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Faro Waste Rock Project:

An Integrated Study of Hydrological and Geochemical Processes in Sulfide- and Carbonate-rich Waste-Rock Dumps

Zhongwen Bao (PDF)

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December 3, 2020, 2020 BC MLARD
via Zoom, Waterloo, ON, Canada

Background

Faro Mine Complex

- **Location**

  20 km N of Faro town

- **Operation**

  1969 – 1998

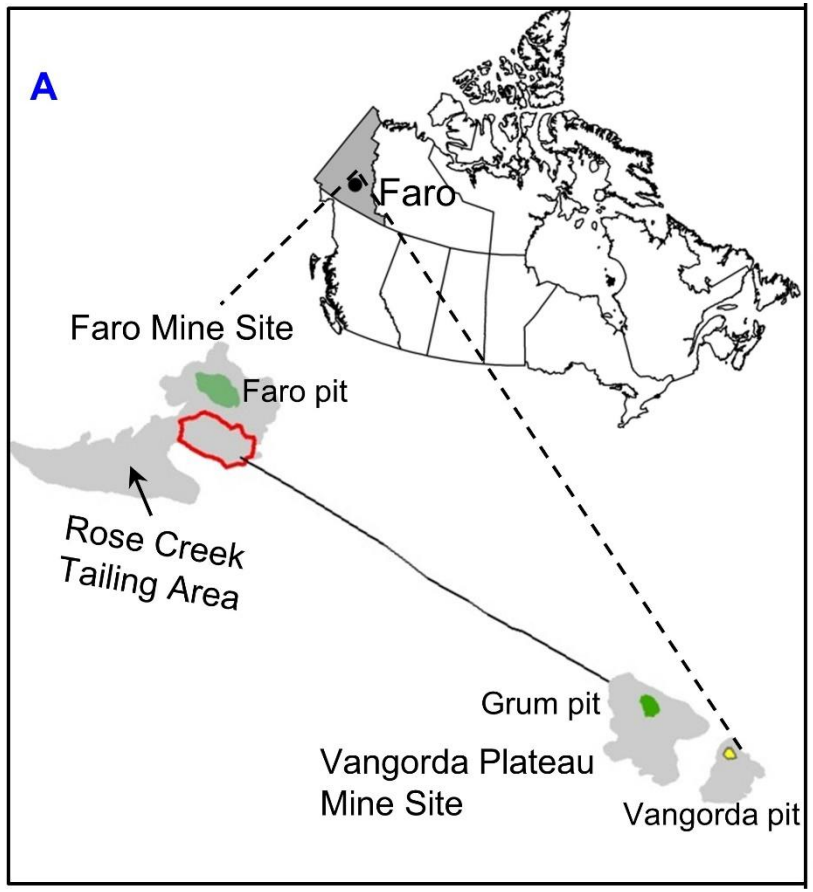
- **Lead-Zinc mine**

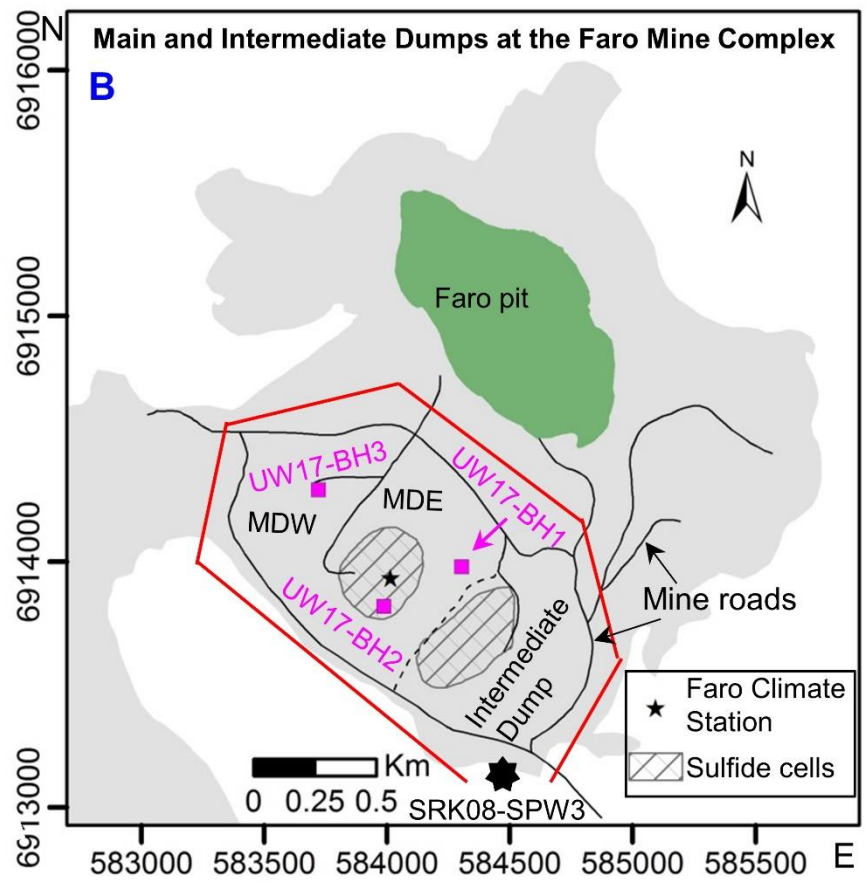
- **Tailings (milling waste)**

  ≈ 70 M tonnes fine sand-like materials

- **Waste Rock (of little economic value)**

  ≈ 320 M tonnes

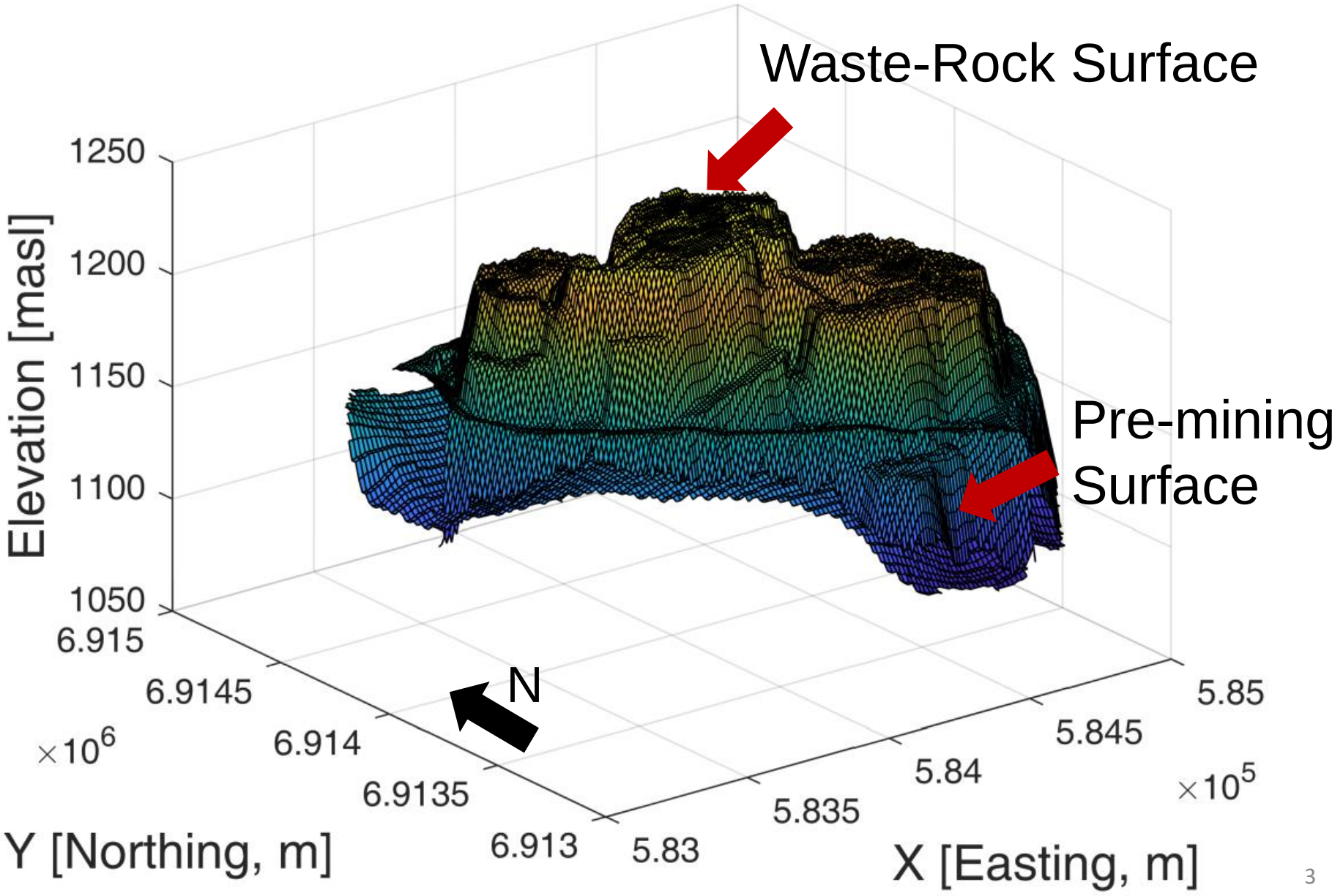




