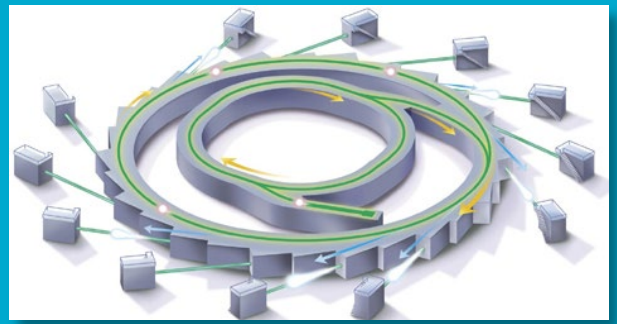
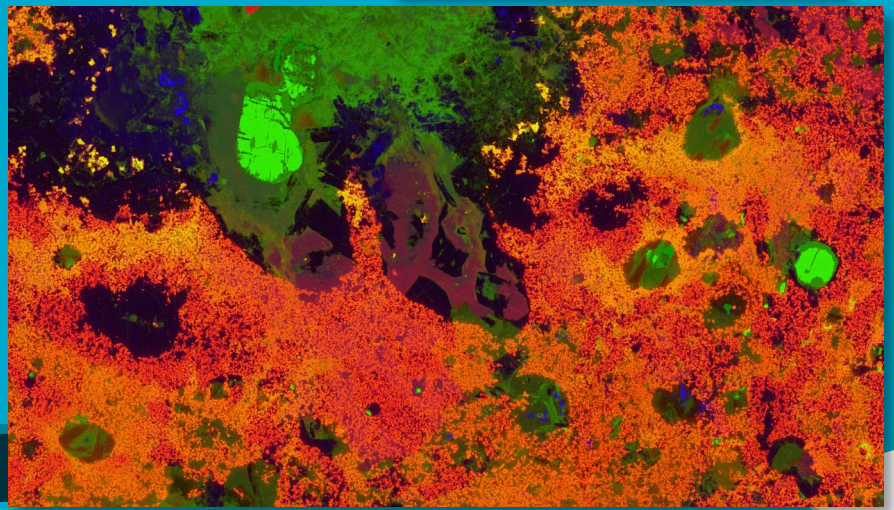
Finding Platinum Needles in Igneous Haystacks : X-Ray Fluorescence Mapping with the Maia Detector Array at the Australian Synchrotron





- Igneous geochemistry of Pt
- The sampling problem – why XFM?
- Pt, sulfides, magmas and gas bubbles – the Norilsk story

Steve Barnes **CSIRO Mineral Resources**

Platinum Group Elements: the tastiest elements in the Periodic Table

Pt, Pd, Rh, Ru, Ir, Os – geochemically significant group of Highly Siderophile (metal-loving) elements

Important traces for planetary differentiation (formation of planetary cores) and impact events (e.g. Ir anomaly at K-T boundary)

Very efficiently concentrated by immiscible sulfide liquid – high concentrations in magmatic sulfide ore deposits, tracers for Ni-Co-Cu exploration

Very low (~1 ppb) abundances in the Earth's crust

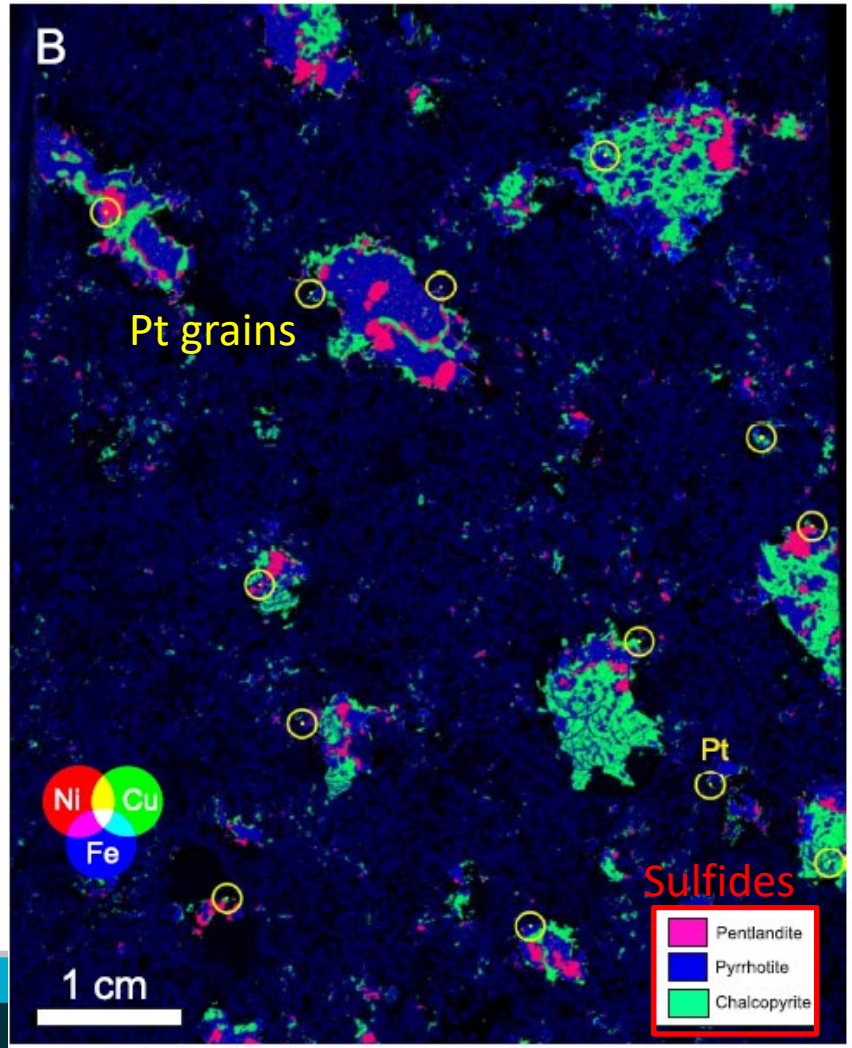
Why? PGEs are extremely insoluble in silicate magmas (basalts) - ~ 10 ppb max.

What form does Platinum (Pt) take in igneous rocks?

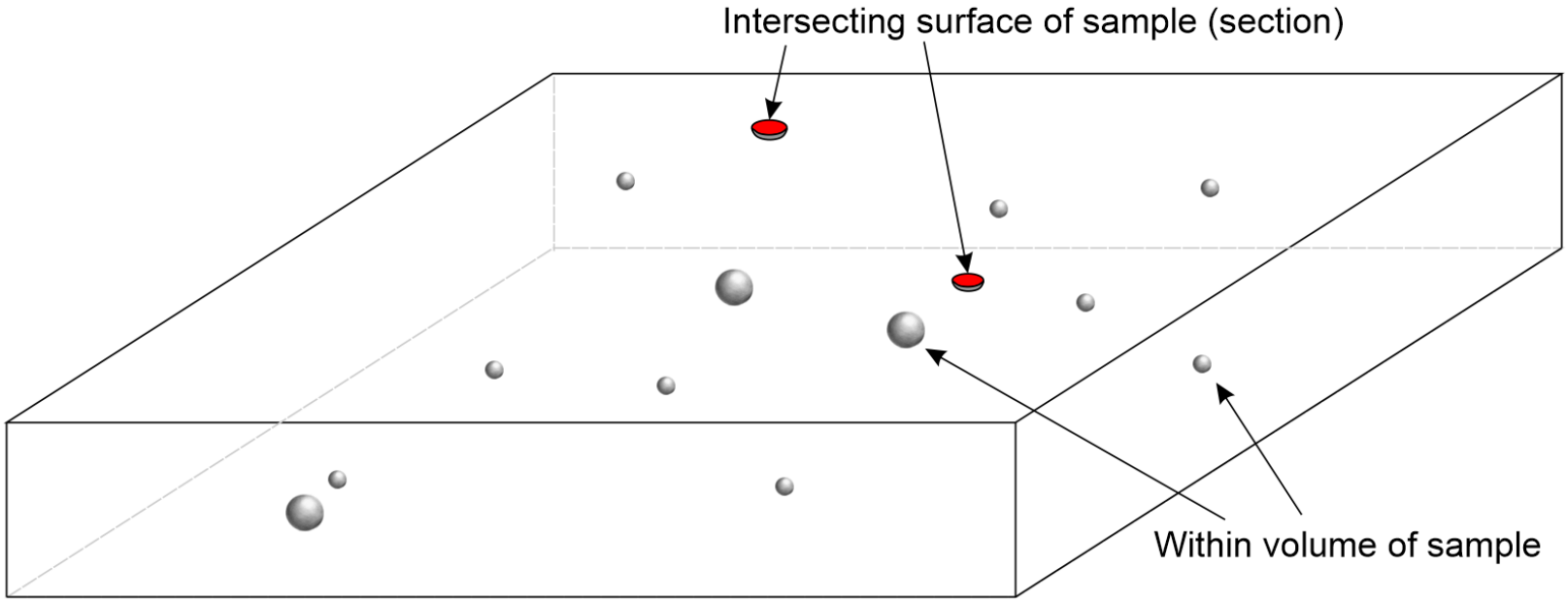
Pt very efficiently collected by droplets of immiscible sulfide liquid – high concentrations in magmatic sulfide ore deposits

But – Pt concentration in basalt magmas seems to decrease as they crystallise, even if there's no sulfide involved.

Why? Pt is extremely insoluble in silicate magmas (basalts) - ~ 10 ppb max.

