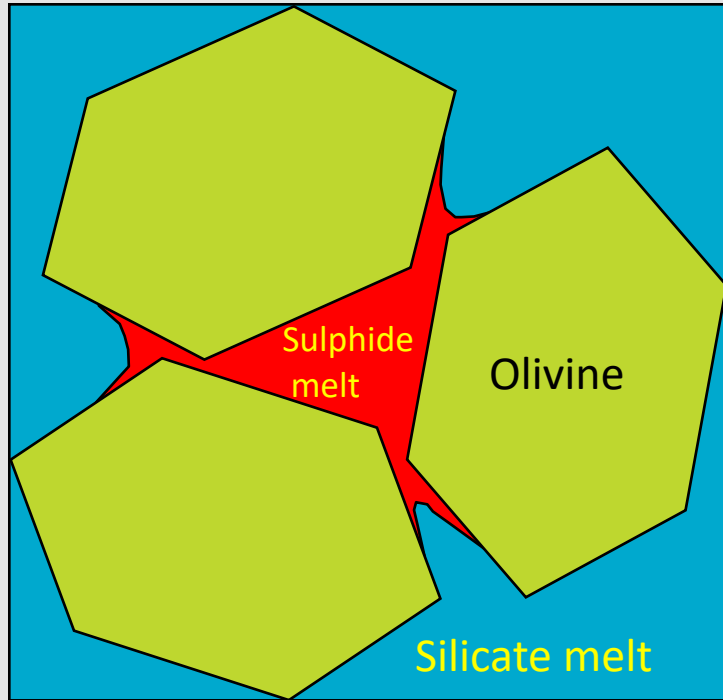
θ Low ($<60^\circ$) = wetting –
sulphide penetrates along
grain boundaries

θ high ($>120^\circ$) = non-wetting –
sulphide forms isolated droplets



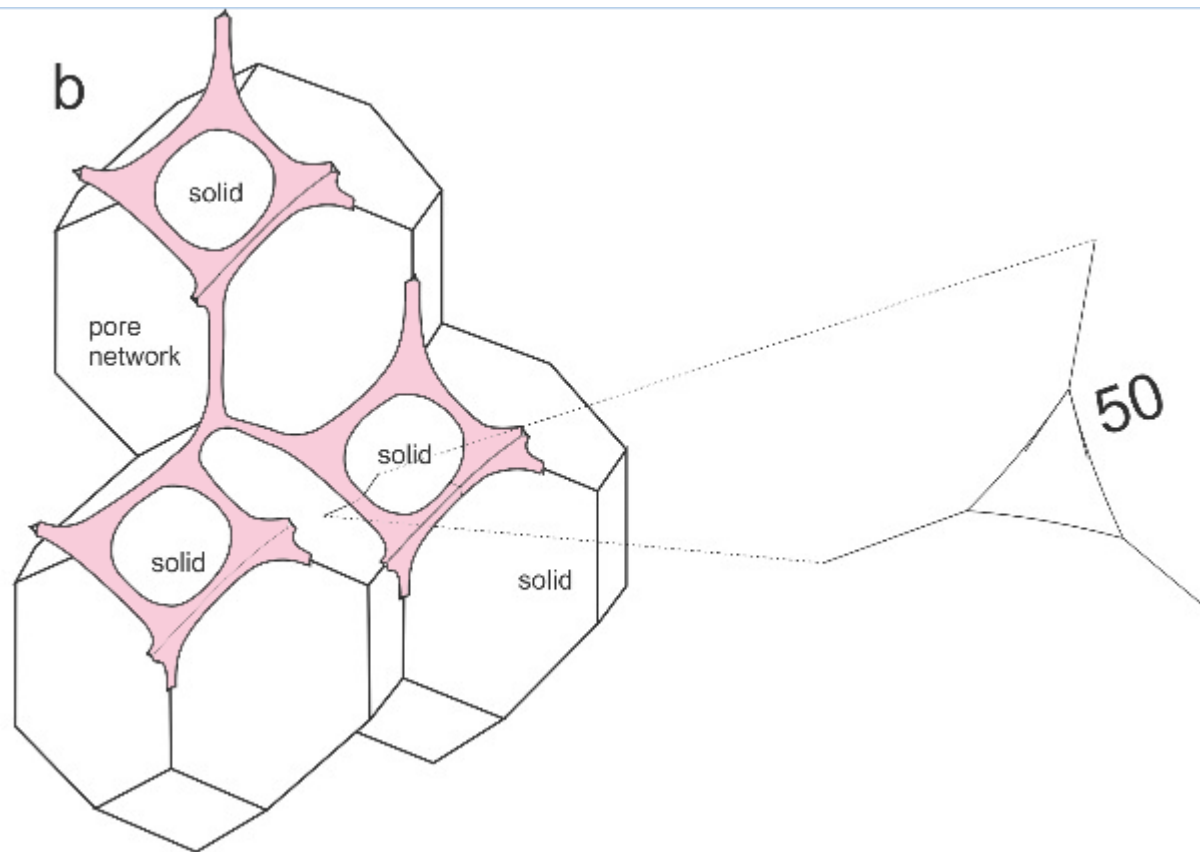
θ depends on sulphide
composition, especially O
content – higher O content
more wetting, but higher Ni +
Cu, lower O.

Wetting angle and sulfide textures



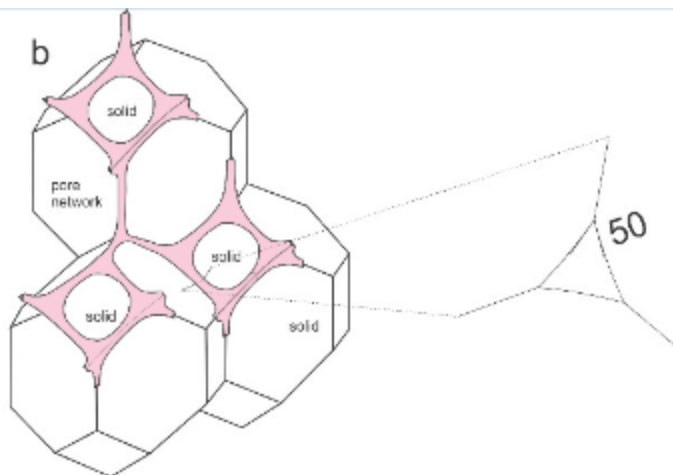
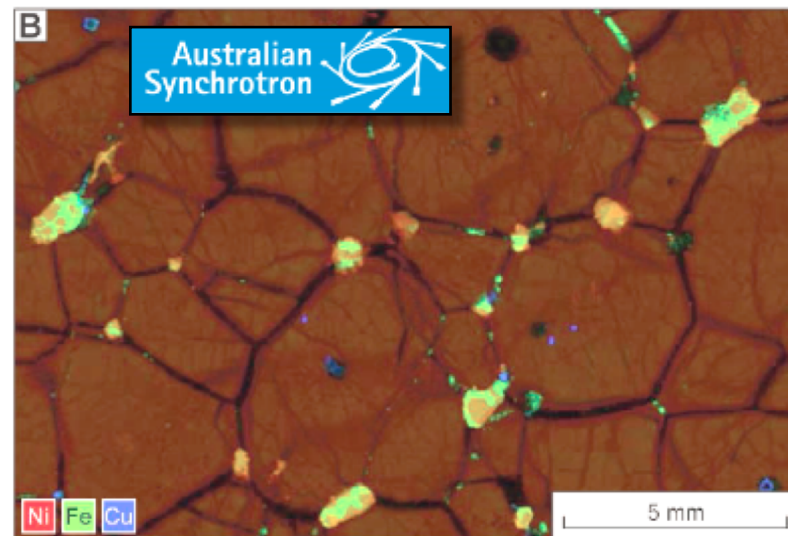
Expected geometry if sulfide does not wet olivine – isolated spherical sulfide droplets, low mobility of sulfide in pore space, “what you see is what you get”.

Wetting angles and sulfide textures

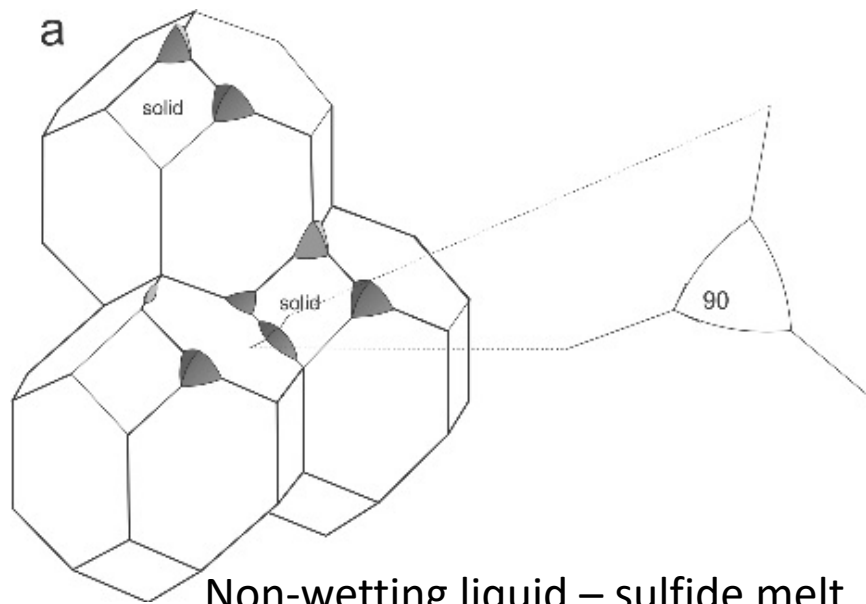


Wetting liquid – silicate melt

Wetting angles and sulfide textures



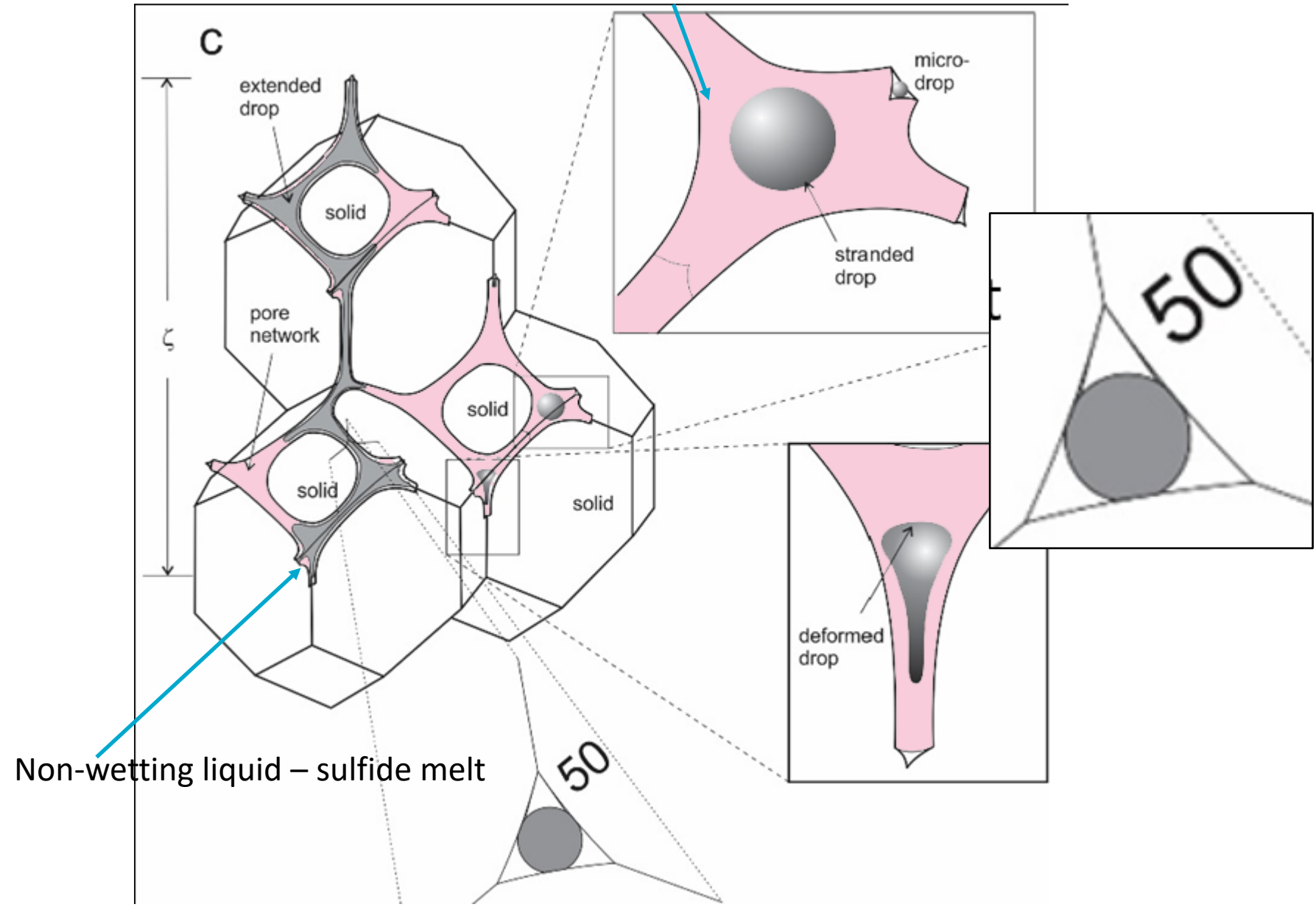
Wetting liquid – silicate melt



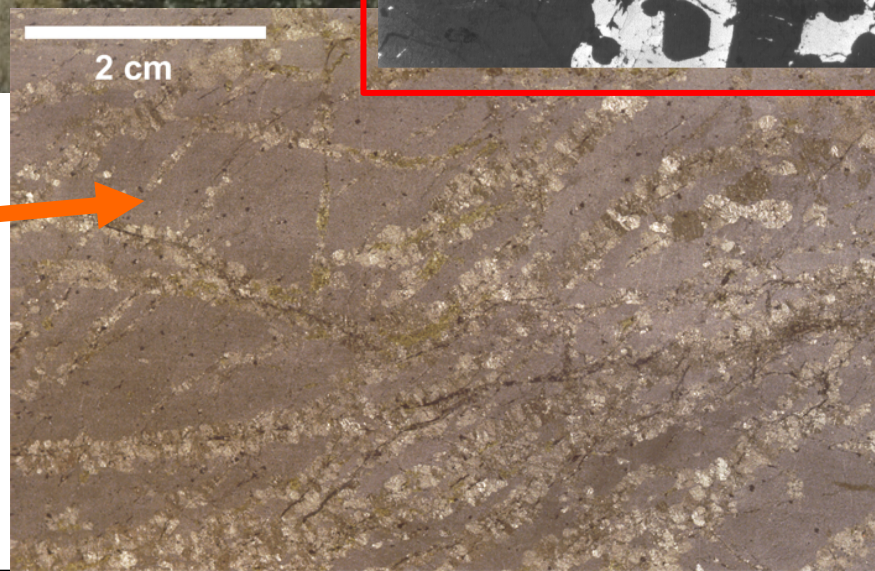
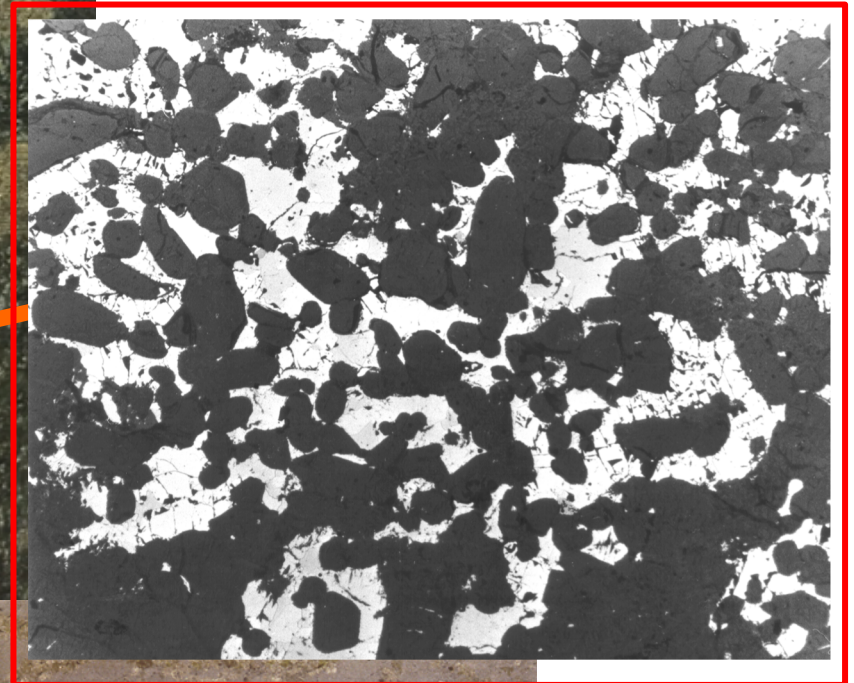
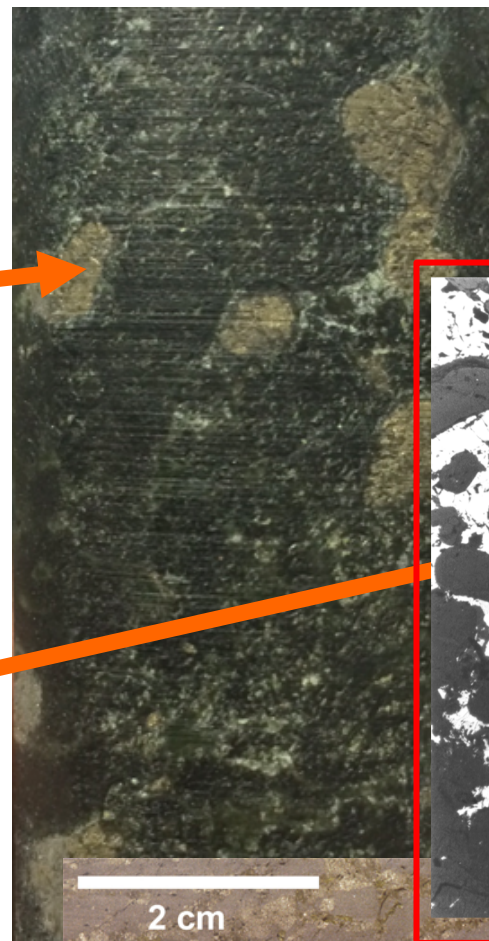
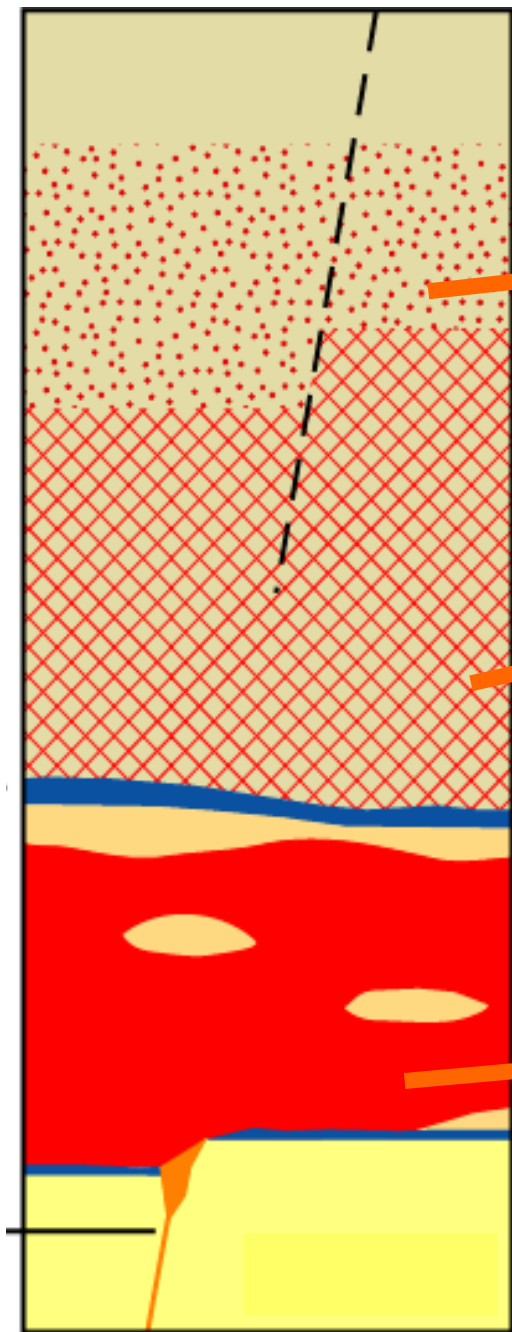
Non-wetting liquid – sulfide melt

Wetting angles and sulfide textures – silicate and sulfide together

Wetting liquid – silicate melt

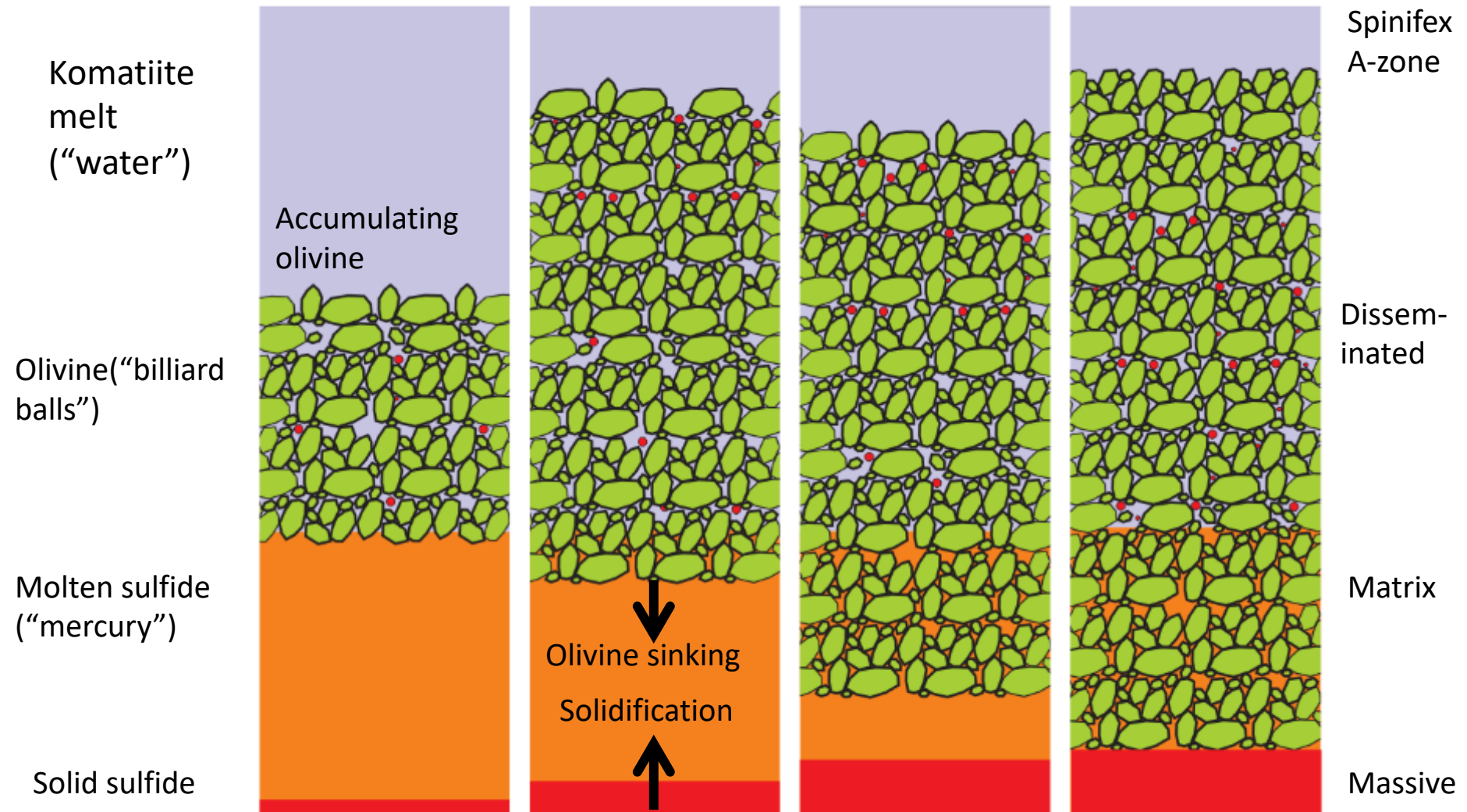


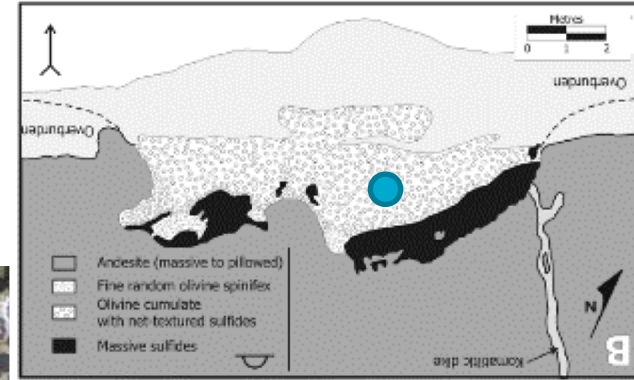
Komatiite-hosted nickel ores
The standard “billiard-ball” story



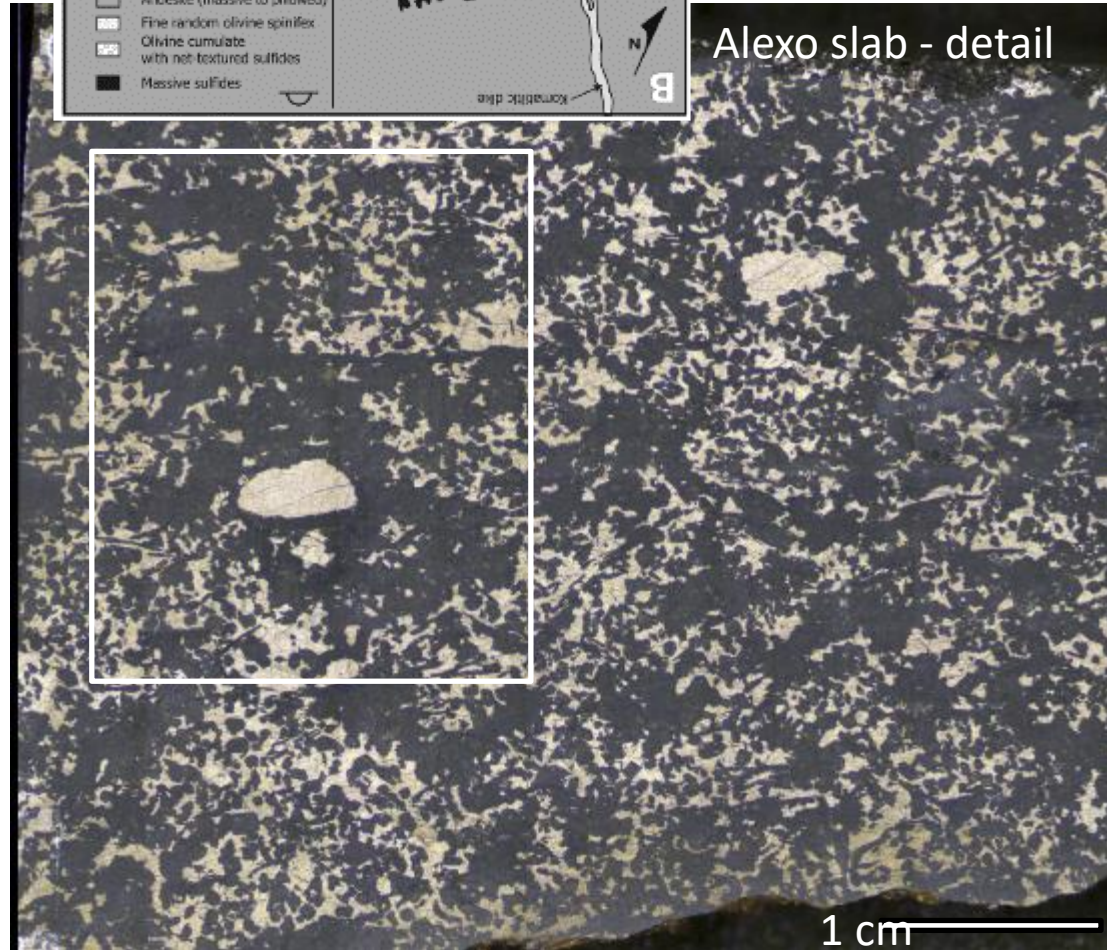
**Type 1 Ore
profiles**

“Billiard Ball Model” Naldrett (1973), Usselman et al (1979)



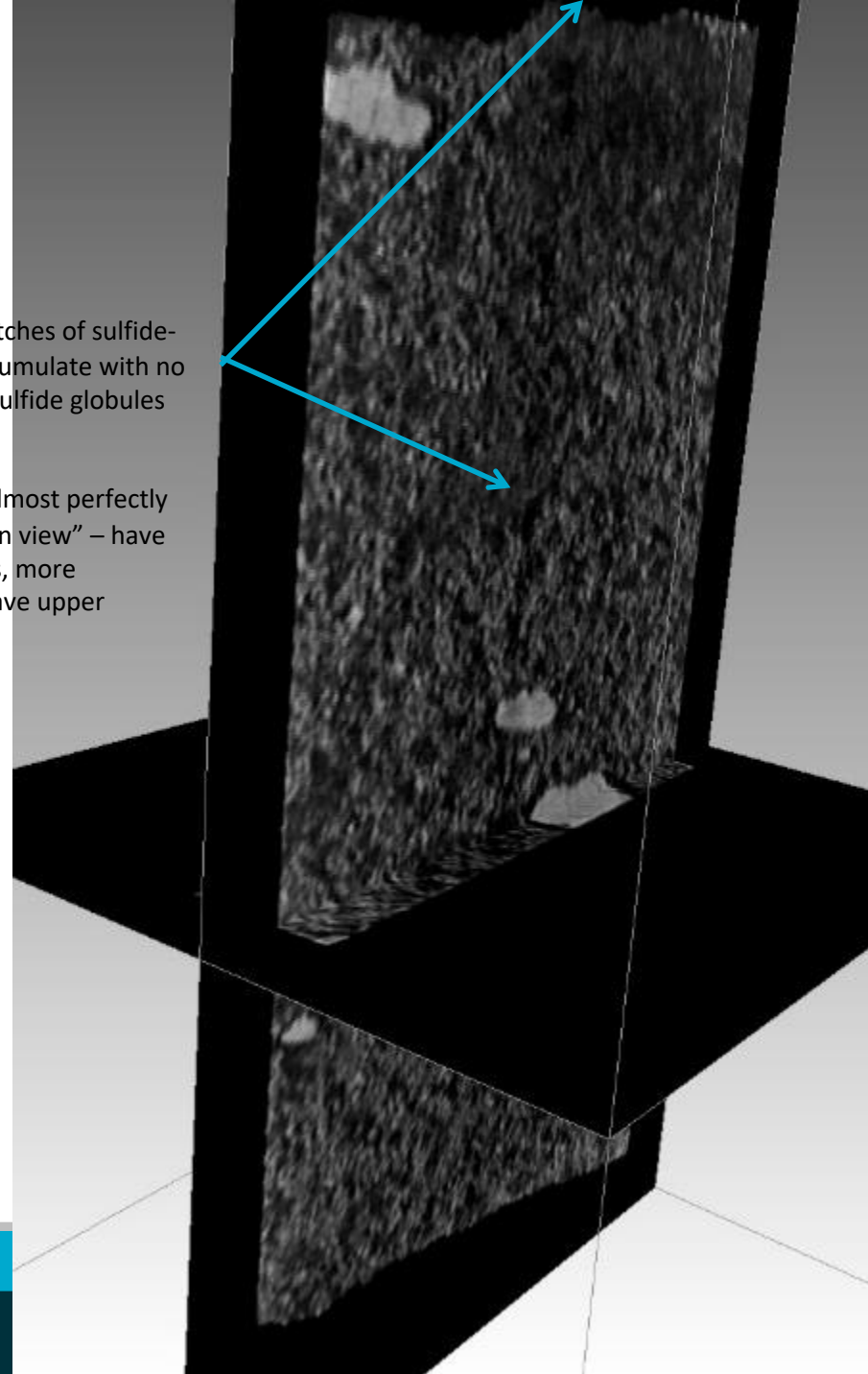
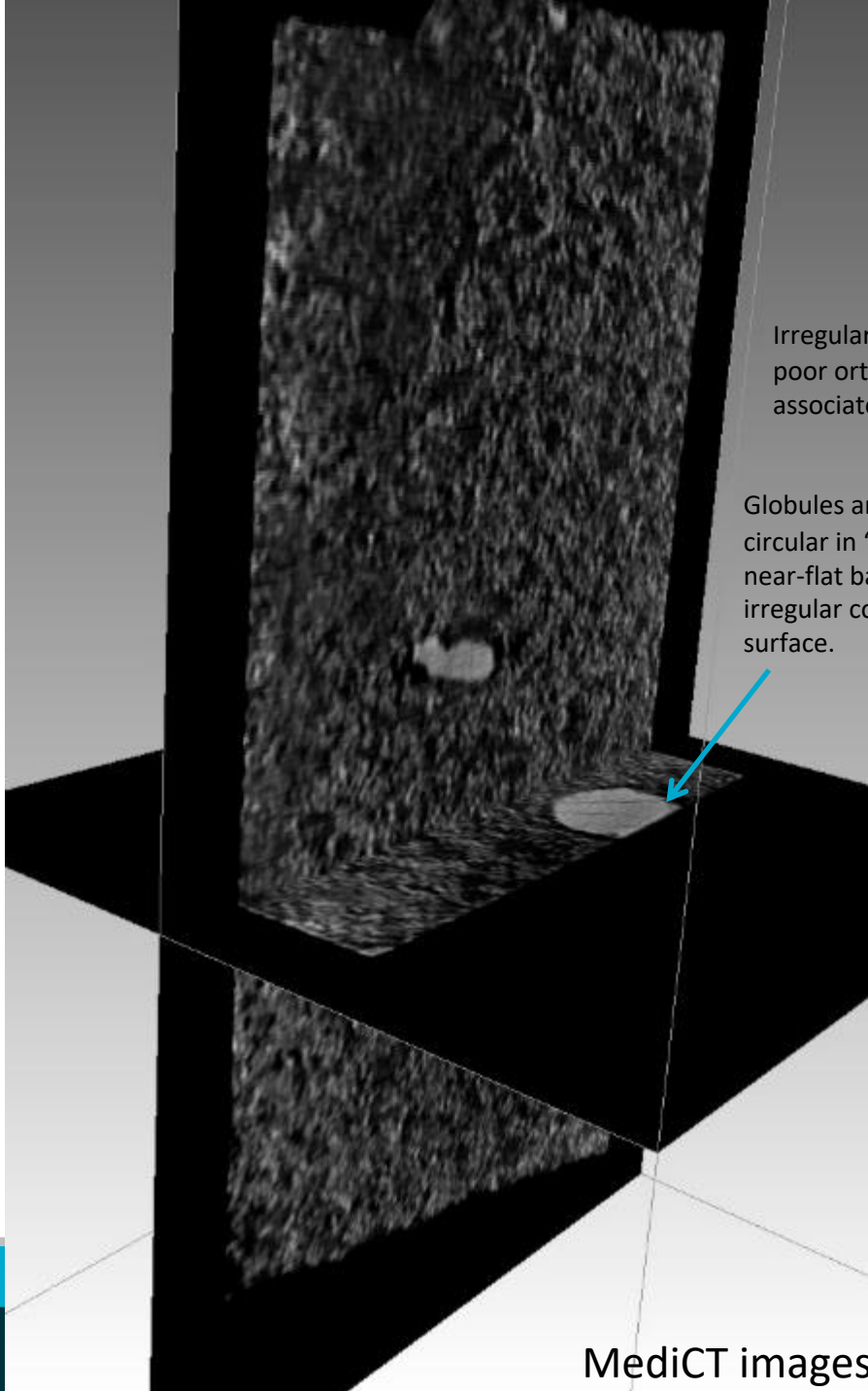


Alexo slab - detail



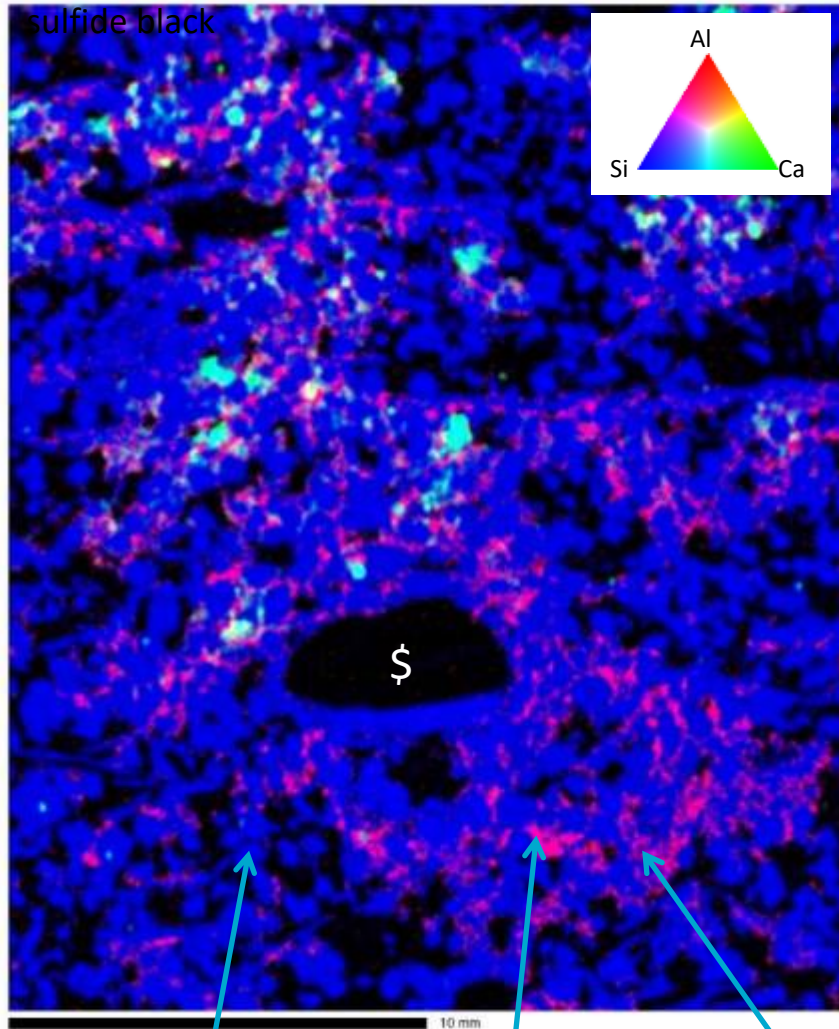
Alexo, Abitibi Belt, Ontario

(Sample from Mike Lesher)



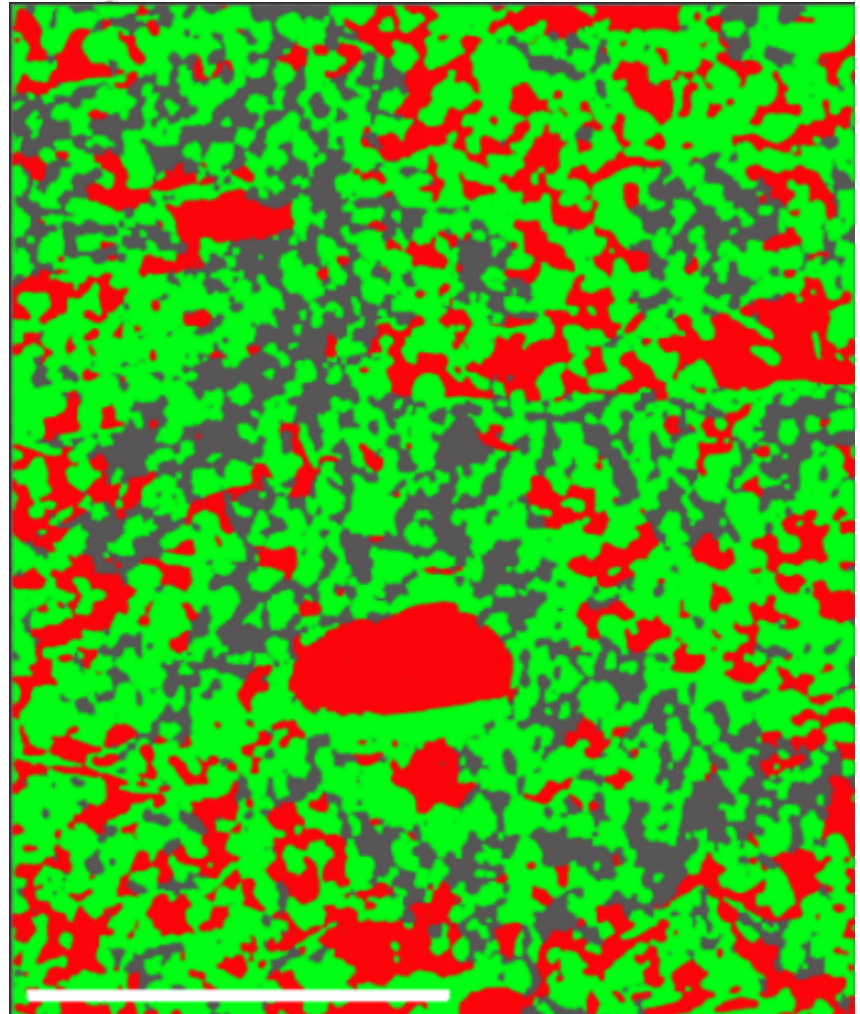
Alexo net-textured ore – Tornado maps

Olivine in blue, chlorite after trapped melt red, relic cpx (micrspx) turquoise, sulfide black



olivine

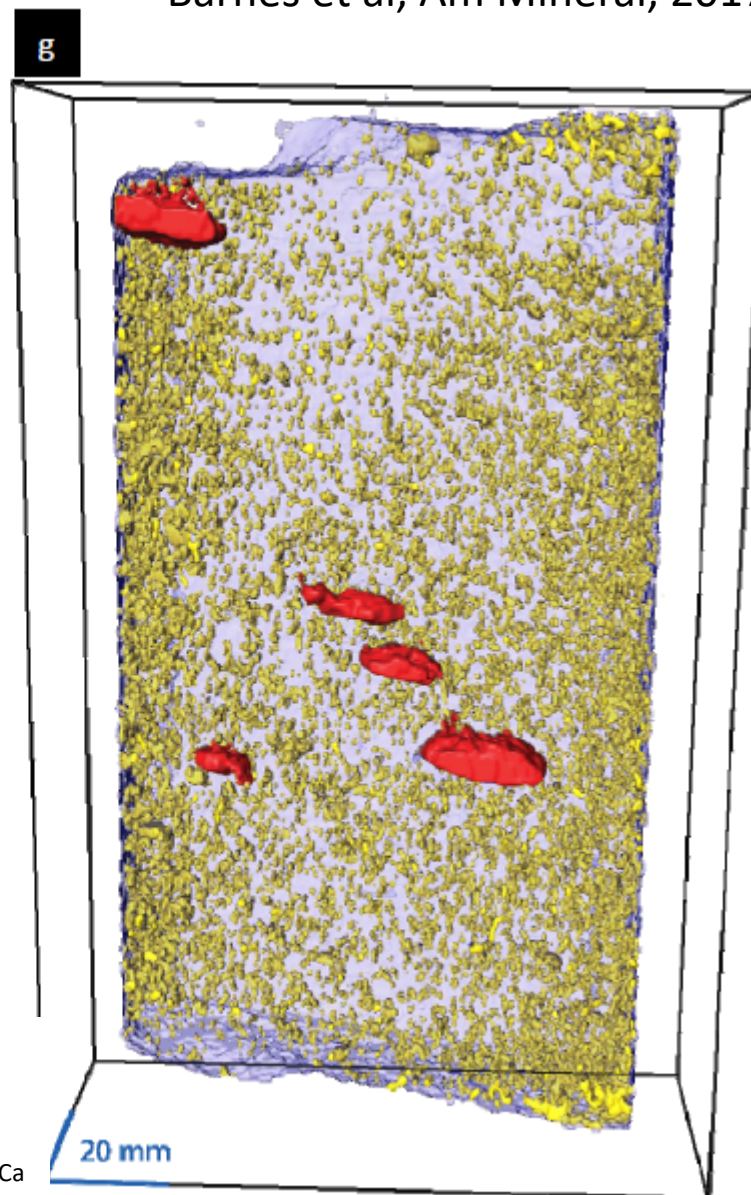
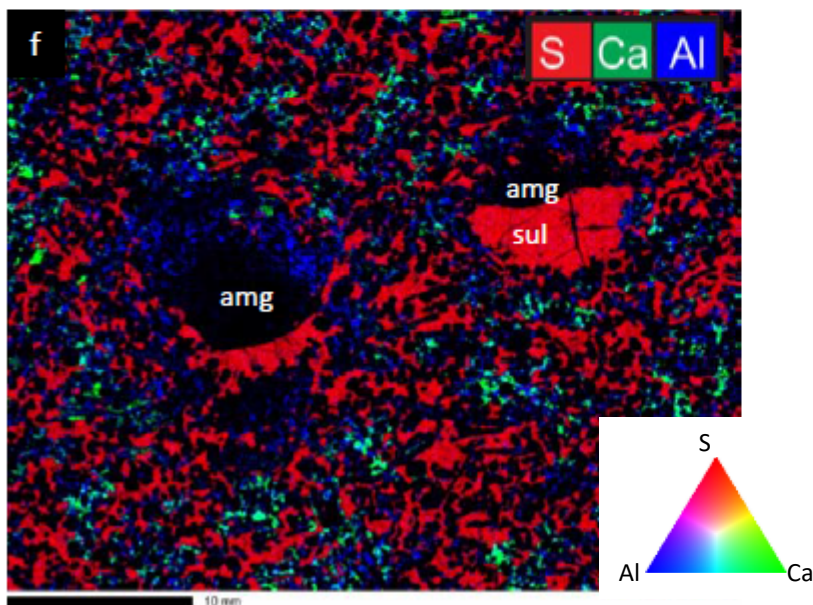
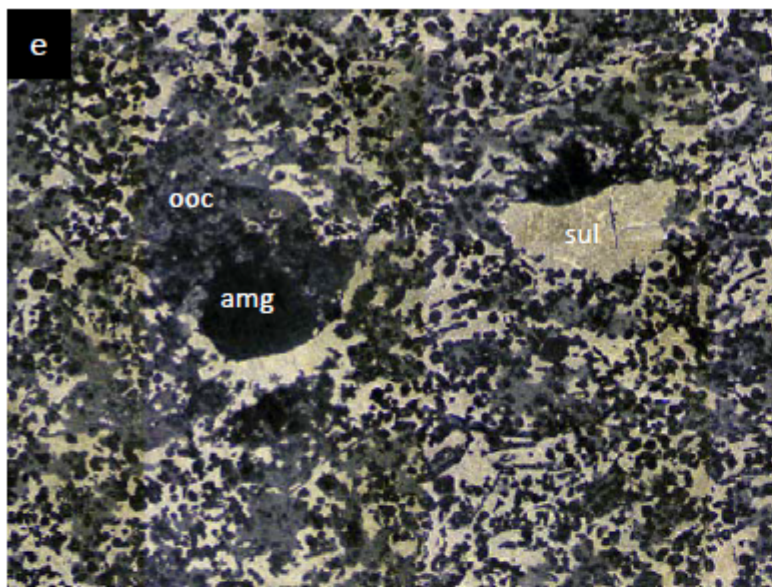
Trapped melt



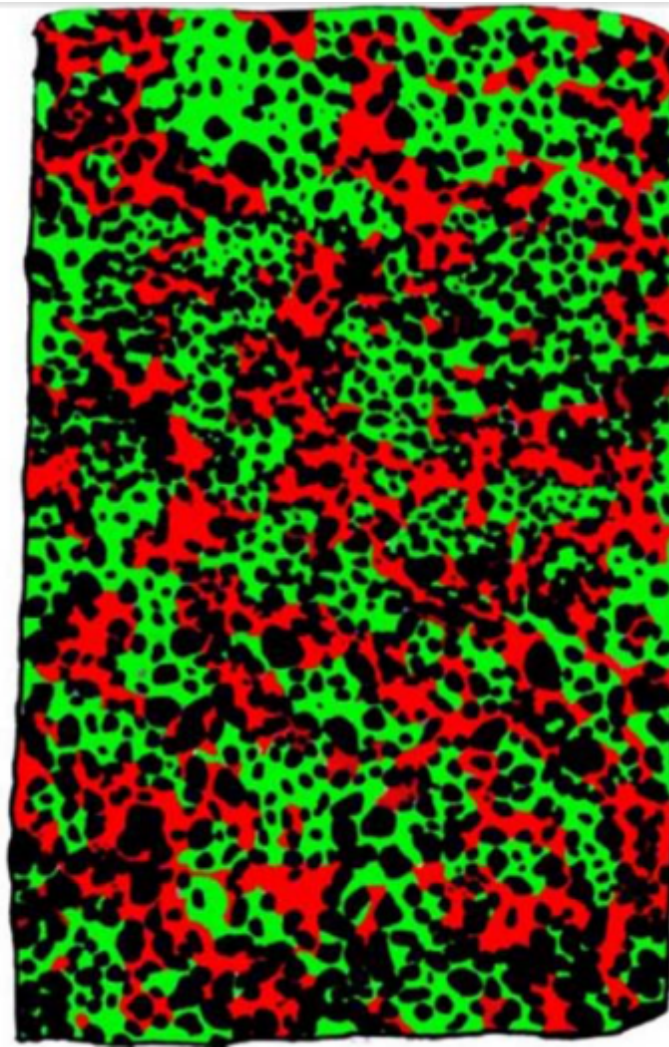
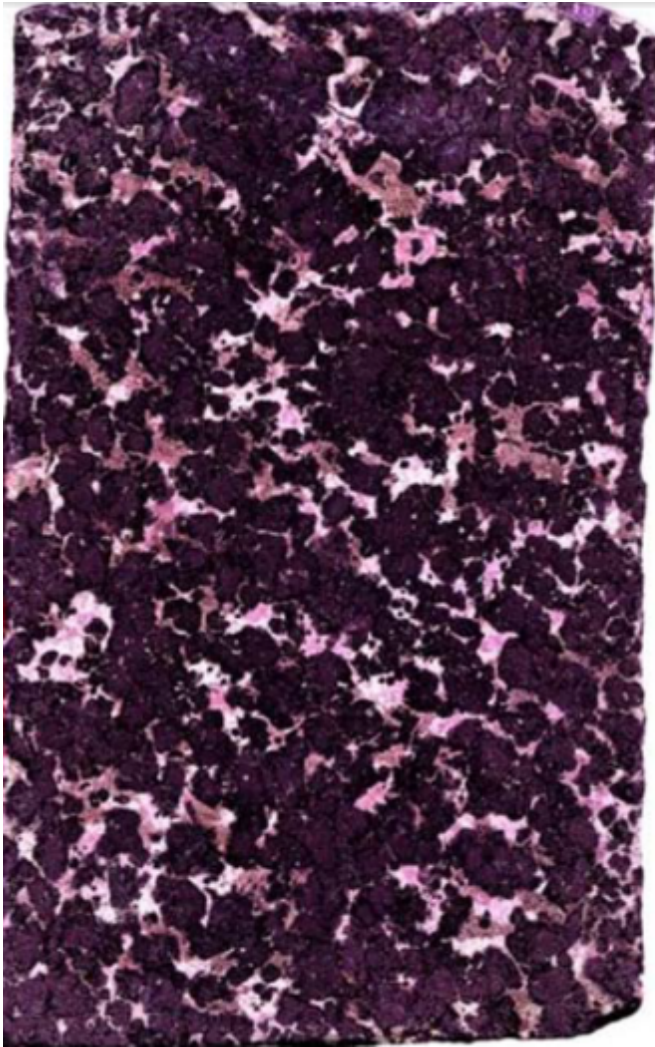
Olivine

Chlorite (trapped melt)

Patch of sulfide-poor olivine orthocumulate

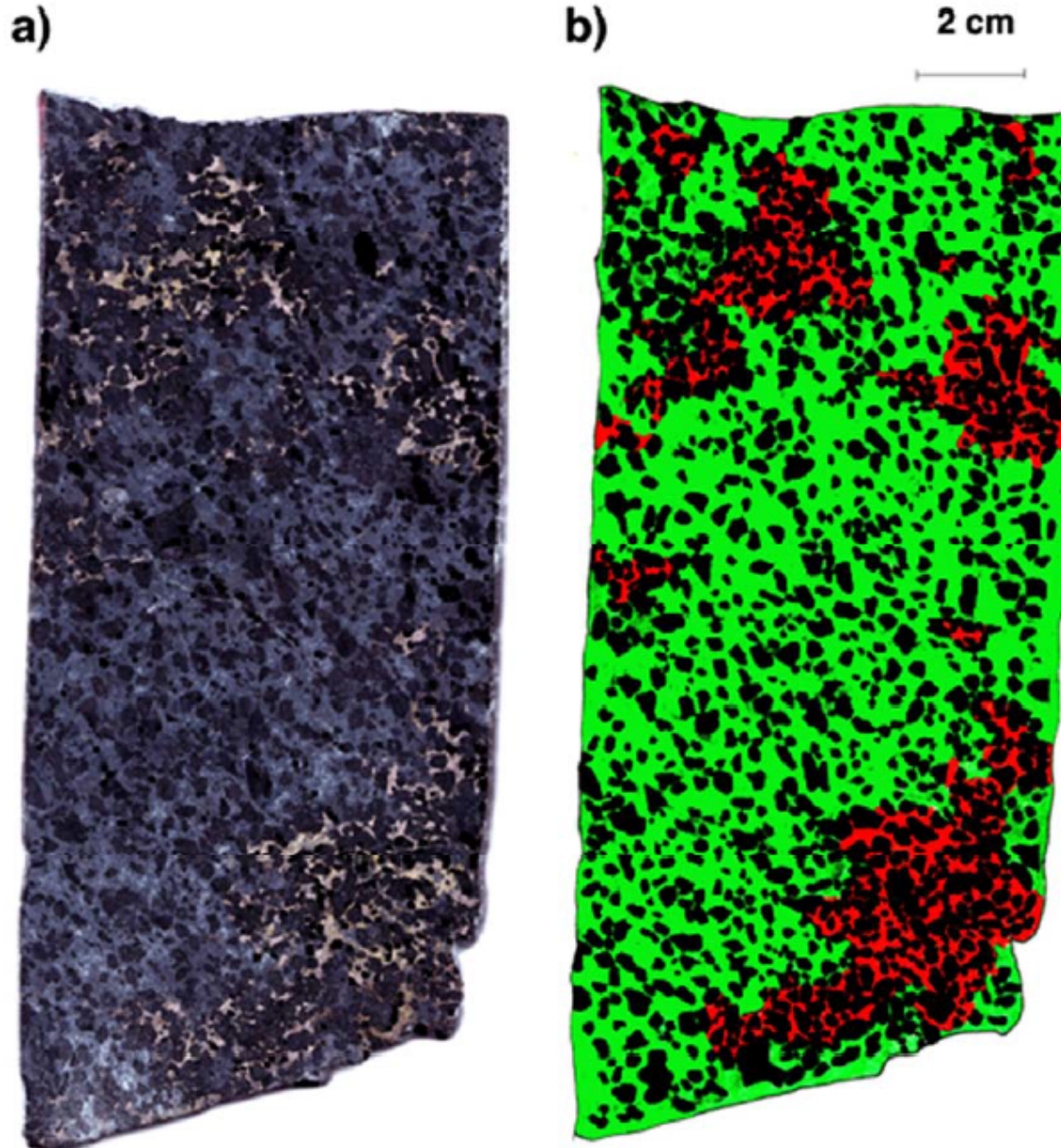


Jinchuan ore textures (Tonnelier PhD thesis 2009)



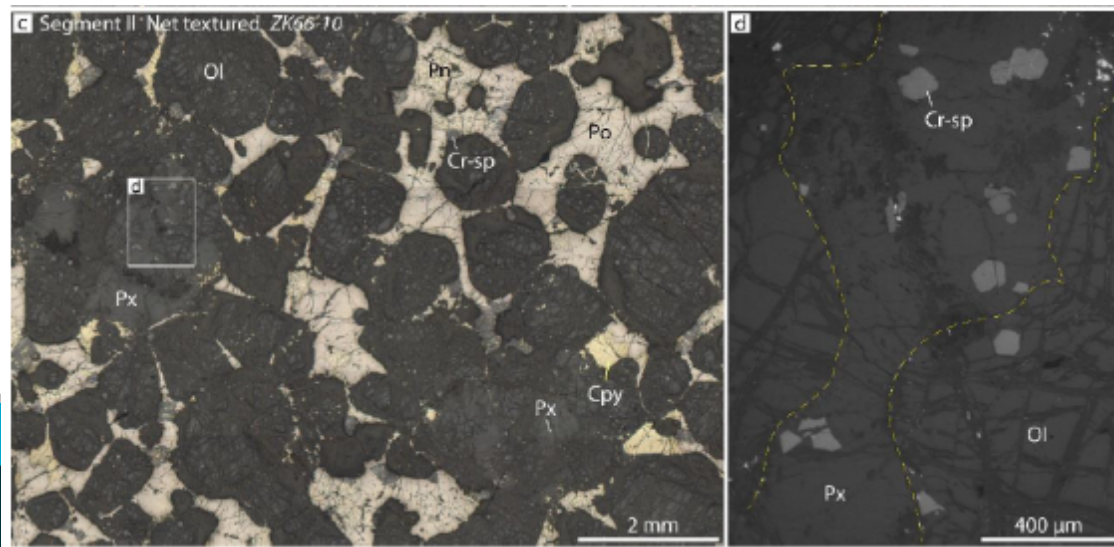
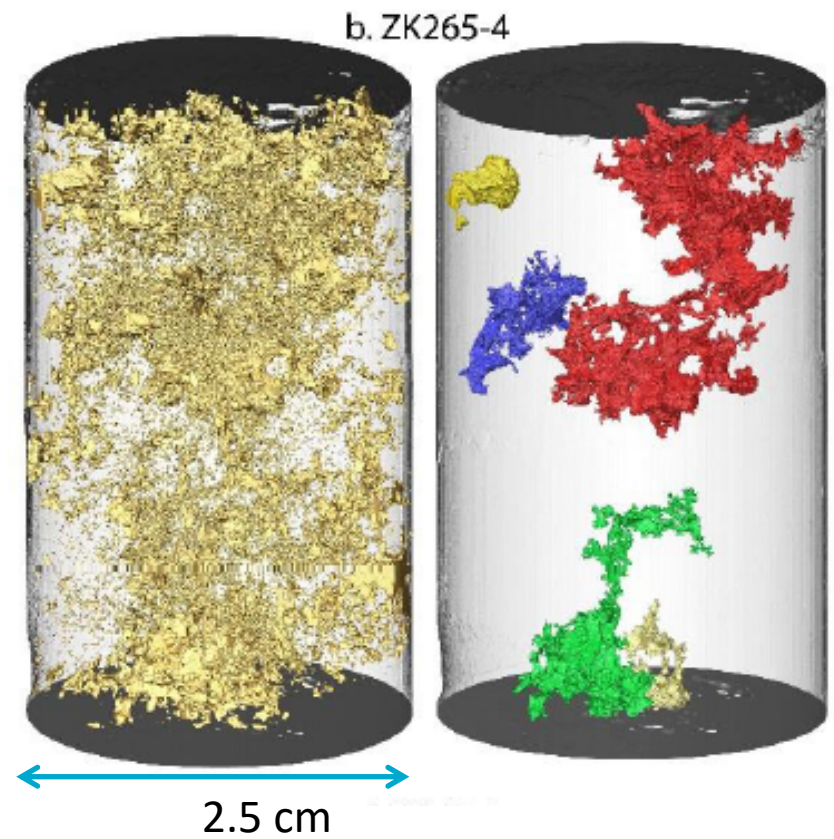
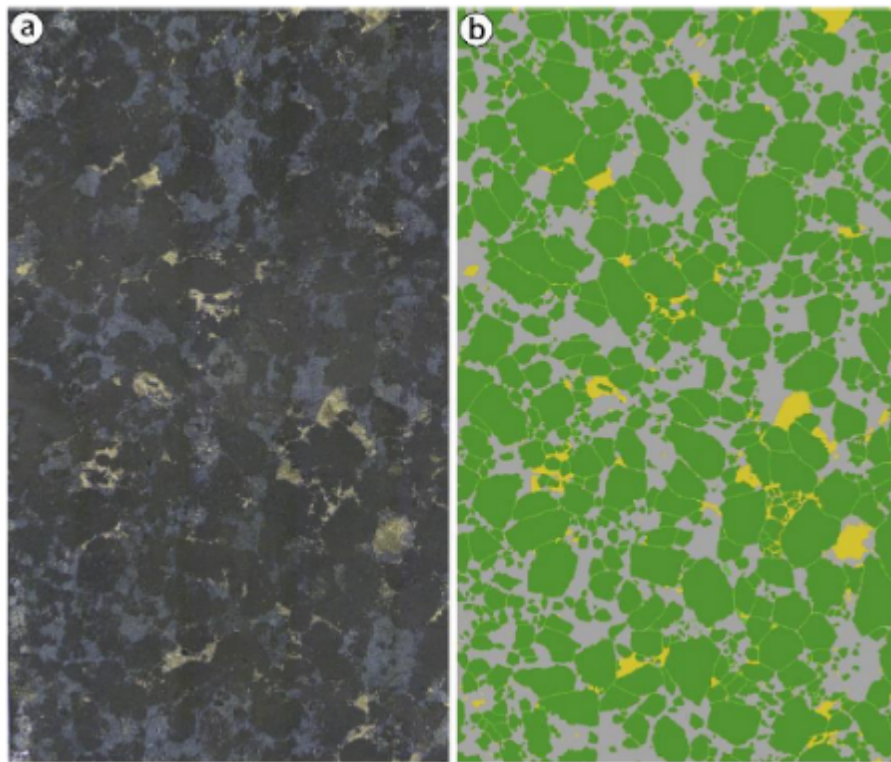
Olivine
Sulfide liquid
Silicate liquid

Jinchuan ore textures (Tonnelier PhD thesis)

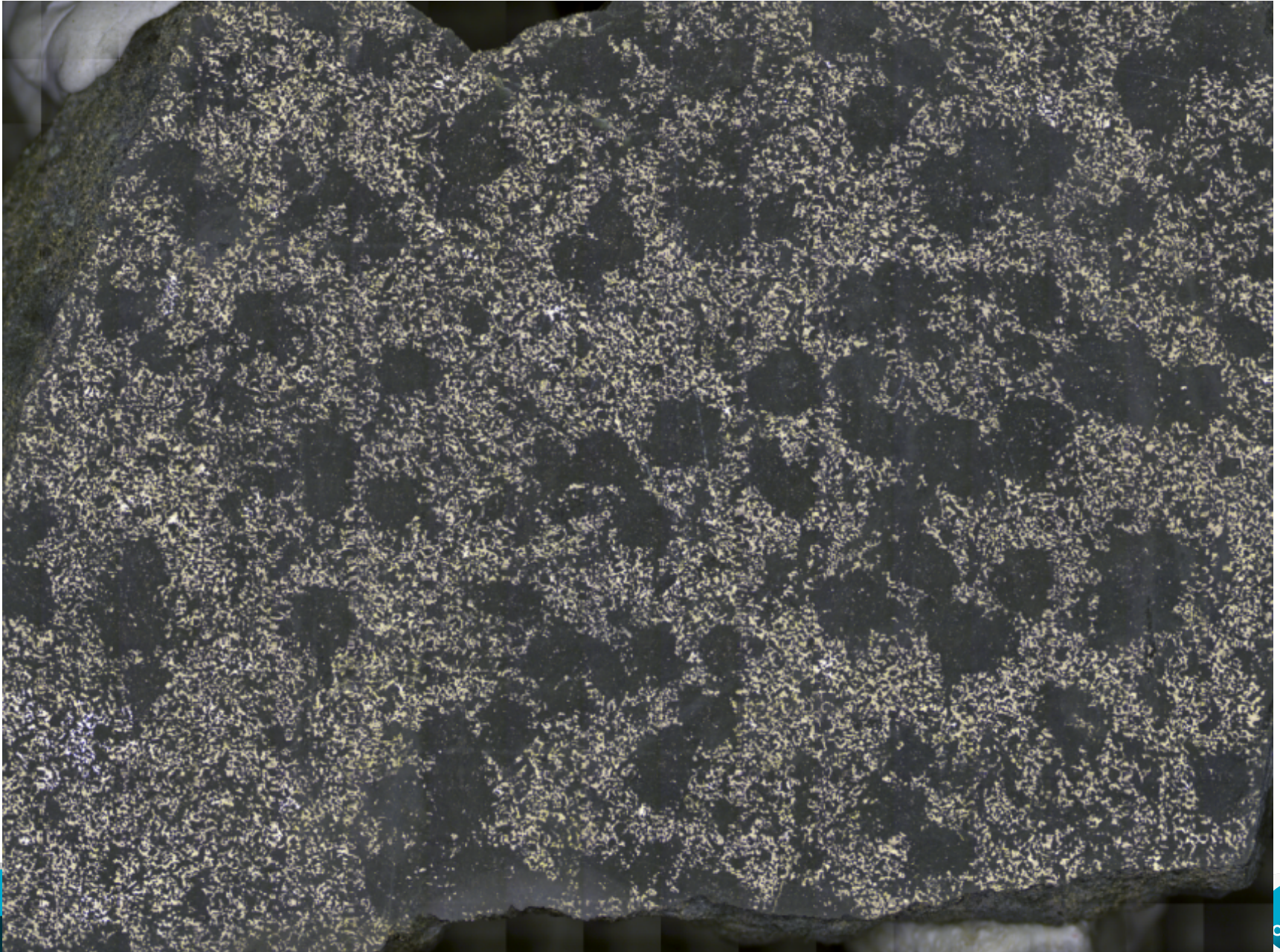


Olivine
Sulfide liquid
Silicate liquid

3D-connected sulfide channel?



