

Life on the edge

The combination of **Synchrotron XFM** and **other techniques** improves our understanding of life activities in extreme environments

Si-Yu Hu | 20.05.2021

Australia's National Science Agency



Arsenic (As)



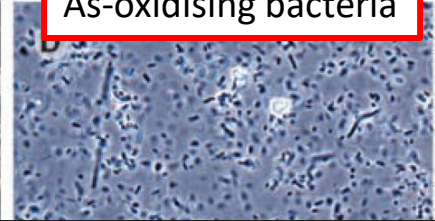
(Image source: Google)

US environment protection agency:
a **serious risk** to human health

Mono Lake , California



As-oxidising bacteria



ABC NEWS LOCATION: Sydney, NSW Change

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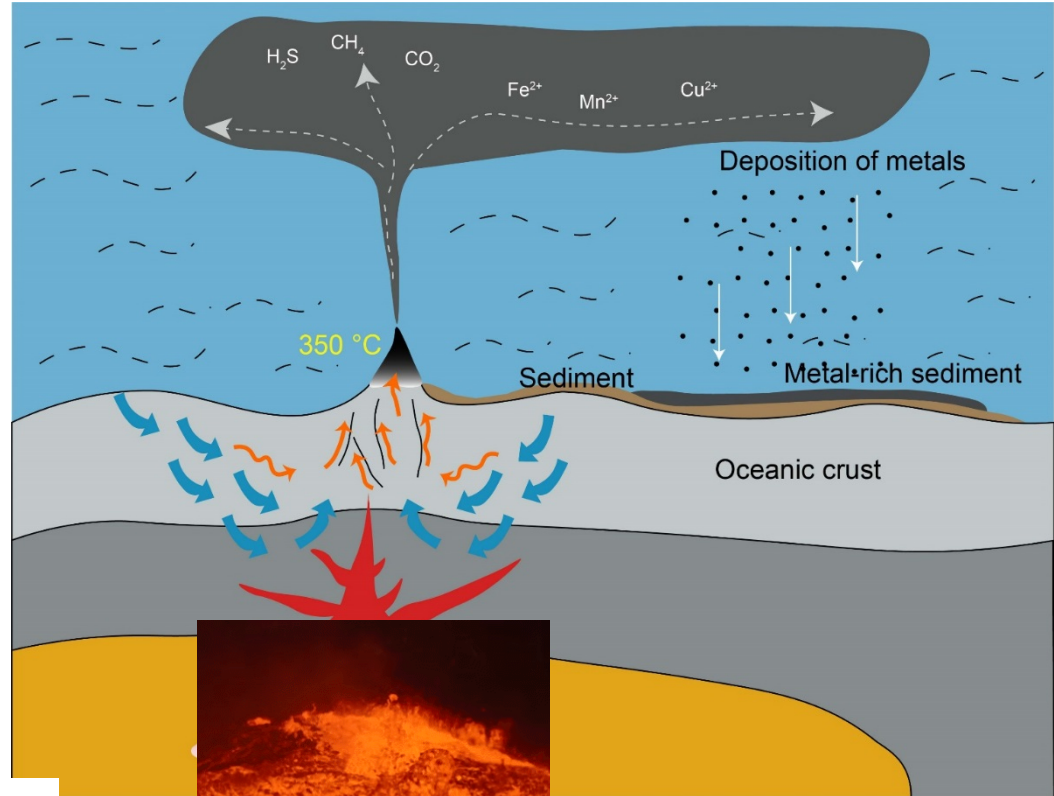
Arsenic-eating bacteria may help in hunt for ET

Jill Colgan and wires
Updated 3 Dec 2010, 6:30pm



Research questions:
Can/How life adapt to high-
As extreme environments?

Deep-sea hydrothermal vents



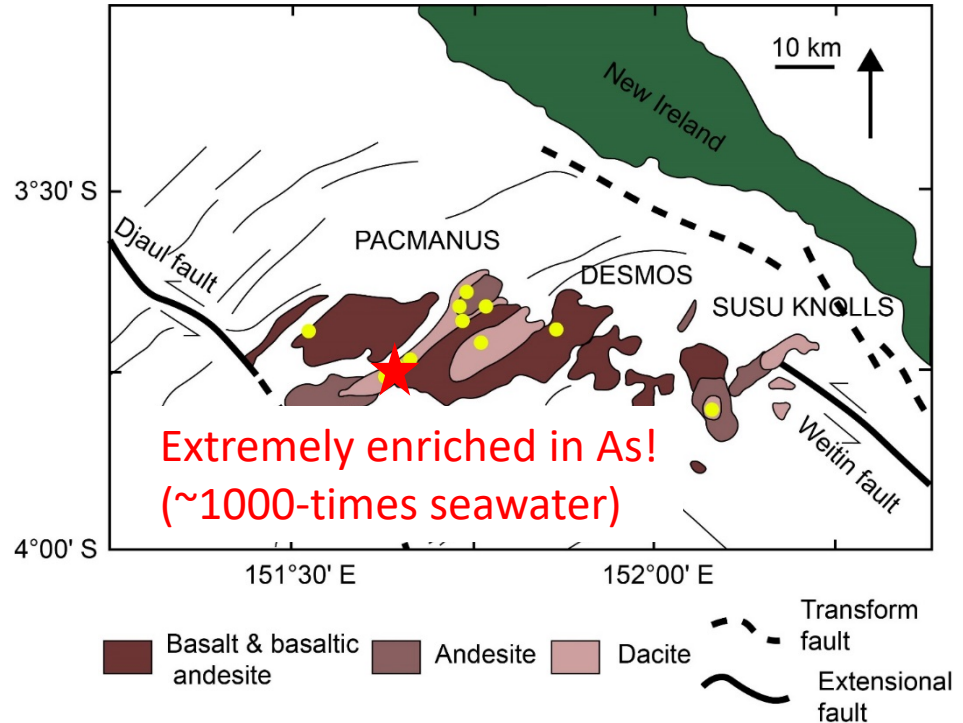
Microbial habitats



Warm, acid (pH: 2-4), toxic (As, Cu, Zn, Pb) (Google)