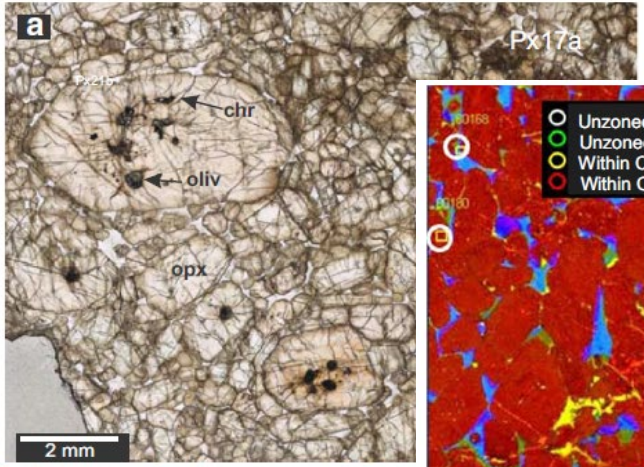


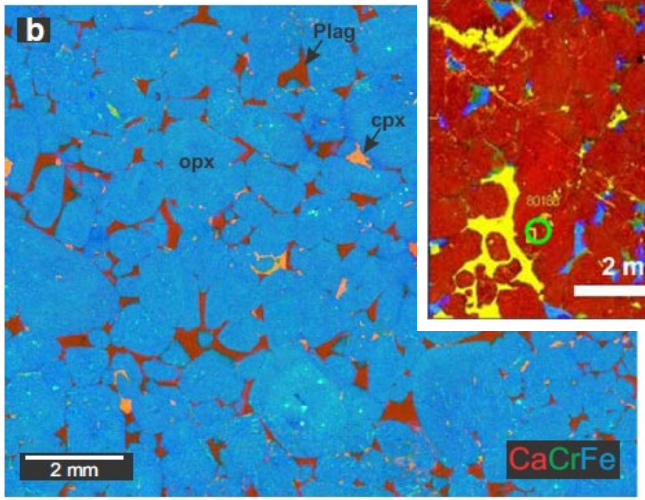
Needles in haystacks: Sampling sparse grains at ppm levels



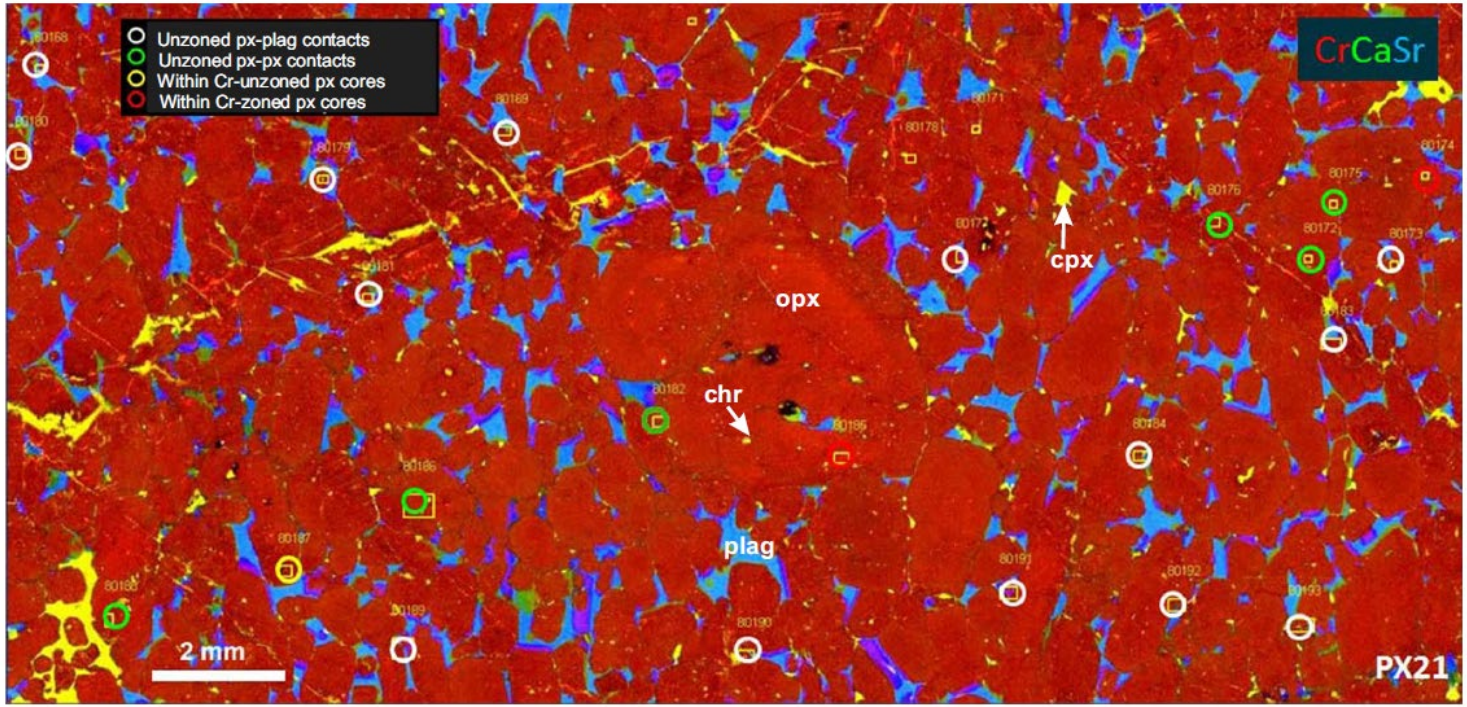
At one ppm, ~10% of typical sized Pt (or Au) grains in a 100 micron slice are visible in 2D section. Synchrotron X-ray beam penetrates entire 100 micron thickness

Pt in a sulfide-free rock (Mont de Cristals, Gabon, West Africa)





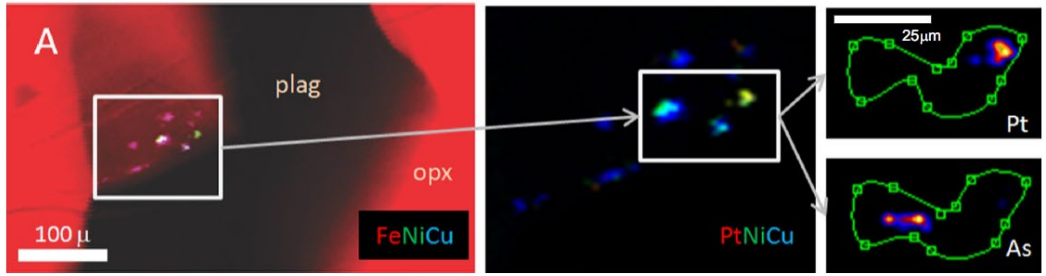
Pyroxene cumulate, no visible sulfide, ~100 ppb Pt

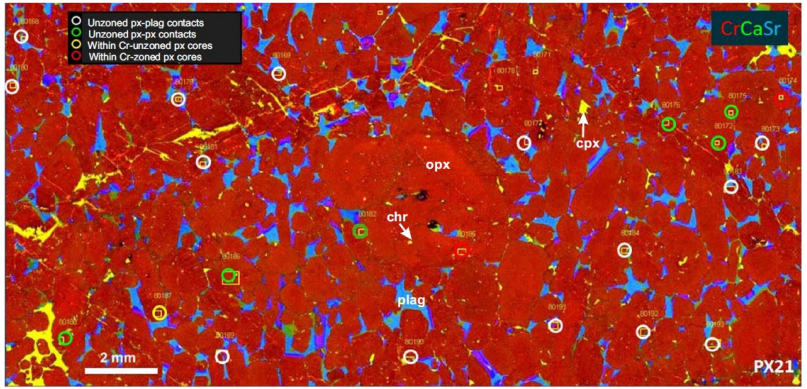


Reconnaissance cm^2 map finds hotspots

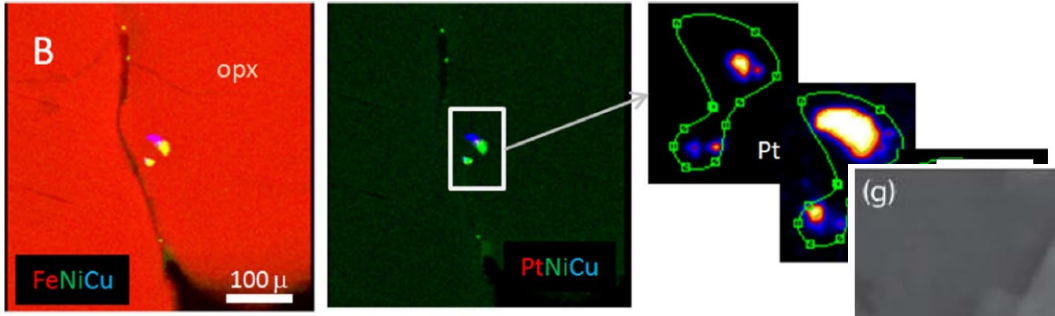
Micro-prospecting at 100 ppb level…

Detailed “boxes” at 1 micron resolution

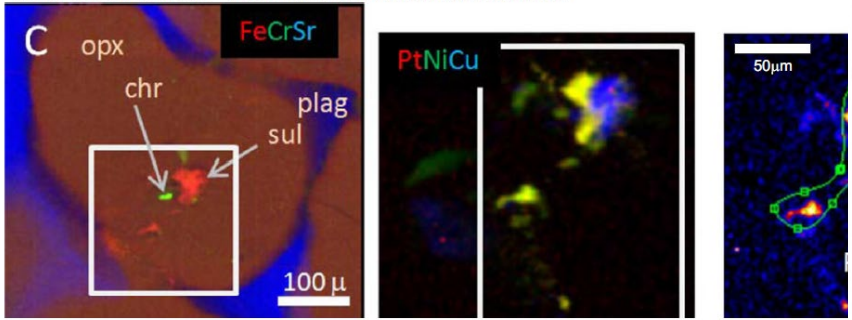


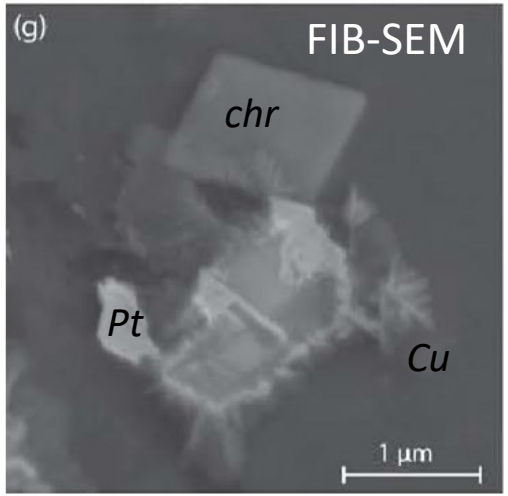


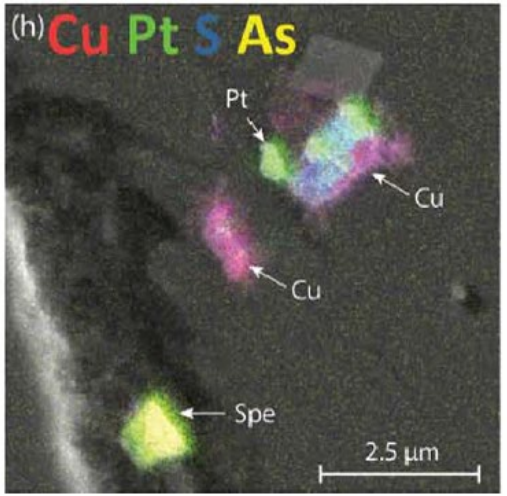
80155 - co-located sulfide + Pt + As



62363 - co-located sulfide + Pt associated with chromite enclosed in opx

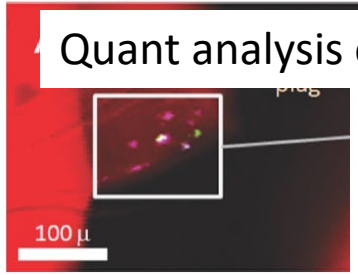




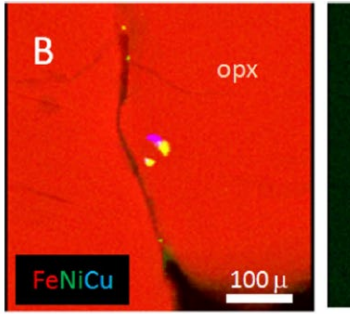


Pt in a sulfide-free rock (Mont de Cristals, Gabon, West Africa)

