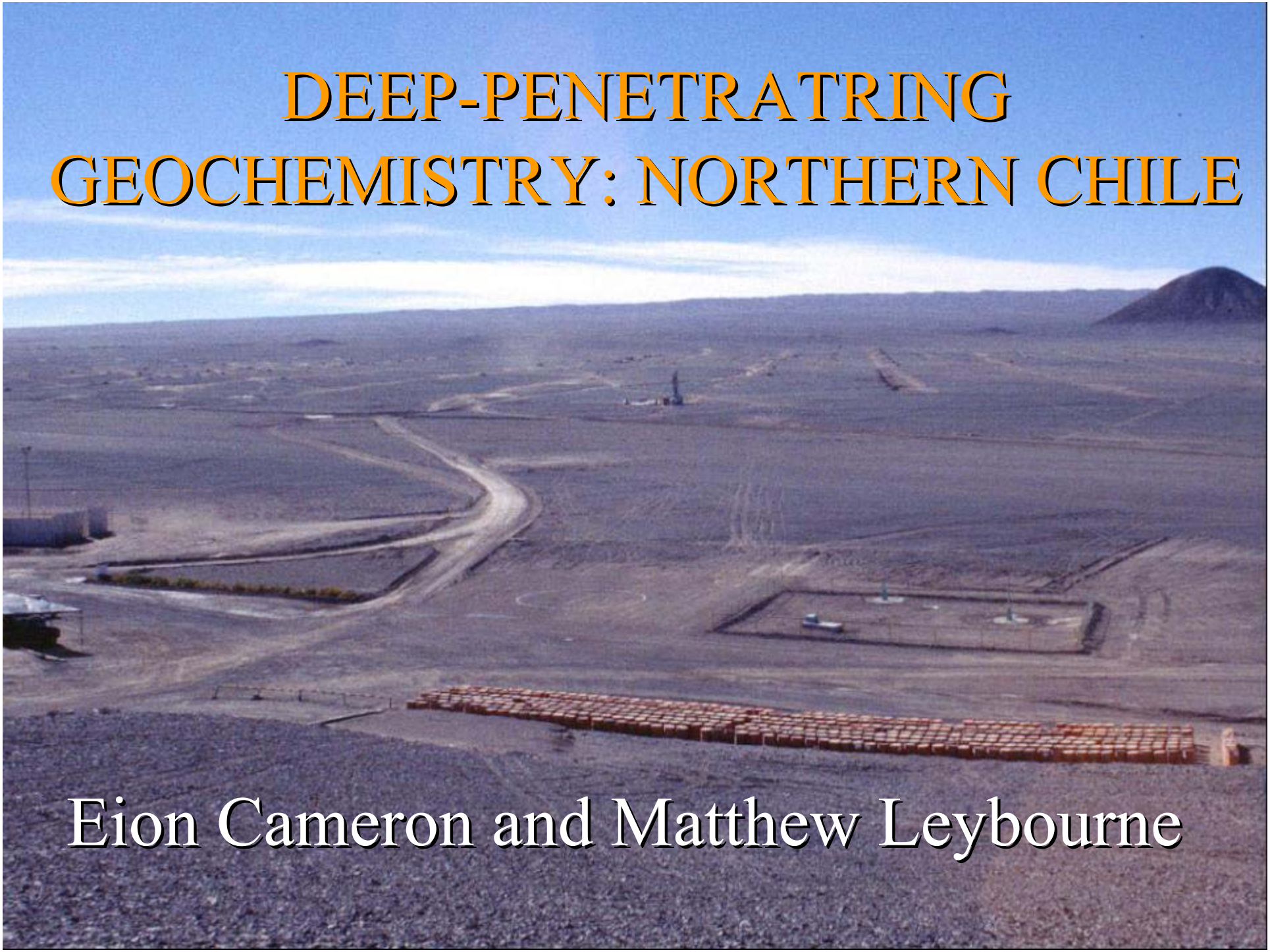
DEEP-PENETRATRING GEOCHEMISTRY: NORTHERN CHILE



Eion Cameron and Matthew Leybourne

DEEP-PENETRATING GEOCHEMISTRY

Project Sponsored by:

Canadian Mining Industry Research Organization (CAMIRO)

- Richard Alcock, Research Director
- Tom Lane, Research Director
- Bill Coker, Chair Geochemistry Committee

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- XRAL Labs

Principal Co-Participants

•Abitibi Belt:

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•Nevada:

•Mary Doherty, Patrick Highsmith, Robert Jackson

•Chile:

•Matthew Leybourne

Studies in Chile: Porphyry Deposits Covered by Miocene Gravels

Deposit	Grade	Depth of Cover
Spence	400 Mt 1.0% Cu	30 to 180 m
Gaby Sur	400 Mt 0.54% Cu	20 to 40 m
Mansa Mina	325 Mt 1.0% Cu	50 to >300 m

Radomiro Tomic: Miocene Gravel over Porphyry

Studies Carried Out in Chile

- Soil Sampling and Analysis:

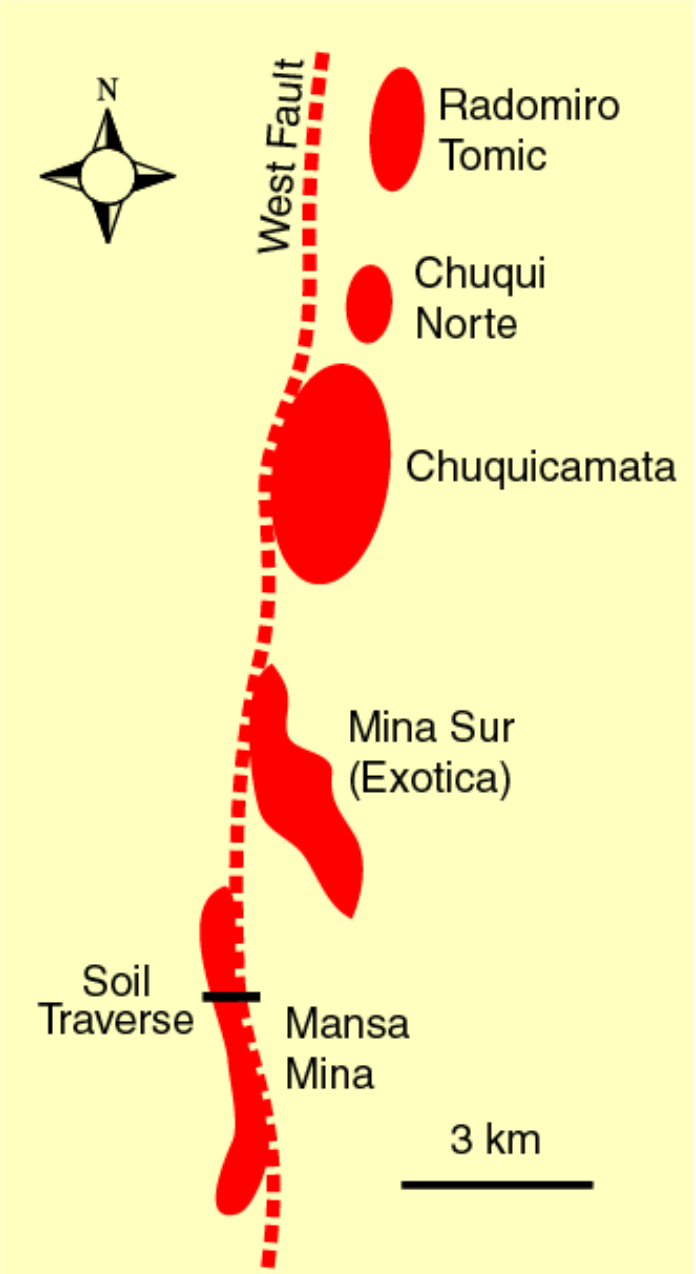
  Leaches: Deionised Water, Enzyme, Ammonium Acetate, MMI, Hydroxylamine, Aqua Regia

