

# Ultra-high definition trace element mapping provides new clues on the origin of the McArthur River (HYC) sediment-hosted Zn-Pb deposit.

**Sam Spinks**<sup>1</sup>, Mark Pearce<sup>1</sup>, Chris Ryan<sup>1</sup>, Gareth Moorhead<sup>1</sup>, Robin Kirkham<sup>1</sup>, Heather Sheldon<sup>1</sup>, Marcus Kunzmann<sup>1, 2</sup>, Weihua Liu<sup>1</sup>, Teagan Blaikie<sup>1, 2</sup>, Peter Schaub<sup>1</sup>, William DA Rickard<sup>3</sup>

<sup>1</sup>CSIRO Mineral Resources,

<sup>2</sup>Northern Territory Geological Survey

<sup>3</sup>John De Laeter Centre, Curtin University

MINERAL RESOURCES

[www.csiro.au](http://www.csiro.au)



AGES – Alice Springs; NT 19 March 2019

# HYC Sediment-hosted Zn-Pb Deposit

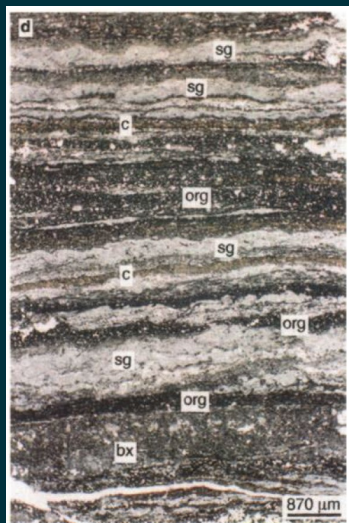
## The Genetic Debate!

Observation	Syn depositional Model	Diagenetic-epigenetic model
Laminated ore textures	Consistent with deposition from water column	Can be produced by replacement of sedimentary (carbonate) layering
Timing of sphalerite and galena mineralization	Not consistent	Deposition of base metal sulfides after latest diagenetic pyrite indicate diagenetic-epigenetic model
Lithogeochemical haloes (TI)	Enrichment of TI up to 200 m above ore zone could result from low-T fluid after main-stage mineralization	Enrichment of TI up to 200 m above ore zone <i>indicate</i> fluid flow <u>well after</u> deposition of ore-hosting sediments low-T fluid after main-stage mineralization

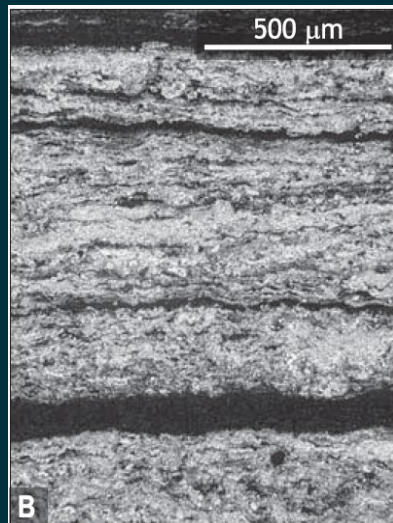


After Huston et al. 2006; Econ. Geol.

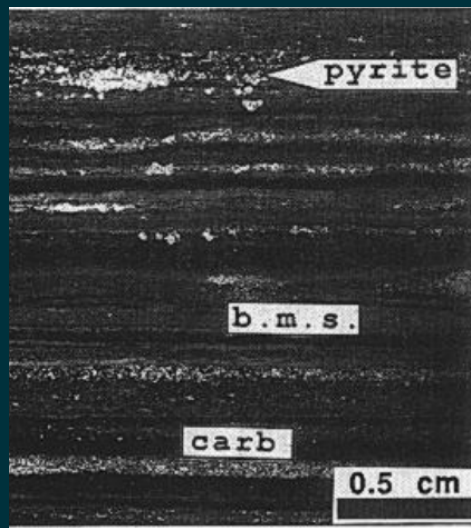
Current understanding is based on interpretations from old technologies, usually from thin sections



Large et al., 1998.



Ireland et al., 2004



Eldridge et al., 1993

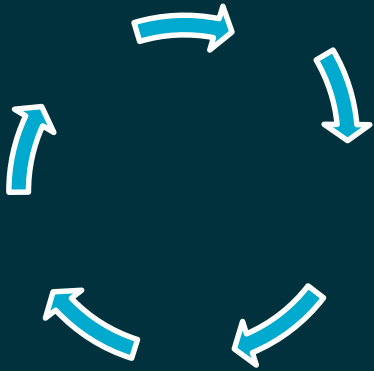
*'carbonate replacement during the oreforming process might seem a reasonable textural interpretation. Although, the ore-hosting Pyritic Shale Member in the HYC deposit contains abundant carbonate.'*

Sangster, 2018; Min. Dep.

*The point has been made by Leach et al. (2010) that sulfide layering, by itself, is not sufficient proof of exhalative ore. By the same token, however, sulfide mimicking of syngedimentary textures is not proof of replacement processes....*

*...Although replacement is frequently mentioned to be responsible for sulfide layering, the replaced mineral phase is seldom identified.'*

Sangster, 2018; Min. Dep.



**The debate is going in circles.**

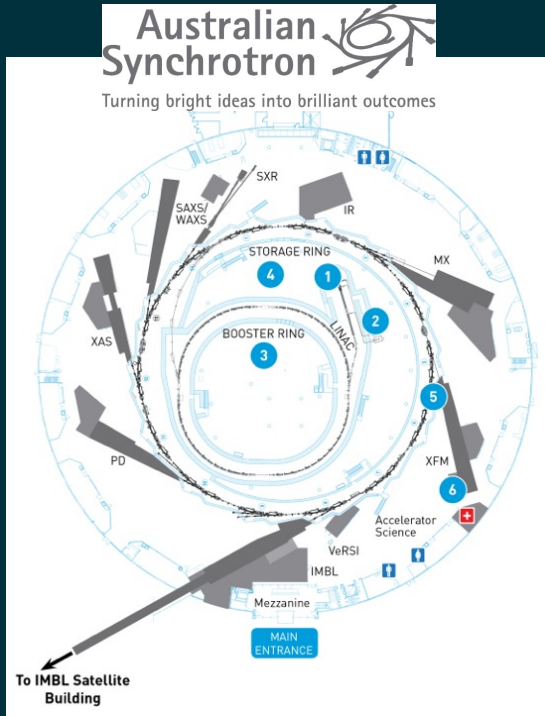
**A quantitative approach is needed....across different scales**