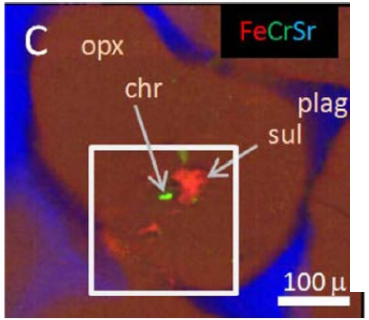
Quant analysis of hotspot areas

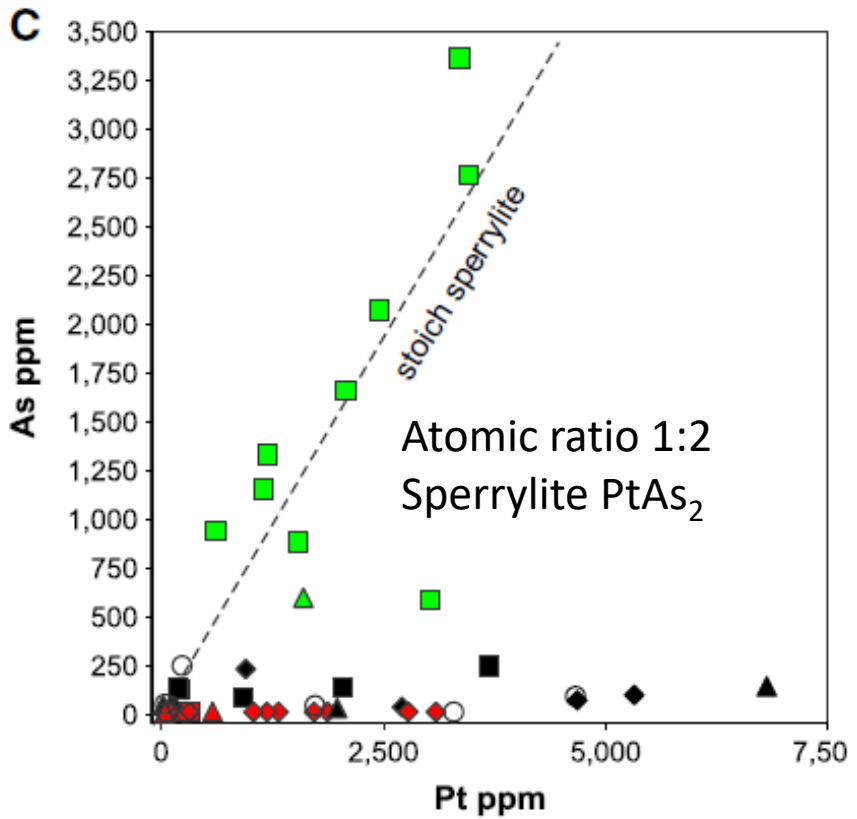


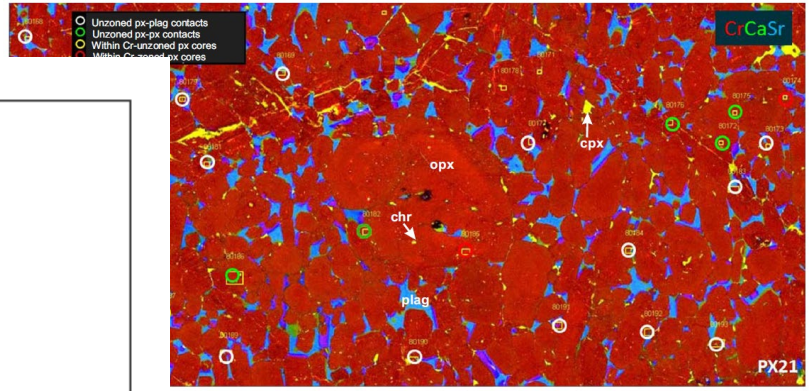
80155 - co-located sulfide + Pt + As



62363 - co-located sulfide + Pt associated w





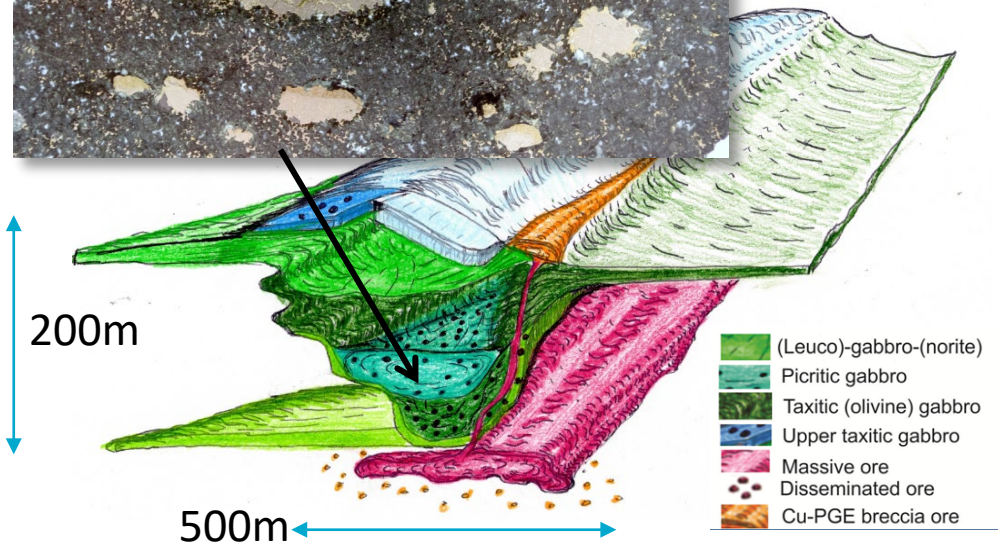


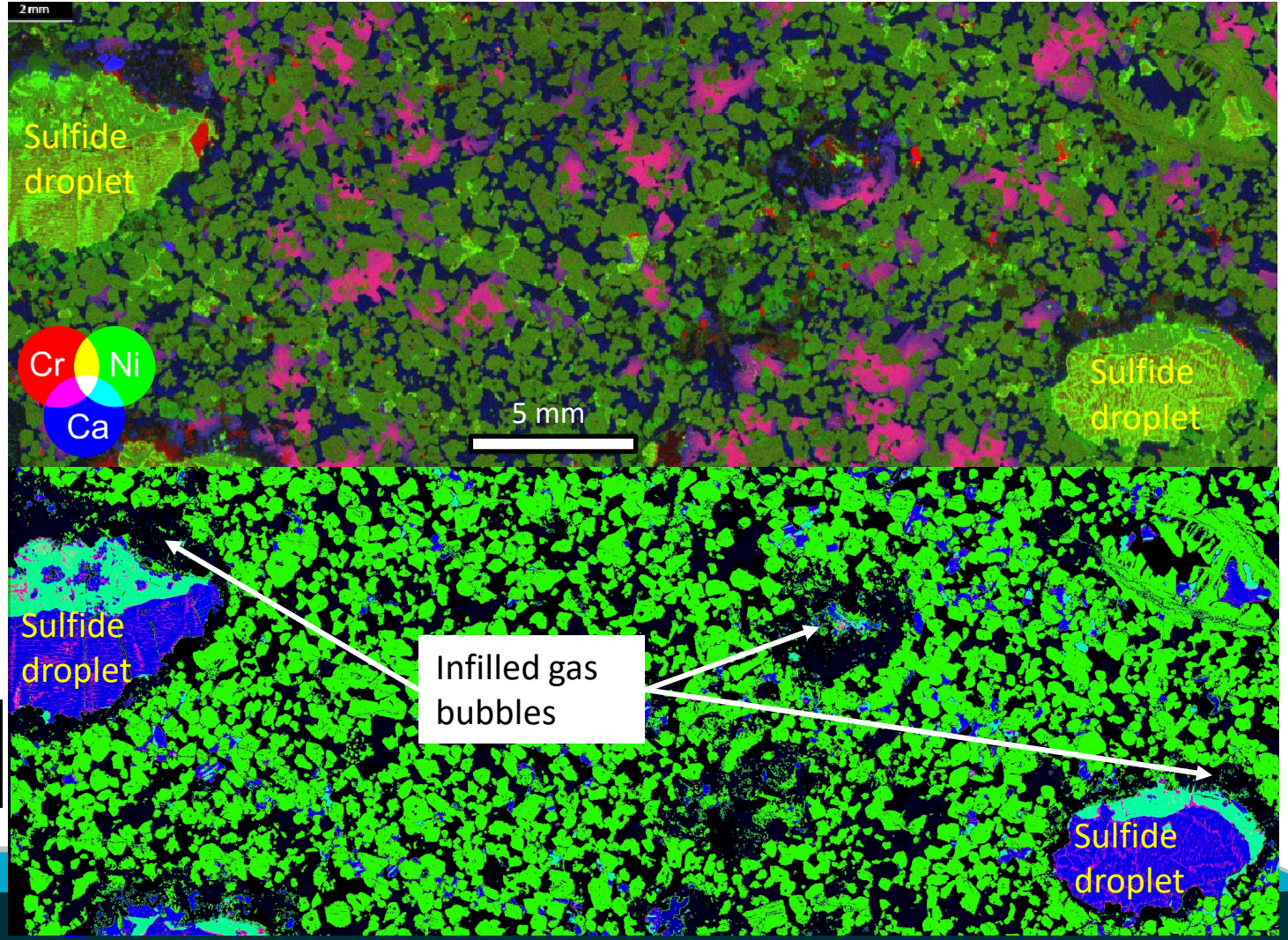
Sperrylite and Pt-Fe alloys are crystallising directly from the silicate magma – presence of chromite (CrFeAl oxide) seems to be critical to nucleating these phases at super-low concentrations

Barnes et al., 2016, DOI: 10.1007/s00410-016-1232-1.