Study area

- Abundant hydrothermal vents
- Deep sea mining targets



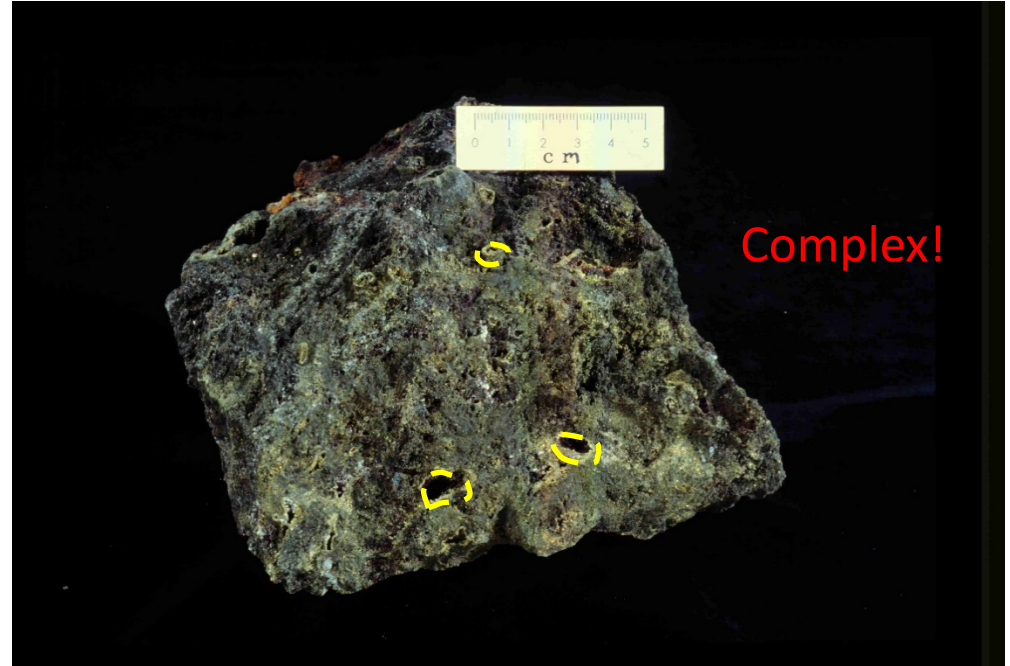
The geological settings of Manus basin (modified from Binns et al., 2007, *Proc. Ocean Drill. Program*)

Chimney characterisation



Single conduit

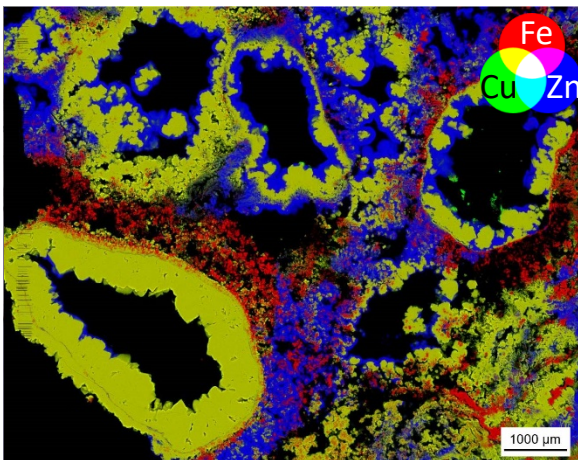
(Berkenbosch et al., 2012, Economic Geology)



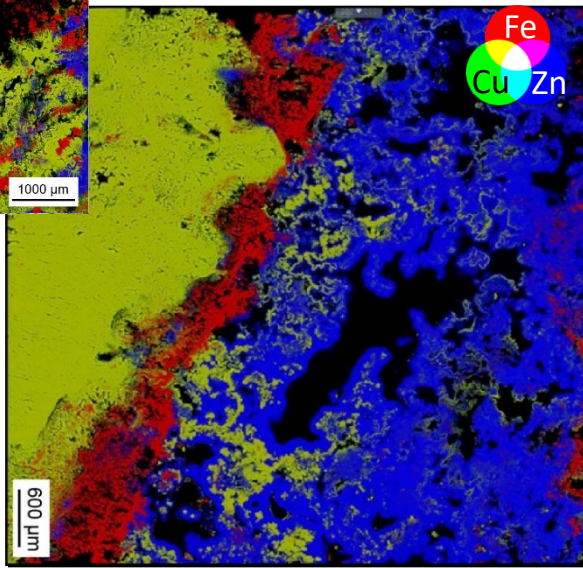
Multiple conduits

Chimney characterisation

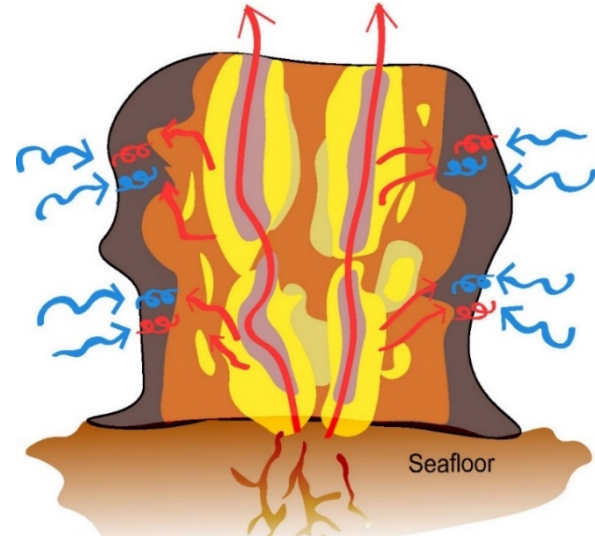
Synchrotron XRF images revealed three main mineralogical zones



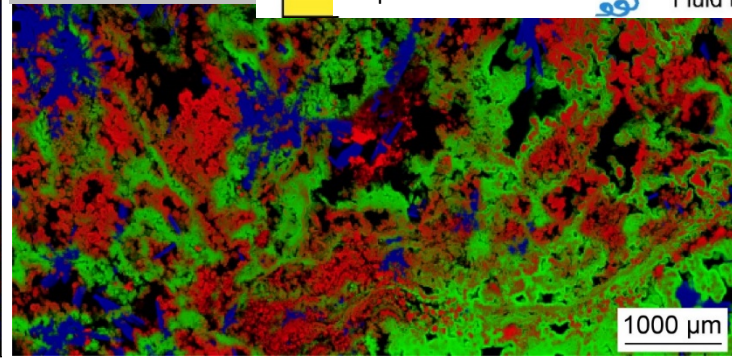
Chalcopyrite (CuFeS_2)
Pyrite (FeS_2)
Sphalerite (ZnS)



Pyrite (FeS_2)
Sphalerite (ZnS)
Barite (BaSO_4)