Faro Waste Rock Project

2017

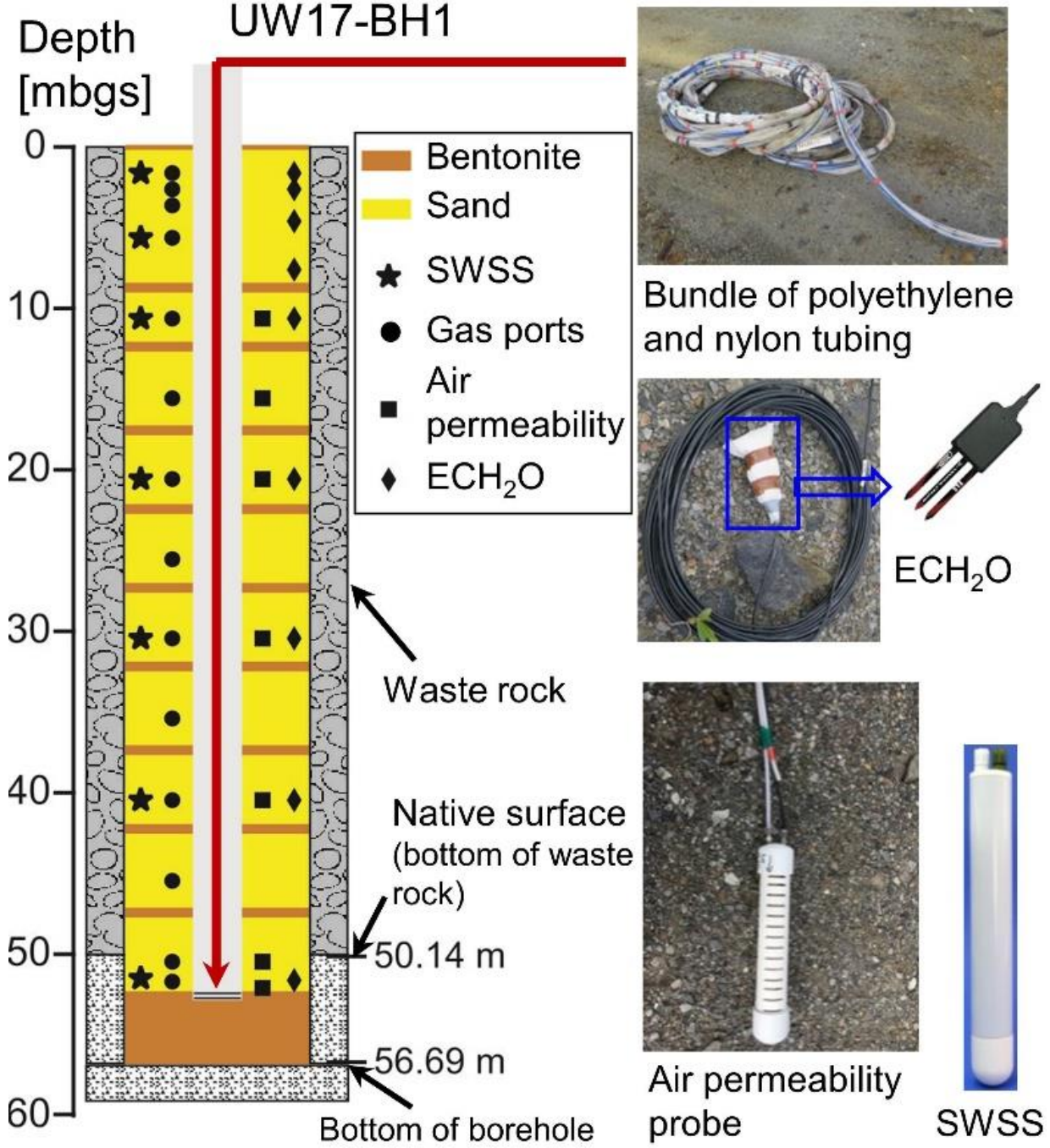
3D Geometry


Waste-Rock Surface
Pre-mining Surface
Elevation [masl]
1250
1200
1150
1100
1050
6.915
6.9145
6.914
6.9135
6.913
×10^6
Y [Northing, m]
N
5.83
5.835
5.84
5.845
5.85
×10^5
X [Easting, m]

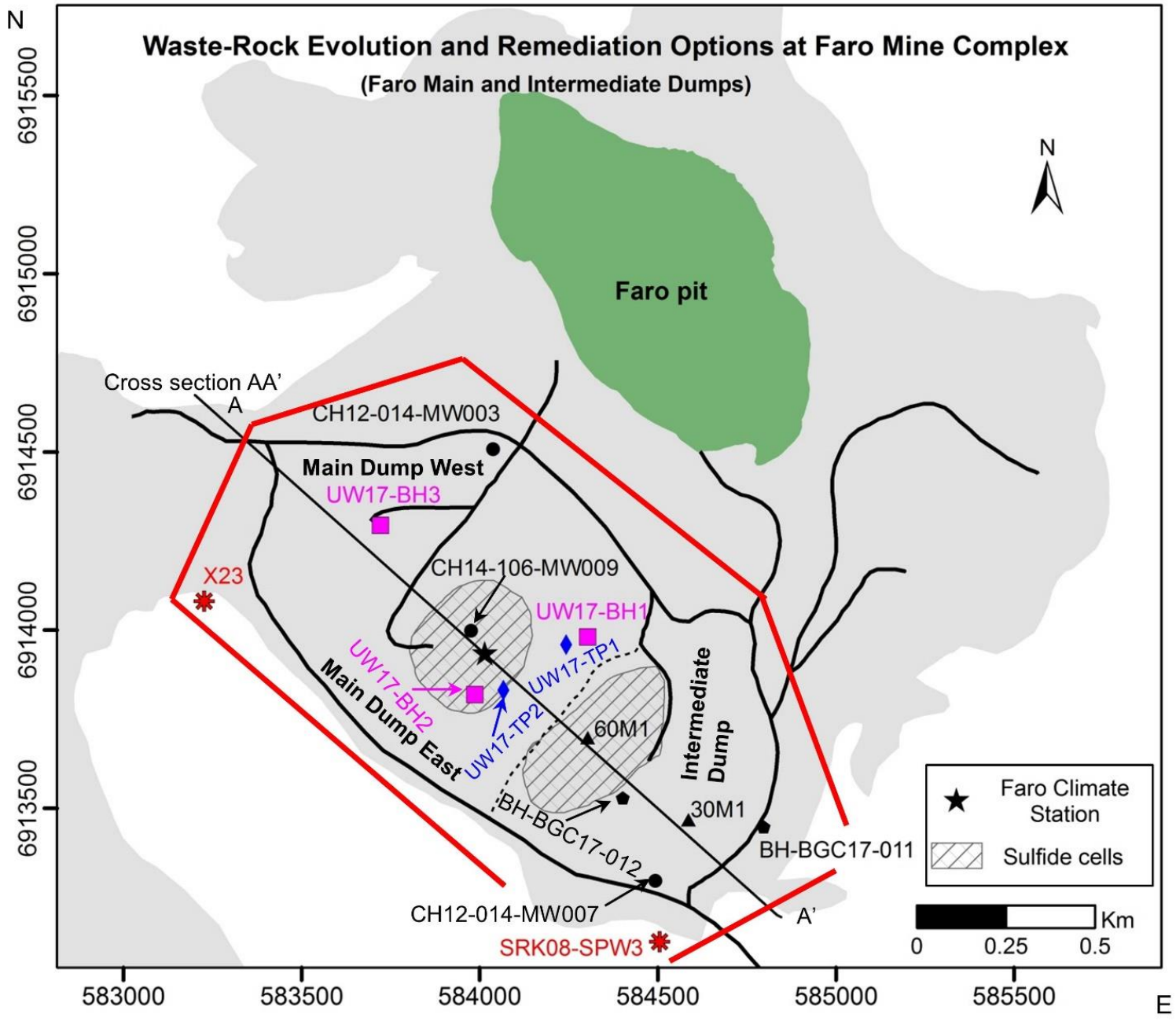
UW Borehole Drilling and Sampling in the Main Dump

- UW17-BH1
  - Borehole depth: 56.69 m
  - Height of waste rock: 50.14 m
- UW17-BH2
  - Borehole depth: 68.88 m
  - Height of waste rock: 65.84 m
- UW17-BH3
  - Borehole depth: 78.33 m
  - Height of waste rock: 74.07 m

Instrumentation at three UW boreholes

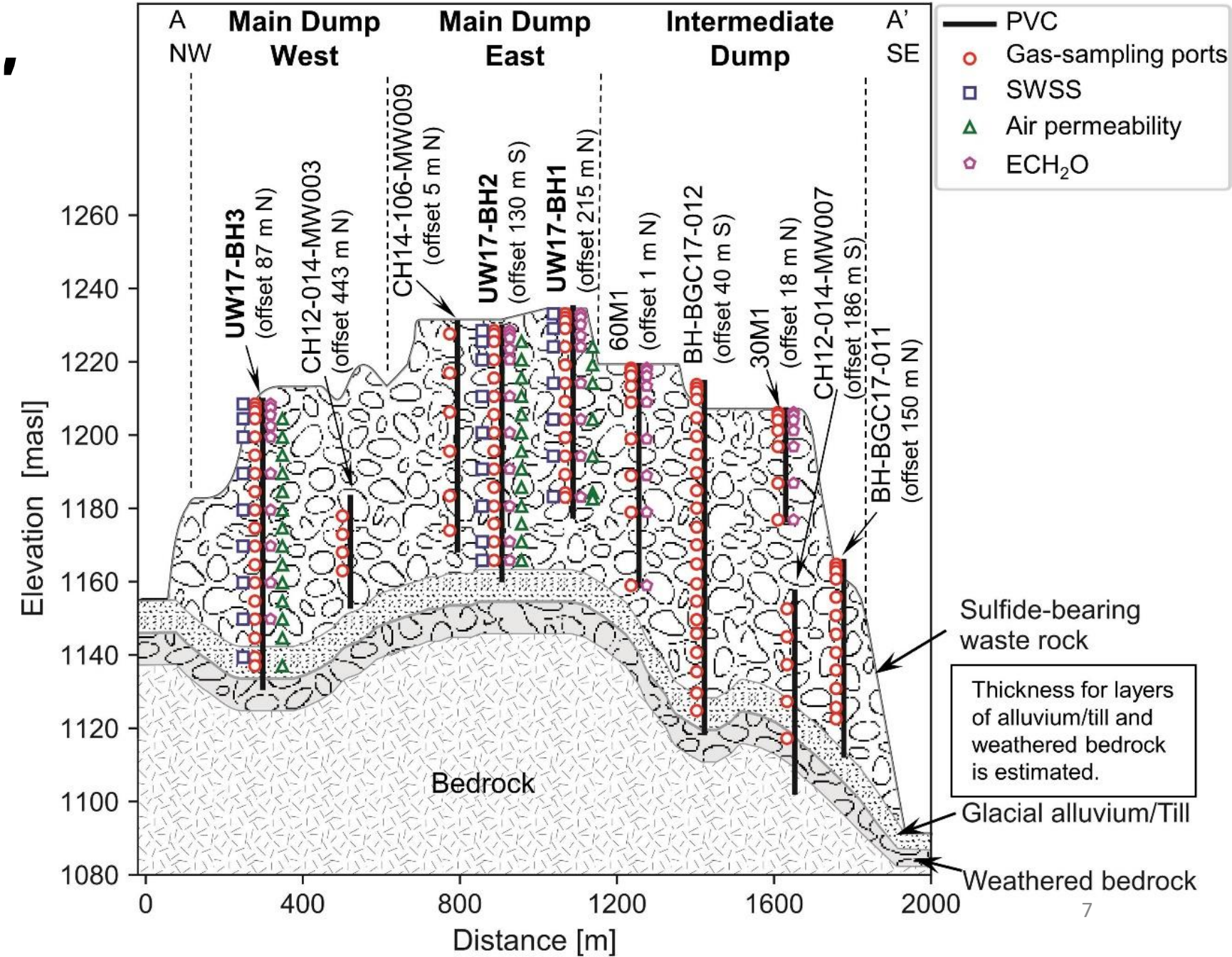


Cross Section AA'