Sulfide droplets and gas bubbles – Norilsk, Siberia

2 cm

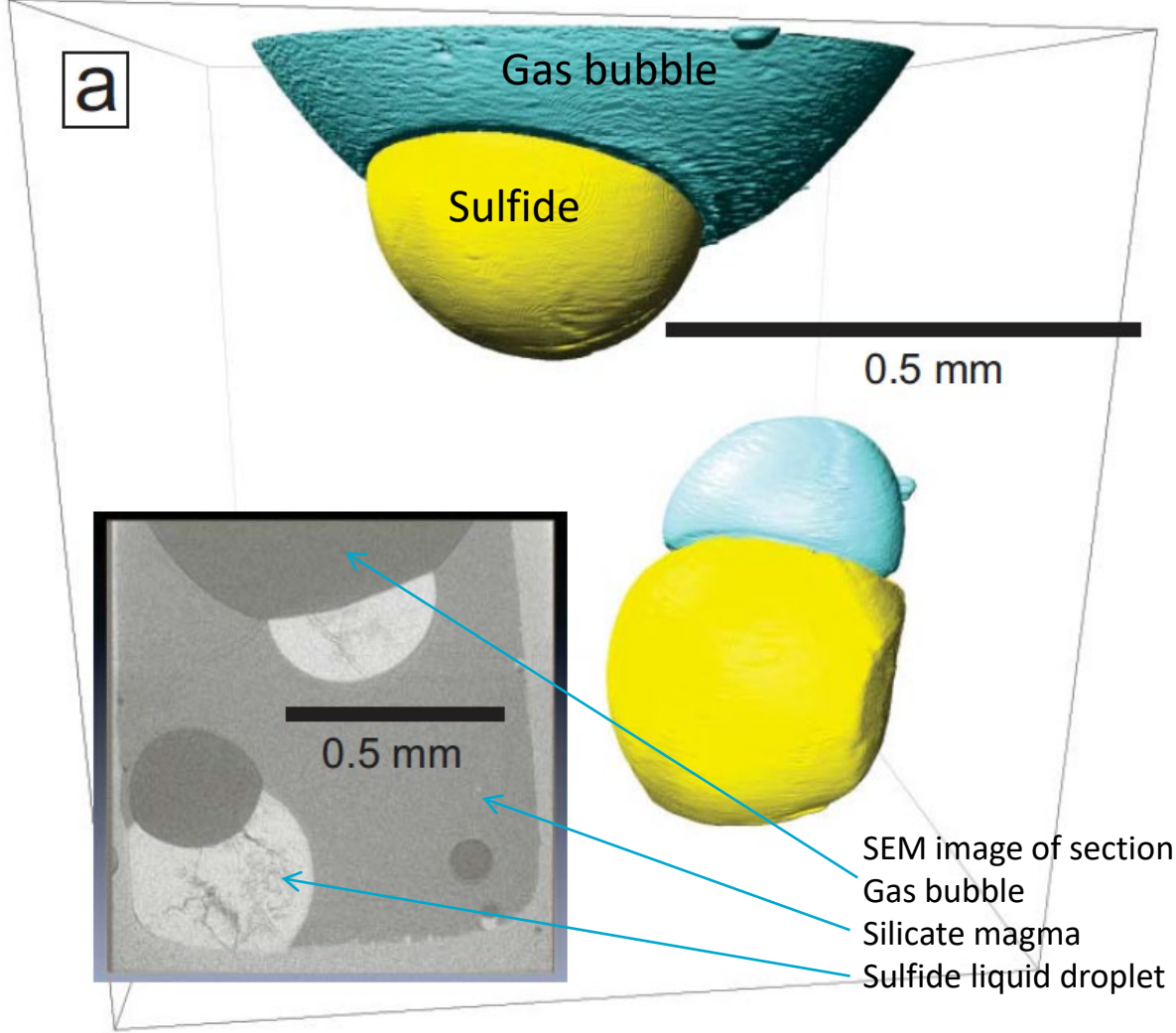




Olivine crystals

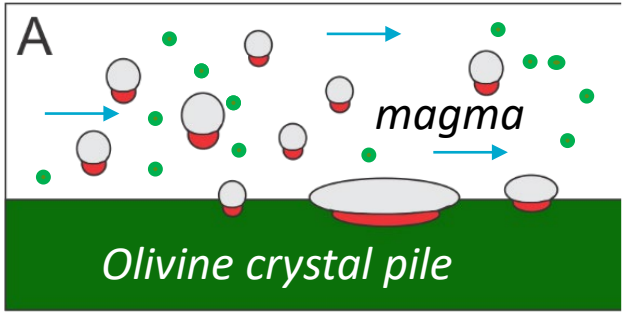
Meet the Drobble…

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

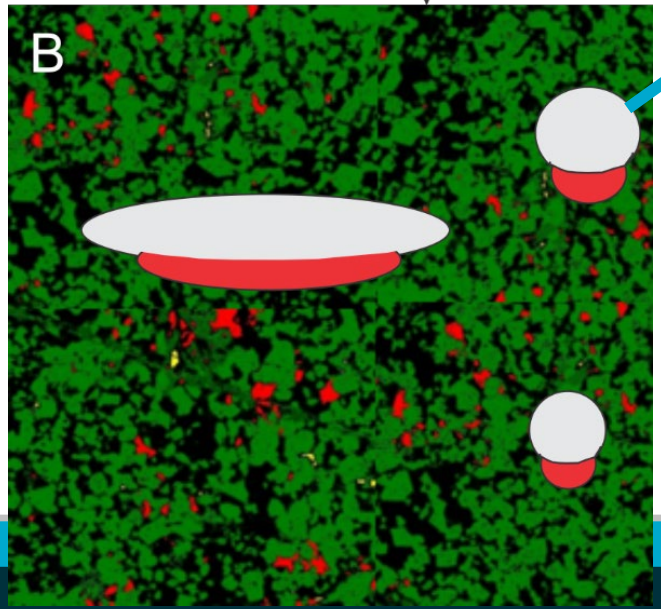


Snapshot from 3D x-ray computed tomography image (CT scan) of bubble-sulfide droplet capture – gas bubbles in blue, droplets in yellow

SEM image of section through experimental charge.
Gas bubble
Silicate magma
Sulfide liquid droplet

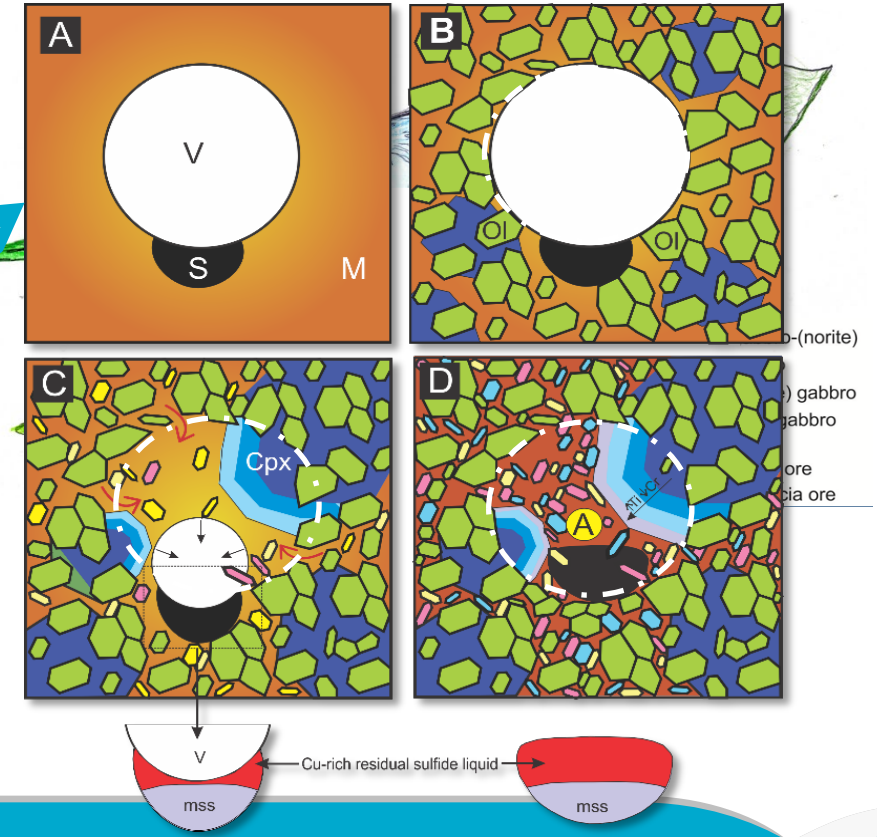


Settling, flattening



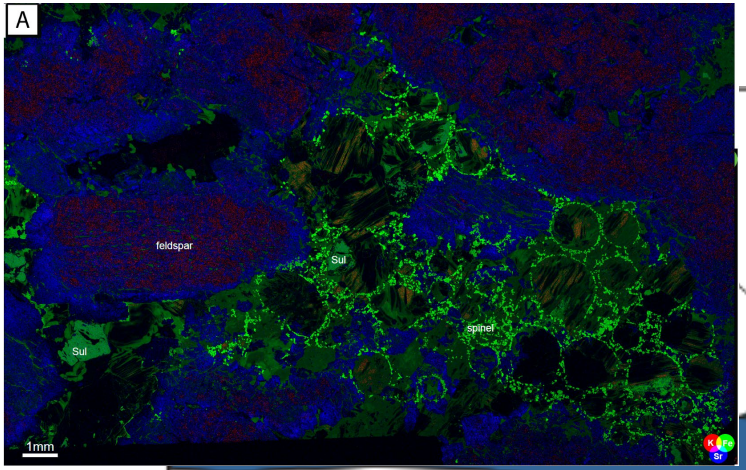
Flowing suspension of “drobbles” and olivine crystals