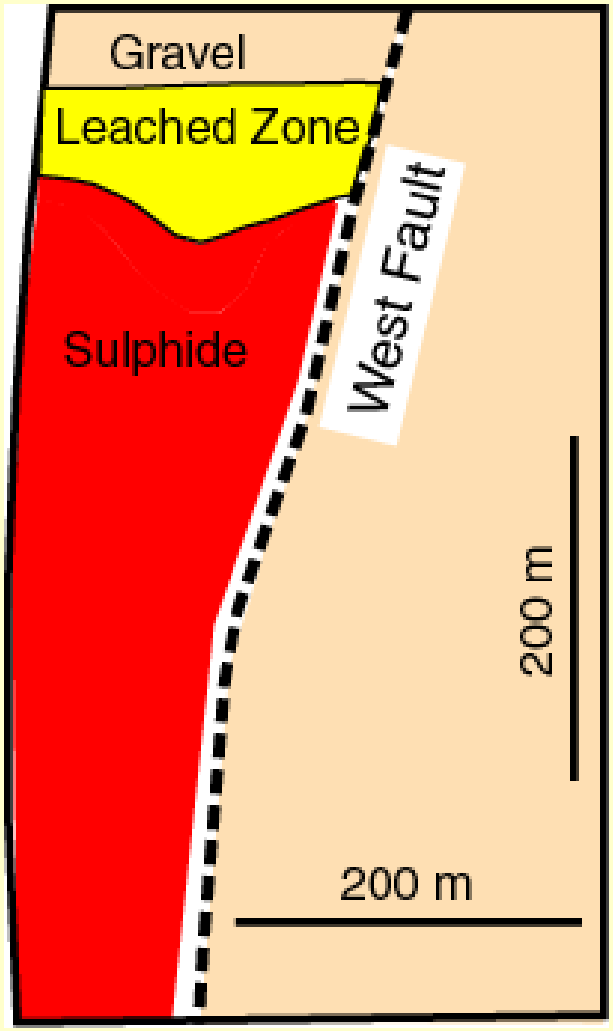
- Groundwater Sampling and Analysis

- Stable Isotope Analysis: Groundwater and Soils

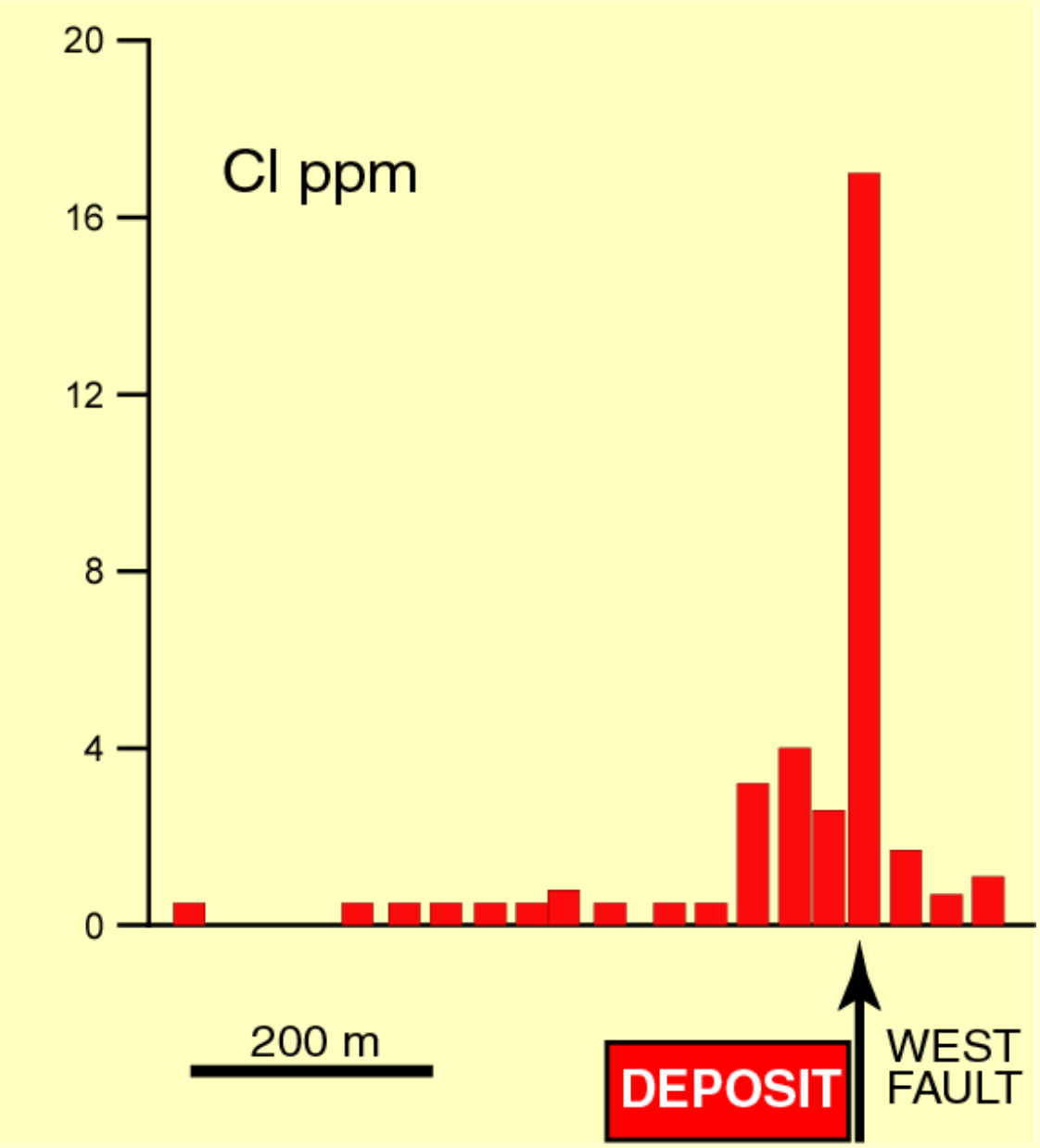
- Metals in Soil Gas

Mansa Mina - 325 Mt 1.0% Cu