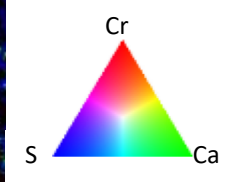
Katiniq – “leopard” matrix ore



Katiniq – “leopard” matrix ore

CrCaS

Sulfides in blue, opx black-red, olivines black, cpx green

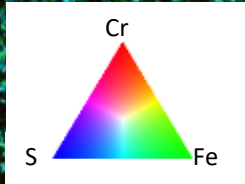


opx

Katiniq – “leopard” matrix ore

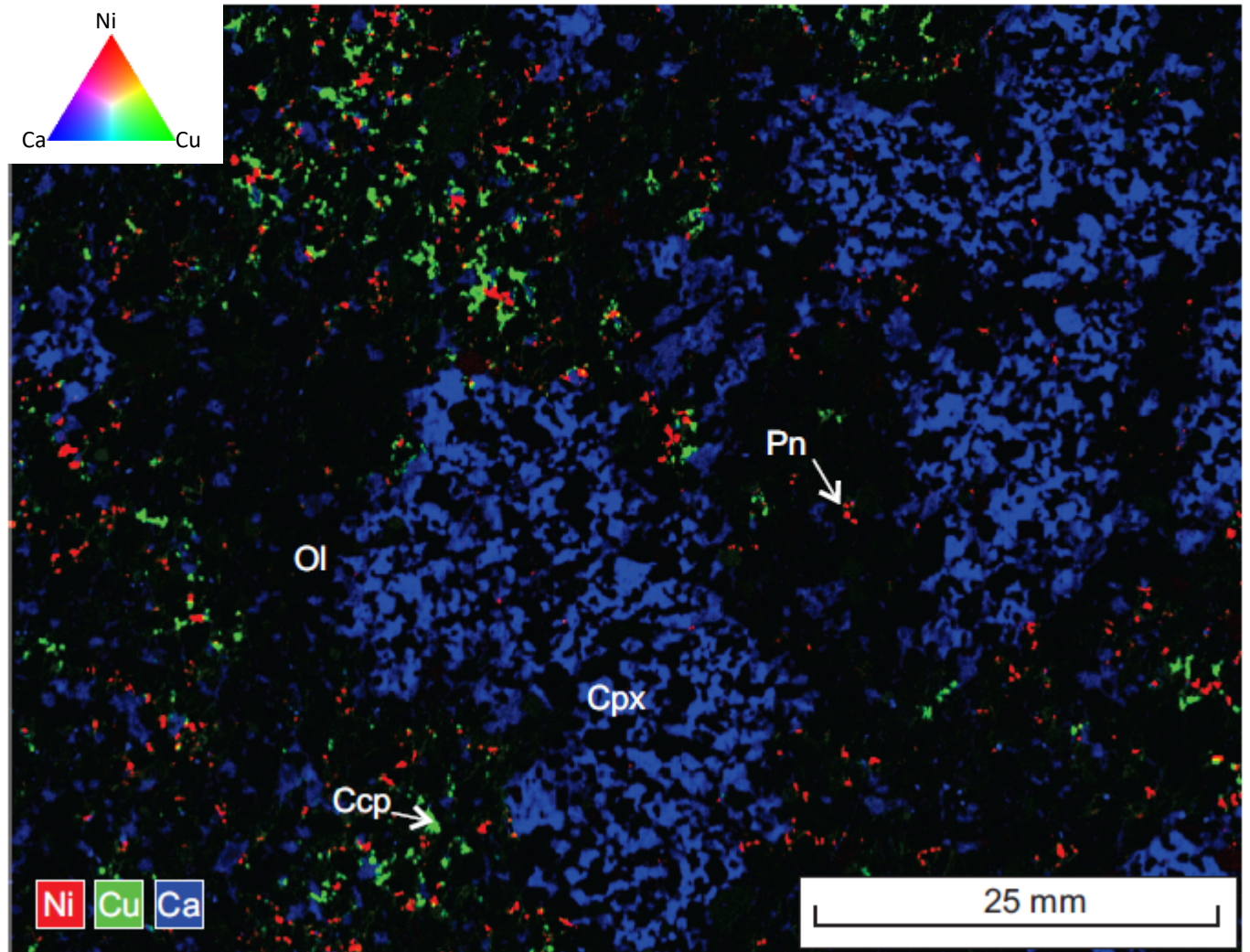
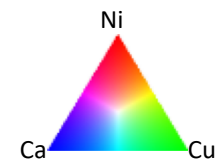
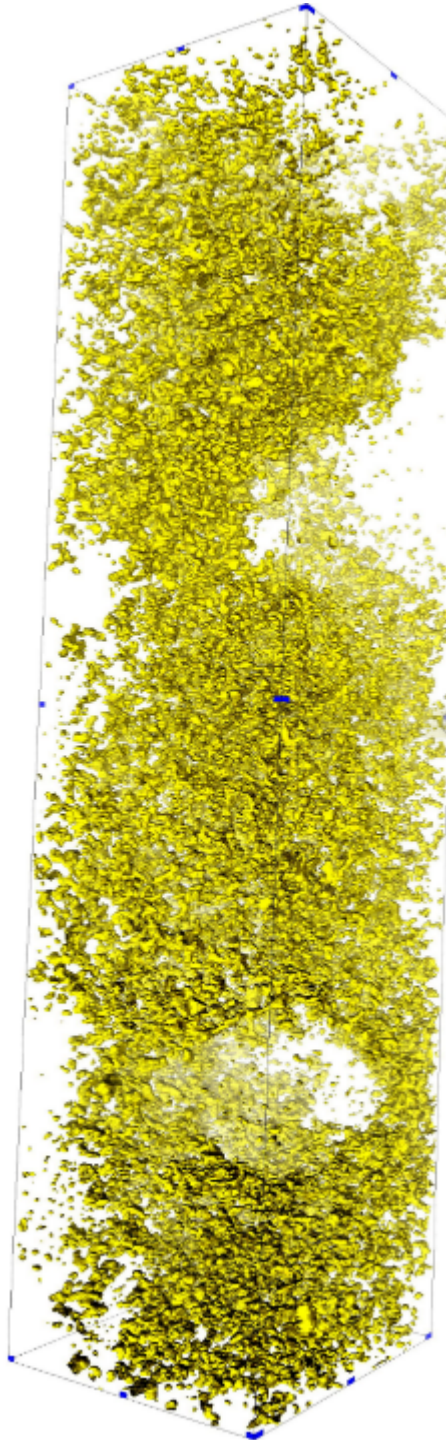
CrFeS

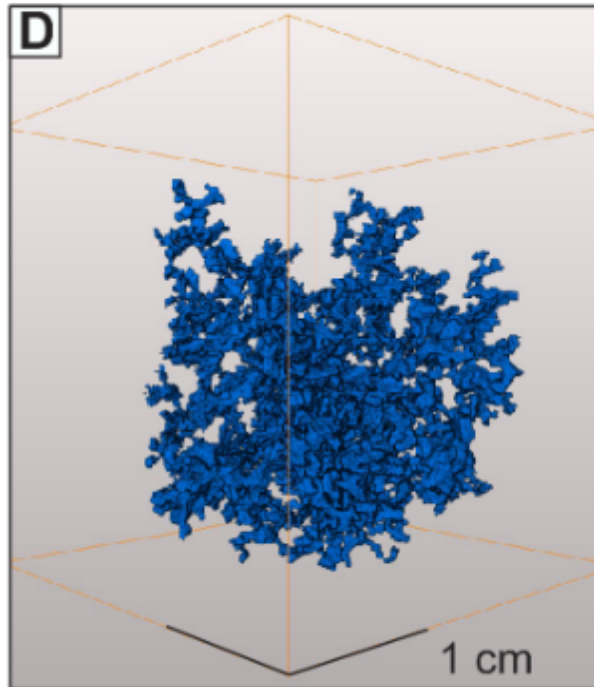
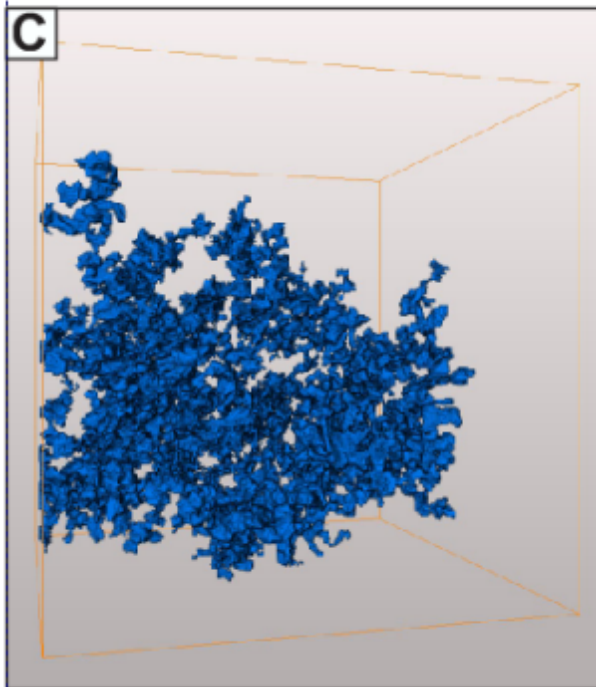
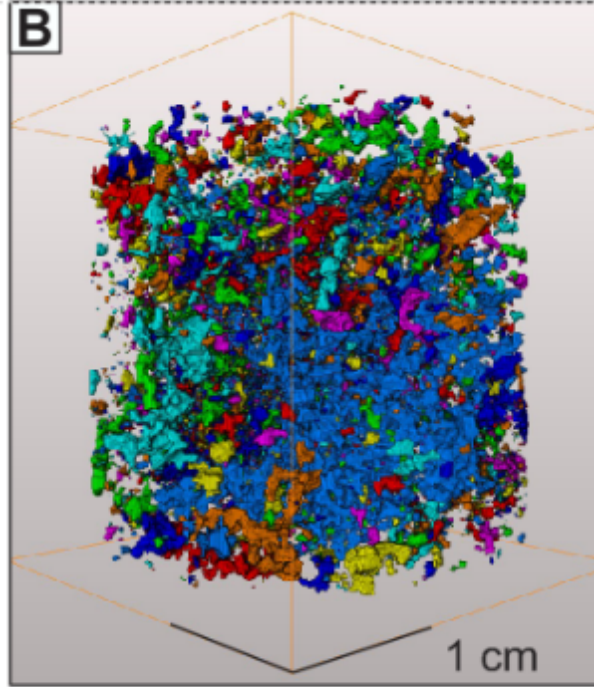
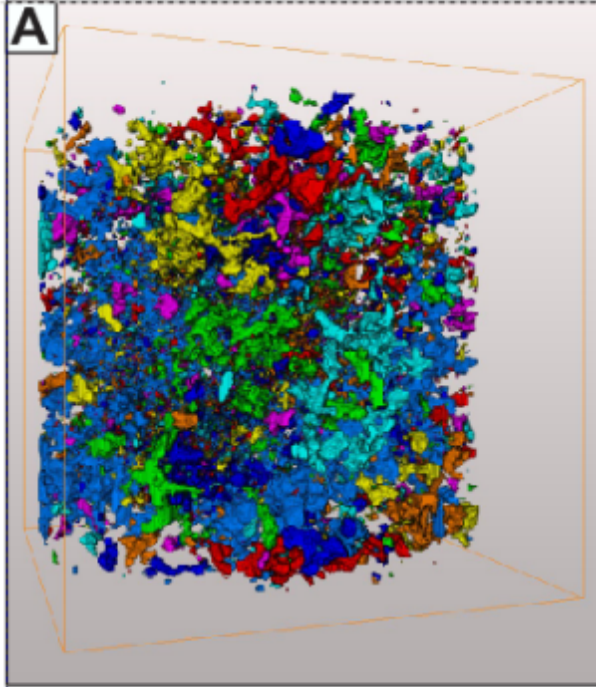
Two-stage growth of large opx “oiks” – these are actually zoned opx phenocrysts with euhedral Cr-rich cores and abundant olivine inclusions



opx

Kevitsa



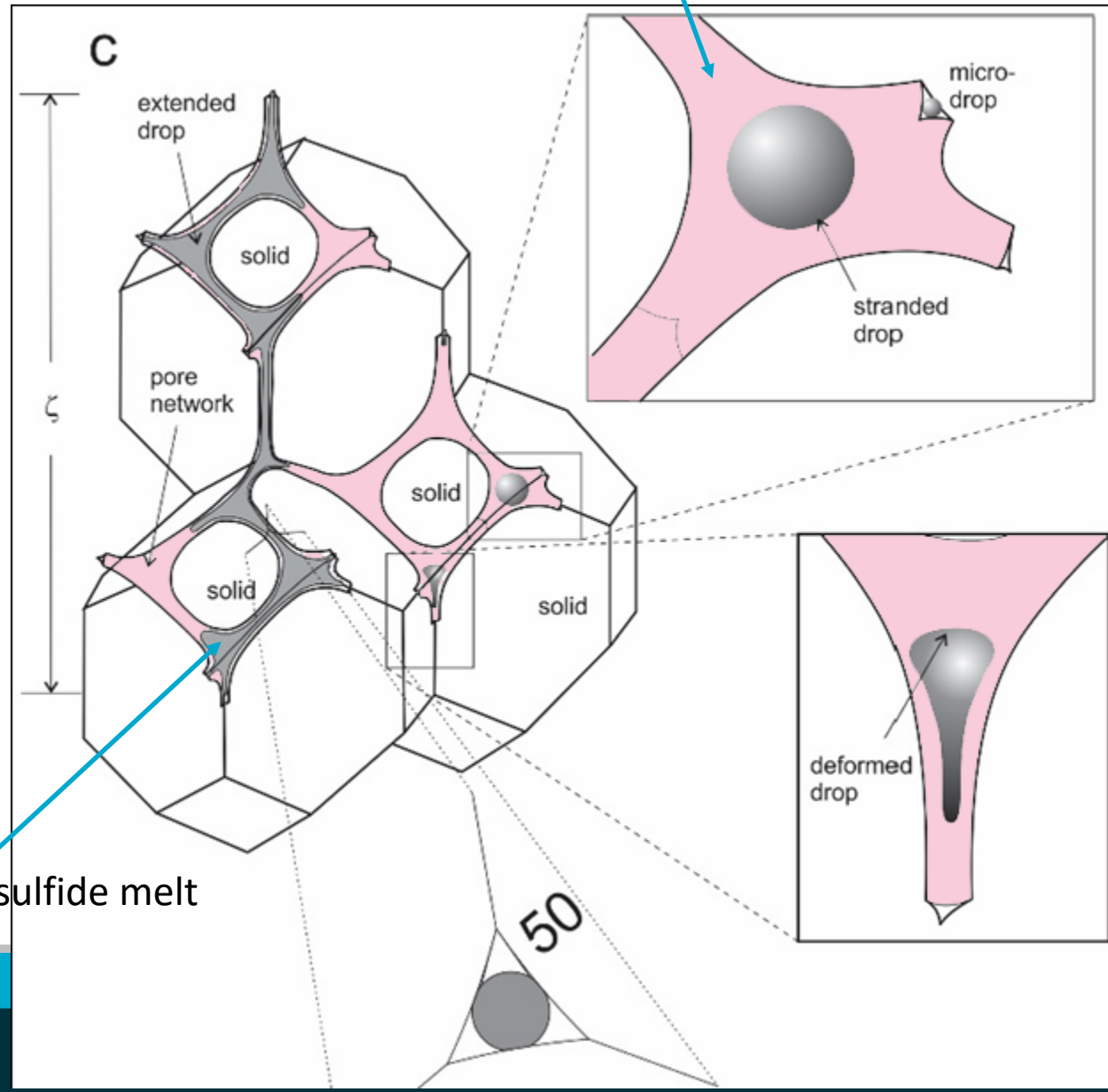


~5% sulfides

Wetting angles and sulfide textures

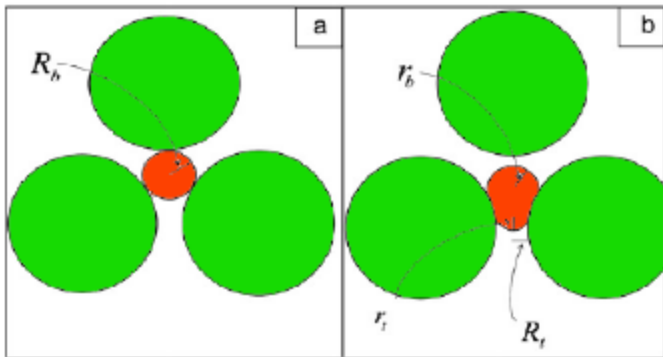
Wetting liquid – silicate melt

Non-wetting liquid – sulfide melt

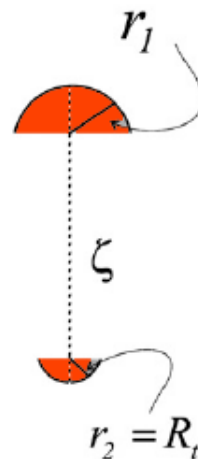
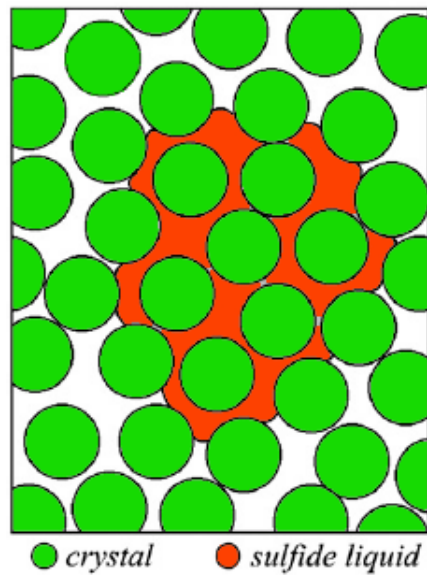
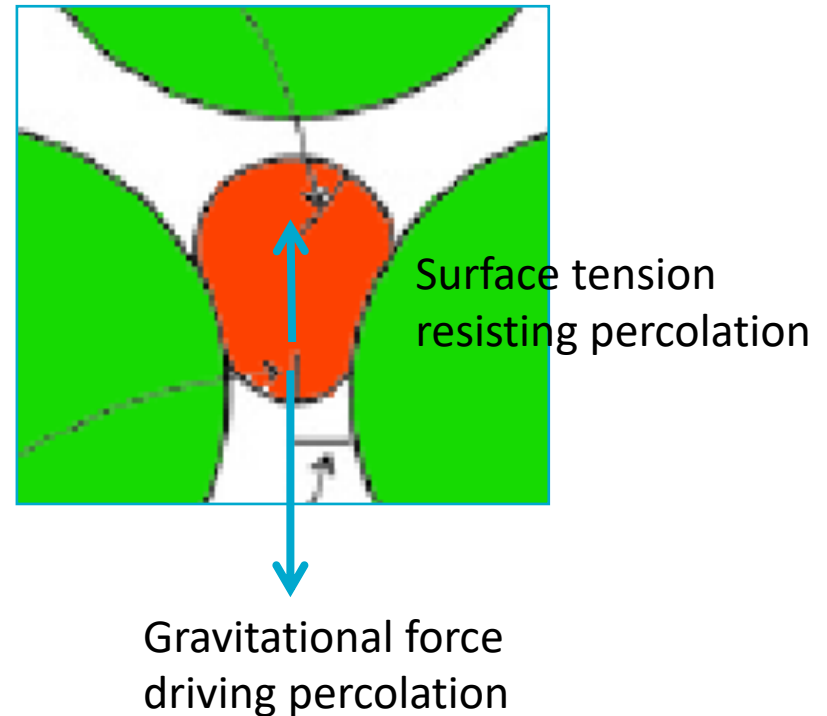


Migration of sulfide droplets through pore space in cumulates

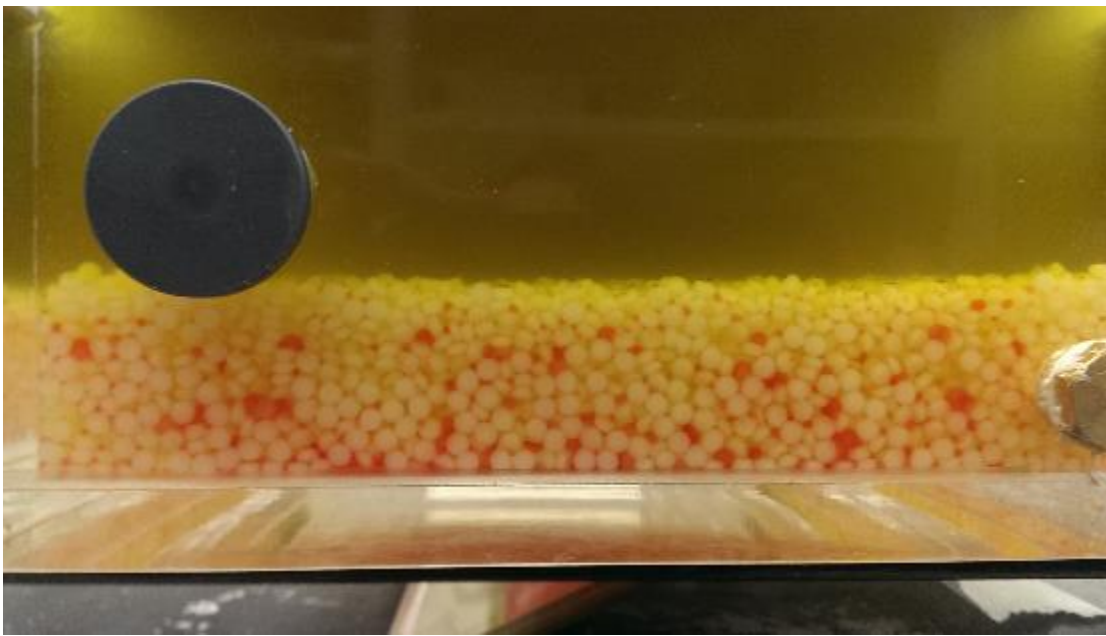
(Chung and Mungall EPSL 2009)



Small droplets can migrate through pore throats, larger ones only if wetting angle is low



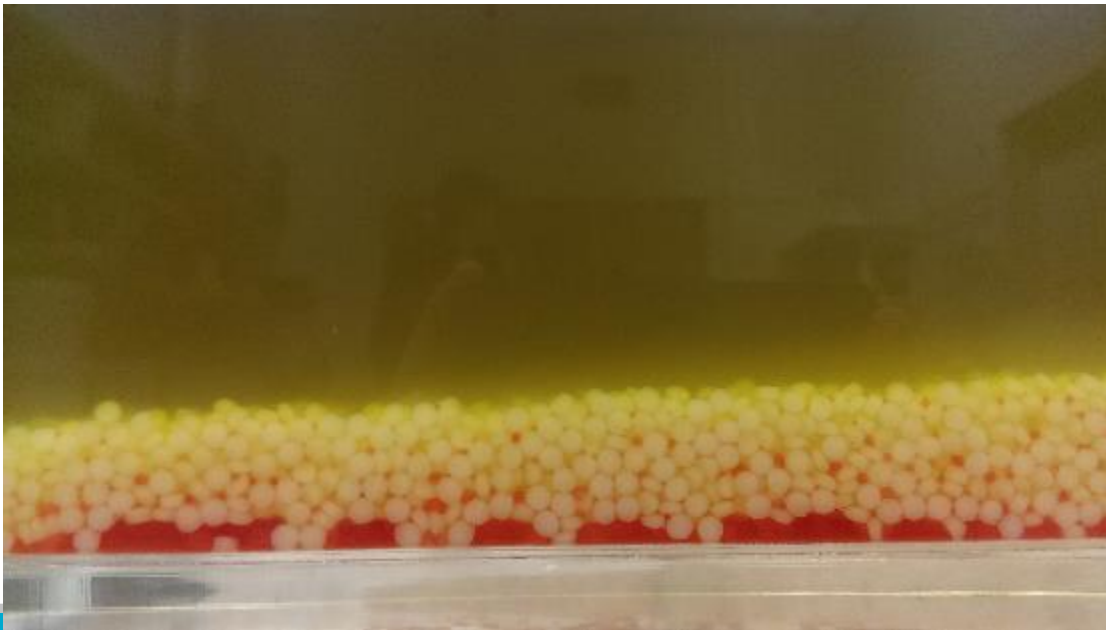
Large enough blebs with sufficient rise height can force themselves through pore space



Analogue experiments
Anja Slim (Monash)
Margaux Le Vaillant (CSIRO)

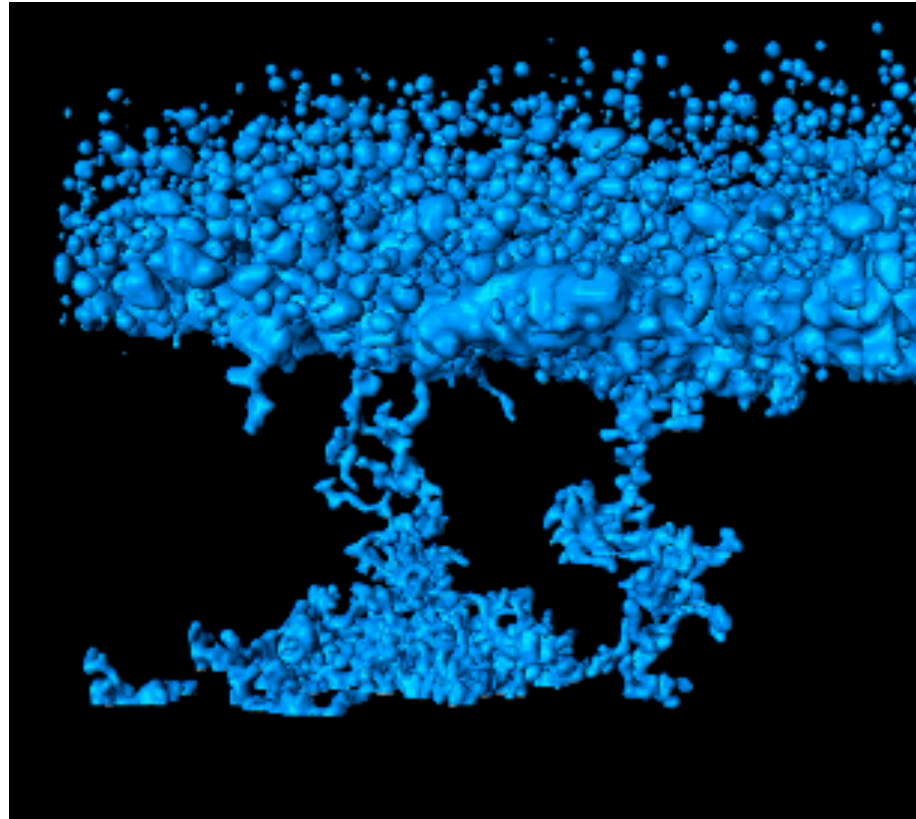
Olive oil = magma
Water = sulfide liquid
Plastic beads = olivine

Oil wets the beds, water doesn't

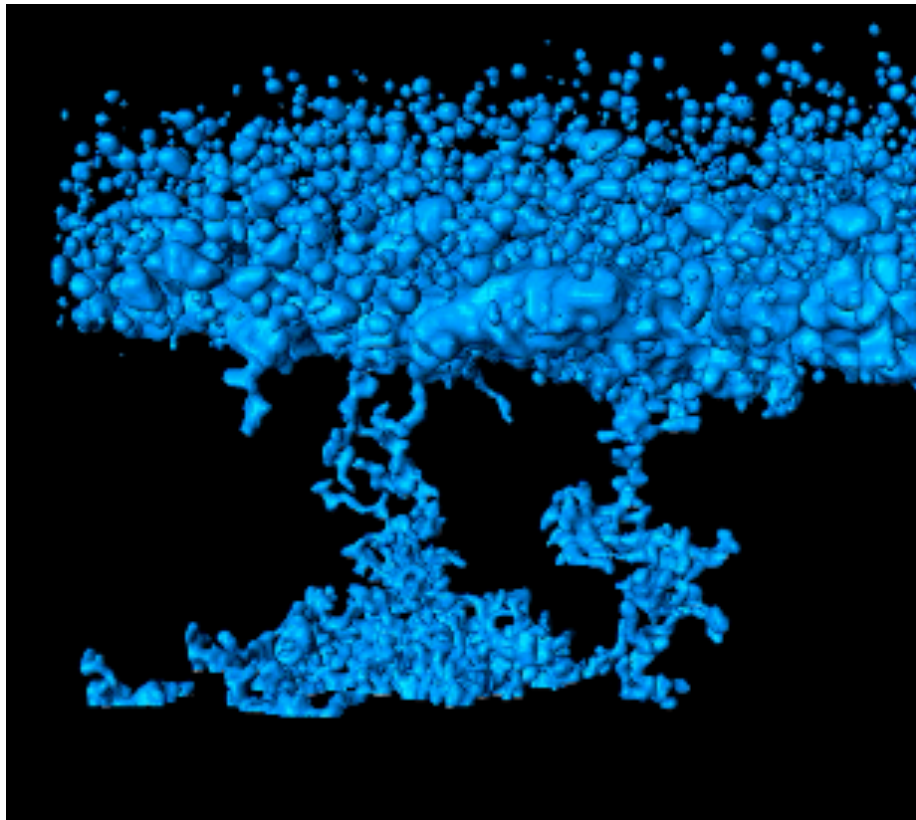


Analogue fluid experiment (Anja Slim, Margaux Le Vaillant)

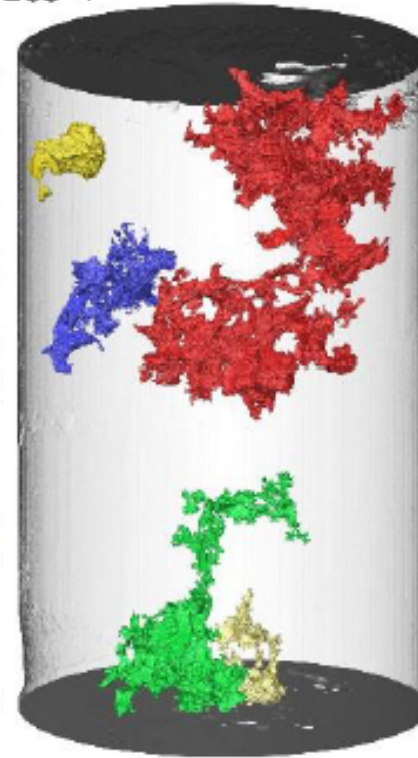
(movie)



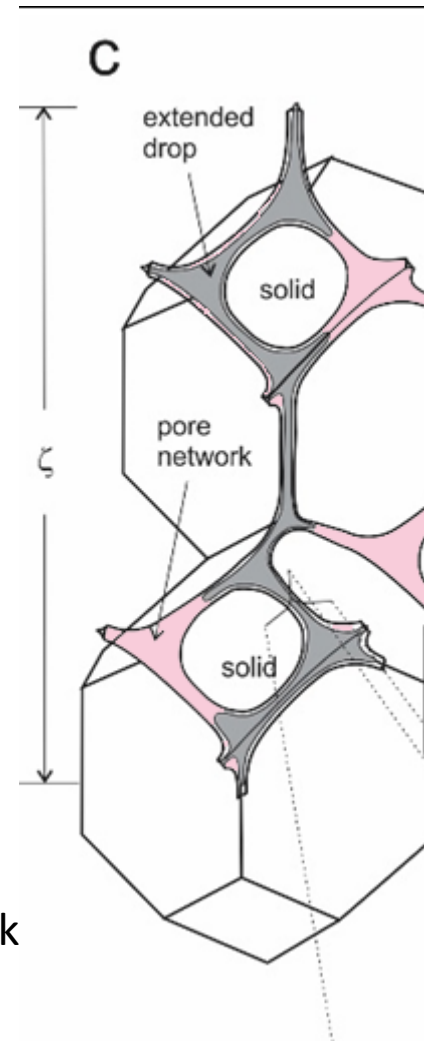
Analogue fluid experiment (Anja Slim, Margaux Le Vaillant)



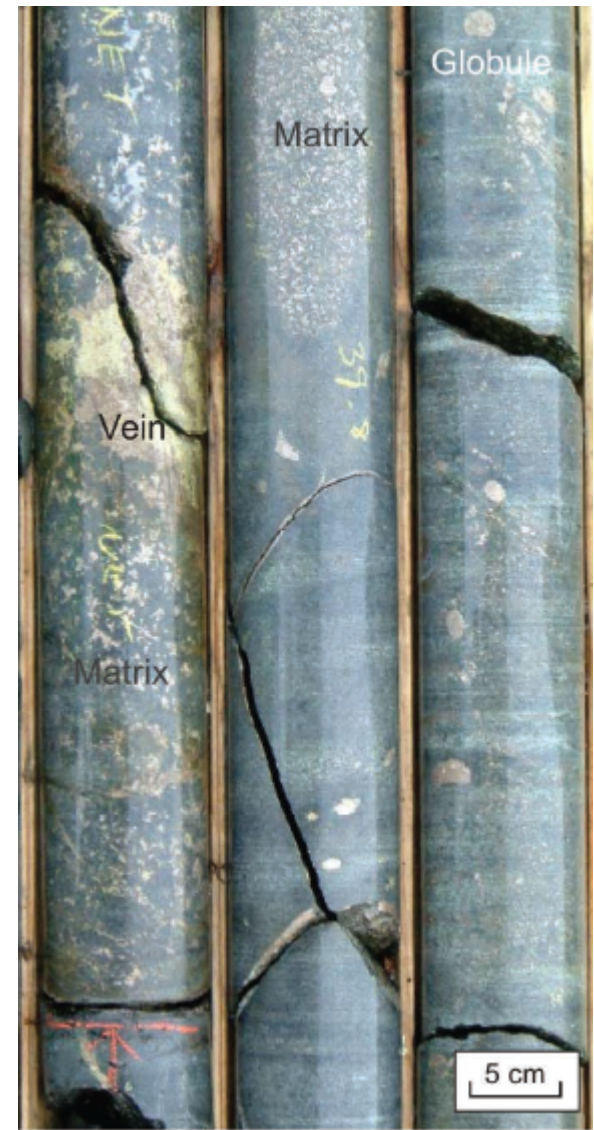
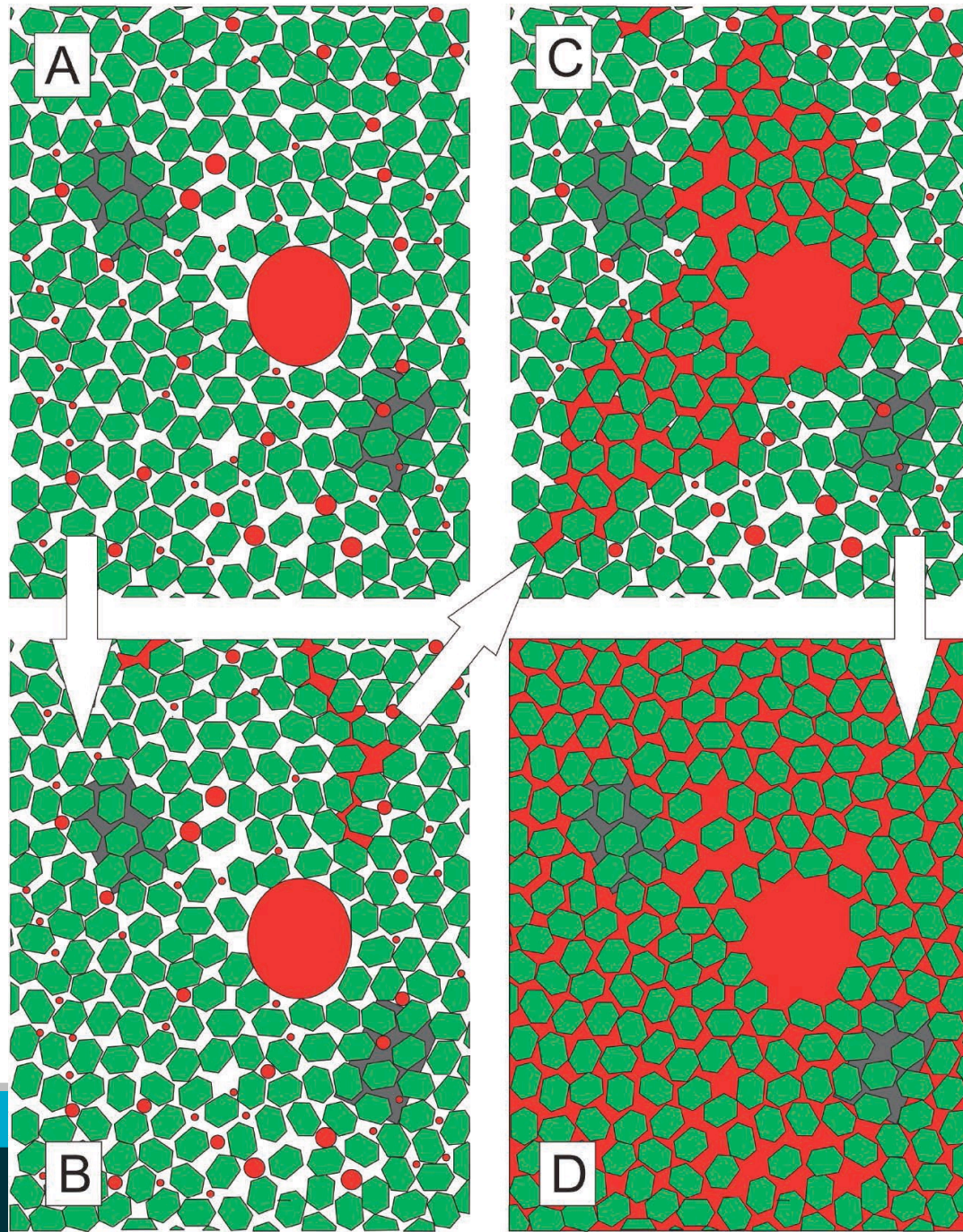
265-4



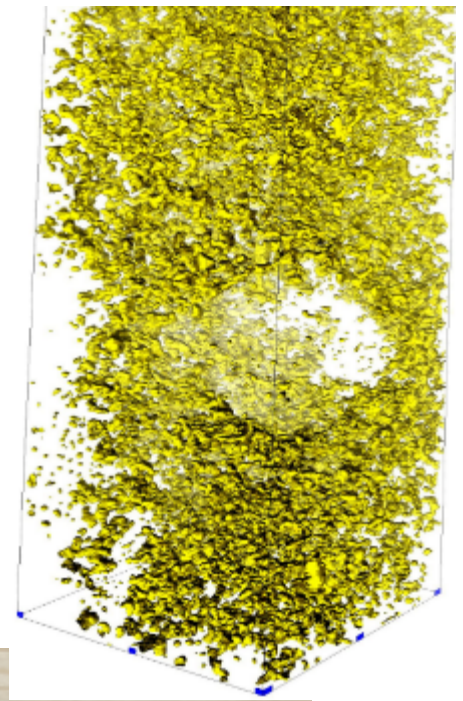
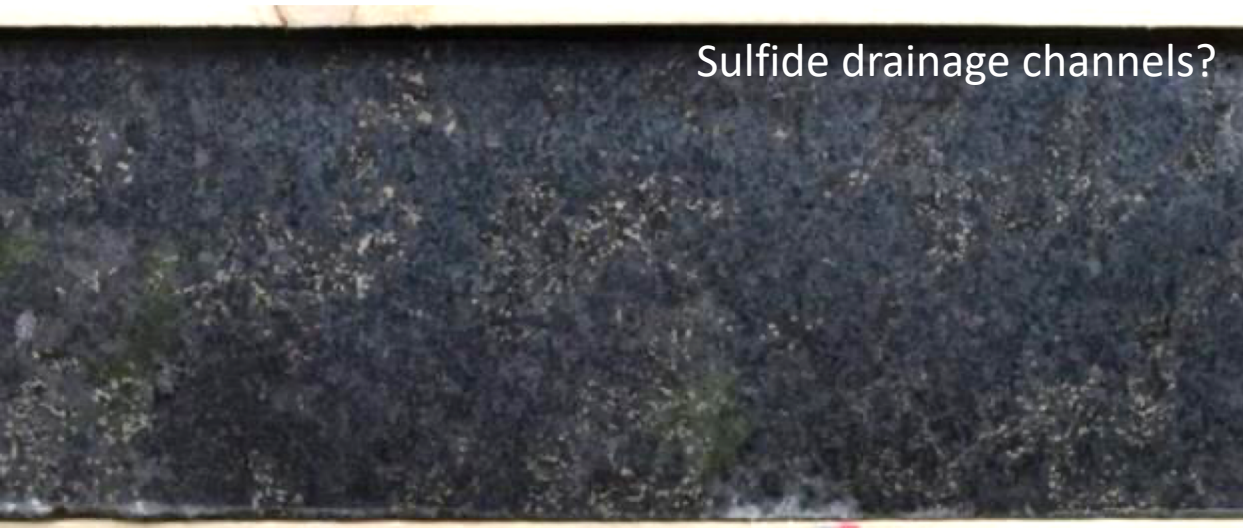
Jinchuan sulfide network



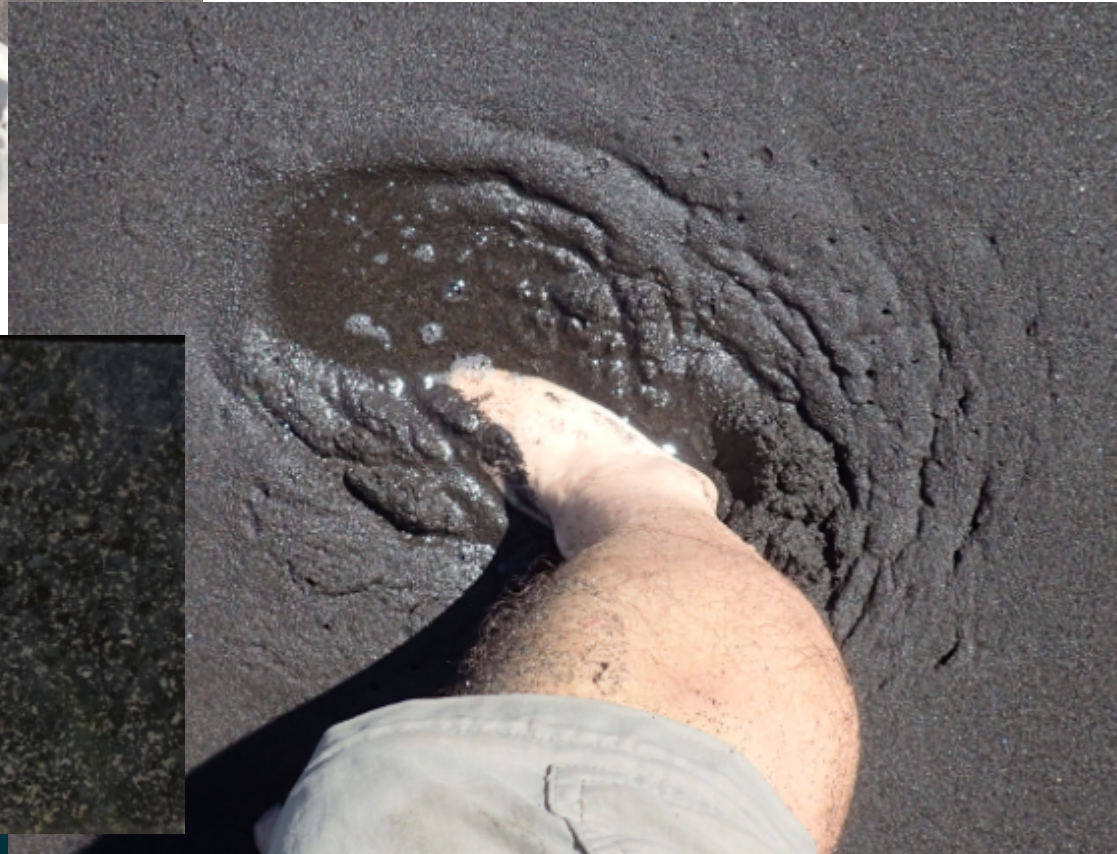
Sulfide percolation model for net-textured ores Barnes et al., Amer Min 2017



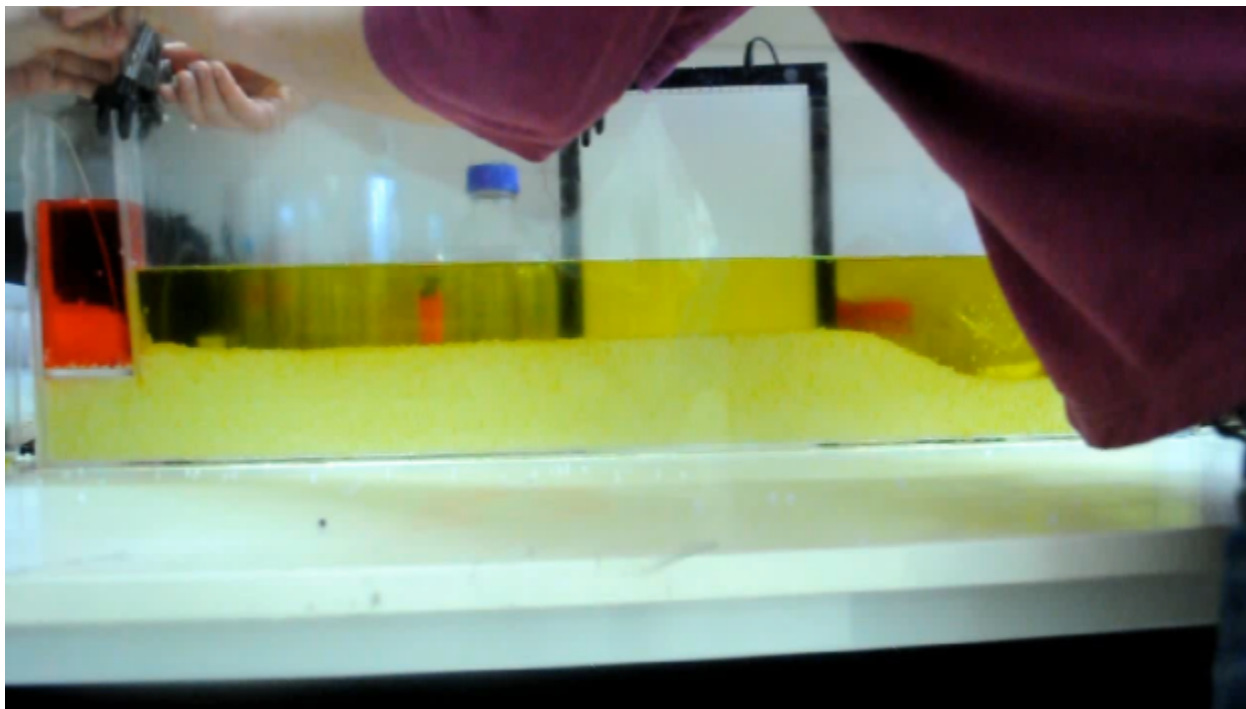
Kevitsa



Strain-rate dependent rheology
(thixotropic behaviour)



(movie)



Strain-rate dependent rheology
(thixotropic behaviour)



Particle-fluid mixtures flow
at slow strain rates but
fracture at high strain rates

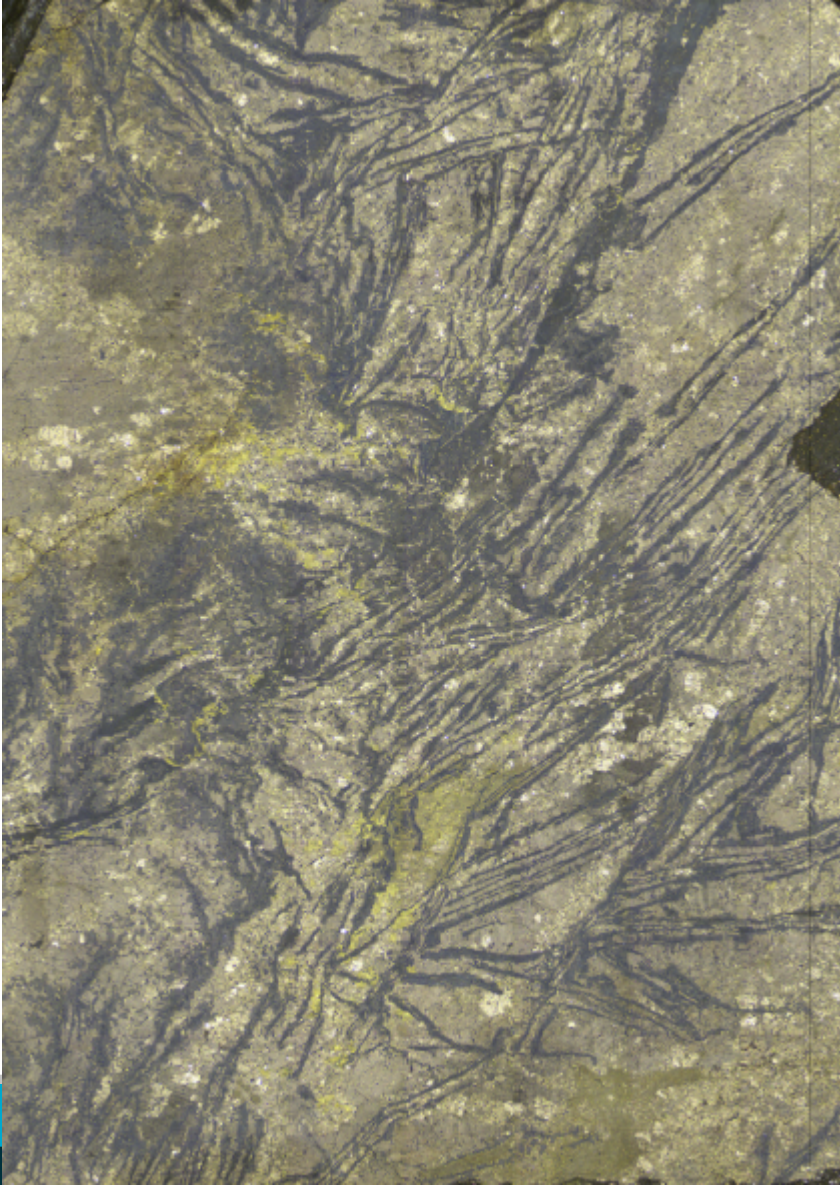


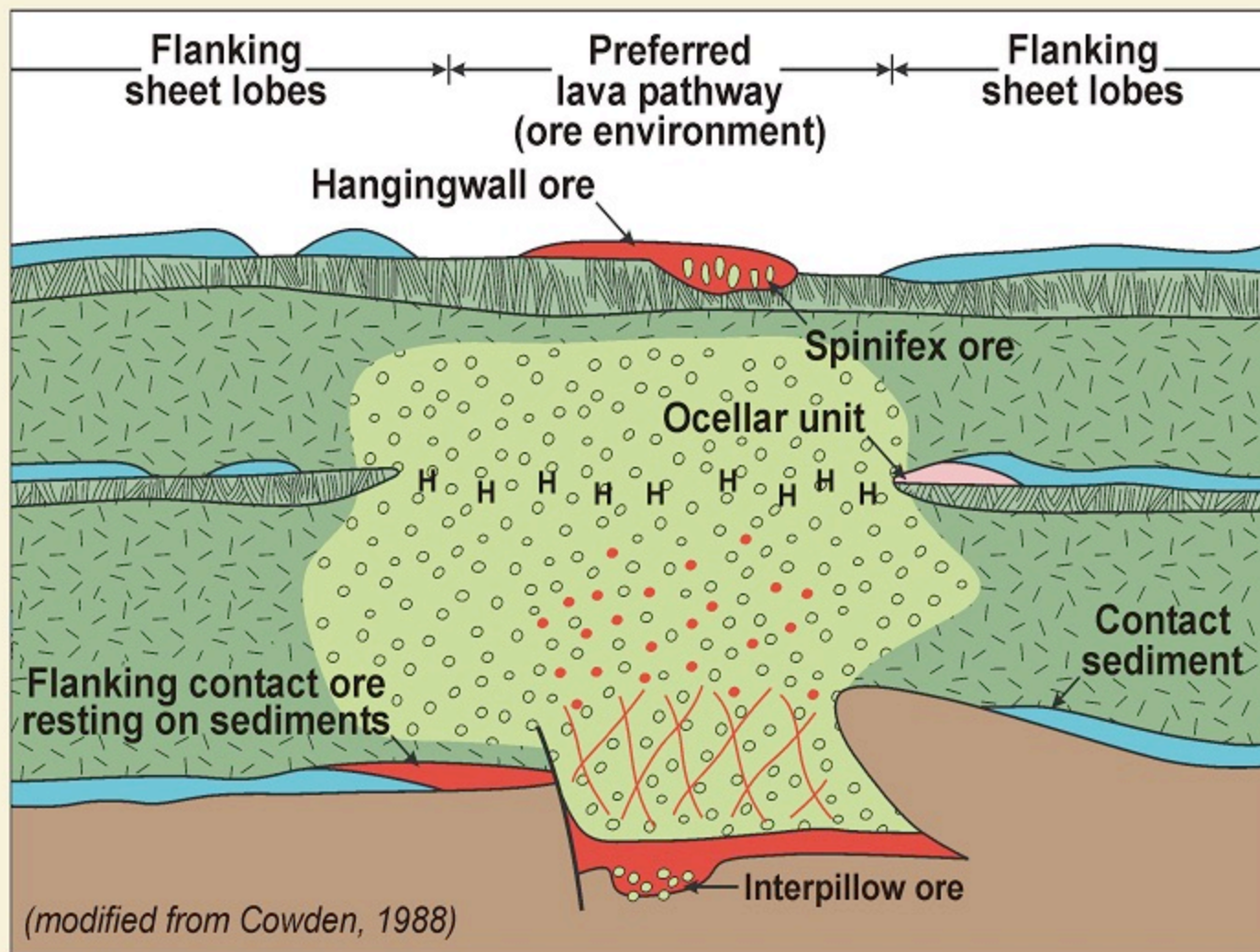
Sul Vein

50 cm

2 cm

Spinifex ores (the smoking gun)





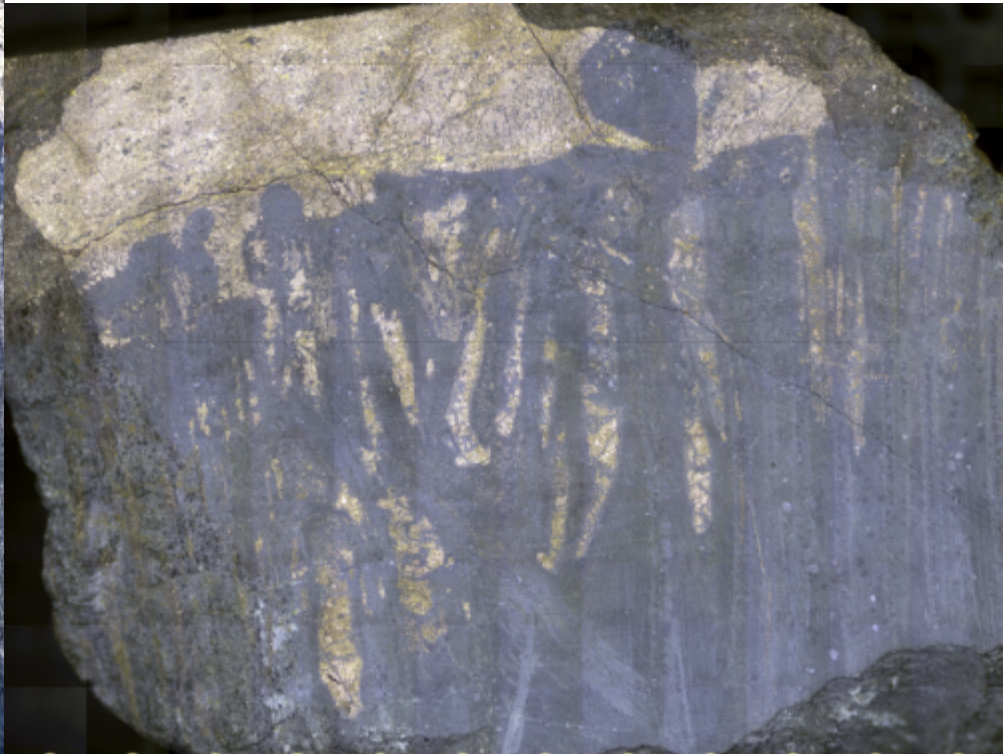
-  Olivine orthocumulate-mesocumulate
-  Thin spinifex-textured flows
-  Flow top

-  Harrisite layer
-  Interflow sediments
-  Basalt

-  Massive ore
-  Matrix ore
-  Disseminated ore

**Sulfide percolation, the smoking
gun: spinifex ore in komatiite
flows (Lunnon and Coronet
Shoots, Kambalda)**

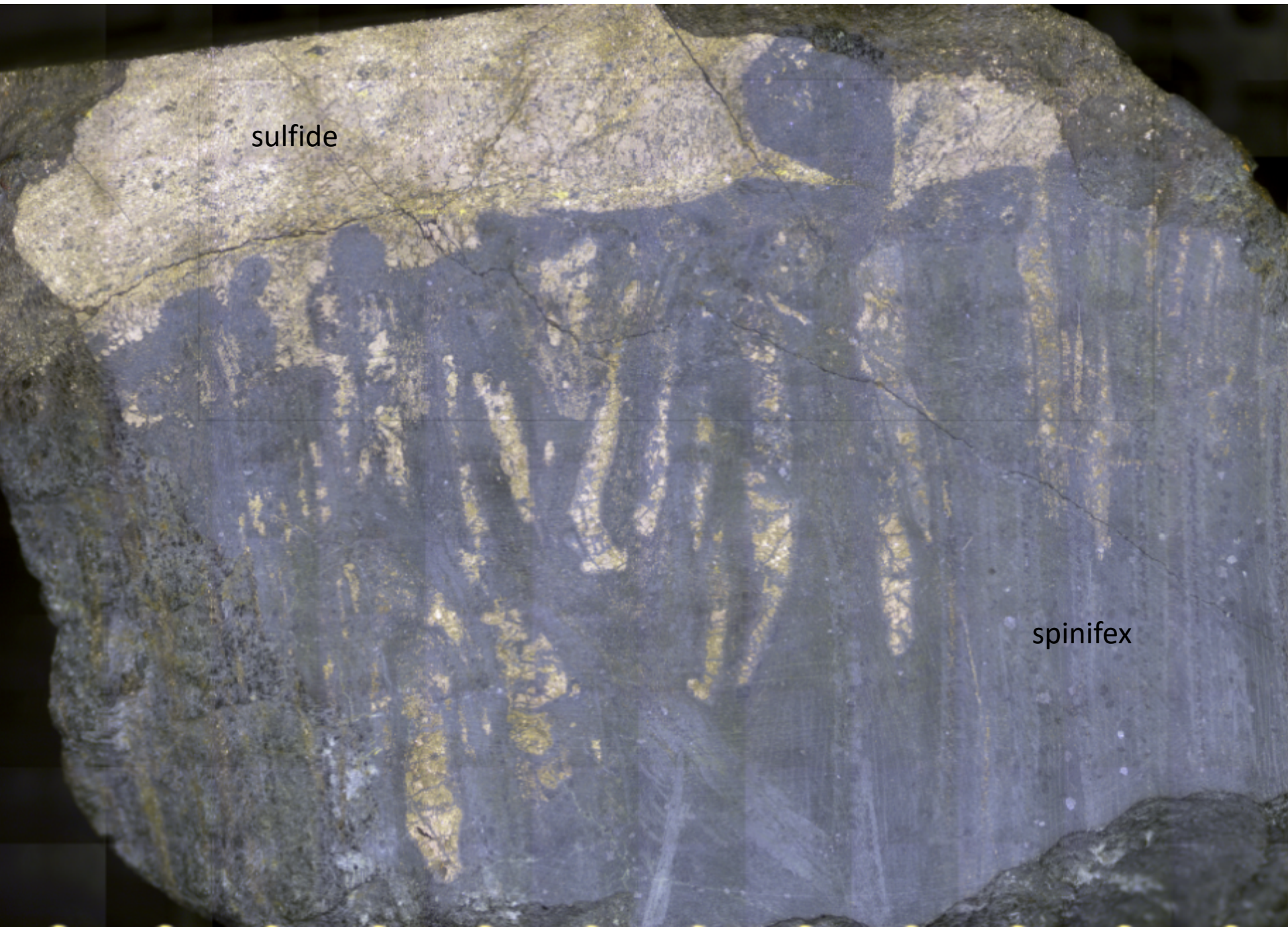
Groves et al, Econ Geol 1986
Barnes et al, Econ Geol 2016