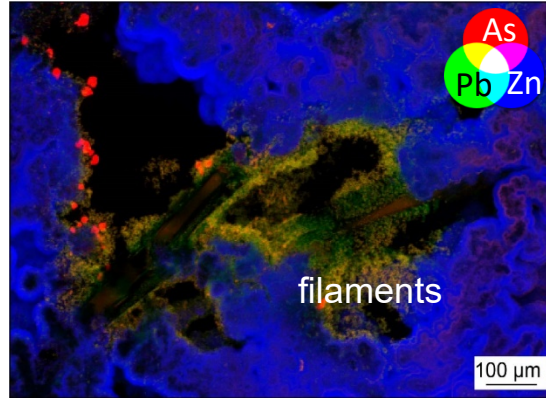
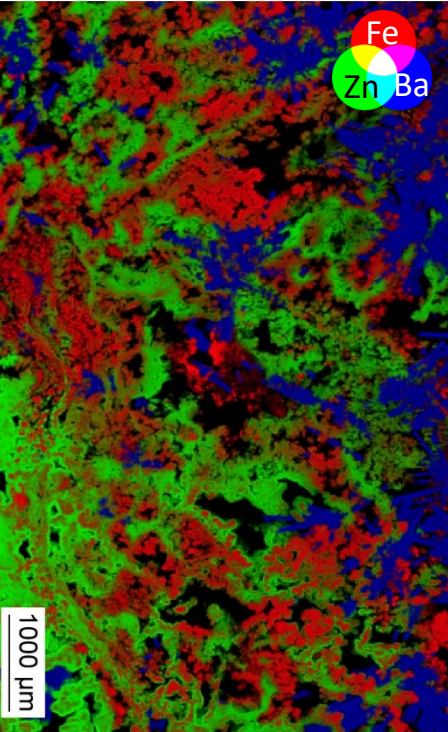


- | | |
|------------------------|-----------------|
| Br- dominated zone | Conduit |
| Sp- dominated zone | Hot vent fluids |
| Ccp-sp transition zone | Cold seawater |
| Ccp- dominated zone | Fluid mixing |



Further chimney characterisation

Synchrotron XRF observations + other advanced techniques



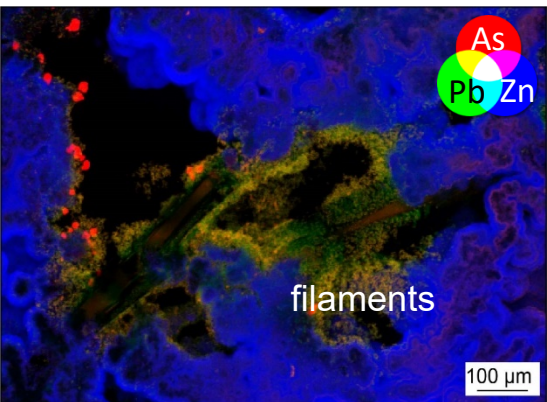
Realgar (As_4S_4)
Sphalerite (ZnS)
Barite ($BaSO_4$)



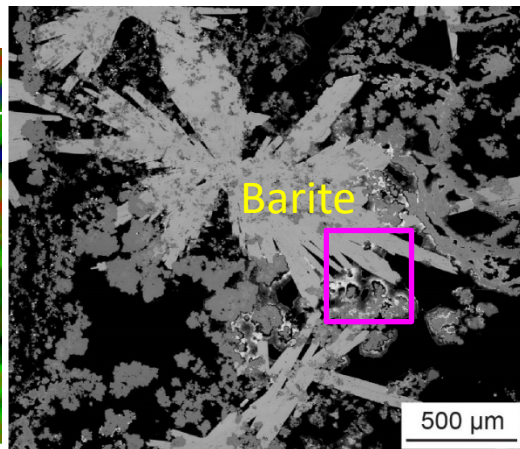
Focused ion beam-Scanning electron microscopy (SEM)
Transmission electron microscopy (TEM)

Pyrite (FeS_2) Sphalerite (ZnS) Barite ($BaSO_4$)

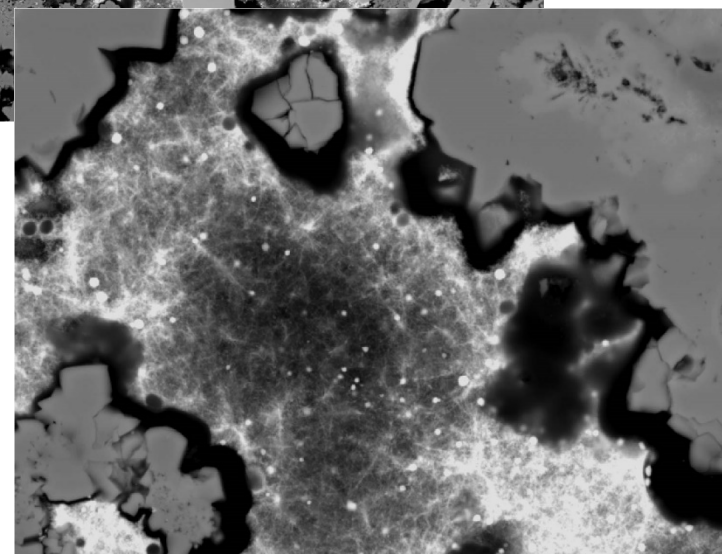
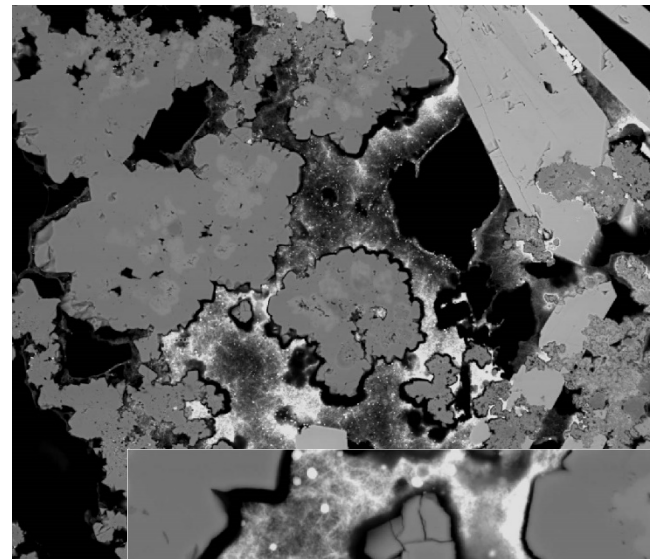
Microbial filaments



Realgar (As_4S_4)
Sphalerite (ZnS)
Barite ($BaSO_4$)