Cross Section AA′

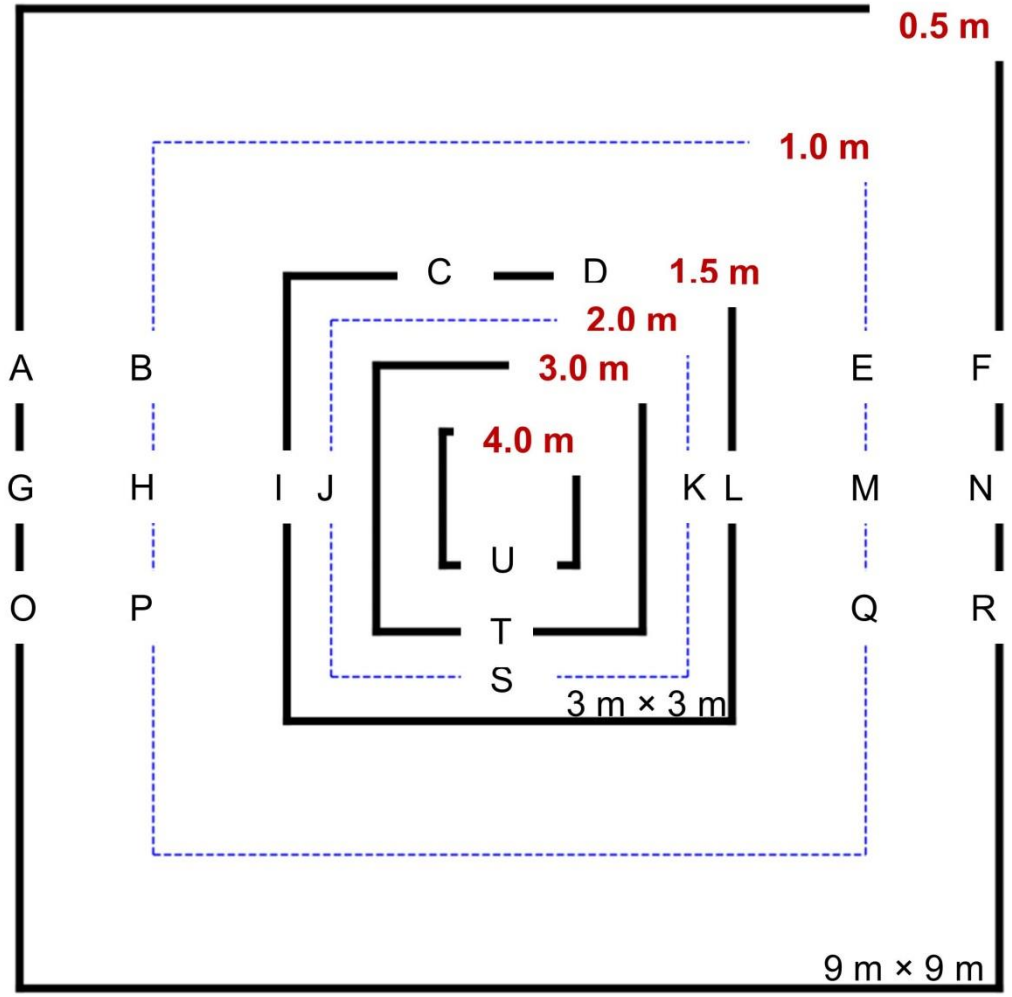
- Phyllite/calc-silicate/schist
- Weathered bedrock
- Glacial alluvium/Till
- Sulfide-bearing waste rock



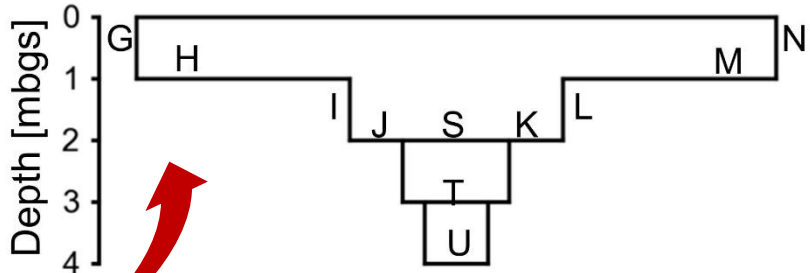
Test Pit Program and Sampling

Two test pits in 2017

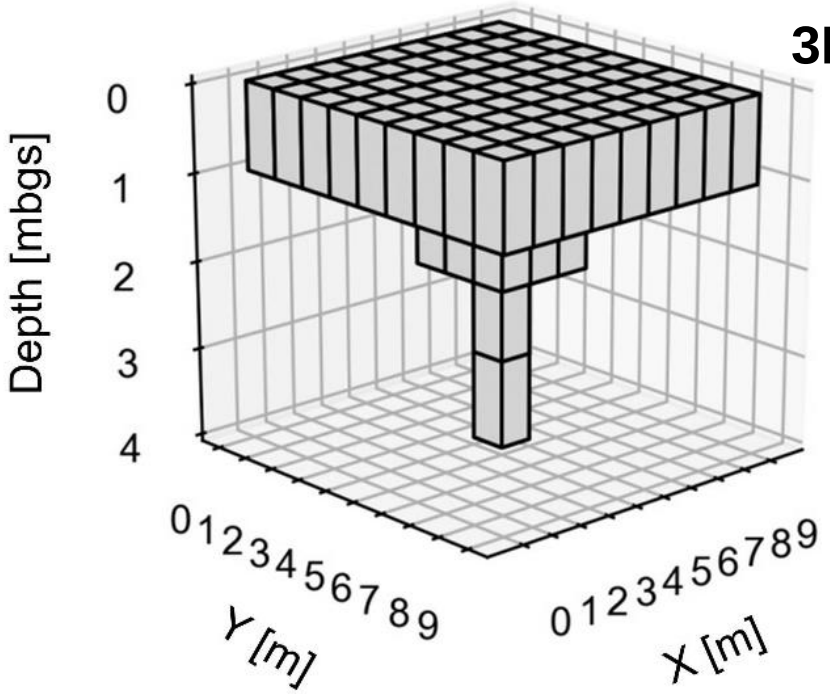
- UW17-TP1
- UW17-TP2



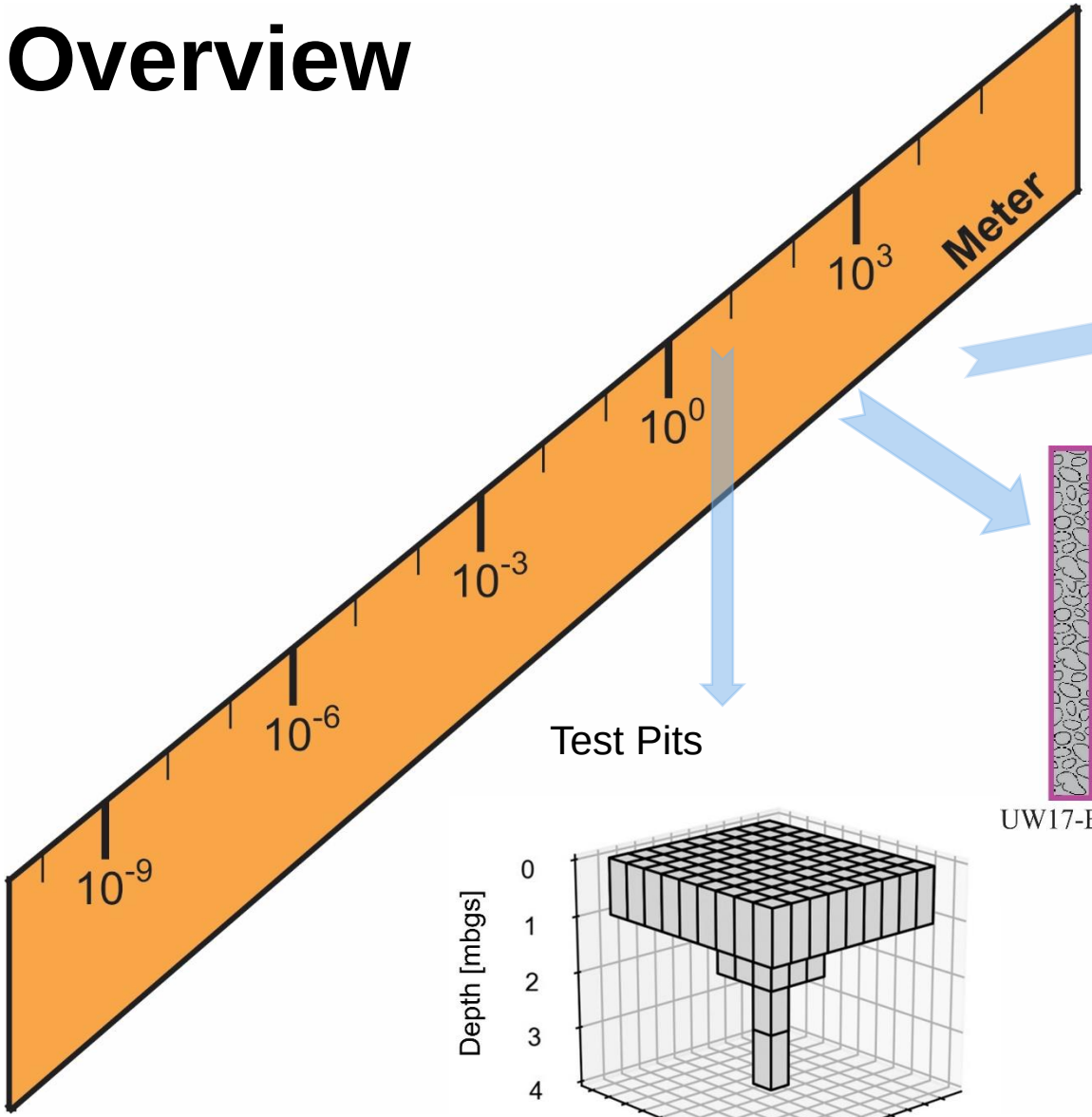
Cross section of test pit sampling locations