Coronet spinifex ore (sample from Steve Beresford)

sulfide

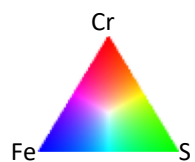
spinifex



Sulfide

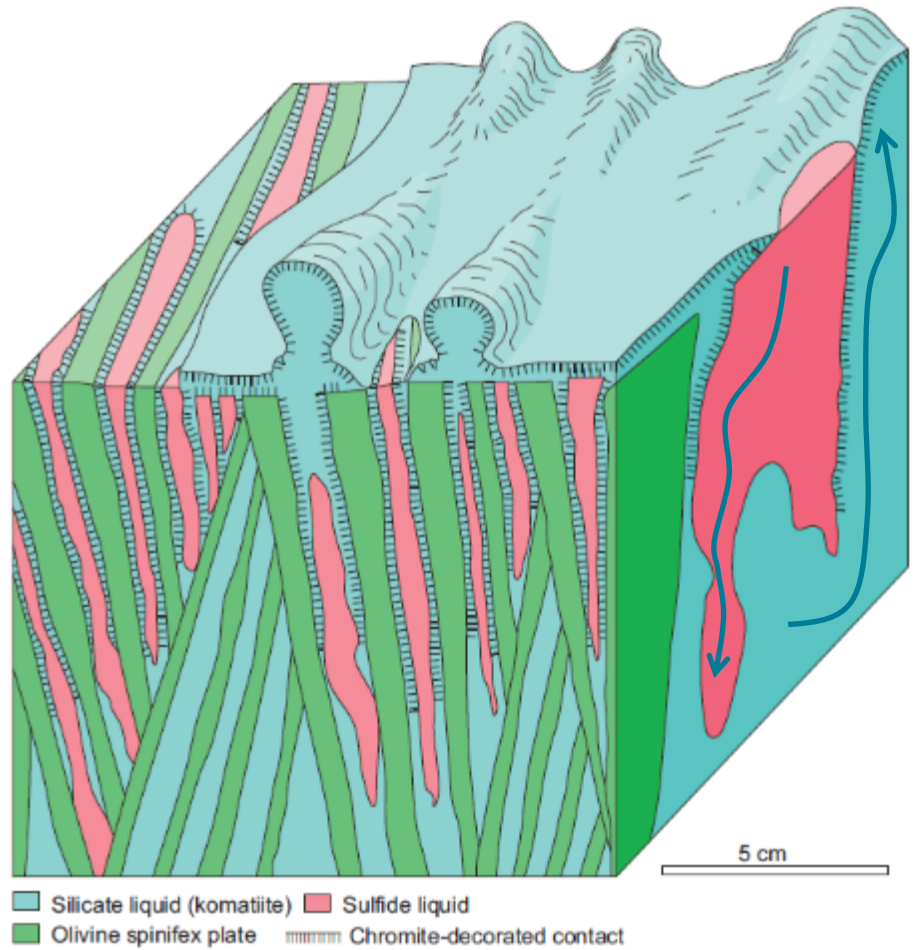
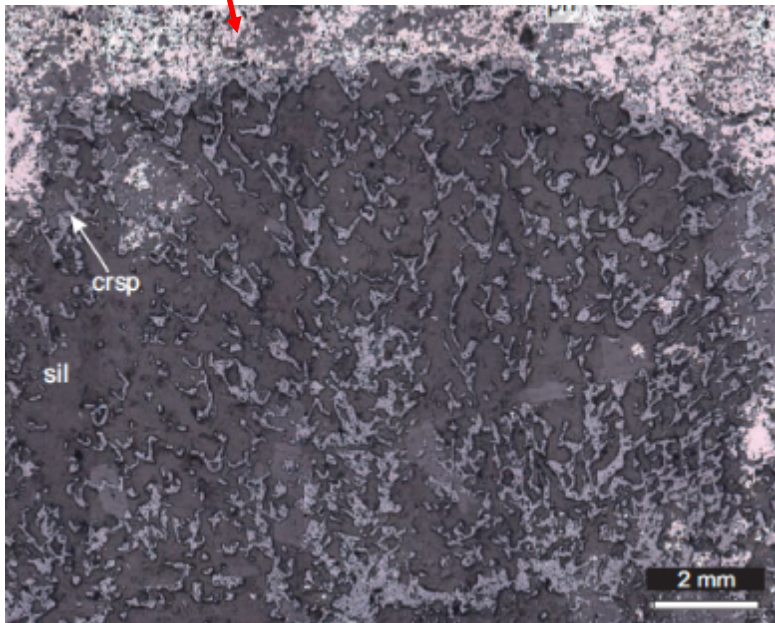
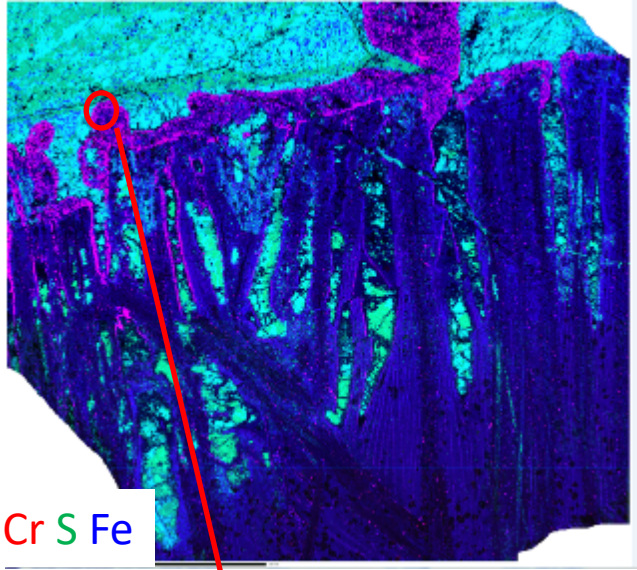
Silicate melt
film with
dendritic
chromite

Sulfide
almost
entirely
interstitial
to spinifex
plates
(apart from
a few late
veinlets)



10 cm

Cr S Fe



A



Massive ore

Msul

Random spinifex ore

rspxo

pspxo,
bent

Msul vein

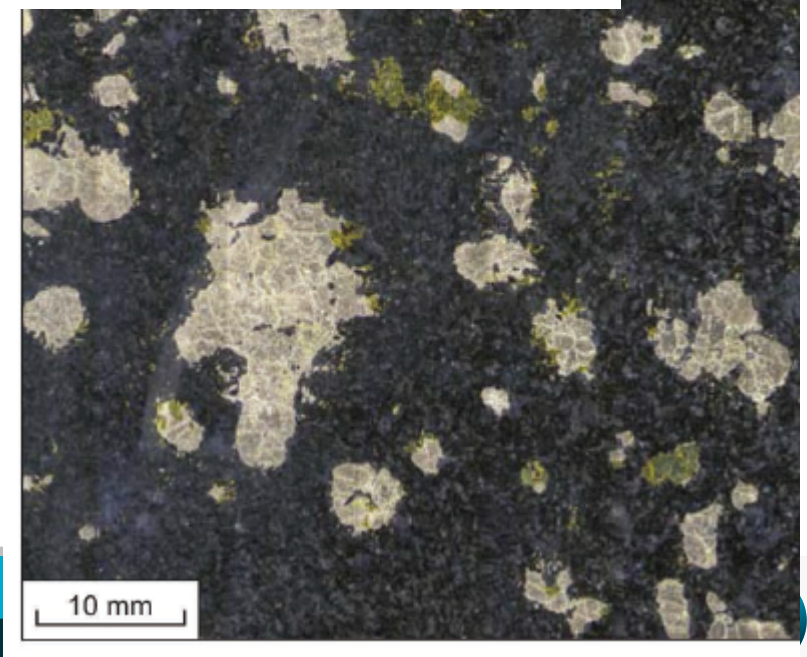
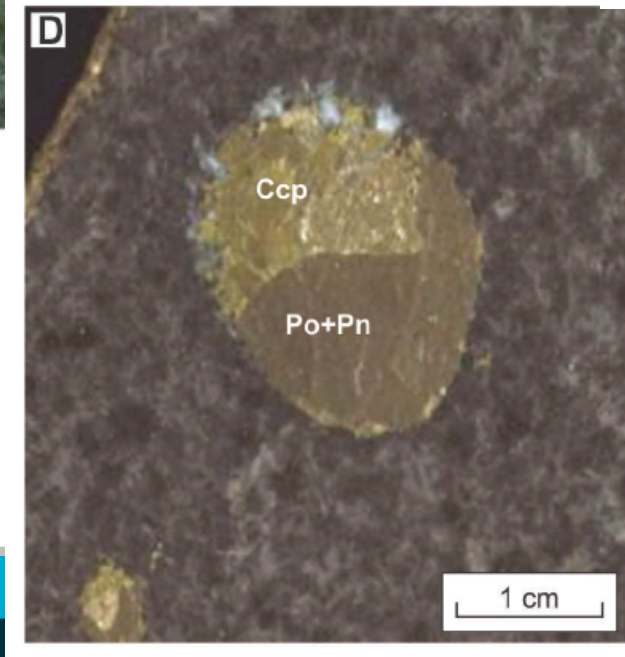
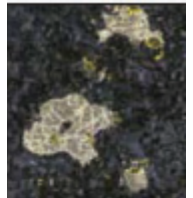
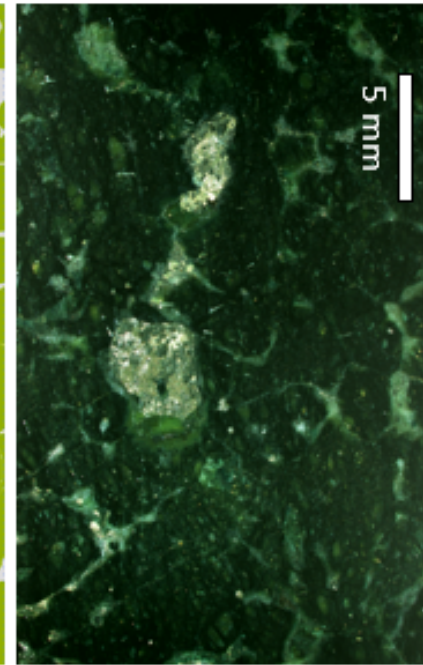
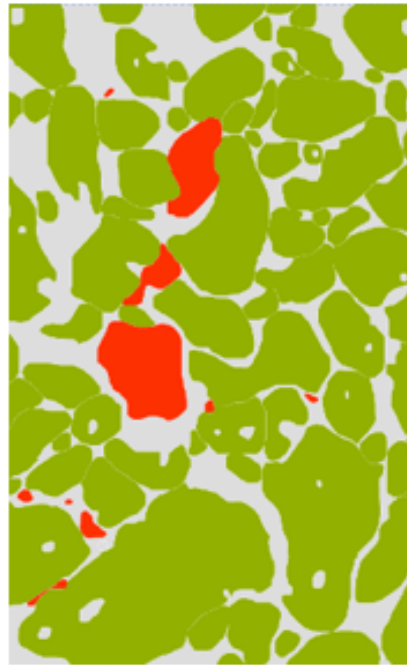
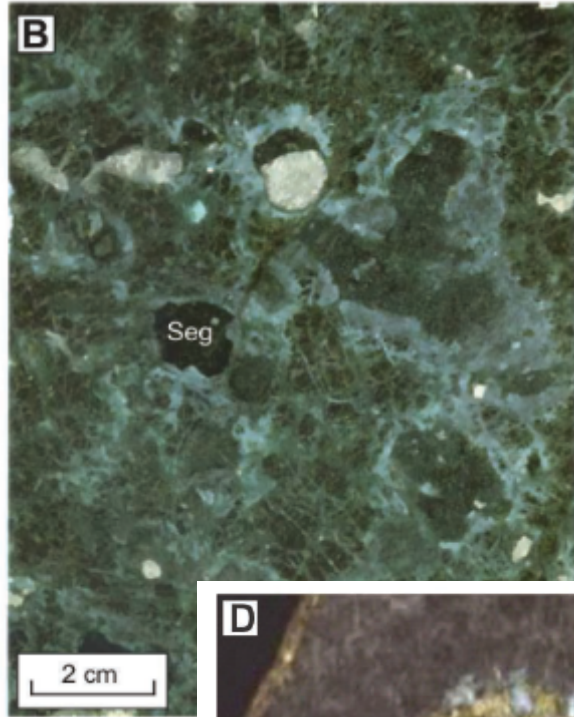
plate spinifex ore

pspxo

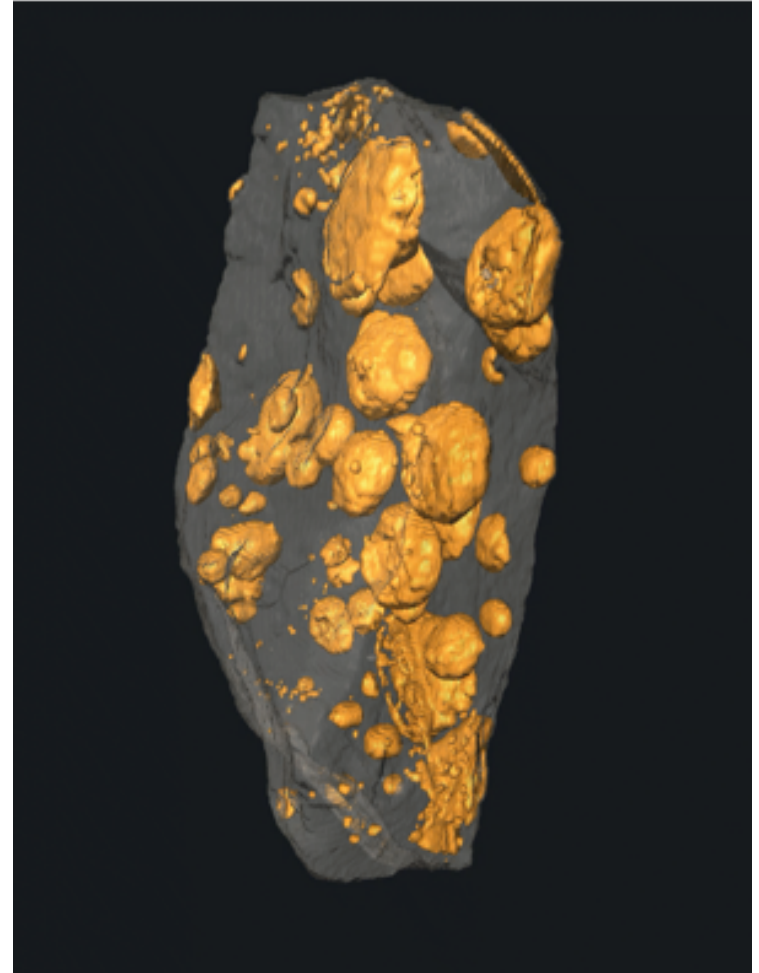
~10 cm

Coronet
Massive sulfide
vein in spinifex
ore

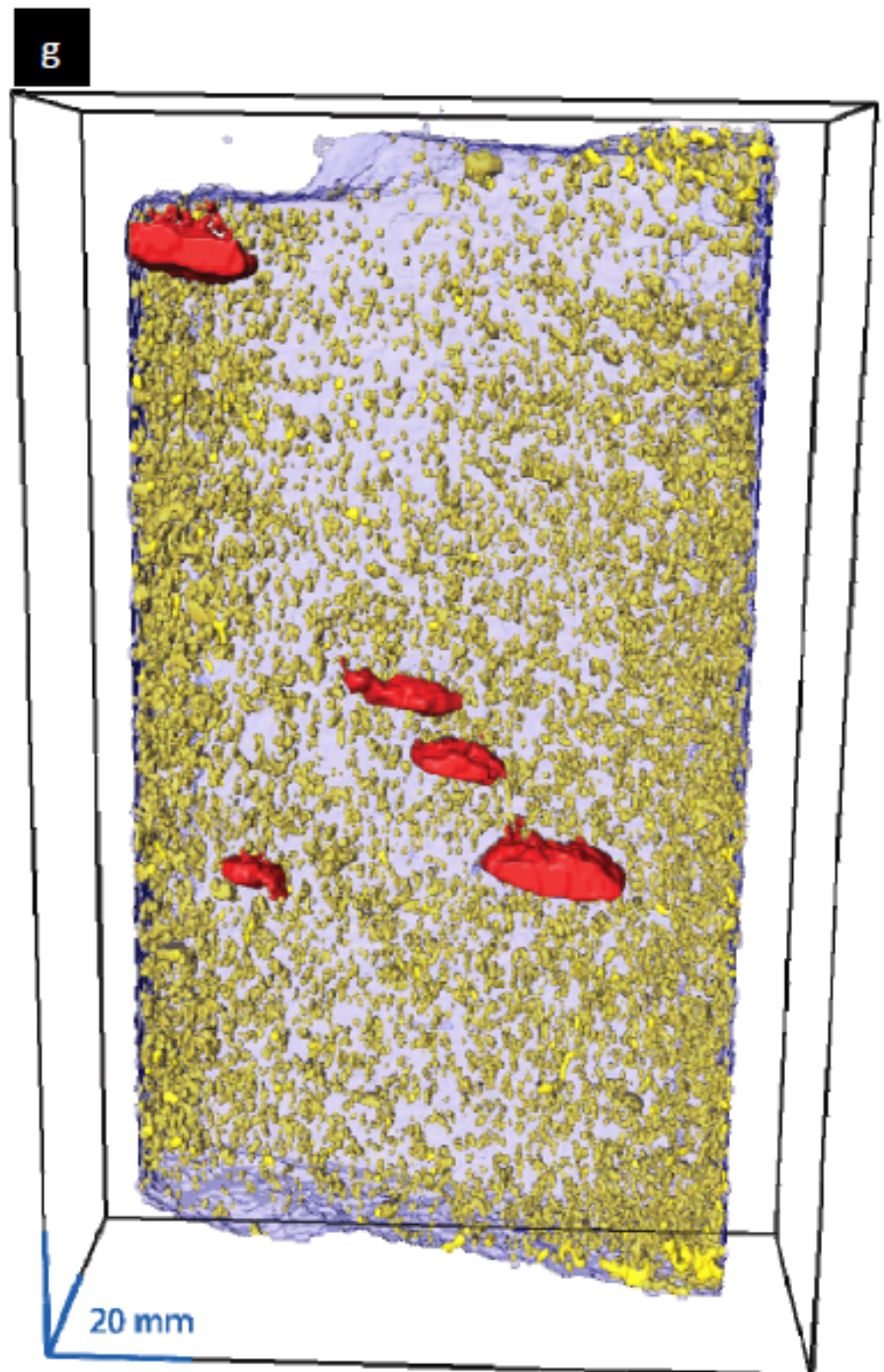
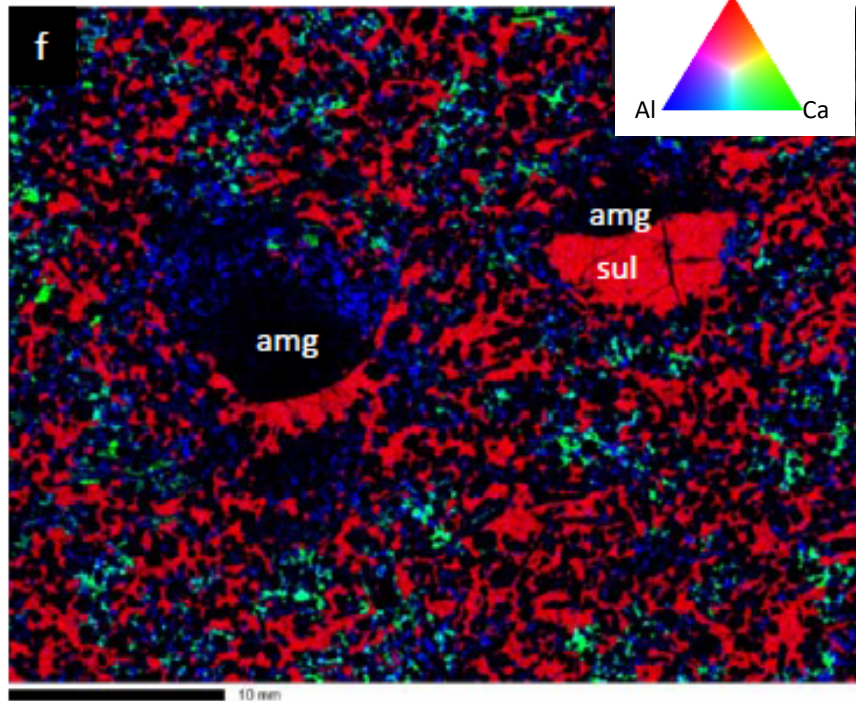
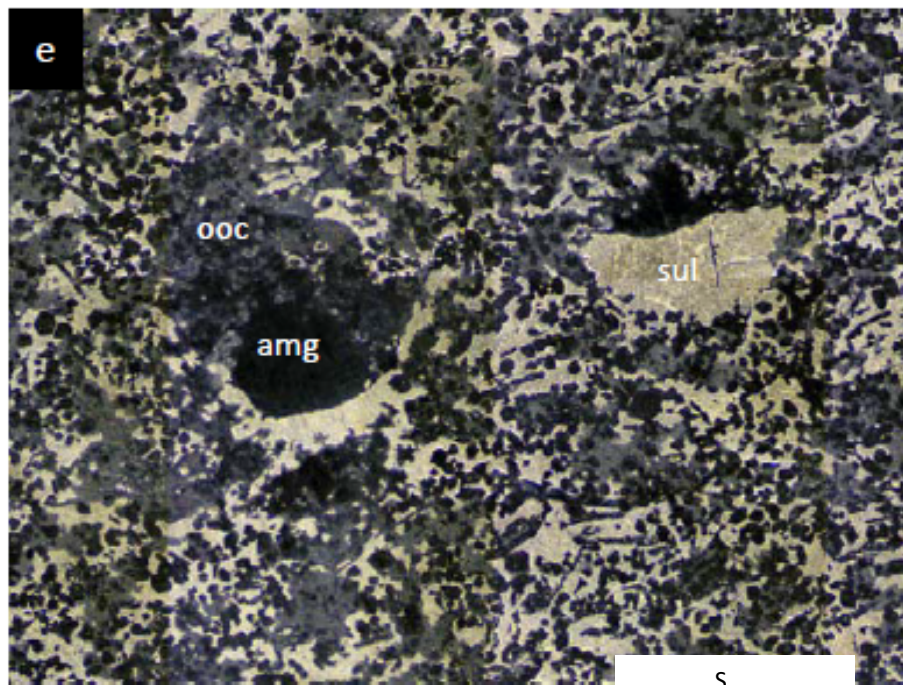
Globular disseminated ores



Low-resolution X-ray computed tomography at 200 micron resolution using medical scanning technology

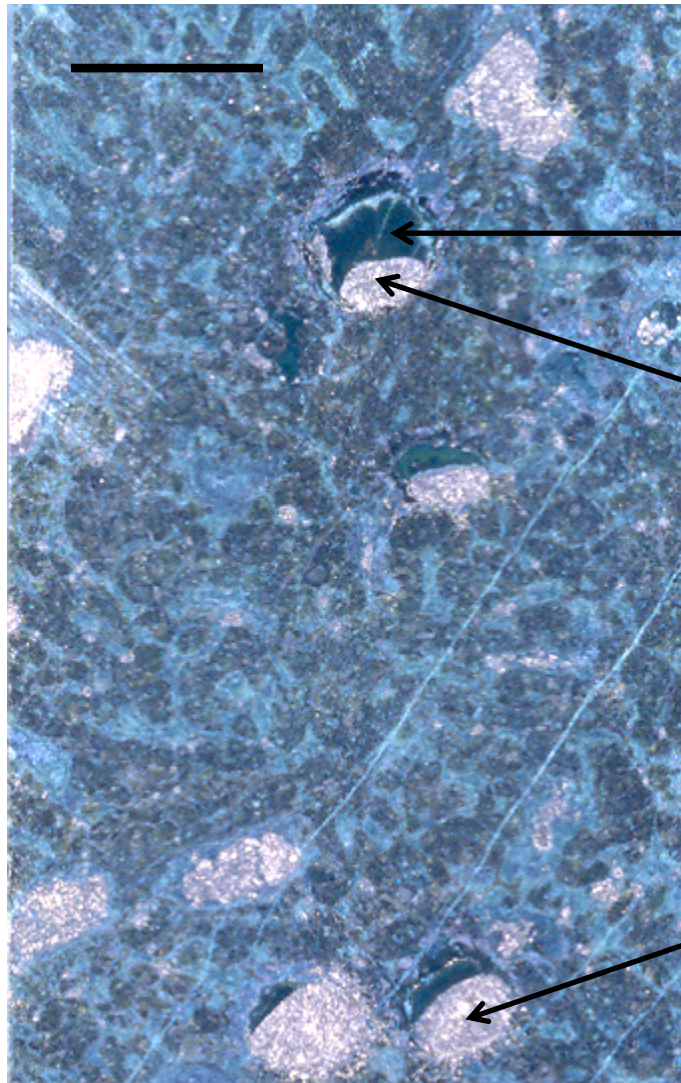


Globular sulfide ores

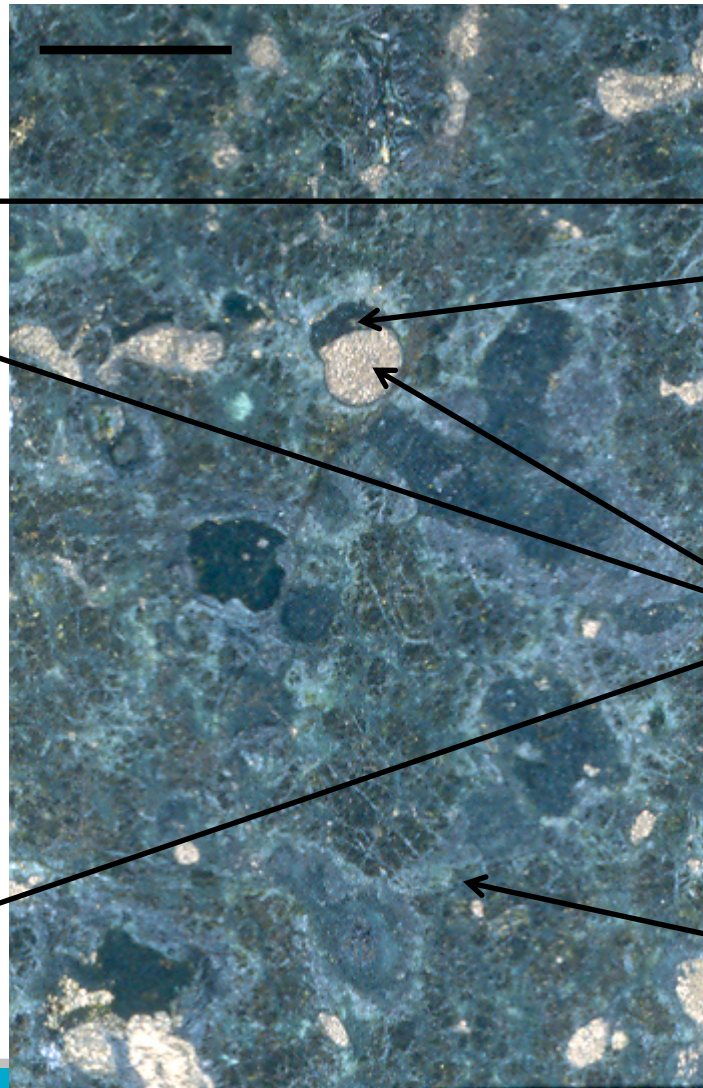


Black Swan nickel sulfide deposit, WA – capped globules -sulfide droplets inside vestigial gas bubbles.

Barnes et al, 2009, 2017



Scale bar 2 cm

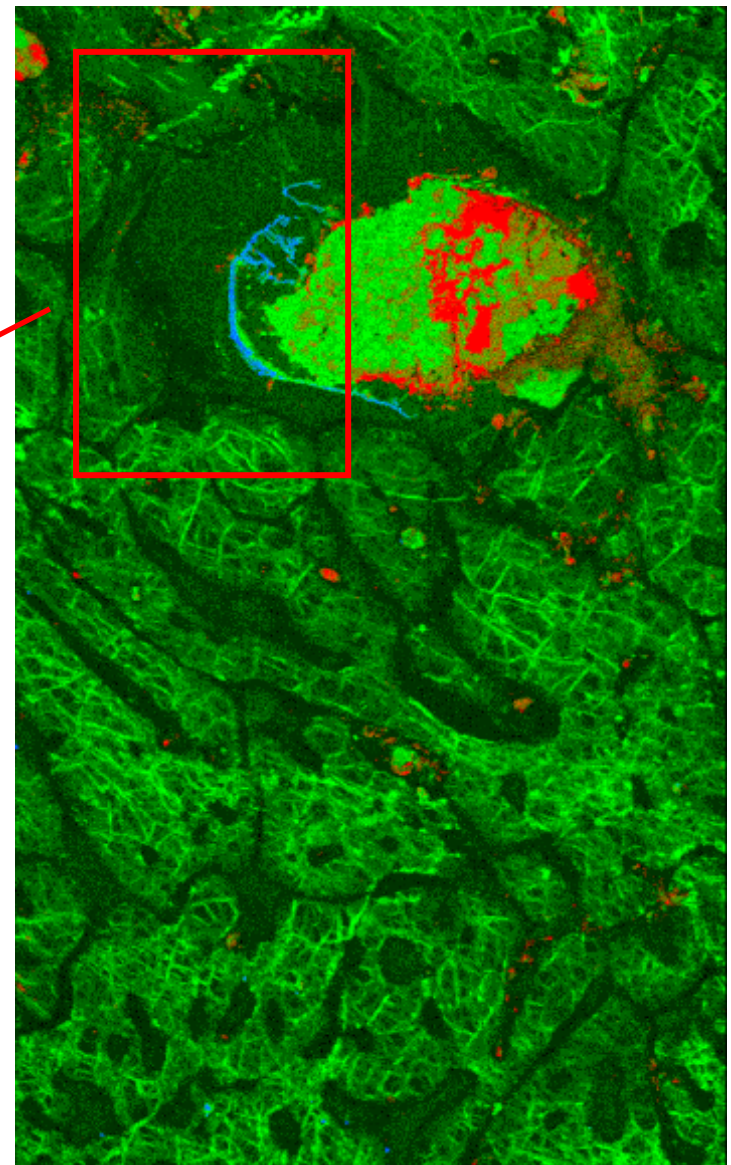
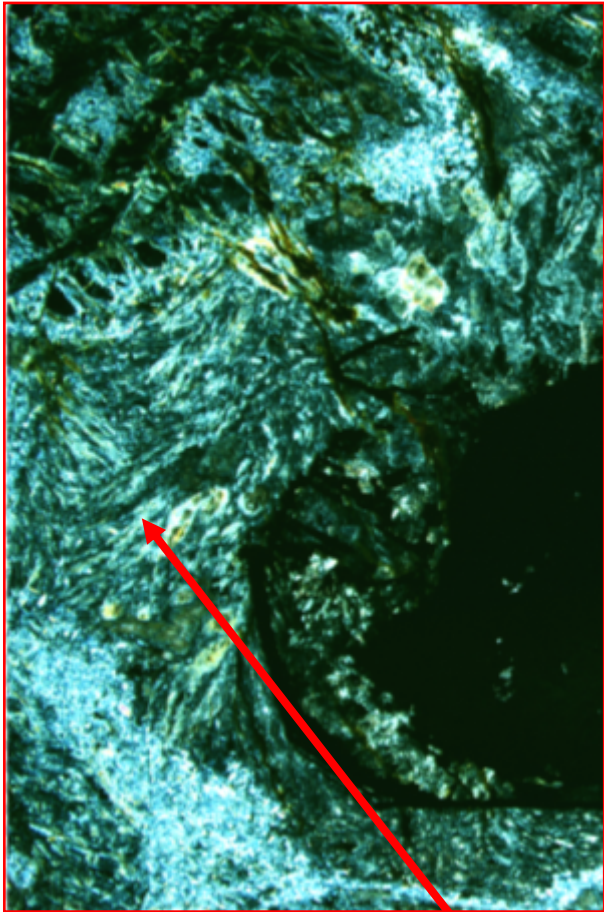


Original volcanic gas bubbles (now filled in by low temperature silicate minerals)

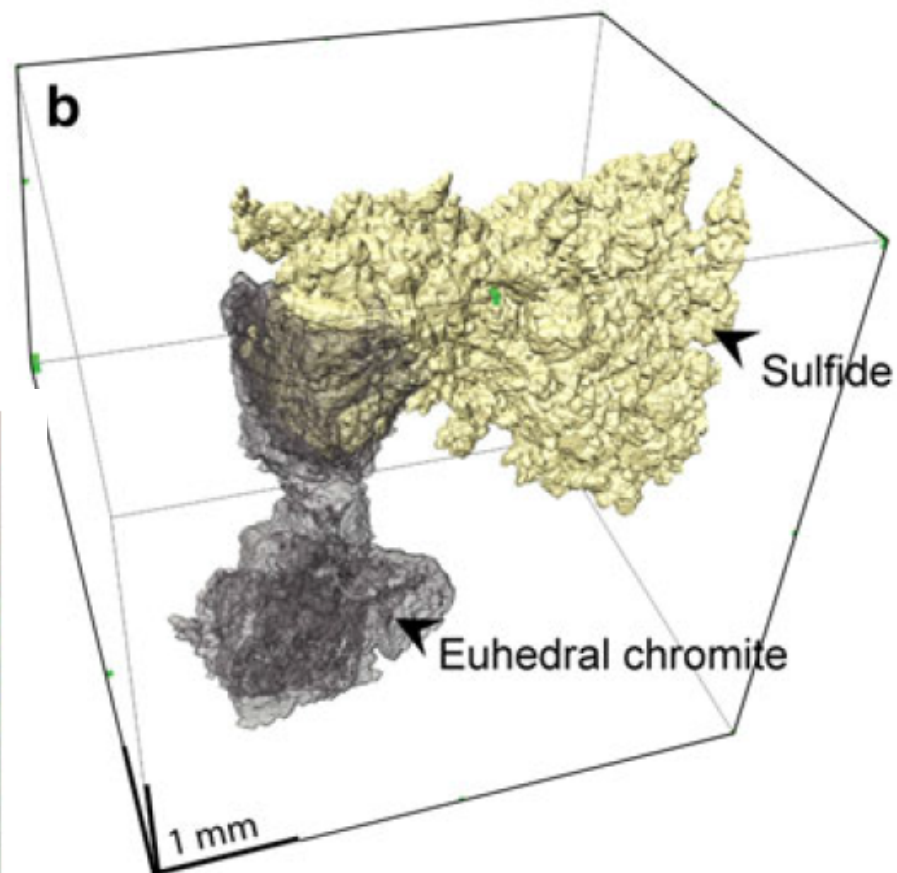
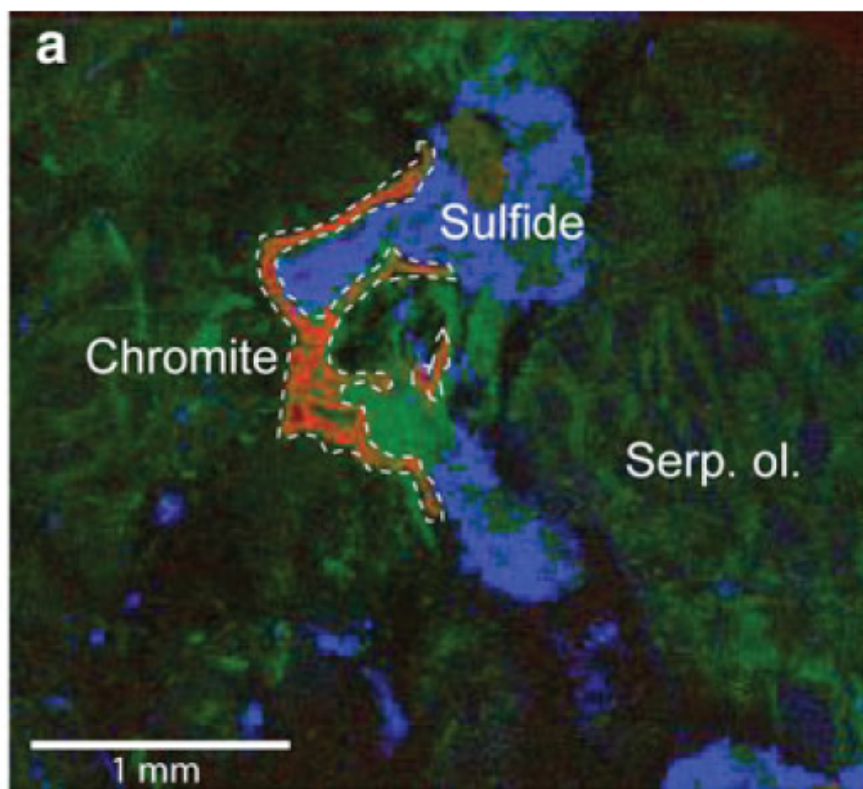
Sulfide minerals crystallised from original droplets of molten iron-nickel sulfide (natural matte)

Crystallisation products of the original silicate magma(natural slag)

Disseminated ores, Black Swan(Australia)
Sulfide globules attached to filled gas bubbles



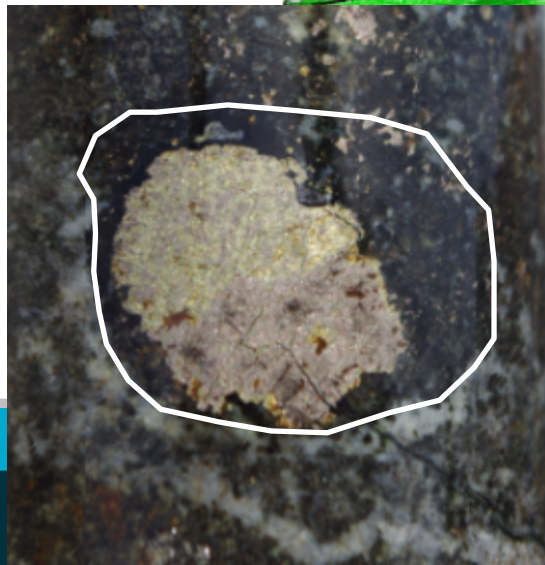
Relic pyroxene microspinel texture after komatiite liquid



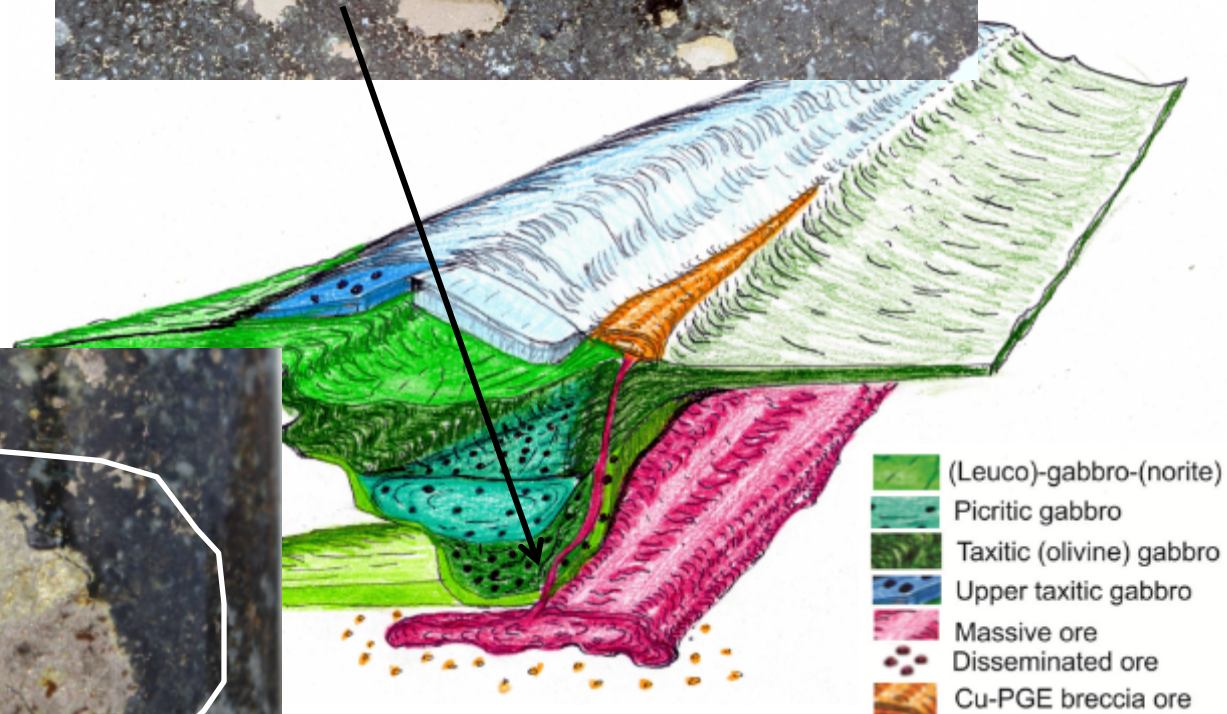
Globular disseminated sulfide ores

Noril'sk

Le Vaillant et al PNAS 2017
and in prep.



2 cm



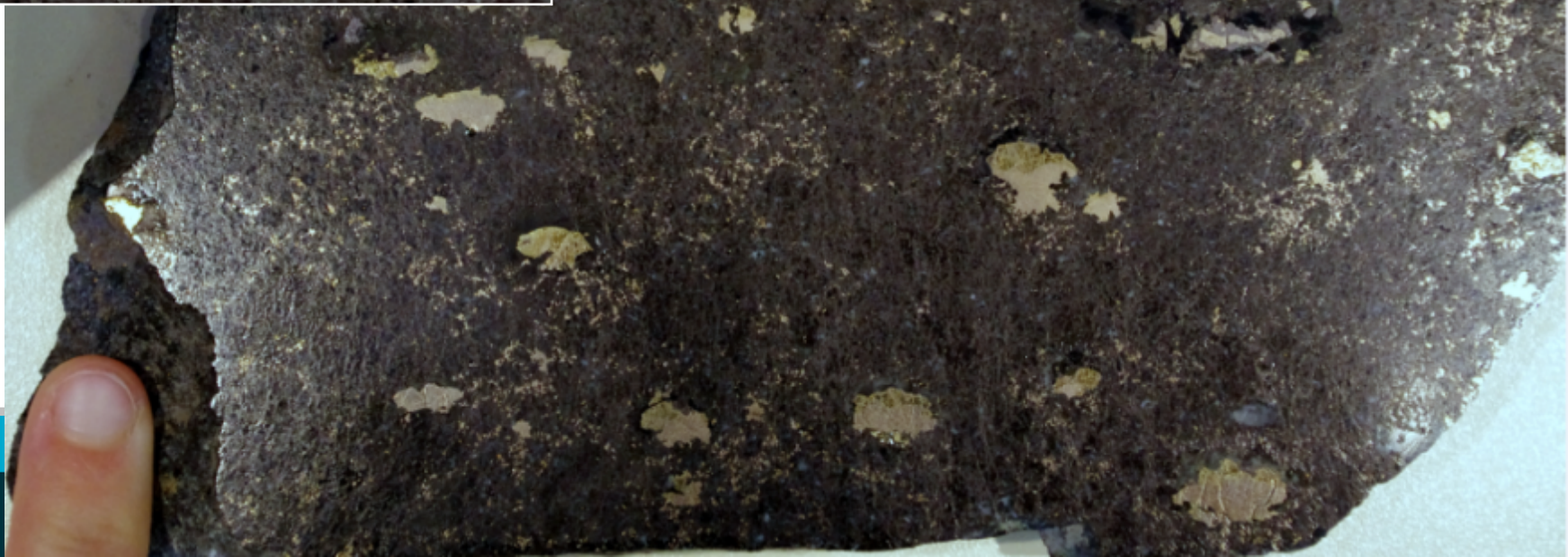
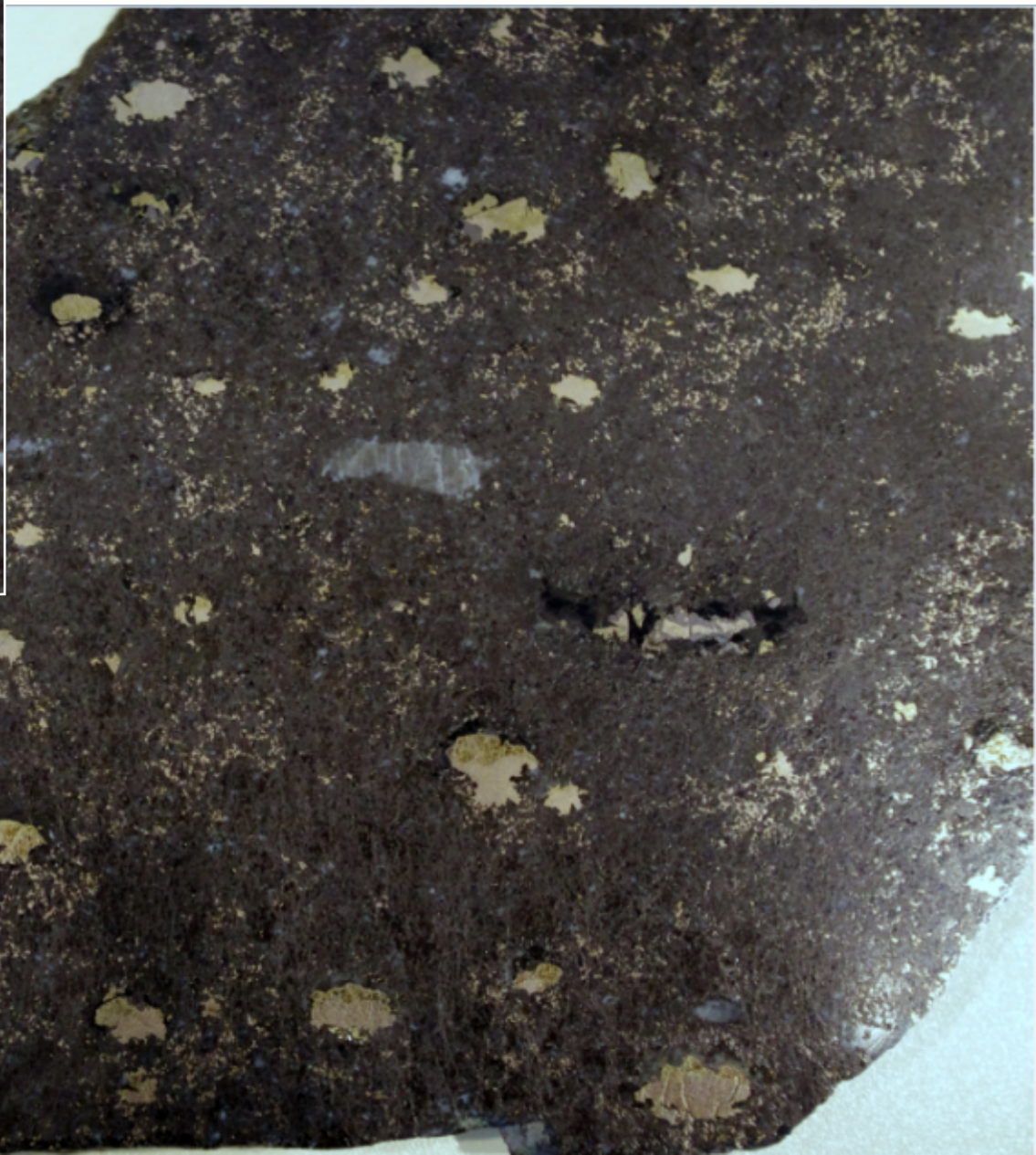
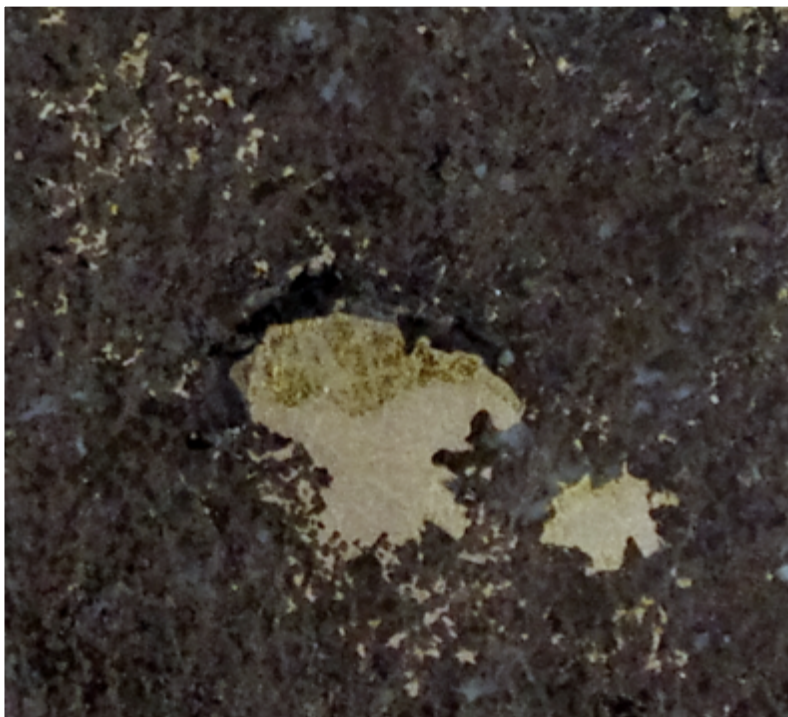
Taxitic olivine gabbro with
sulfide blebs



Differentiated sulfide blebs
with silicate caps

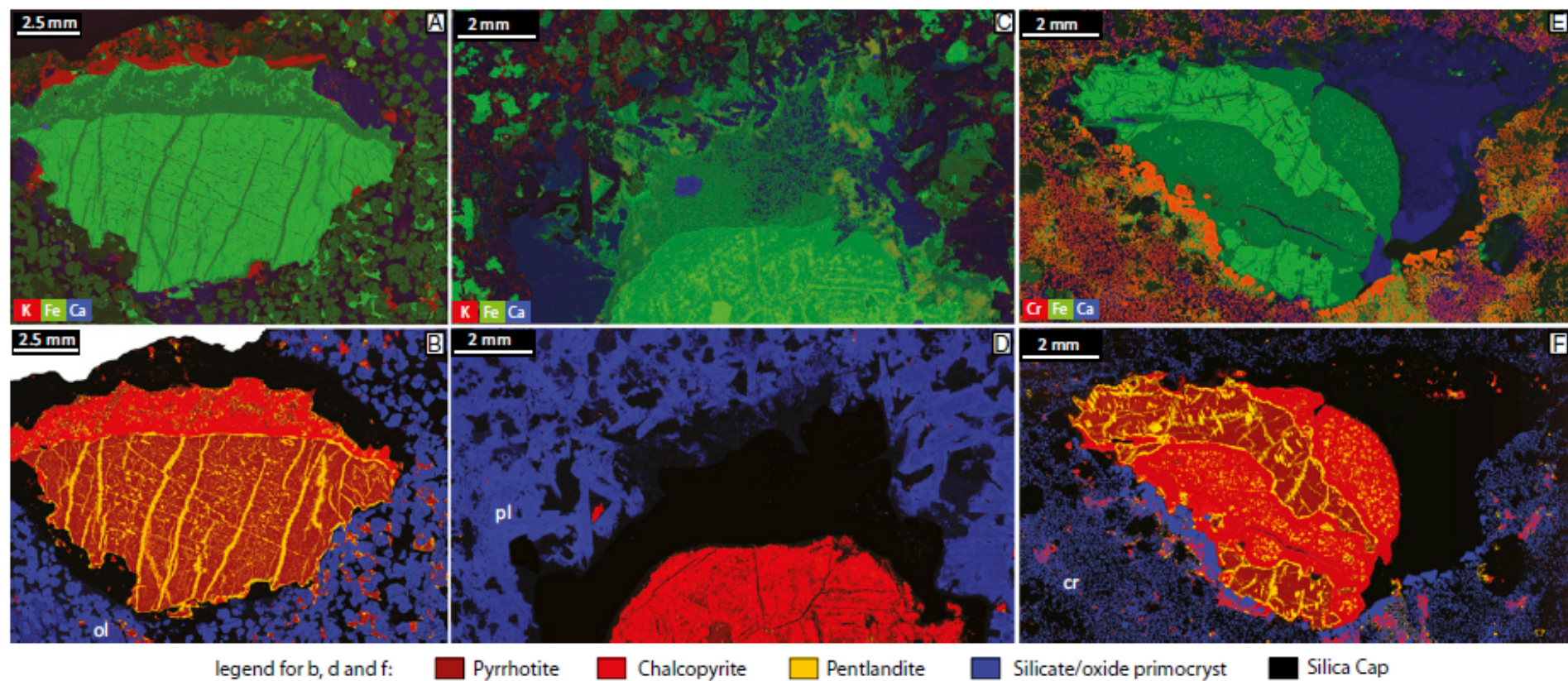


Differentiated sulfide blebs with
silicate caps, bimodal sulfide texture

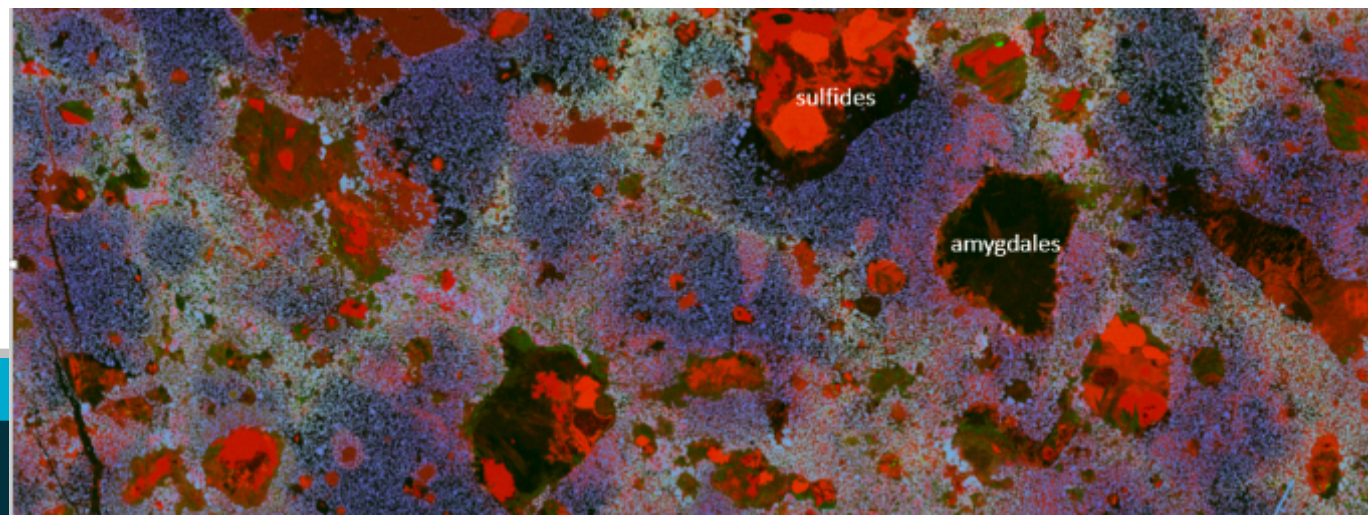


Noril'sk-Talnakh ore textures

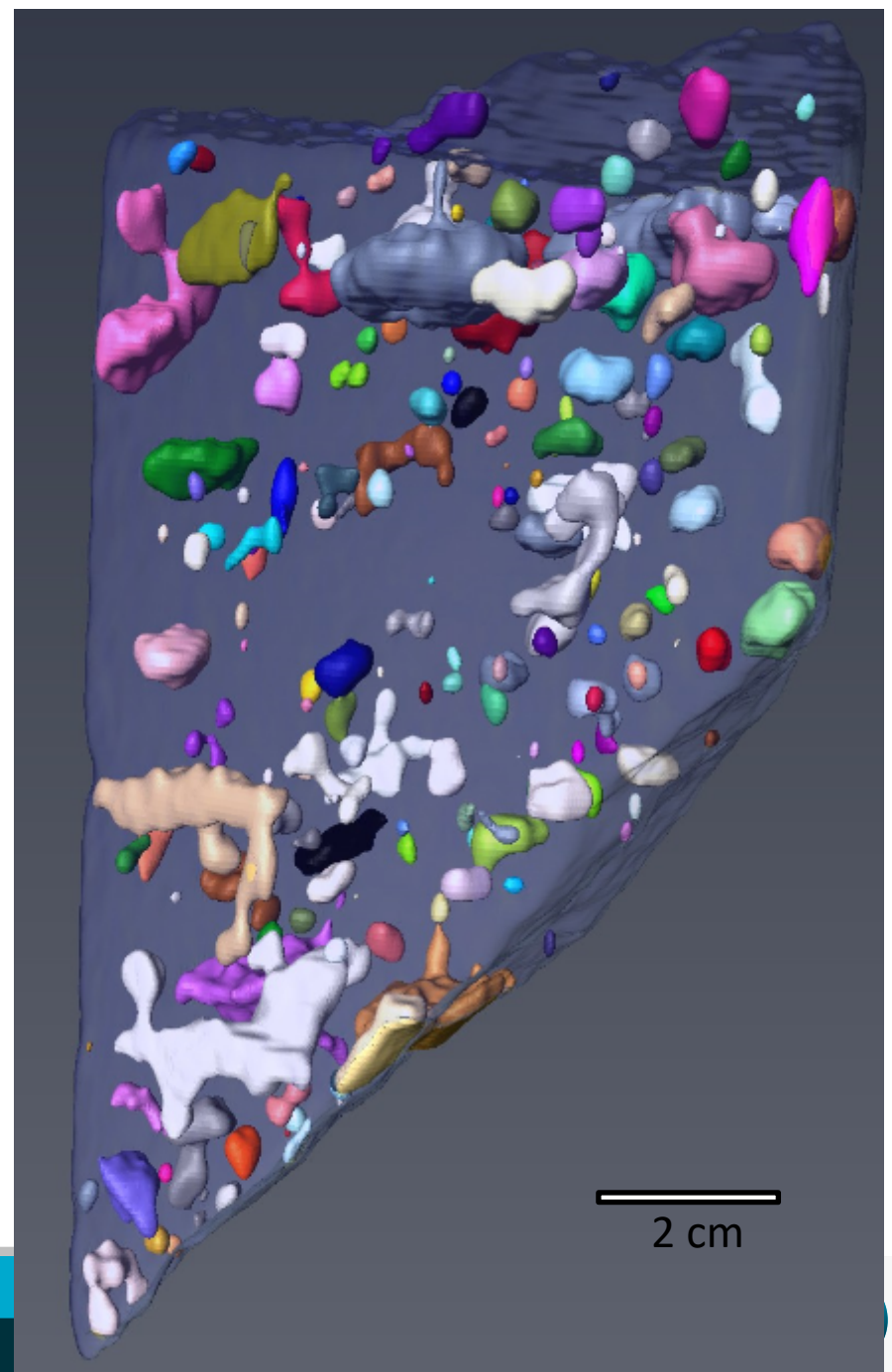
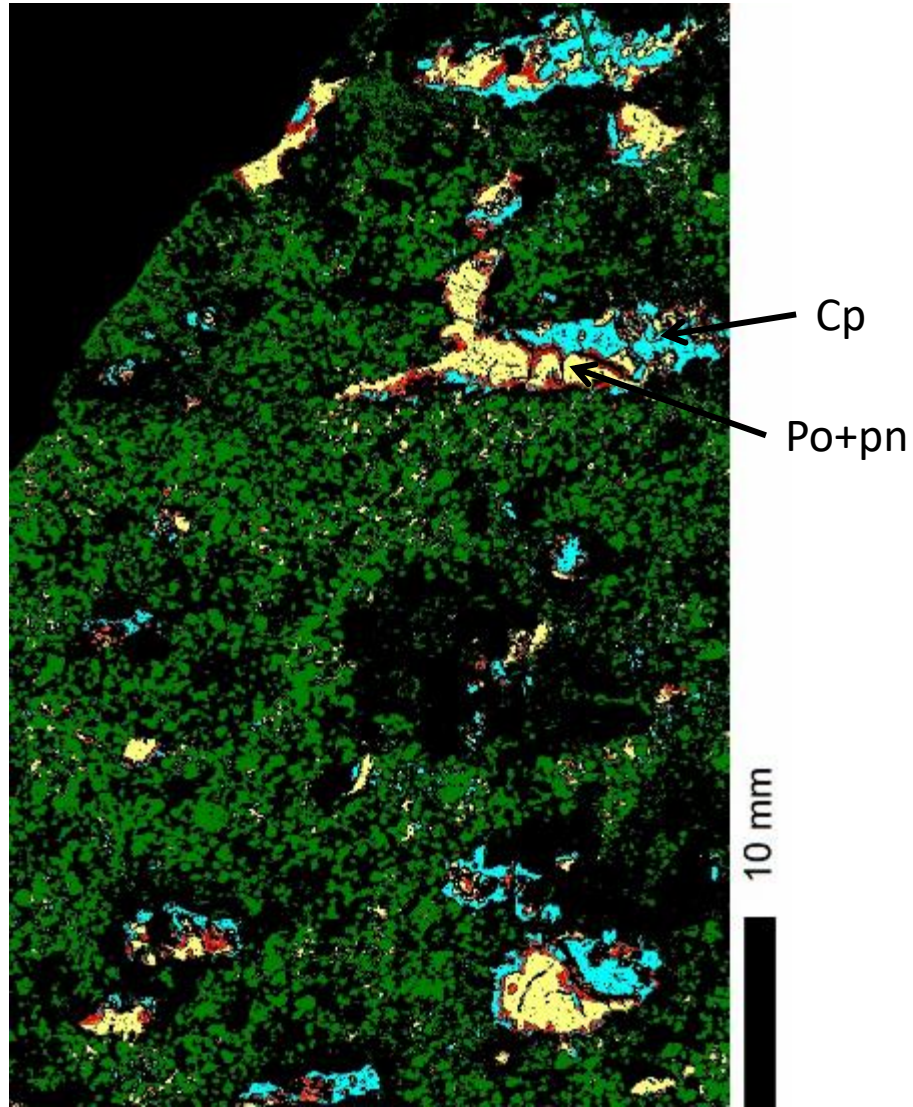
Differentiated sulfide blebs inside segregation vesicles