Actual size of a thin section on this screen



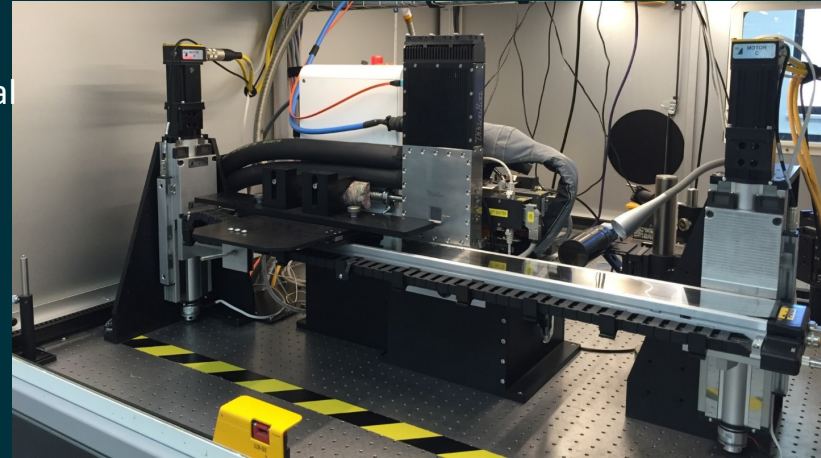


# 21<sup>st</sup> Century Technology: New Maia Mapper for ultra-high definition drill core & slab-scale XFM Mapping



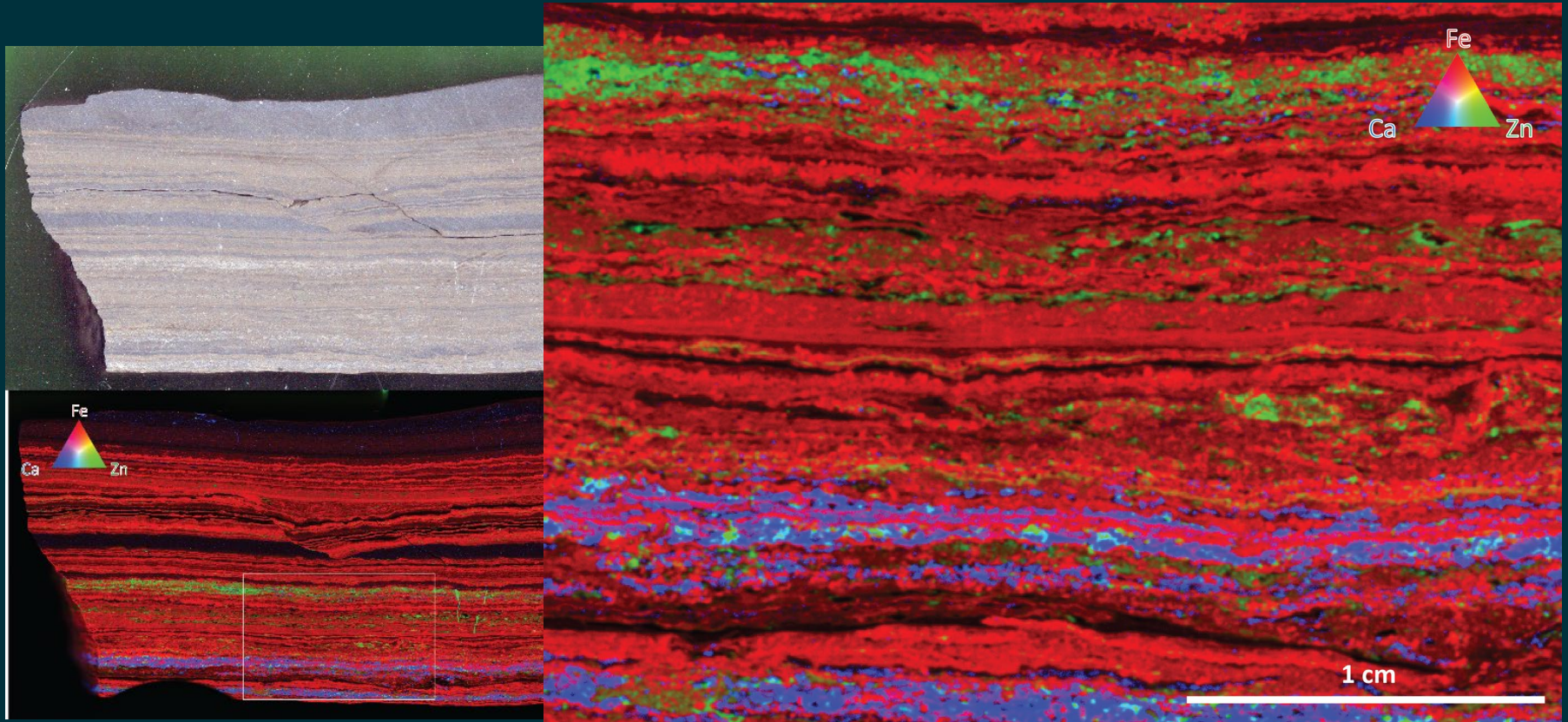
## Exploits new developments

- Excillum high flux, liquid metal micro-focus source
- Maia Detector (used on the Australian Synchrotron)
- New X-ray lenses for higher energies  $>20$  keV
- 'Mimic' Synchrotron conditions in the lab, on drill core scale samples

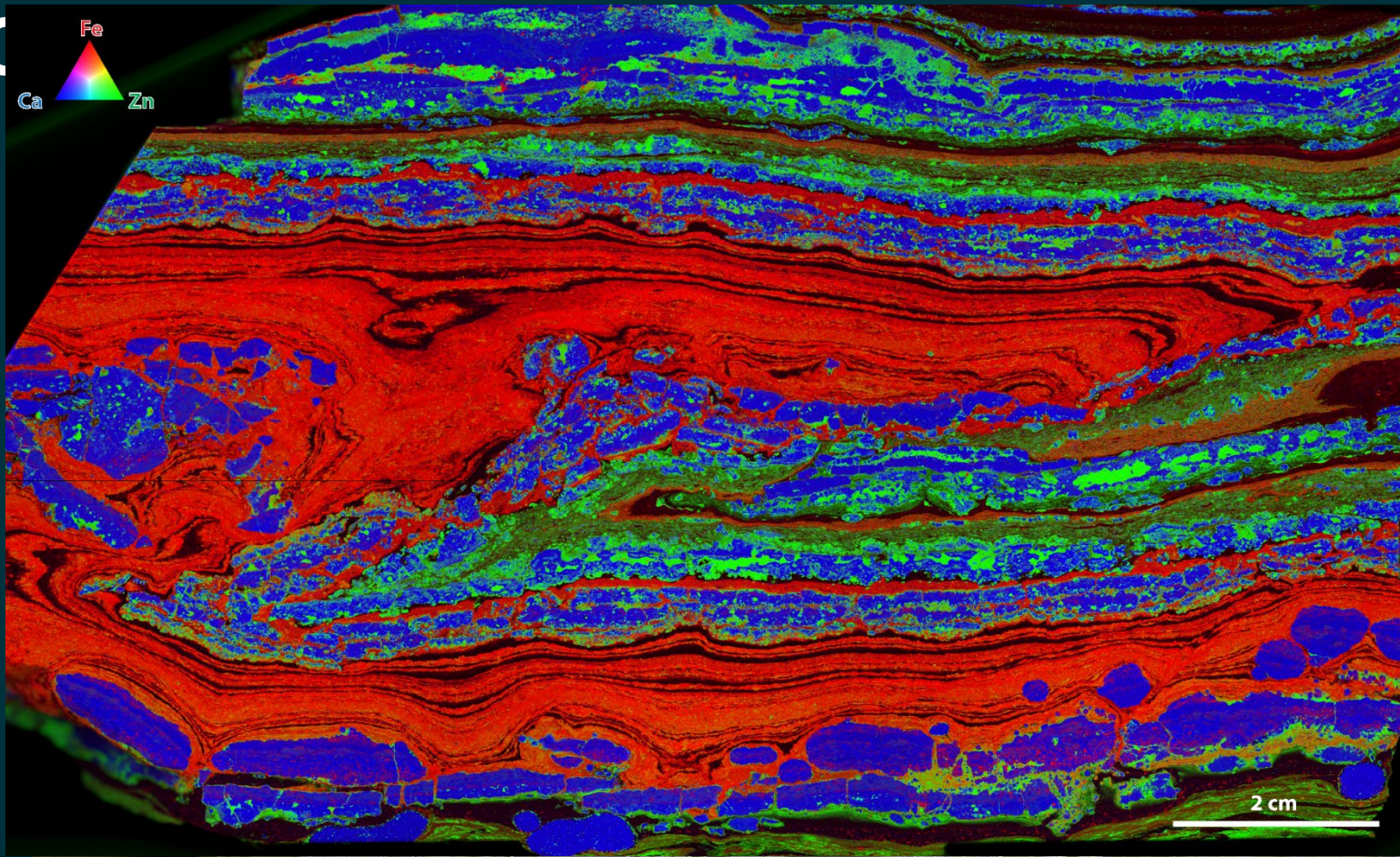


# Part 1: Ore Textures and 'Carbonate Replacement'

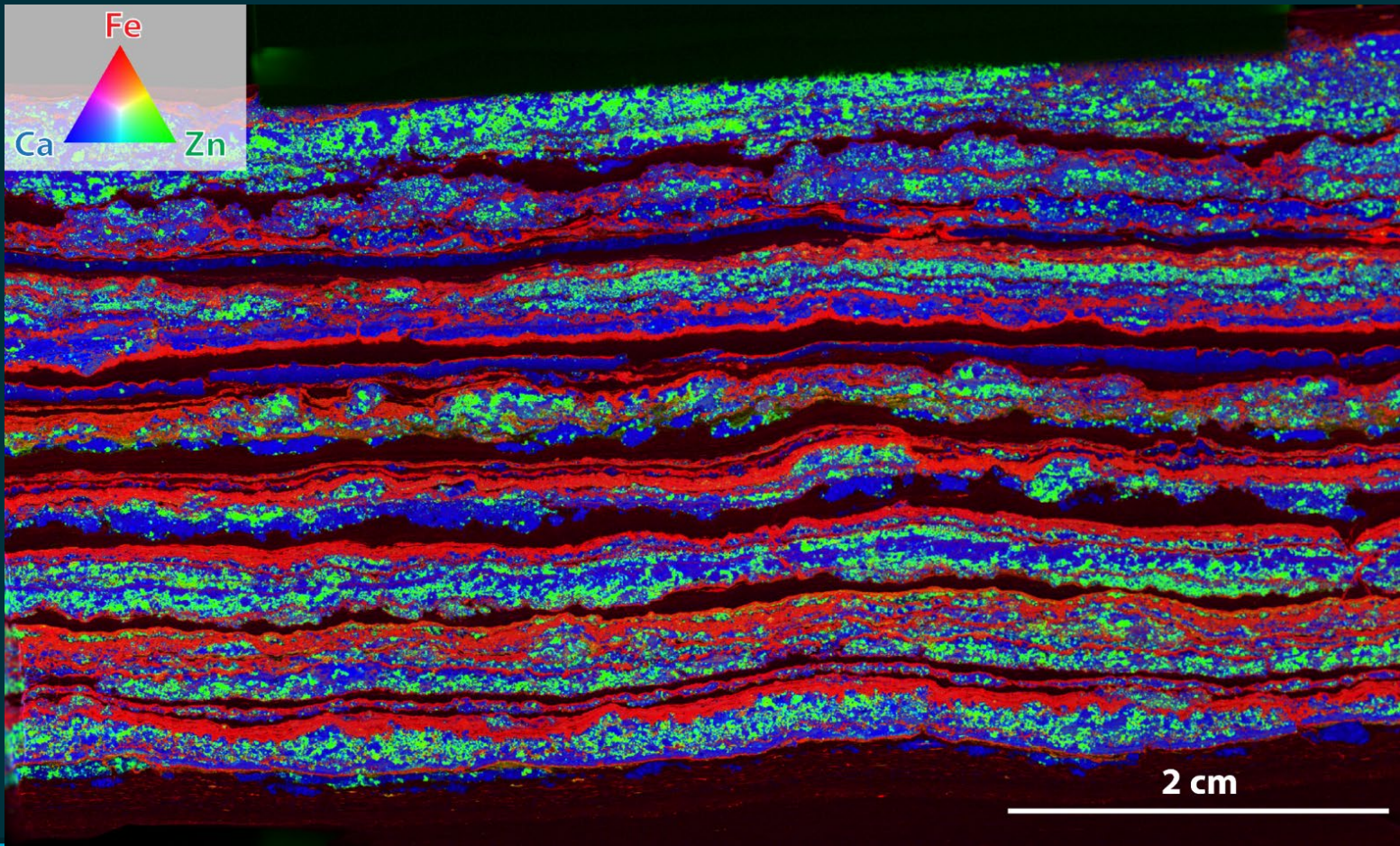
## Laminated ore (central HYC). Carbonate partially replaced.