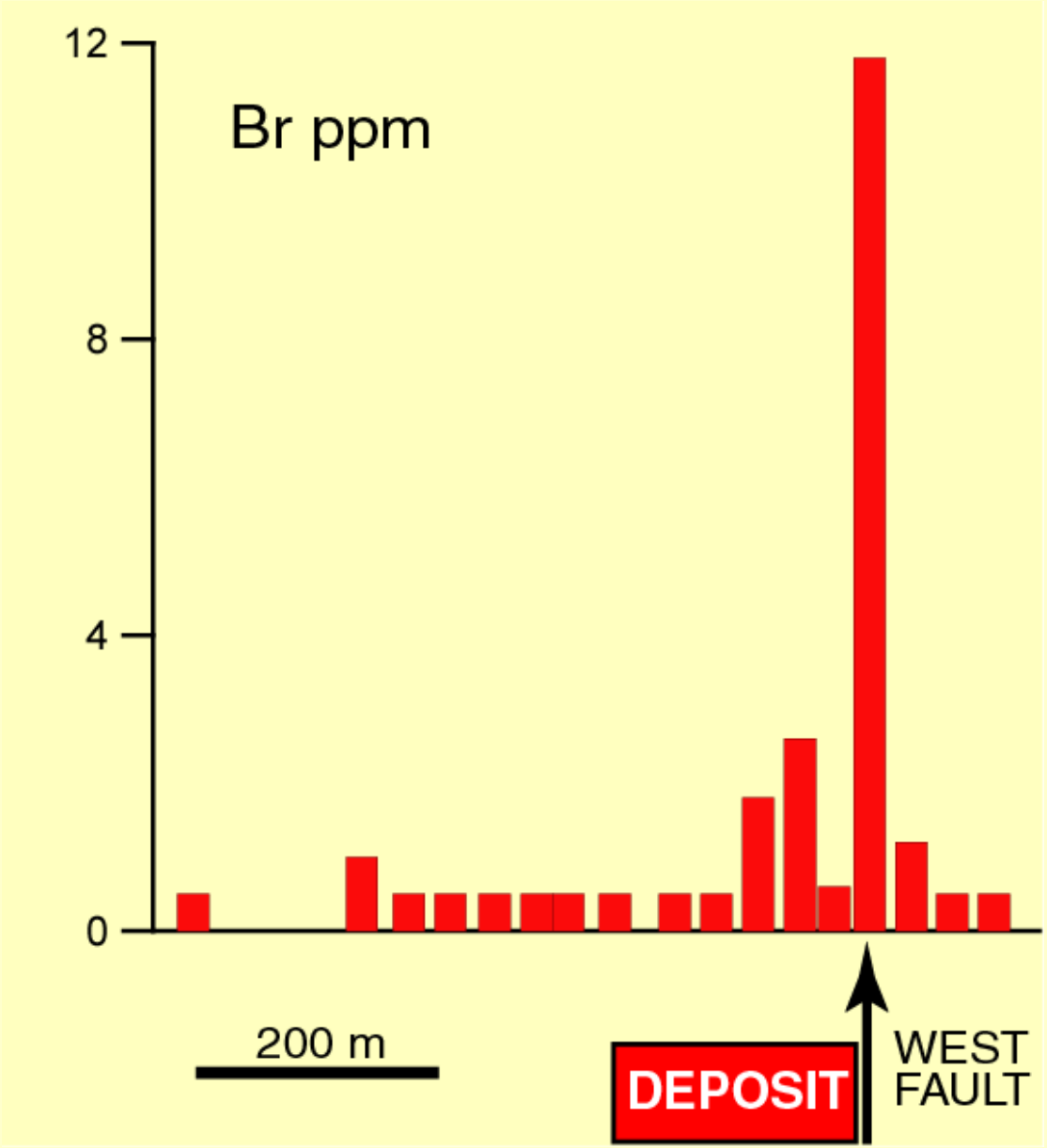




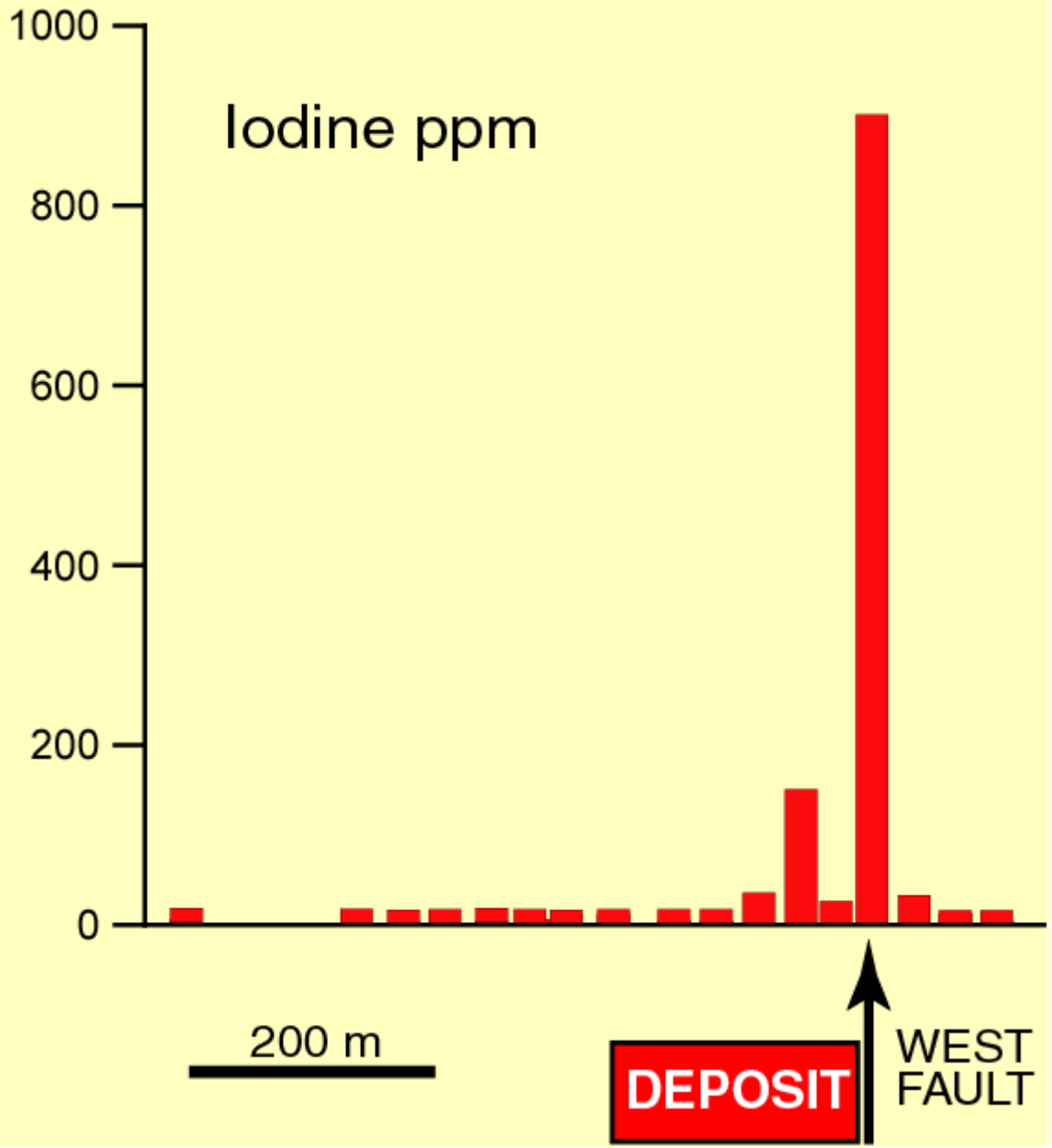
Mansa Mina: Chlorine in Soil (Enzyme Leach)



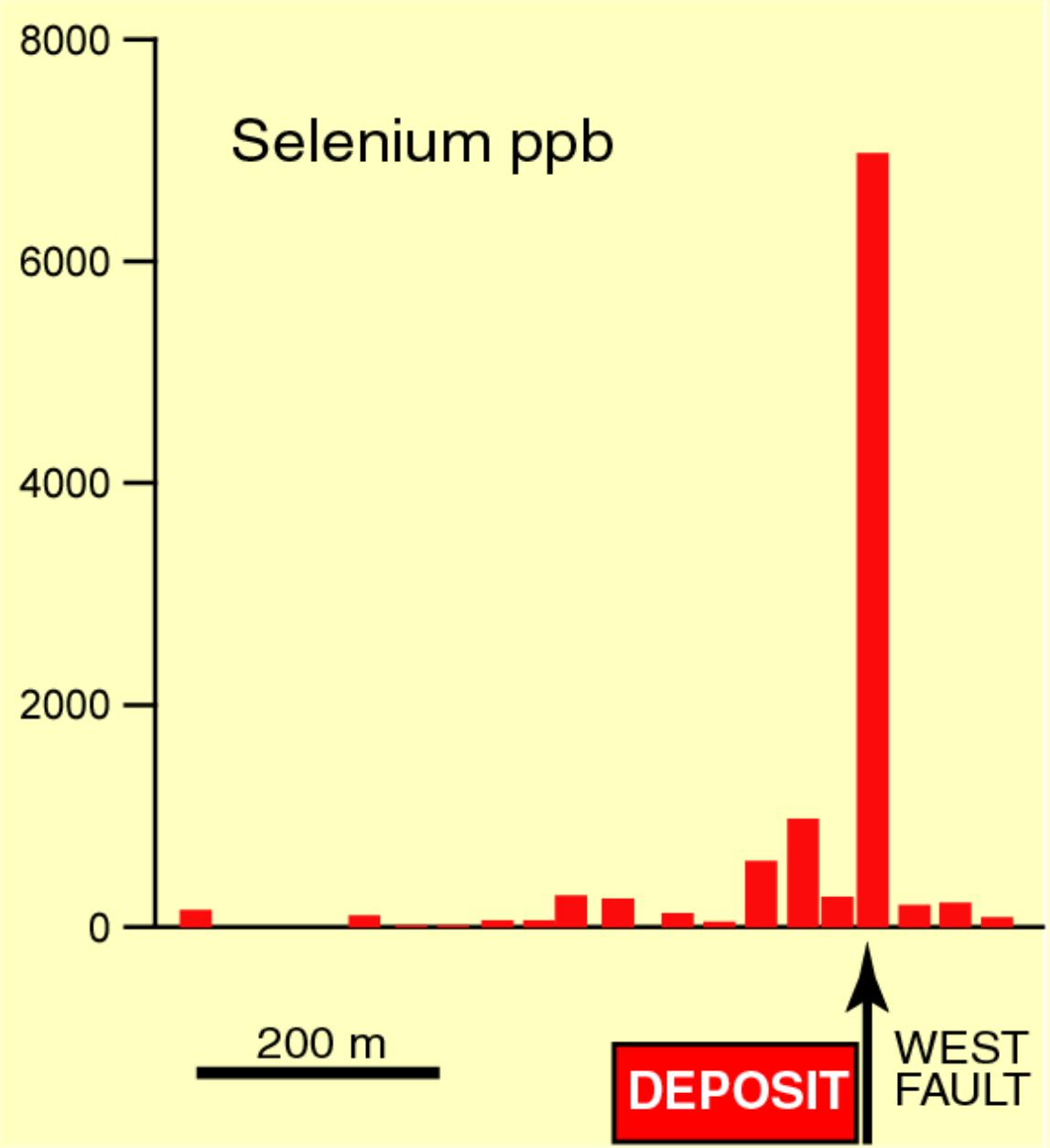
Mansa Mina: Bromine in Soil (Enzyme Leach)