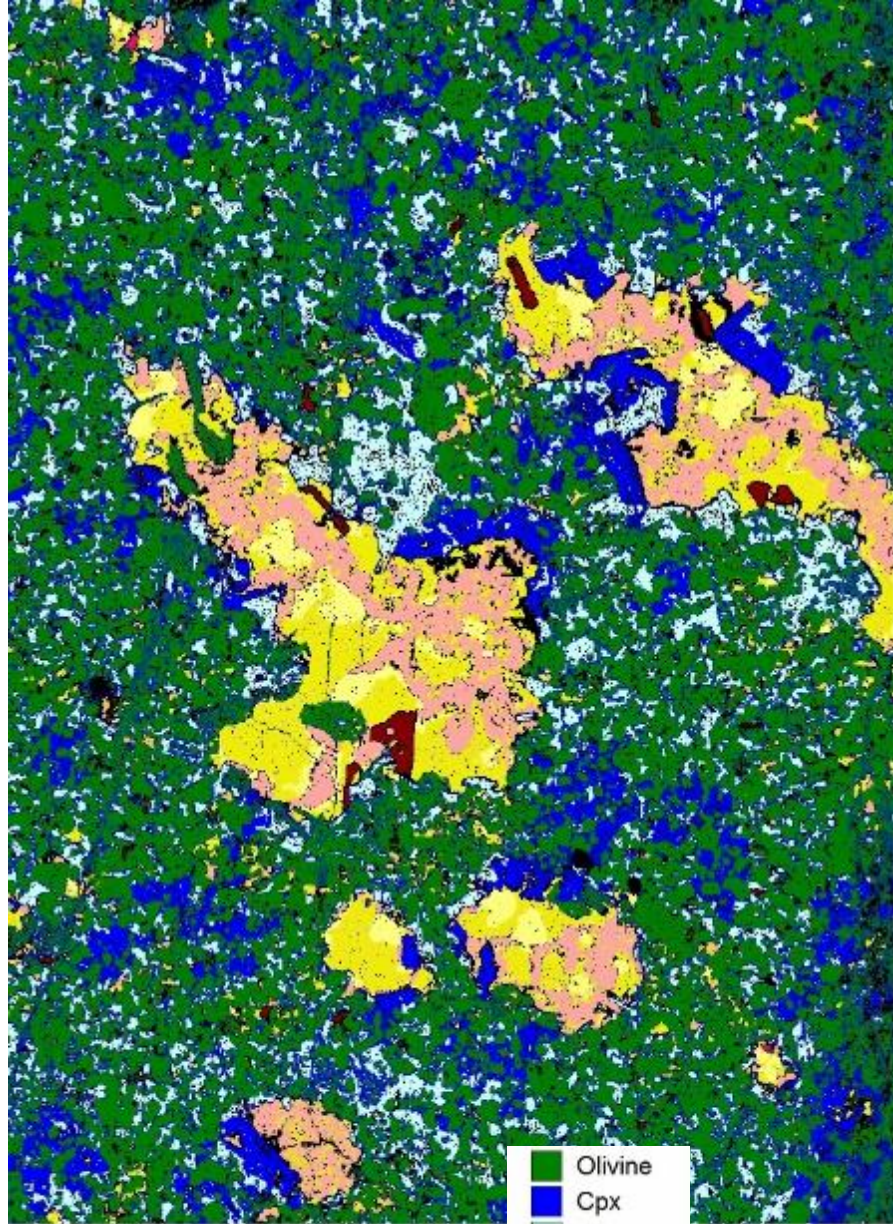


Le Vaillant et al.,
PNAS 2017



Noril'sk-Talnakh ore textures

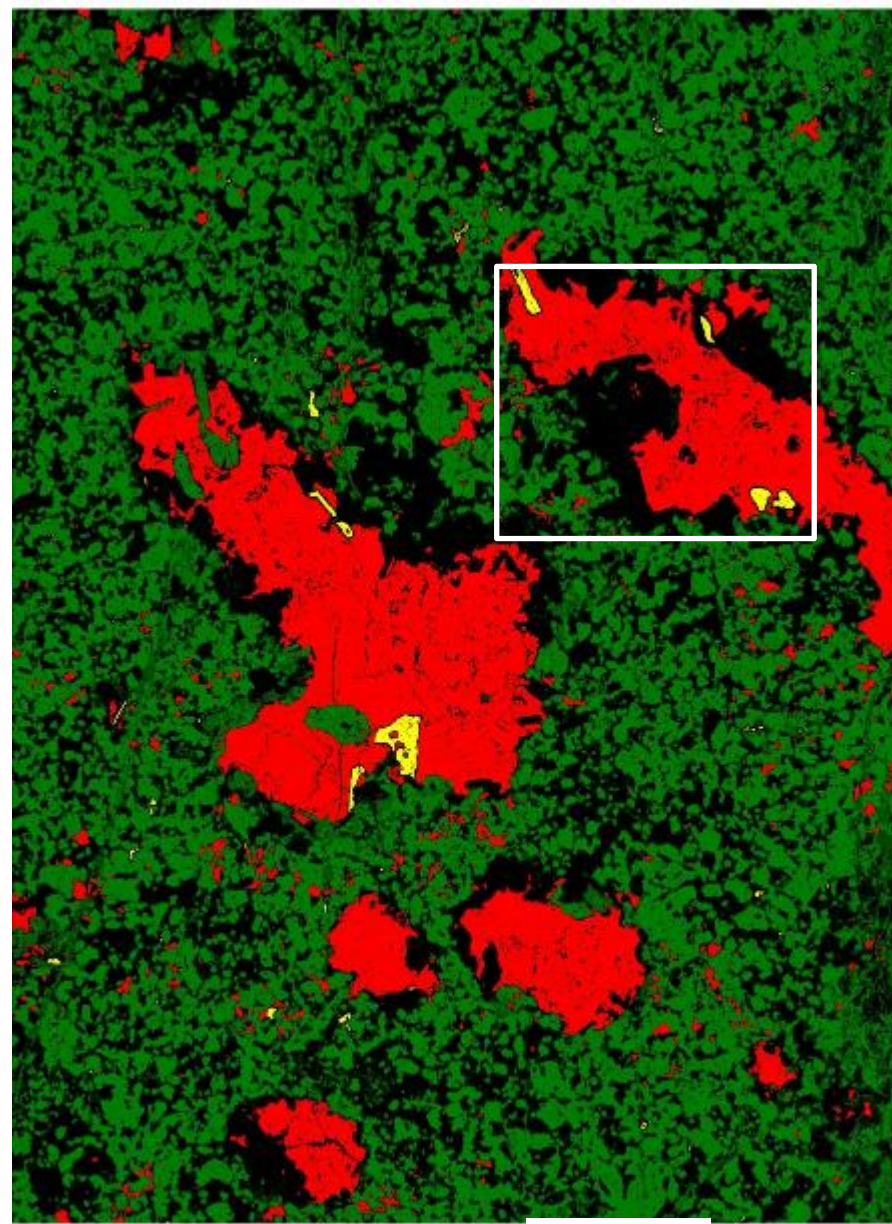




10 mm

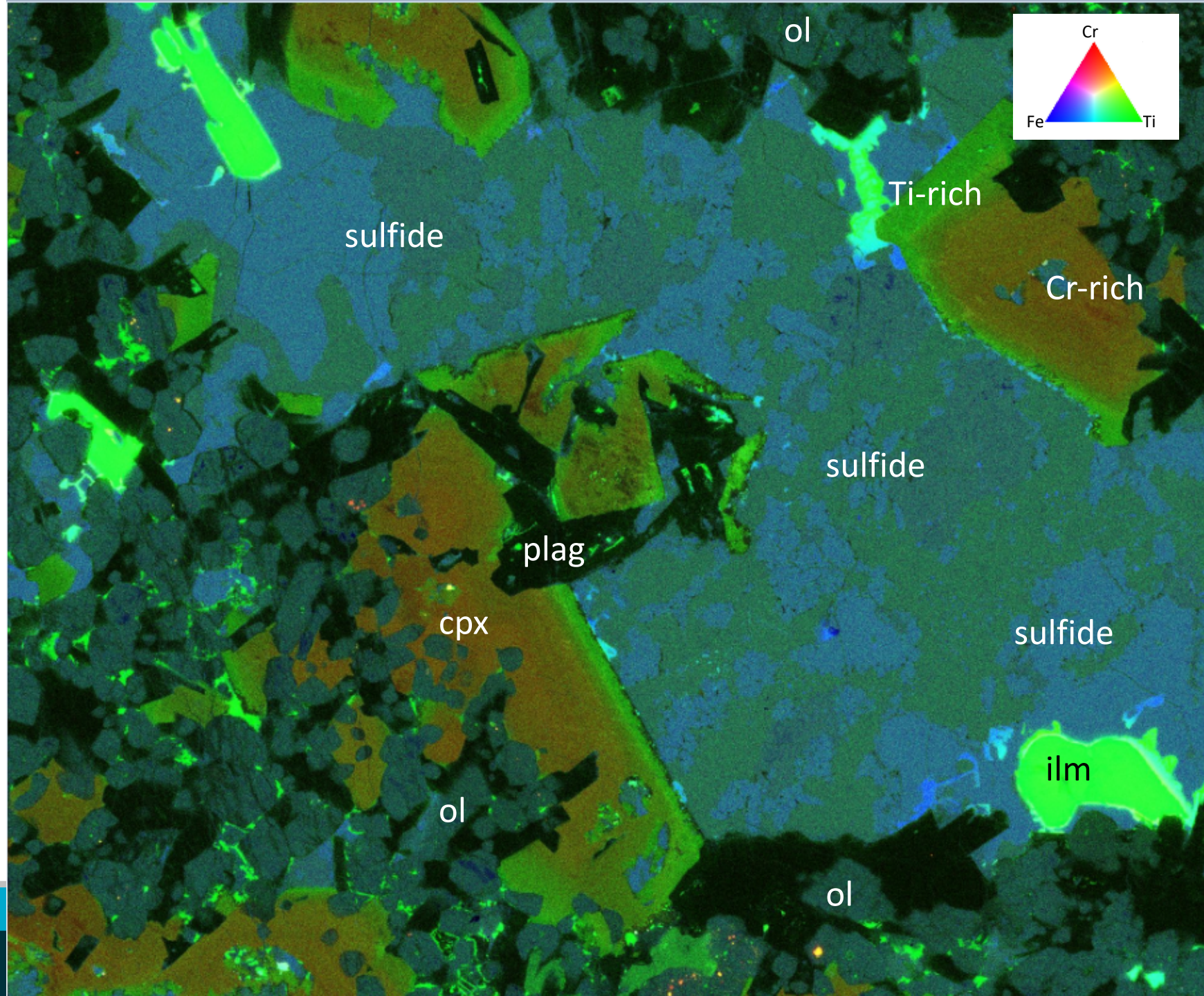
- Olivine
- Cpx
- Plag
- Po
- Cp
- Pn
- Apatite
- Ilmenite

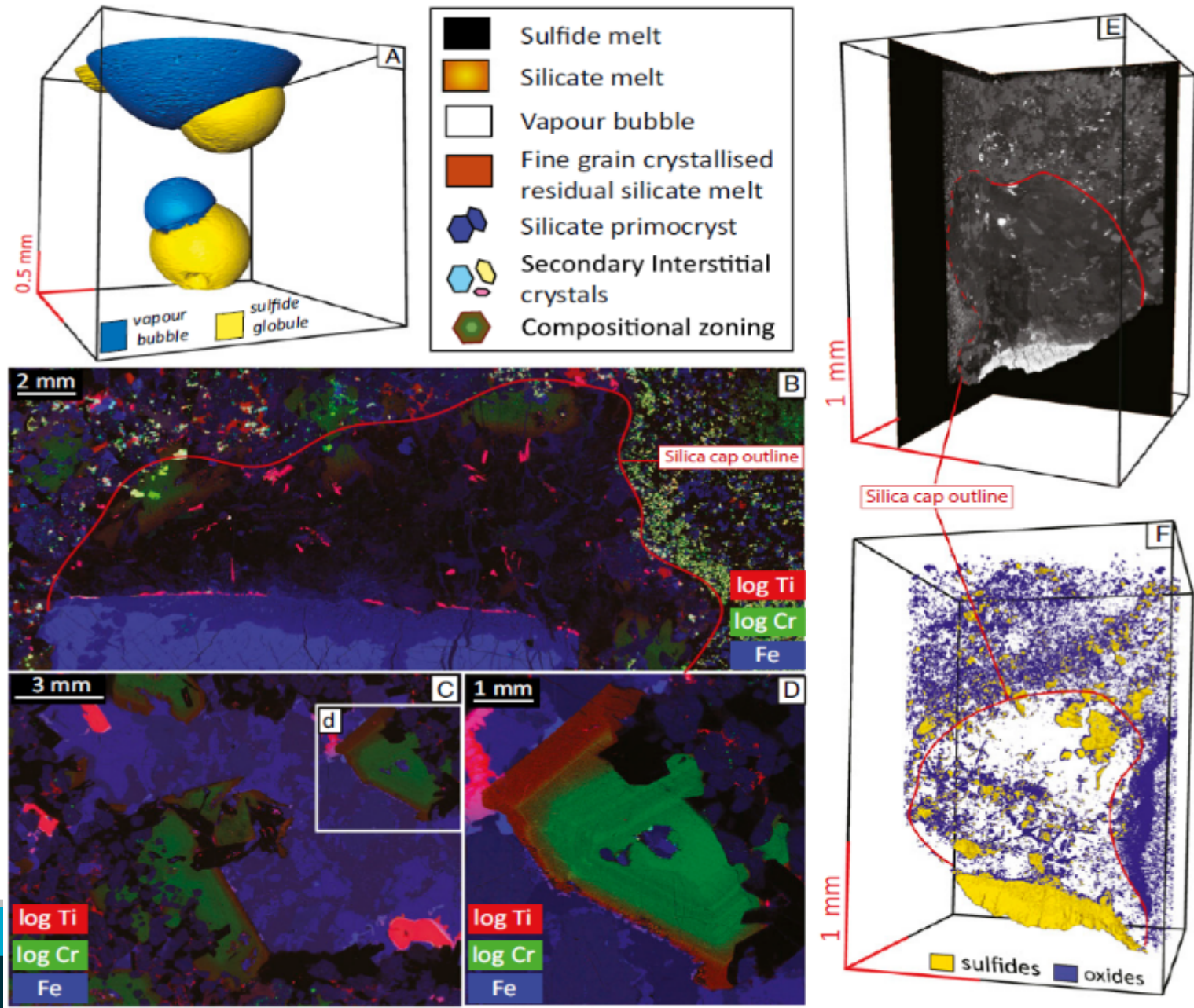
VZU3c



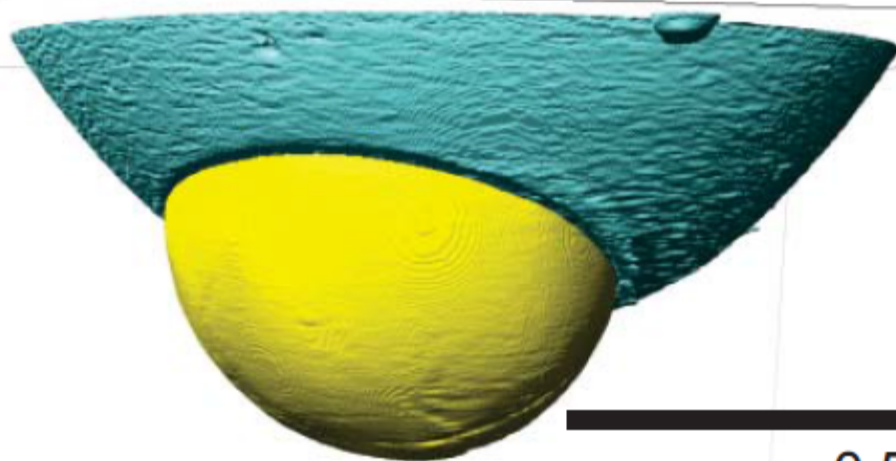
10 mm

- Olivine
- Ilmenite
- sulfide



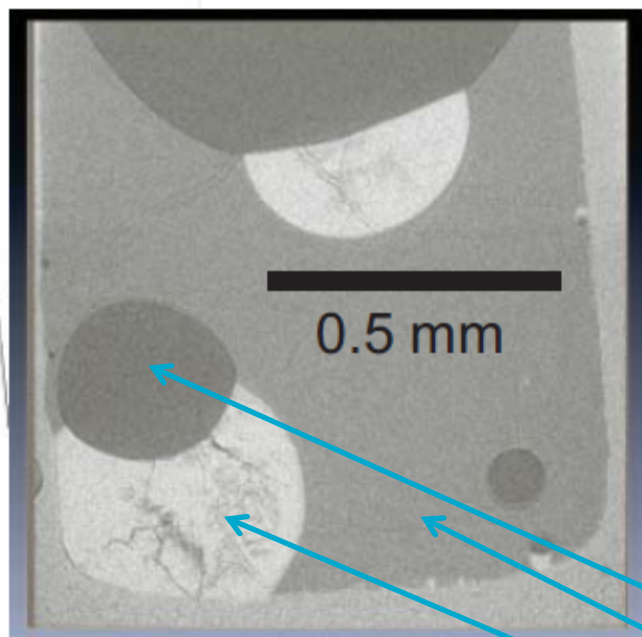


a



0.5 mm

Experiments
with sulfide
droplets and
vapour bubbles
(Mungall et al Nature
Geoscience 2015)



0.5 mm



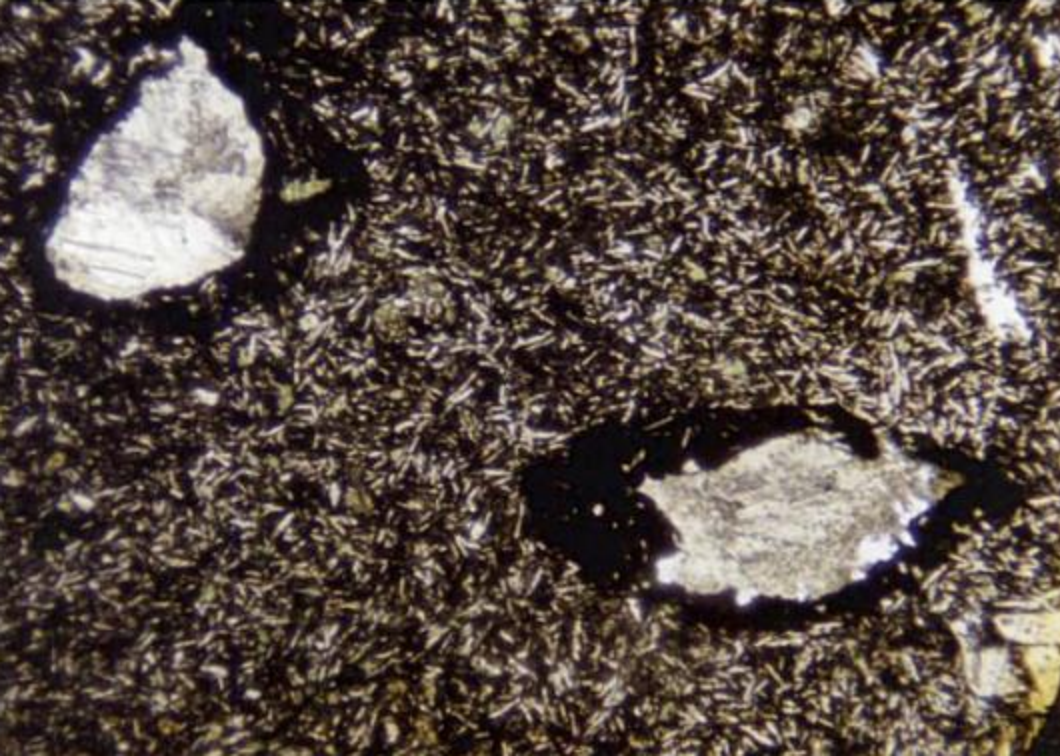
Snapshot from 3D x-ray
computed tomography
image (CT scan) of
bubble-sulfide droplet
capture – gas bubbles in
blue, droplets in yellow

SEM image of section through experimental charge.

Gas bubble

Silicate magma

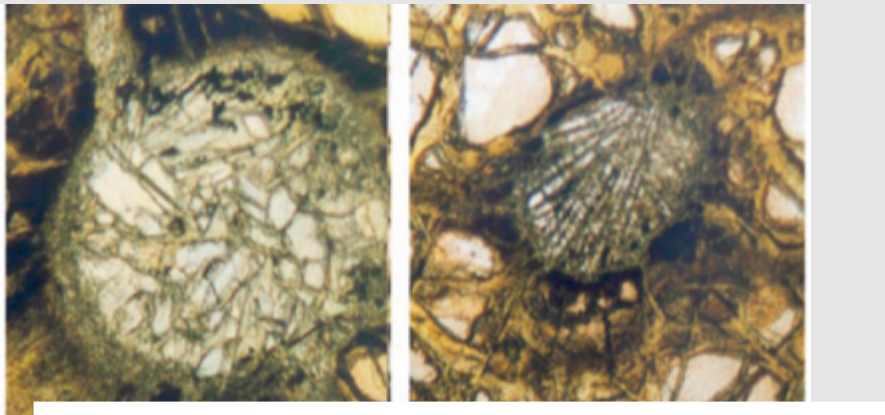
Sulfide liquid droplet



Segregation vesicles in
basalt



Fractionated residual melt driven into
vesicular void space – vapour-driven
filter pressing – Anderson et al 1984

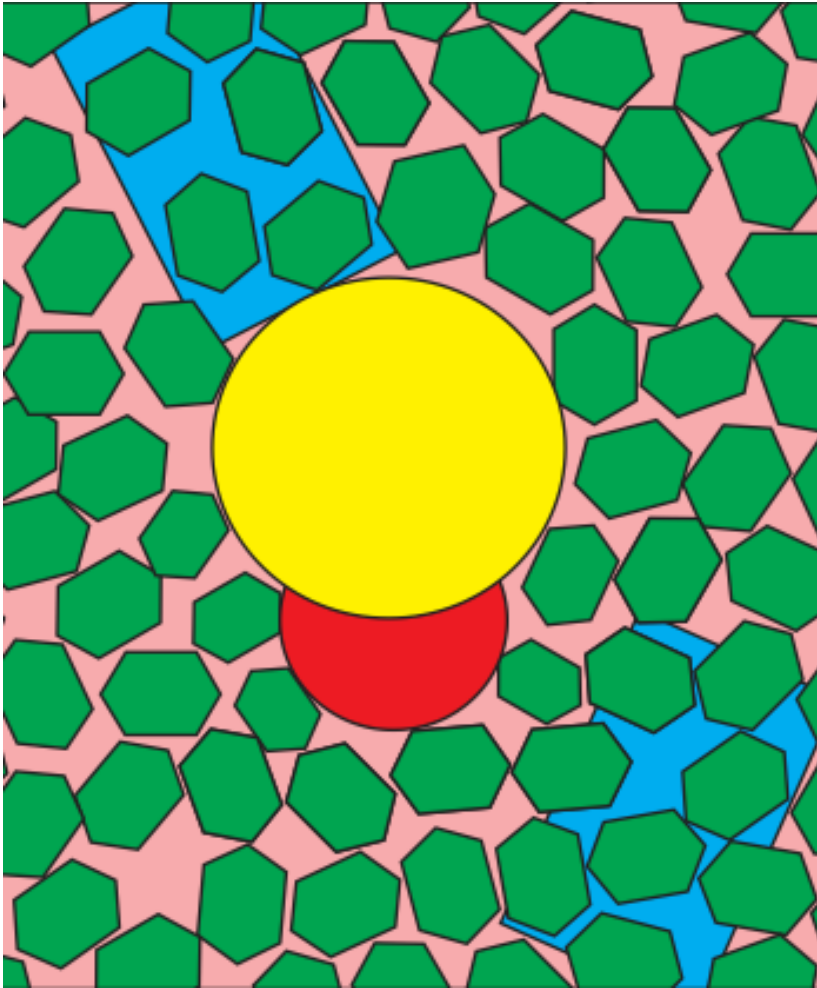


SEGREGATION VESICLES, GAS FILTER-PRESSING, AND IGNEOUS DIFFERENTIATION¹

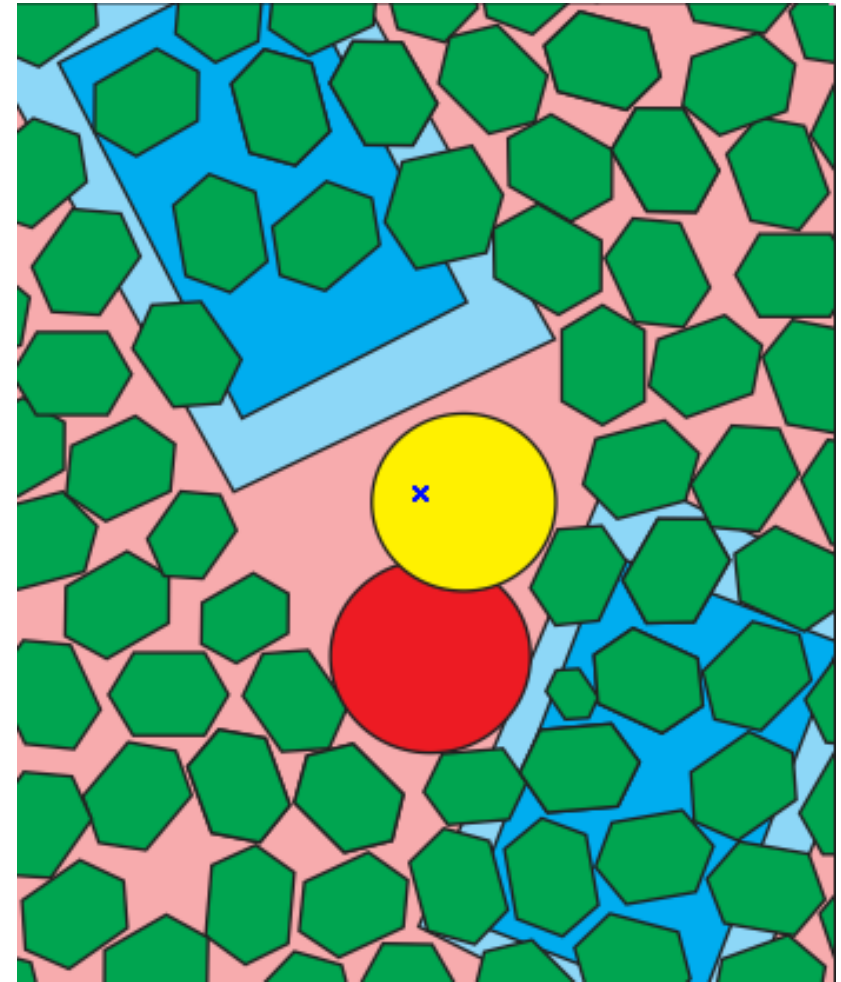
J Geol 1984

ALFRED T. ANDERSON, JR., GEORGE H. SWIHART, GILBERTO ARTIOLI, AND CHARLES A. GEIGER

Segregation vesicles – silicate melt migration due to pressure increase



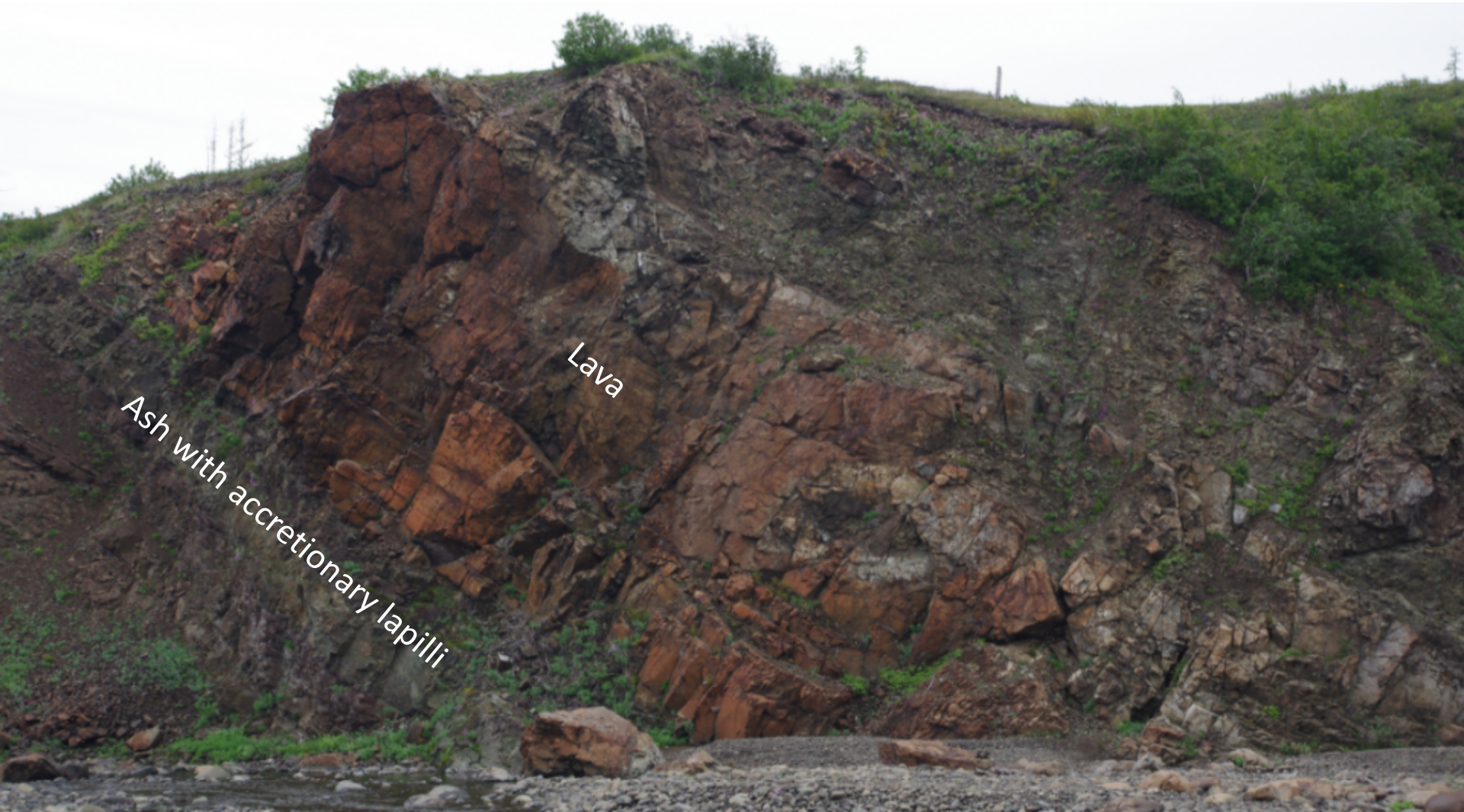
Accumulation of compound bubble-rider droplet in olivine framework with growing pyroxene oikocrysts

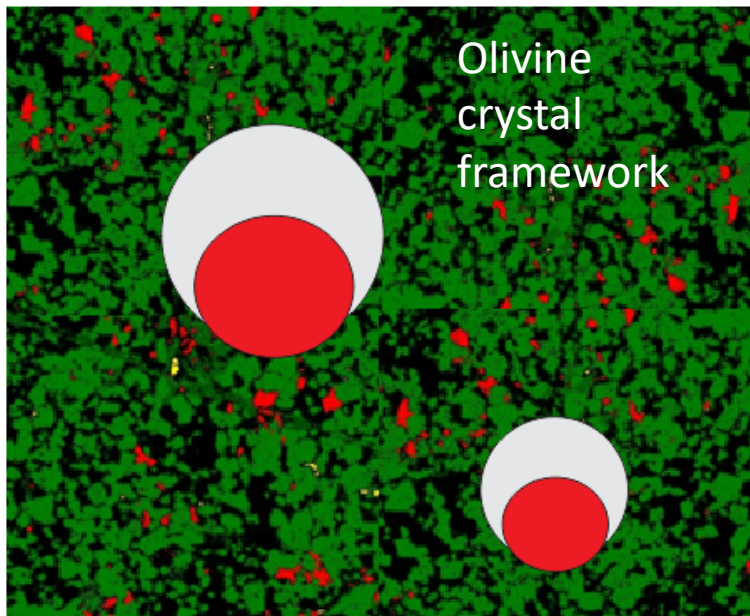
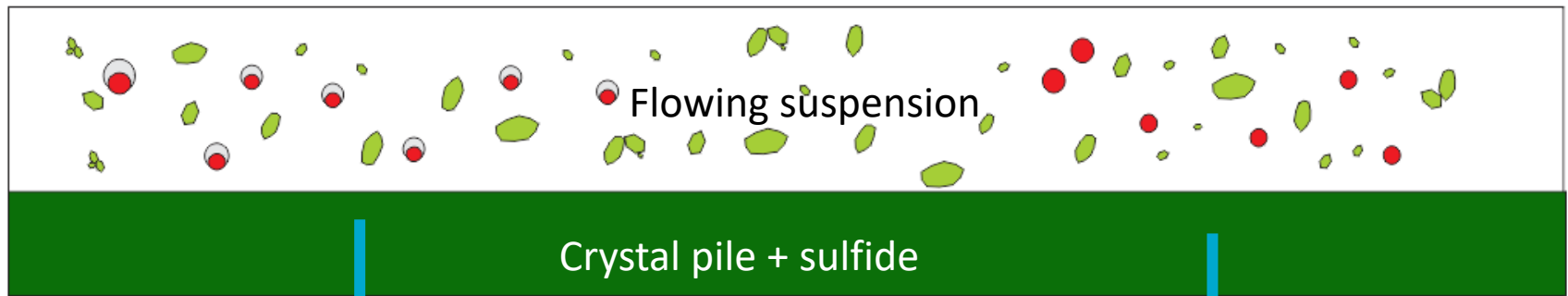


Increased confining pressure, droplet volume reduces, silicate melt drawn into cavity, oikocryst growth continues

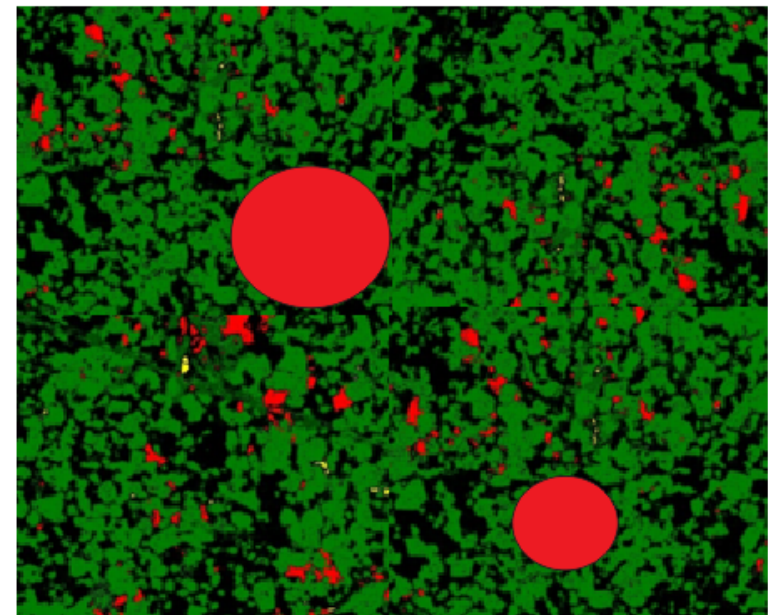
Tuff layers in the Nadezhdinsky formation

Noril'sk intrusions periodically vented to the surface – lithostatic to hydrostatic pressure drop

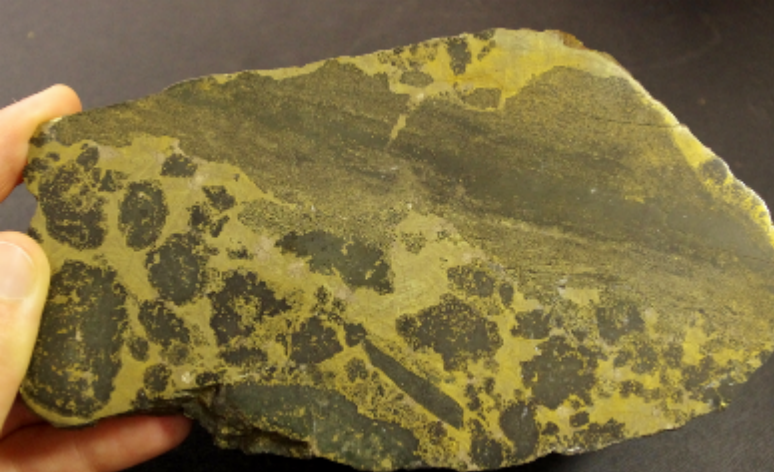




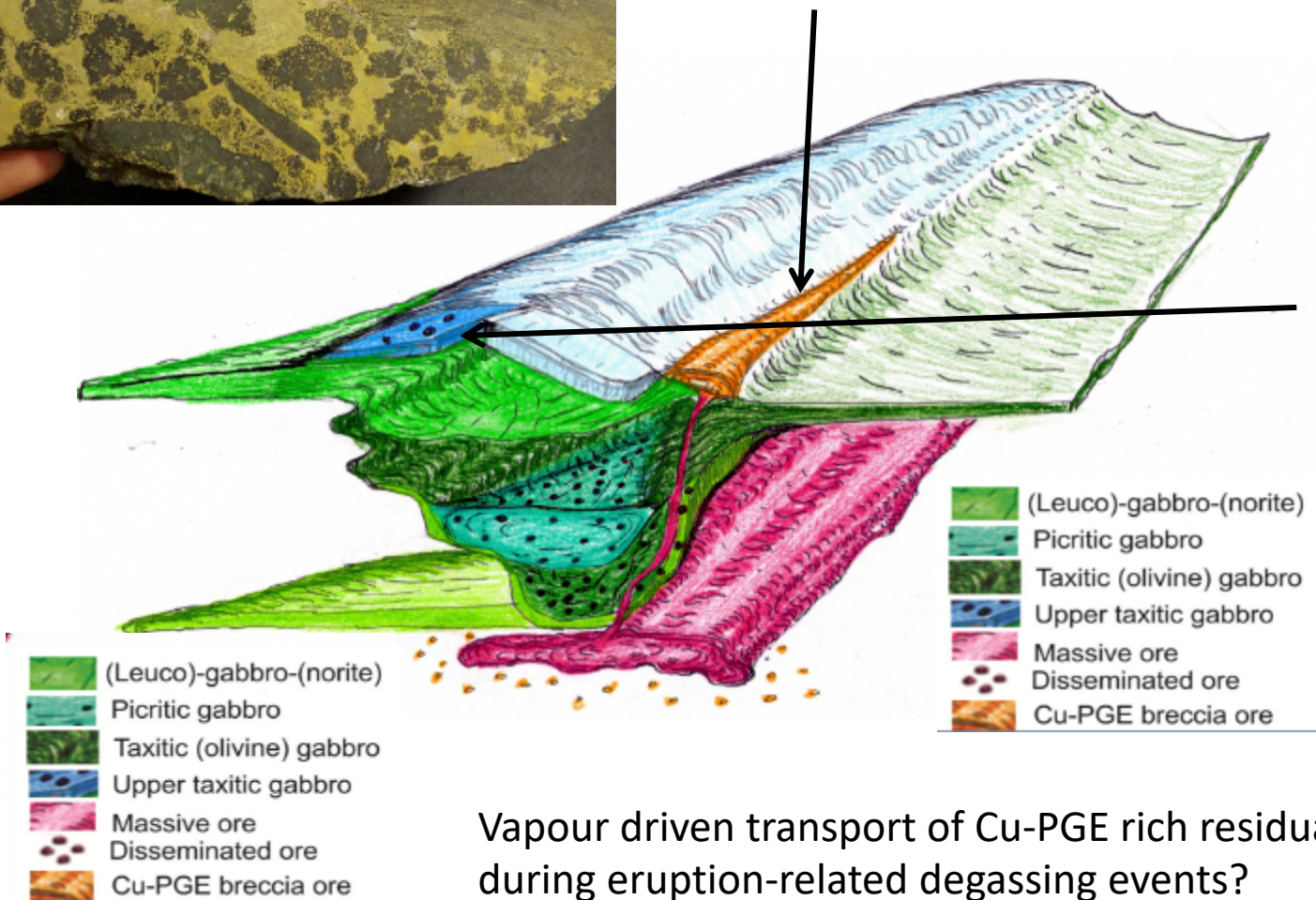
Composite droplet-bubble pairs
deposited from volatile-saturated
magma.... Or



Droplets deposited from volatile-
undersaturated magma followed
by degassing of interstitial liquid
during crystallisation

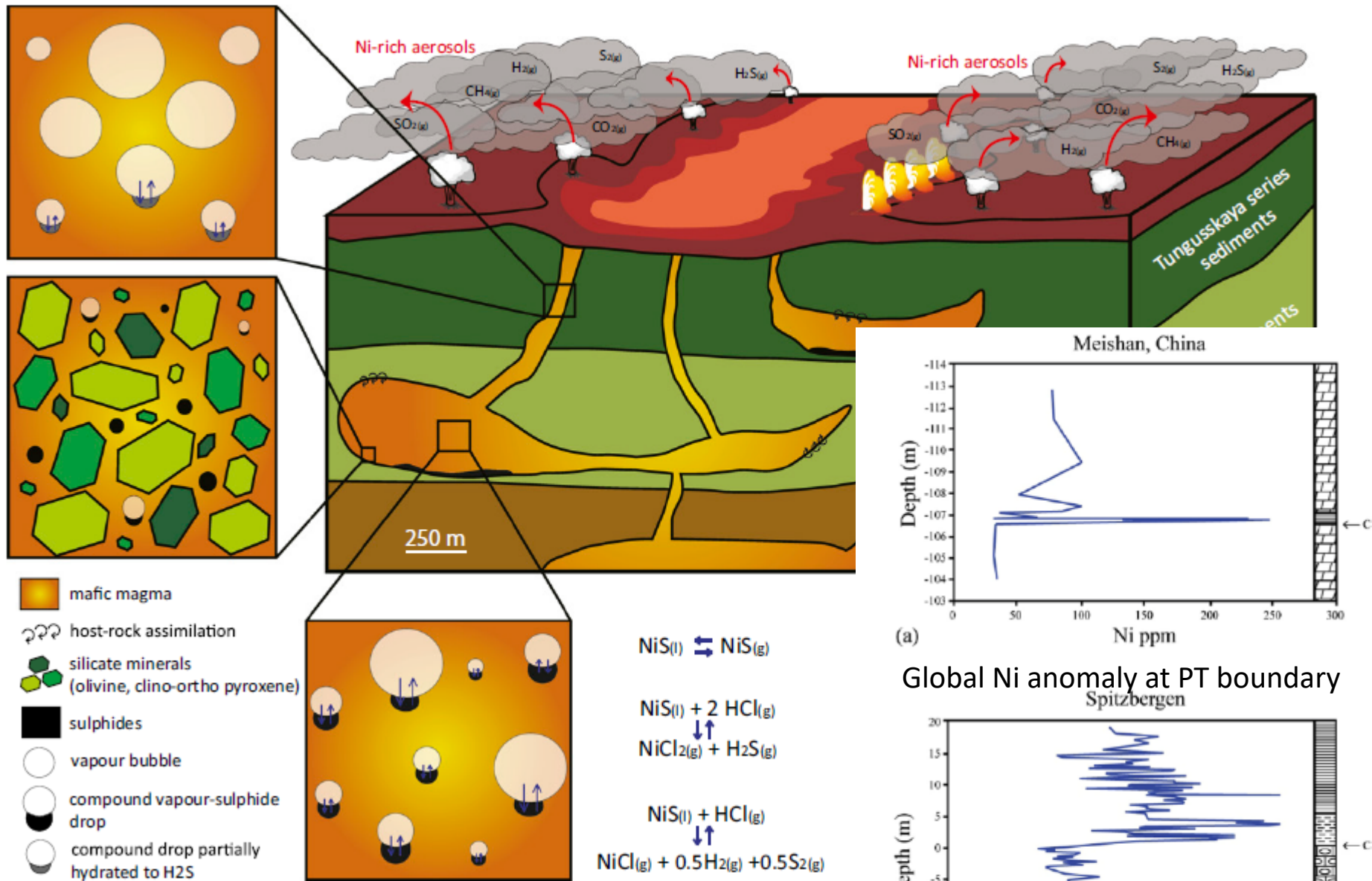


Cuprous ores – exo-skarn breccias
Immediately overlying thickest zone of
differentiated massive ores (Sluzheniskin et al)



High PGE, low-S
disseminated ores
at tops of sills

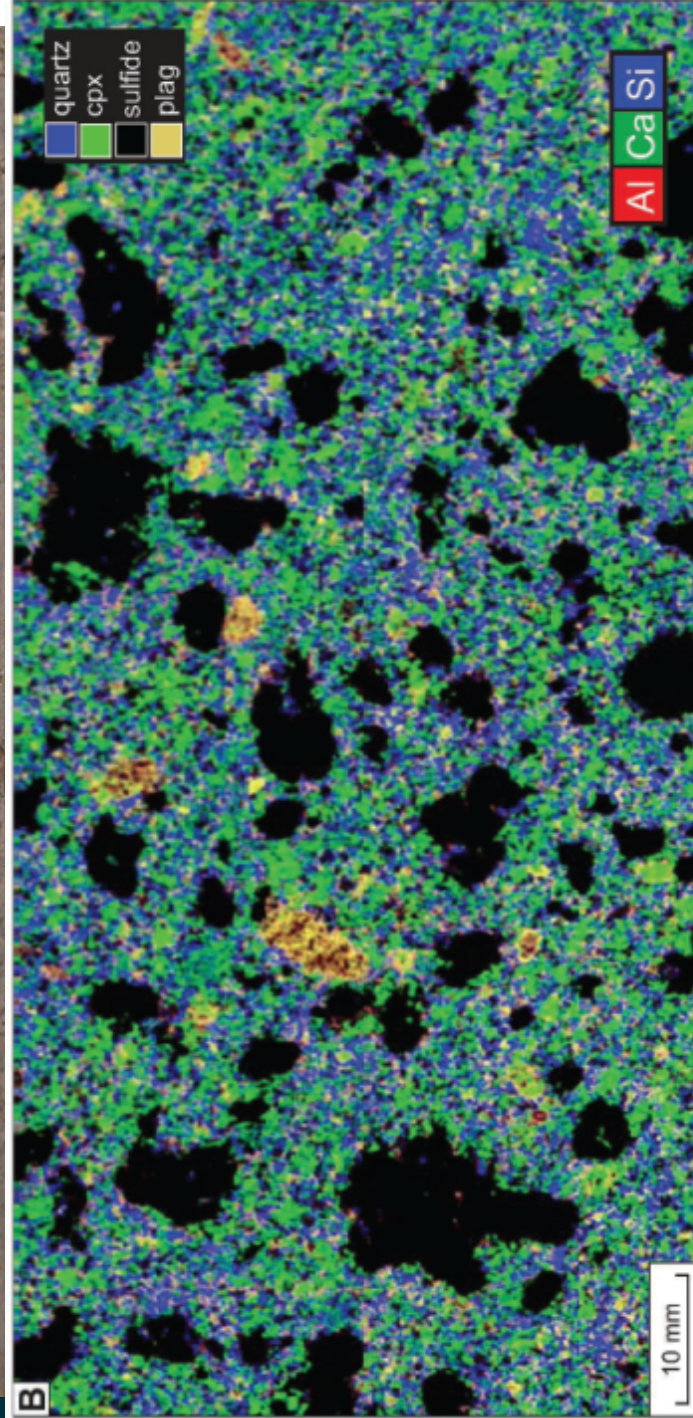
Vapour driven transport of Cu-PGE rich residual sulfide liquid
during eruption-related degassing events?



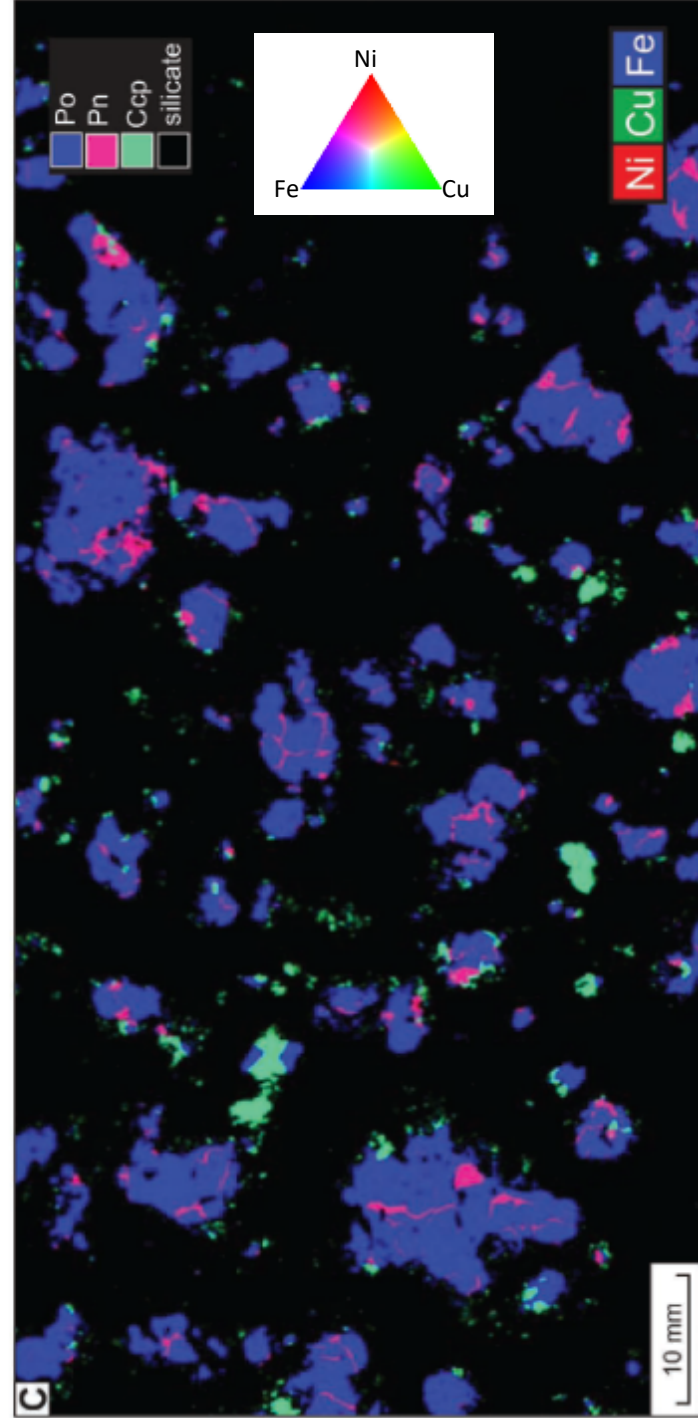
Norilsk sulfides, bubble riding and the “great dying”
Permo-Triassic mass extinction

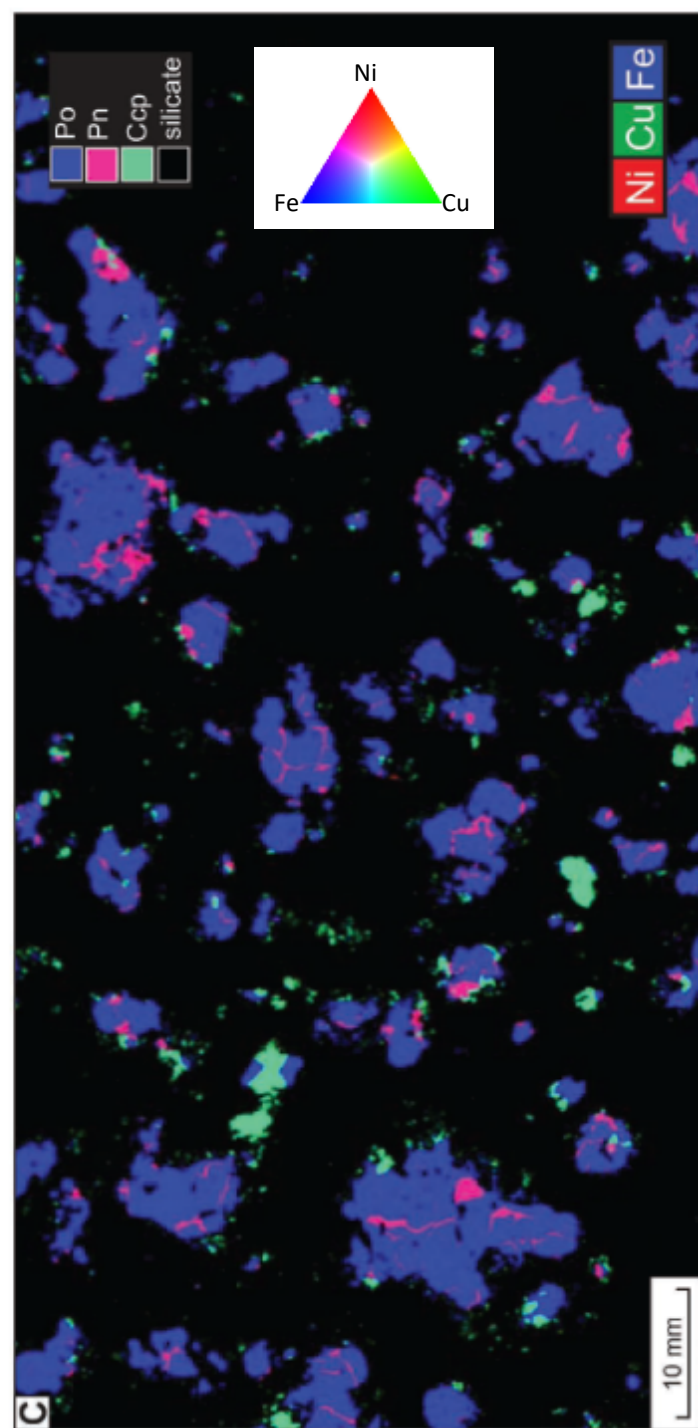
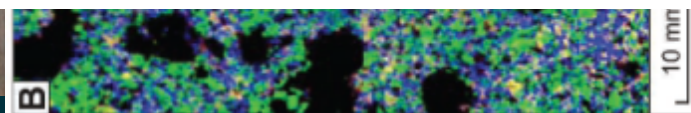
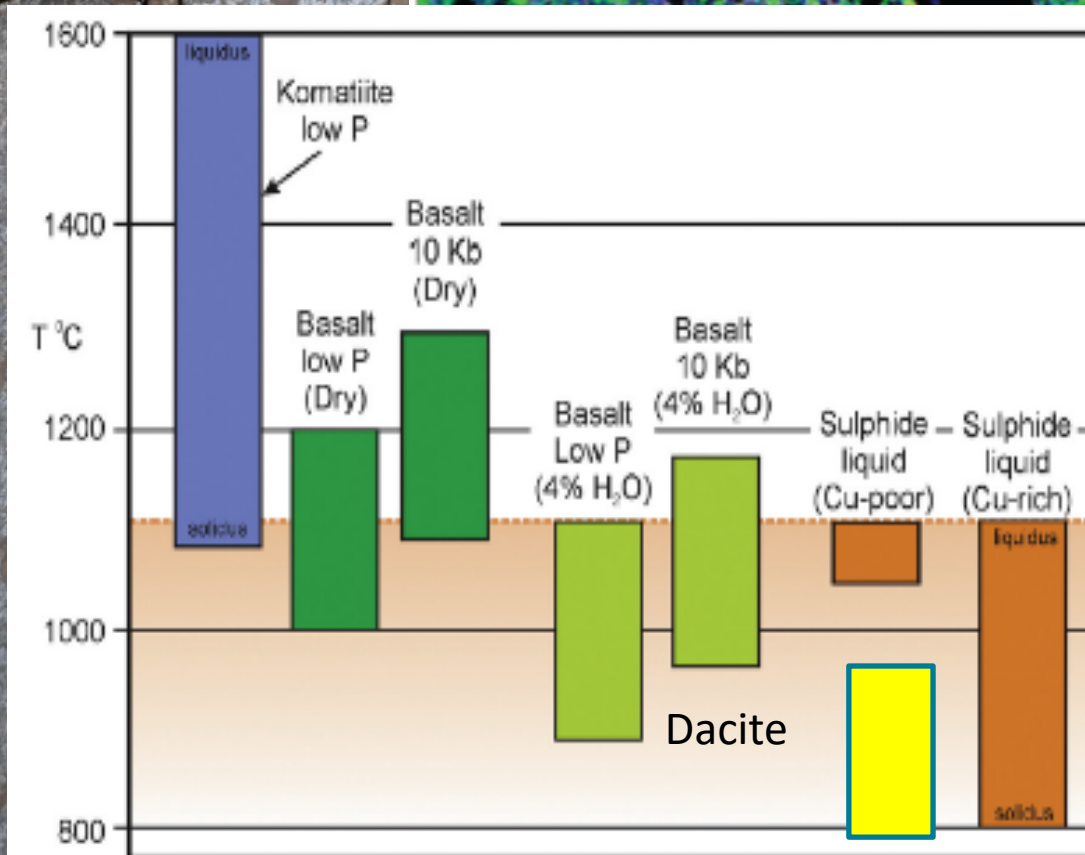
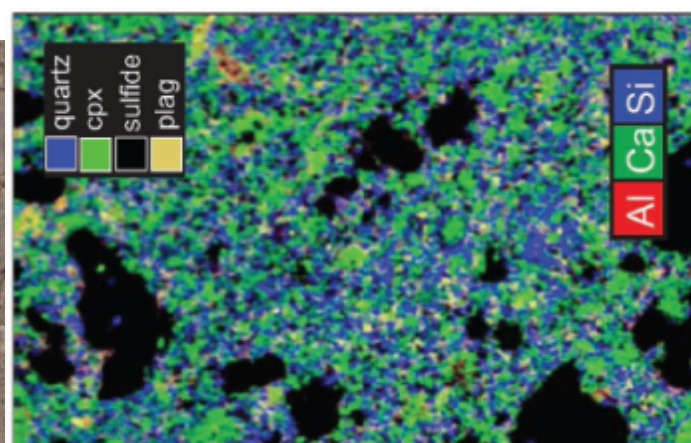


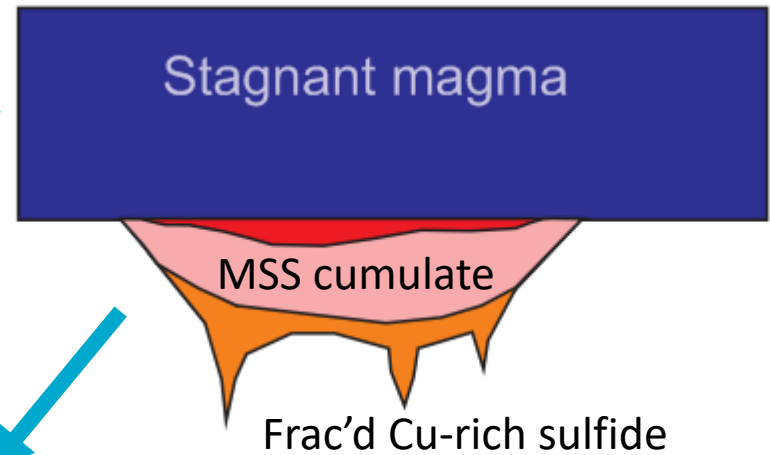
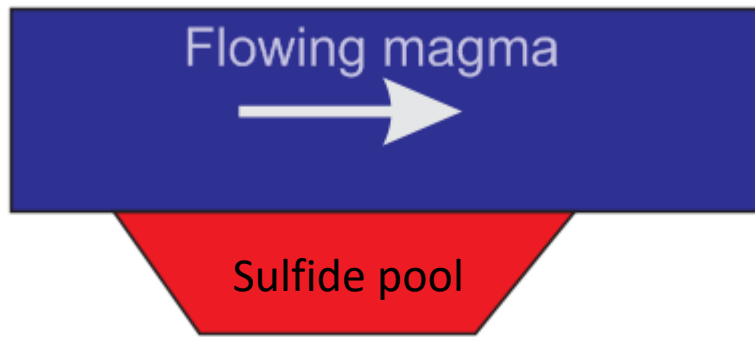
B



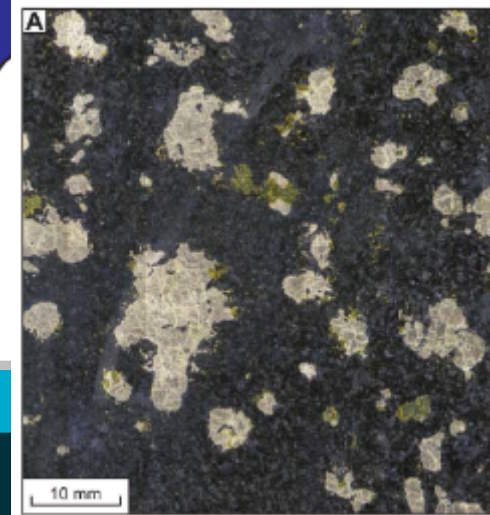
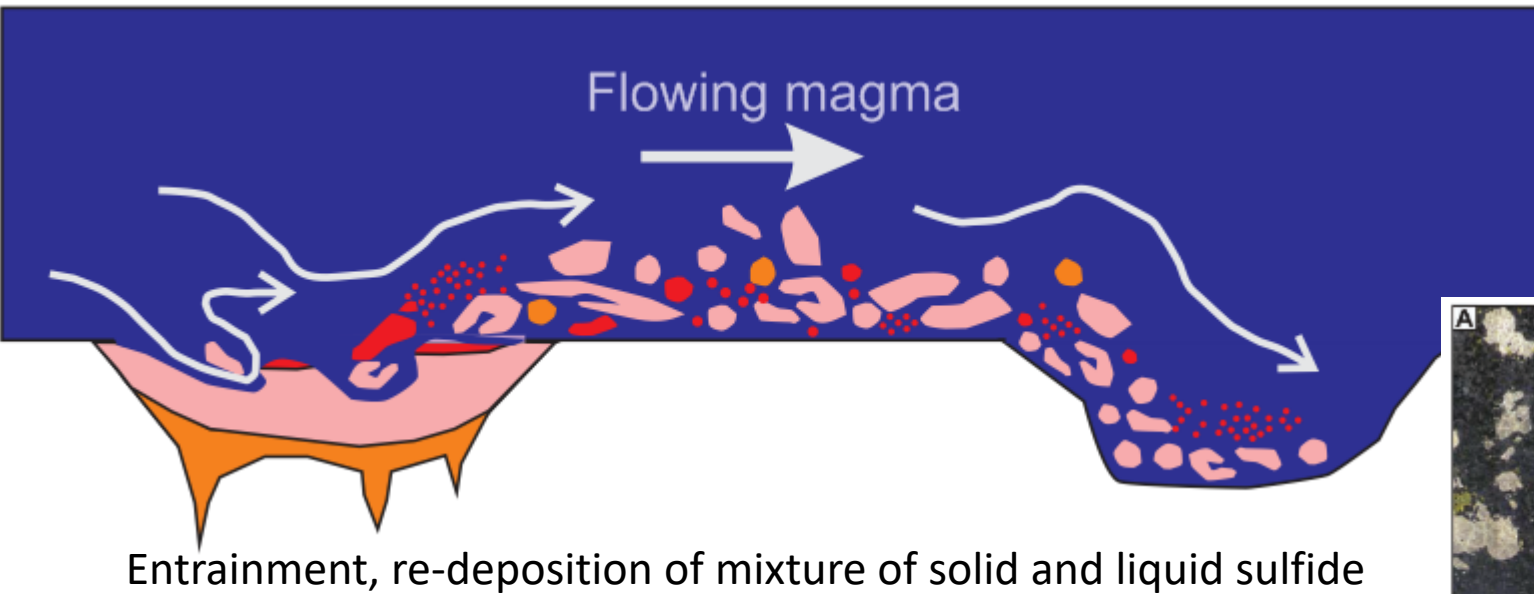
C







Rejuvenation of flow



(after Mike Lesher, pers comm)

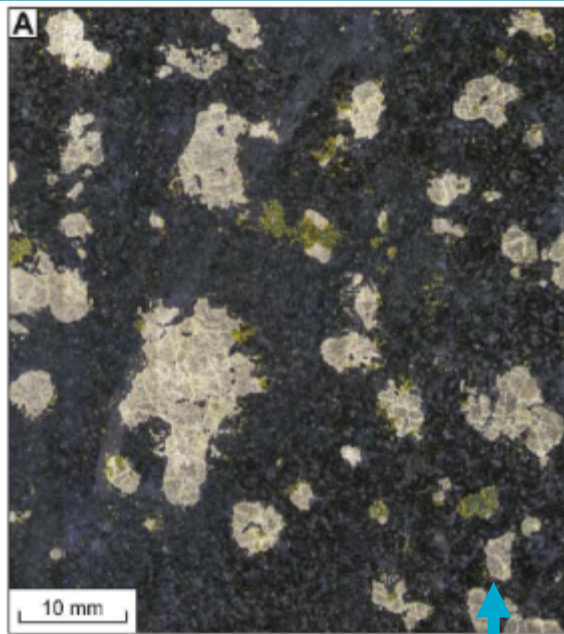
Significance of globular ore textures



1 cm

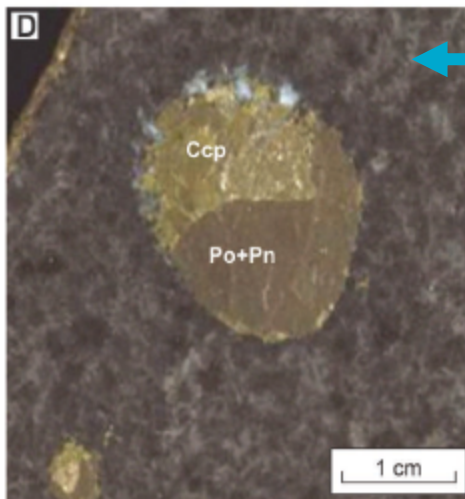
Dispersed sulfide blebs, mixed size population

PROXIMAL



Irregular large globules
mainly high Ni/Cu

TRANSPORTED/RECYCLED
PROXIMAL



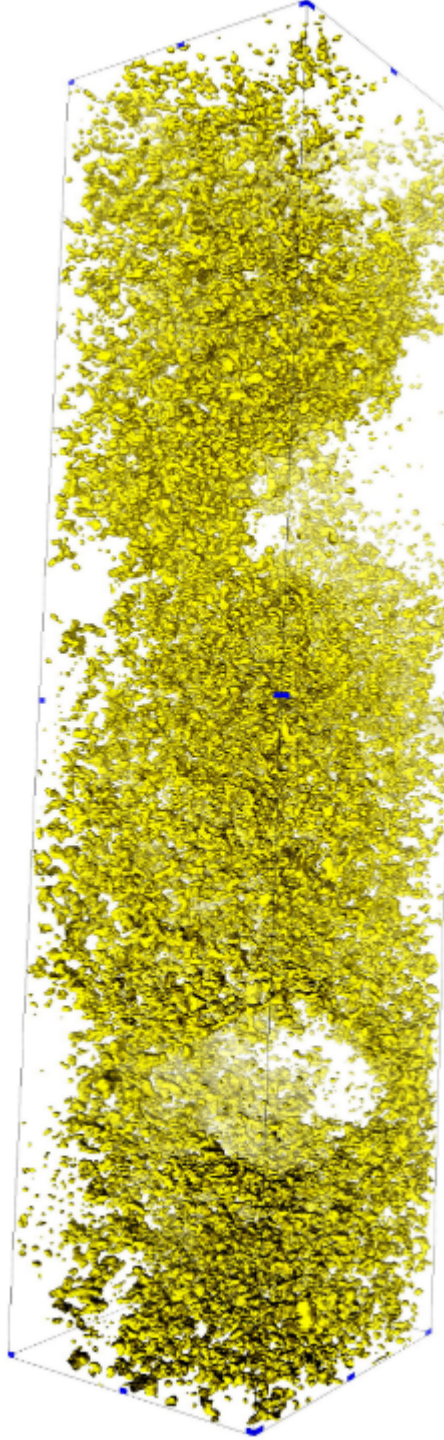
Isolated capped
globules,
differentiated

BUBBLE-RIDING
TRANSPORTED
NOT NECESSARILY
PROXIMAL

Side-wall above
basal accumulation

Mixed
globules,
veins, patchy
matrix
PERCOLATING
NETWORK
HALO





1. Disseminated ores, matrix ores and sulfide liquid percolation, leading to...
2. **Sulfide/silicate melting fronts**
3. and finally “breccia ores”

Sulfide-matrix breccias: silicate aggregates (rock fragments, molten or partially molten silicate and disaggregated grains) in a matrix of sulfide melt



Aguablanca

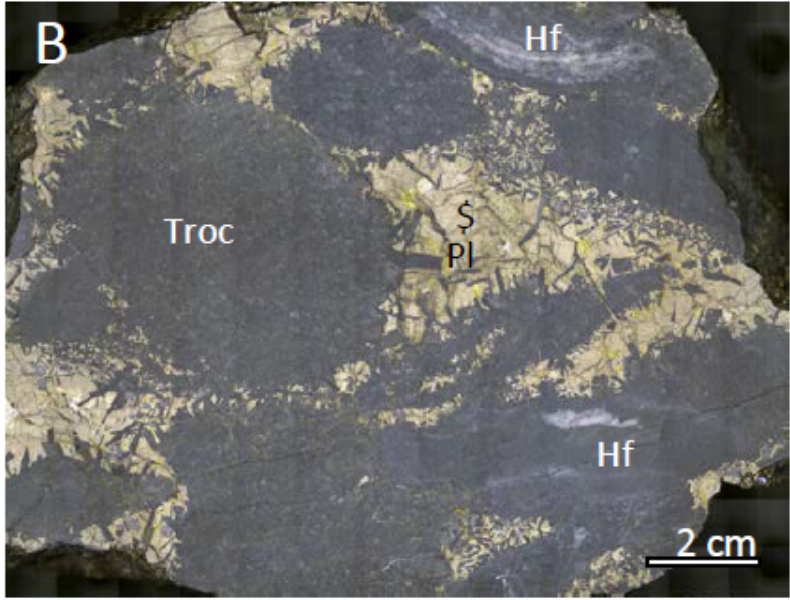


Totten mine, Sudbury



Savannah (Sally Malay) WA

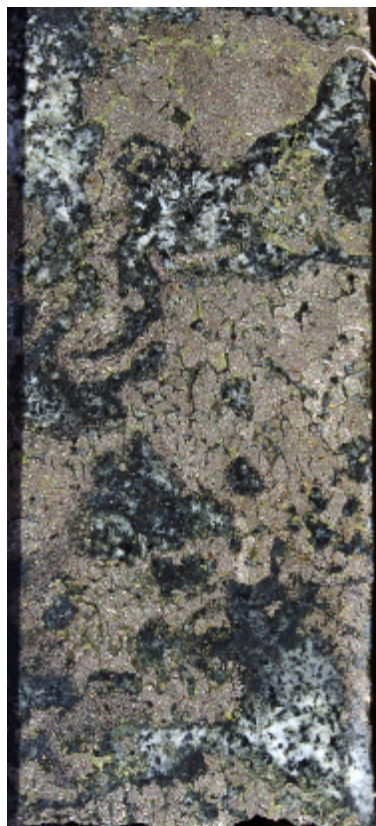
Voisey's Bay



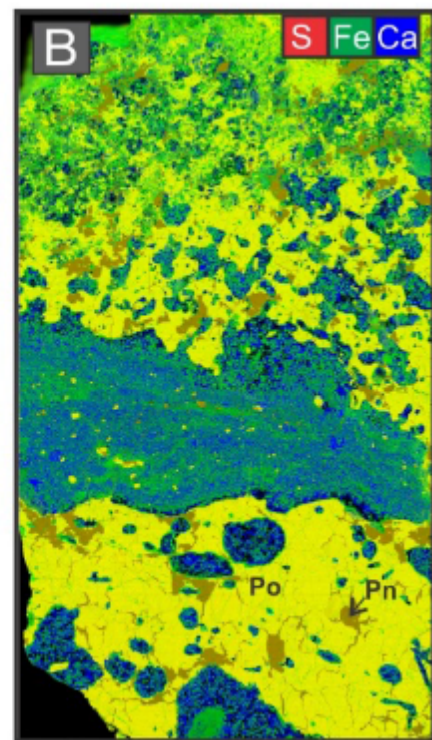
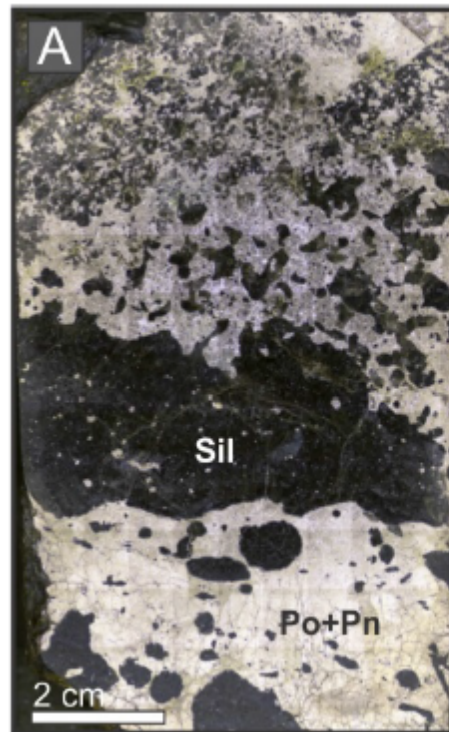
Breccias ain't breccias...