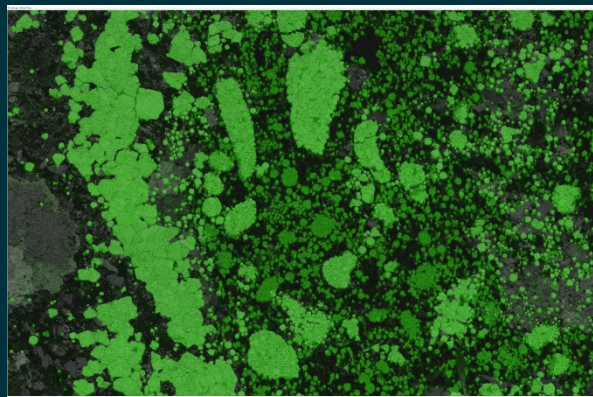




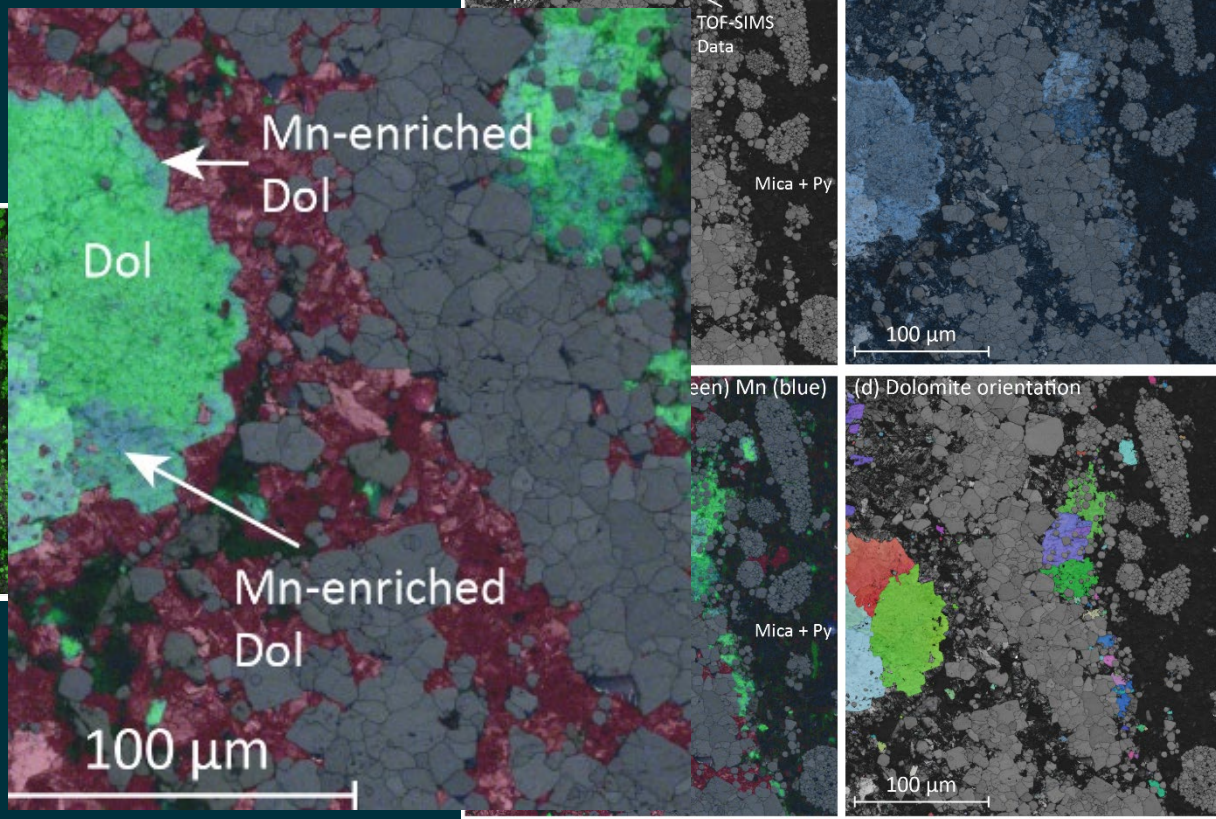




# Electron Backscatter Diffraction (EBSD)

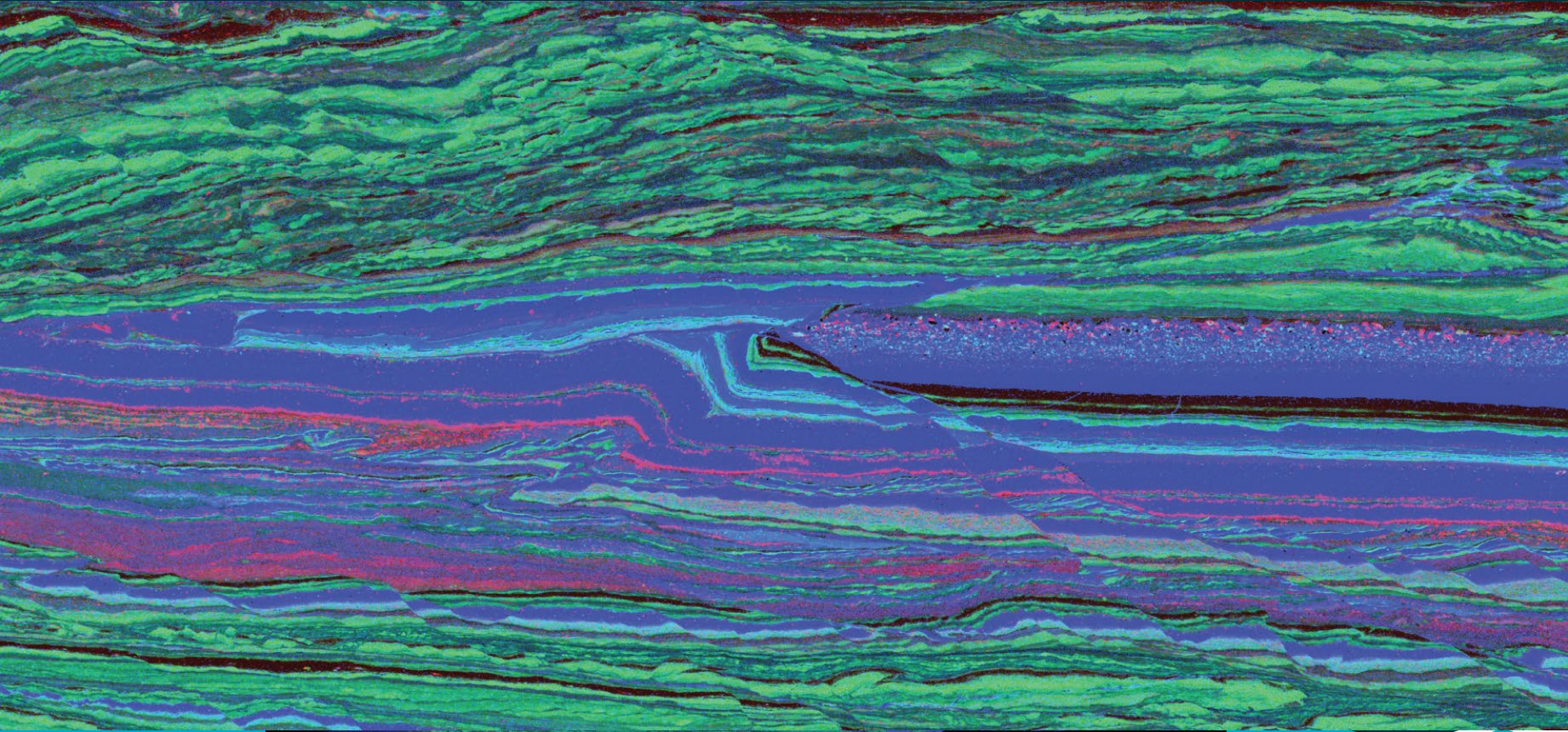


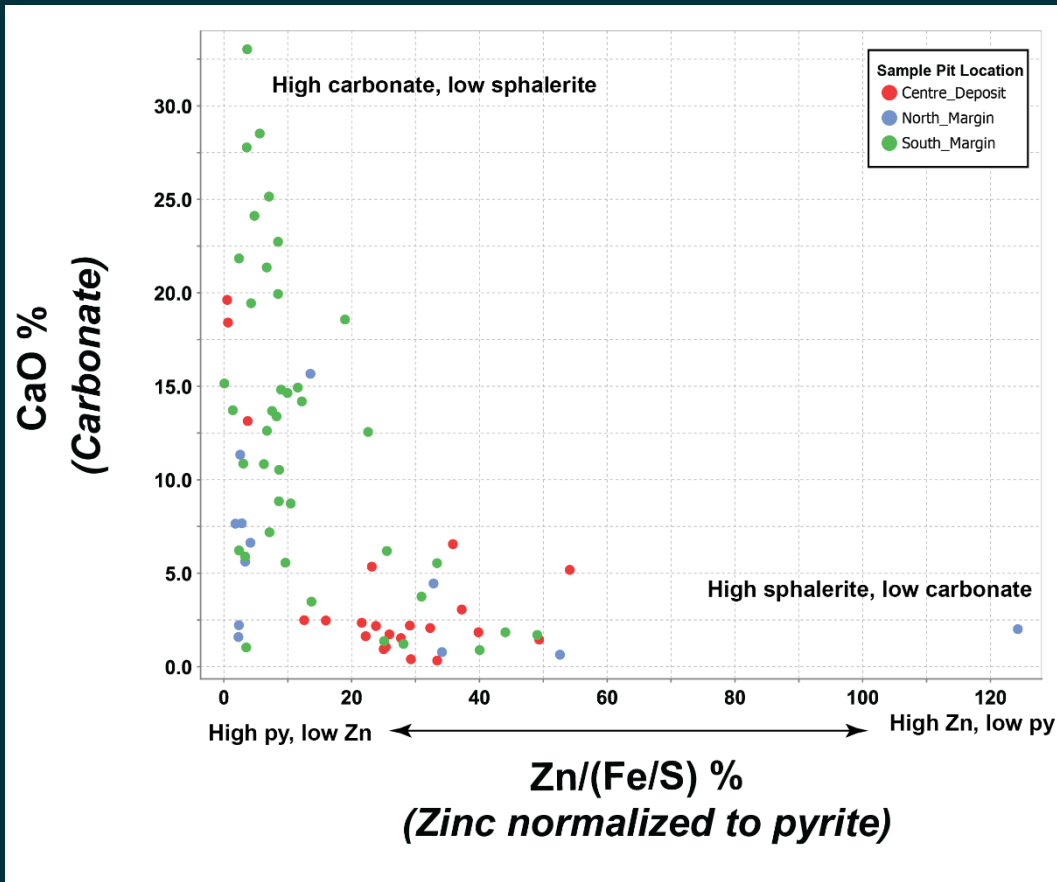
Manganese alteration along  
rims of carbonate at  
replacement interface





## Laminated ore, central HYC. Carbonate almost fully replaced





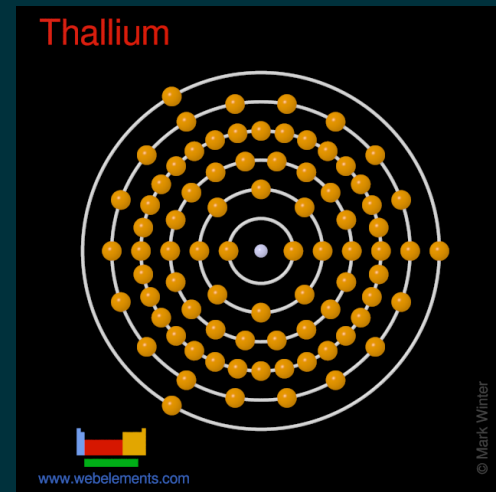
Unmineralized laminated dolomitic BCF