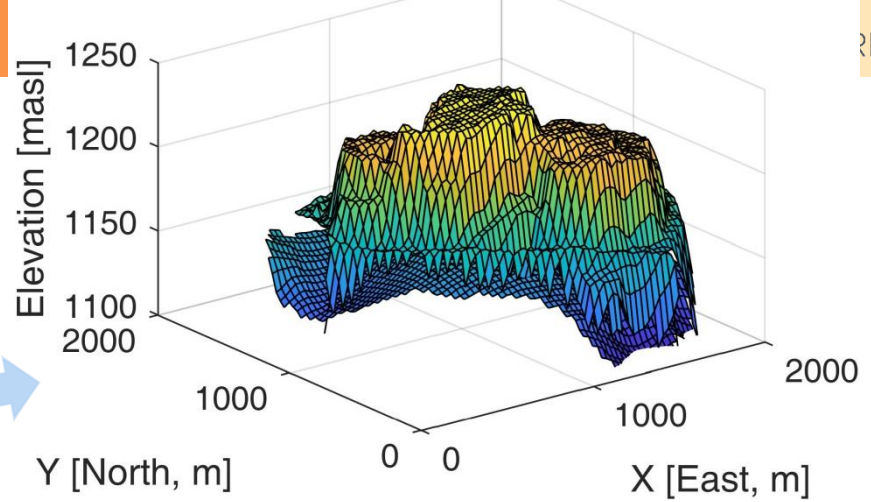


3D geometry

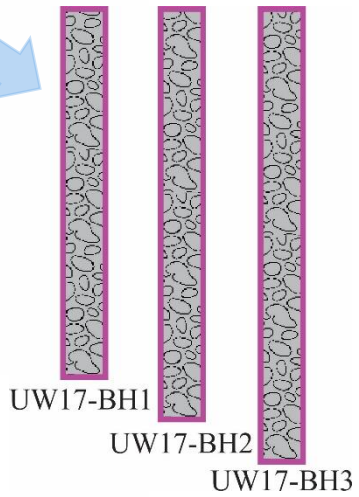


Overview

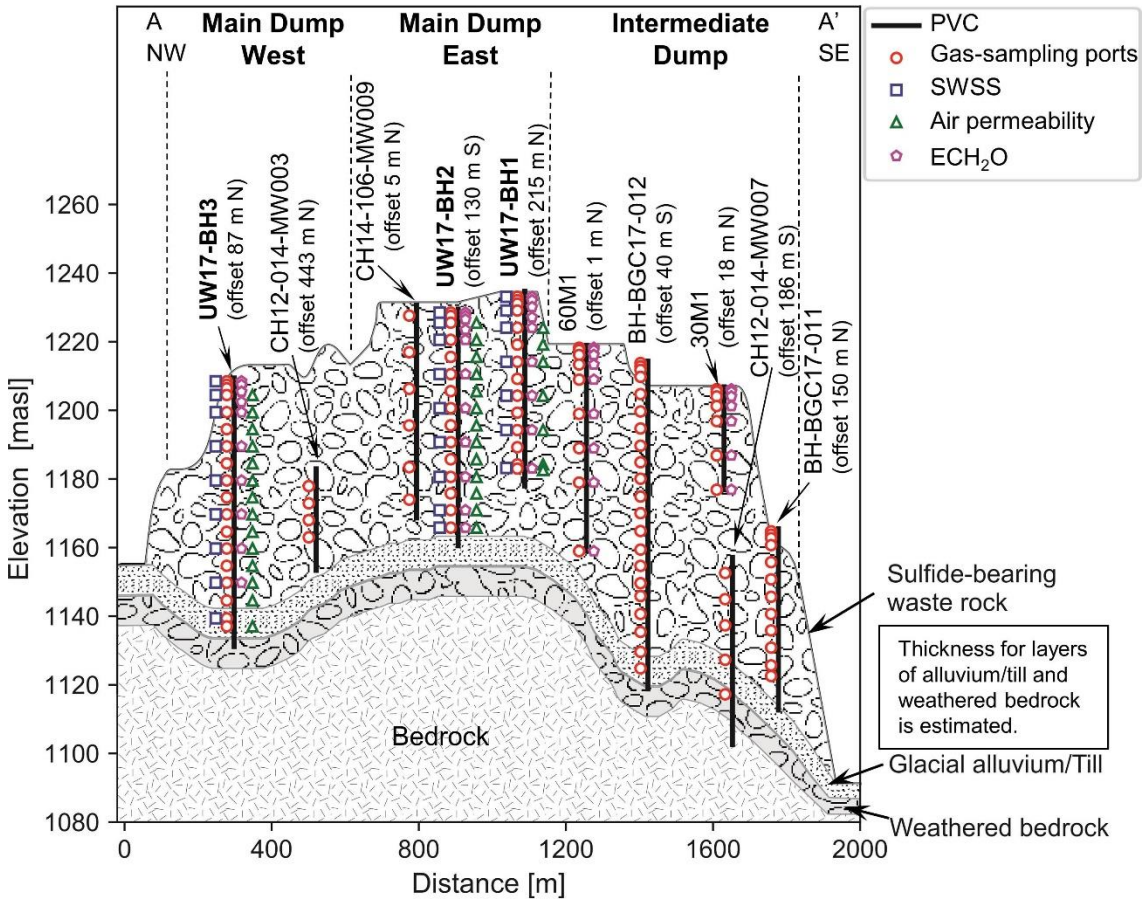




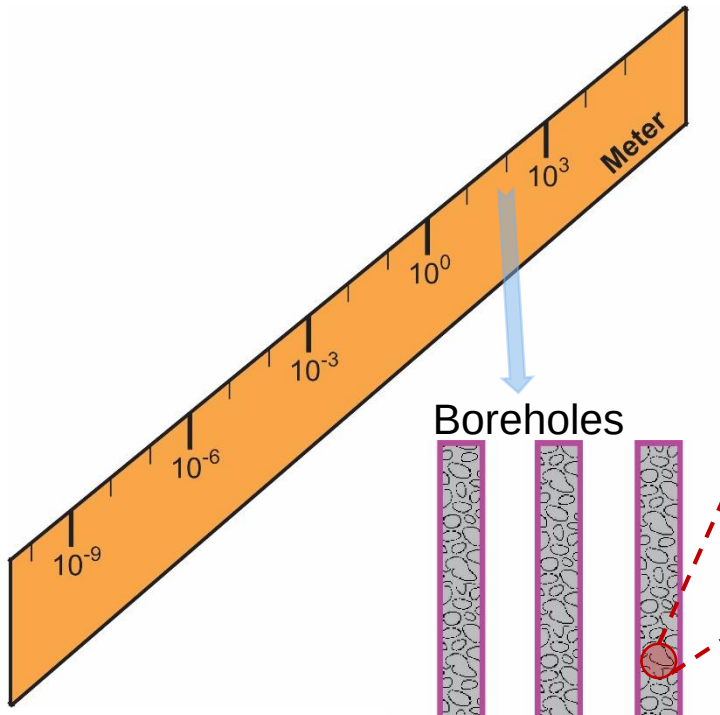
Boreholes

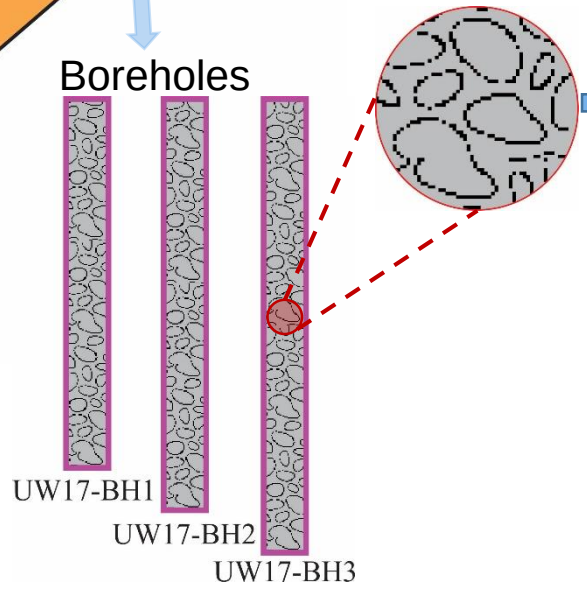


Test Pits



Site-Specific Characterization of Mine Wastes

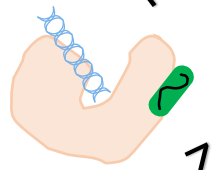




Hydrology

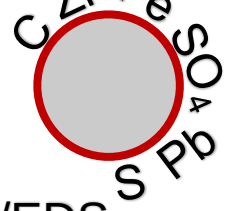
Geochemistry

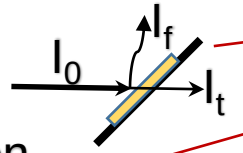
Microbiology

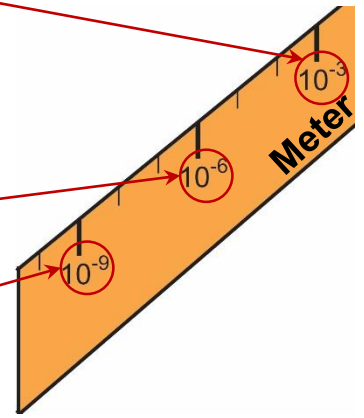


Mineralogy

- C/S
- XRF
- SEM/EDS
- EMPA
- Synchrotron
- TEM







Reactive transport modeling

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Faro Waste Rock Project:

Variably saturated water flow through the waste-rock dumps

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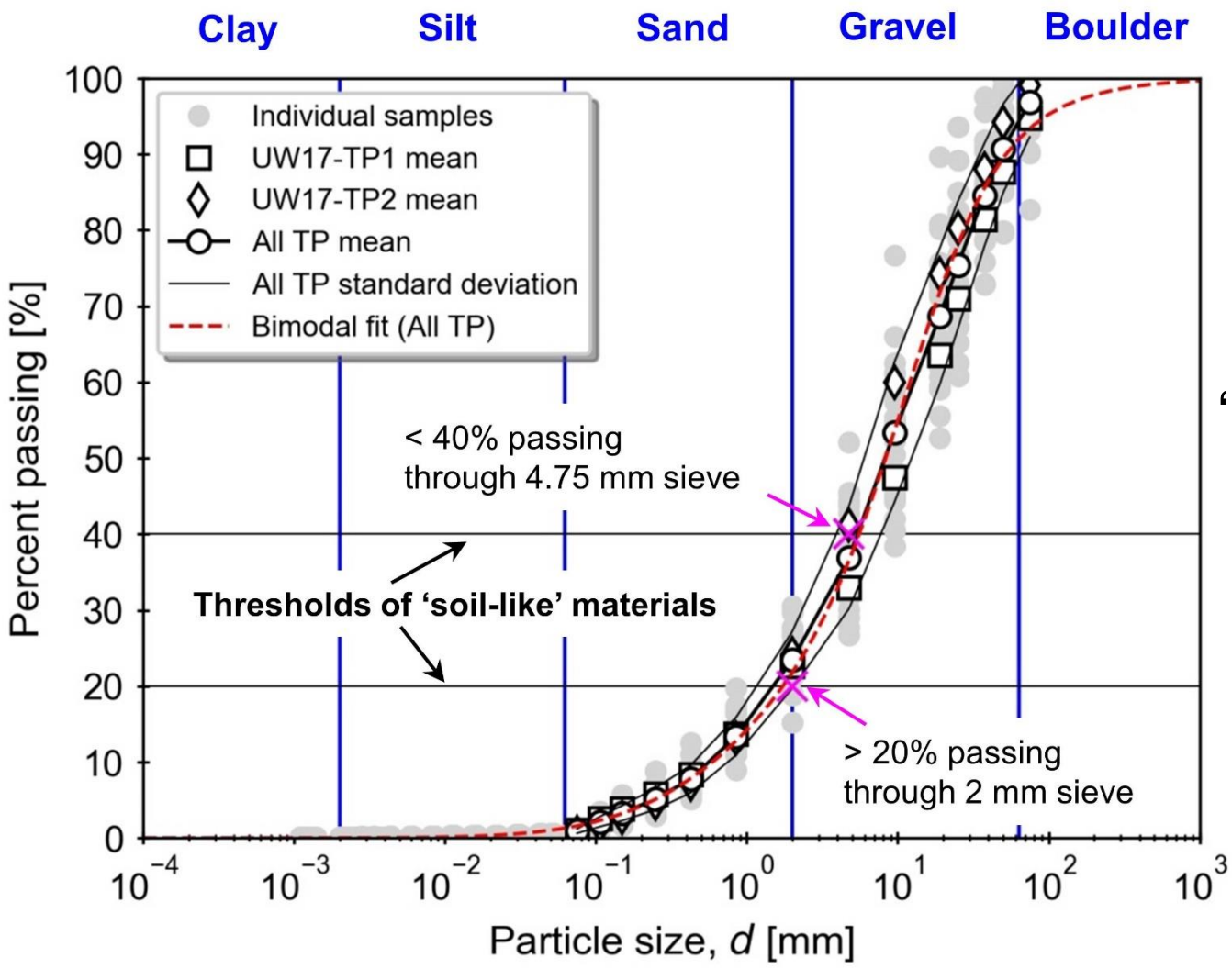
CRSNG