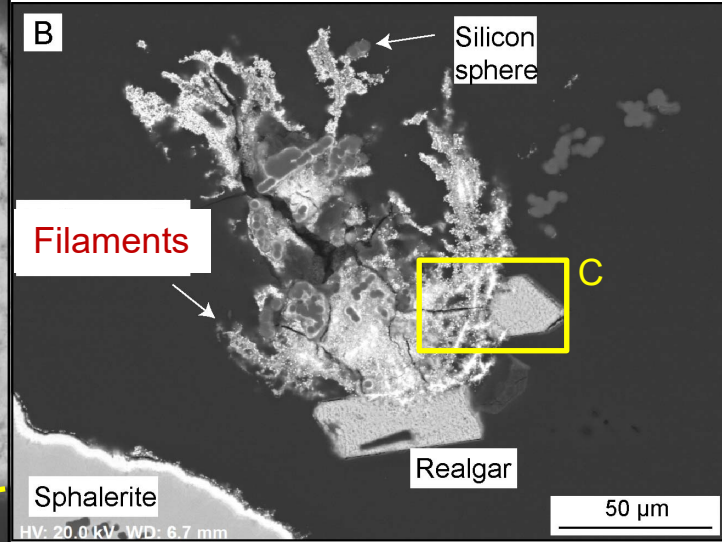
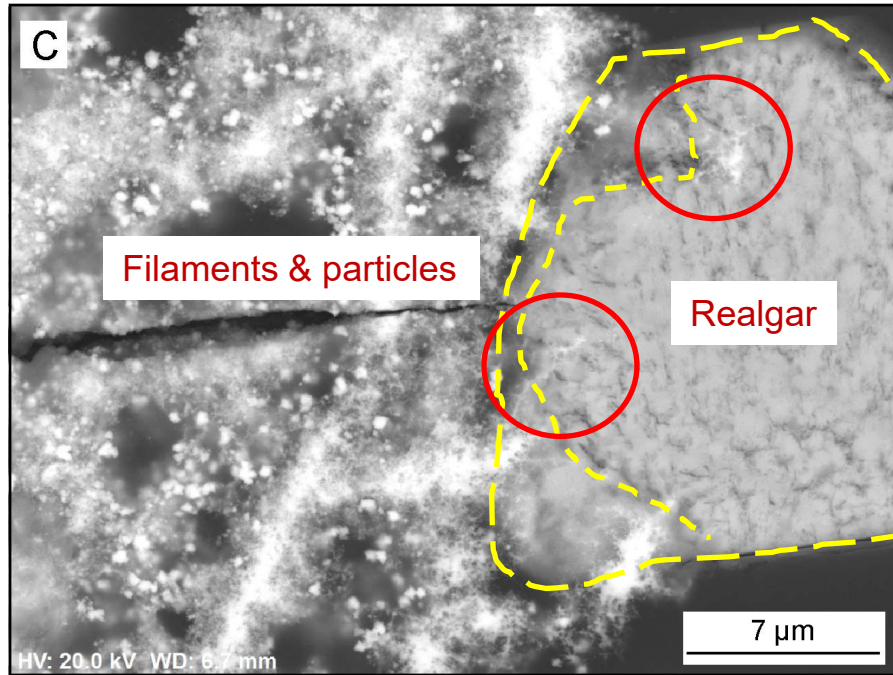
SEM-backscatter image



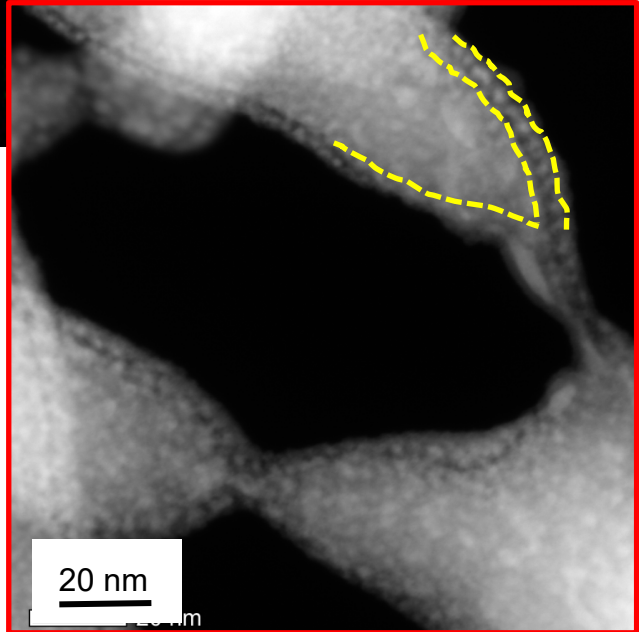
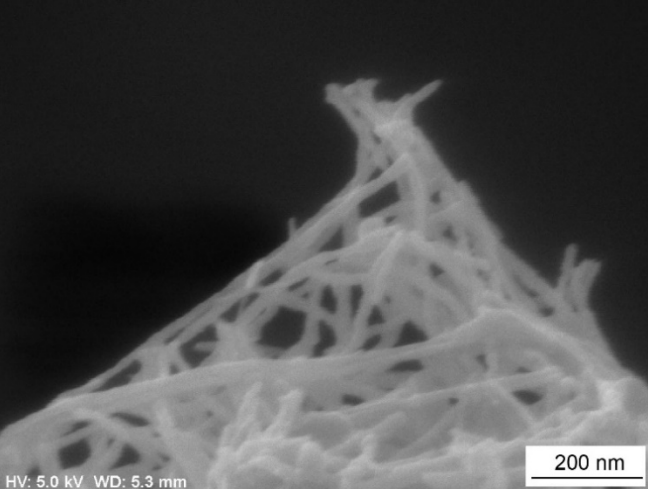
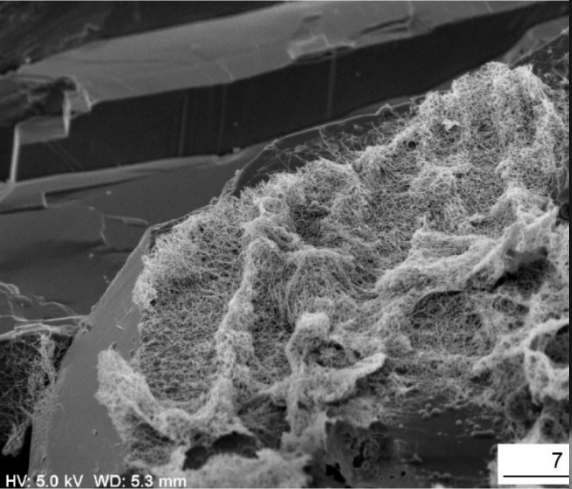
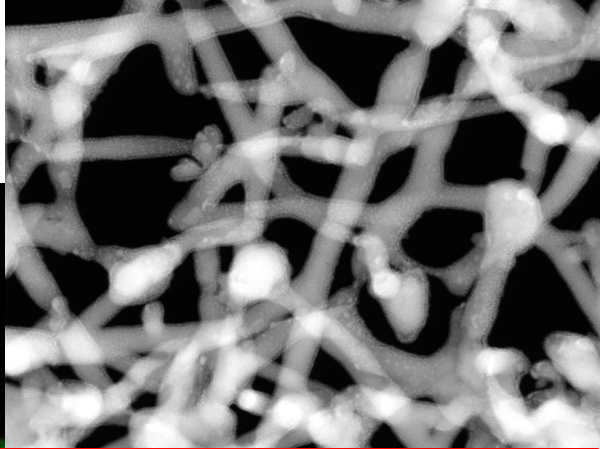
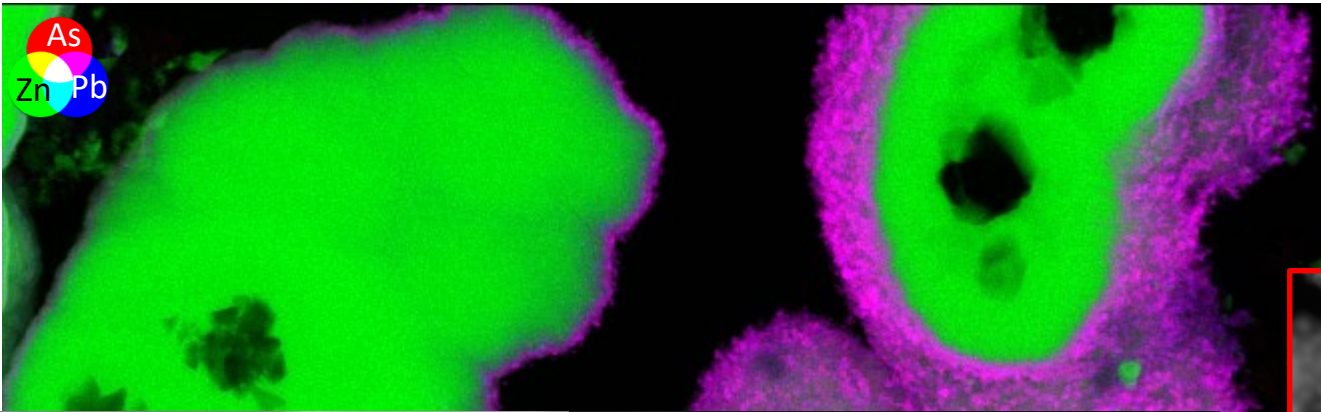
Mineralized to Pb-As-S (sulfosalt)