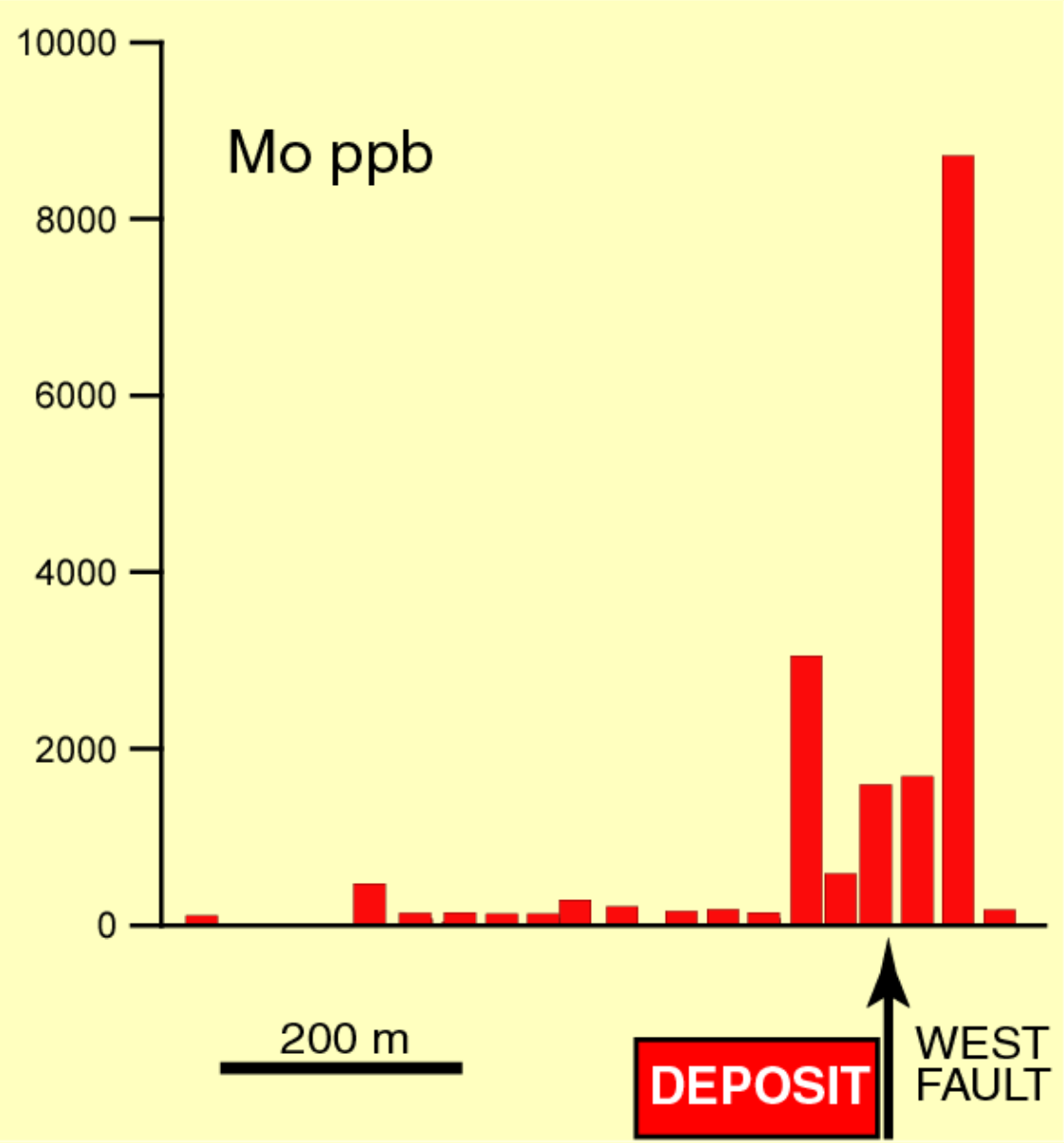
Mansa Mina: Iodine in Soil (Enzyme Leach)



Mansa Mina: Selenium in Soil (Enzyme Leach)



Mansa Mina: Molybdenum in Soil (Enzyme Leach)