Gas filter pressing forces residual melt into bubble

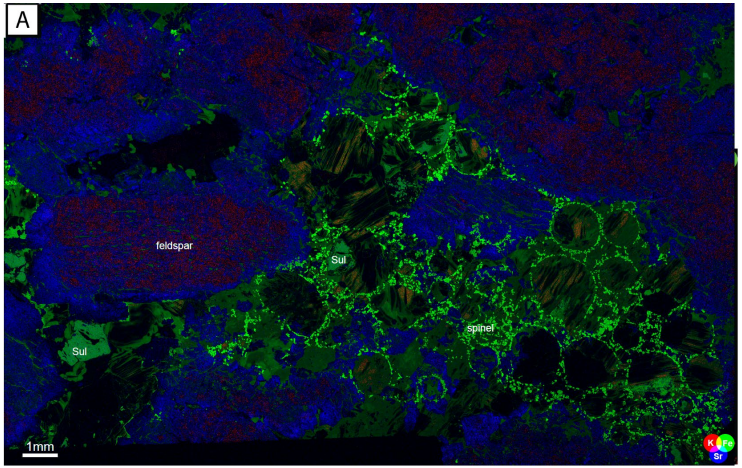


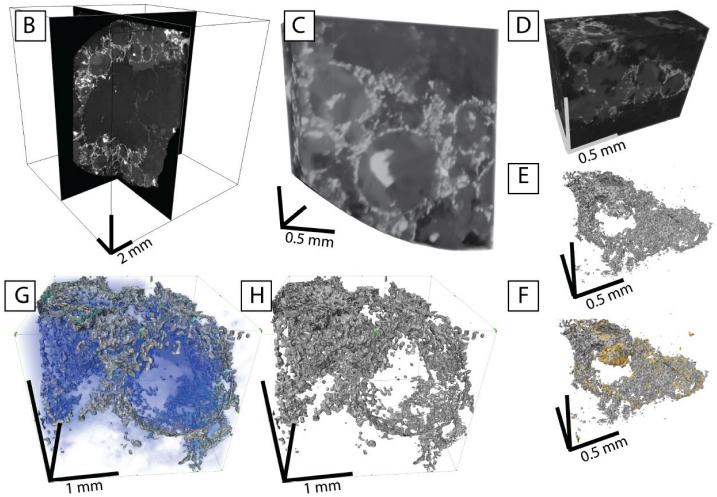
doi: 10.1093/petrology/egy114

Upper ore zone – low-S high PGE

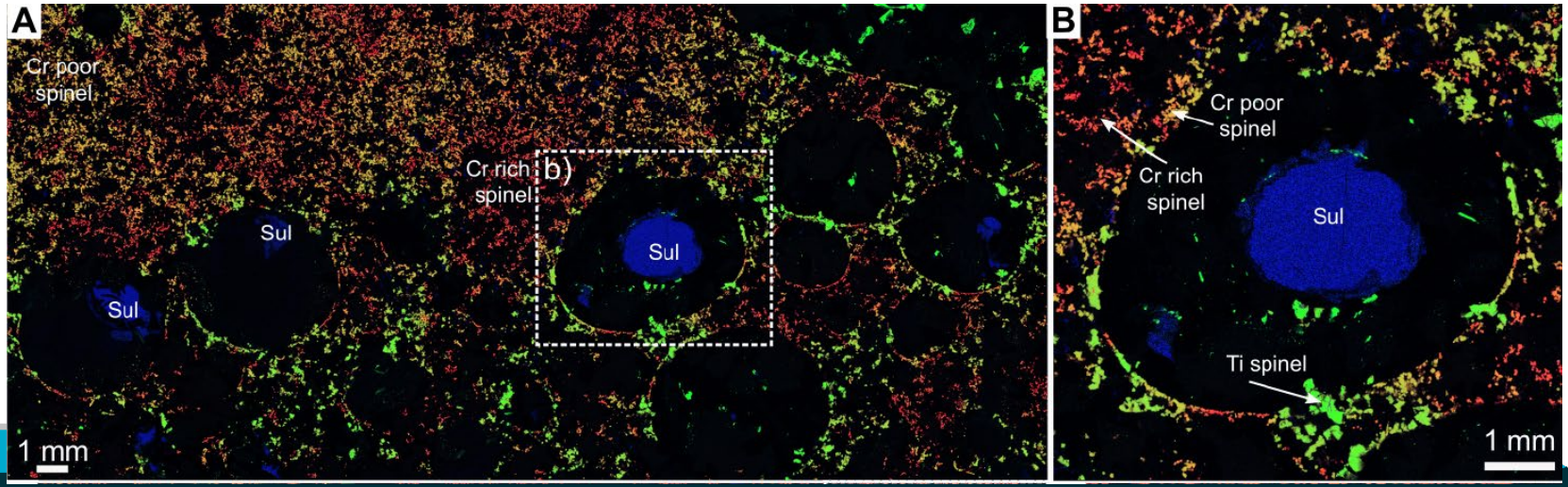


Slide from Tony Naldrett





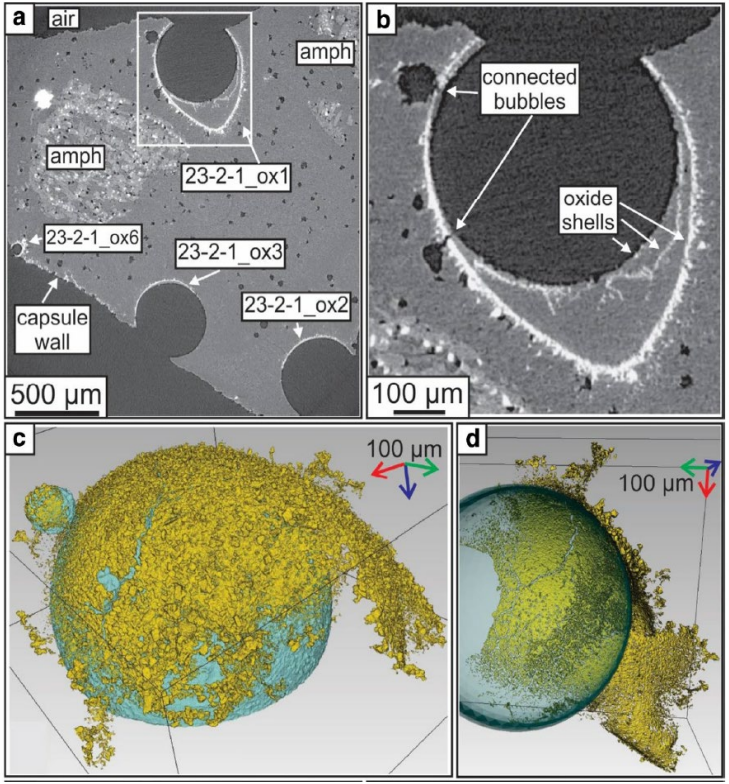
Australian Synchrotron

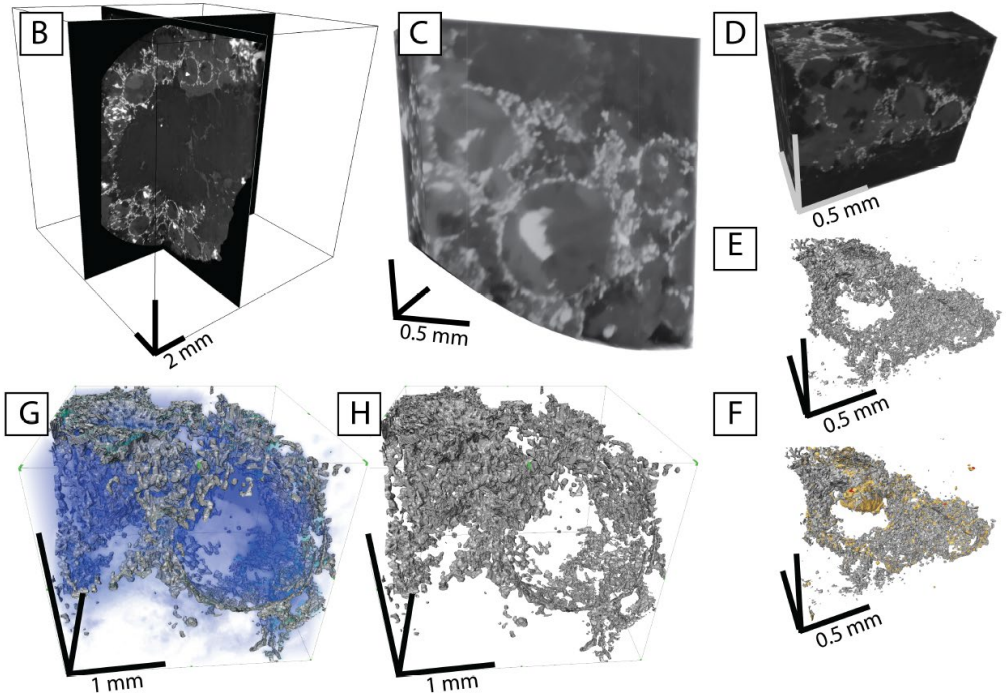


Upper taxite – low-S high PGE (Schoneveld et al., Econ Geol 2020)

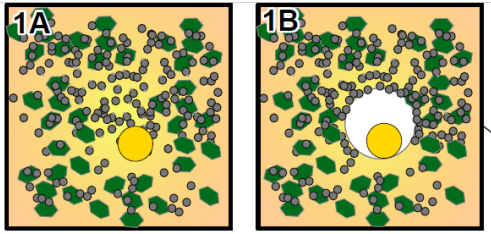
Plese et al. 2019

3D images: oxide shells around infilled gas bubbles

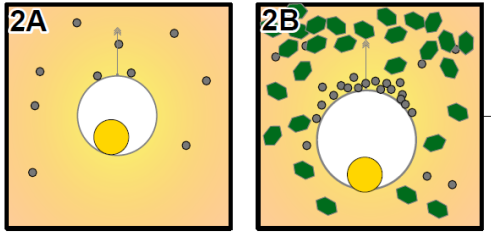




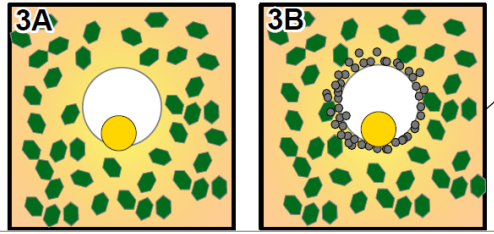
Model 1)
bubbles form in
spinel seams

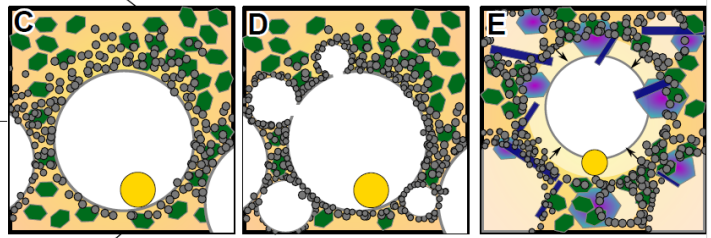


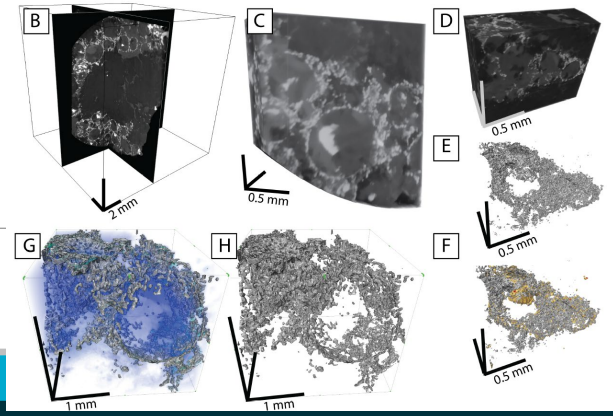
Model 2)
spinel rafted and
collected at roof