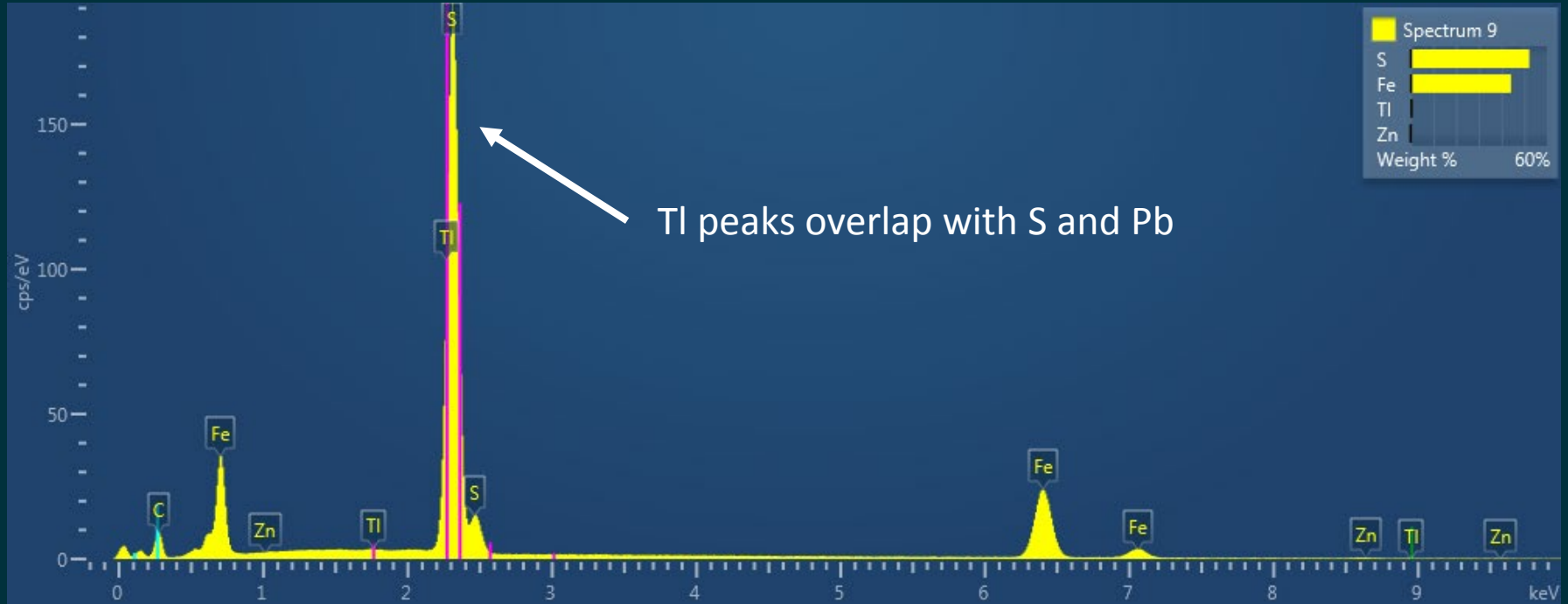
# Part 2: Thallium Lithogeochemistry

# Geochemistry of thallium (Tl)

- Highly incompatible trace element, often associated with K-bearing phases because it occurs primarily in the form of  $Tl^+$ , which is similar in size to the large monovalent cations  $K^+$ ,  $Rb^+$  and  $Cs^+$ .
- Tl also exhibits chalcophile behaviour in sulfide melts and hydrothermal fluids.
- Behavior in mineral systems is poorly understood.