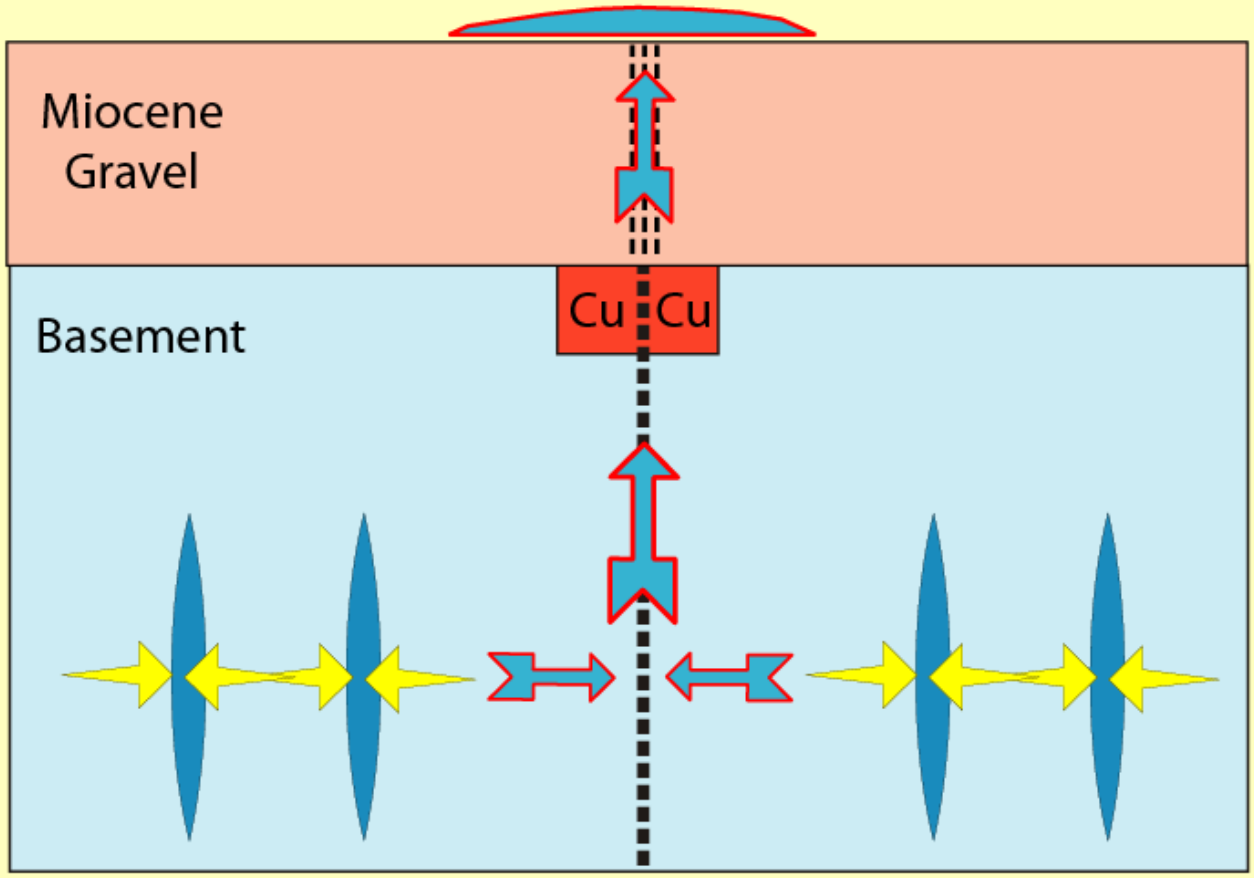
Mansa Mina

Anomalous Elements in Soils Above West Fault are:

1. Constituents of saline groundwater in Chile: NaCl, Br, I
2. Porphyry Indicator Elements: Se, Re, Mo, Cu, As

Interpretation: Seismic Pumping of Saline Groundwater to Surface above West Fault