Waste-Rock Hydrology

Surface efflorescent minerals

Frequent dry-wet cycles

Waste-Rock Hydrology

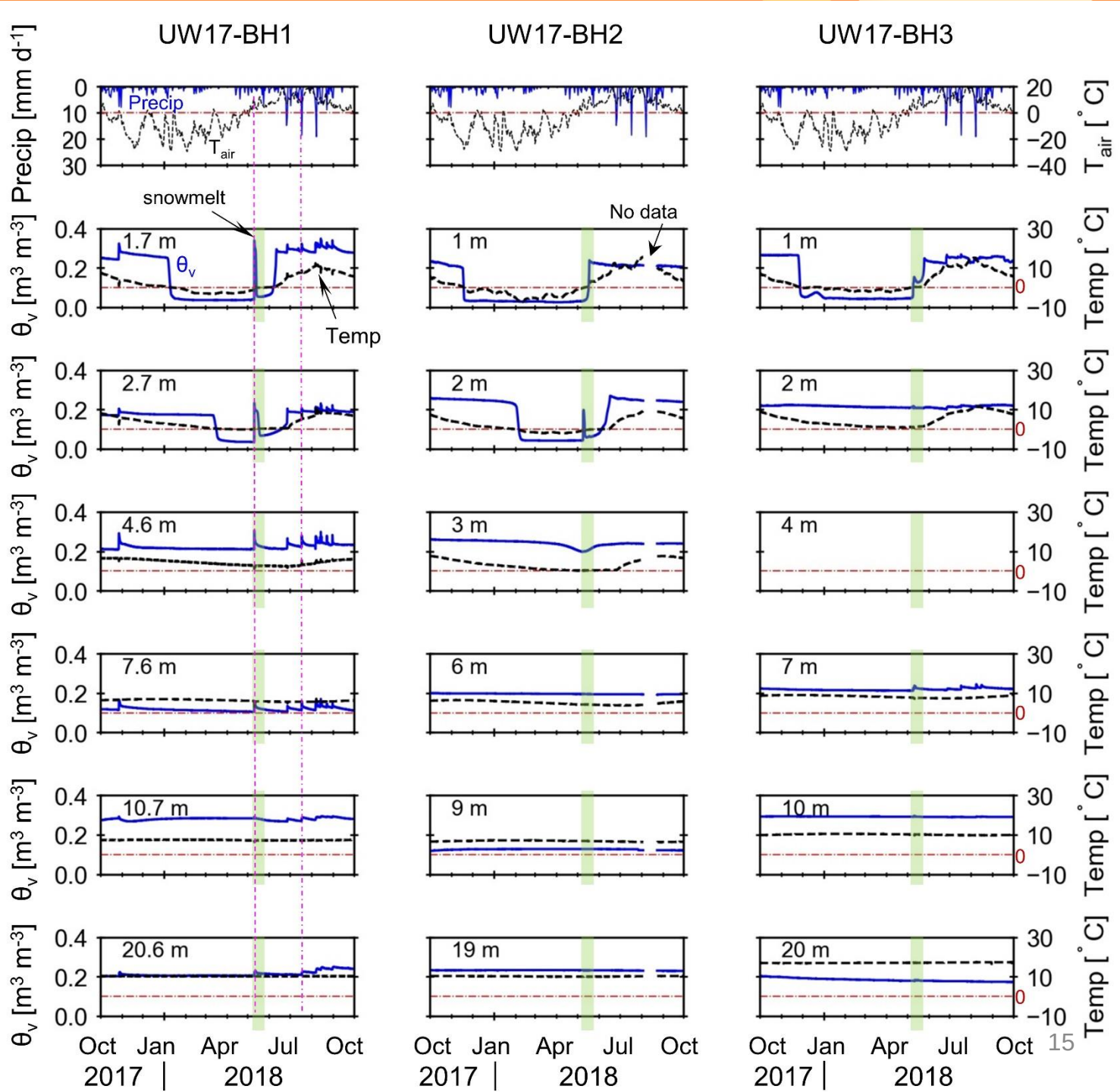


'Soil-like' materials on the surface

Waste-Rock Hydrology

Response of water content in waste rock to precipitation

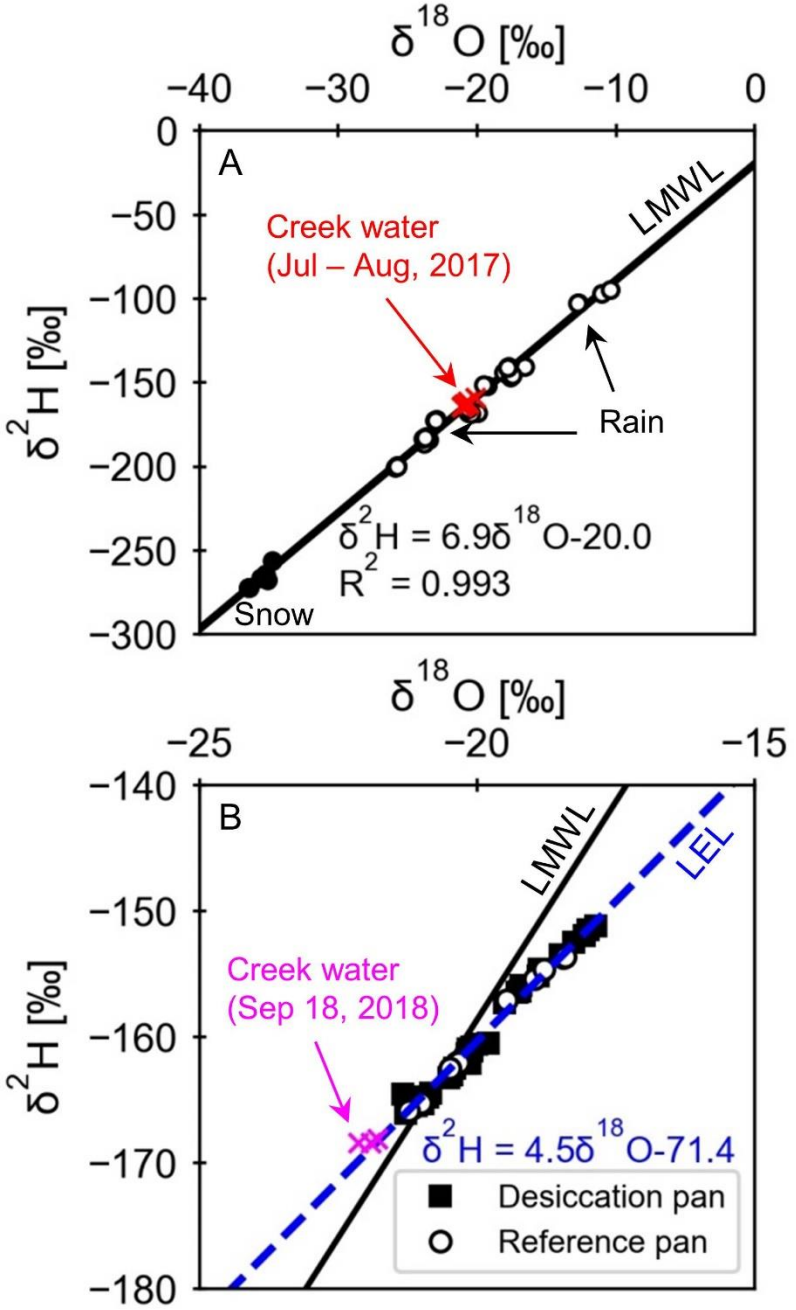
Deeper wetting front in BH1



Waste-Rock Hydrology

LMWL: local meteoric water line

LEL: local evaporation line

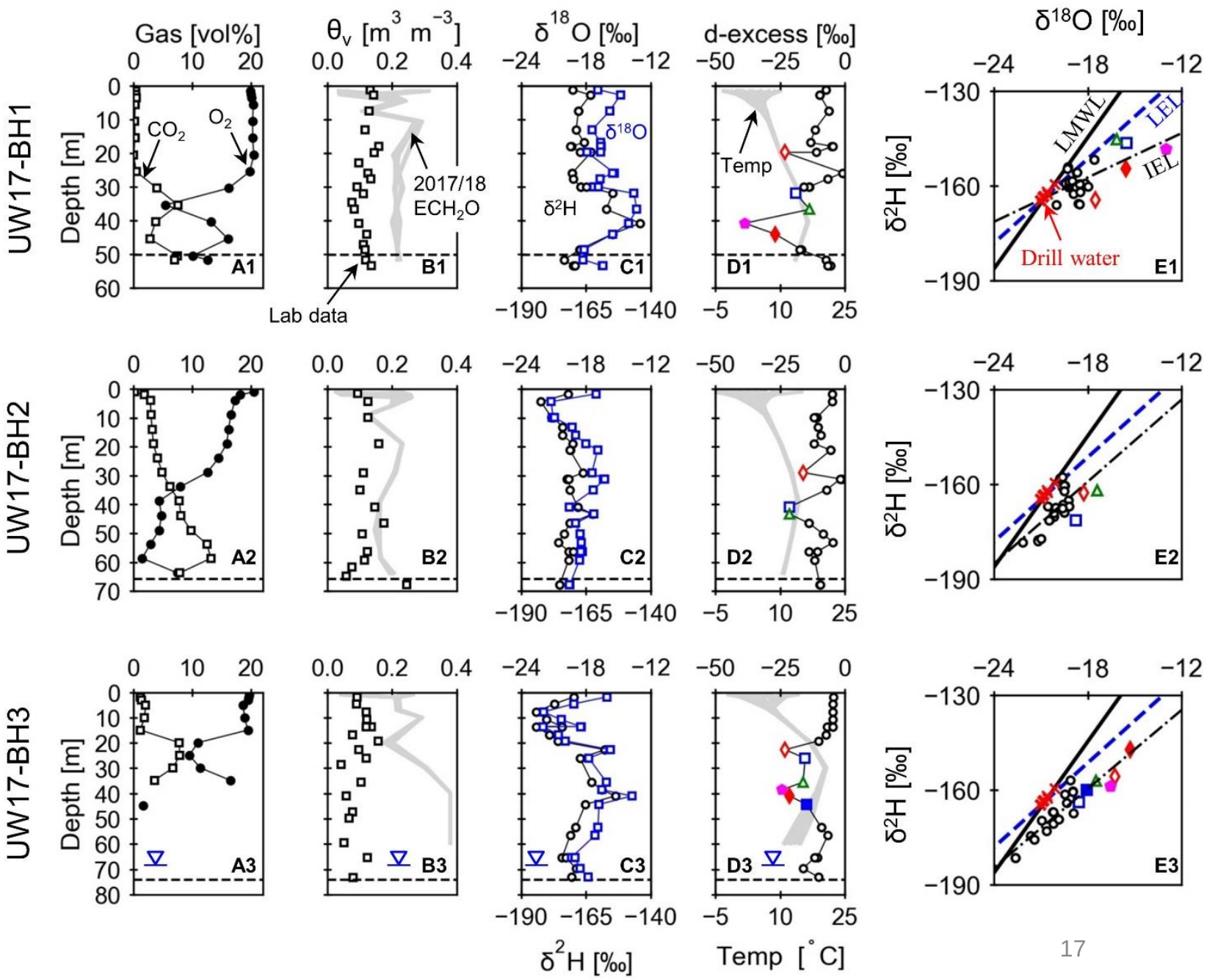


Waste-Rock Hydrology

Higher temperature, stronger internal evaporation

Preferential flow in BH1

Rainfall-dominated infiltration



Summary

Preferential flow vs matrix flow

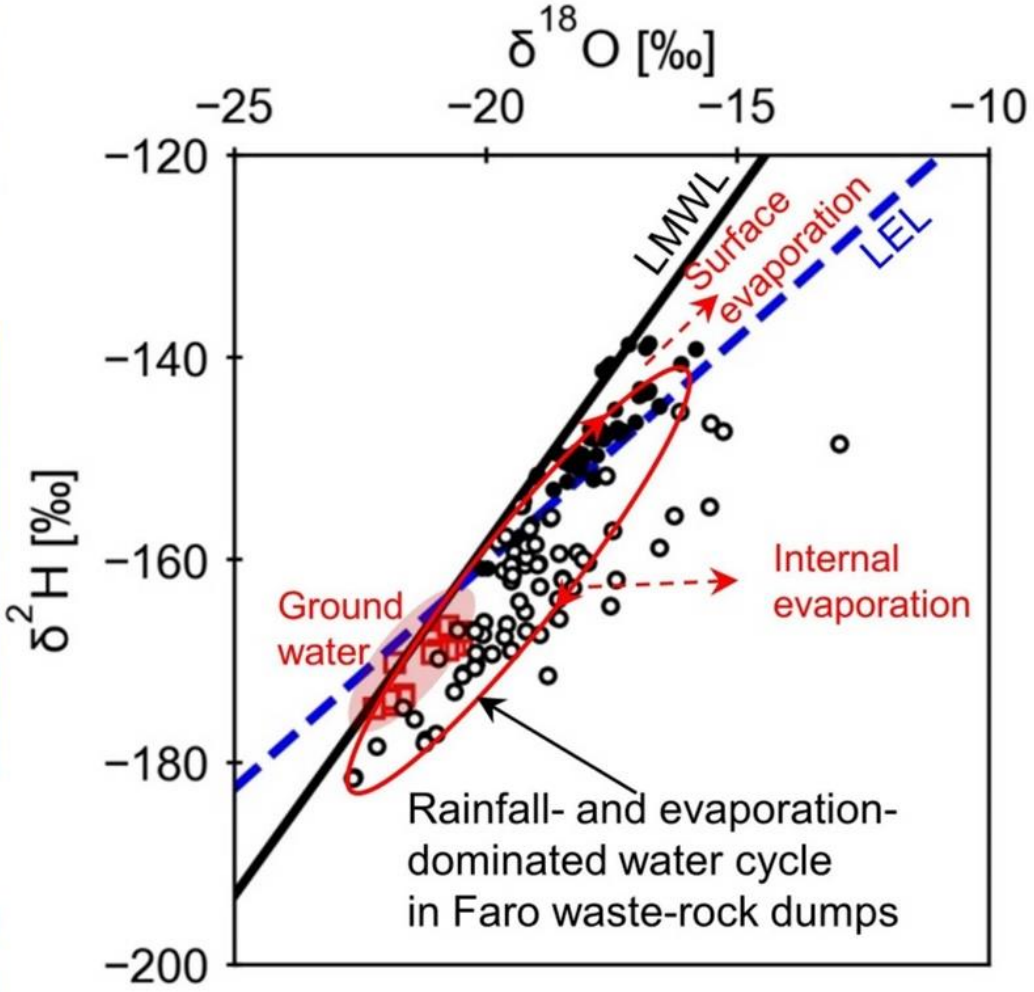
Impact to effluent water chemistry

- Concentrated in winter
- Diluted in summer

Rainfall

Snow cover and snowmelt

Evaporation causing formation of effluorescent salts



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Faro Waste Rock Project:

Geochemical heterogeneity in the waste-rock dumps

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Geochemical Heterogeneity

pH 1.4

Fe 36,900 mg/L

Zn 14,200 mg/L

Pb 6.16 mg/L

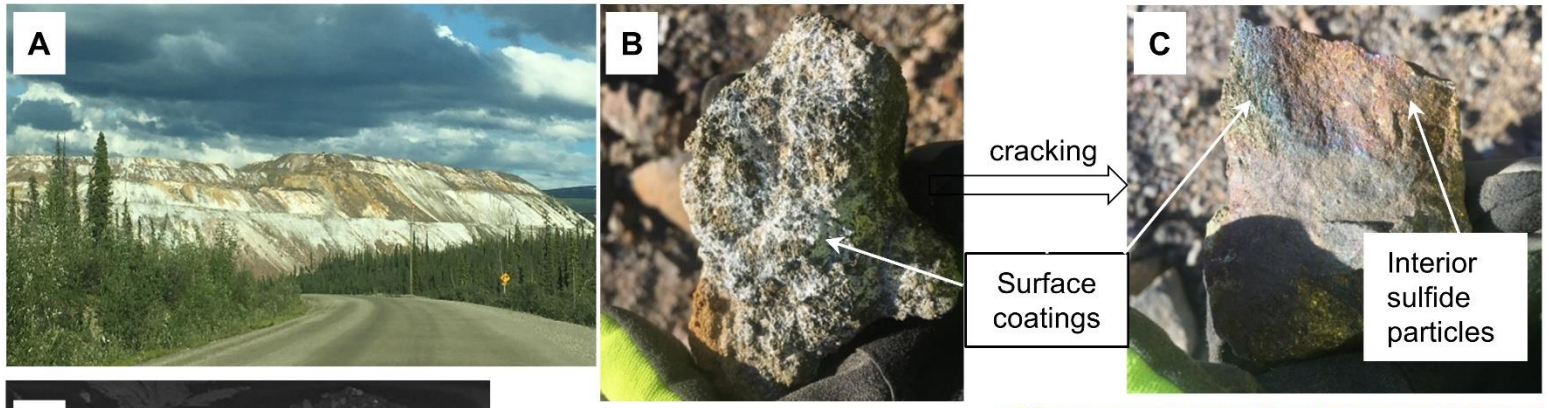
Al 8,750 mg/L

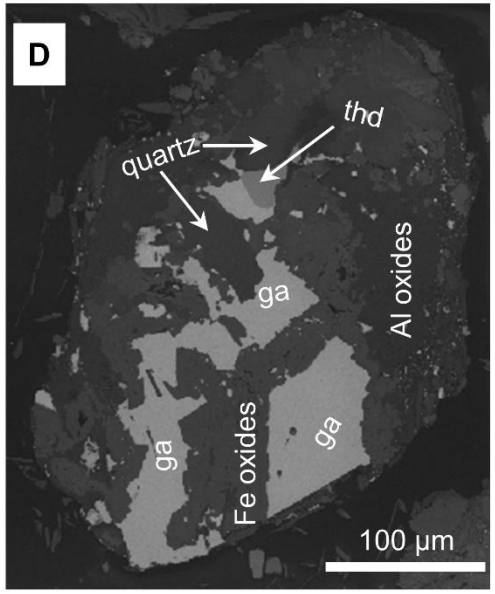
As 63.6 mg/L

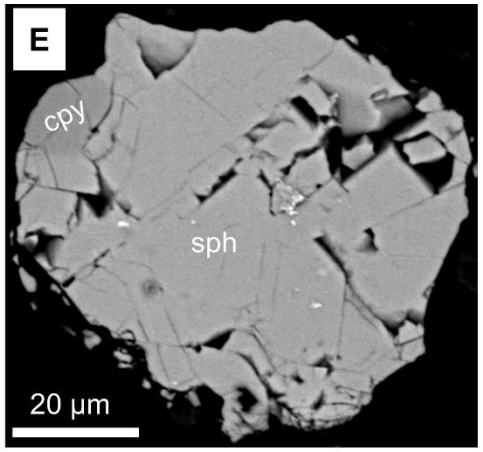
Mn 2,170 mg/L

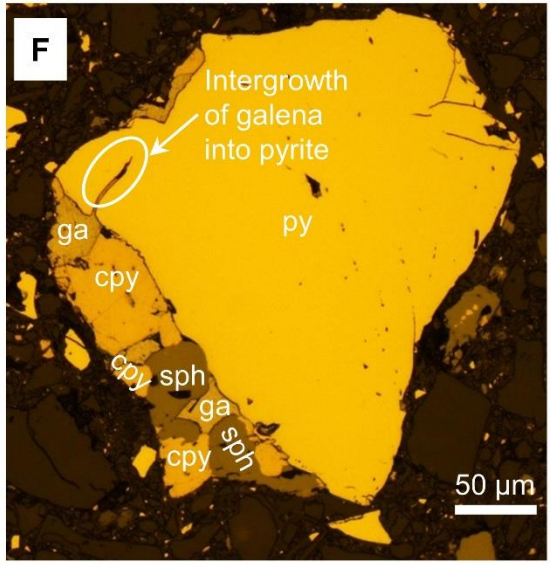
Cd 21.7 mg/L

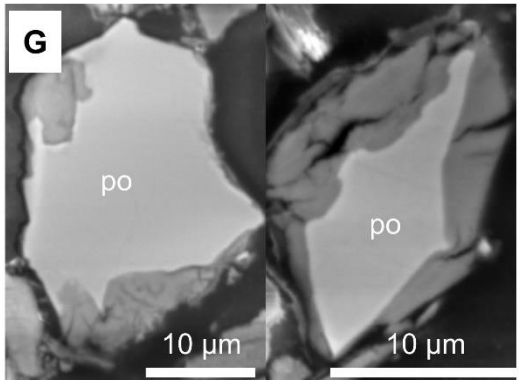
SO_4 114,000 mg/L

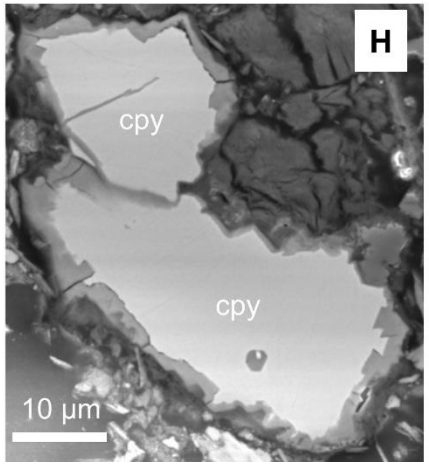