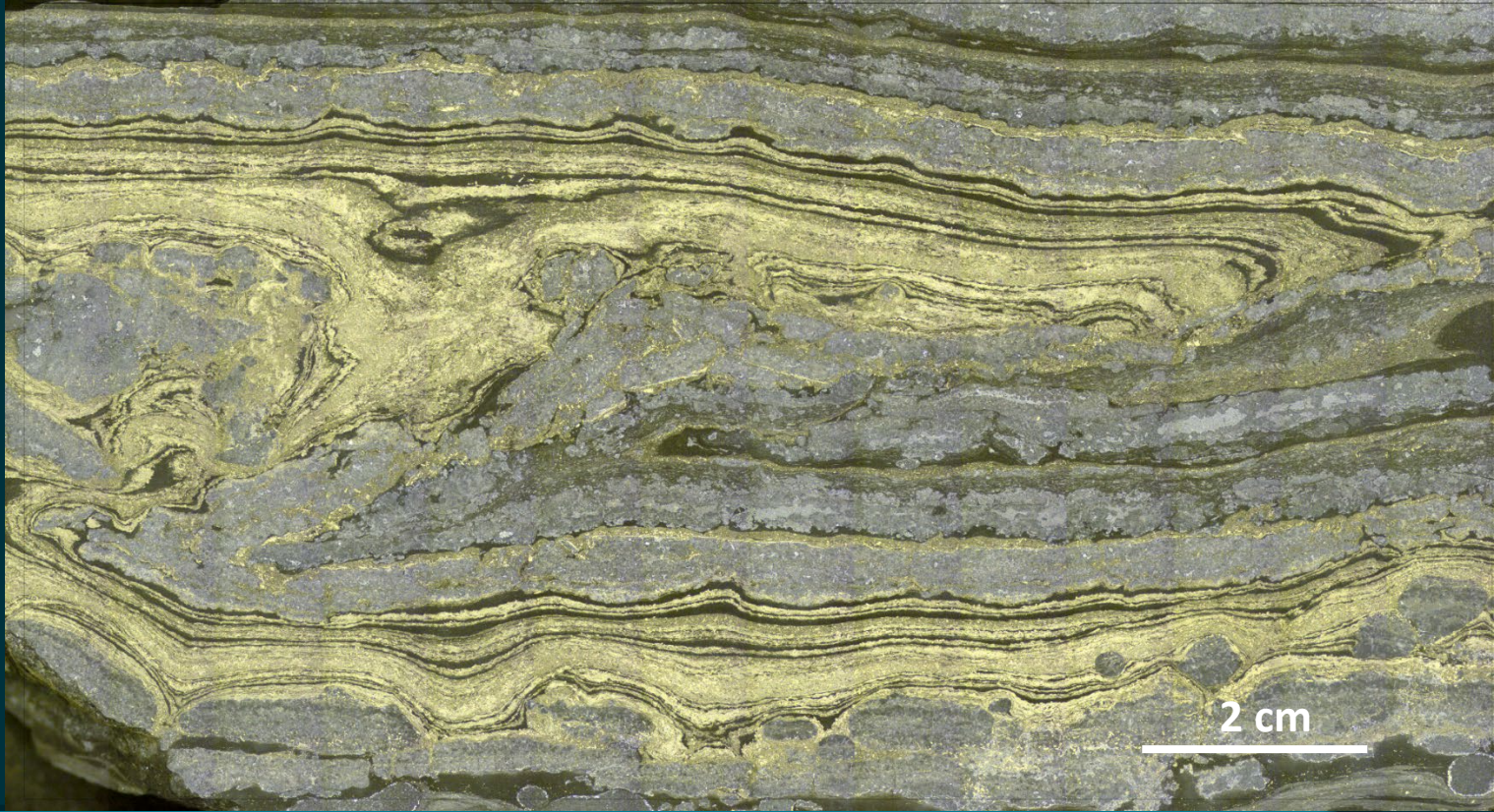


# Issues with mapping thallium (with XRF Methods)

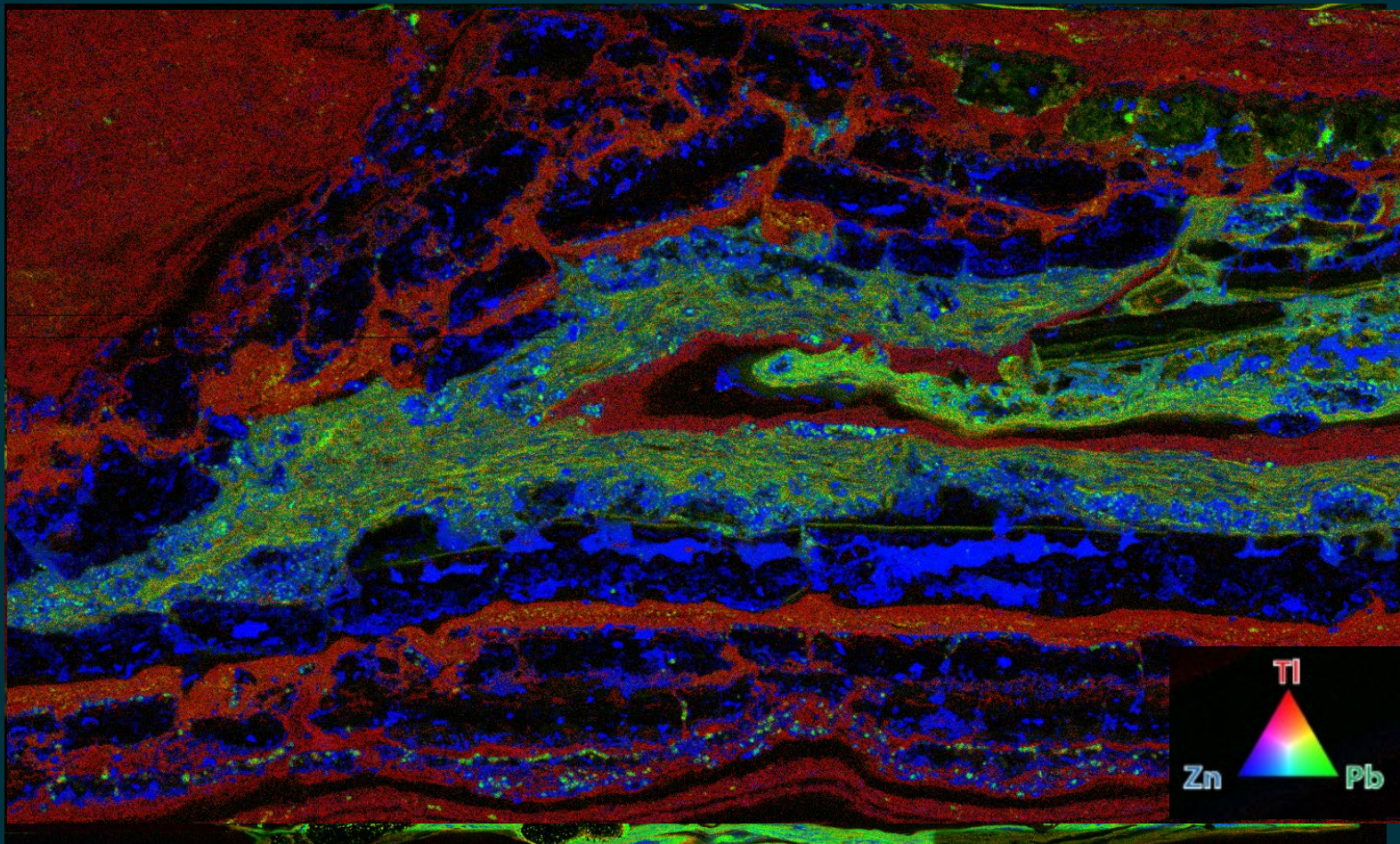


Pyritic-sphaleritic shale with >350 ppm Tl

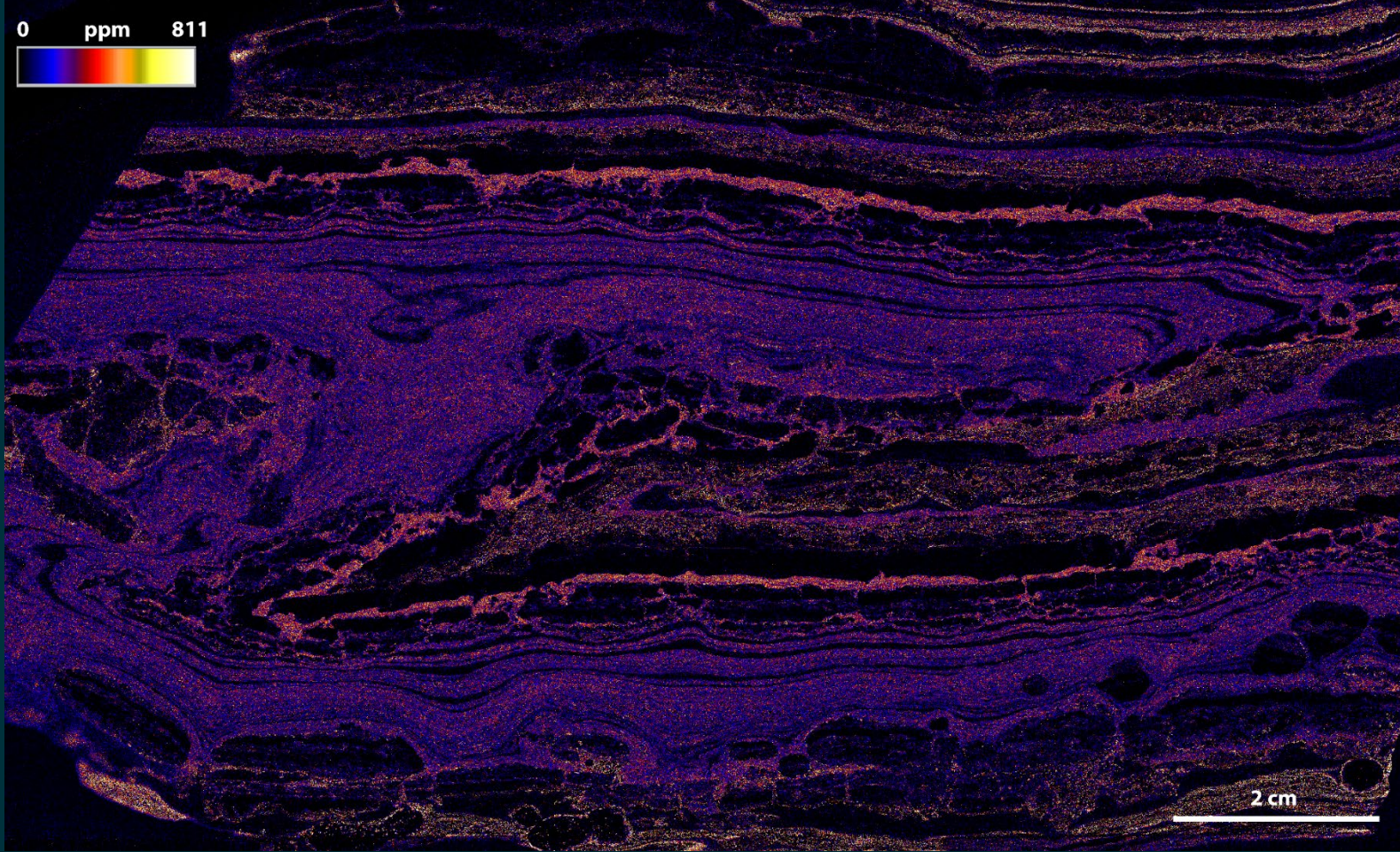
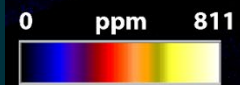
# HYC Slumped laminated pyritic ore lens