Silver Swan, WA

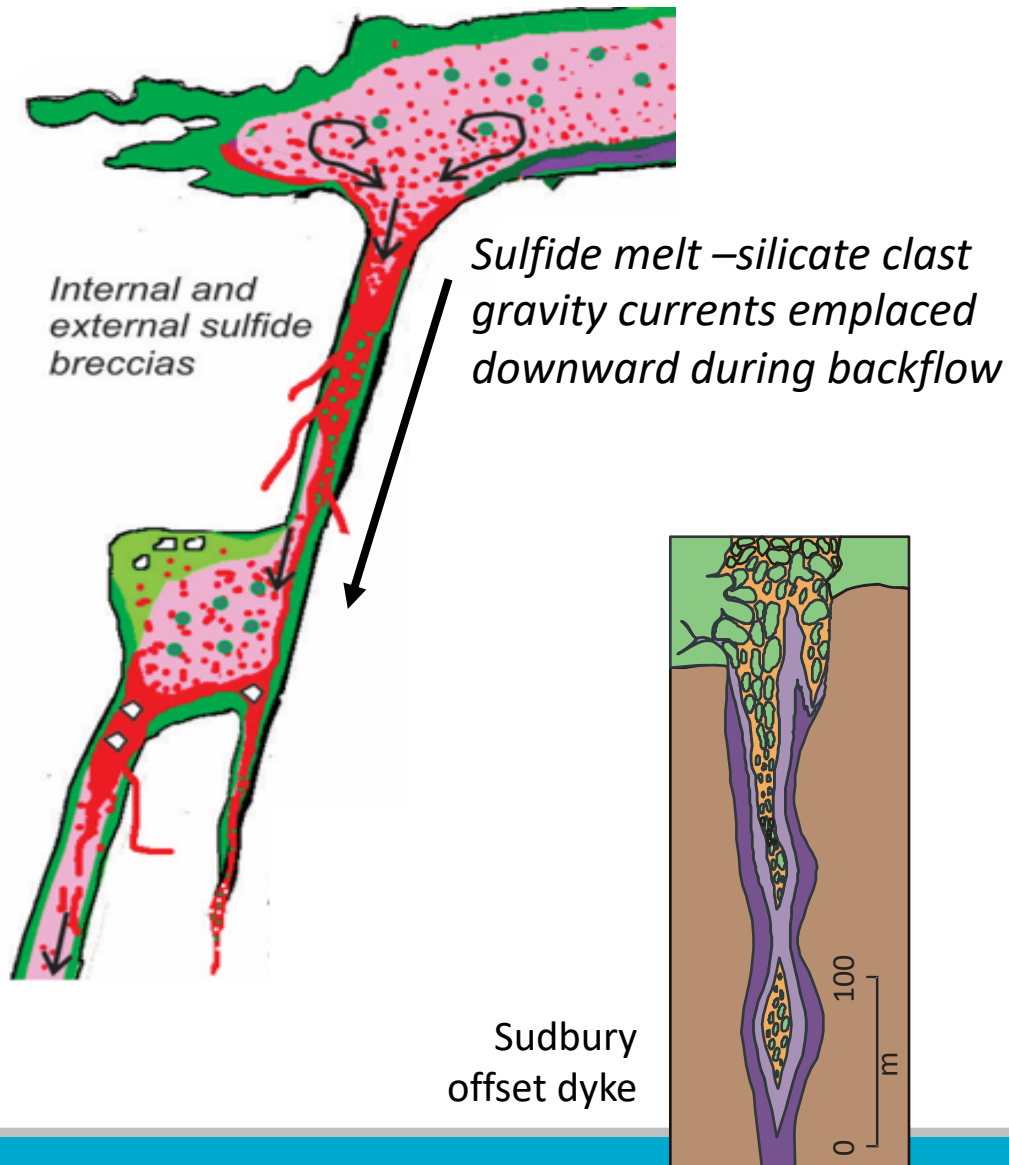


Talnakh



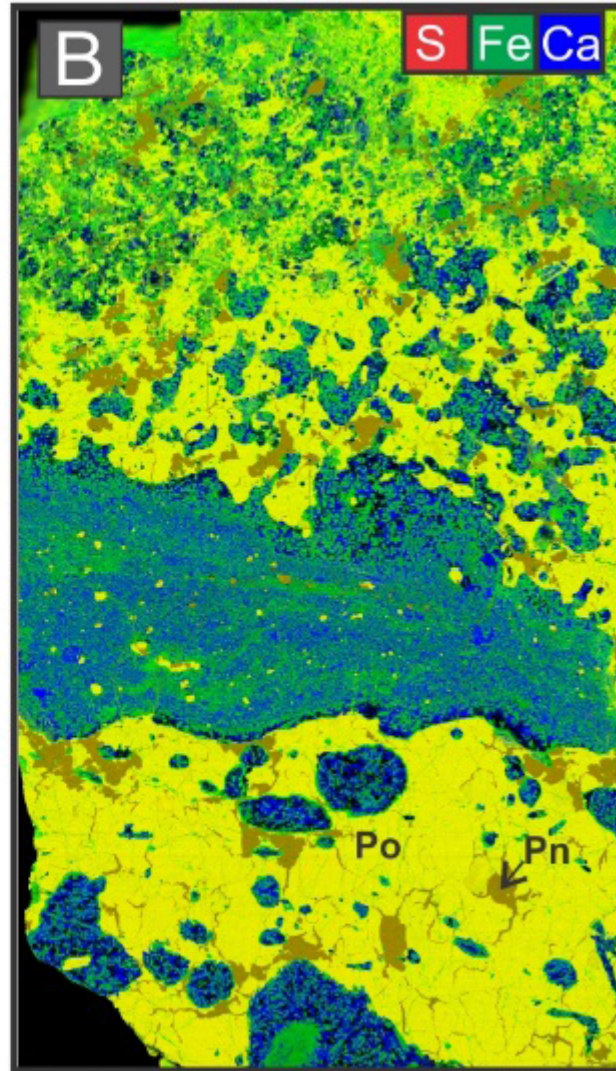
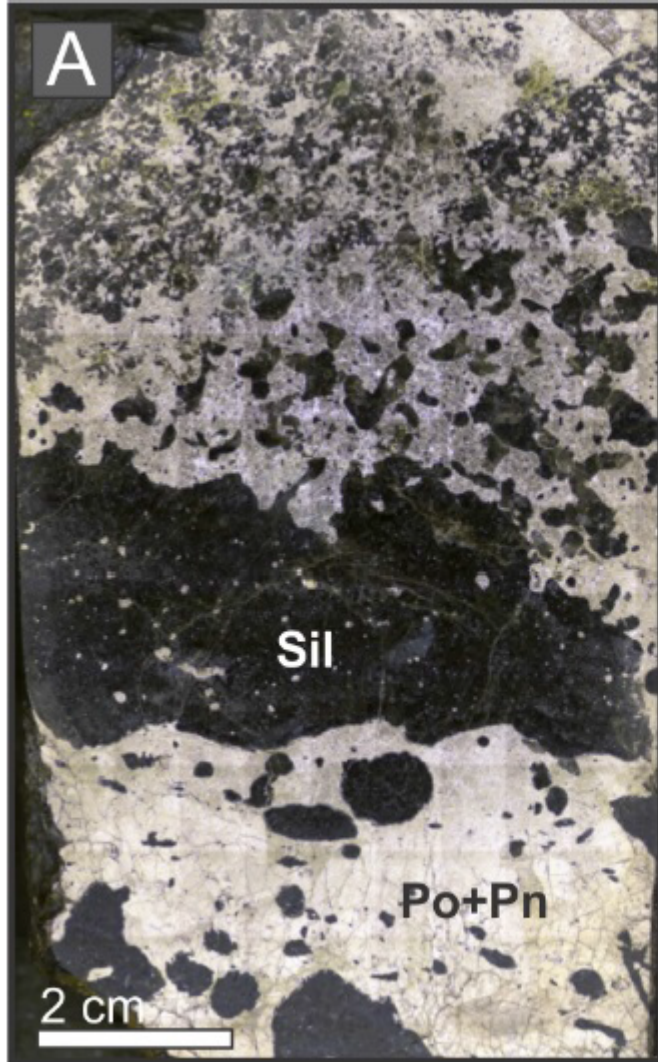
Sudbury emulsion textures (Hawley, 1962)

Origin of non-tectonic sulfide ore breccias:



Or...percolation of sulfide melt at silicate-sulfide melting-infiltration fronts.

Sudbury emulsion textures (Hawley, 1962)

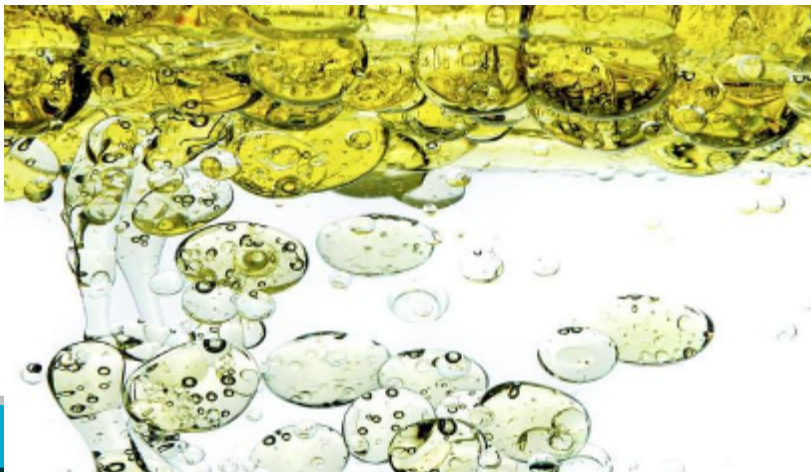


Emulsions – salad dressing or mayonnaise?

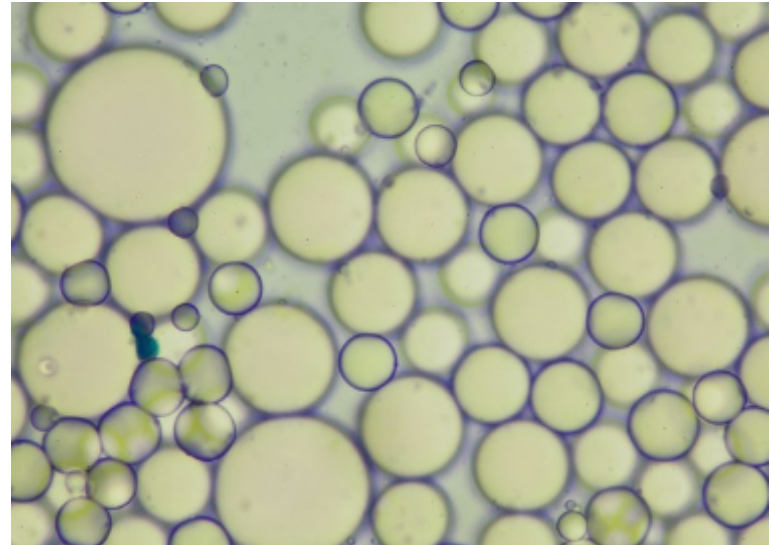
Salad dressing...



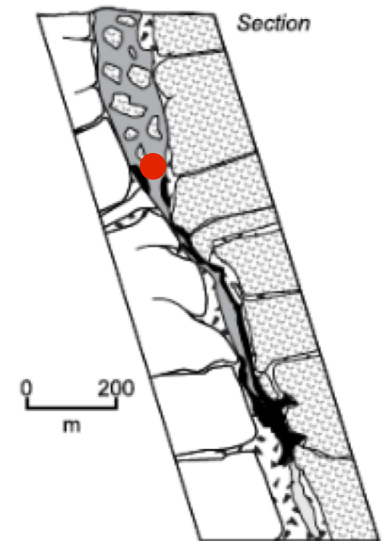
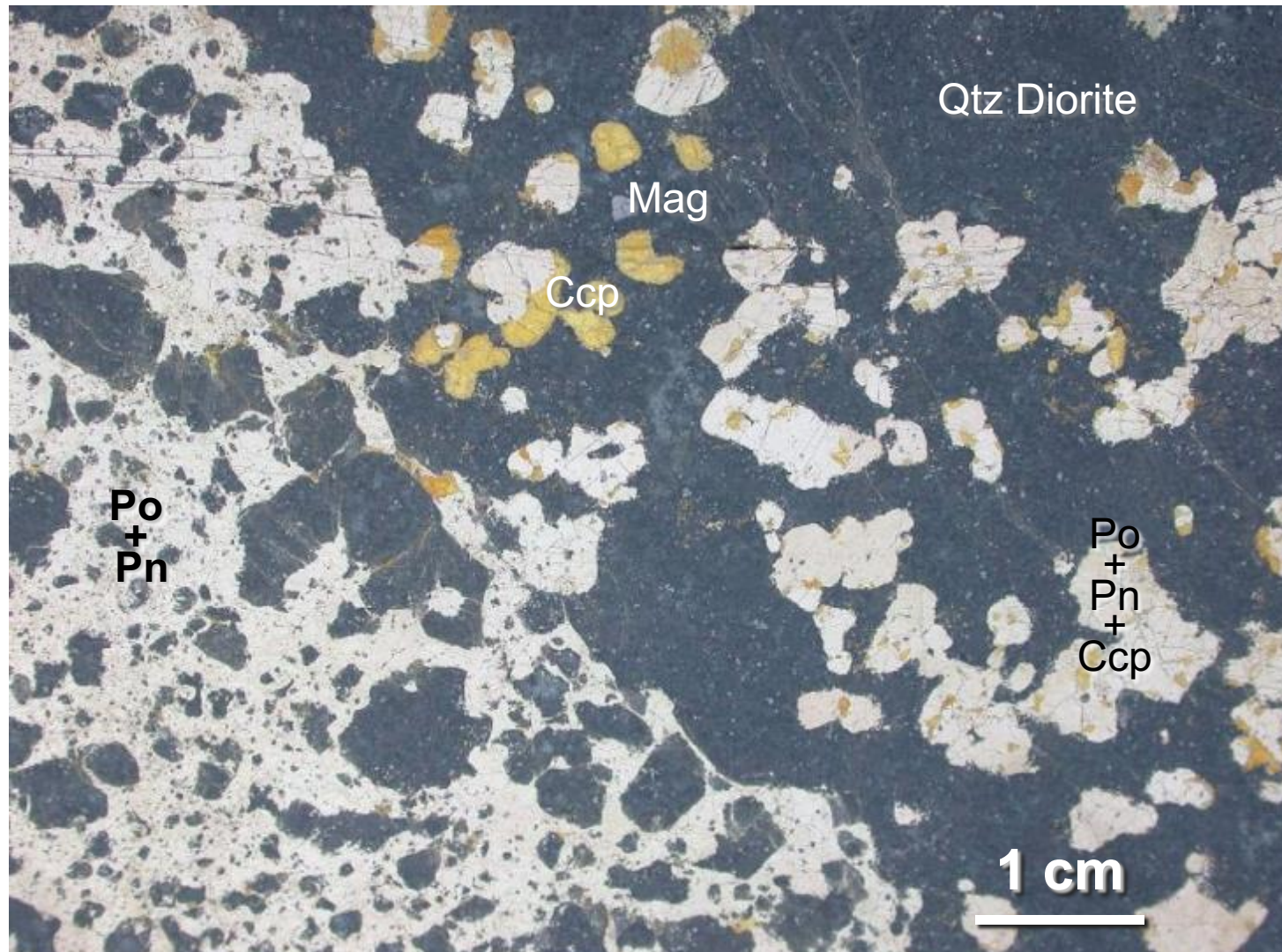
Oil droplets in water...



Mayonnaise – water droplets in oil...

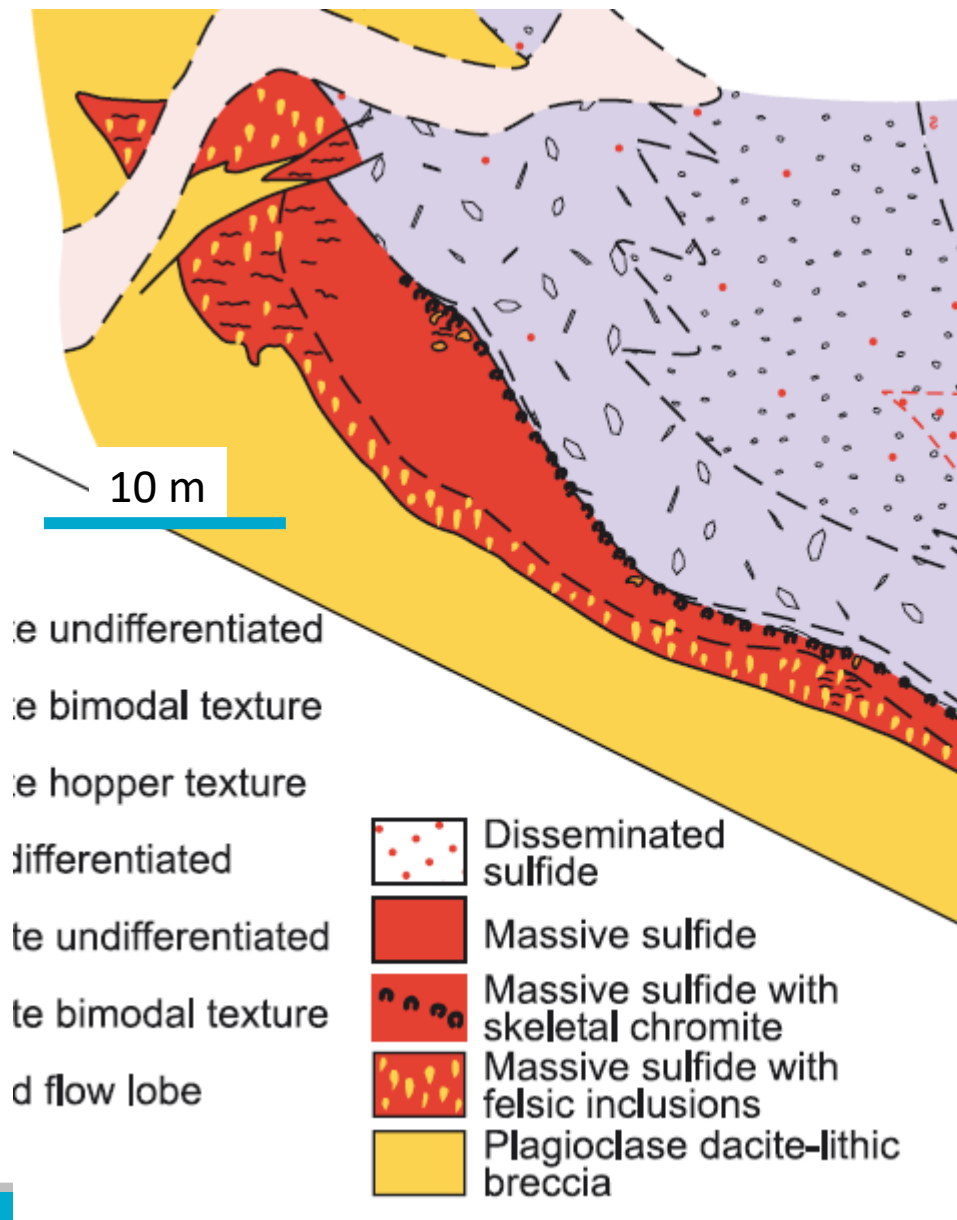


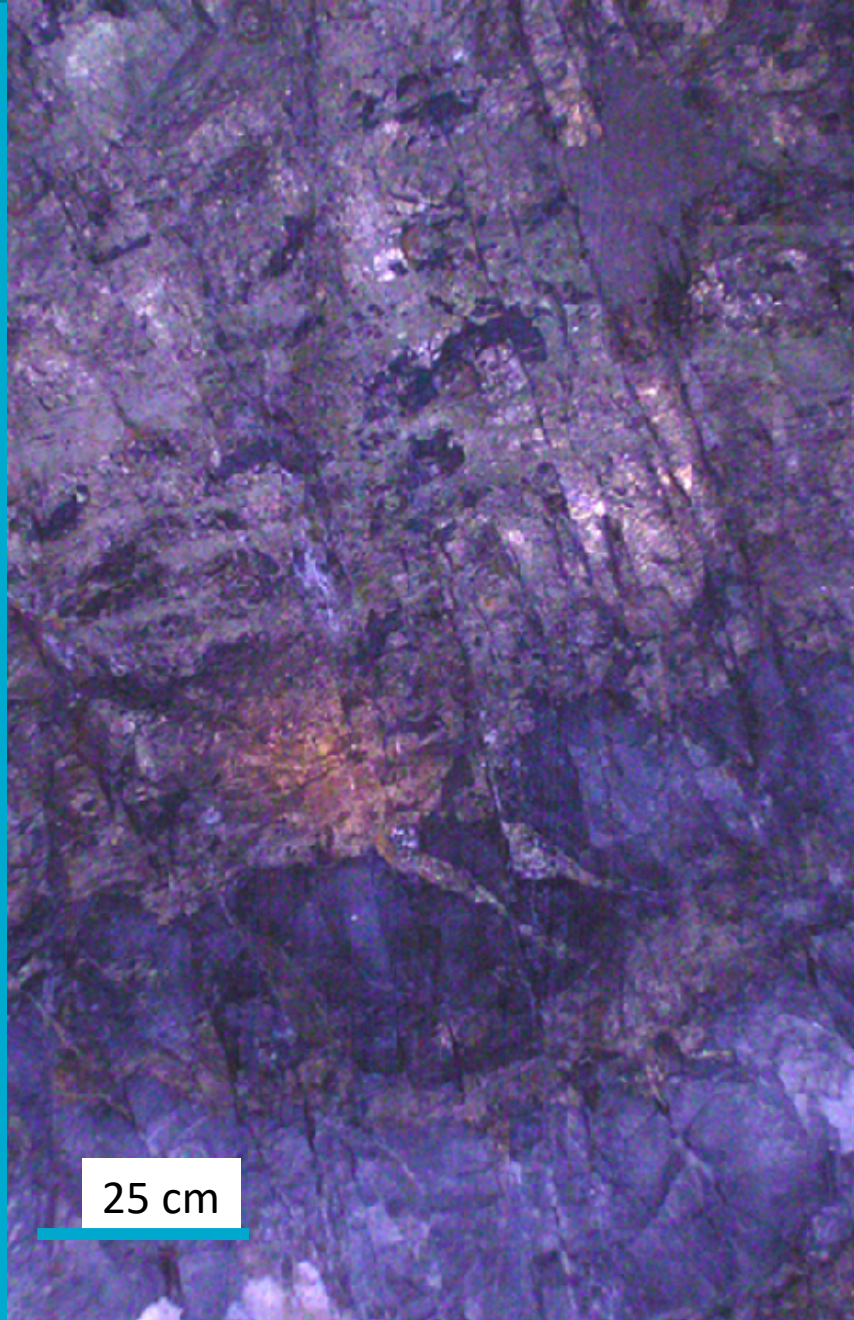
Salad dressing to mayonnaise...



Inclusion-bearing massive MSS cumulate (left), local Cu-rich liquids (centre), and relatively unfractionated blebby disseminated ore (right), Frood Mine, Sudbury (photo by Paul Golightly, slide from Mike Lesher)

Silver Swan orebody



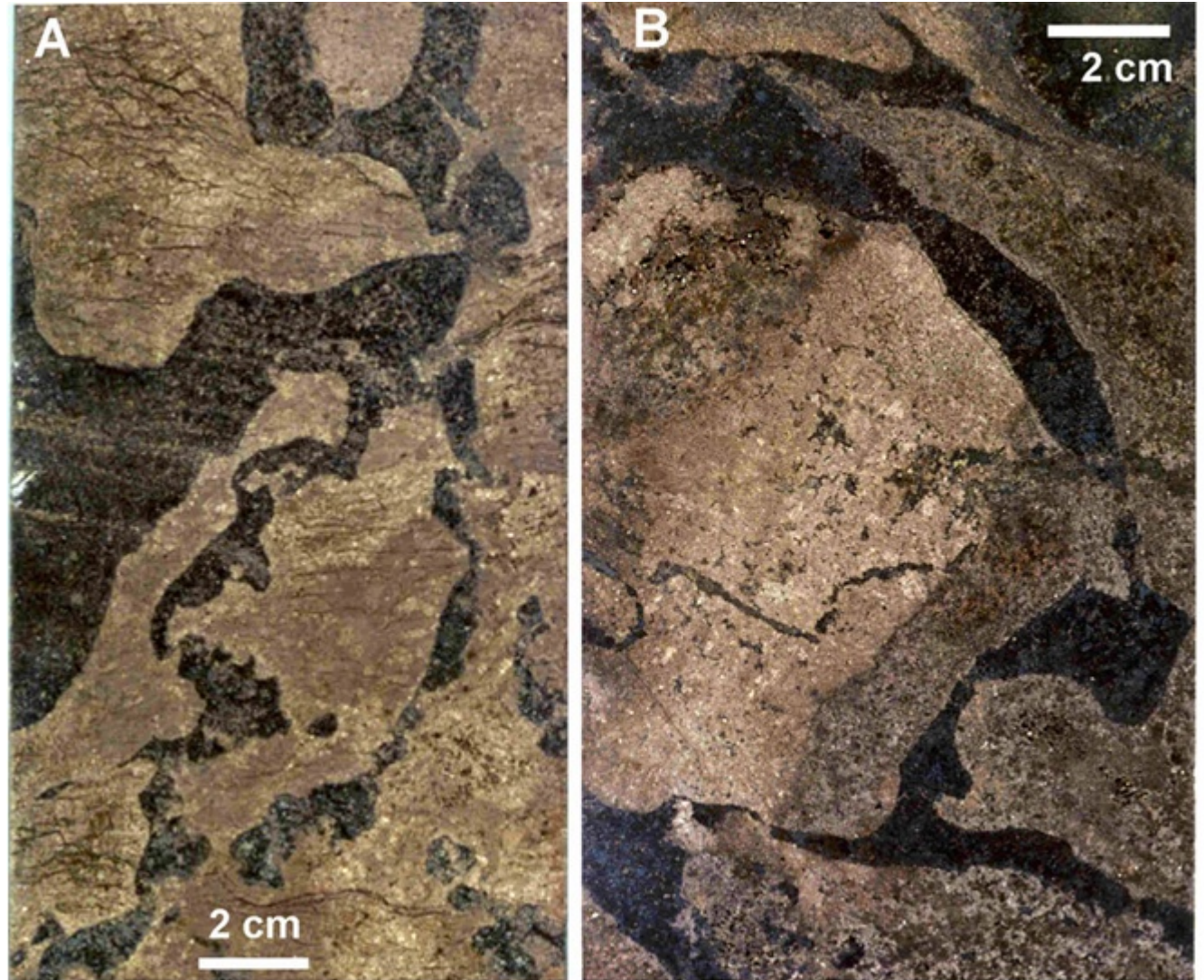


Sulfide liquid melting its dacite floor (Silver Swan, WA)

Disaggregating silicate “plumes” in sulfide



Raindrops

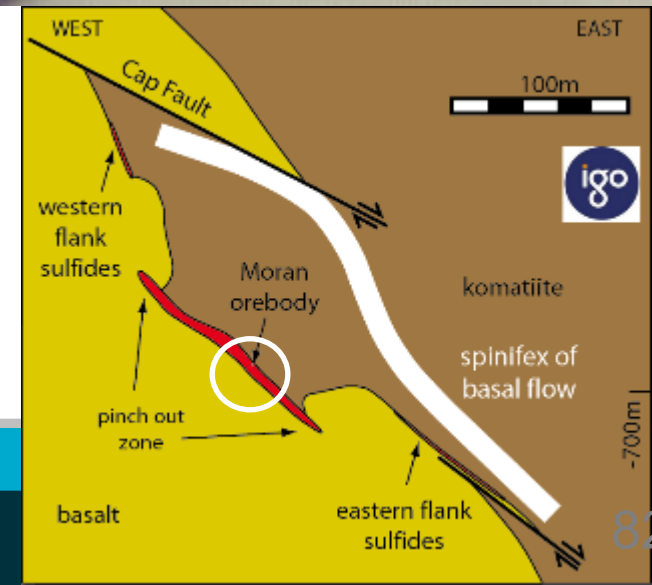
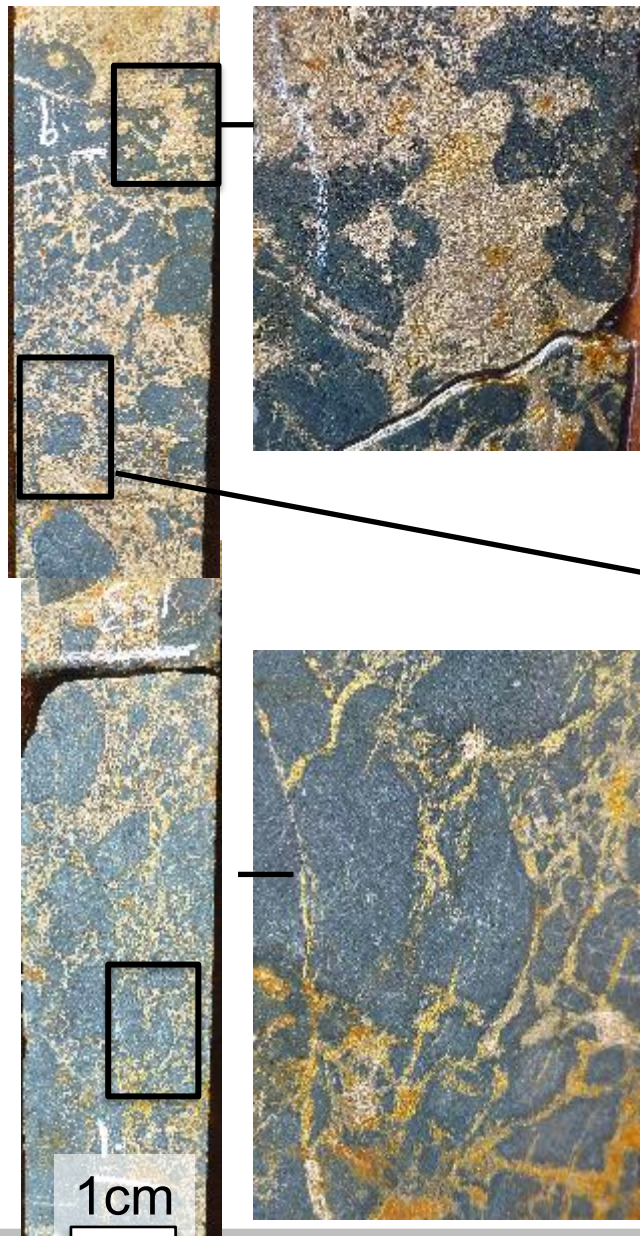


Silver Swan orebody, Black Swan, WA

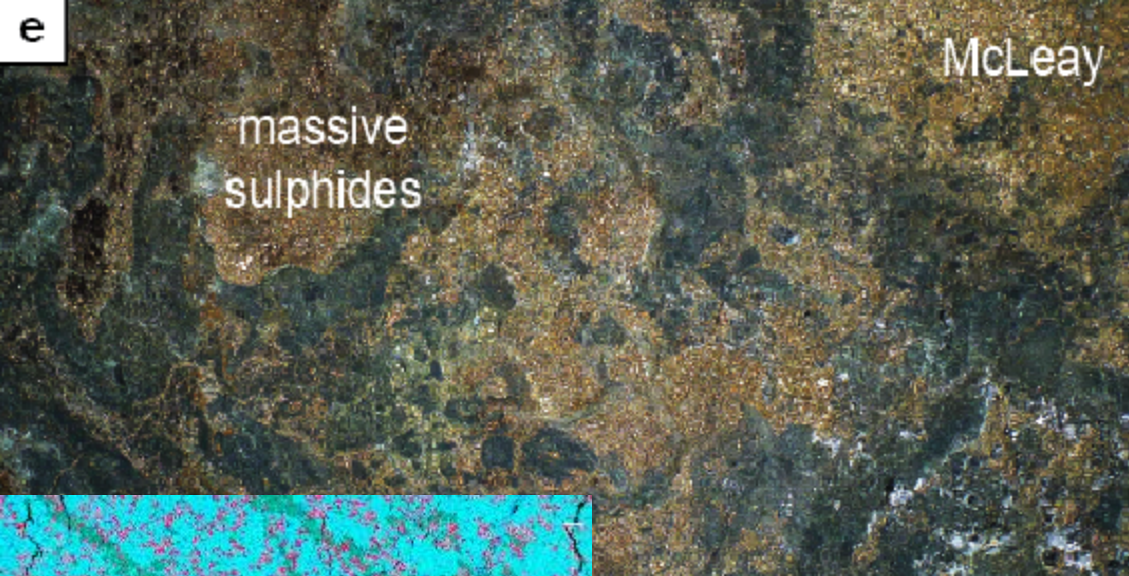
Melting the Footwall

Moran Shoot, Kambalda (samples and photos from Sebastian Staude)

Silicate-sulfide emulsion texture



e

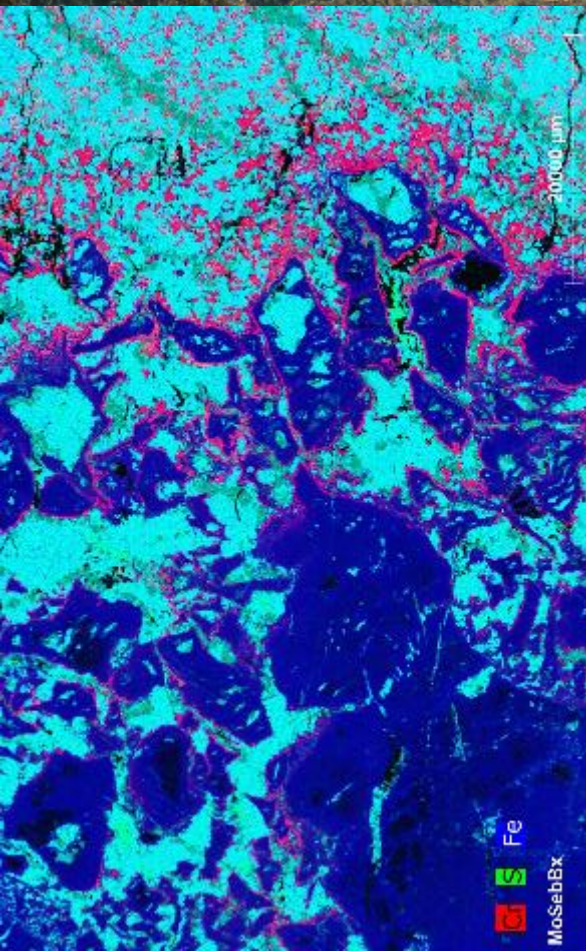


Melting the Footwall

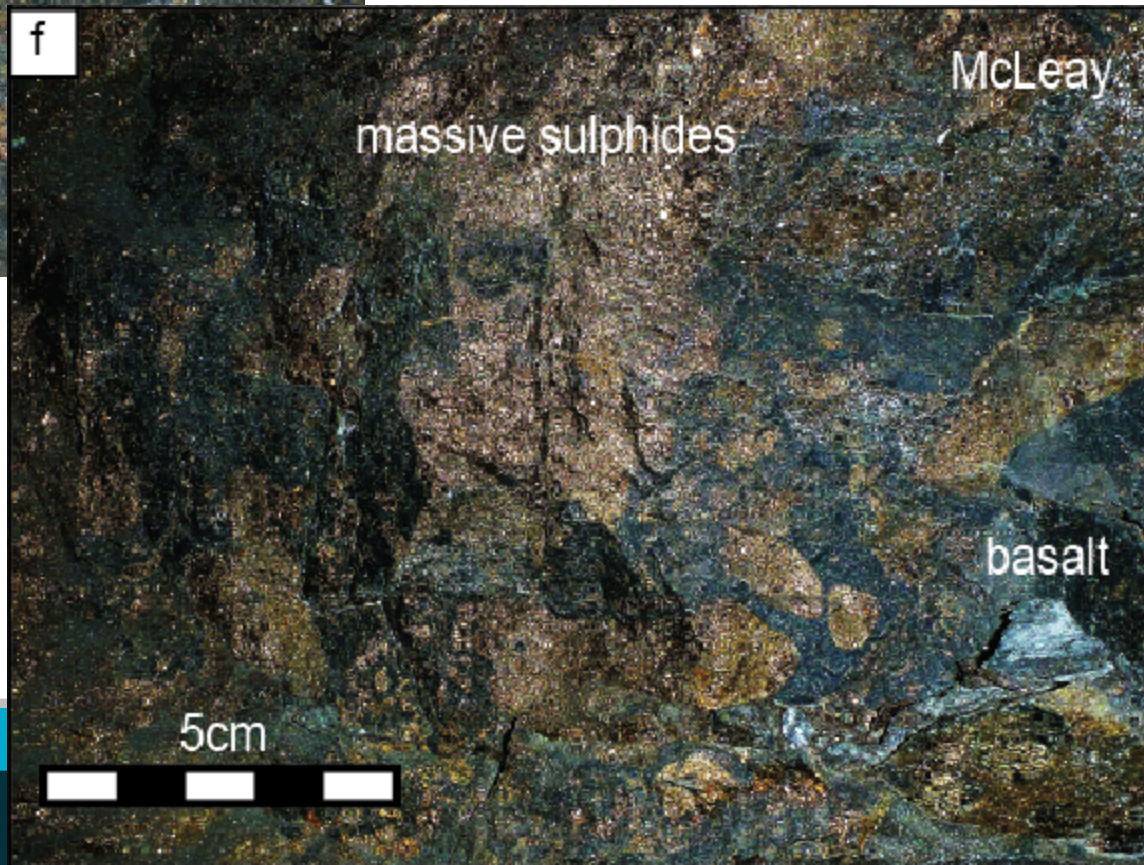
McLeay Shoot,
Kambalda

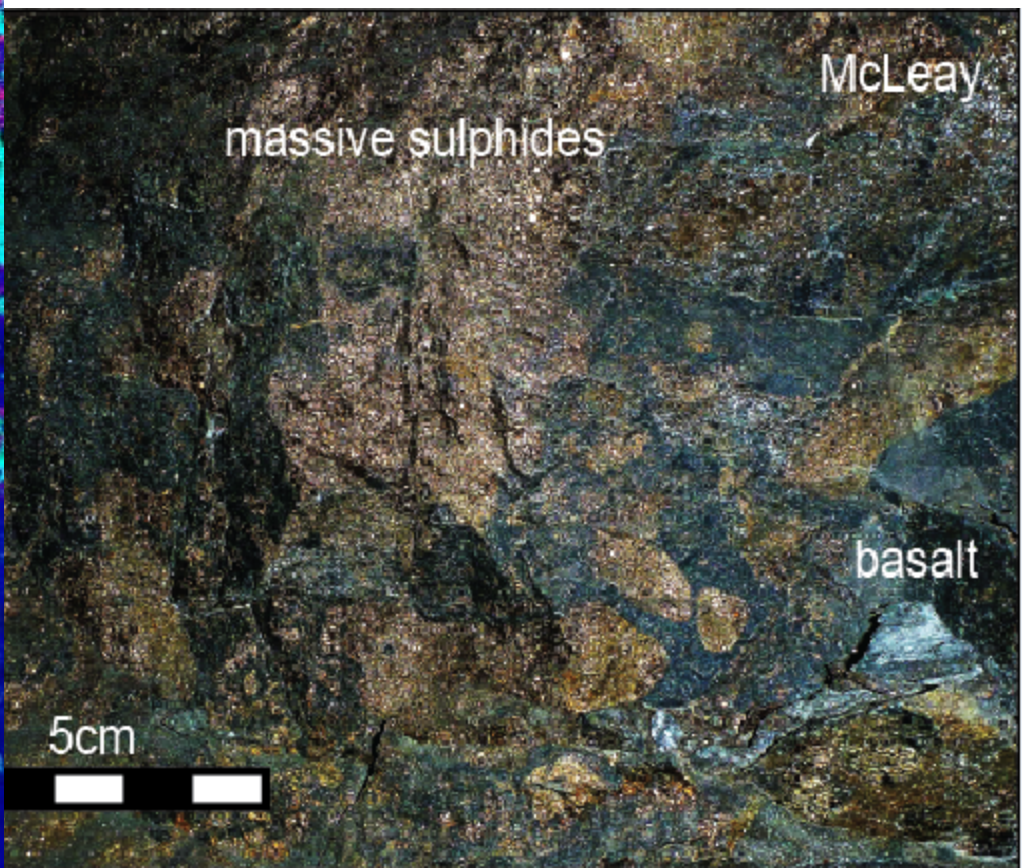
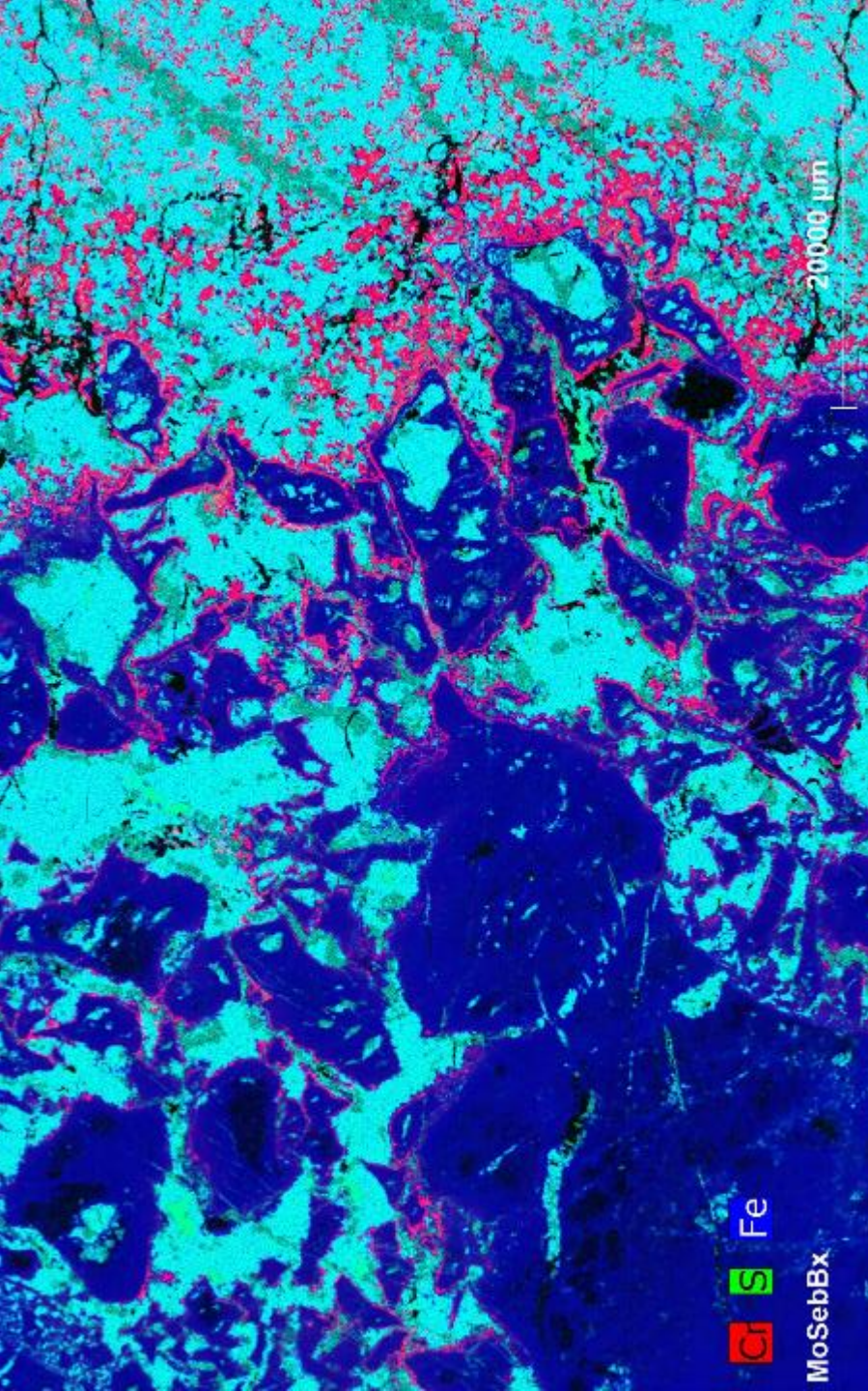
Staude et al Geology 2016

Staude et al OGR 2017

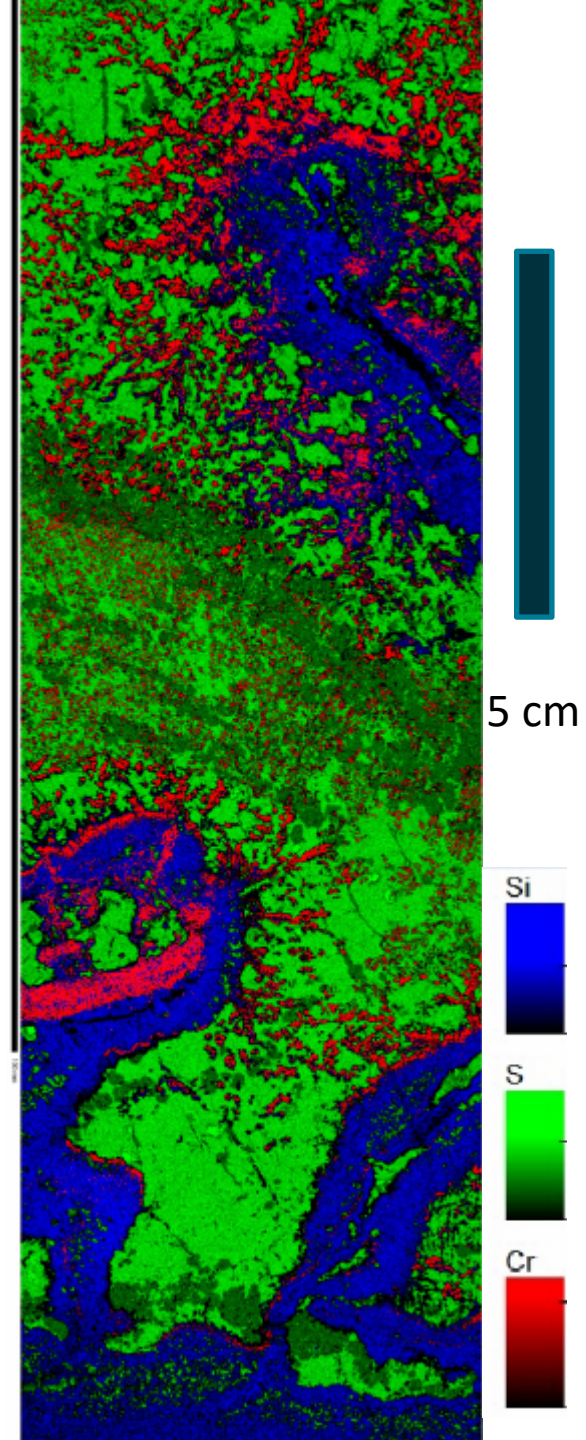
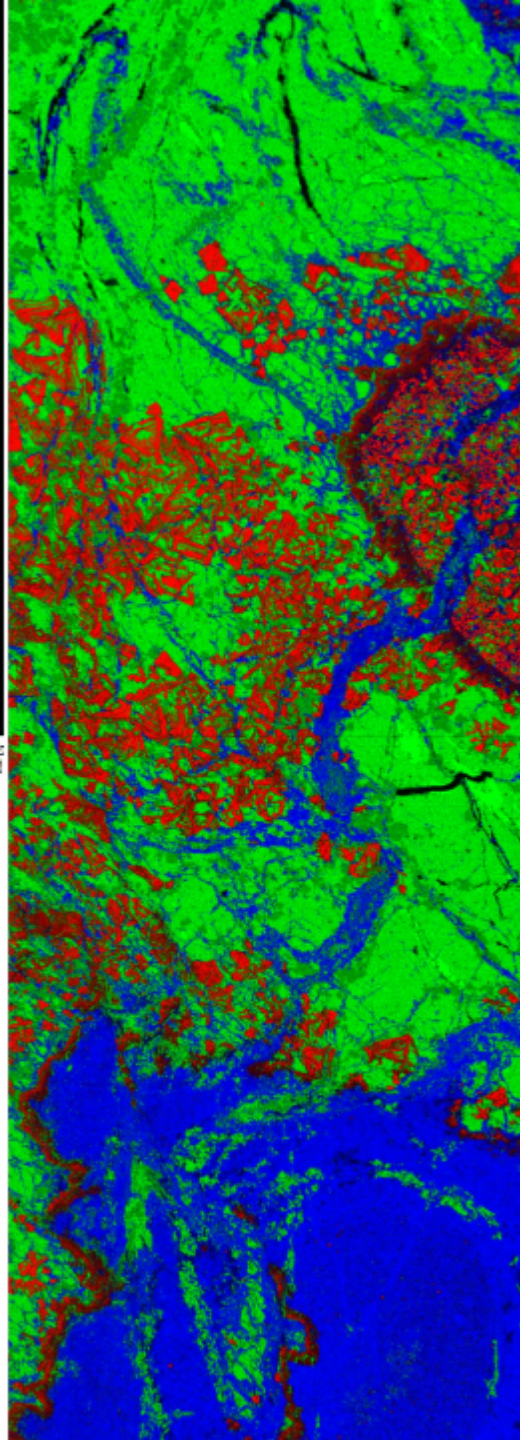


f

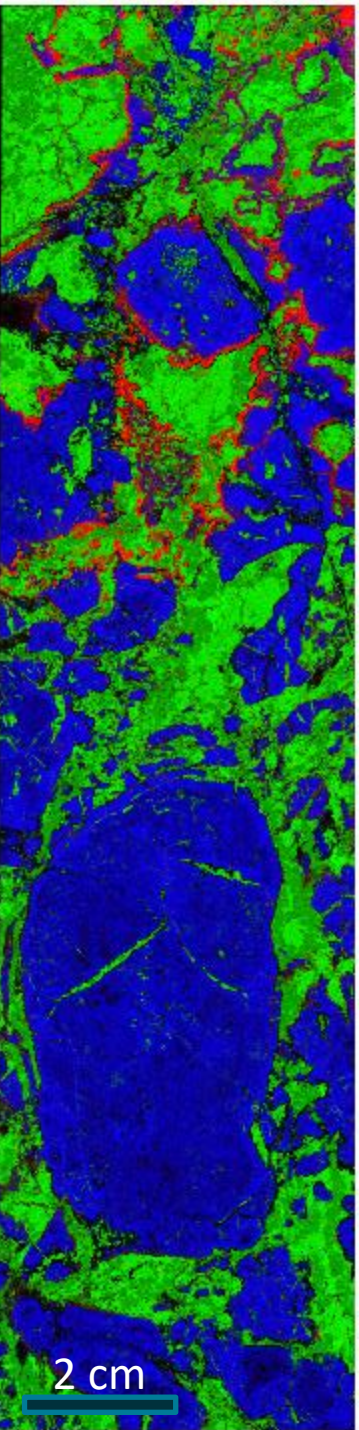




Basalt melt plumes



Sulfide-silicate infiltration-melting front: Moran Shoot, Kambalda

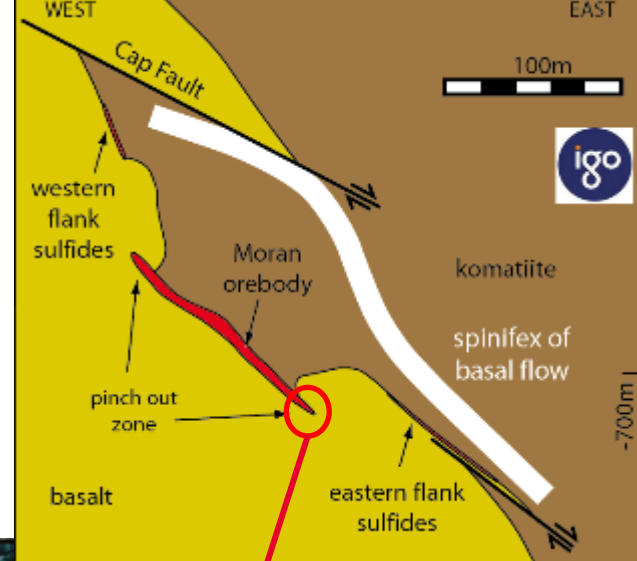


“Floating” basalt
plumes

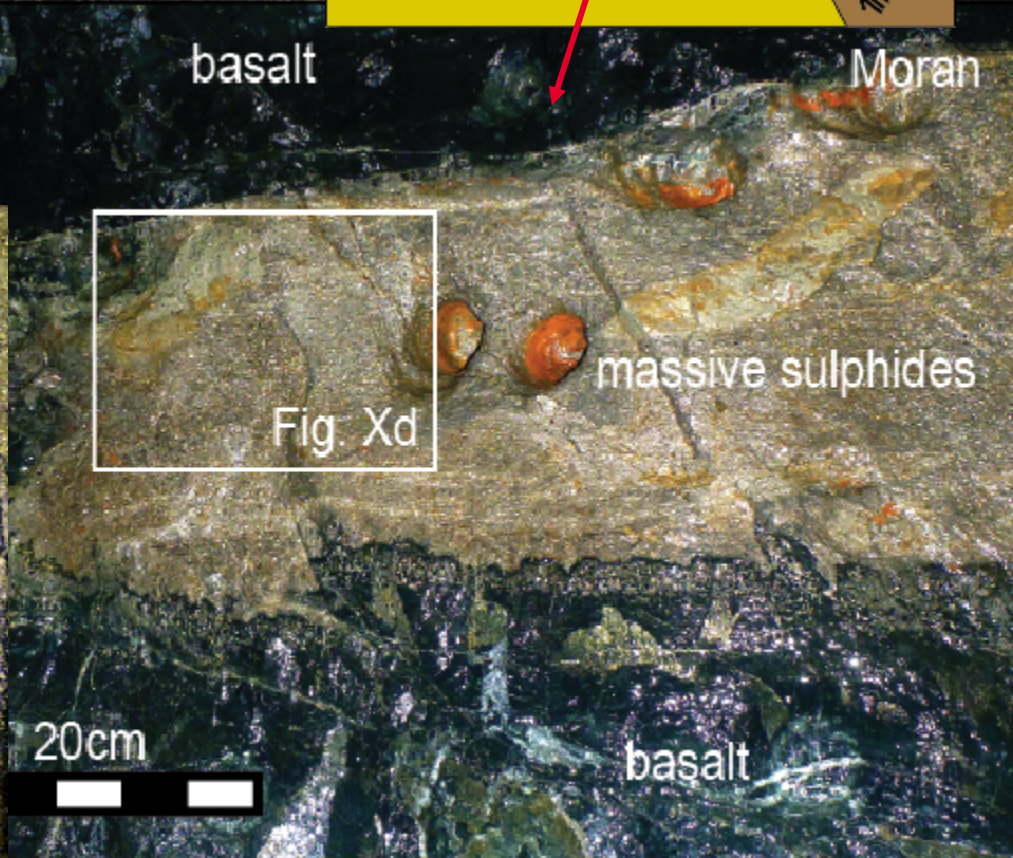
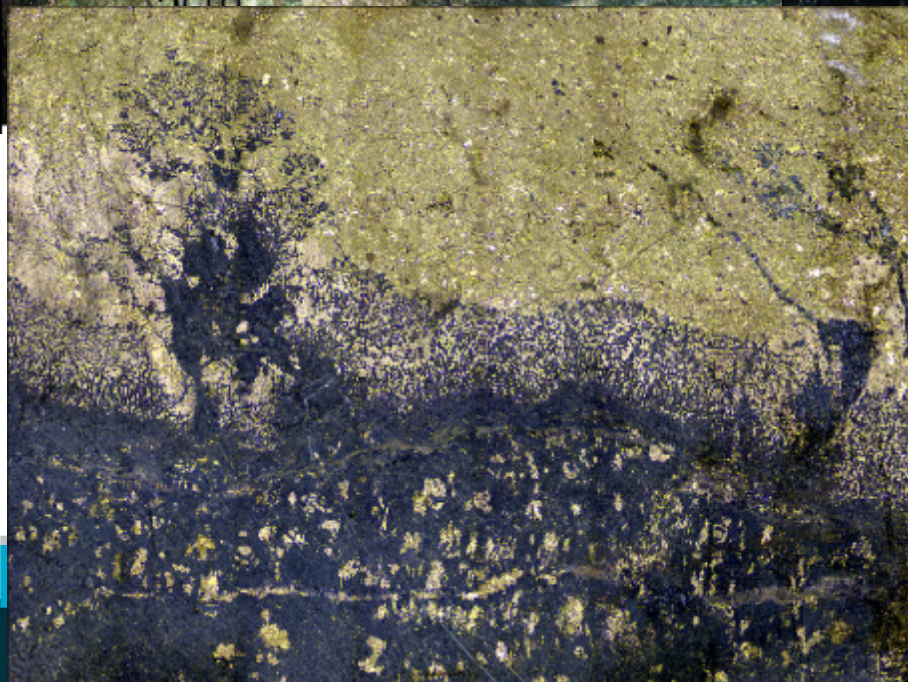
“Hydrostatic”
Differential
pressure at tip of
sulfide network
increases as veins
propagate
downwards