30 μm

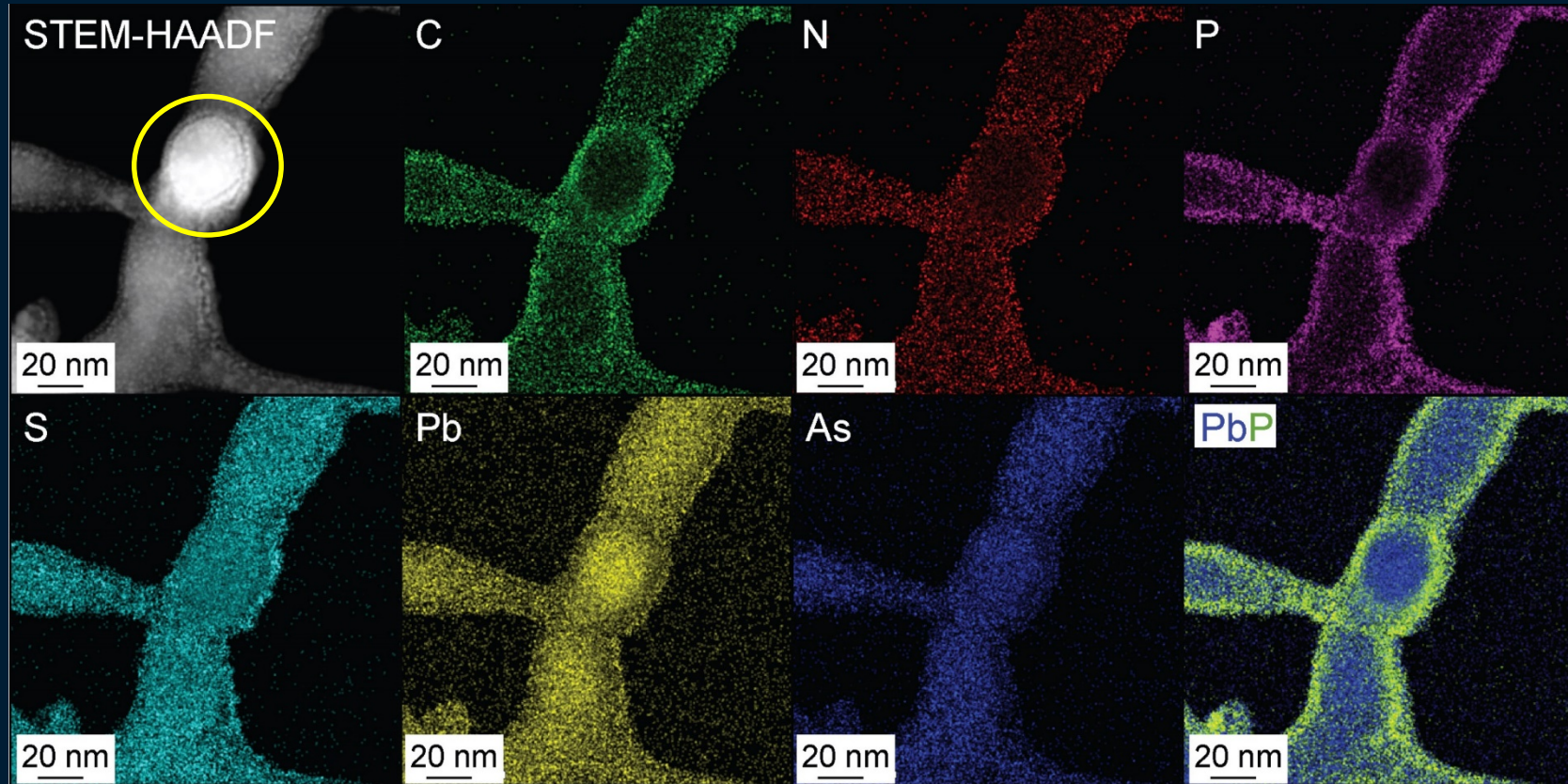
Microbial filaments



Microbial filaments

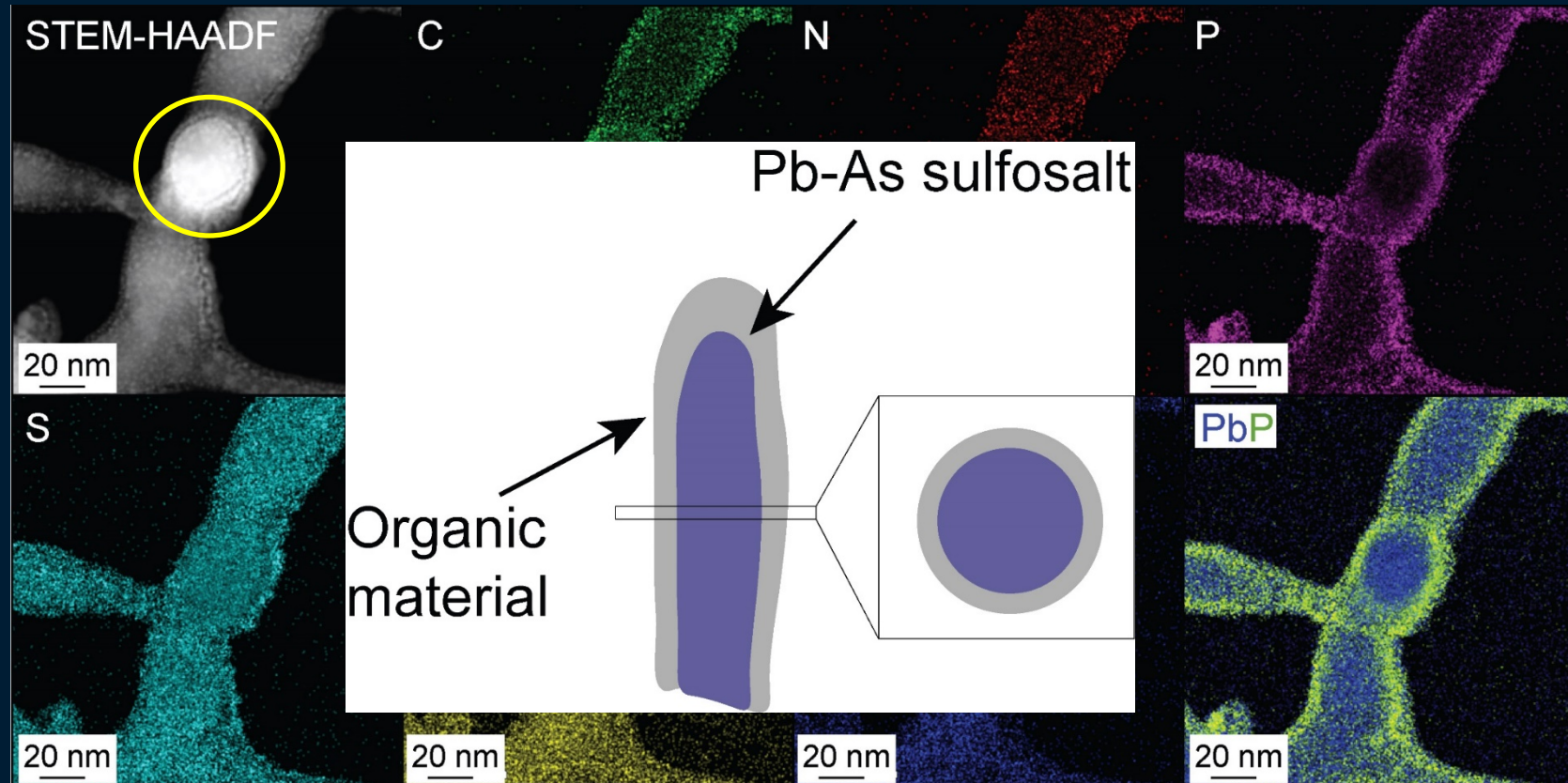


EDS elemental mapping



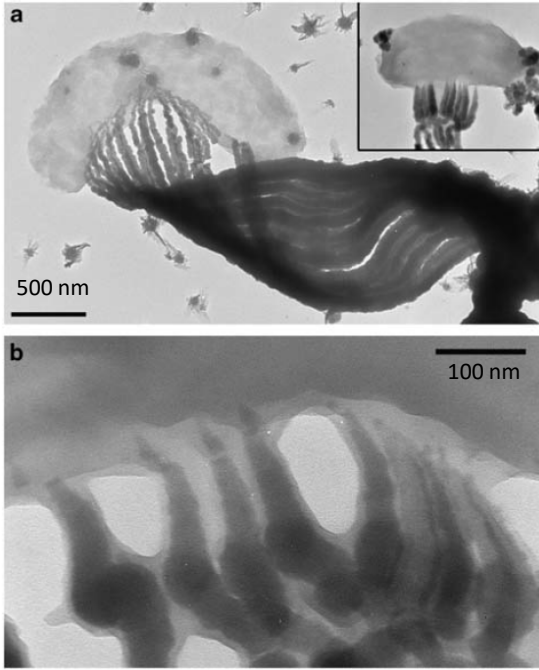
EDS elemental mapping of the filaments