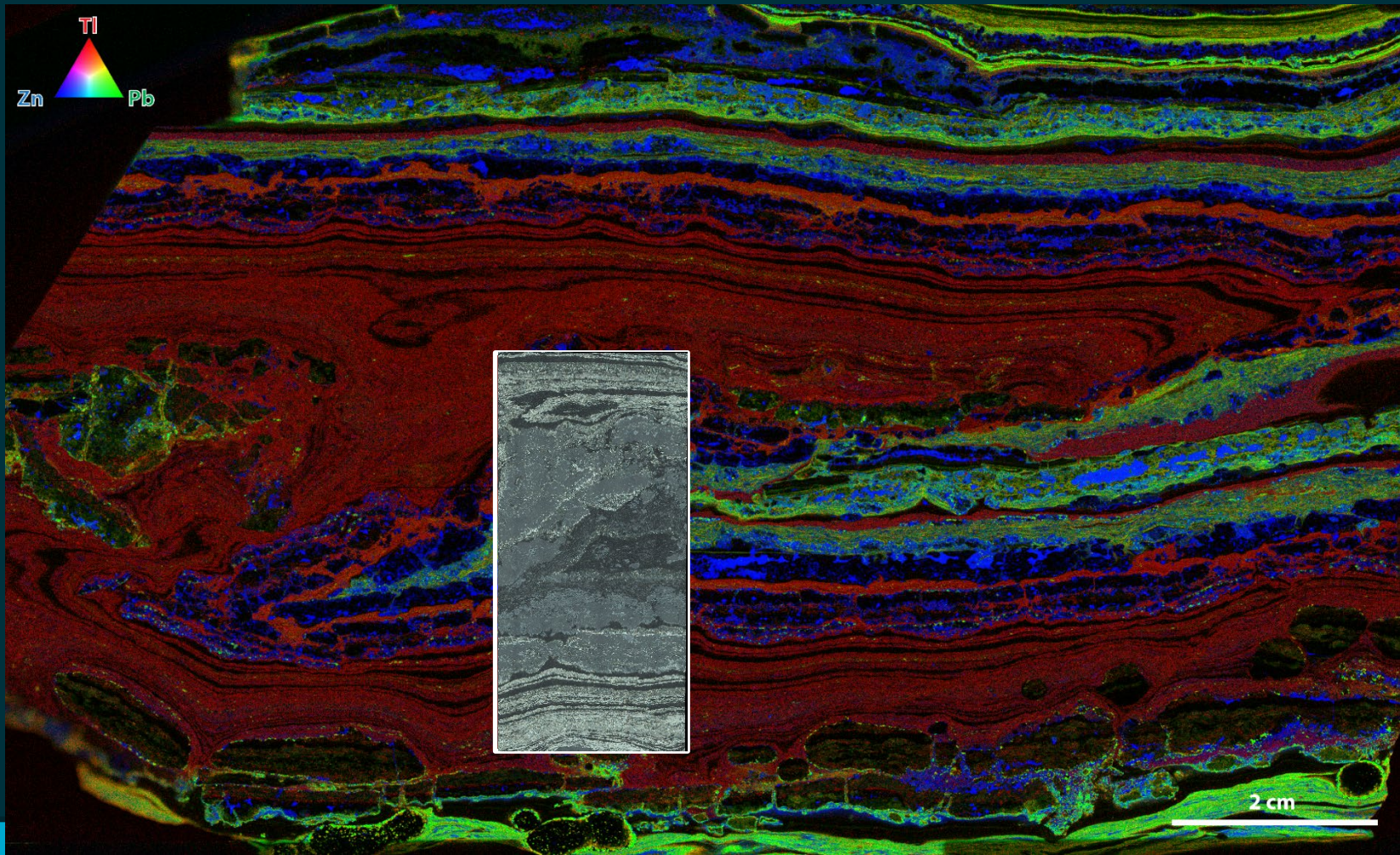




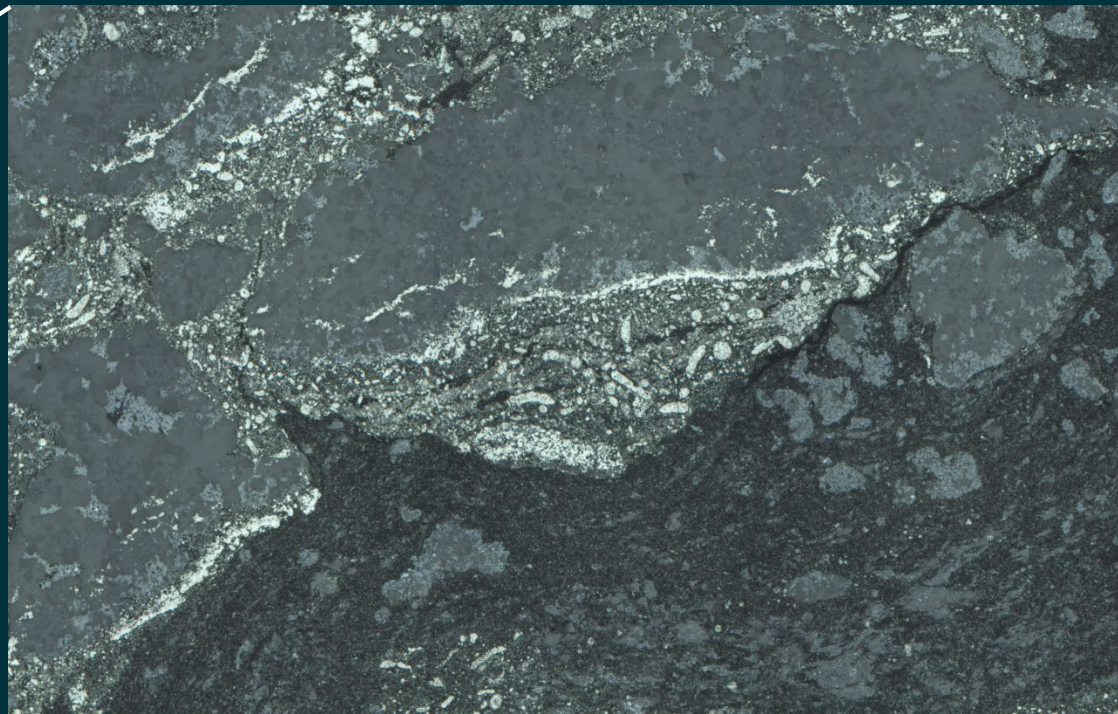
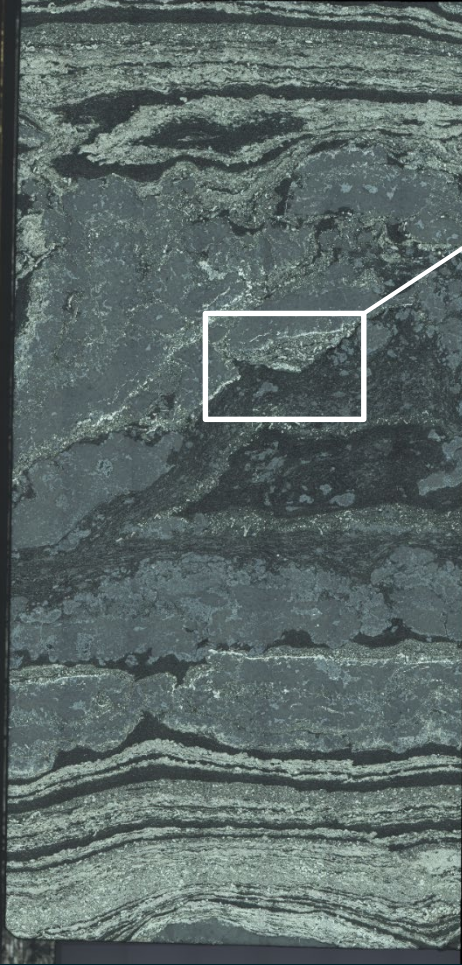