Hydrofractured
basalt with sulfide
penetrating along
fractures

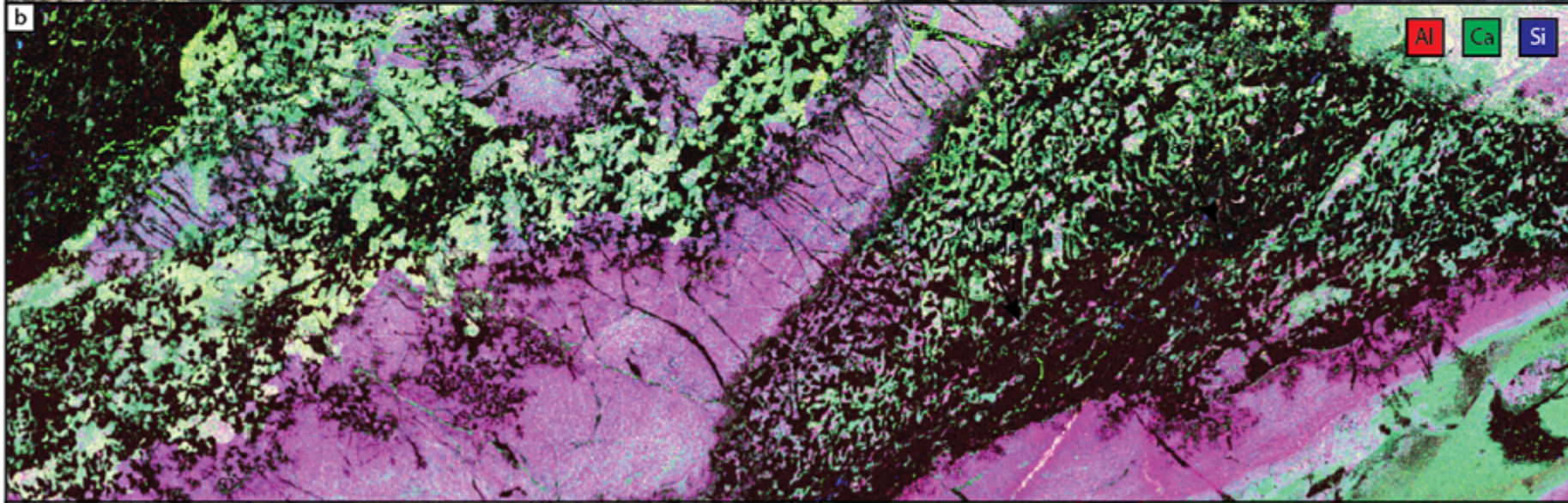
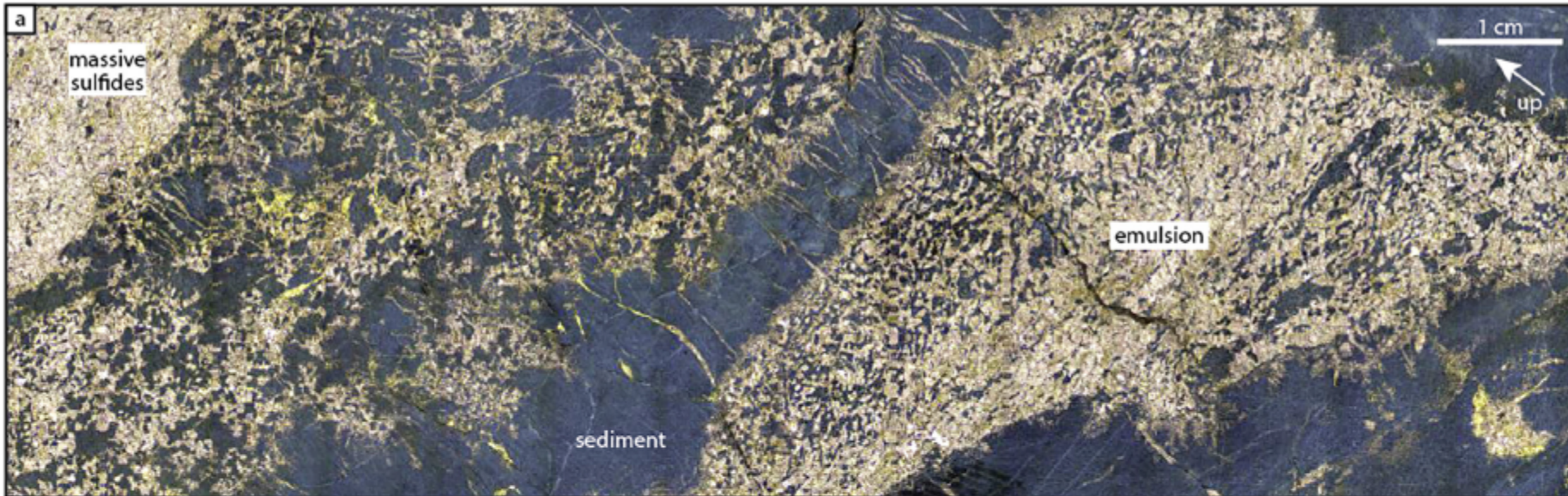
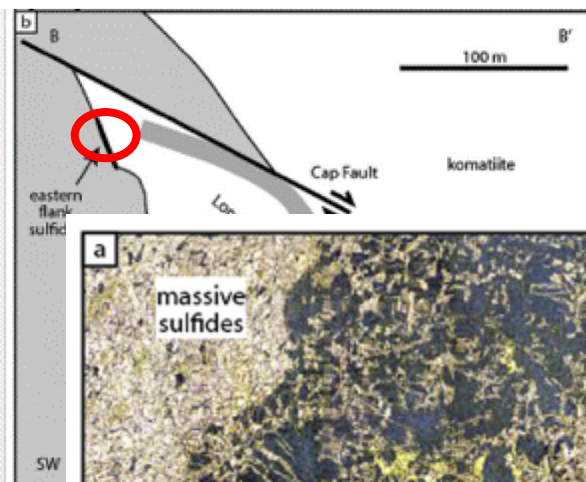
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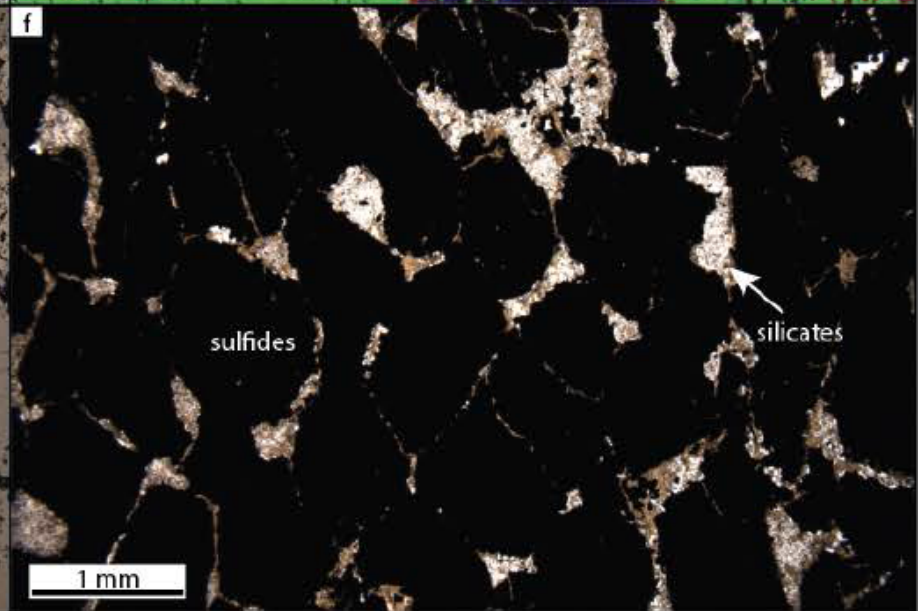
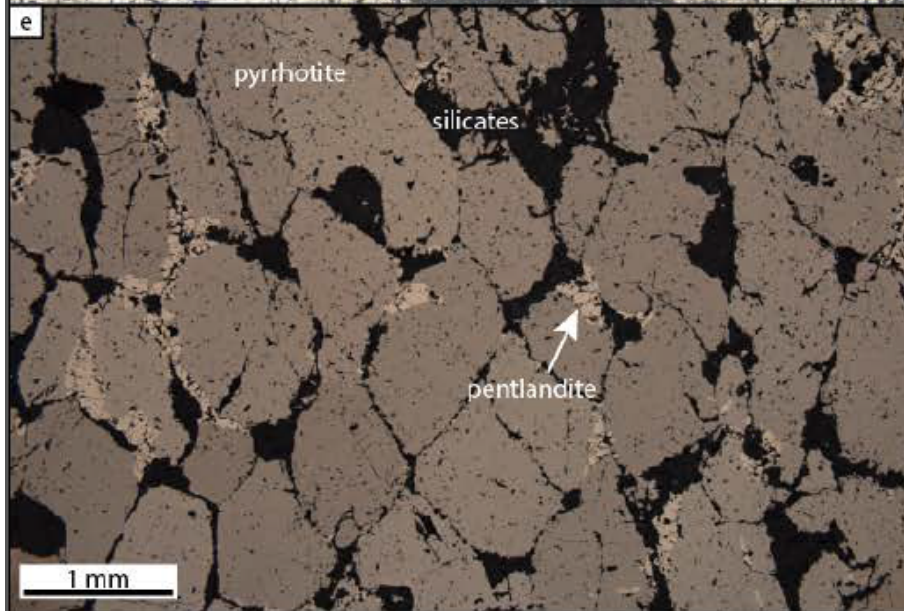
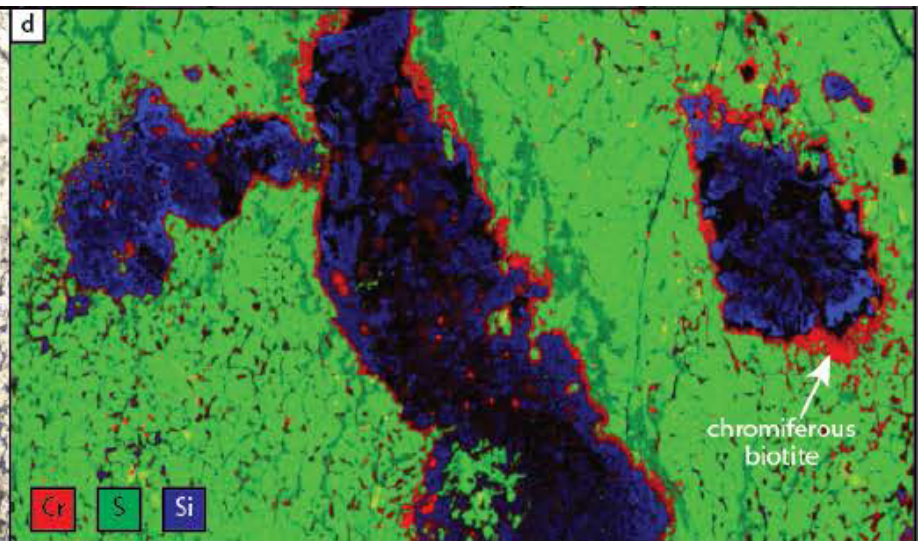
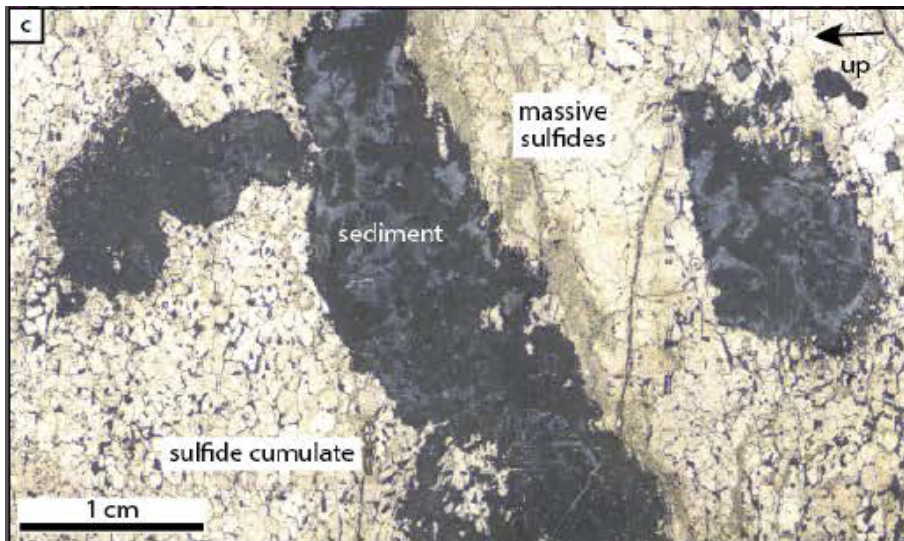


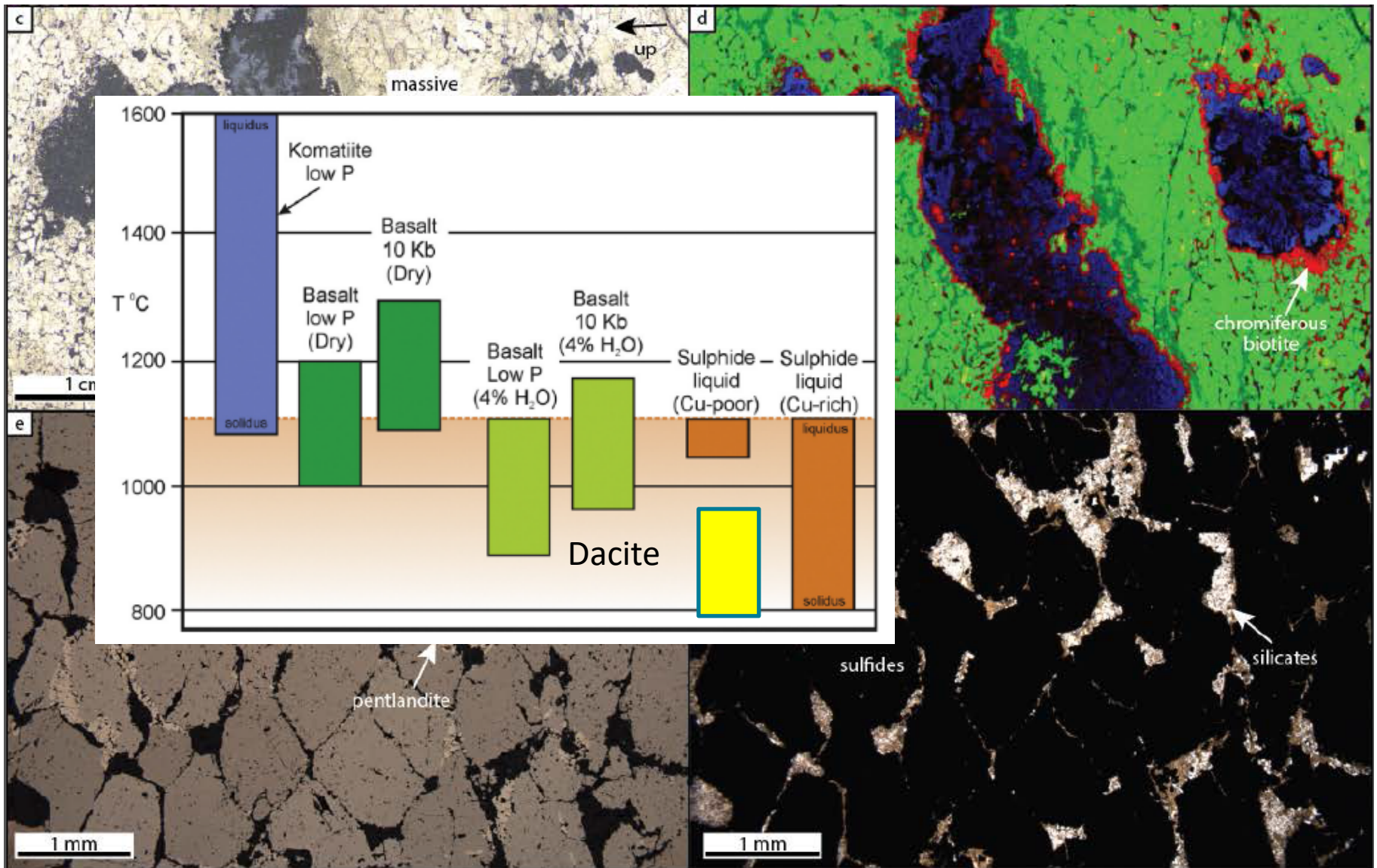
c



Sulfide melting into sediments



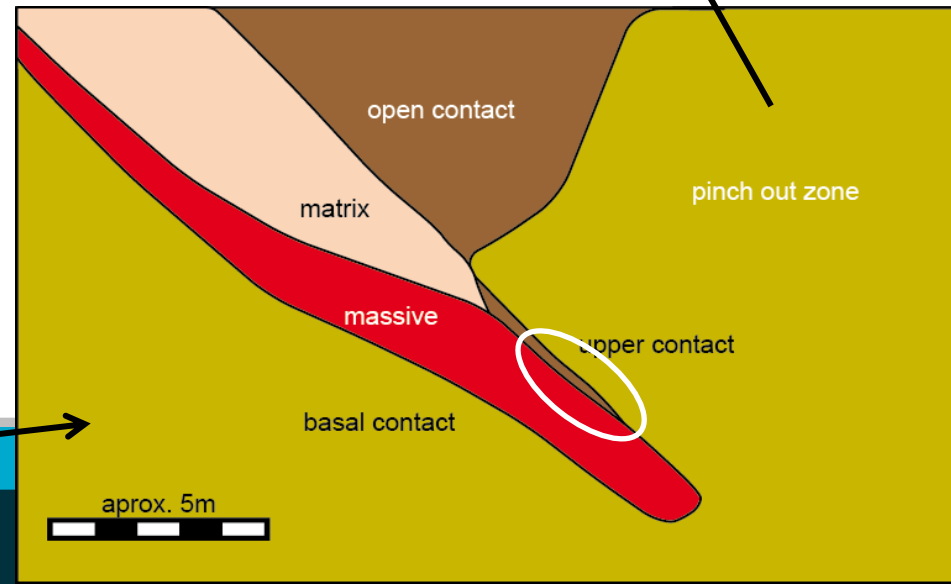
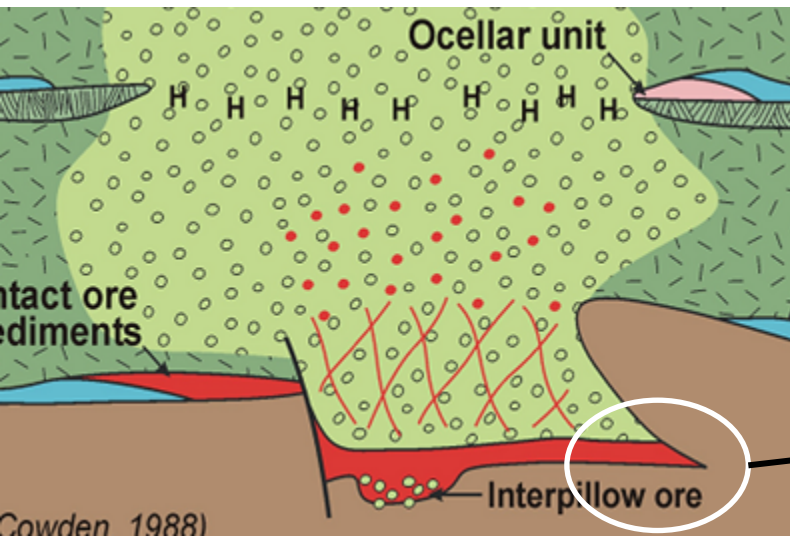


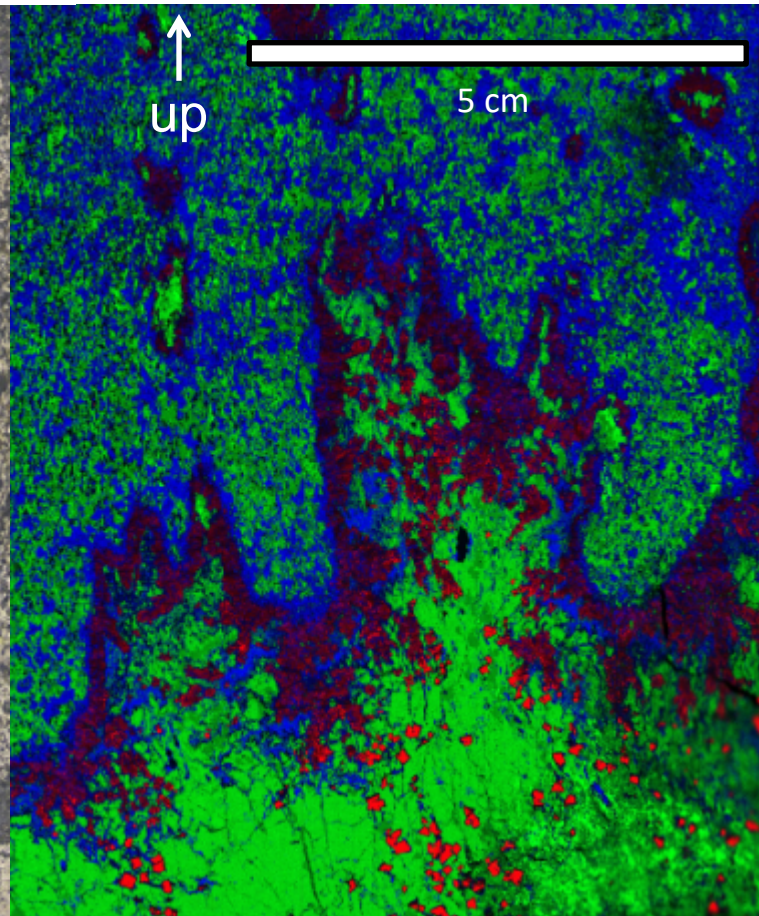
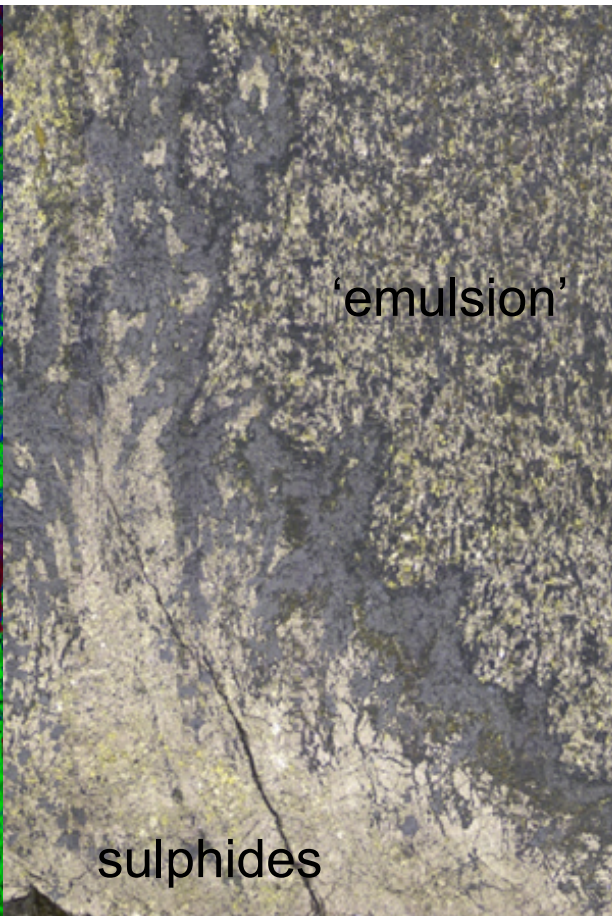
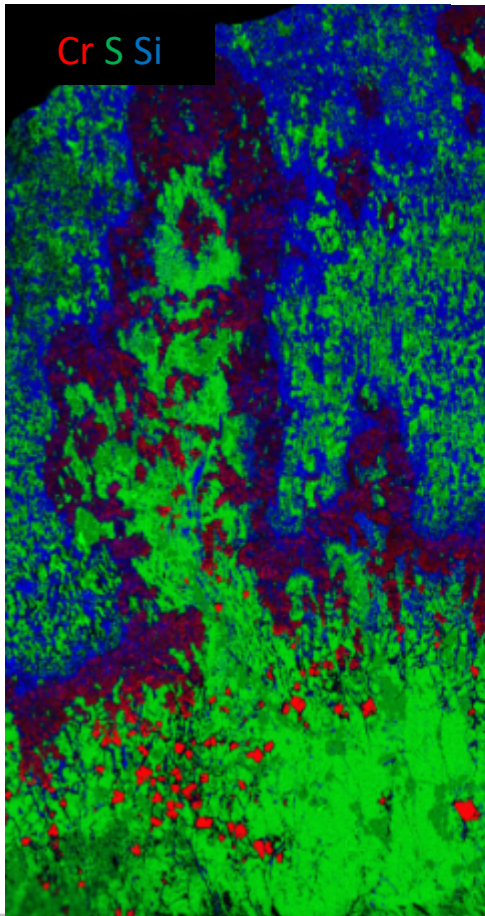
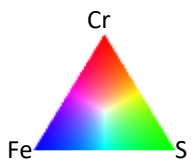


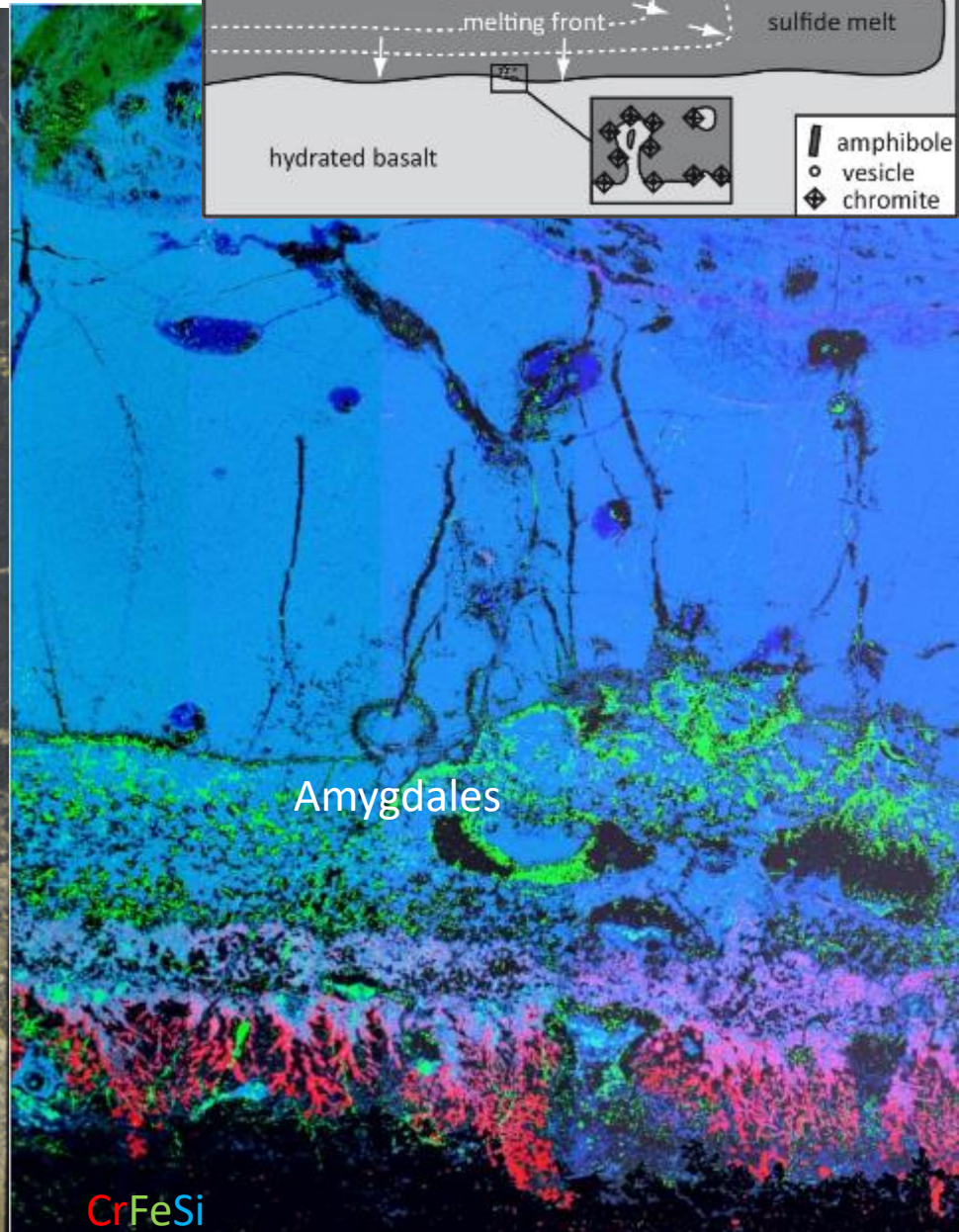
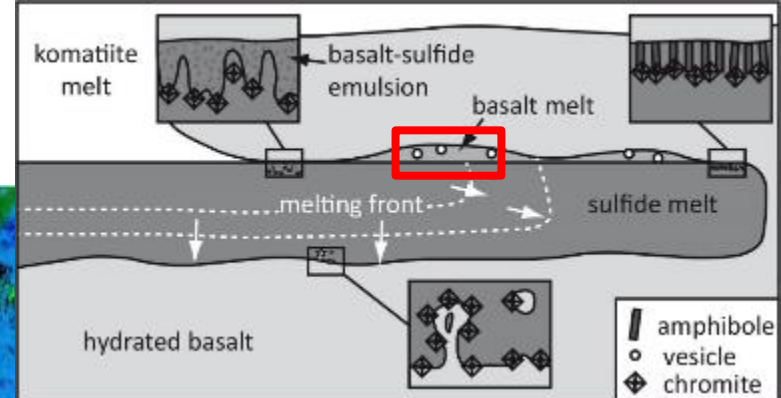
Moran Shoot pinchout zone

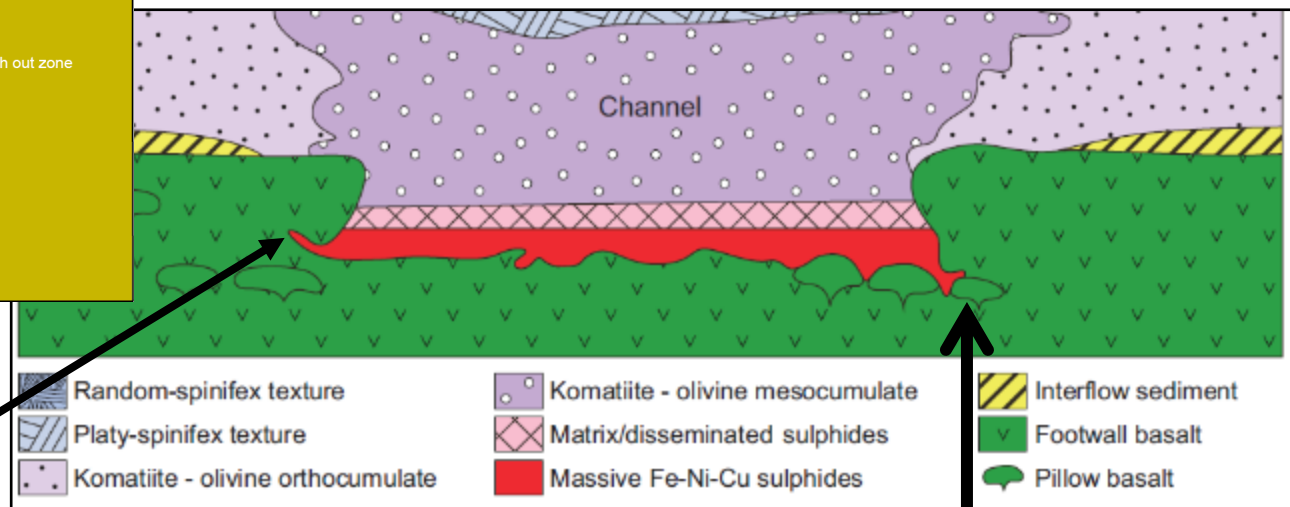
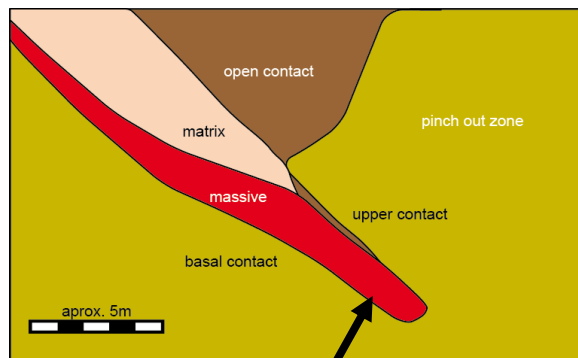
Silicate-sulfide emulsion texture

Staude et al Geology 2016





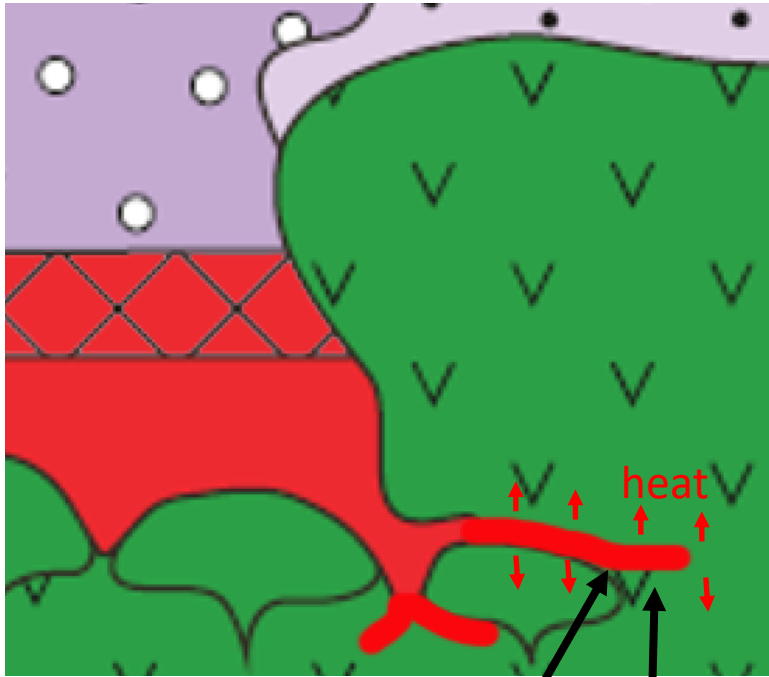




What drives lateral erosion here?

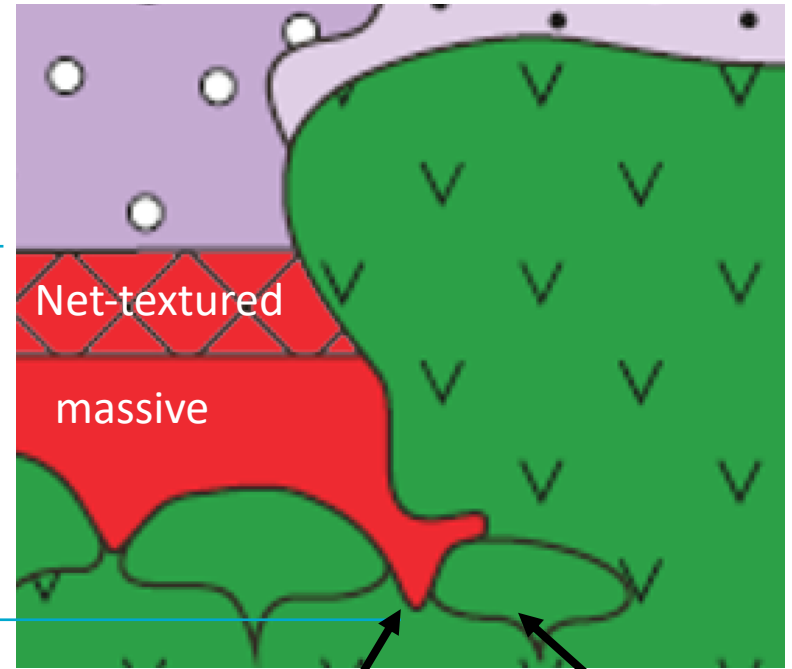
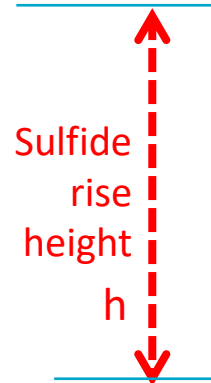
Excess
"magmastatic"
pressure due to
sulfide rise
height





Efficient heat transfer to roof
causes further melting here

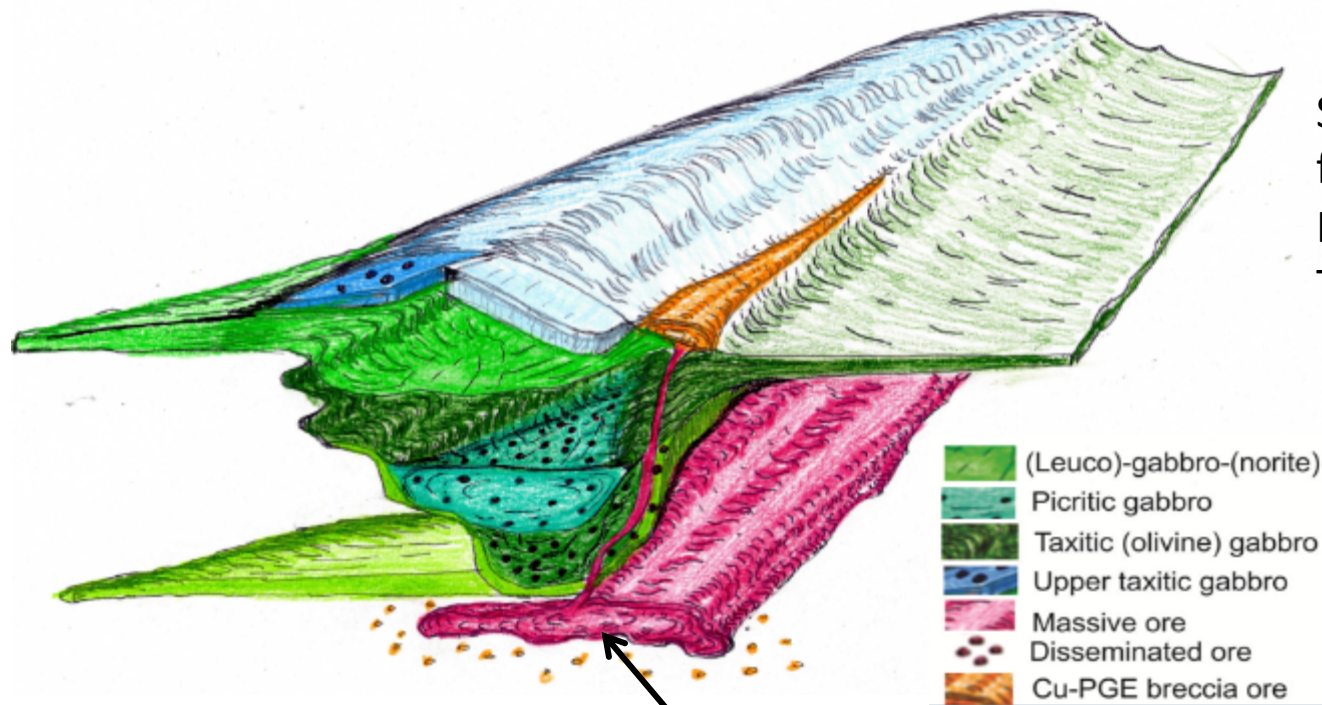
Causes sulfide liquid to
propagate into cracks
laterally and vertically here



Excess pressure here $hg(\rho_{\text{sul}} - \rho_{\text{bas}})$

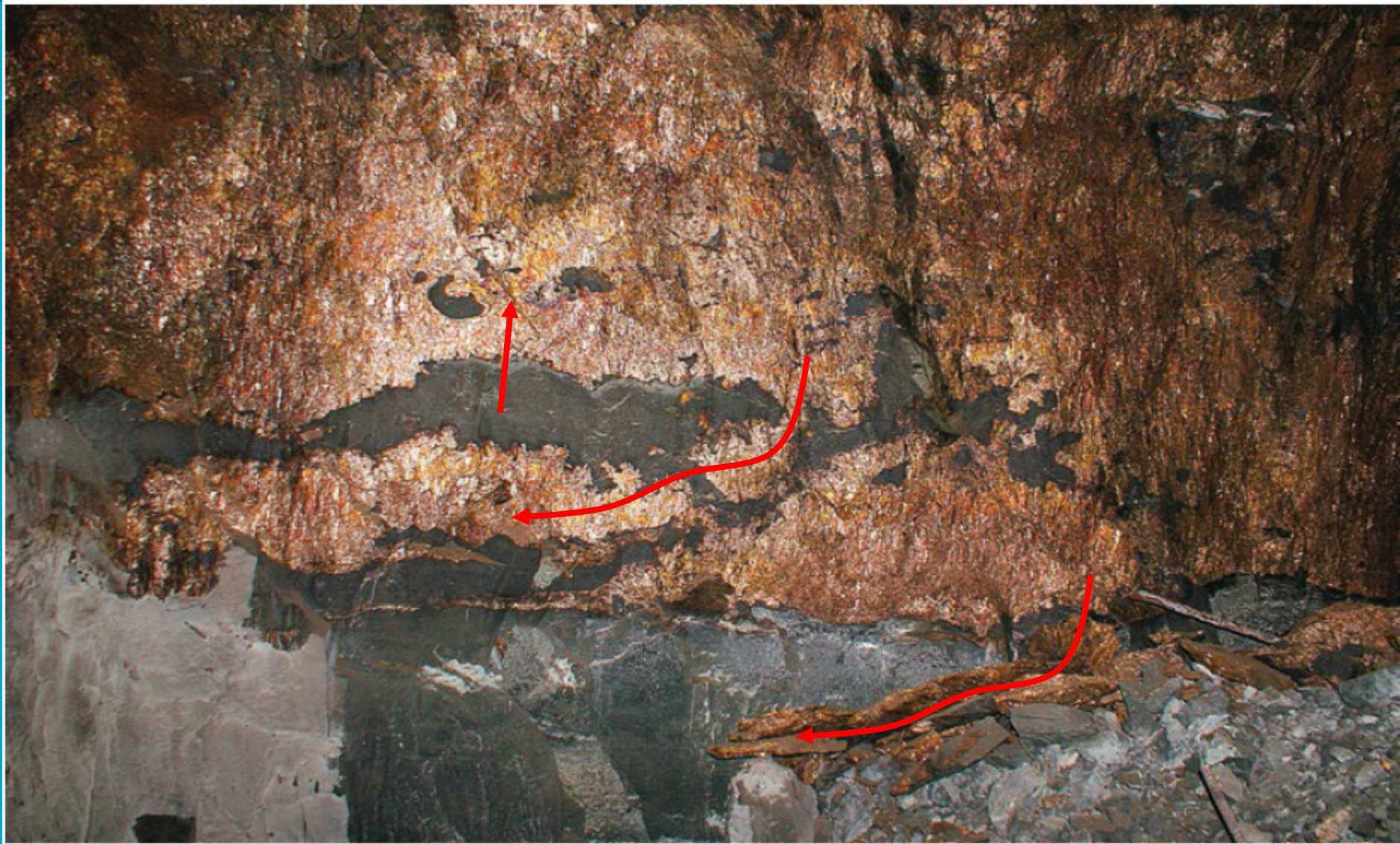
...relative to here

Sulfide melt can excavate its own "traps"



Sulfide – silicate melting fronts
 Kharealakh Intrusion,
 Talnakh (Noril'sk)

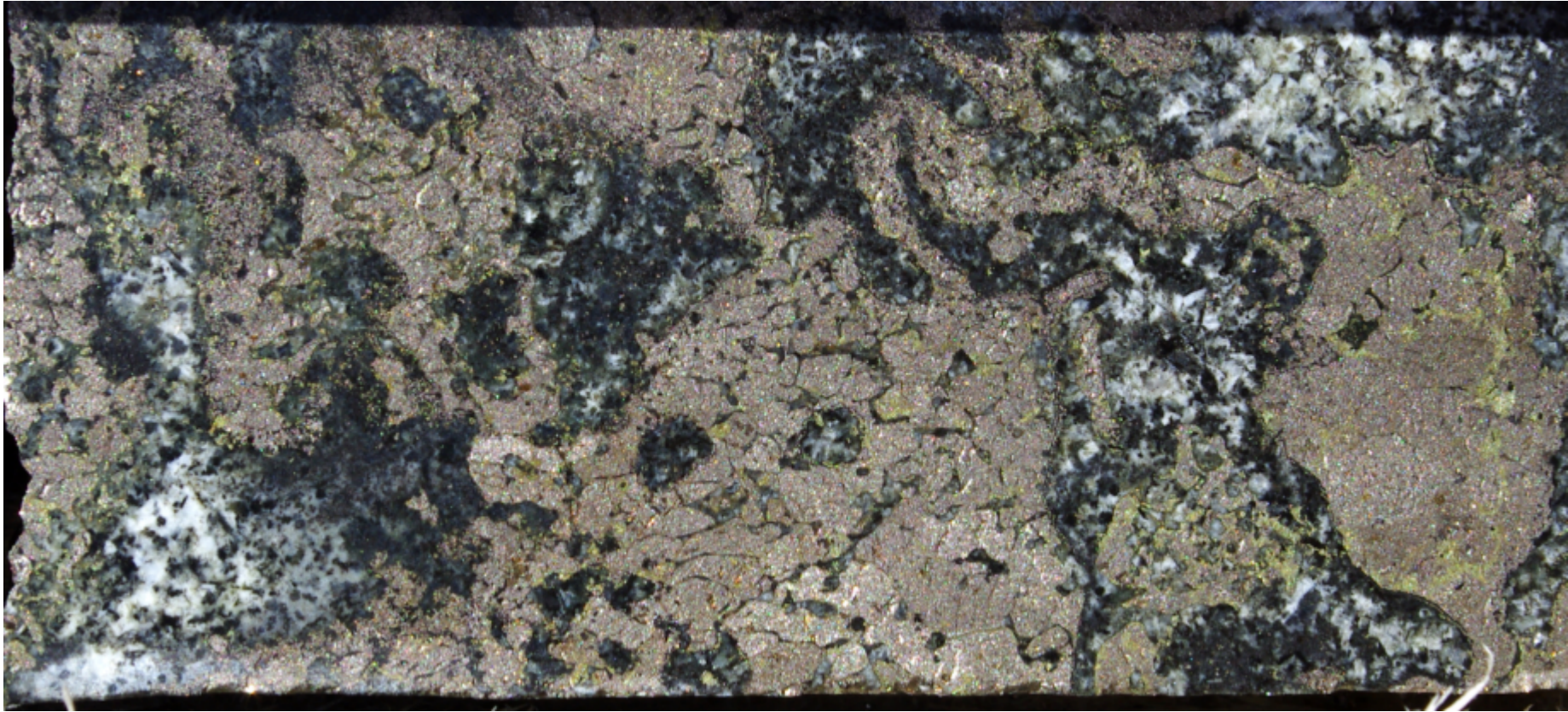


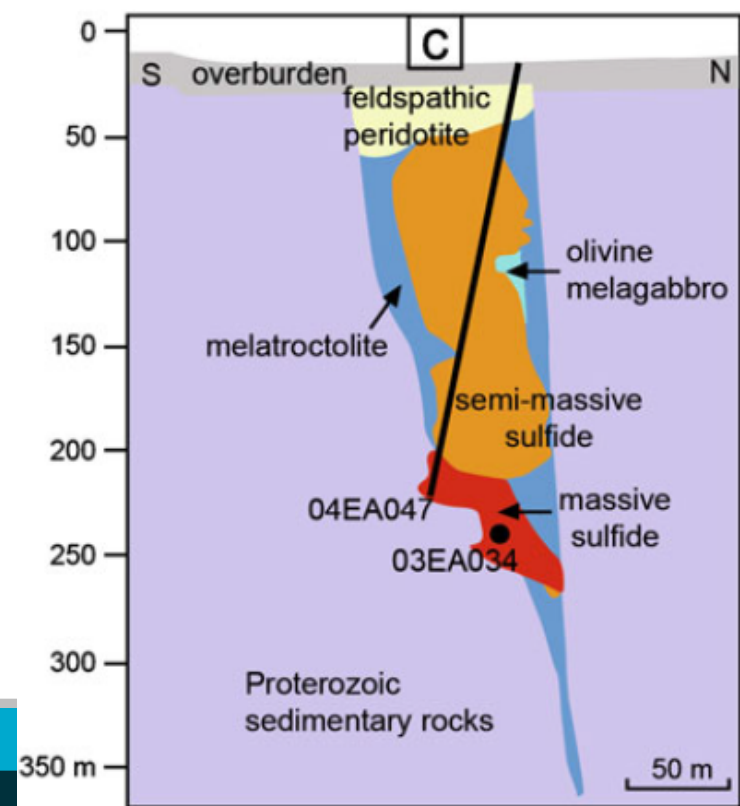
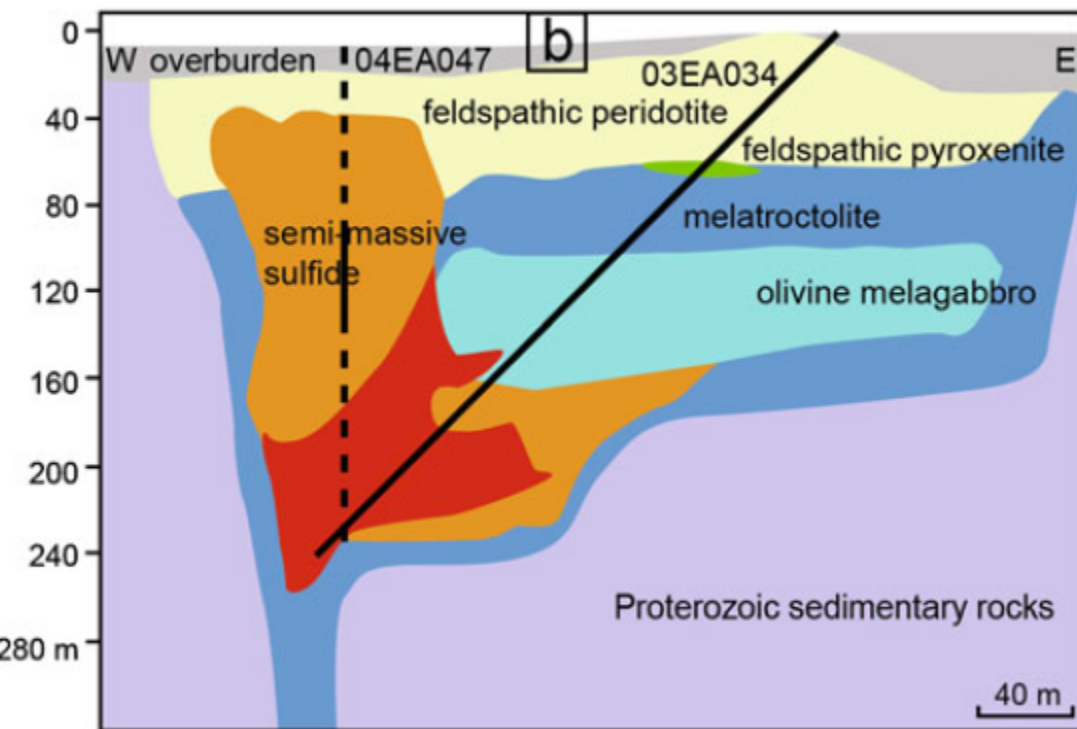
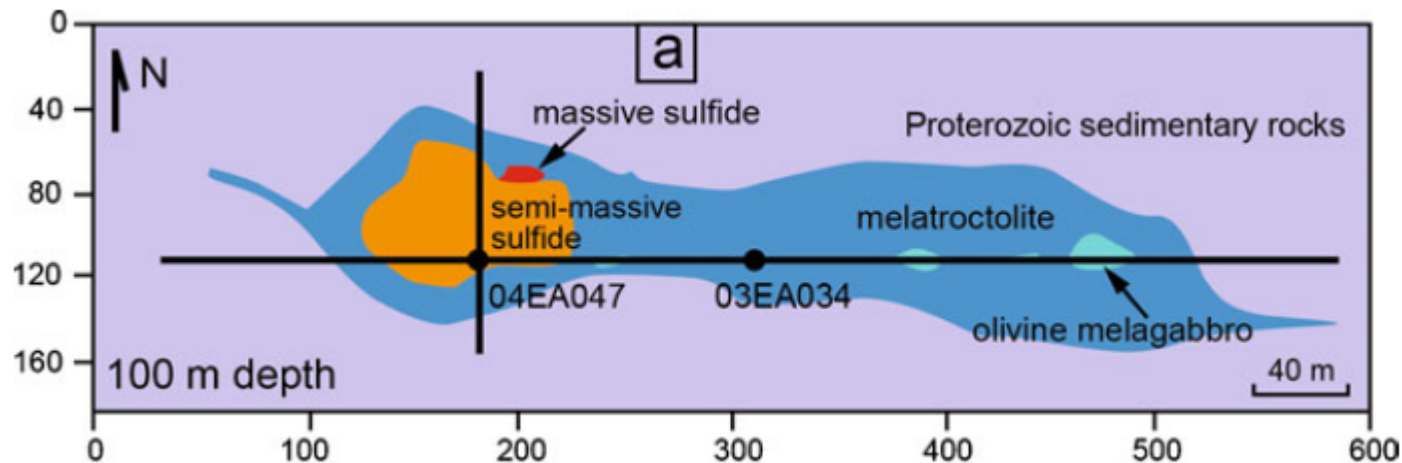


Sulfide melt infiltration front, base of the Oktyabrynsky massive sulfide sheet. This is a melting raft of footwall metasediment floating up into sulfide but still attached to the floor. Photo courtesy of Nadya Krivolutskaya and organising team of 13th International Pt Symposium, Russia, 2013.
Sluzhenikyn et al, (2013)

Noril'sk-Talnakh ore textures

Emulsion textures



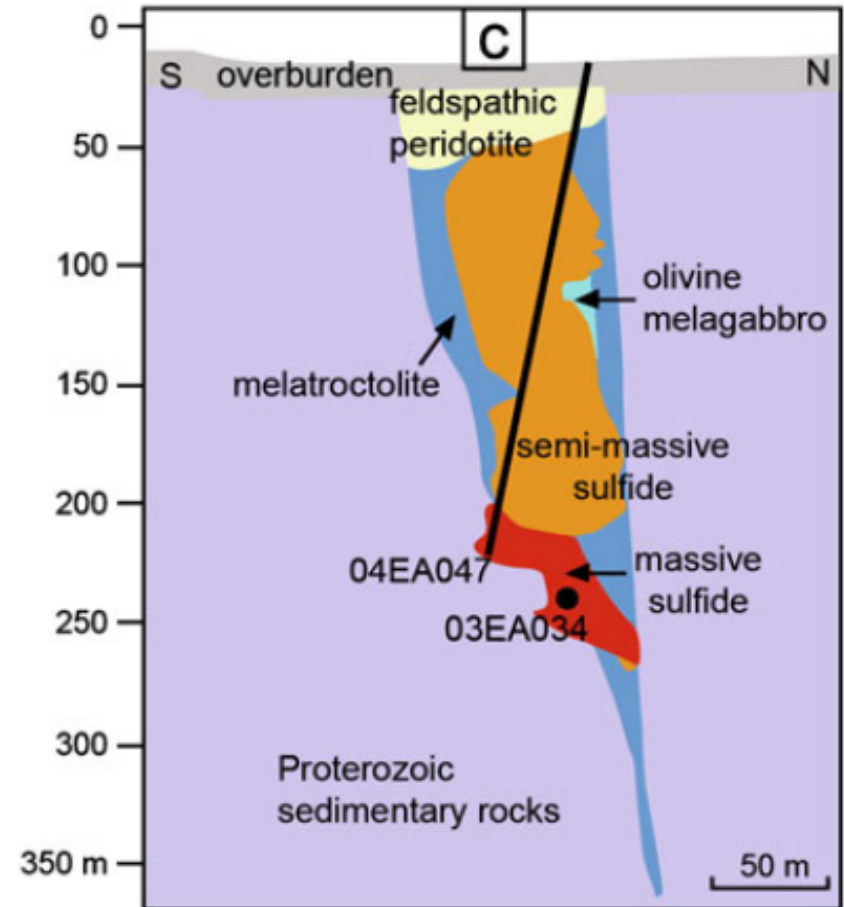


Sulfide infiltration-melting front – sulfide-black shale contact, Eagle



Sulfide ore textures and emplacement mechanisms

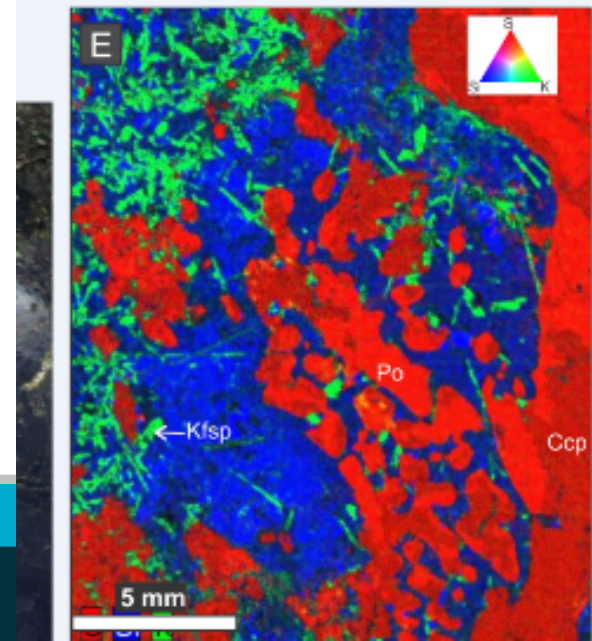
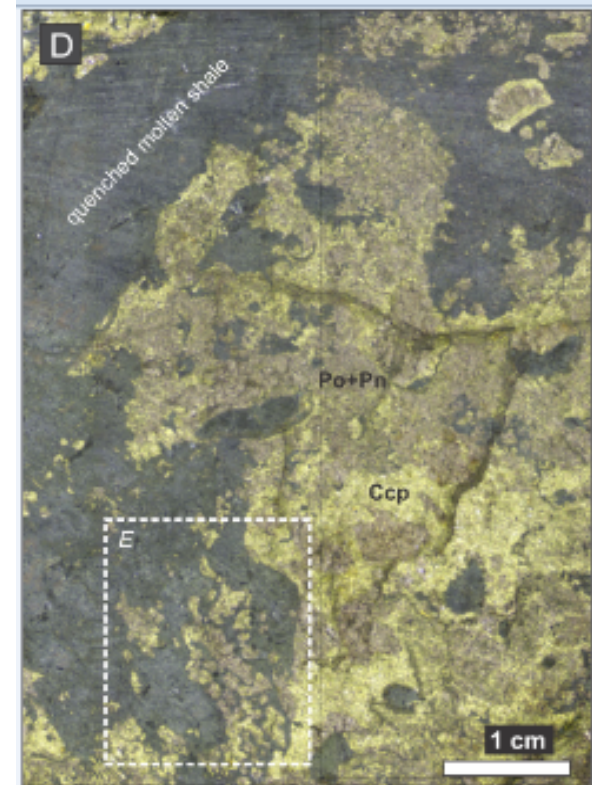
Barnes et al., 2018, in review)



Host intrusion geometries and subvolcanic plumbing systems

Eagle (mid continent rift, USA)

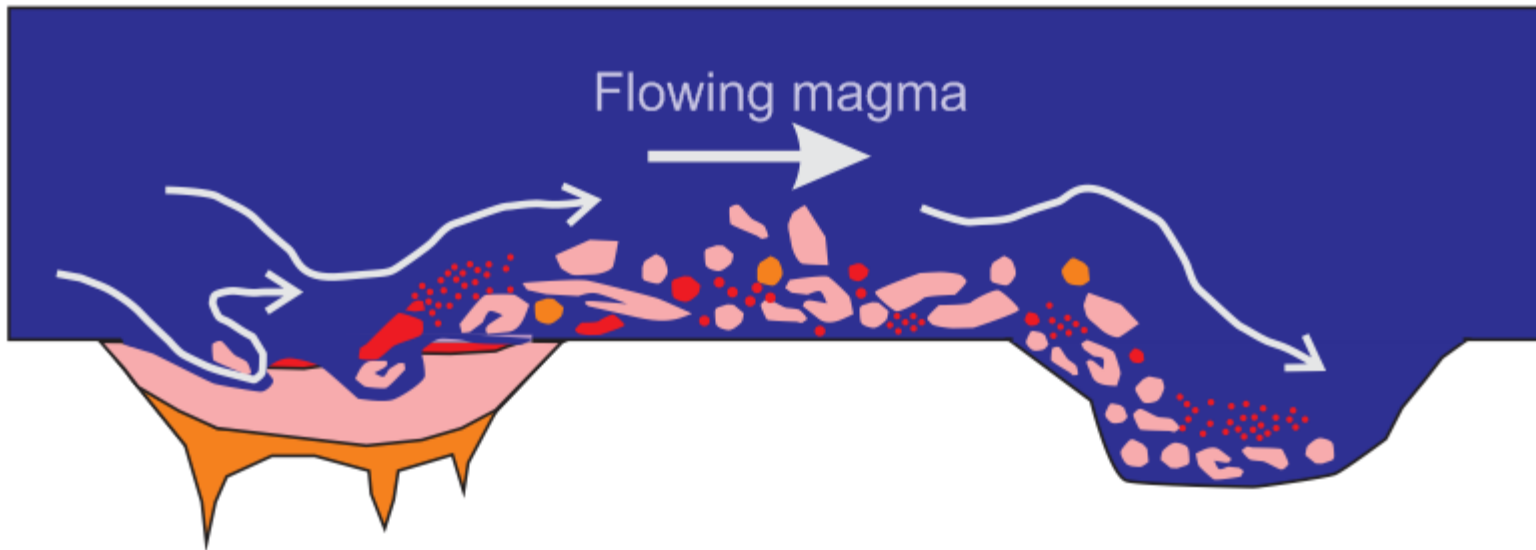




Eagle – sulfide invading black shale at an infiltration-melting front

Take home:

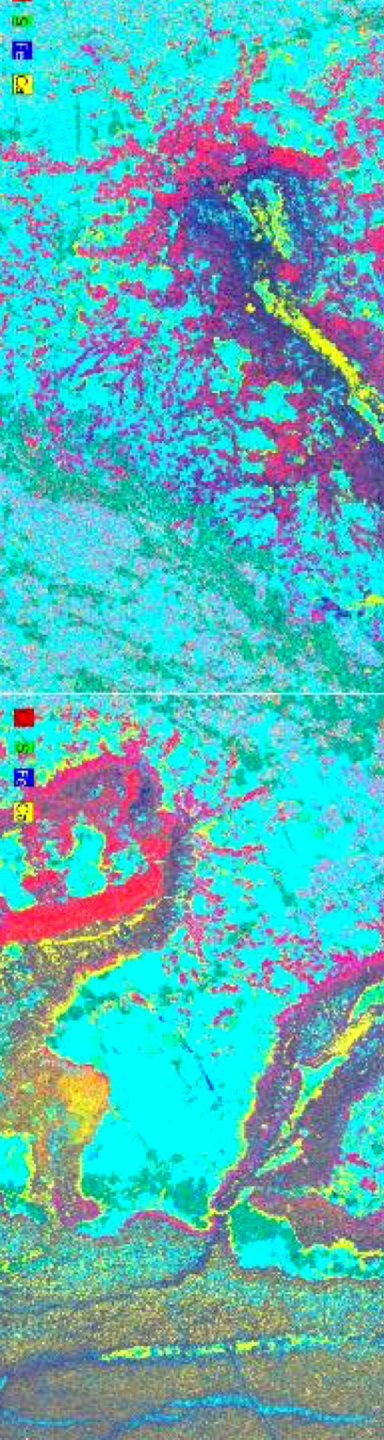
- Sulfide are highly mobile post deposition and can melt or infiltrate their way several metres, maybe tens of metres into country rocks
- Process can be self-reinforcing as long as a heat source is present.
- Chicken ore egg – topographic embayments and sulfide pools? Which came first?



World's Most Accurate Pie Chart

Pause for questions...