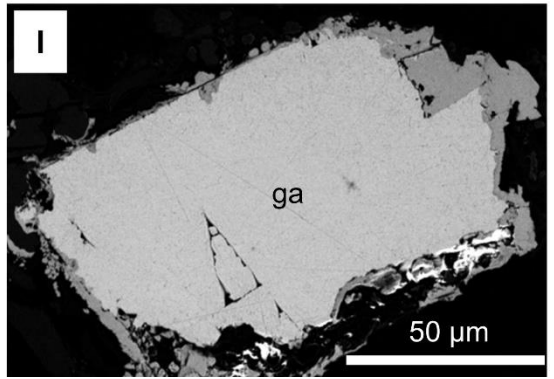












Mineralogy in Faro waste rock

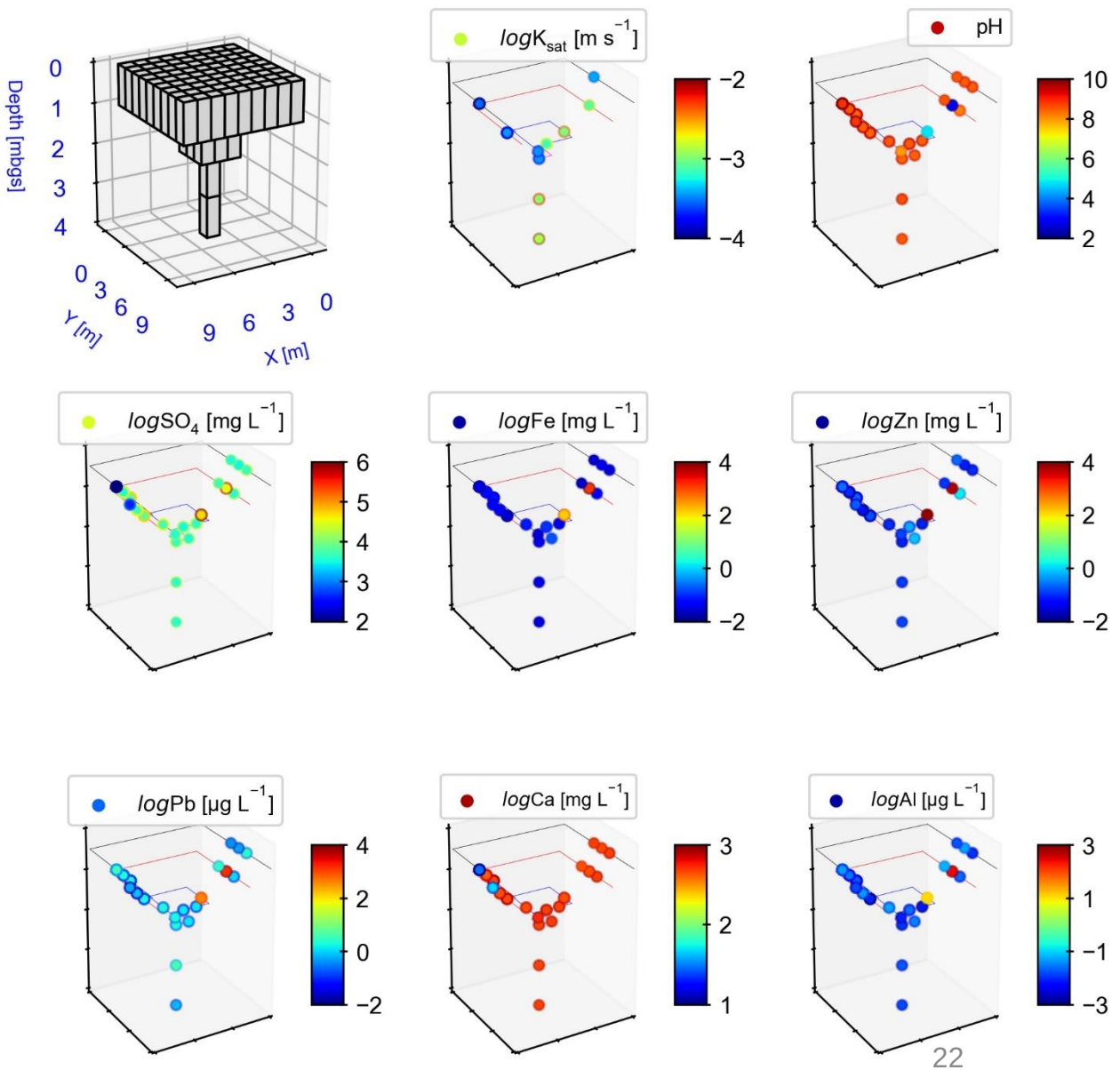
- Presence of multisulfide
- Some are un-oxidized
- Some are strongly altered

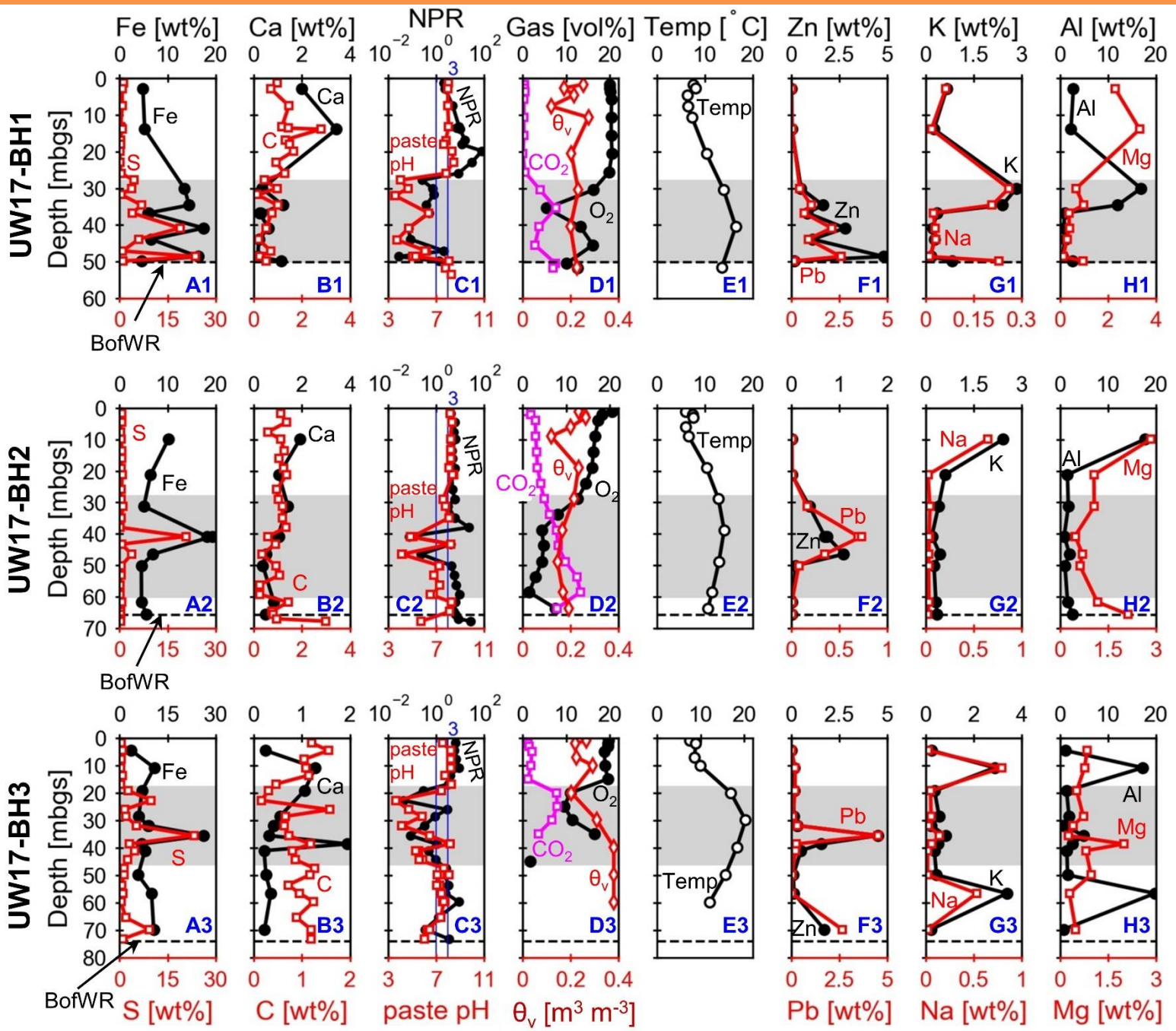
pyrrhotite (po) $Fe_{1-x}S$
galena (ga) PbS
sphalerite (sph) ZnS
pyrite (py) FeS_2
chalcopyrite (cpy) $CuFeS_2$

(Bao et al., 2020b)

Geochemical Heterogeneity

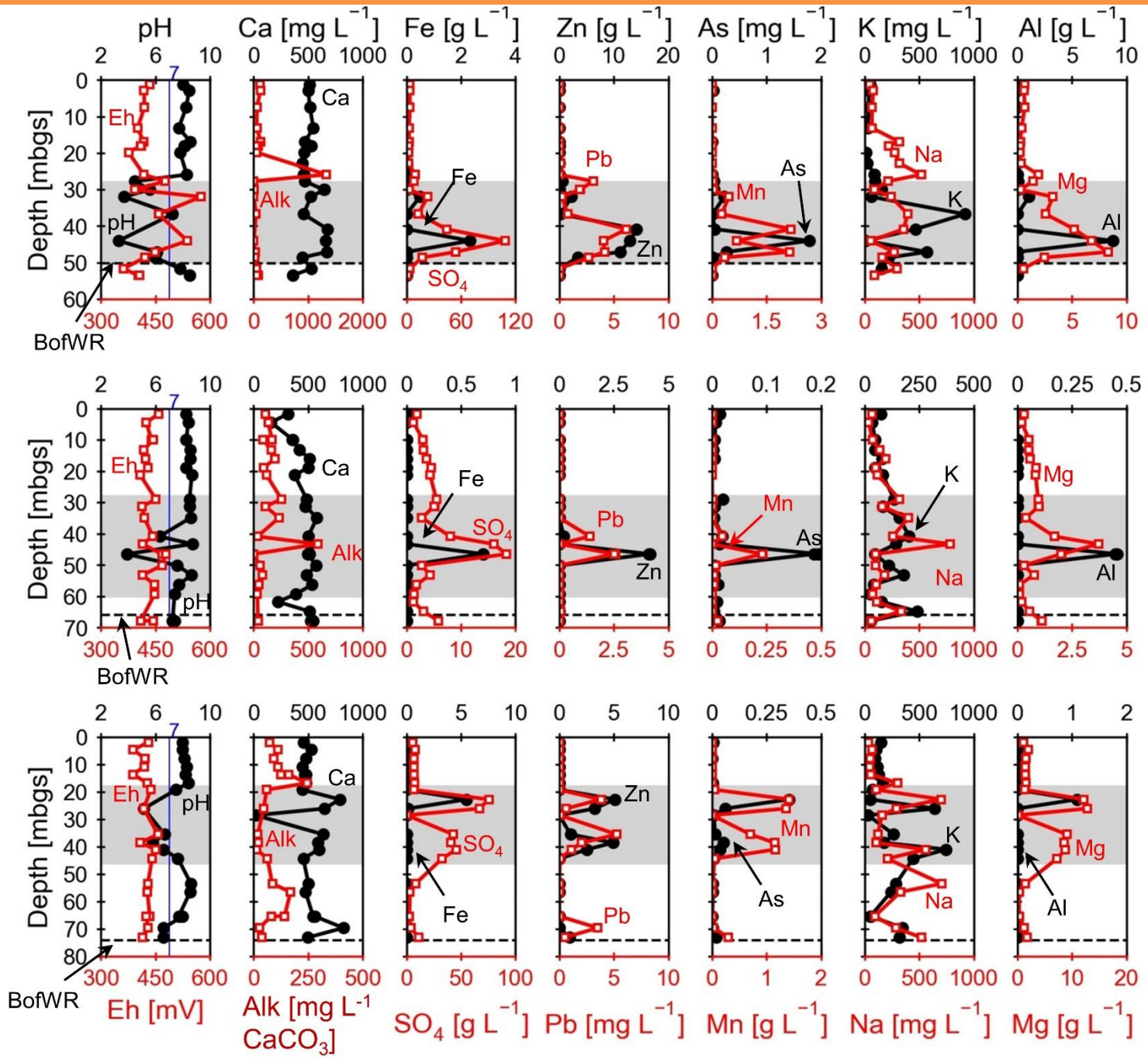
Strong heterogeneity of geochemical parameters near the surface