Model 3)
spinels nucleate
on bubbles

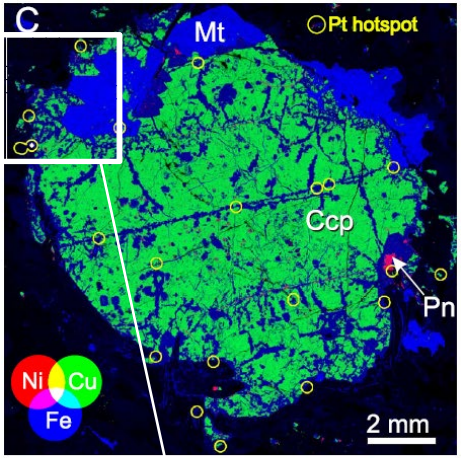


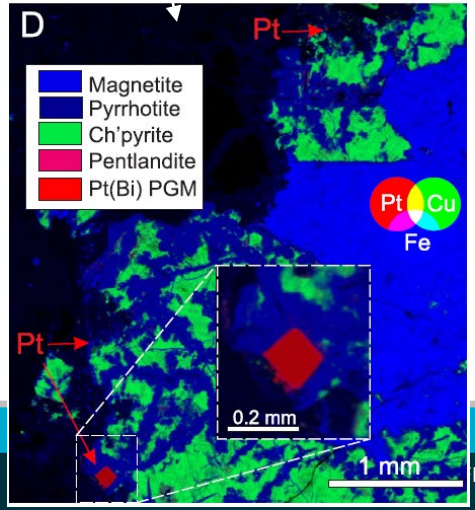




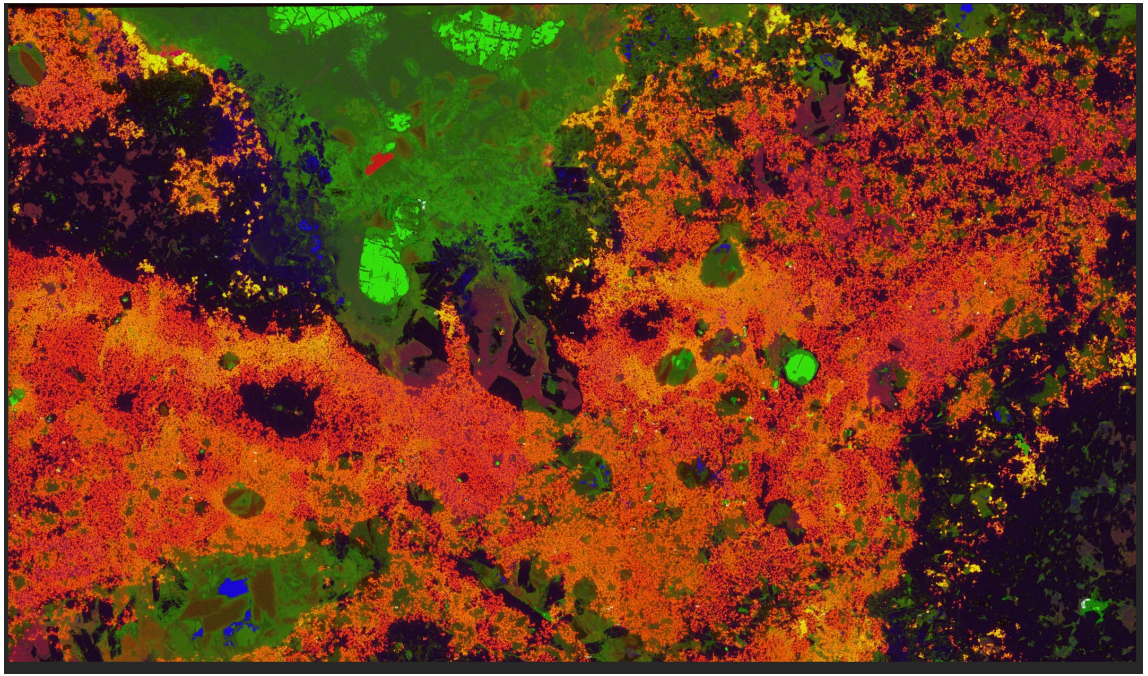
Oxide-sulfide-melt-bubble interactions in spinel-rich taxitic rocks of the Norilsk-Talnakh intrusions, polar Siberia
L Schoneveld, SJ Barnes, B Godel, ML Vaillant, MA Yudovskaya, ...
Economic Geology 115 (6), 1305-1320

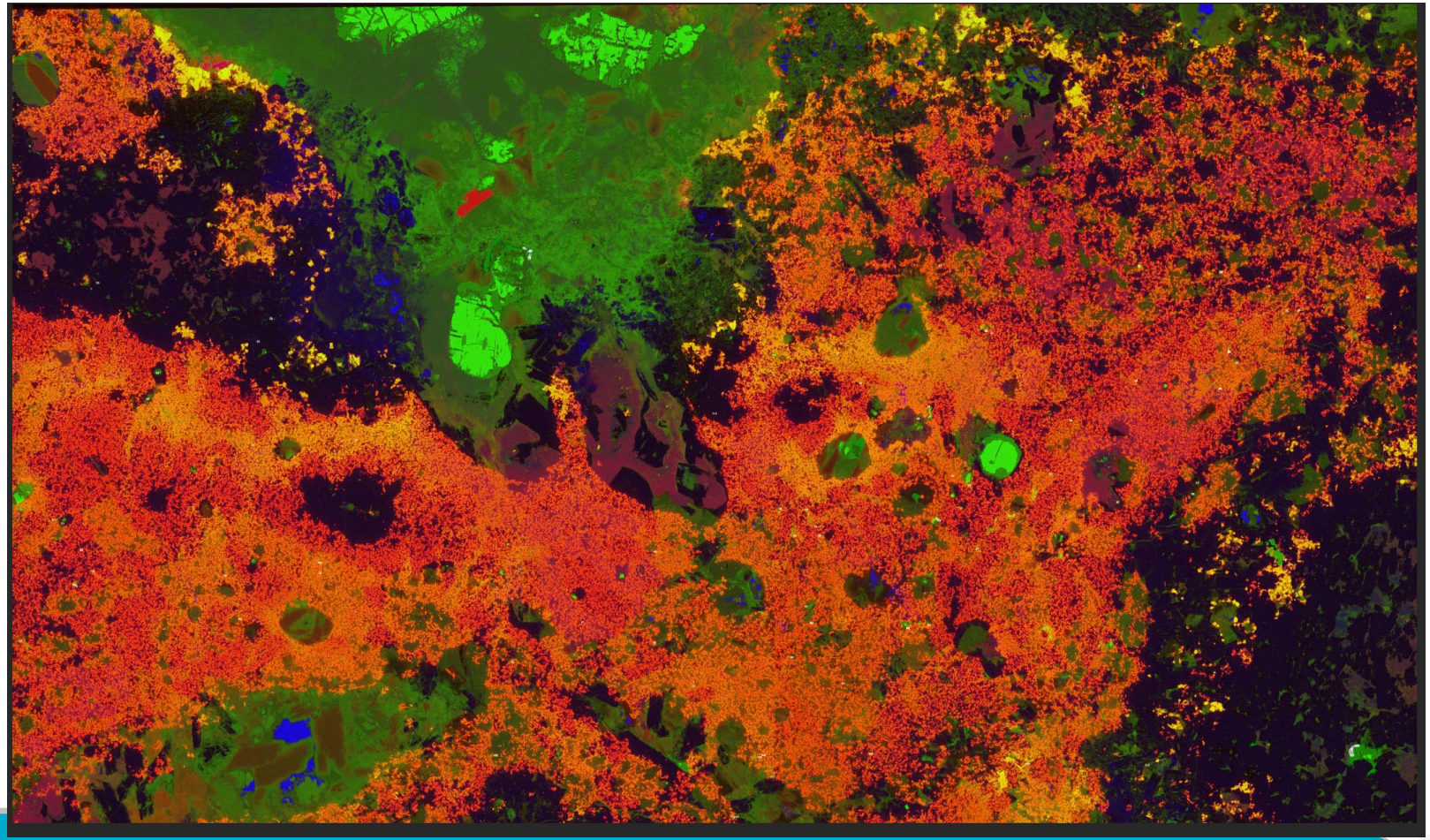
Pt minerals closely associated with sulfides in lower parts of intrusions