2 cm



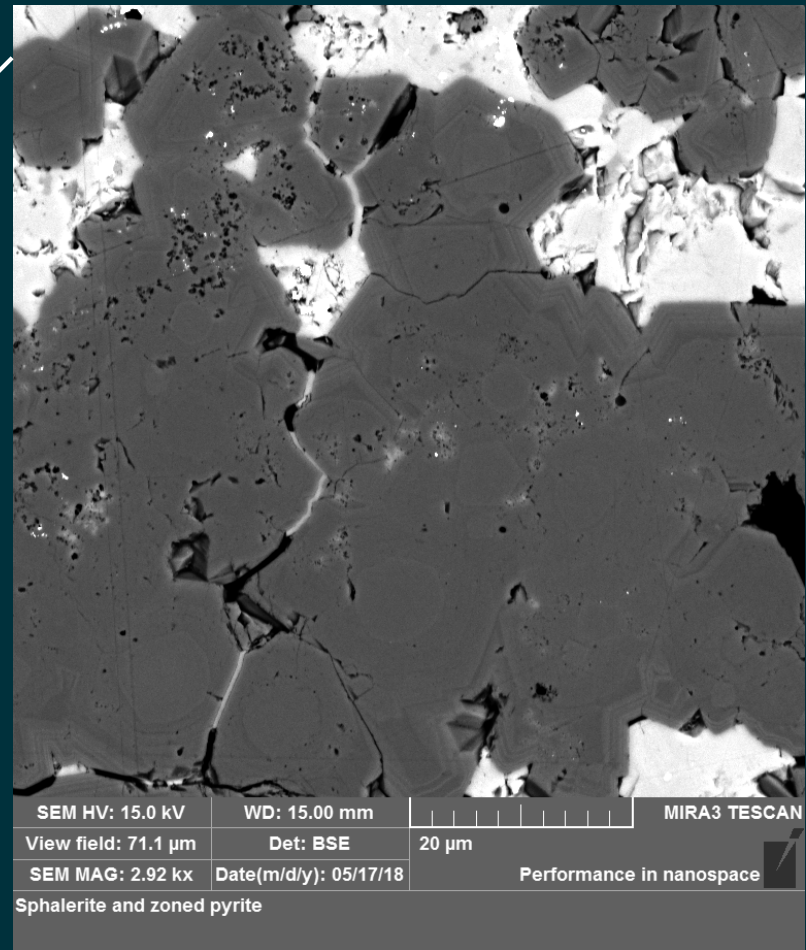
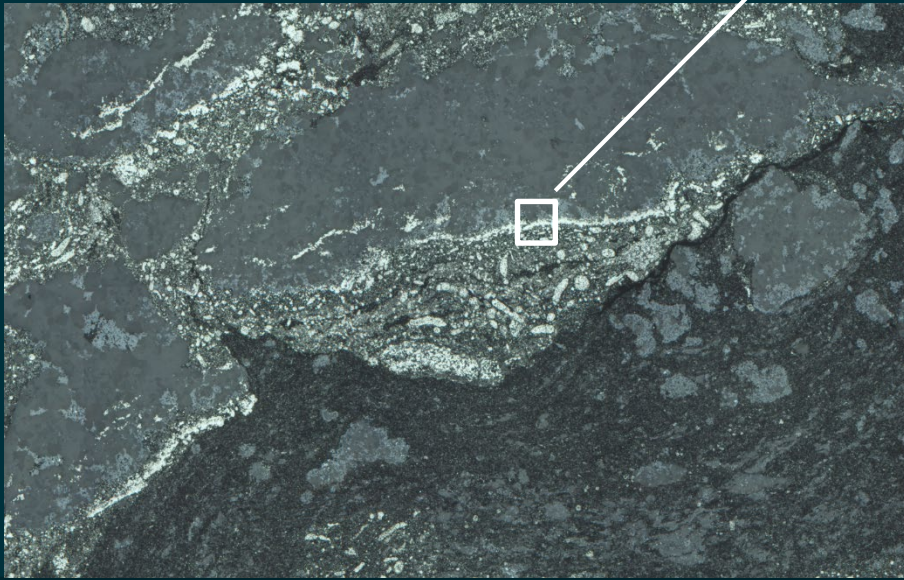