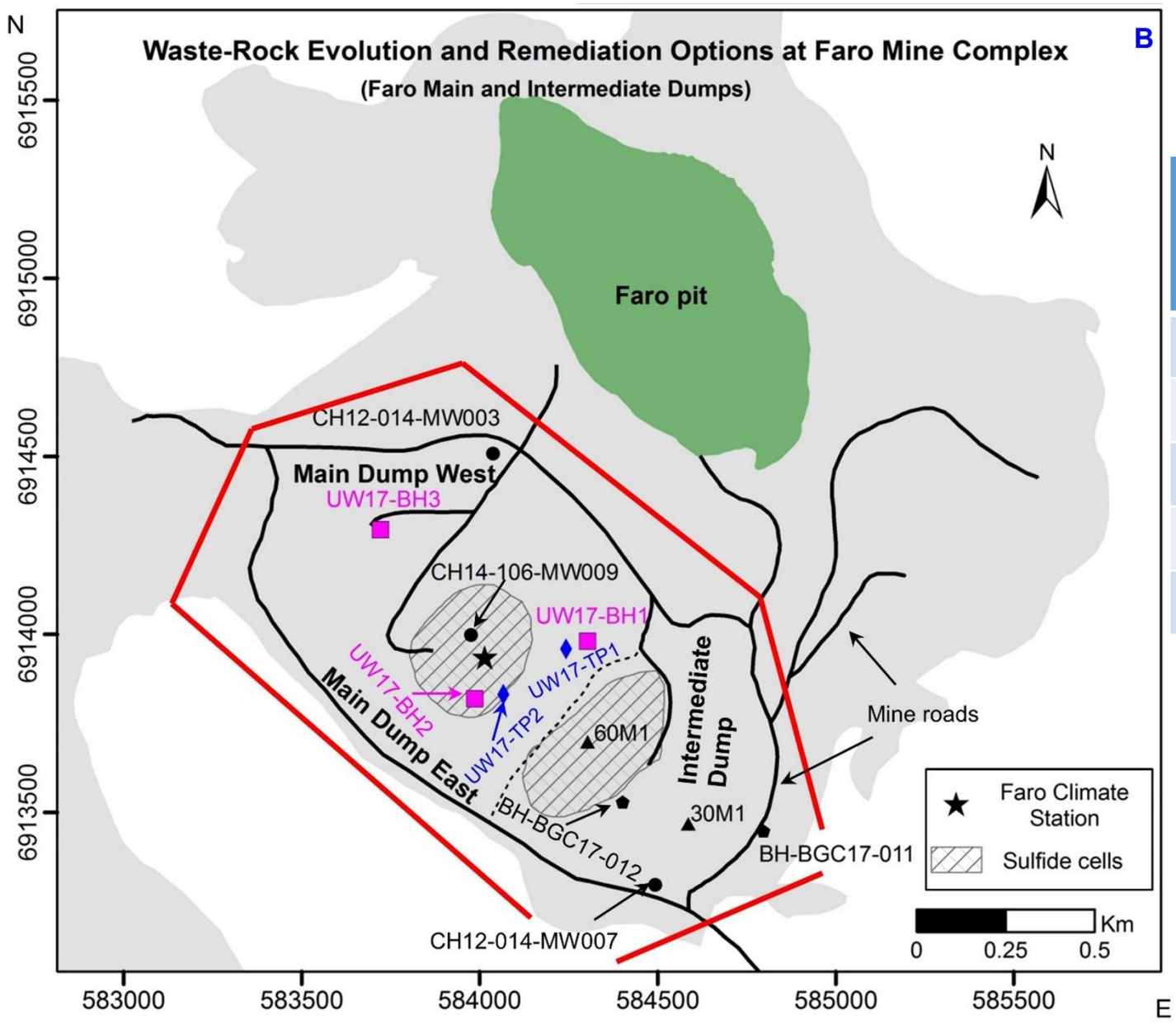
Geochemical Heterogeneity

Waste-rock material segregation



Geochemical Heterogeneity

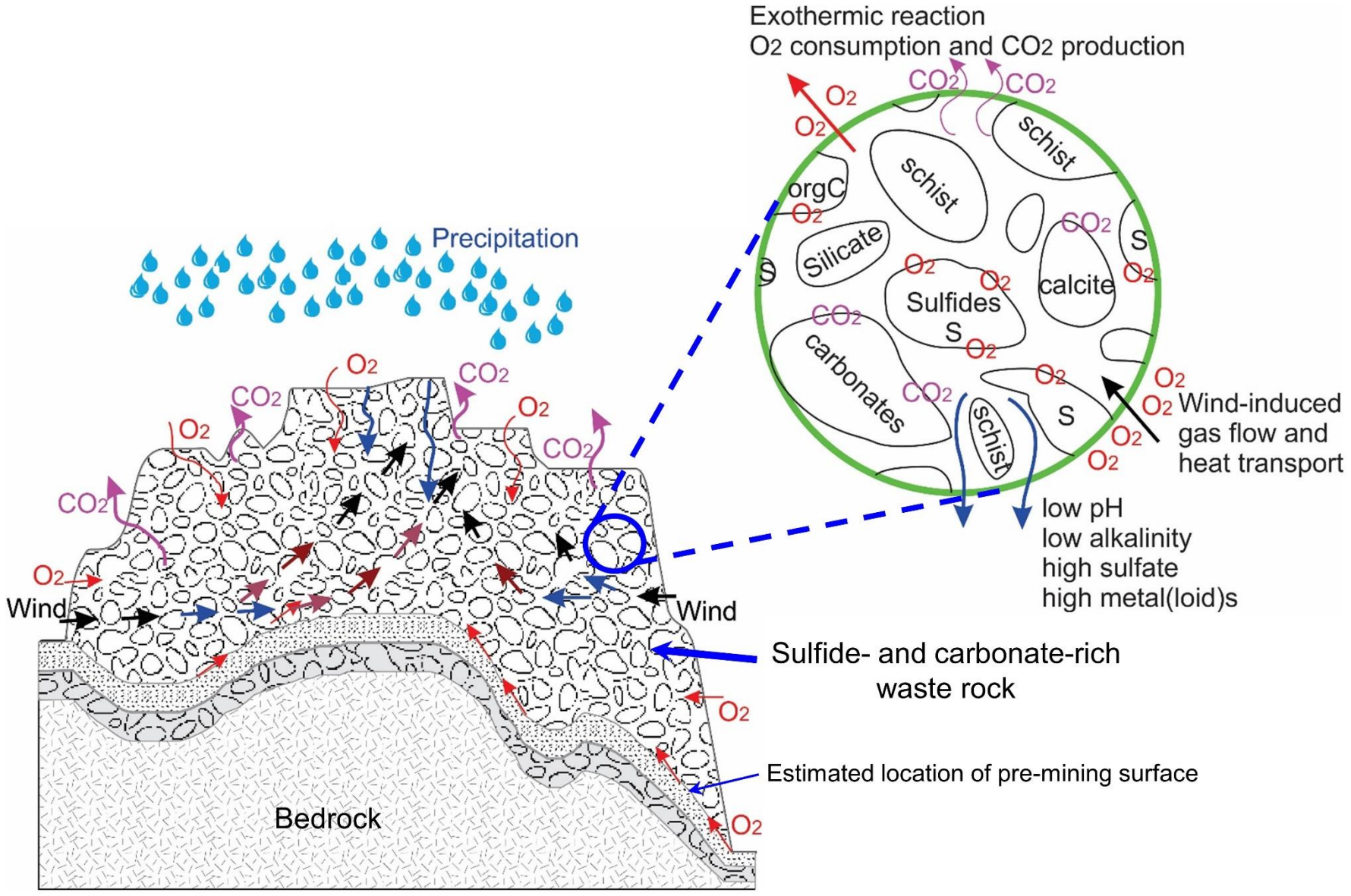
Resulting spatial variability in pore-water geochemistry



Are there sulfide cells?

Location	Max S content [wt.%]	Comments (historical records)
UW17-BH1	23.6	Not sulfide cell
UW17-BH3	23.2	Not sulfide cell
UW17-BH2	**20.7**	Sulfide cell
CH14-106-MW009	**1.6**	Sulfide cell
60M1	**17.1**	Sulfide cell

Summary



More detailed delineation in spatial variability of sulfide minerals is needed for better design of the cover plan.

Conclusions and Implications

Site-specific characterization program can strongly facilitate the decision of reclamation and remediation.

High sulfide waste rock is wide spread, not only in the so-called sulfide cells.

Part of the dumps are pretty wet at current conditions, in particular in the summer.

Water and O_2 are not the only two factors. Temperature, Fe^{3+}, and microorganisms also play roles.

Acknowledgement

NSERC CRSNG N·S·E·R·C TERRENET
(NETGP 479708-15)

Crown-Indigenous Relations and Northern Affairs Canada
Relations Couronne-Autochtones et Affaires du Nord Canada

Ontario Research Fund

Canadian Light Source
Centre canadien de rayonnement synchrotron

PARSONS

BGC

Yukon Government

Argonne NATIONAL LABORATORY
Advanced Photon Source

Lab and beamline personnel

Laura Groza
Joy Hu
David Hilger
Brent Verbuyst
Roberta Parigi
Heather Shrimpton
Filip Budimir
Julia Jamieson-Hanes
Alana O. Wang
Steven Holland
David Wilson
Peng Liu
Shuhuan Li
Yingying Liu
Eva Pakostova
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Viktoriya Bardal
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Joanne Angai
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Grant Mitchell
Arisha Imran
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⋮

Thank you for your attention!

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