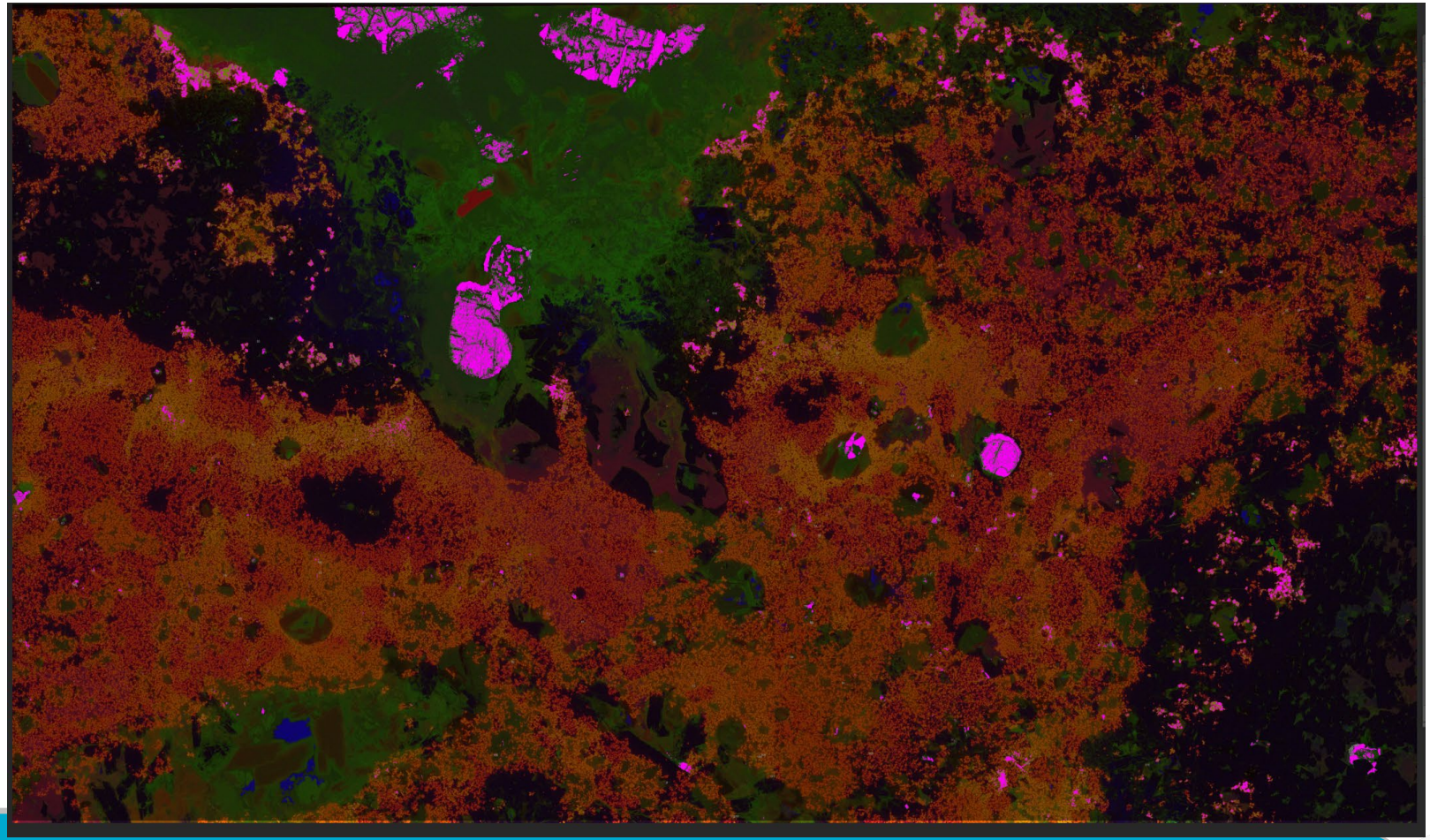


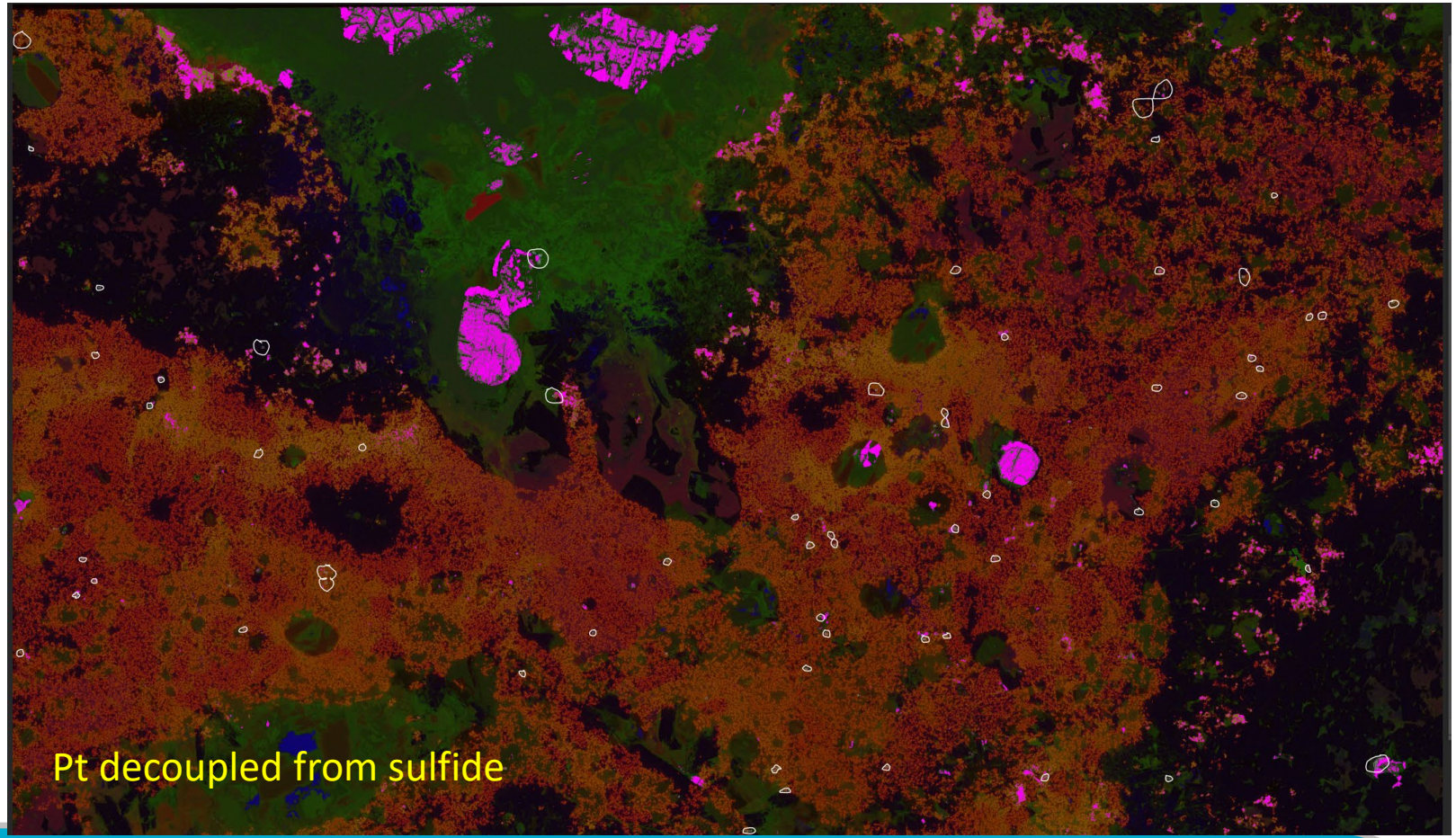


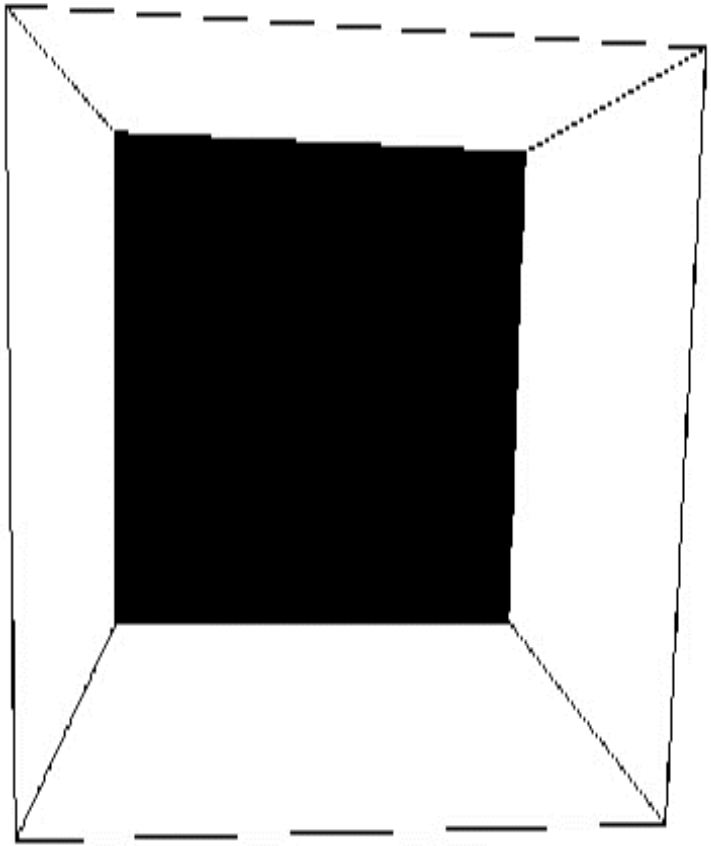
Low-S PGE, Upper Taxite

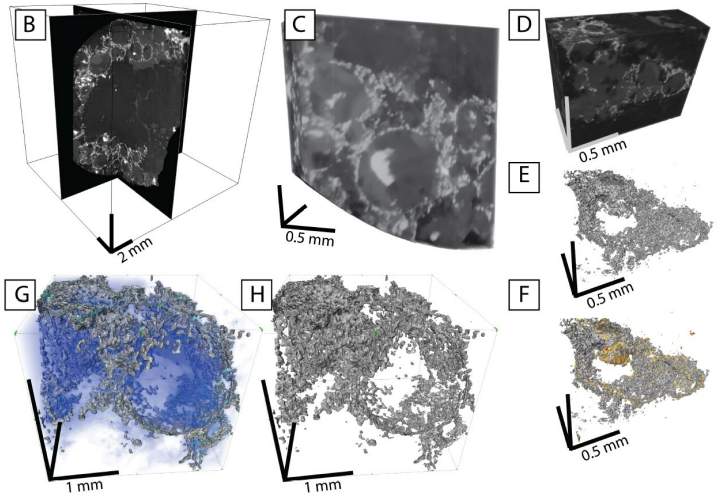







Pt decoupled from sulfide



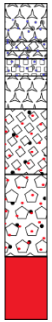

B
2 mm
C
0.5 mm
D
0.5 mm
E
0.5 mm
G
1 mm
H
1 mm
F
0.5 mm

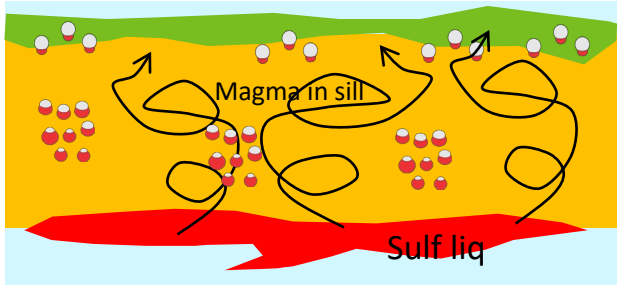
DIY Norilsk in a wineglass

PGE + bubbles

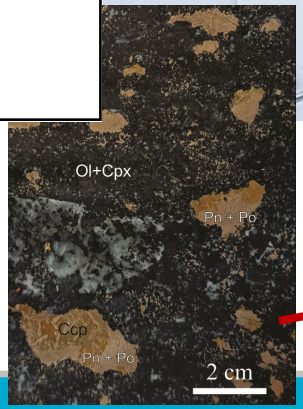
Silicate magma + globules

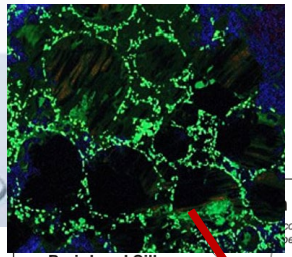
Massive sulfide

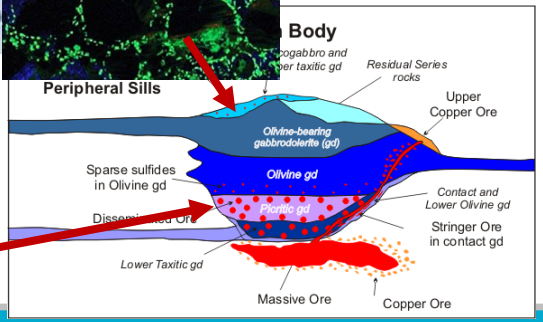


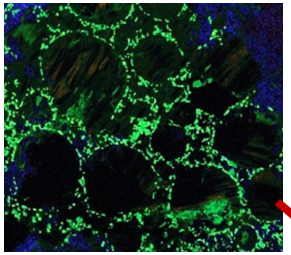


https://imgur.com/gallery/eq38L



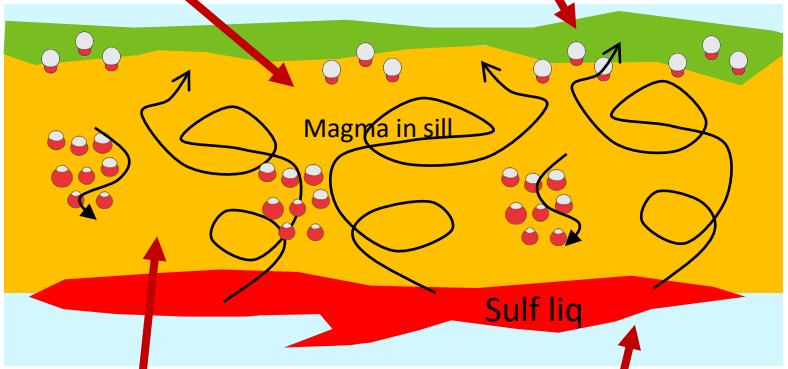


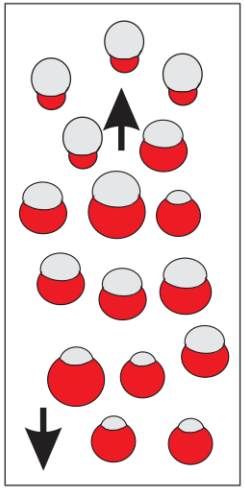


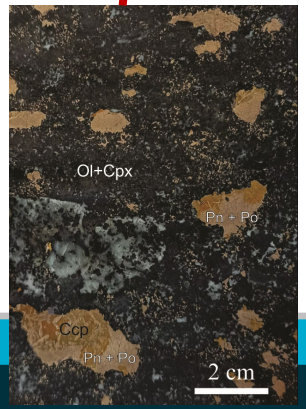


Gas-rich drobbles float and accumulate at tops of sills
S-degassing generates v high PGE tenors