EDS elemental mapping

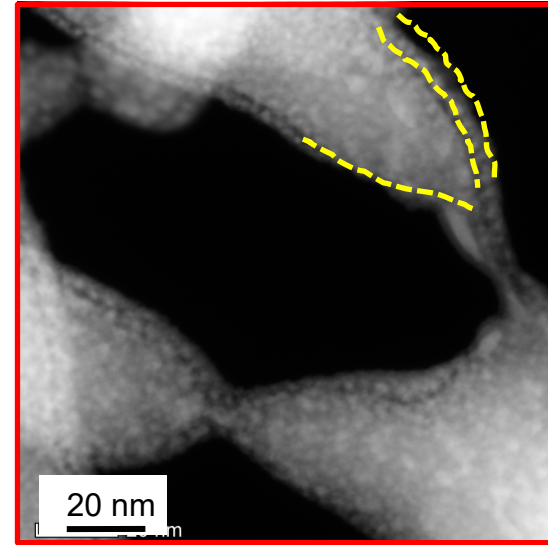
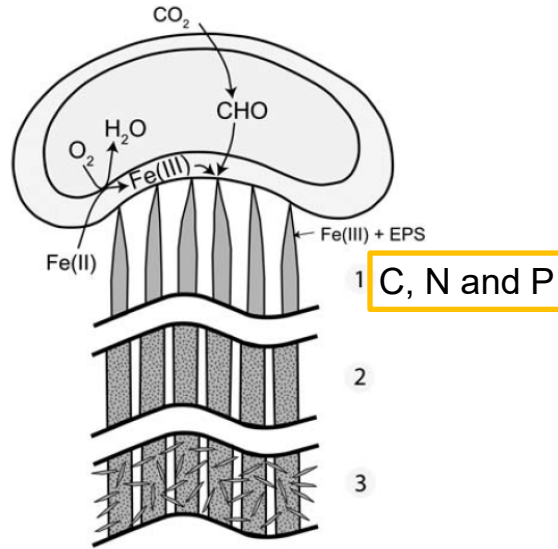


EDS elemental mapping of the filaments

Similar structure in previous studies



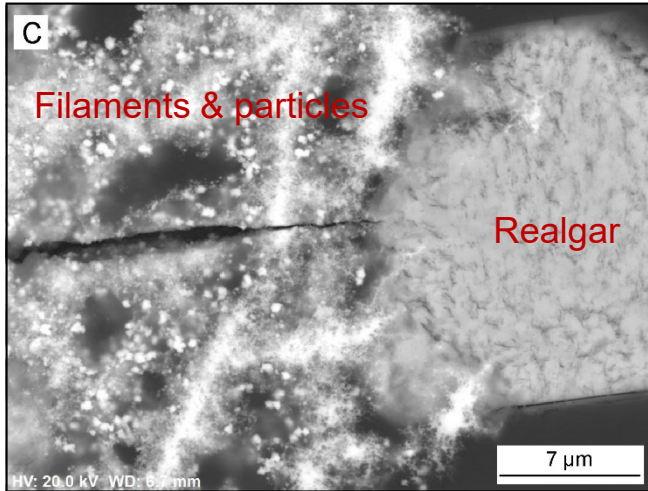
Model



Similar mechanism?