1. Disseminated ores, matrix ores and sulfide liquid percolation, leading to...
2. Sulfide/silicate melting fronts and
3. “breccia ores”

Sulfide-matrix breccias: silicate aggregates (rock fragments, molten or partially molten silicate and disaggregated grains) in a matrix of sulfide melt



Aguablanca

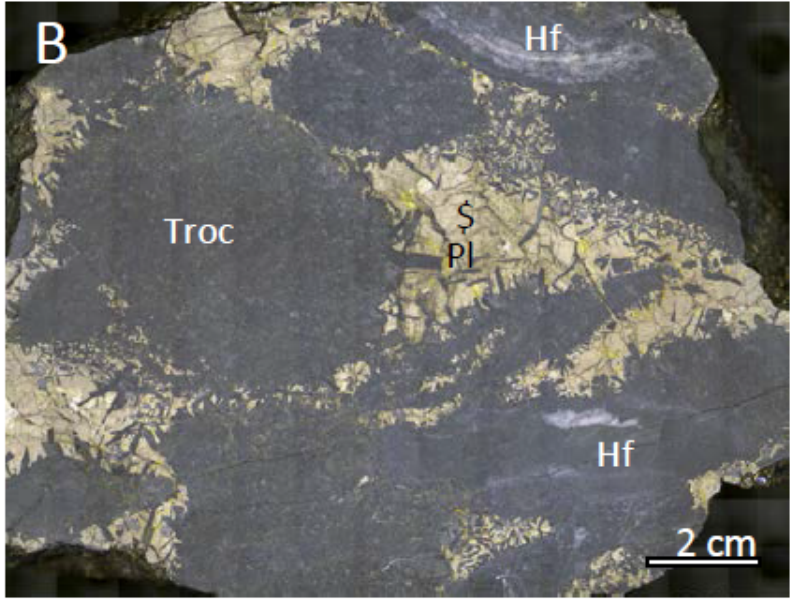


Totten mine, Sudbury

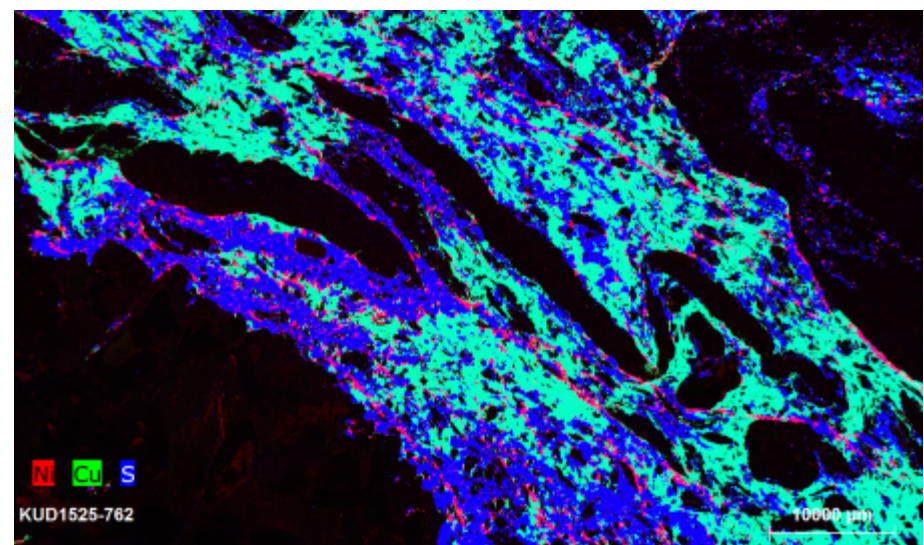
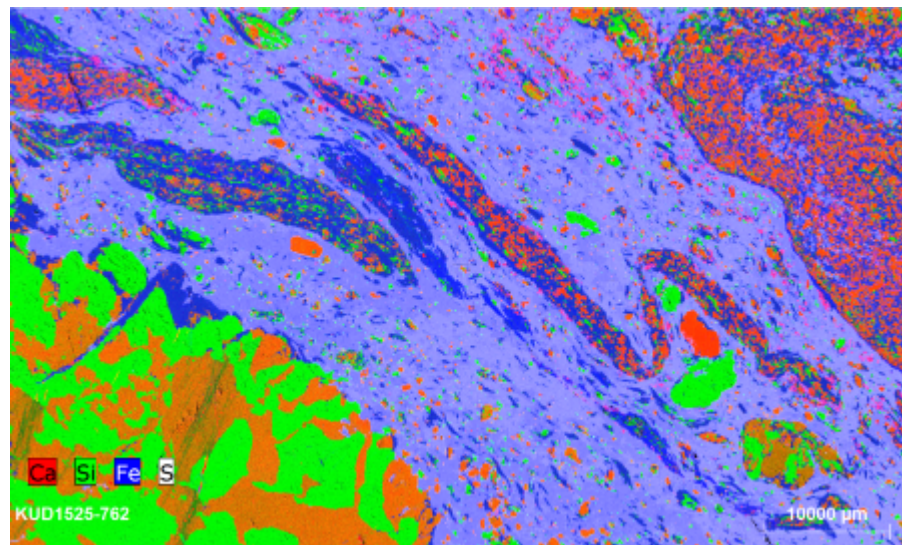
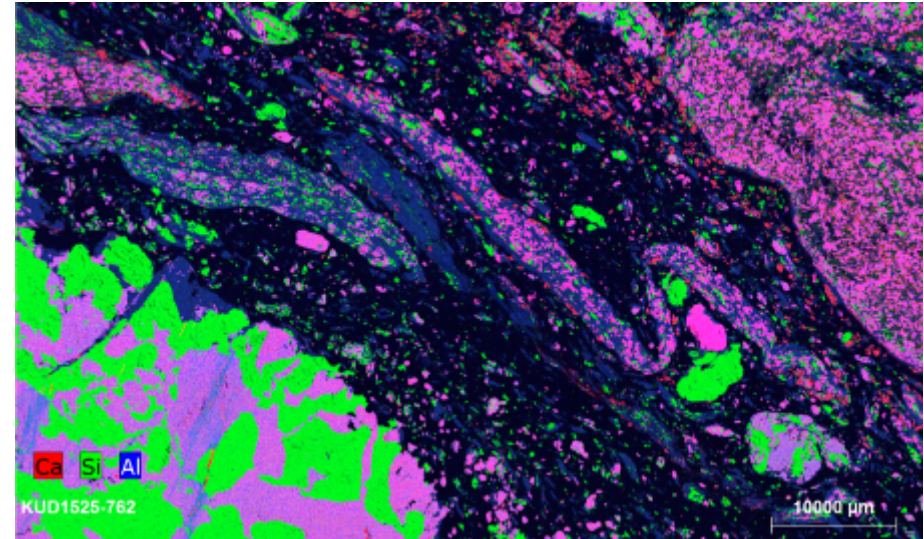
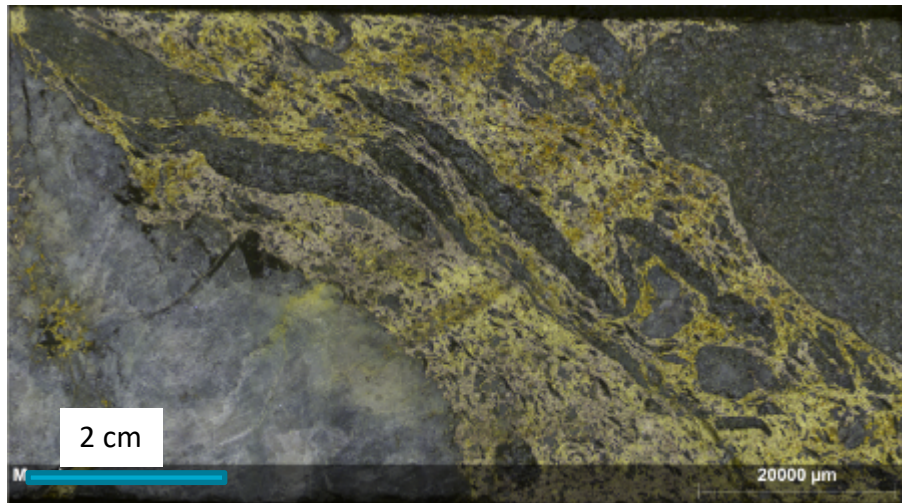


Savannah (Sally Malay) WA

Voisey's Bay



Tectonic (“durchbewegung”) breccias

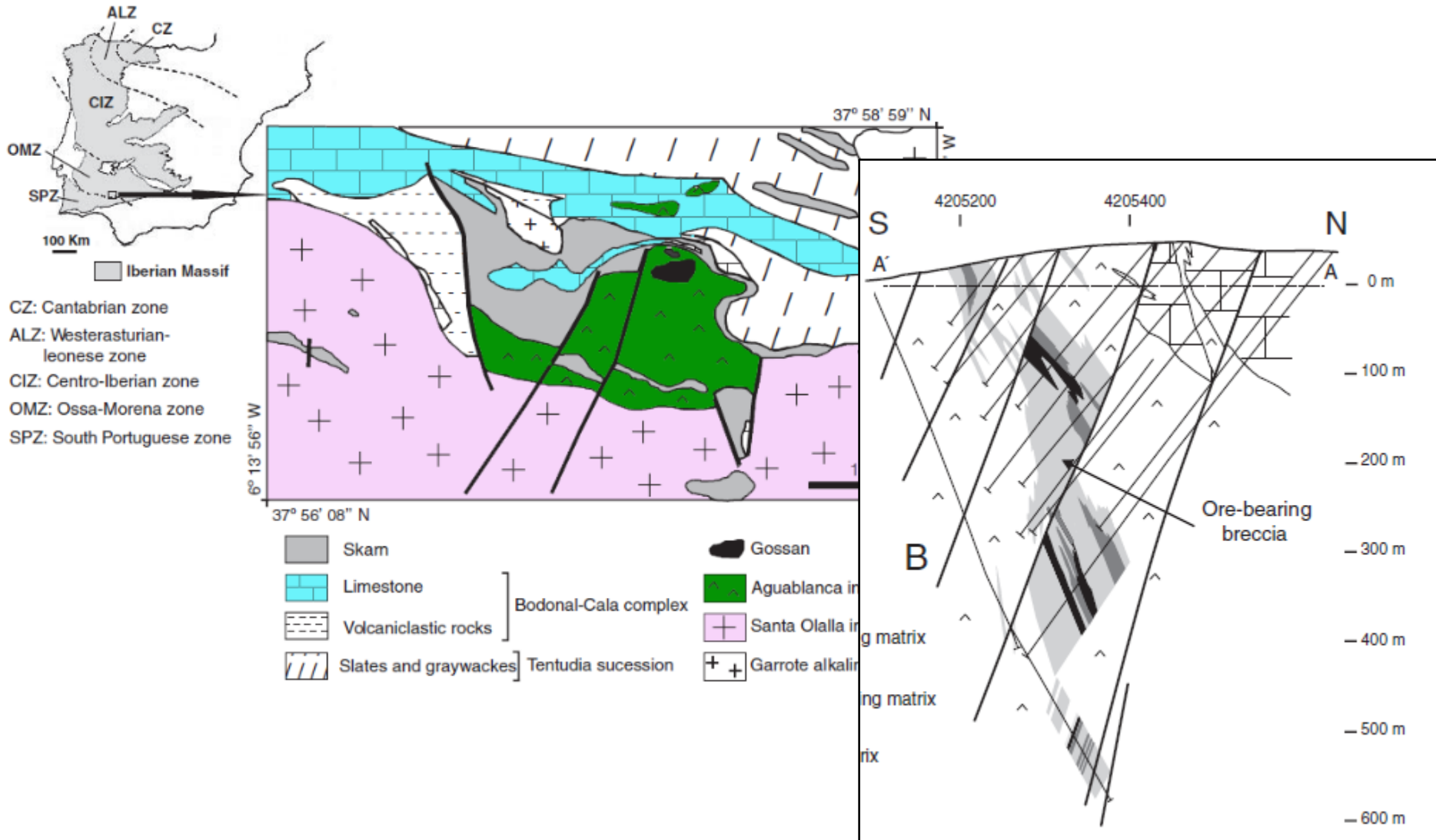


(Savannah North)

Tectonic durchbewegung breccias – Emily Ann



Aguablanca, Spain



Aguablanca sulfide ore breccias

Po-Pnt>Cpy>Py matrix



% Ni >1 high grade
Ni/Cu aprox 3-5

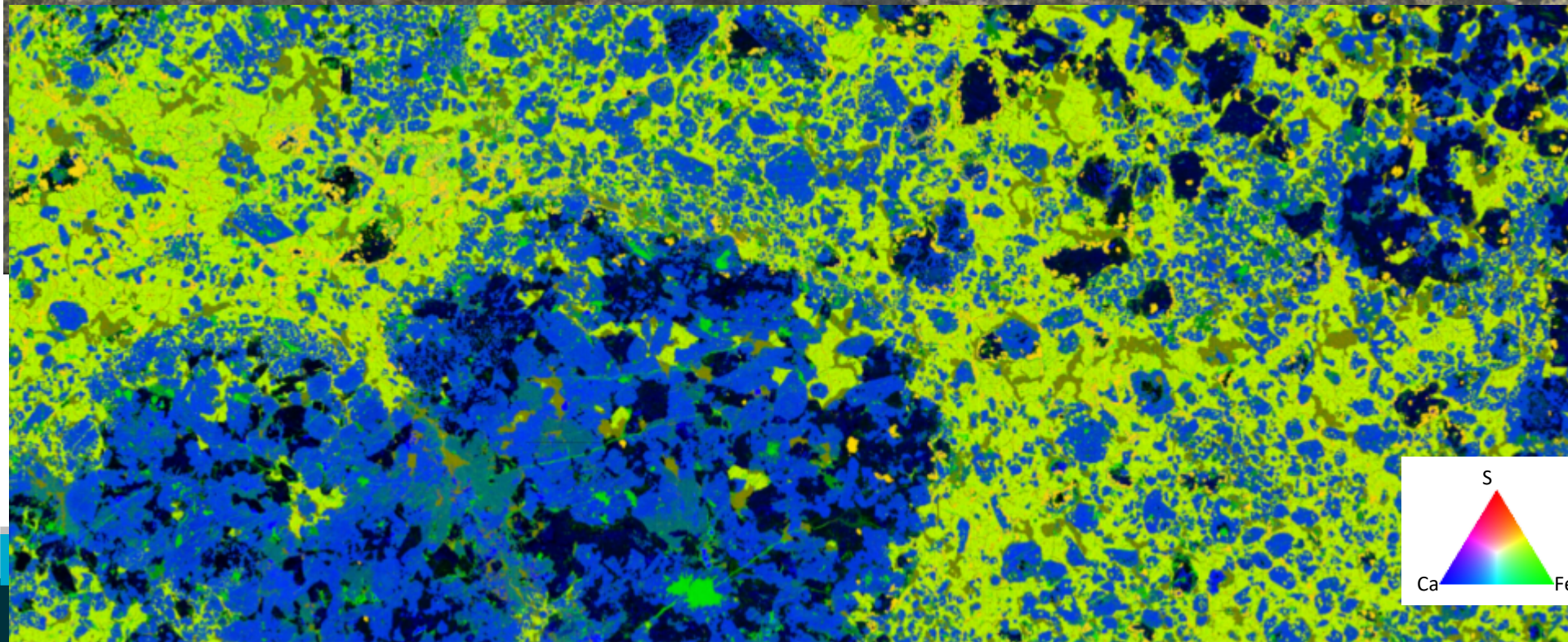


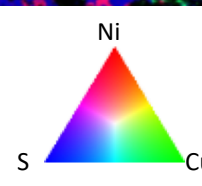
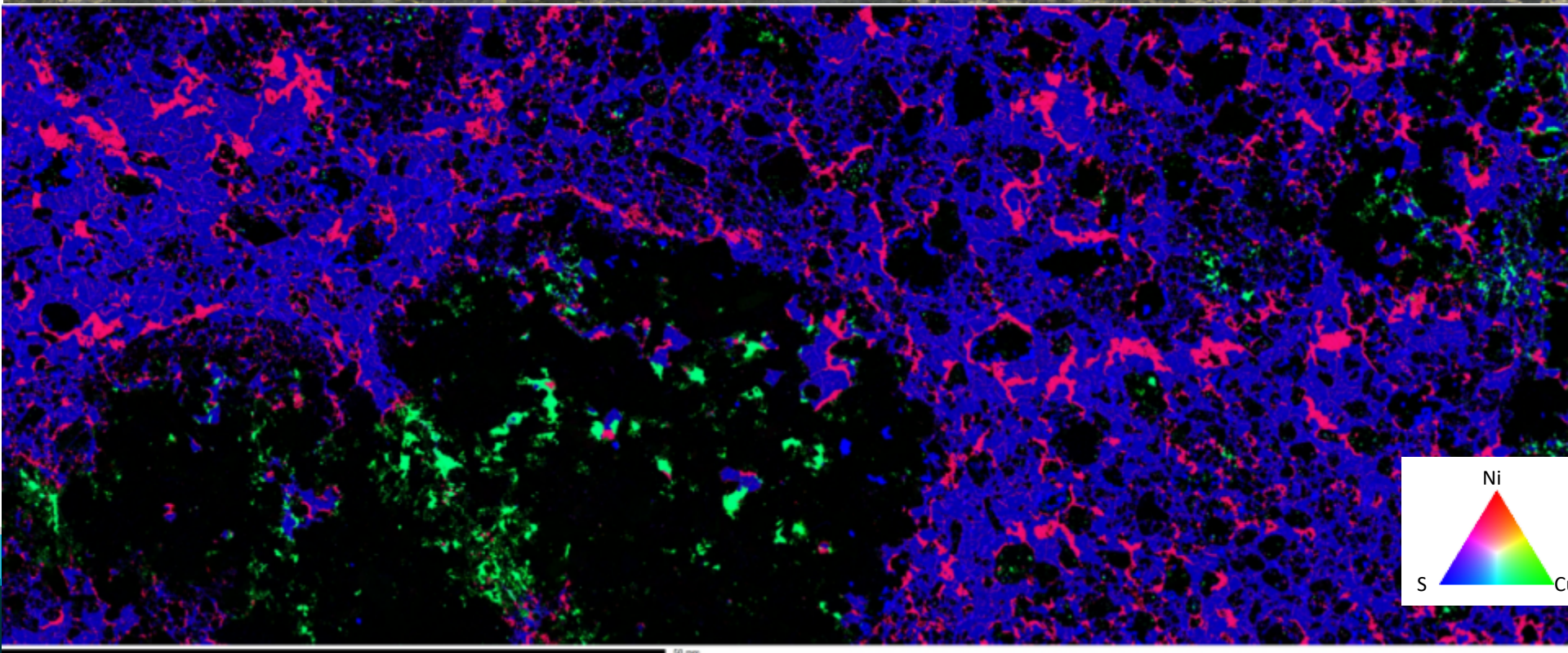
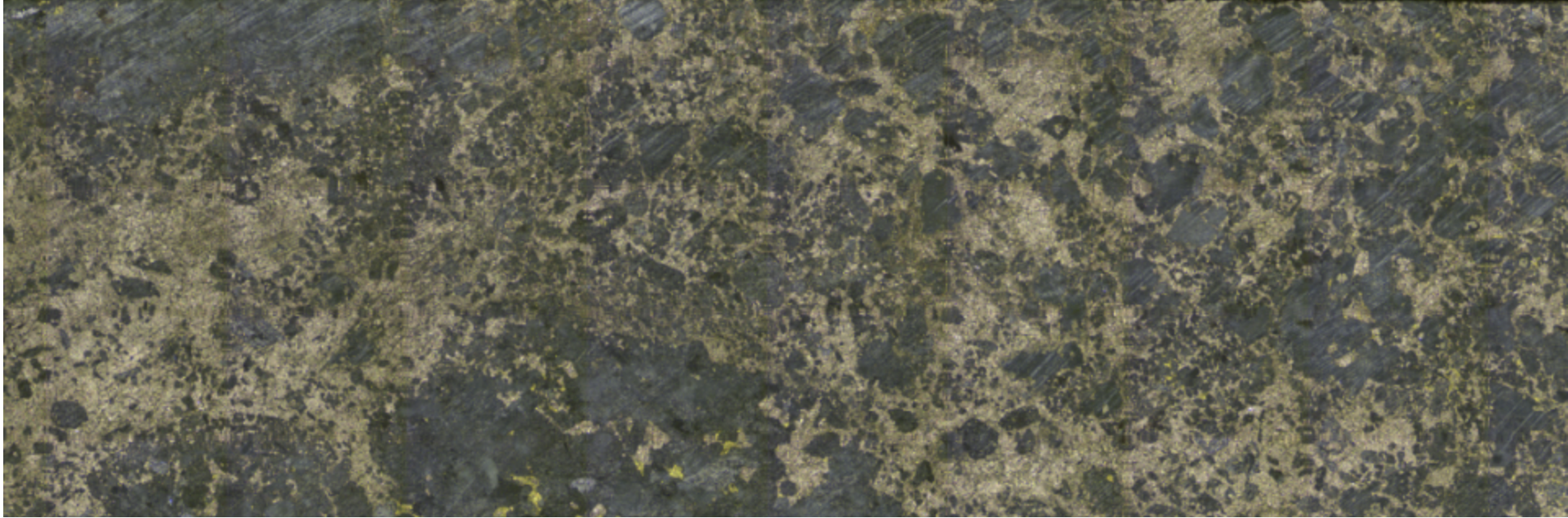
Patchy porphyritic grabbro

Po-Pn>Cpy>Py patches

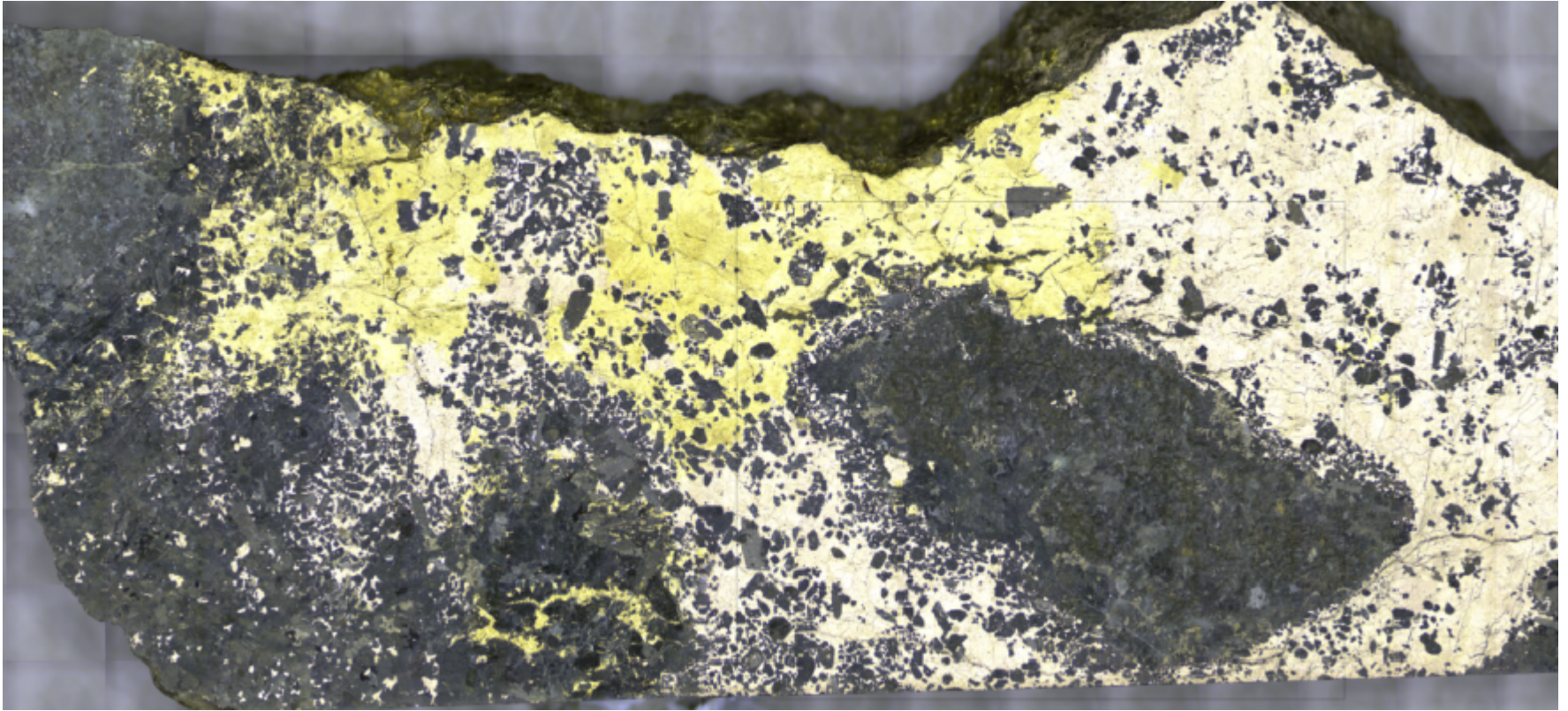


Aguablanca sulfide ore breccias



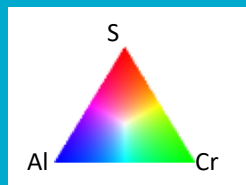
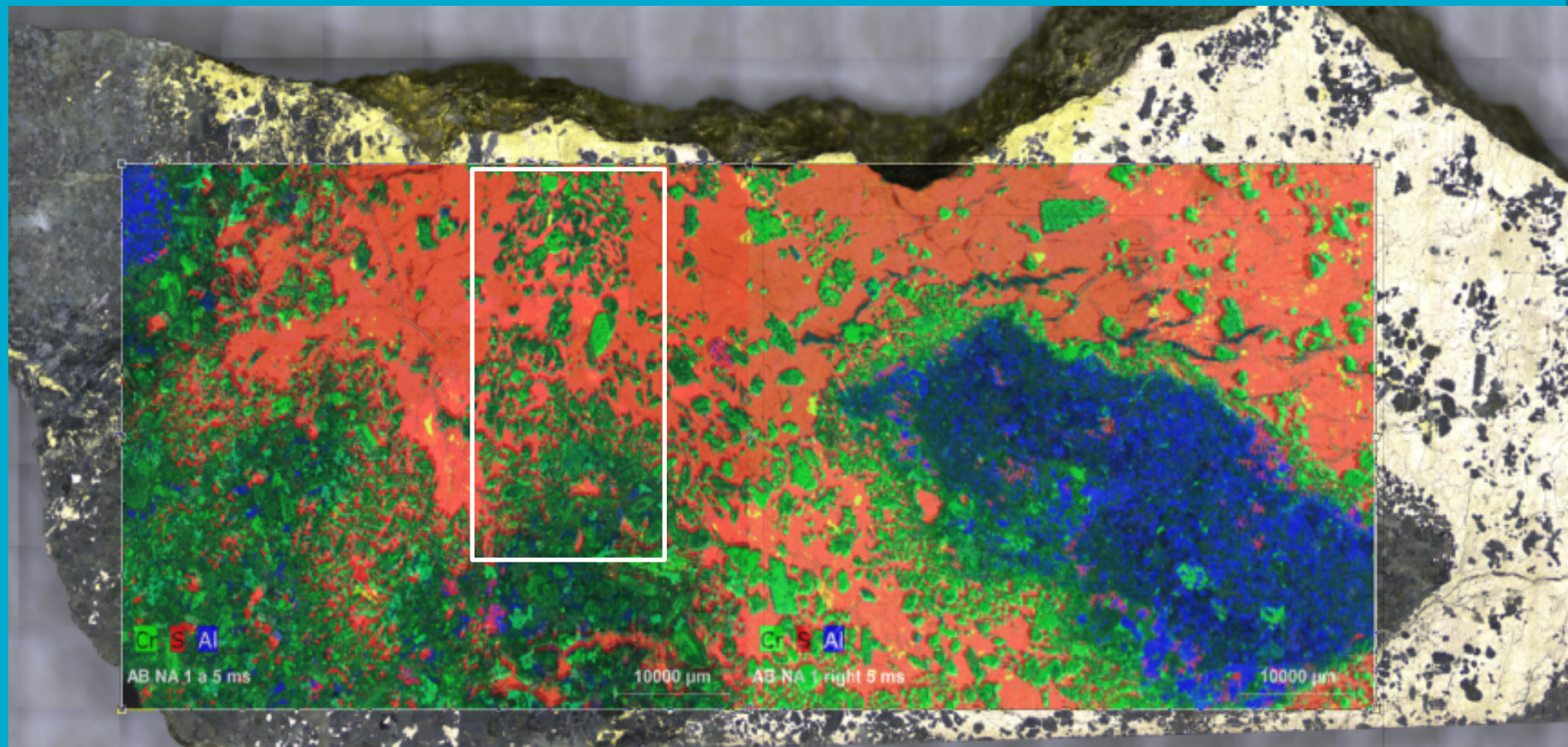


Slab AB-NA1 Tornado scan of wholeslab

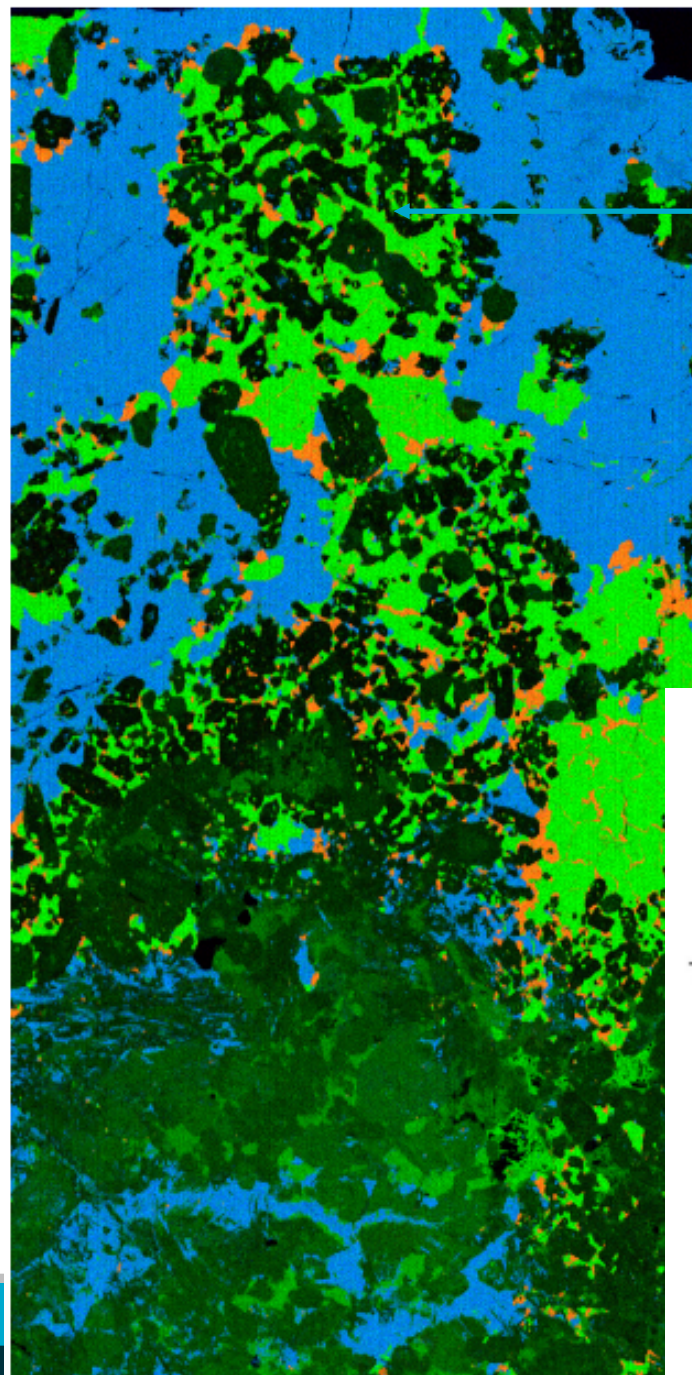
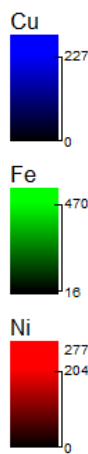


(sample from Nick Arndt)

Slab AB-NA1 Tornado scan of whole slab

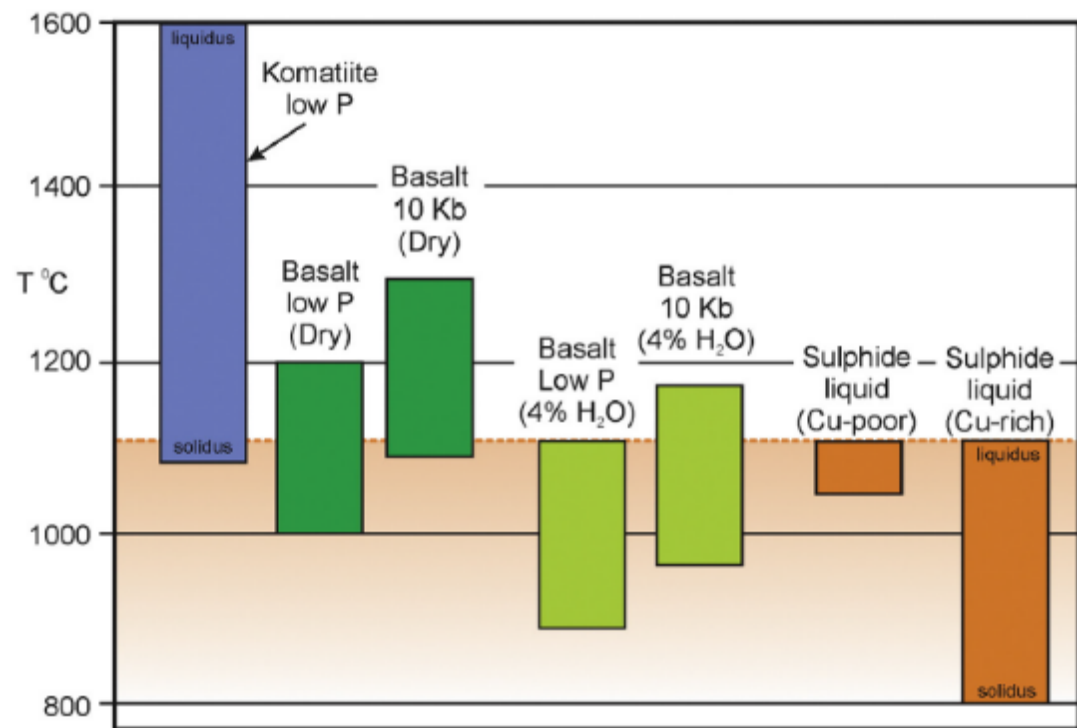


AB-NA-
section 1A

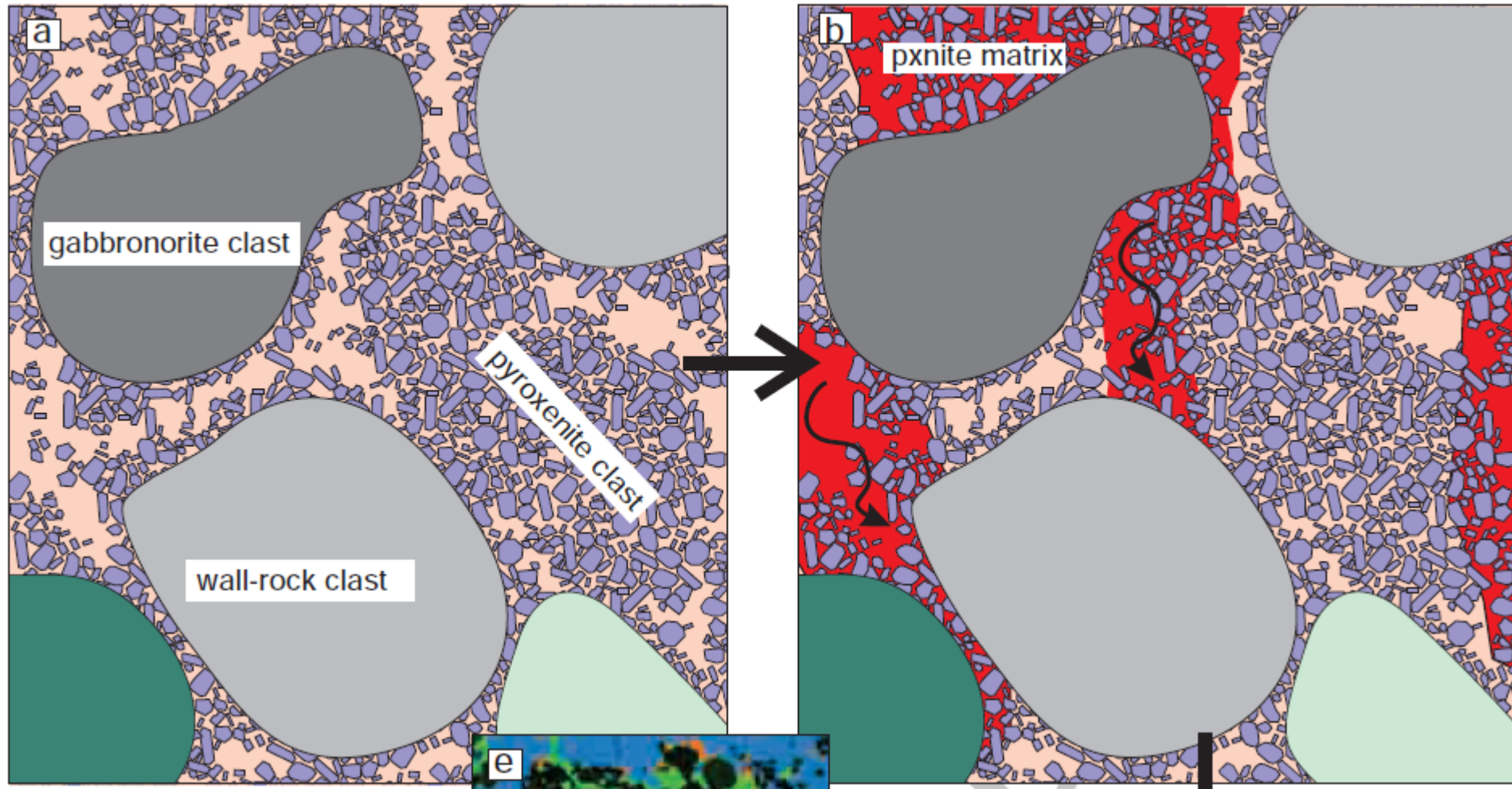


Pyroxenes trapped in early MSS

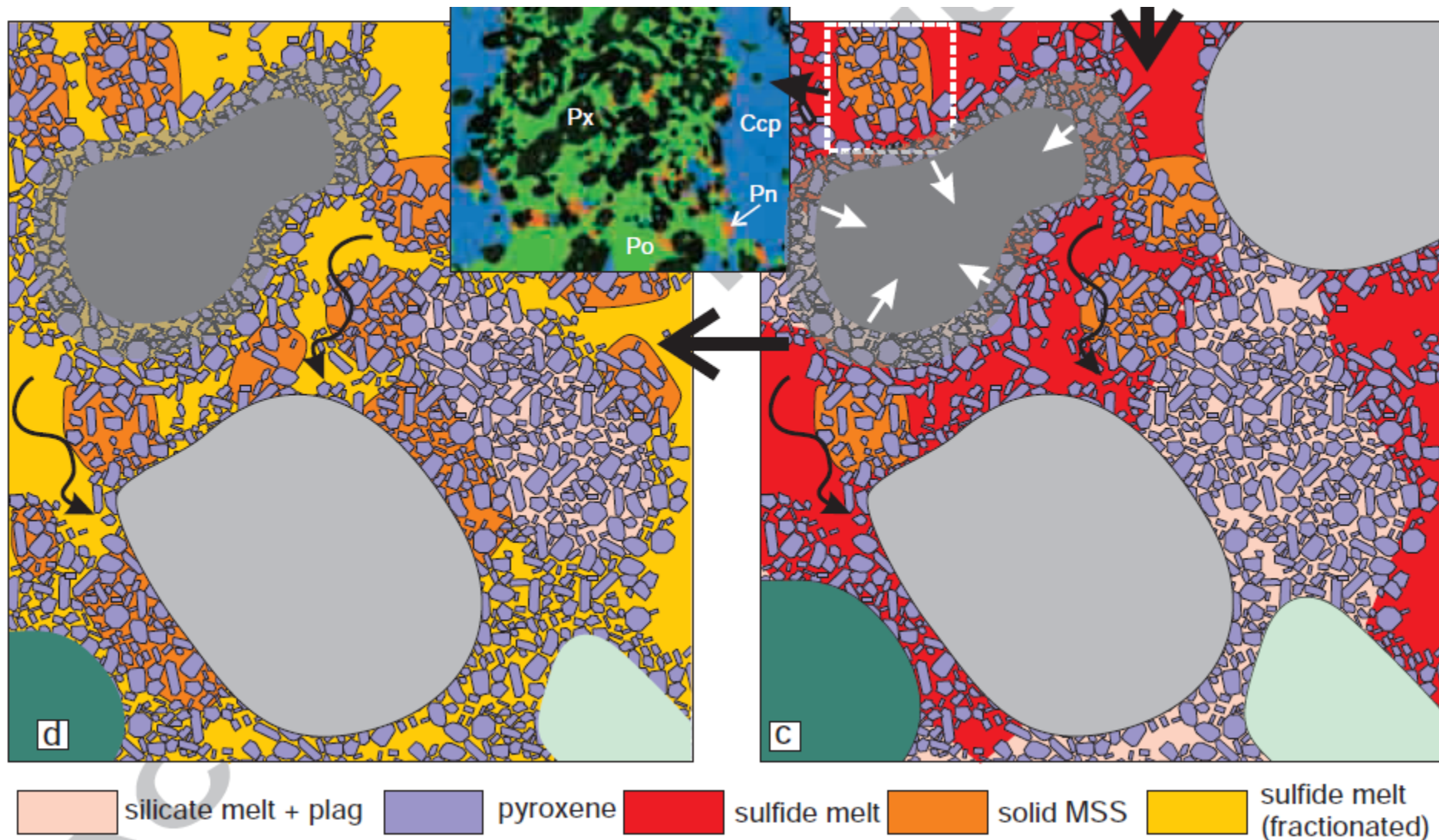
Overlapping melting ranges in mafic-hosted systems



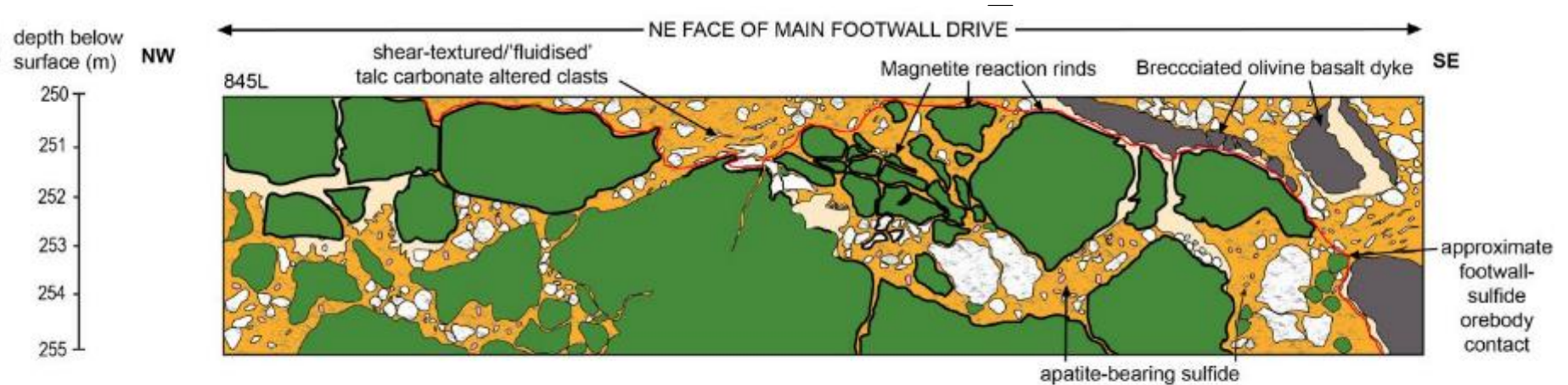
Aguablanca breccia model (Barnes et al., in press, OGR, 2018)



Aguablanca breccia model (Barnes et al., in press, OGR, 2018)



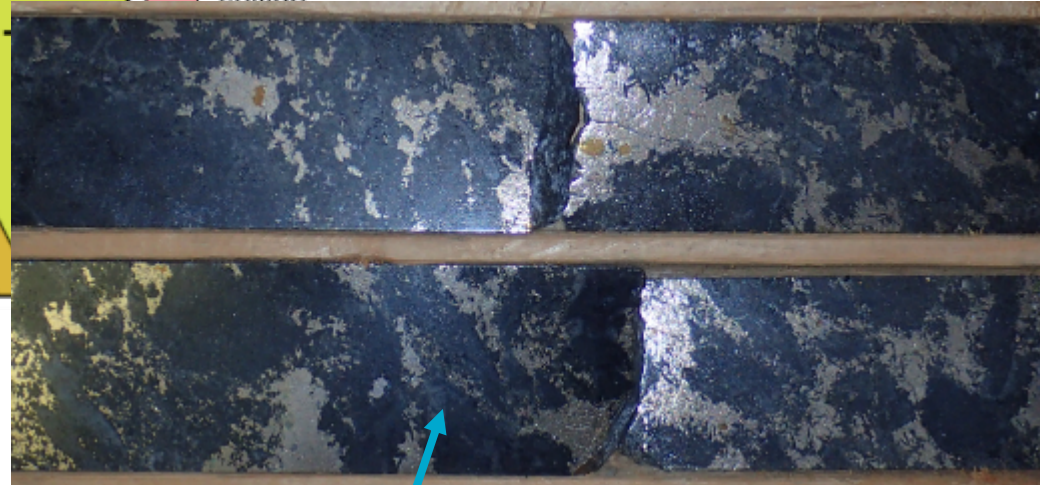
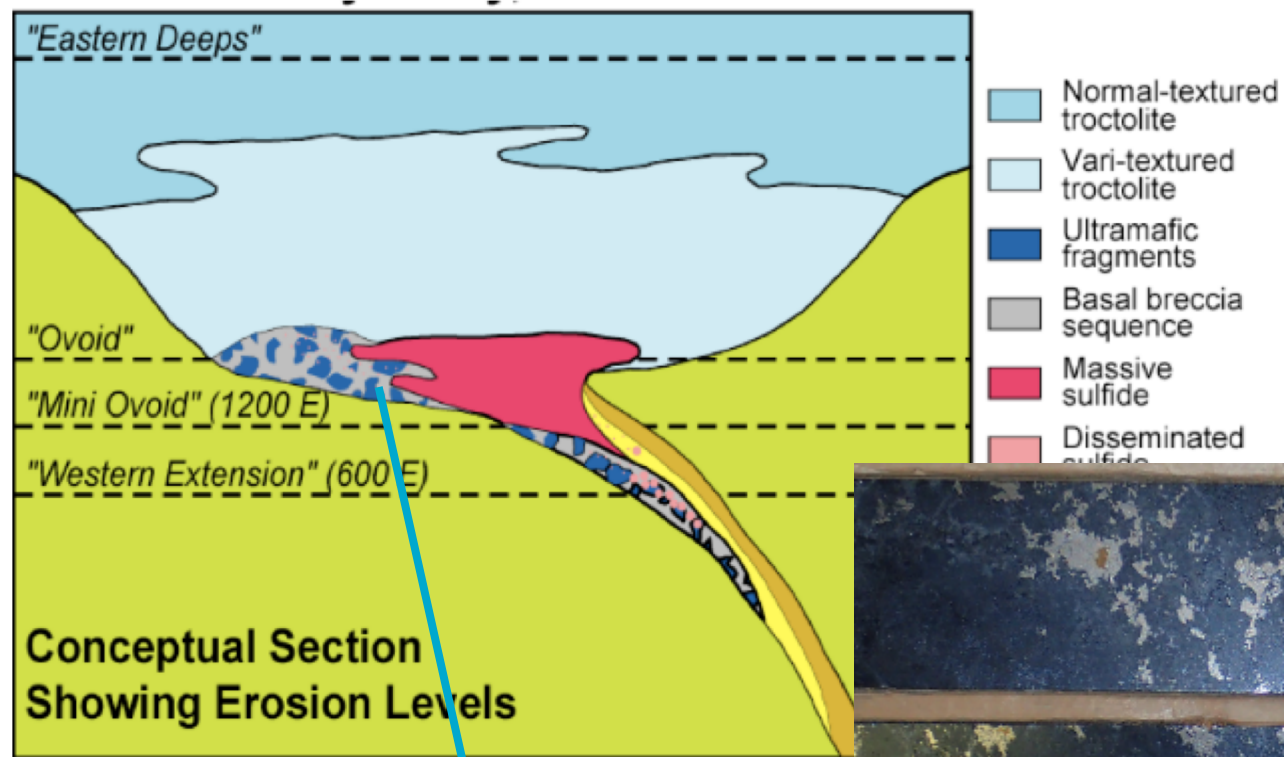
Munali (Dave Holwell + students)

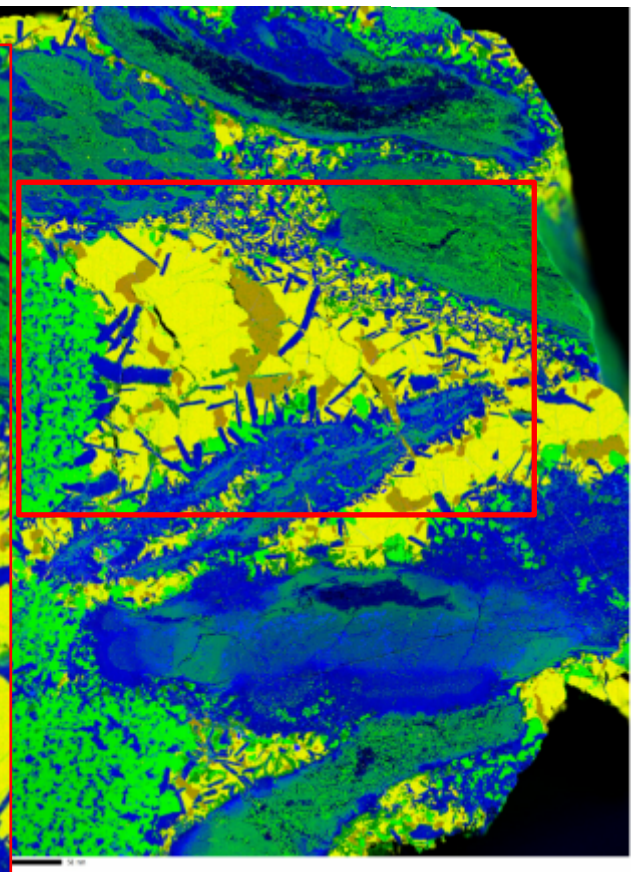
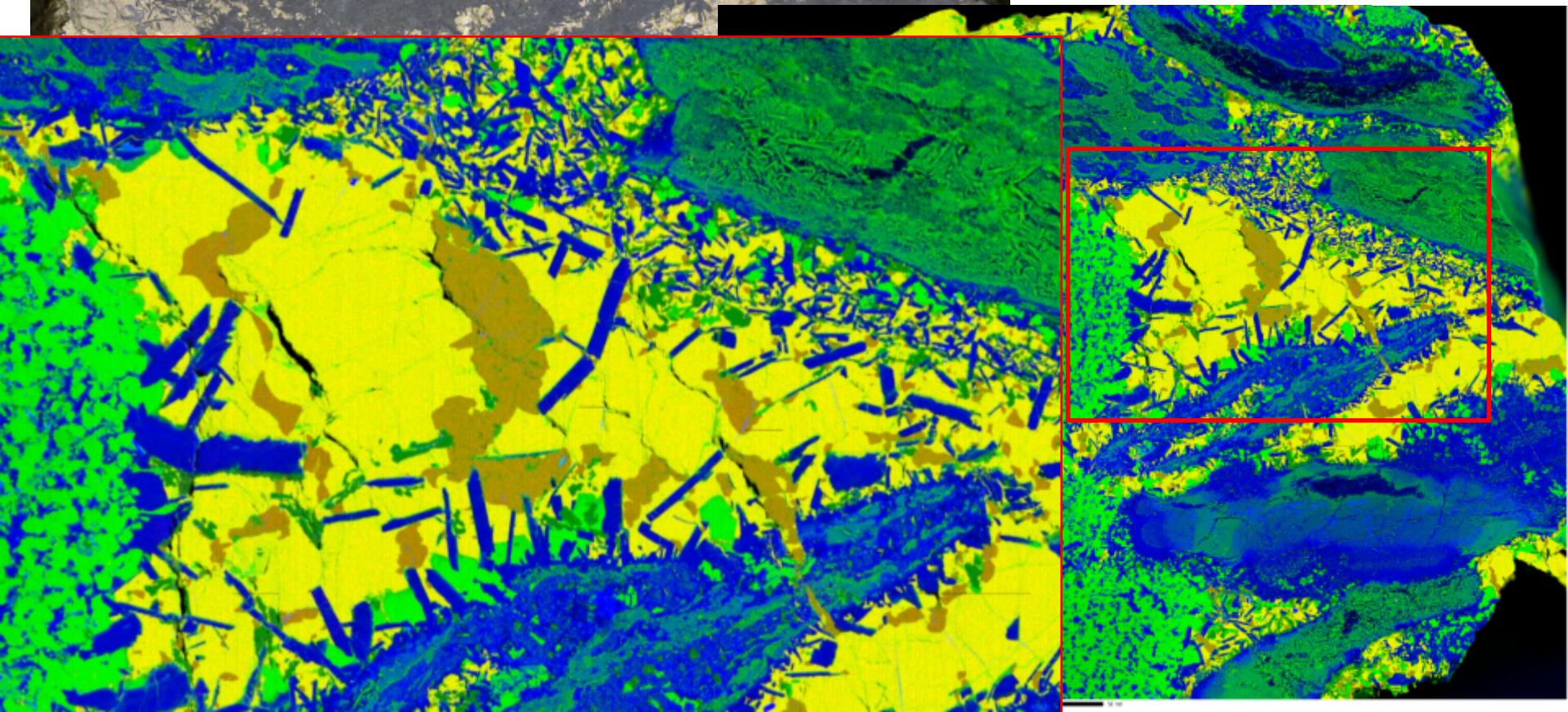
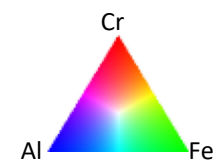
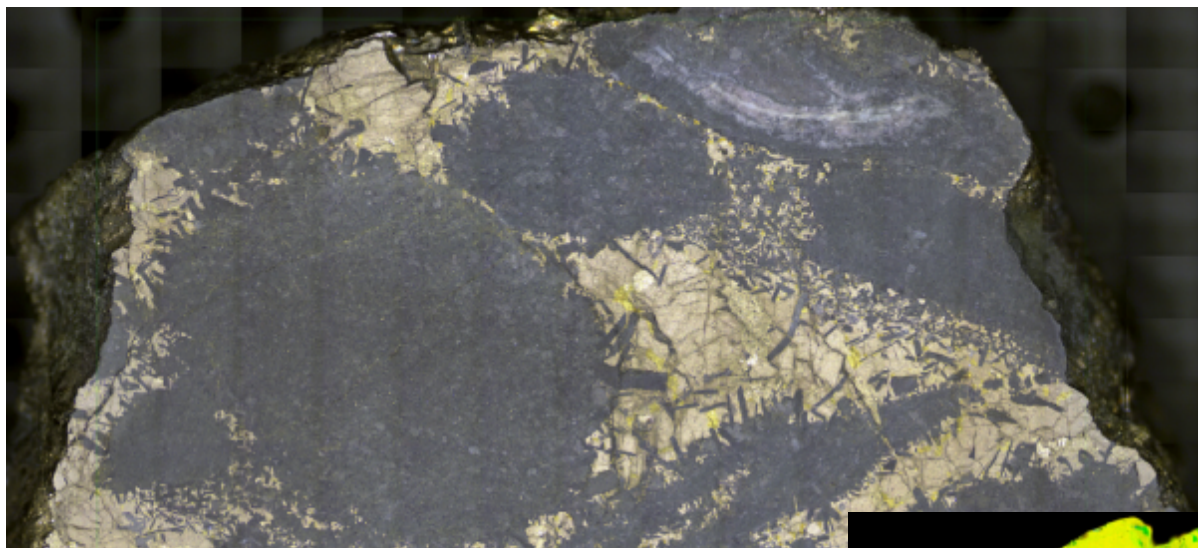


Munali (Dave Holwell + students)

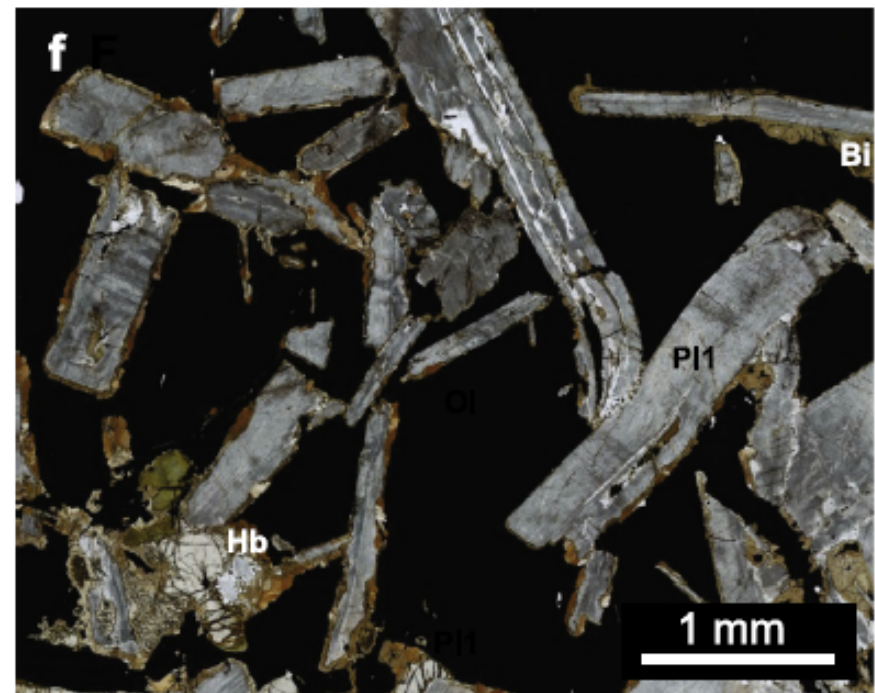
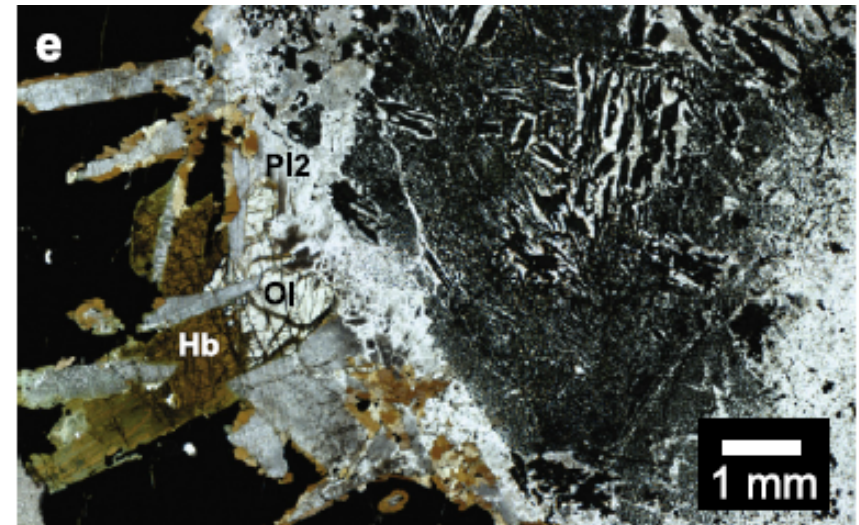
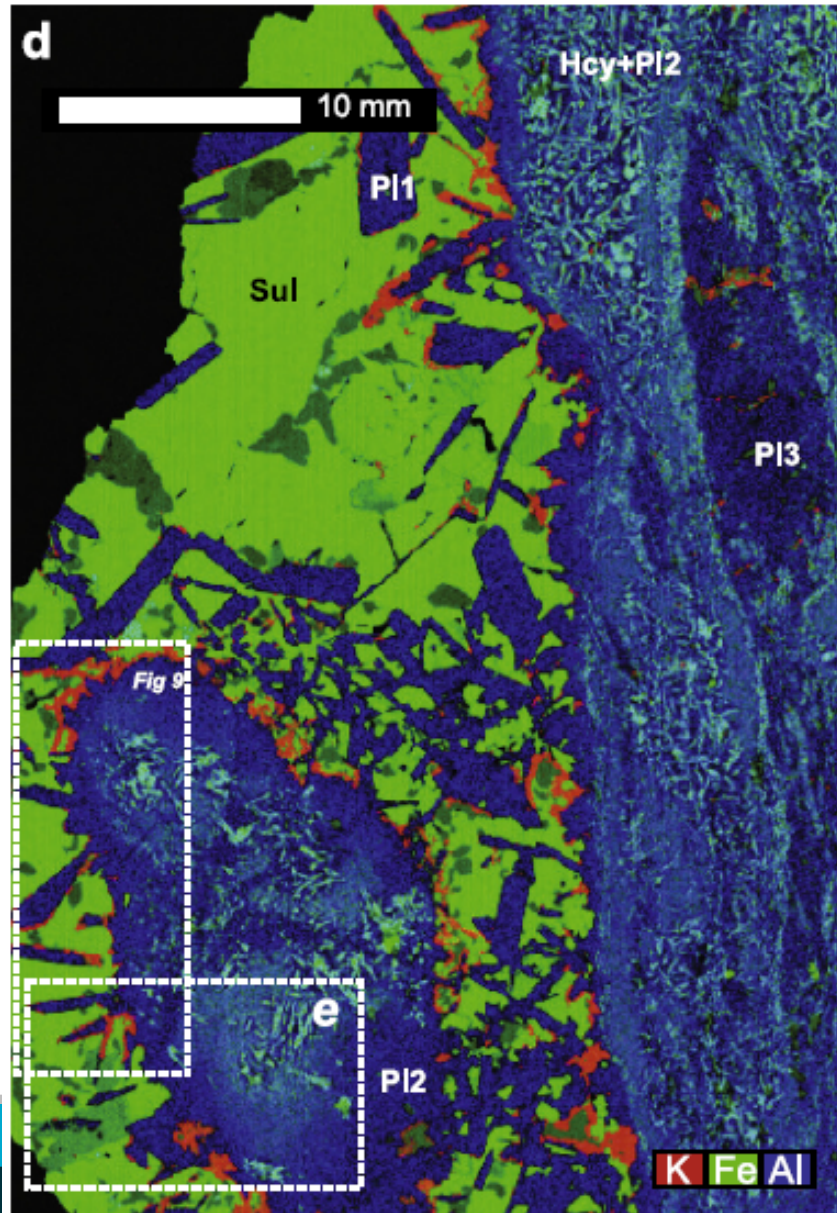


Polymict sulfide-matrix breccias at Voisey's Bay

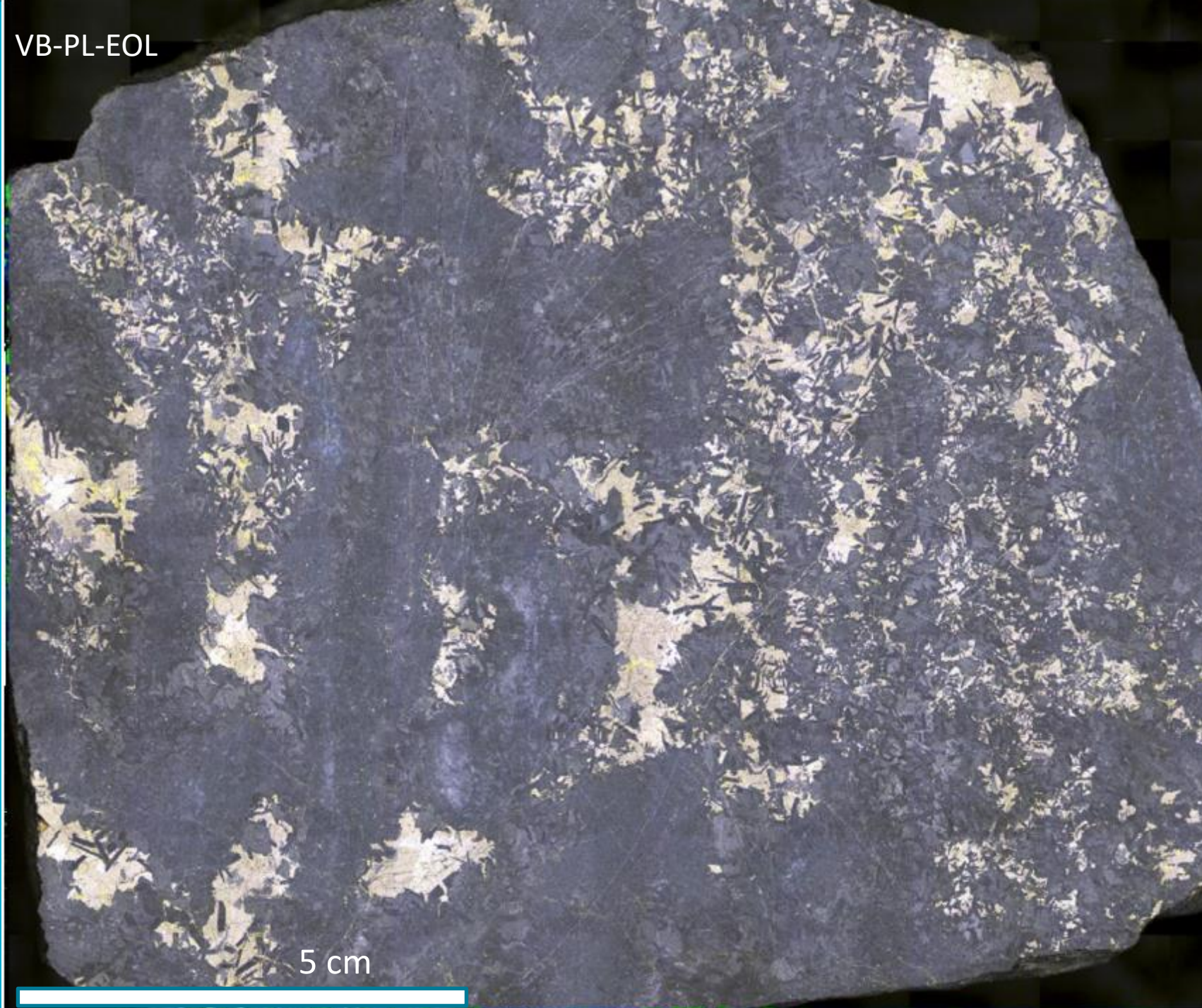




VB sulfide matrix ore breccias

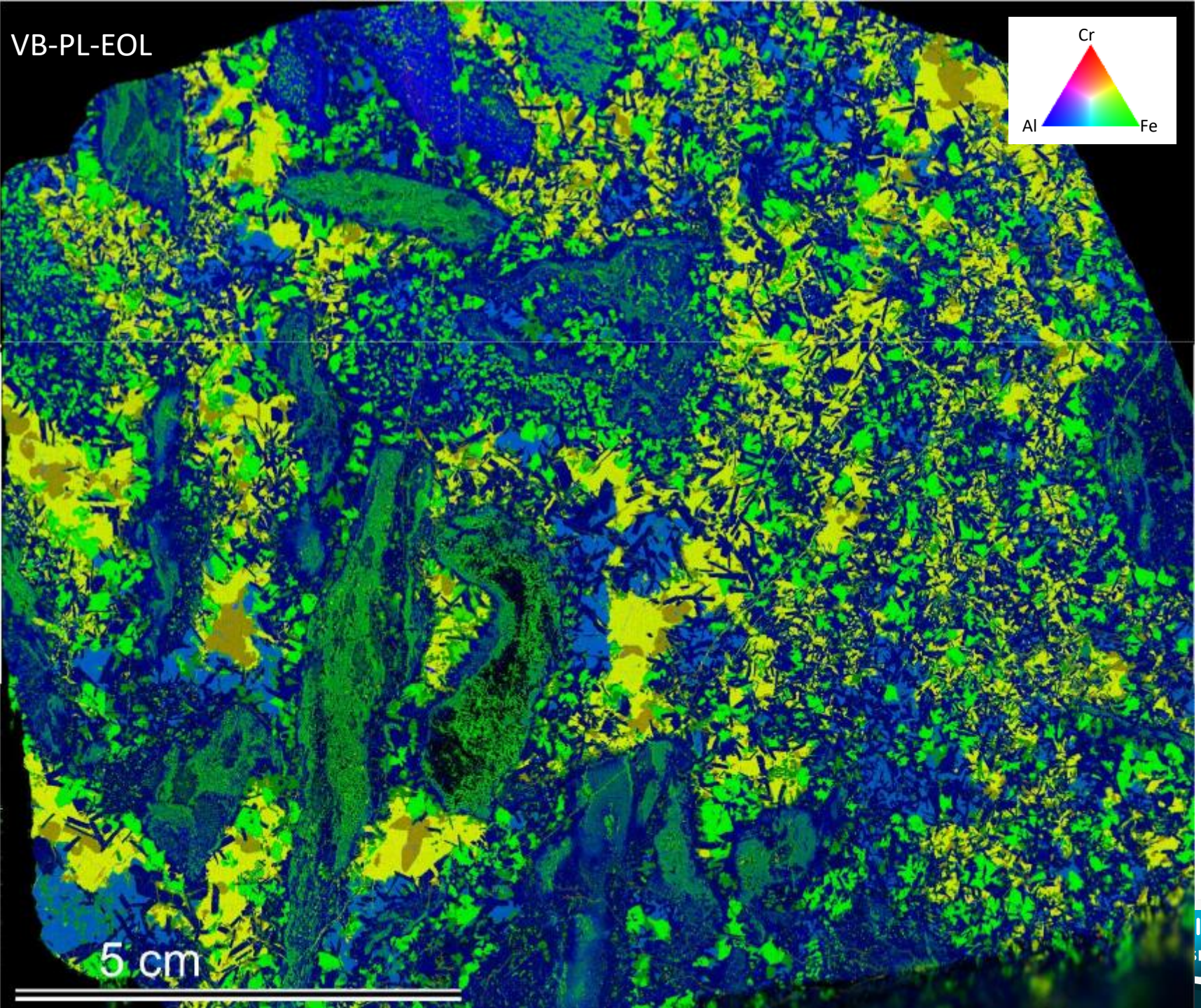
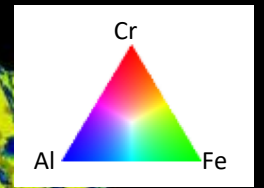