Taxite (inclusion rich roof-melt scum at top of sill)

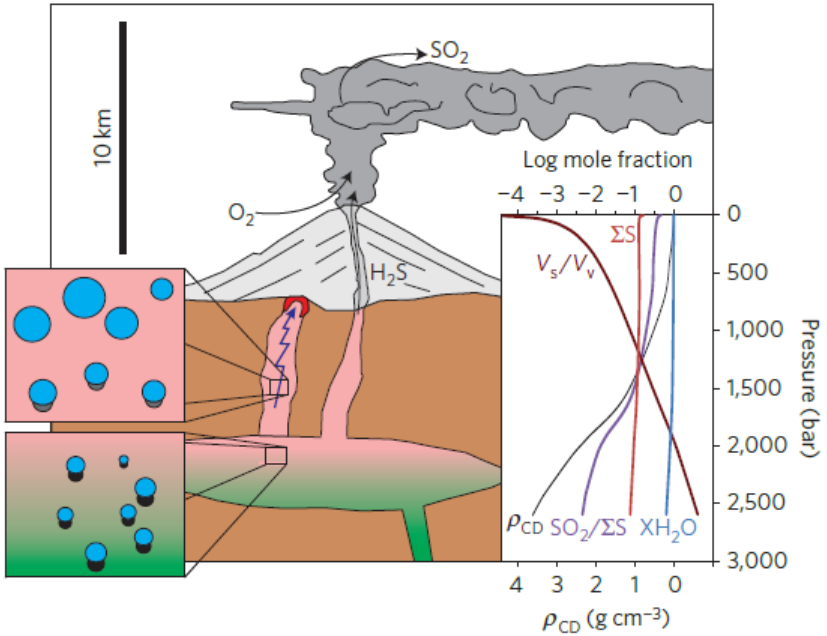






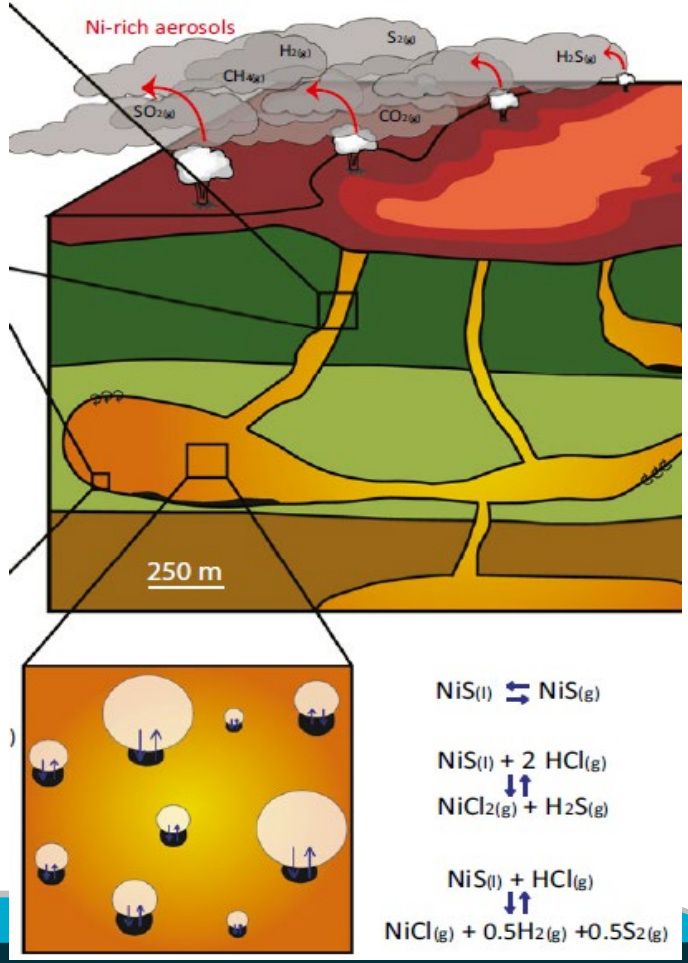
Sulfide melts floor rocks generating vapour bubbles

Sulfide rich drobbles sink and accumulate



Death Metal: mechanism for the Permo-Triassic mass extinction: Ni transported into the atmosphere as aerosols causing bloom in methane-producing biota

(Le Vaillant et al., PNAS, 2017)



Thanks for listening!

Huge thanks to David Paterson, Chris Ryan and the XFM Beamline crew

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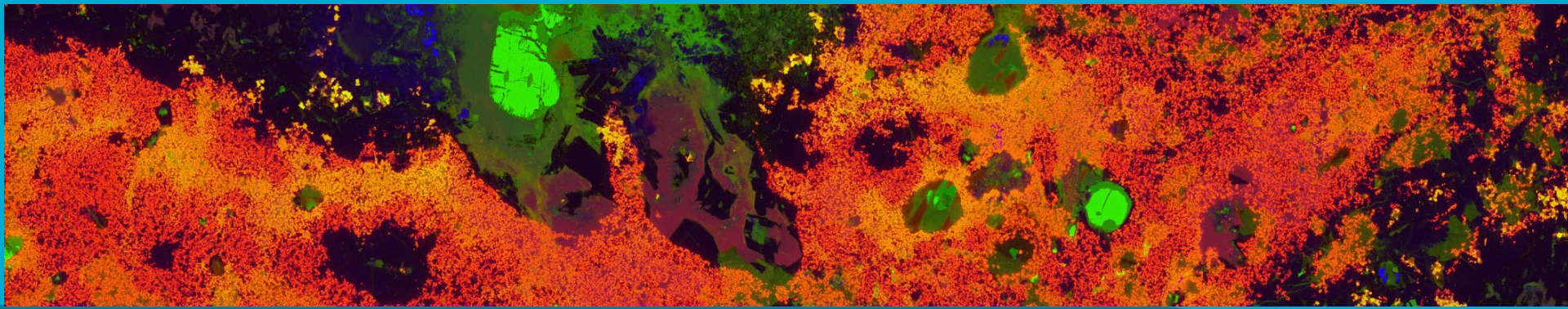
CSIRO Mineral Resources - Magmatic Sulfides Team

We are a small team focused on the targeting, detection and characterisation of magmatic nickel-copper-cobalt–platinum group element (PGE) deposits using geochemistry, petrology and mineralogy.



Steve Barnes

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