TEM images of Fe-oxidising bacteria and the generated stalks (Chan et al. 2010).

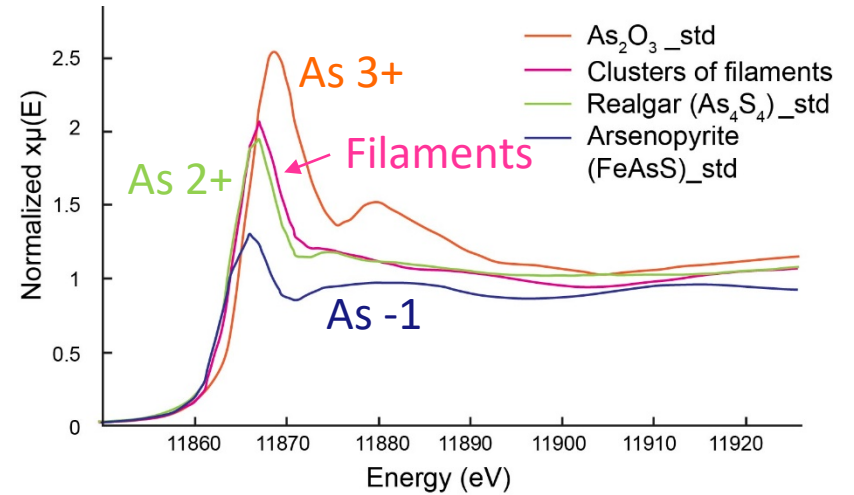
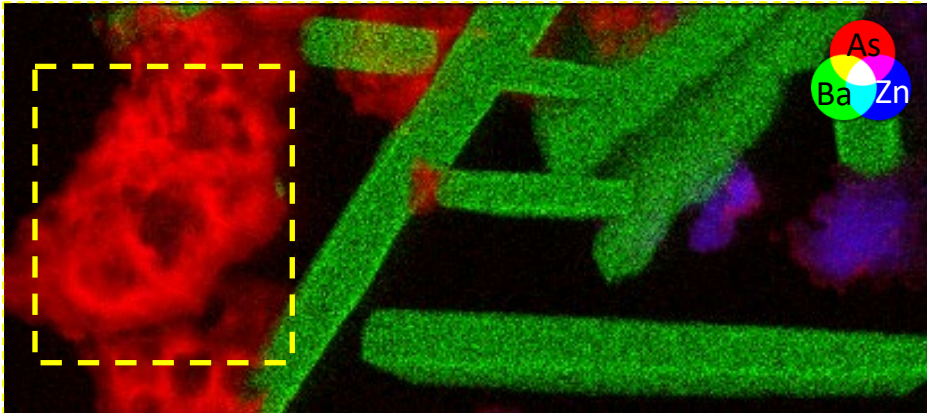
The mechanism



Oxidation states variations?

X-ray Absorption
Spectroscopy, including
both X-ray Absorption Near-
Edge Spectroscopy (**XANES**)

The mechanism

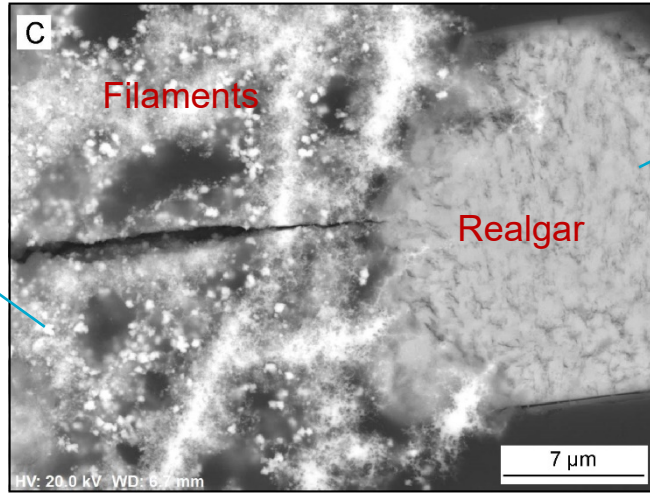


Fitting results:

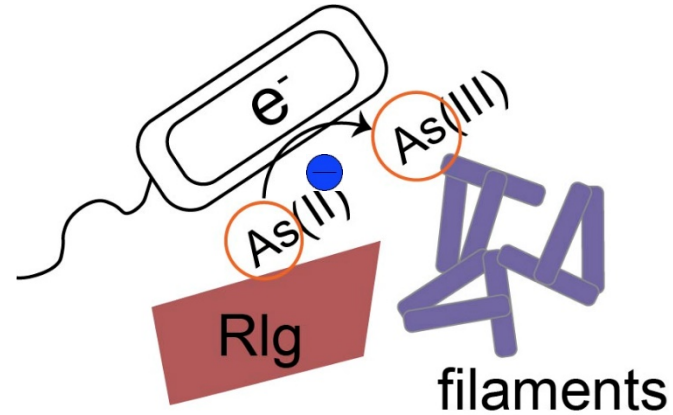
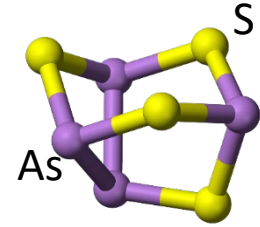
20 % (As_2O_3 ; As: 3+); 80 % (As_4S_4 ; As: 2+)

The mechanism

20 % As: 3+;
80 % As: 2+



Realgar As_4S_4 (As: 2+)



Implications: similar microbial activities may occur on early Earth where magmatic activities are abundant!