Surface Flooding by Seismic Pumping



Mineralized Groundwater Passes up Fracture Zone in Gravels to Surface

Water Ascends Fault, Entraining Groundwater from Porphyry Copper

Earthquake: Dilational Collapse, Water Expelled from Fractures to Fault

Examples of Earthquake-Induced Surface Flooding

Desert Areas of Iran: Earthquakes of 1903, 1923 and 1930

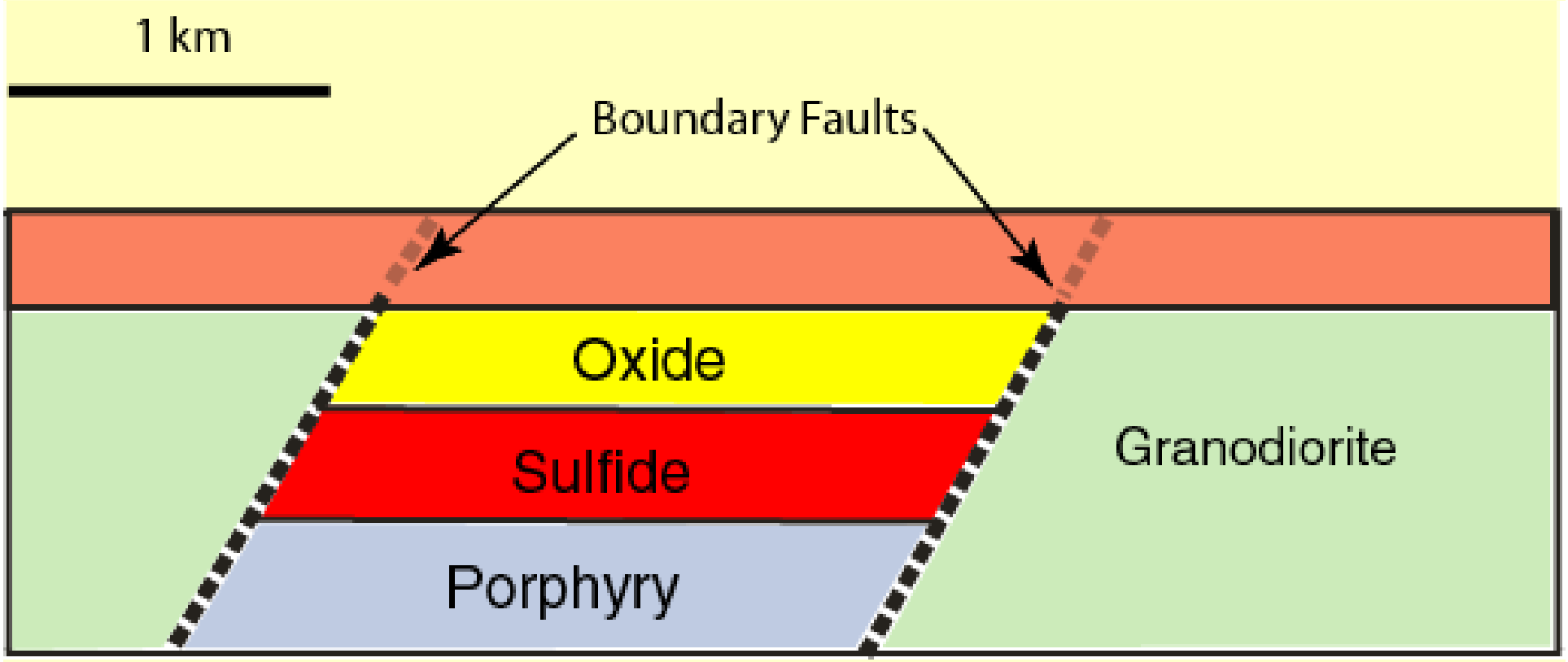
Matsuhiro Earthquake, Japan

Kern County Earthquake, California, 1952

Hebgen Lake Earthquake, Montana, 1959

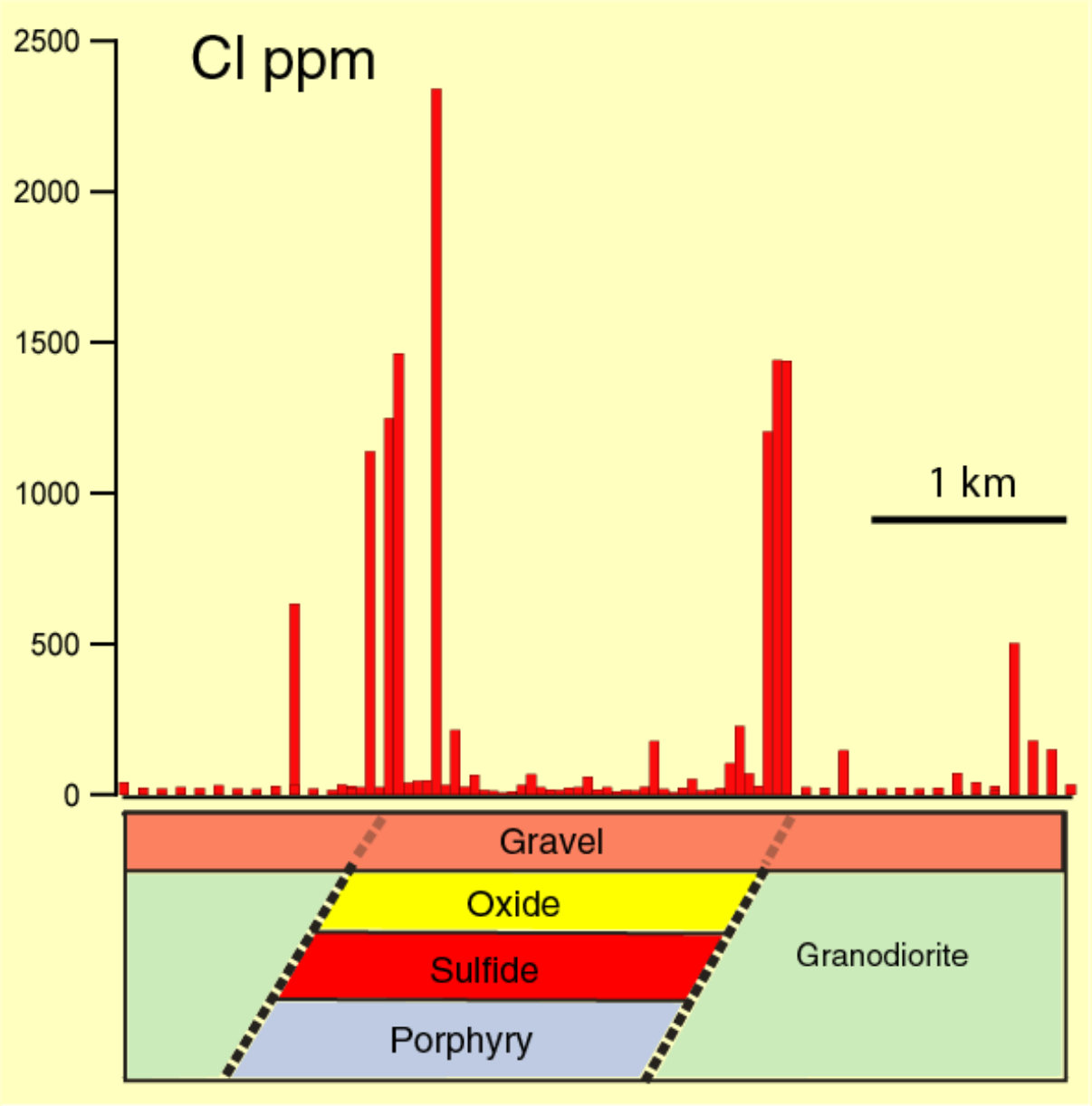
Yucca Flats, Nevada: Basement Fluids have risen through >500 m of vadose zone along permeable fault zone