VB-PL-EOL



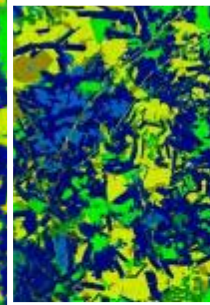
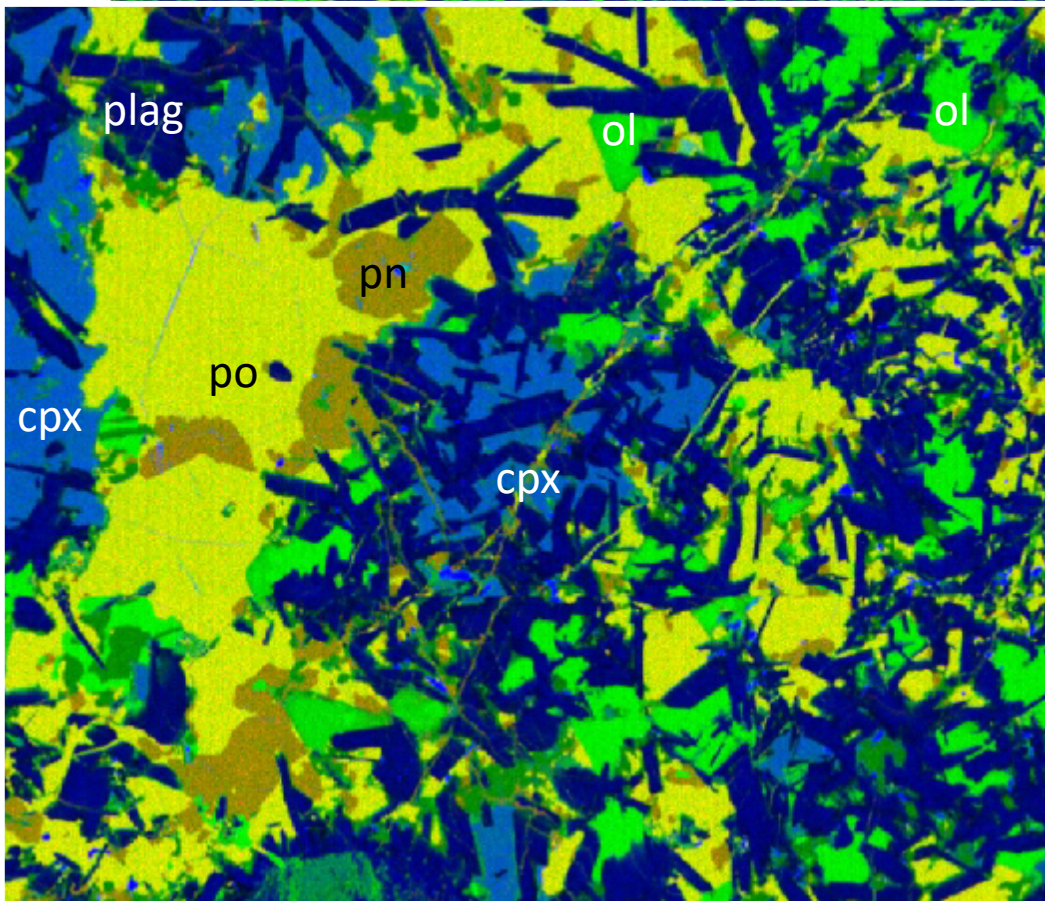
5 cm

VB-PL-EOL

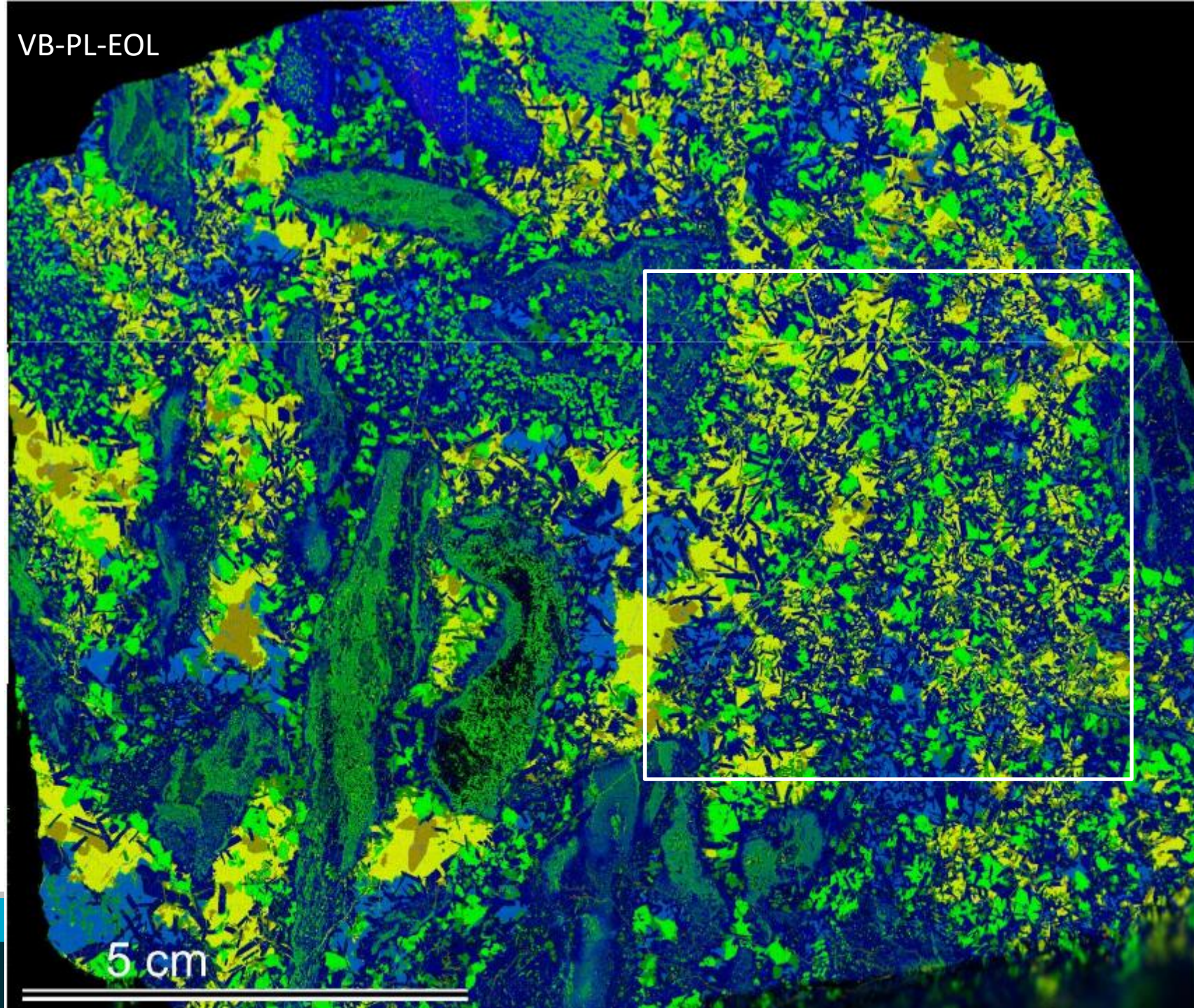


5 cm

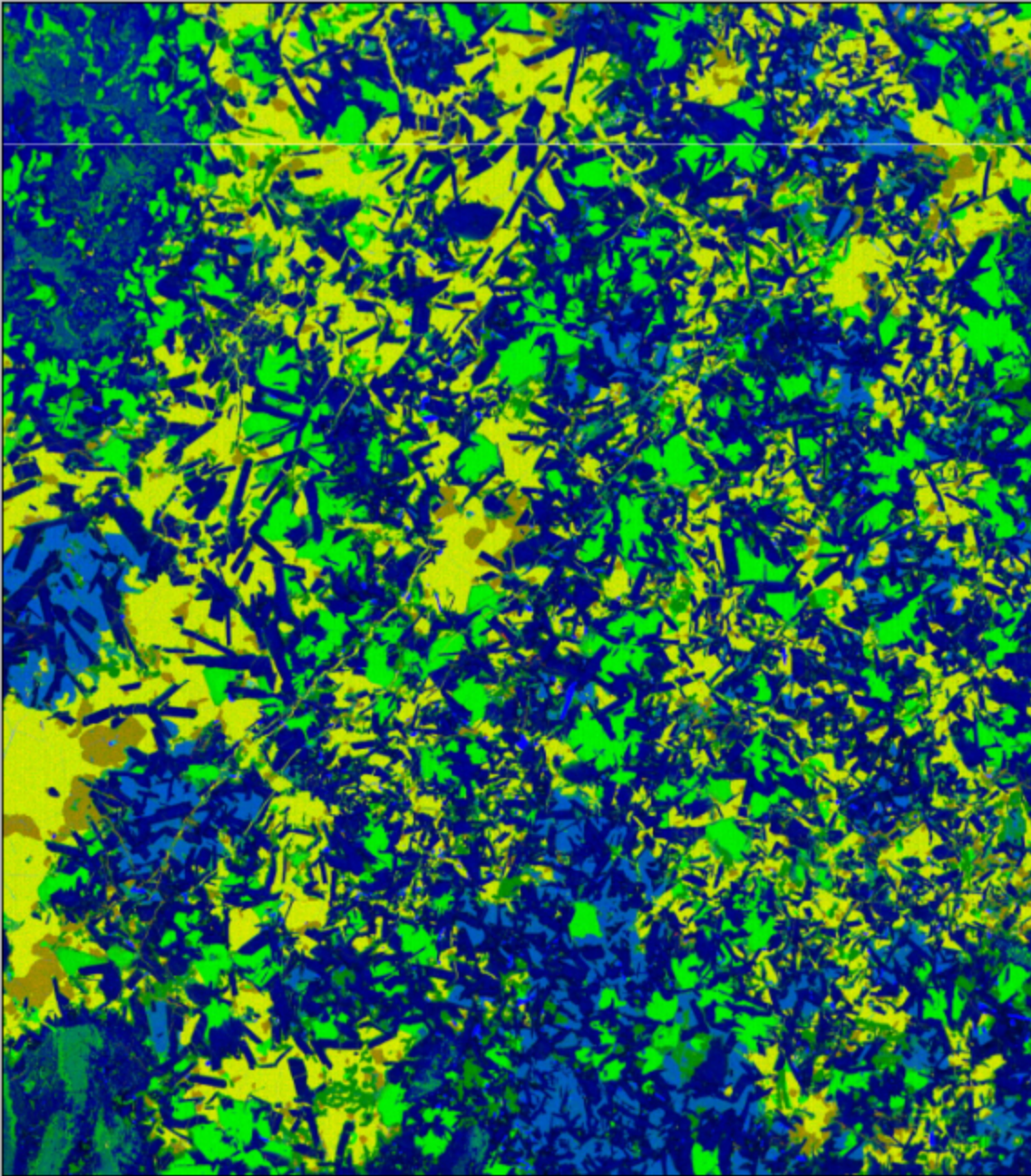
VB-PL-EOL

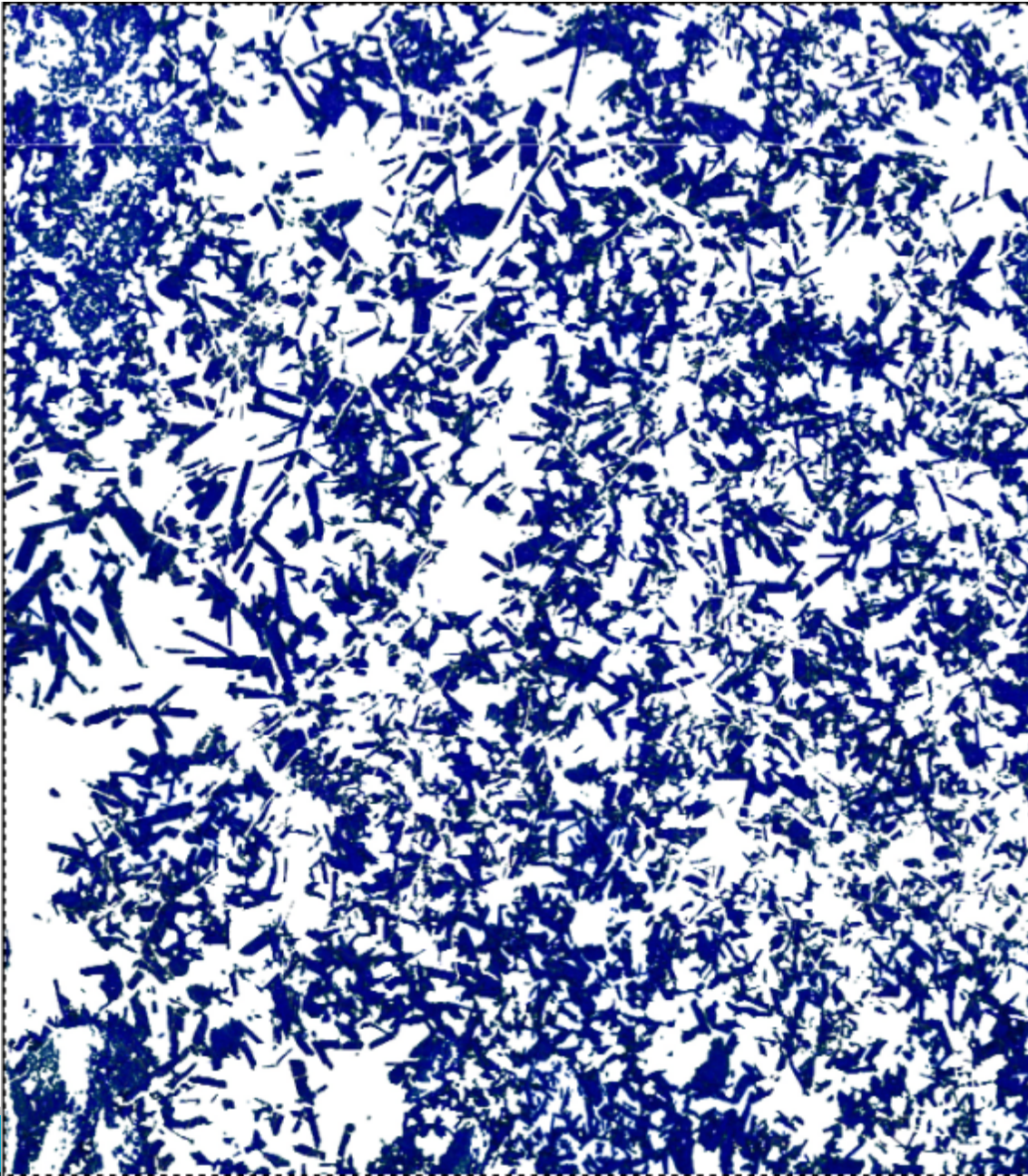


VB-PL-EOL

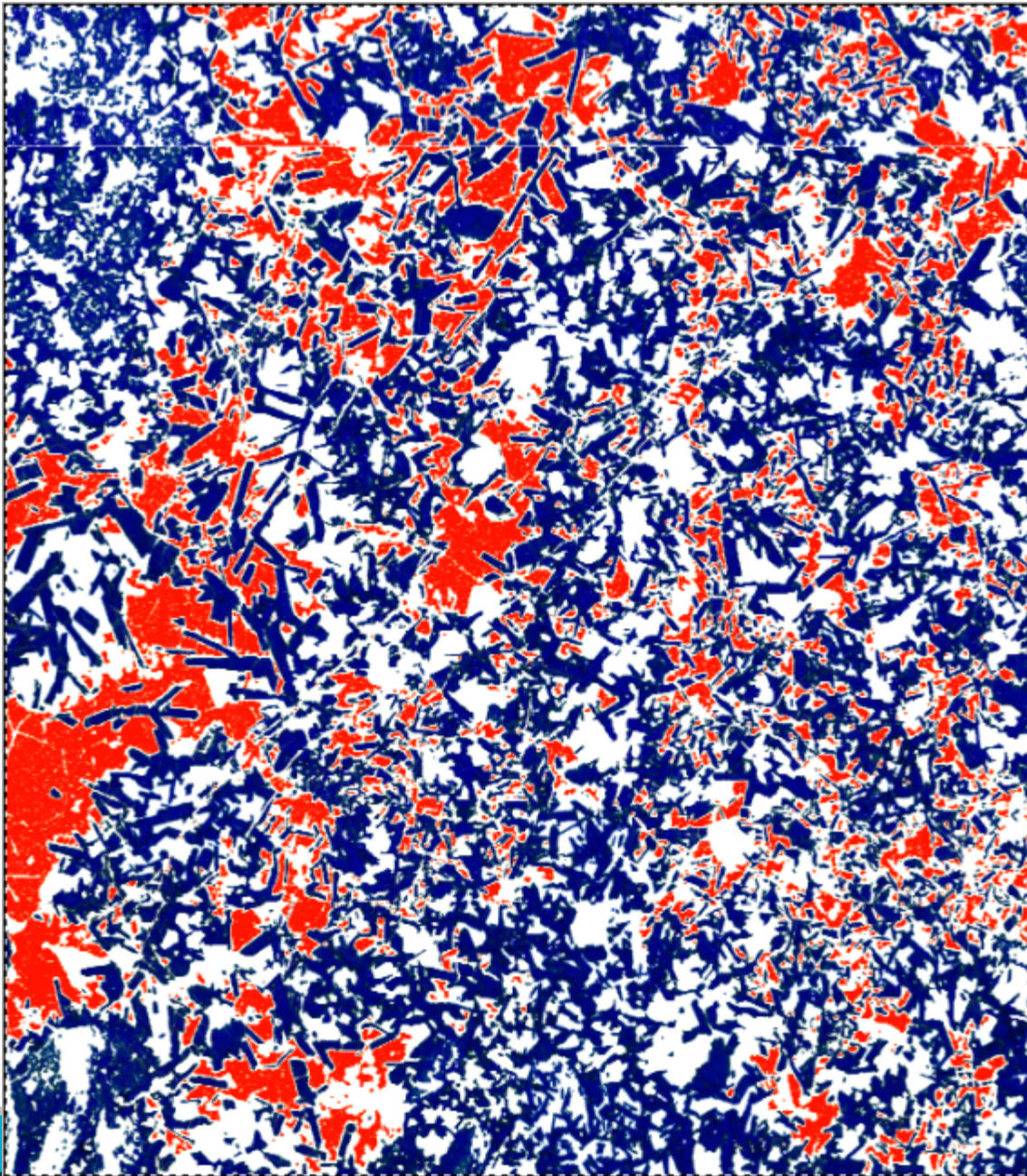


5 cm





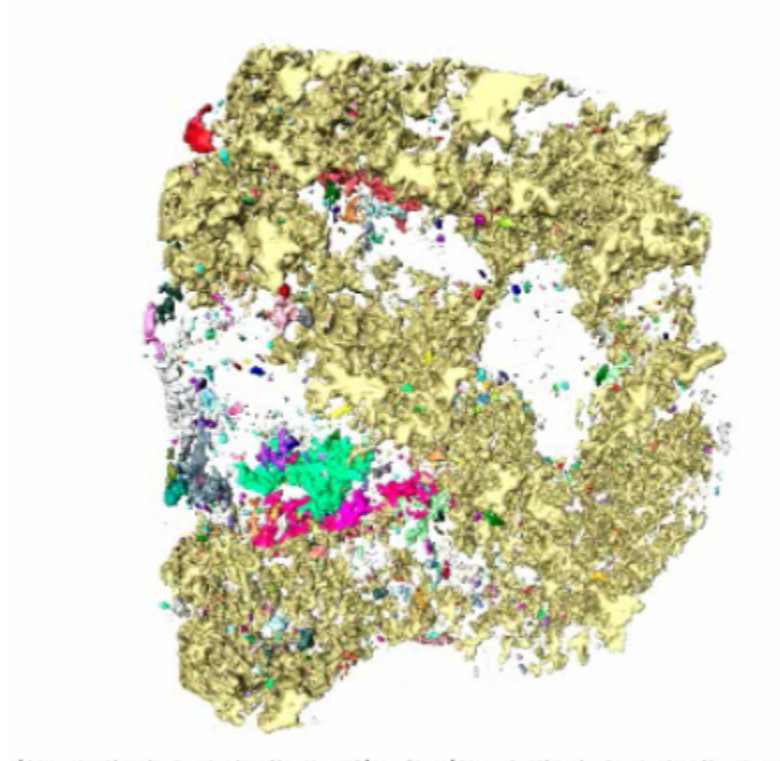
Plagioclase framework



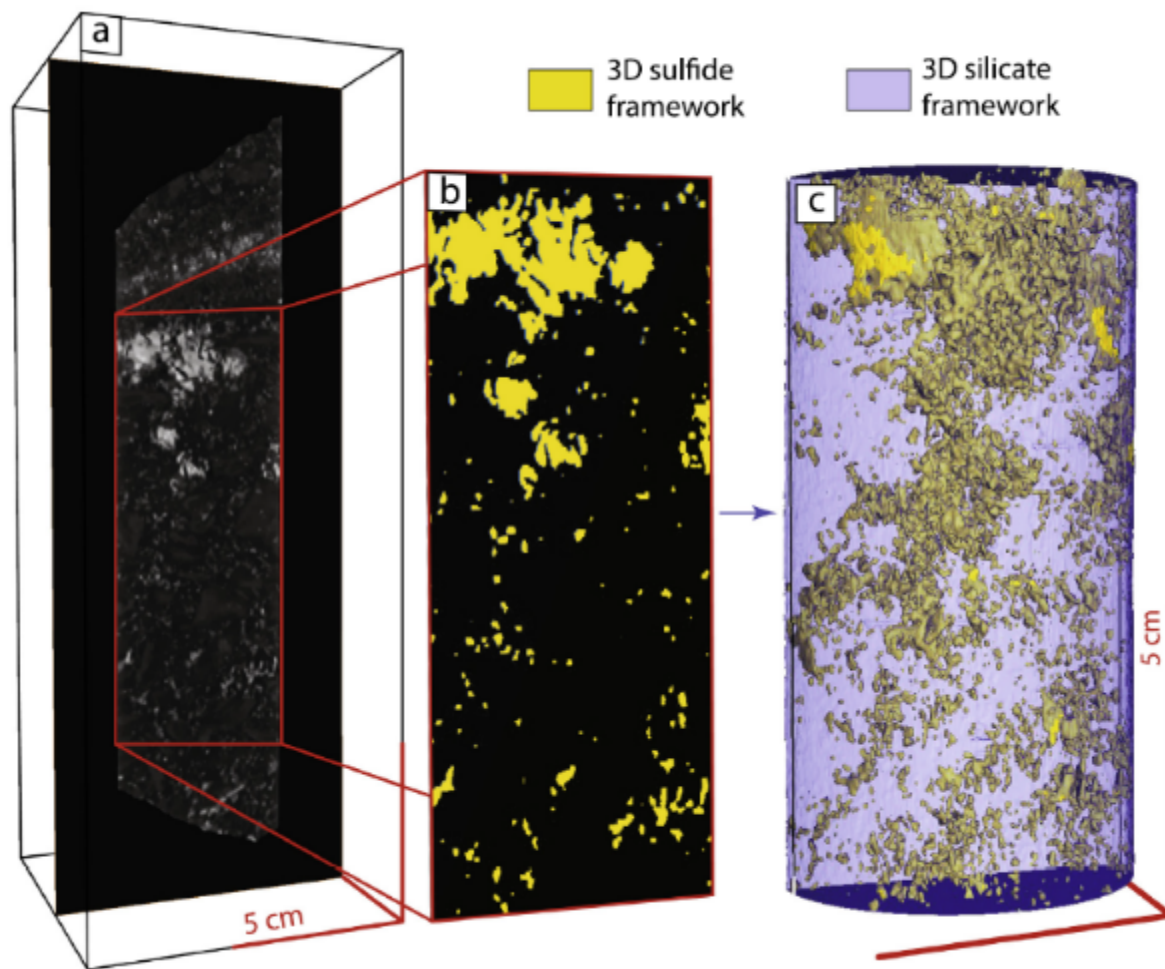
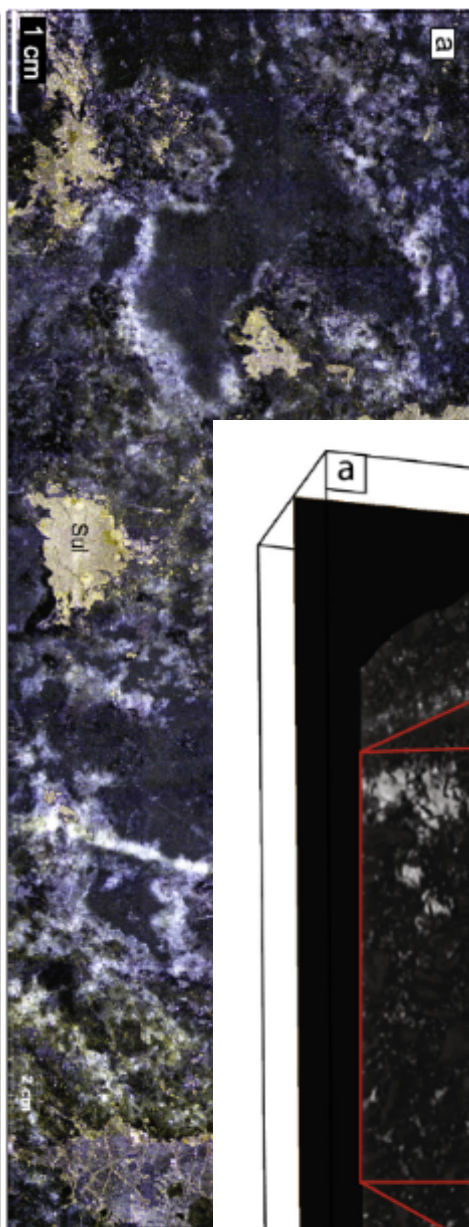
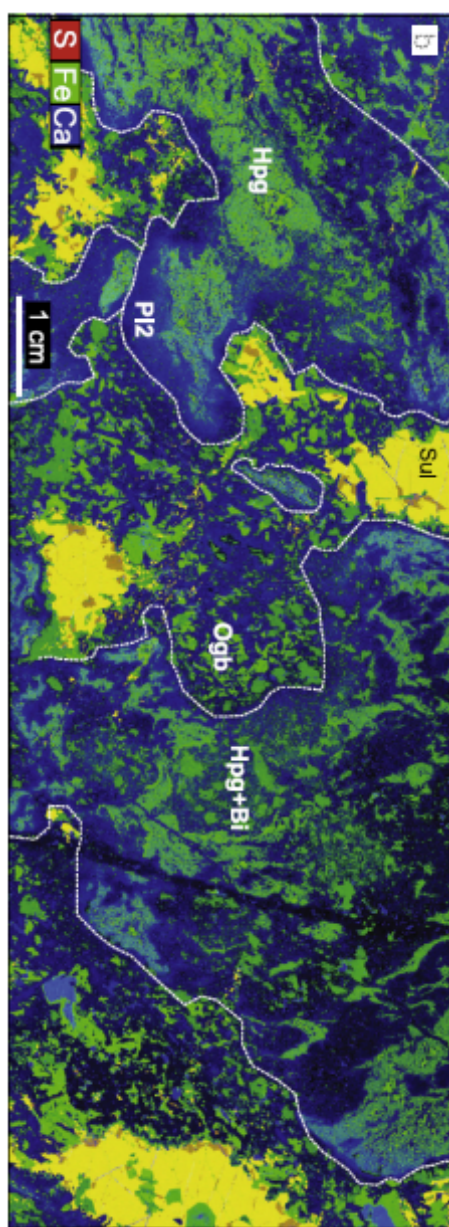
Plagioclase framework + sulfide

- Plagioclase framework is early, pre-dates sulfide
- Delicate texture precludes deformation or flow
- Sulfide liquid percolates through plagioclase framework displacing low-melting multi-phase silicate component
- Refractory plagioclase-olivine component stays put

movie

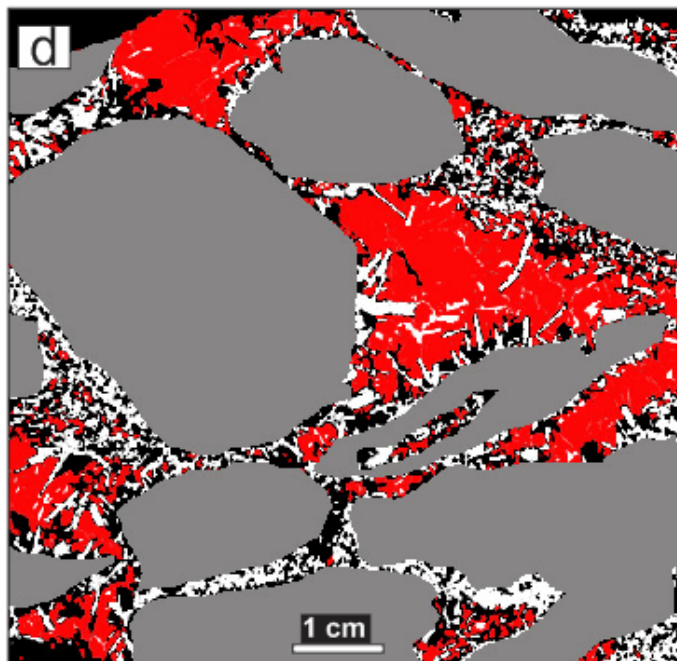
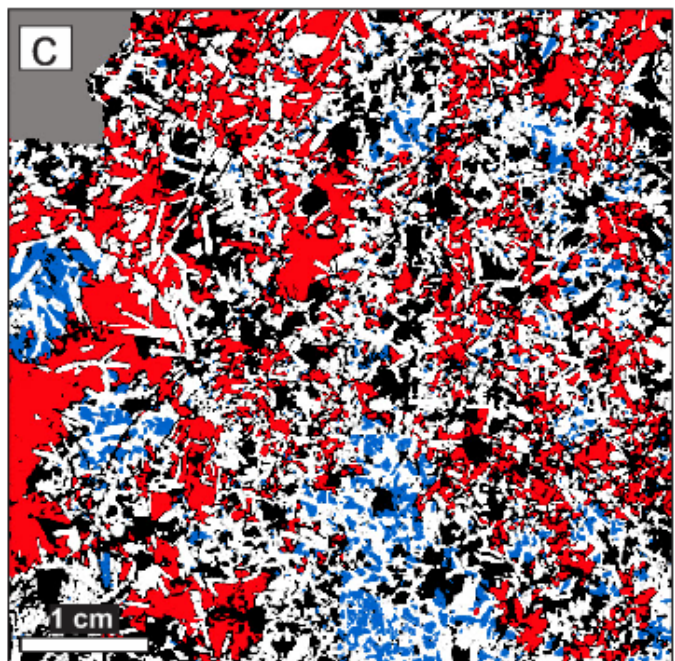
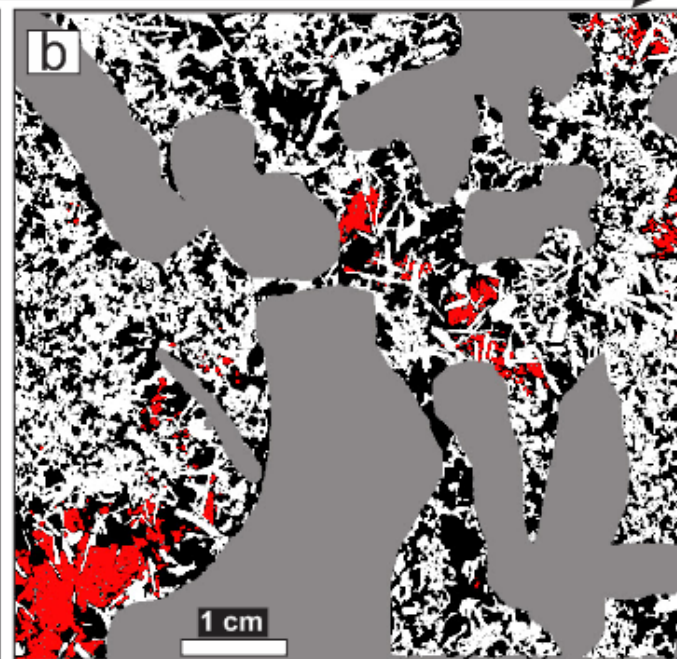
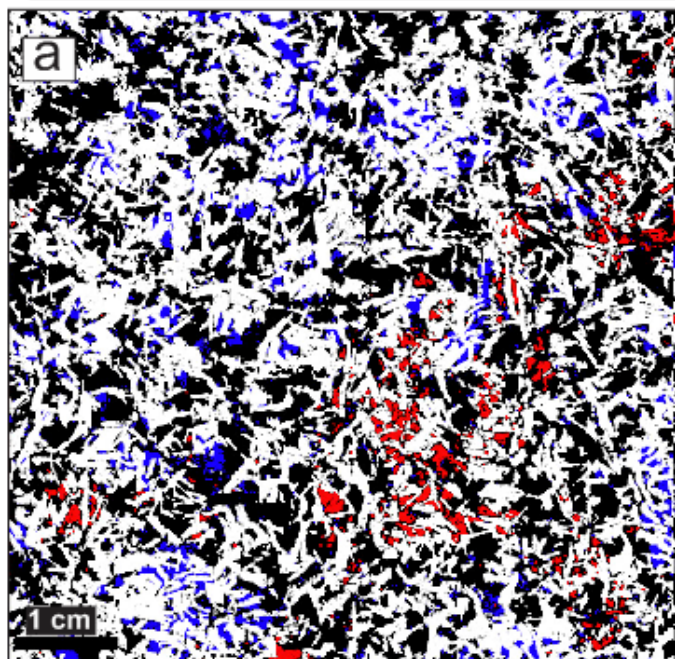


S-poor VB breccias –
interconnected sulfide in 3D

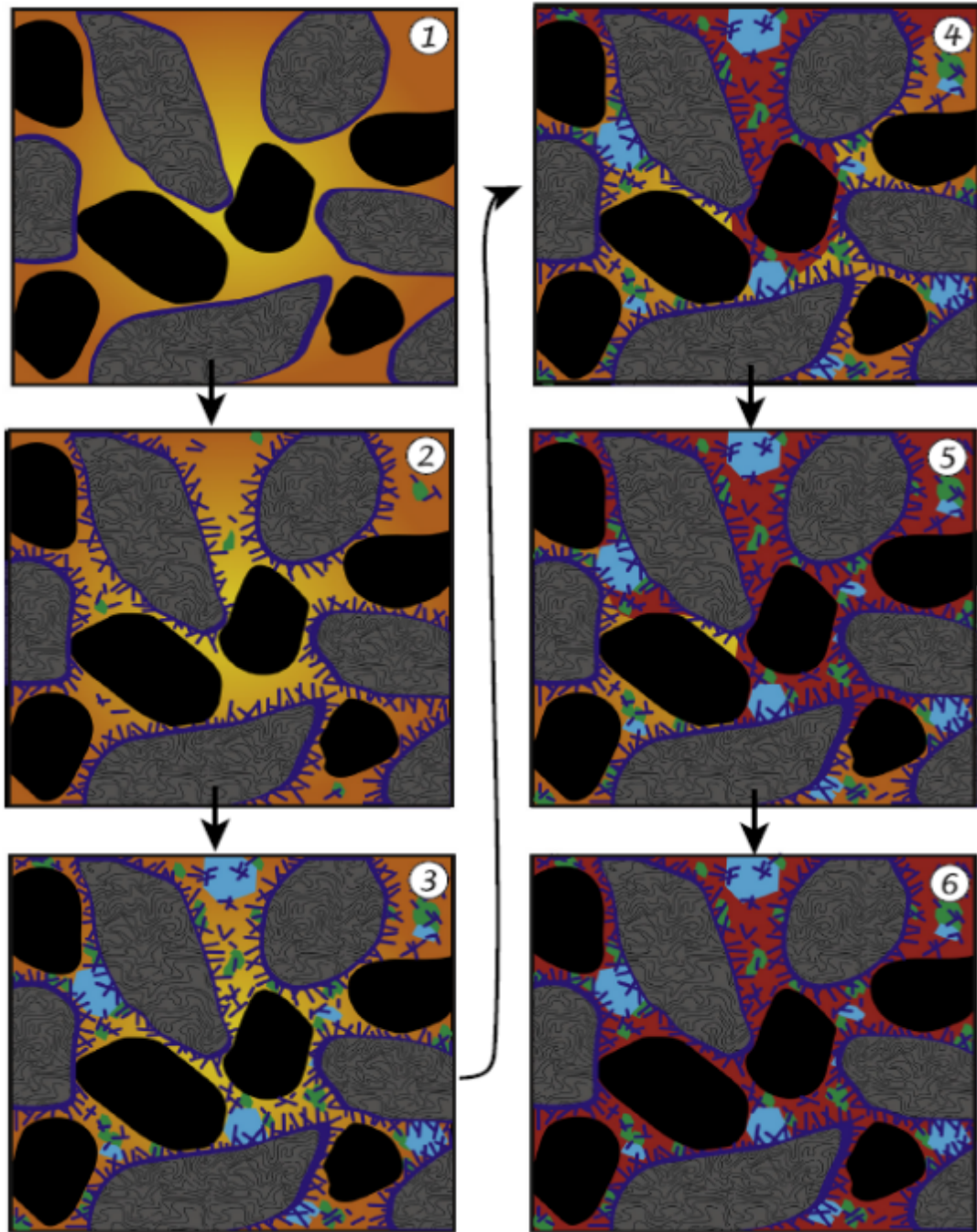
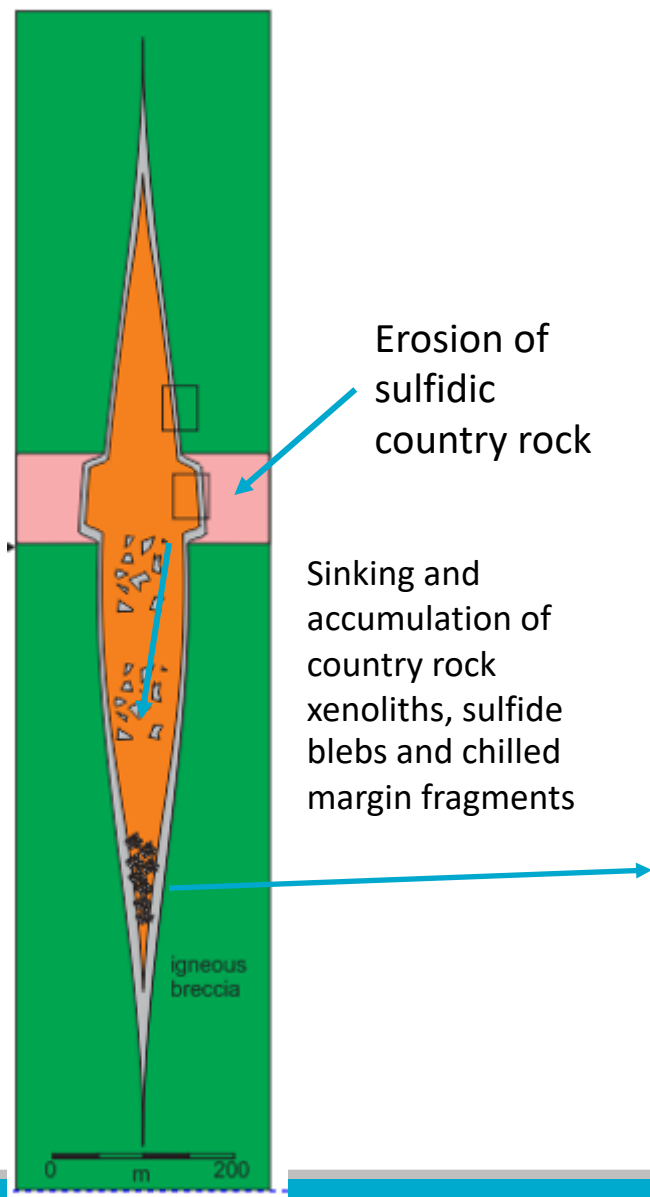


increasing proportion of clasts →

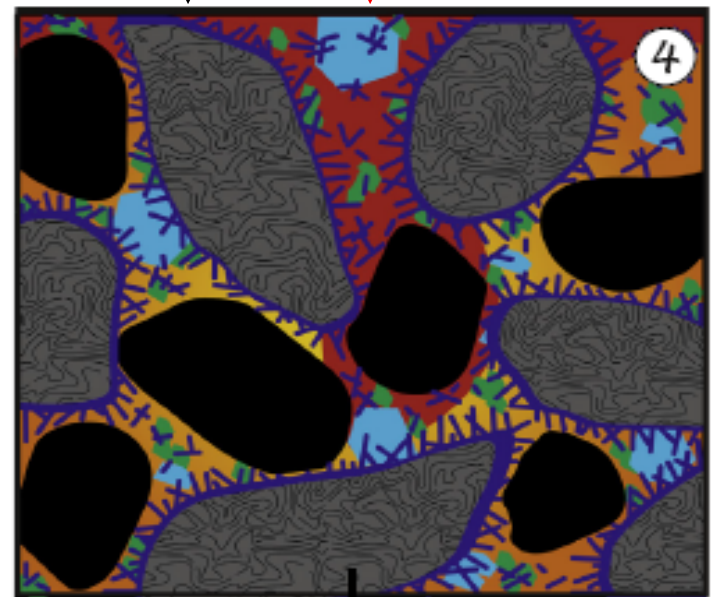
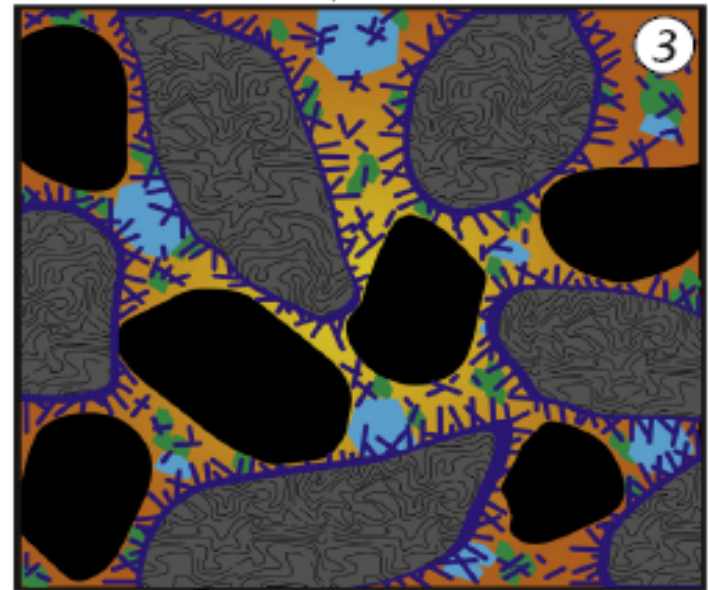
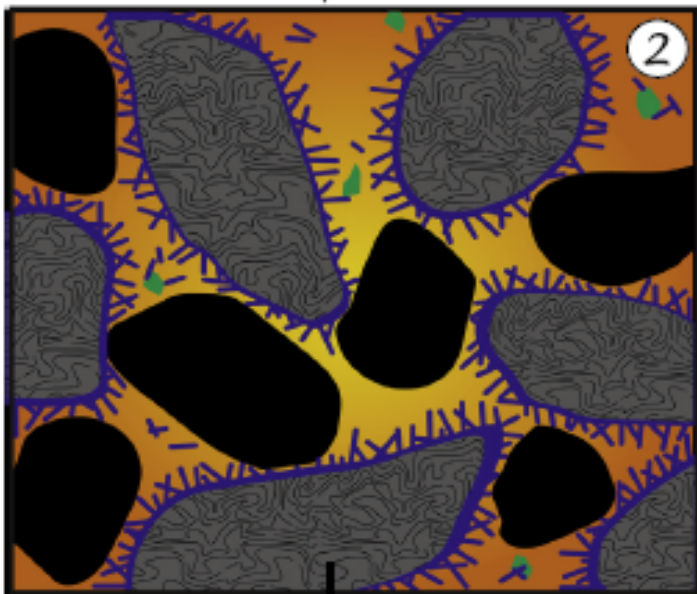
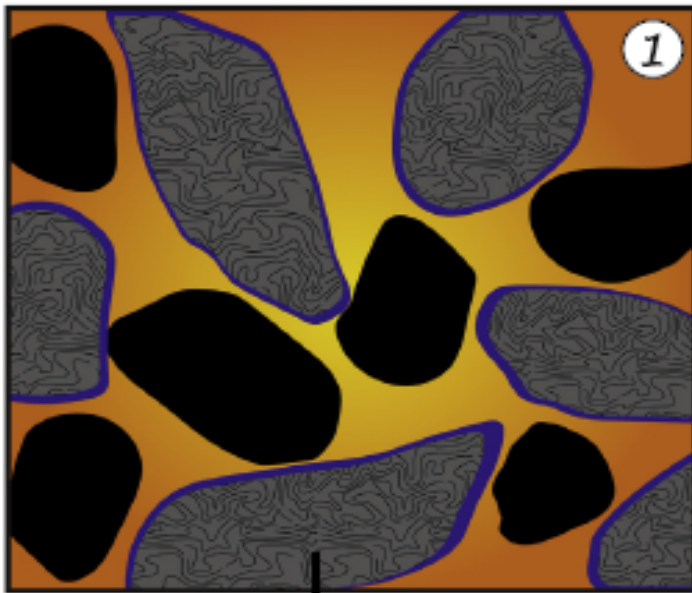
↑ increasing proportion of sulfide



■ Clasts □ Plag ■ Cpx ■ Sulfide ■ Olivine, other phases

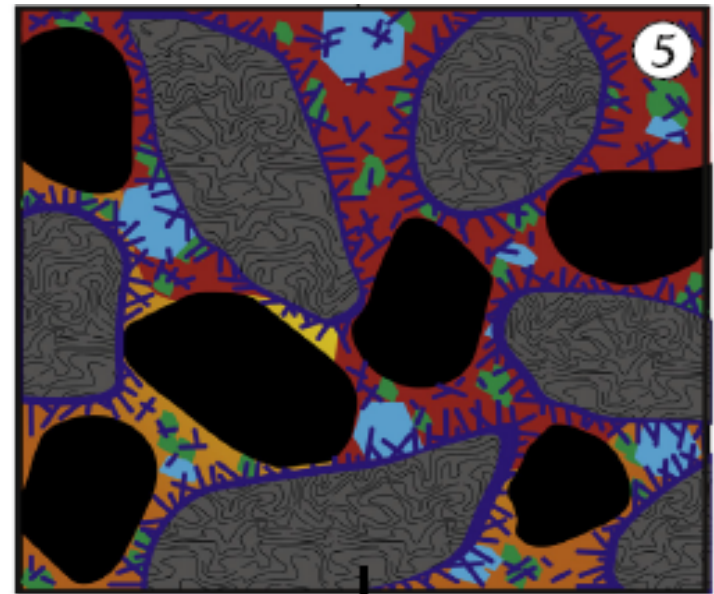
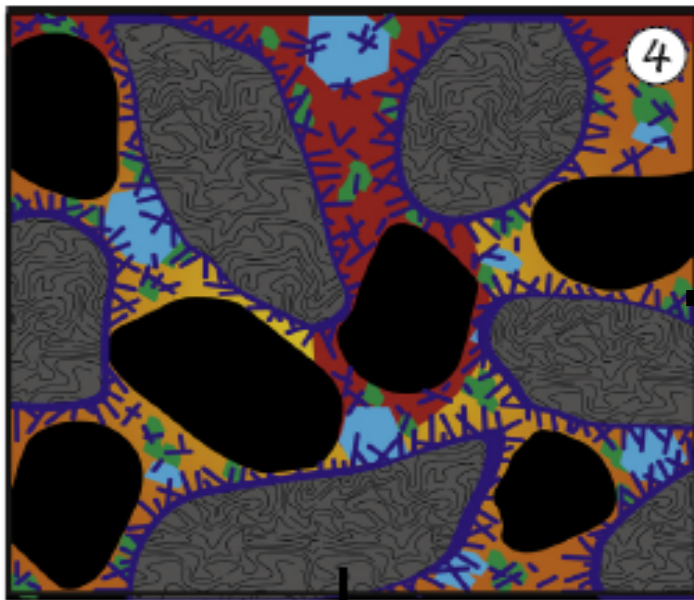


Percolation of sulfide through matrix of breccia

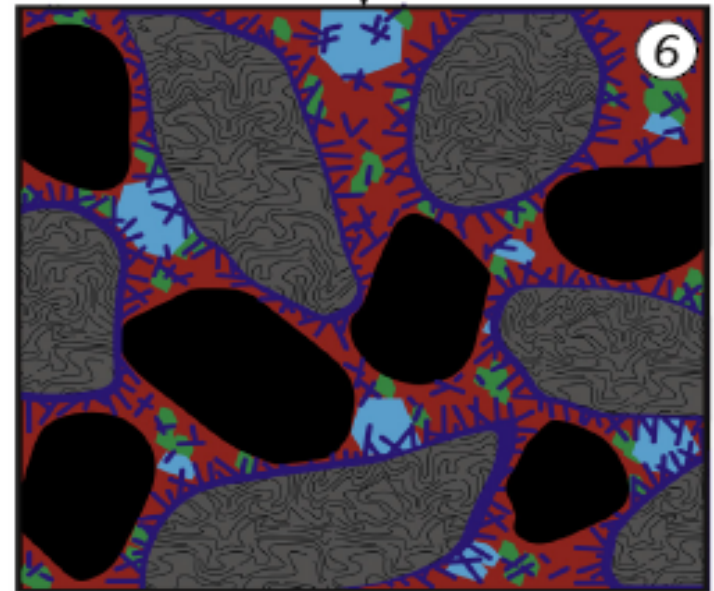


Sulfide liquid

Percolation of sulfide through matrix of breccia



Continuing sulfide percolation



Complete flooding of pore space

Sulfide

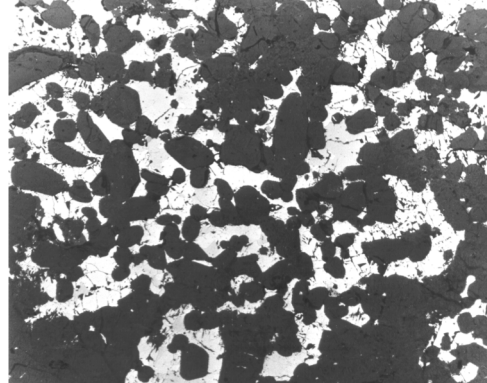
Silicate melt
film with
dendritic
chromite

Sulfide
almost
entirely
interstitial
to spinifex
plates
(apart from
a few late
veinlets)

10 cm

Cr S Fe

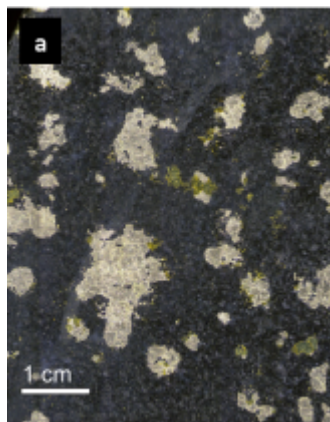
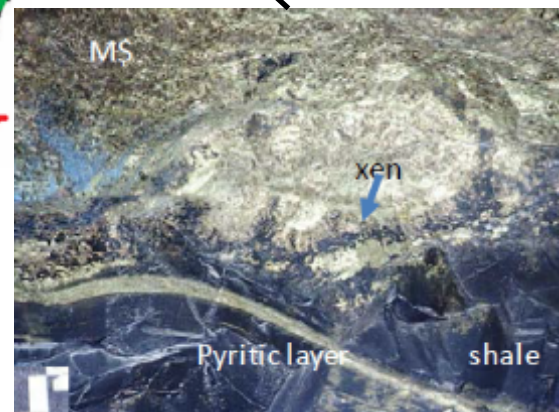
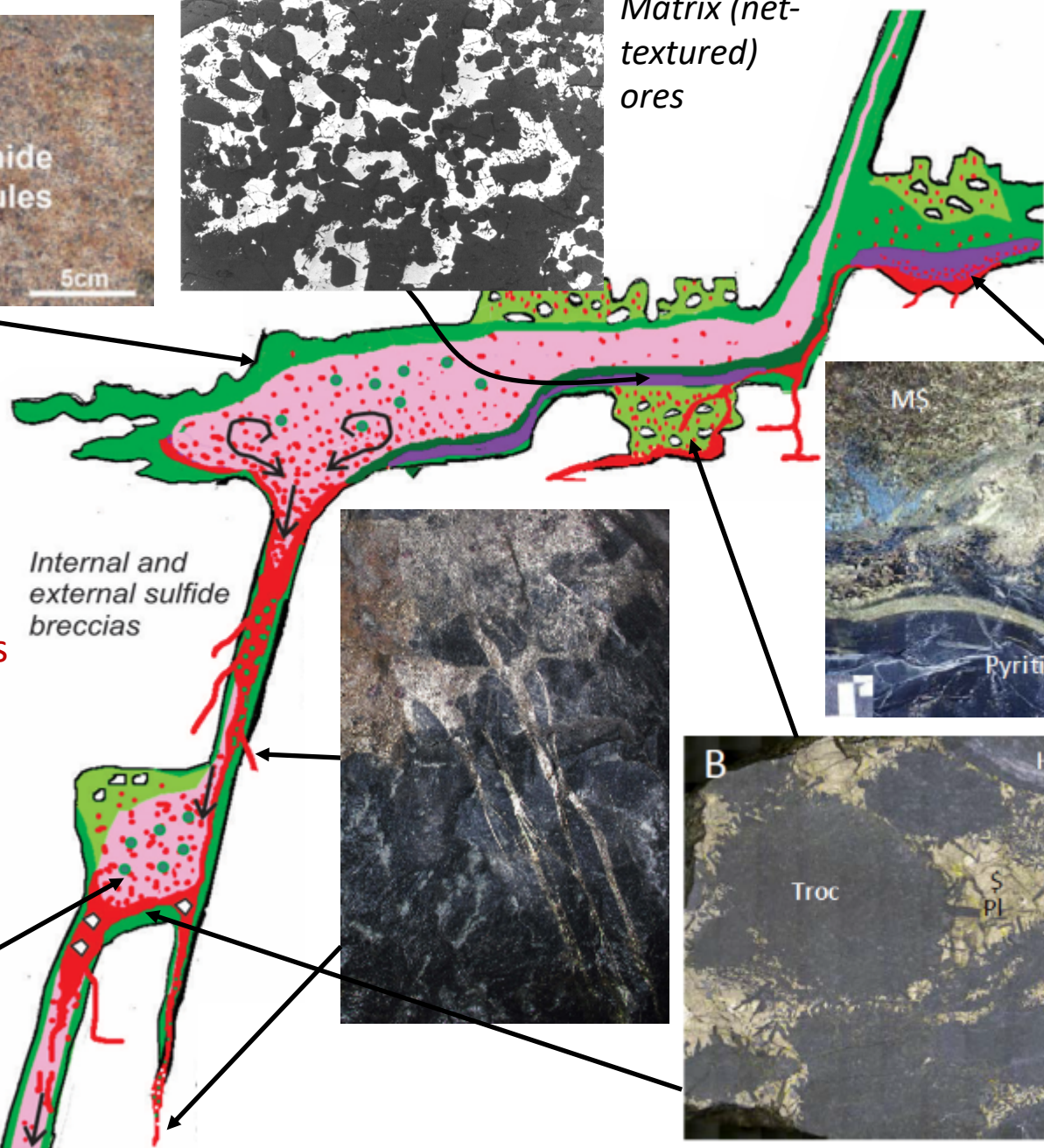




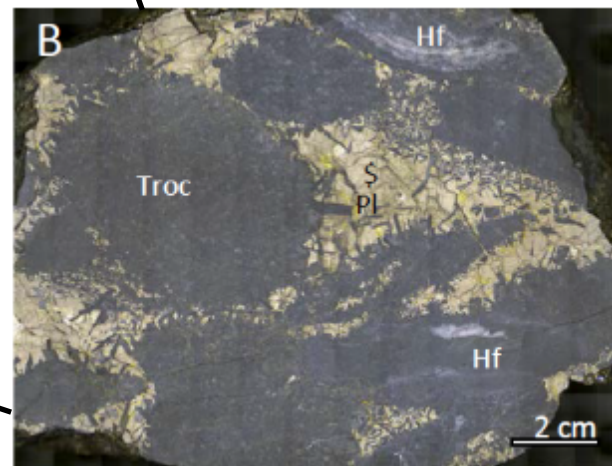
Matrix (net-textured) ores

Sulfide – silicate Infiltration-melting front

Sulfide textures are key evidence for ore forming processes and can serve as deposit scale vectors

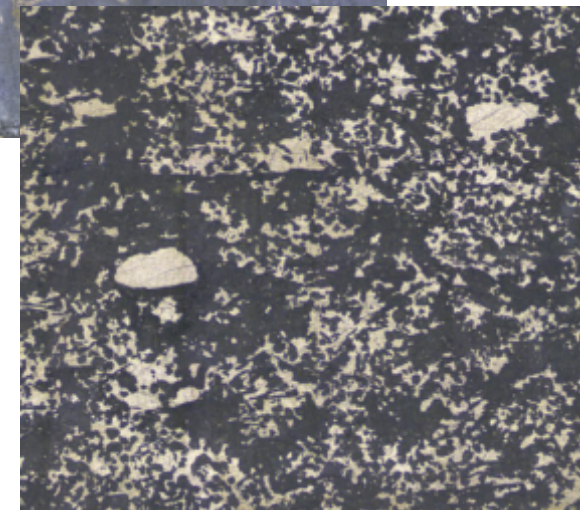
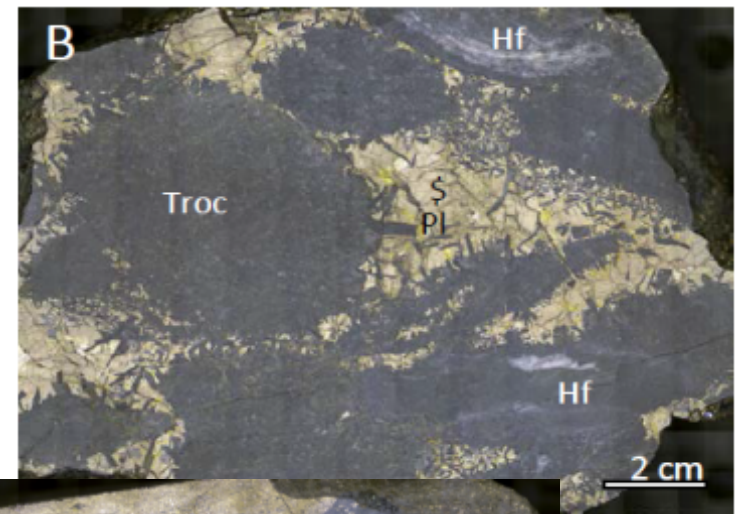


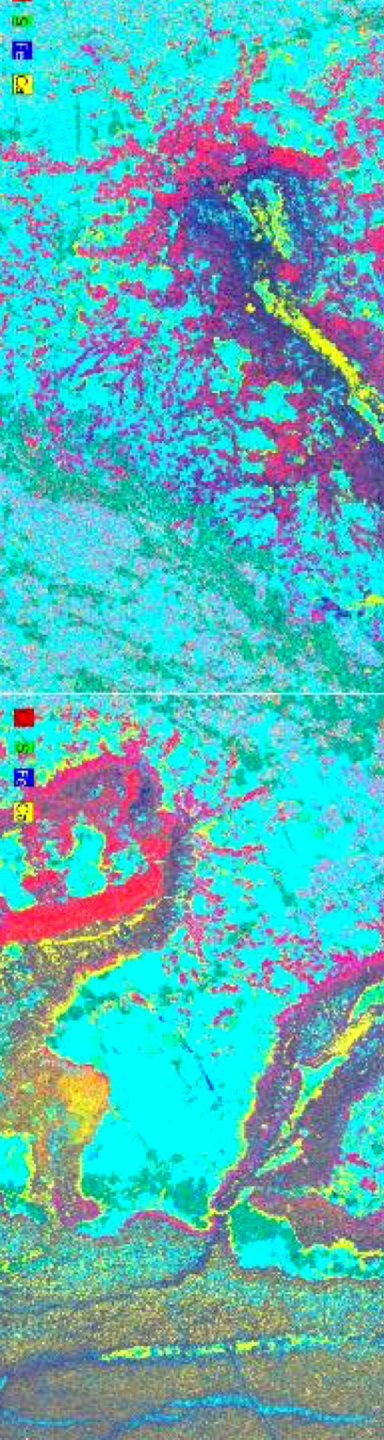
Redeposited ripped-up massive sulfide



Sulfide matrix infiltration breccia

- Continuum between infiltration breccias and emulsion textures
- Continuum between matrix ores, spinifex ores and infiltration breccias
- Process driven by percolation of hot, dense, low viscosity sulfide melt and displacement of low-melting silicate component at infiltration-melting fronts
- These “breccias” form by low energy gravity-driven downward percolation, not high-energy volatile–driven upward emplacement





Main messages

1. Sulfide liquids can percolate through silicate rocks once the sulfide content is high enough
2. Some “breccias” are actually primary sulfide-silicate melt/percolation fronts
3. Large-scale “breccia” ore bodies may be extensive percolation-melting networks, not explosively emplaced volatile-driven breccia pipes
4. Post deposition sulfide liquid migration plays a major role in generating orebodies
5. Spatial distribution of textural types can help vector into and assess potential for high grade ore