SCAN ME

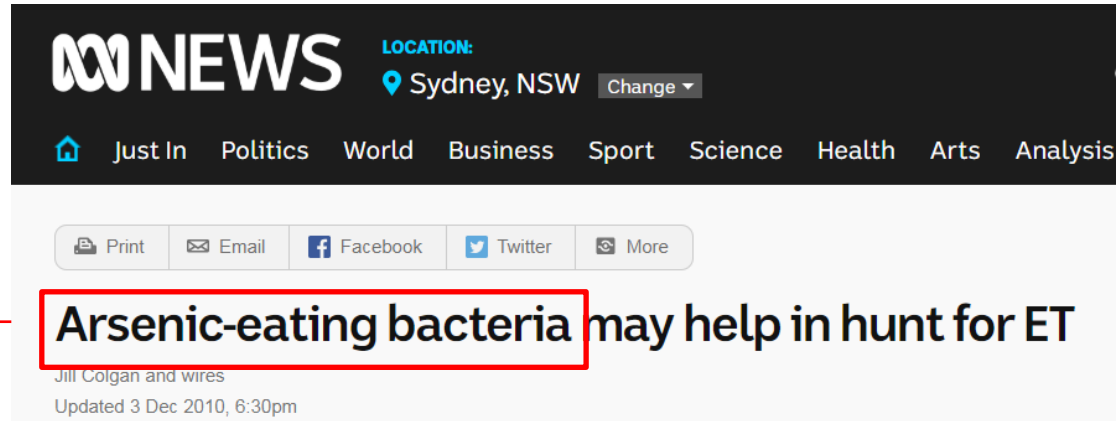
Hu et al., 2020.
Chemical Geology



Take home message

- Microbes can eat As in modern deep-sea hydrothermal vents;
- A great example showing how extremophiles adapt to high toxic environments;

Early life searching ←
Evolution of early life

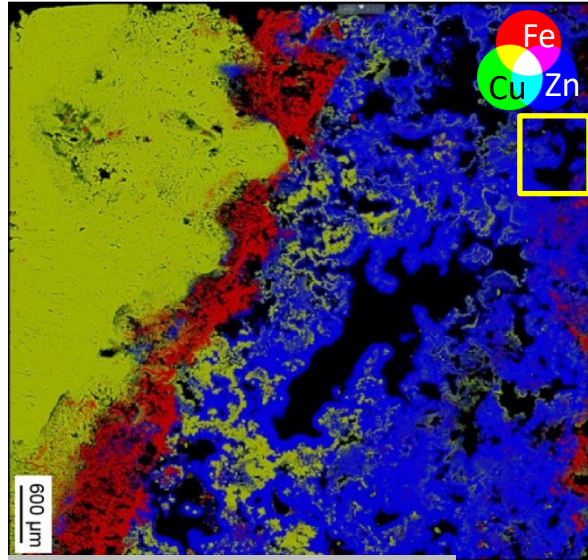


The image shows a screenshot of an ABC News website article. The top navigation bar includes the ABC NEWS logo, a location selector for Sydney, NSW, and a menu with categories like Just In, Politics, World, Business, Sport, Science, Health, Arts, and Analysis. Below the navigation bar are social media sharing options for Print, Email, Facebook, Twitter, and More. The main headline of the article is "Arsenic-eating bacteria may help in hunt for ET", with the words "Arsenic-eating bacteria" highlighted by a red rectangular box. Below the headline, the author is listed as "Jill Colgan and wires" and the update time is "Updated 3 Dec 2010, 6:30pm".

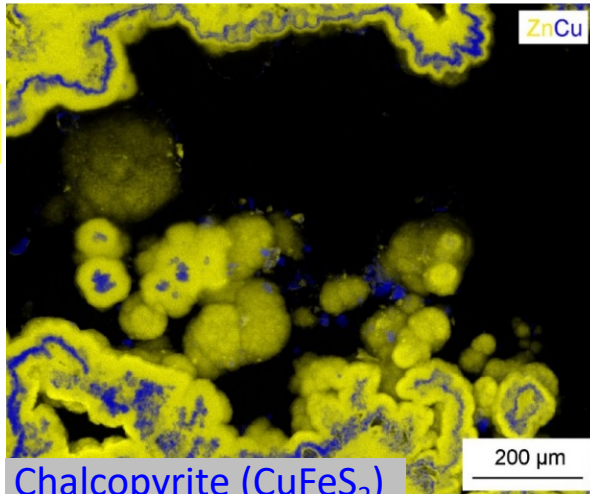
- Synchrotron XFM + other advanced techniques => fancy and important science

Further chimney characterisation

Synchrotron XRF observations + other advanced techniques



Chalcopyrite (CuFeS_2)



Chalcopyrite (CuFeS_2)
Sphalerite (ZnS)



Scanning electron microscopy (SEM)-based Electron backscatter diffraction (EBSD)

Characterising primary microstructures during the gradual mixing between cold seawater and hot hydrothermal fluids.

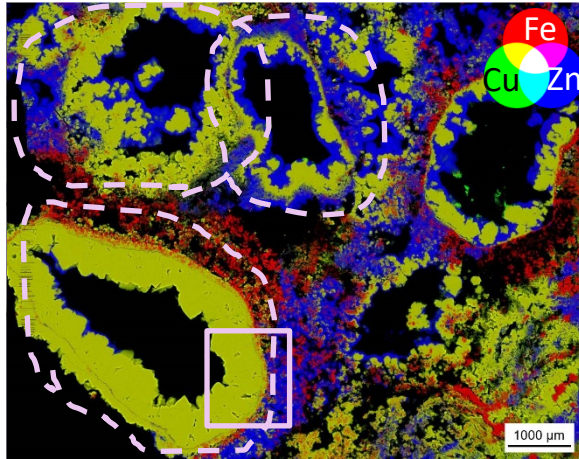


(Hu et al., Economic Geology, 2019)

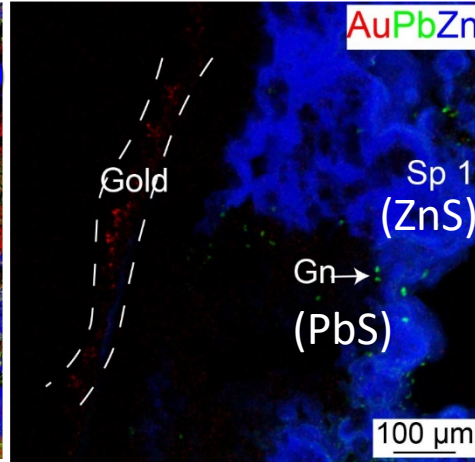


Further chimney characterisation

Synchrotron XRF observations + other advanced techniques



Chalcopyrite (CuFeS_2)
Pyrite (FeS_2)
Sphalerite (ZnS)



Scanning electron
microscopy (SEM)-based
Electron backscatter
diffraction (EBSD)

Uncover new insights into gold precipitation
and future gold searching in chimneys

(Hu et al., in review)



Acknowledgments

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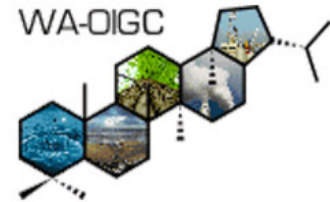
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Dr William Rickard (JdL, Curtin)



John de Laeter Centre



Curtin University



Thank you

Mineral Resources

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