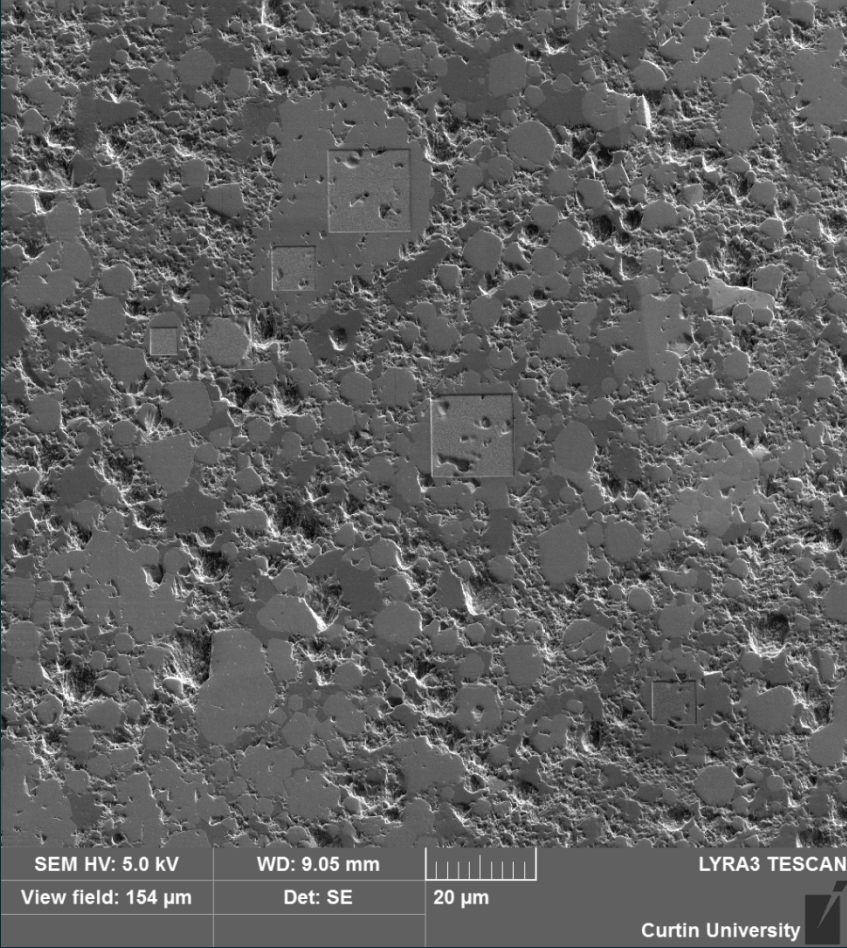


# Late (but still pre-ore) pyrite zonation with anomalous Tl

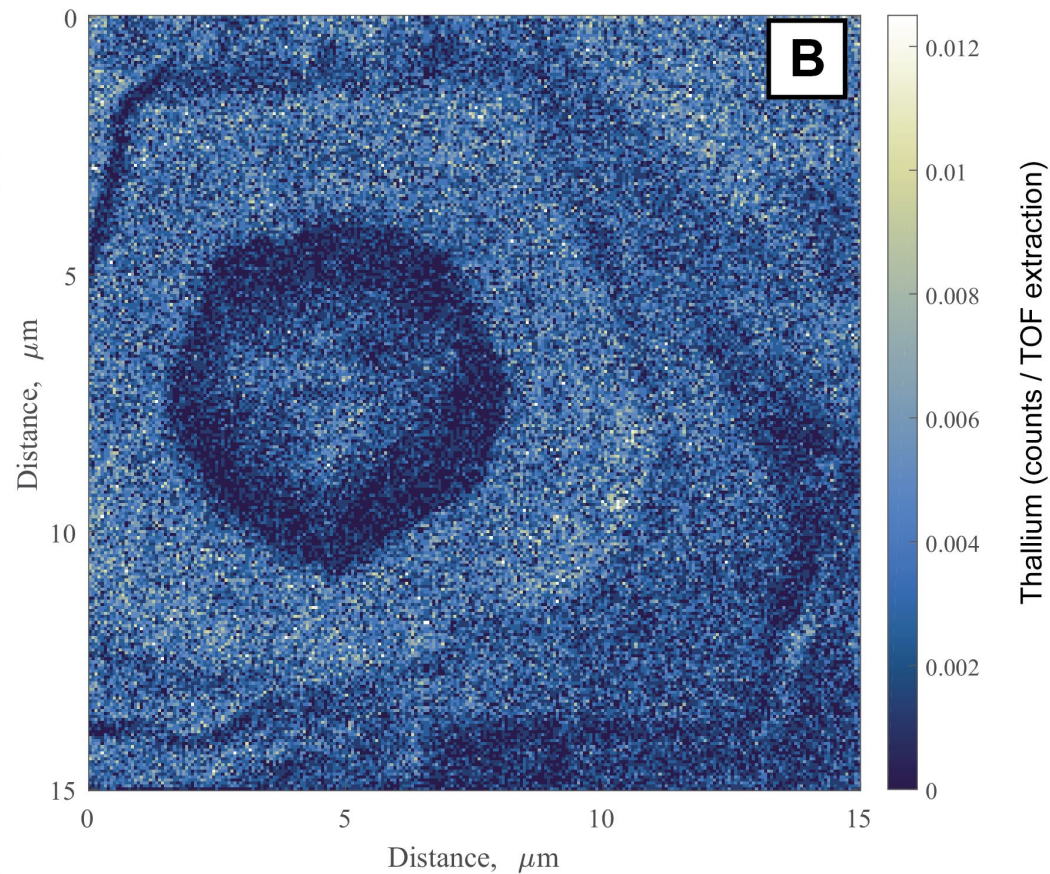
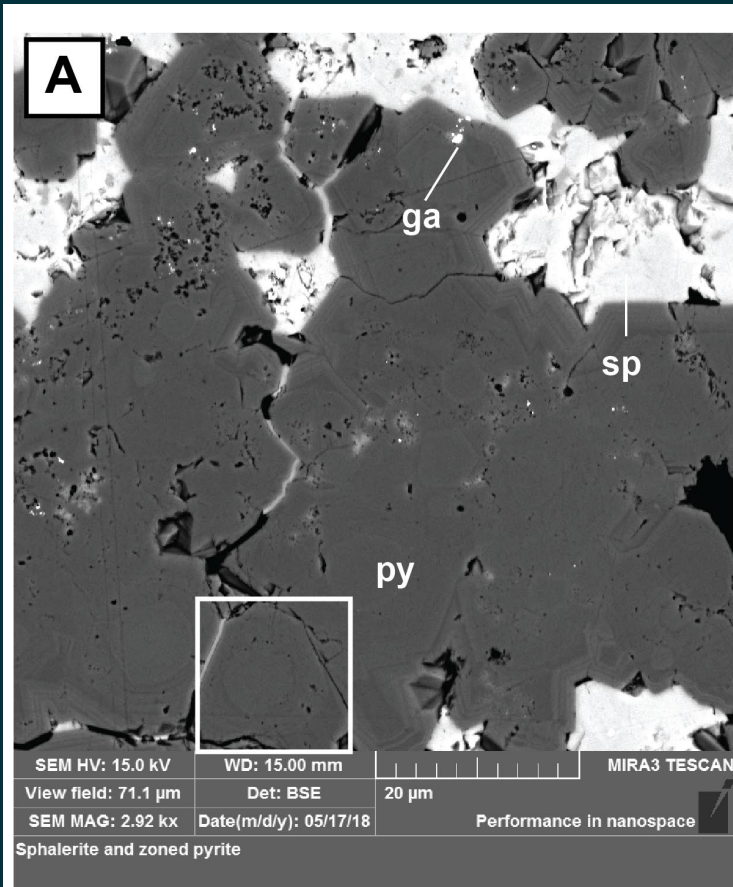


# Quantitative Focussed Ion Beam Time of Flight Secondary Ion Mass Spectrometry (FIB TOF SIMs)

Gallium ions and Xenon ion plasma beam





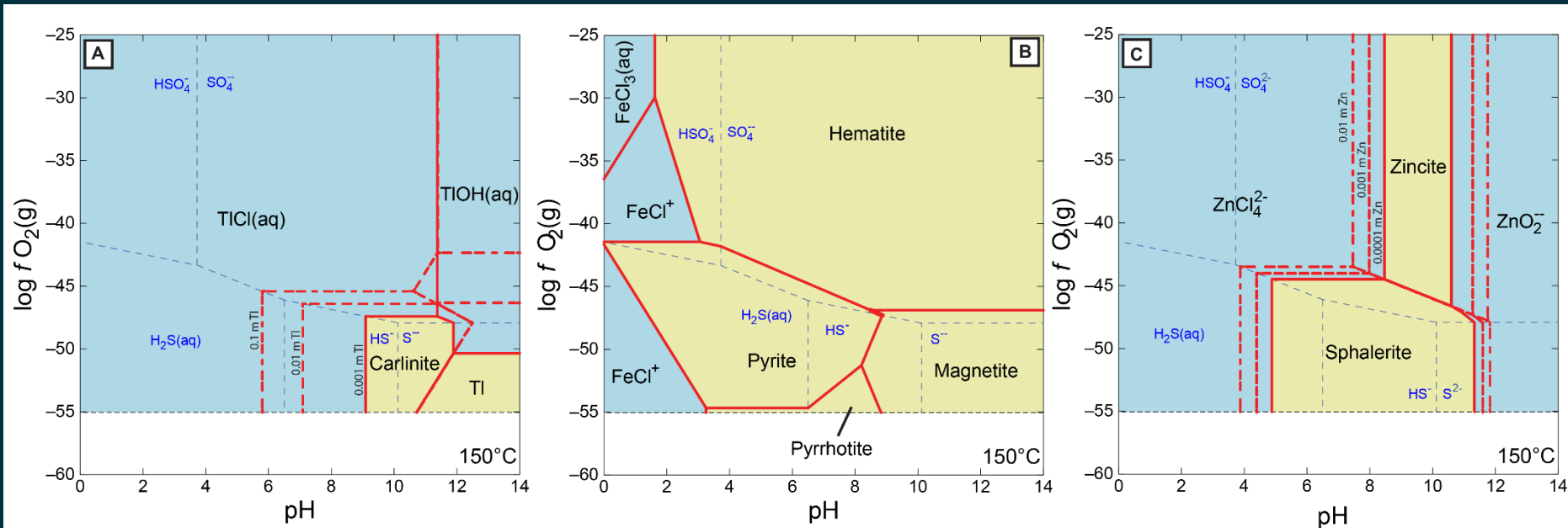


# Part 3: Ore Fluid Modelling



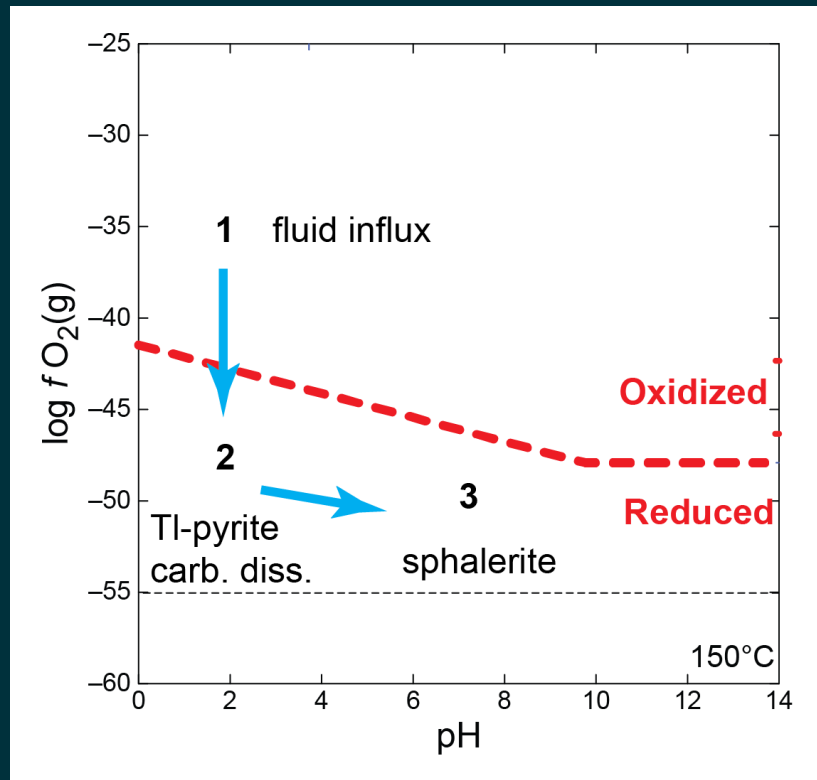
## For those allergic to phase diagrams:

- Ore fluids were initially oxidized very acidic.
- Reduction permitted TI-pyrite precipitation.
- Acid carbonate dissolution allowed sphalerite to precipitate after pyrite



# The simplified version

- Acid carbonate dissolution creates environment favourable for sphalerite precipitation, a 'pH buffer'.
- Not strictly direct *carbonate replacement*, sphalerite precipitates at site of carbonate dissolution.



# Summary 1

- Zn mineralization occurs as 'replacement' of carbonate. Maia Mapping of large scale samples can identify remnant carbonate in laminated ore.
- Thallium enrichment is associated with late pyrite overgrowths, paragenetically before base metal sulfide mineralization.
- Implications for exploration for SHMS deposits using Tl.



# Summary 2

- Acidic, oxidized ore fluids precipitated Tl-pyrite.
- Carbonate dissolution created chemical conditions favourable for sphalerite precipitation.
- Evidence for epigenetic origin of mineralization (syn-late diagenesis at least).
- Quantitatively challenges the paradigm of exhalative deposit models. Time to abandon the term 'sedex'?



MINERAL RESOURCES (DISCOVERY)  
[www.csiro.au](http://www.csiro.au)

CSIRO

# Thank you

Sam Spinks

Senior Research Geoscientist

t +61 8 6436 8590

e [sam.spinks@csiro.au](mailto:sam.spinks@csiro.au)

w [people.csiro.au/S/S/Sam-Spinks](http://people.csiro.au/S/S/Sam-Spinks)

tw @Presambrian