Gaby Sur: 400 Mt 0.54% Cu
40 m of Miocene gravel cover

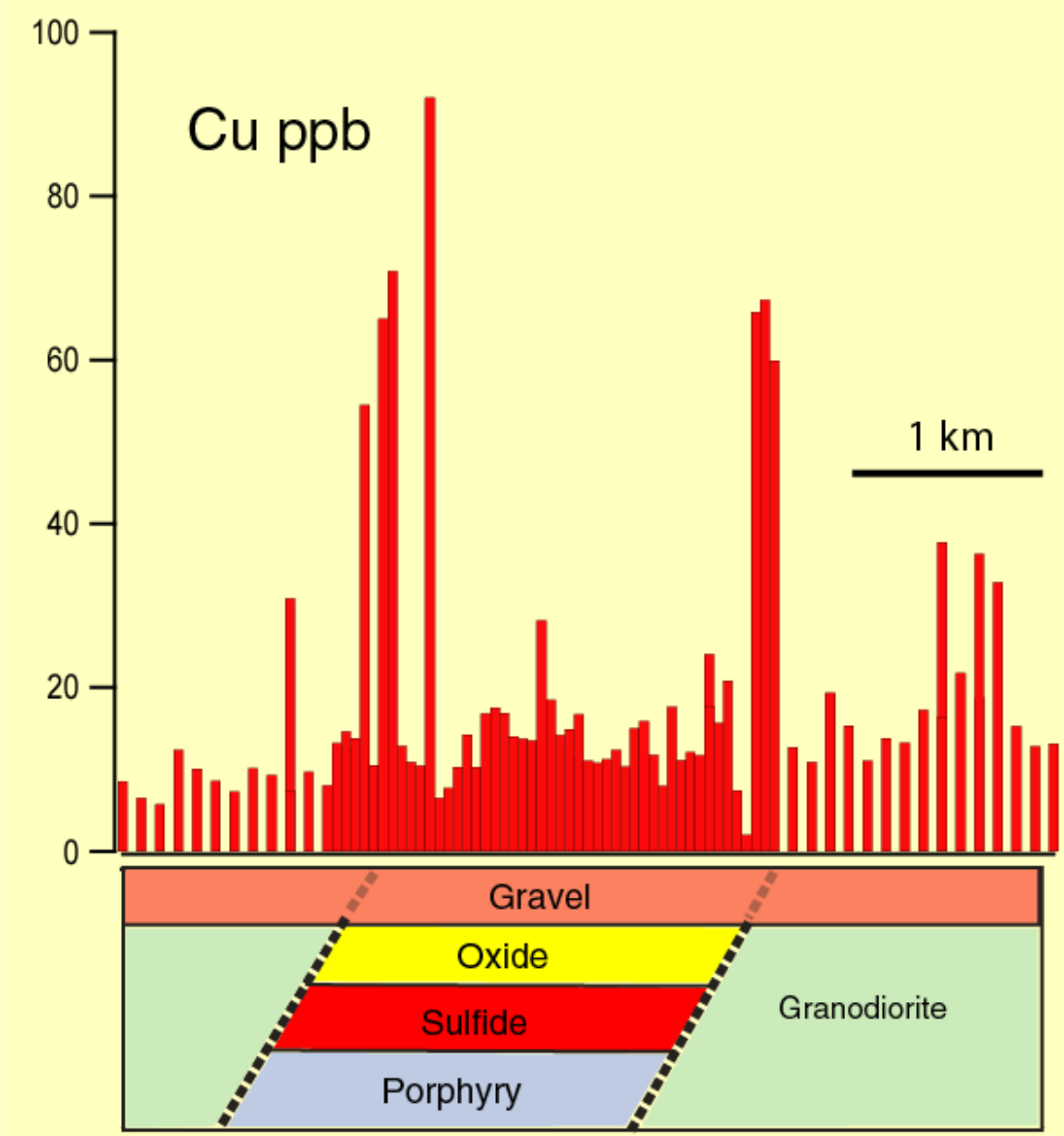


Gaby Sur: Surface of Miocene Gravels

Gaby Sur: Chlorine in Soil (Enzyme Leach)

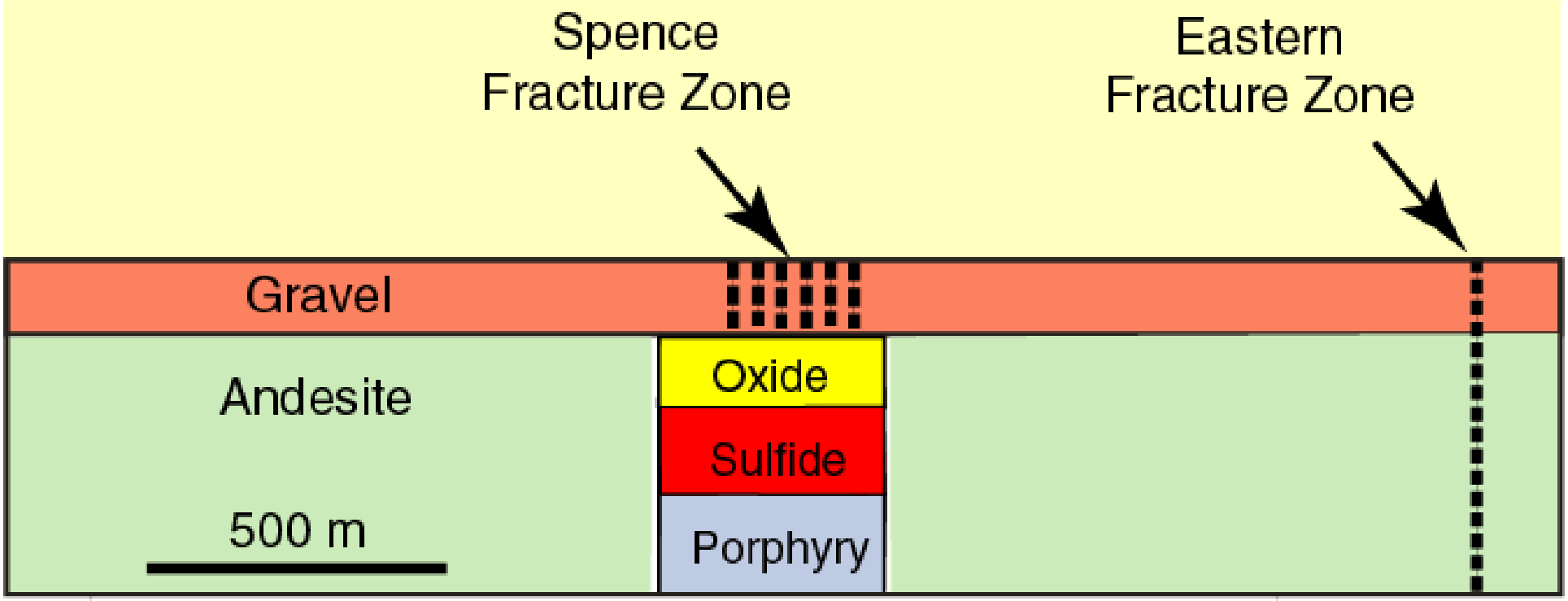


Gaby Sur: Copper in Soil (Enzyme Leach)

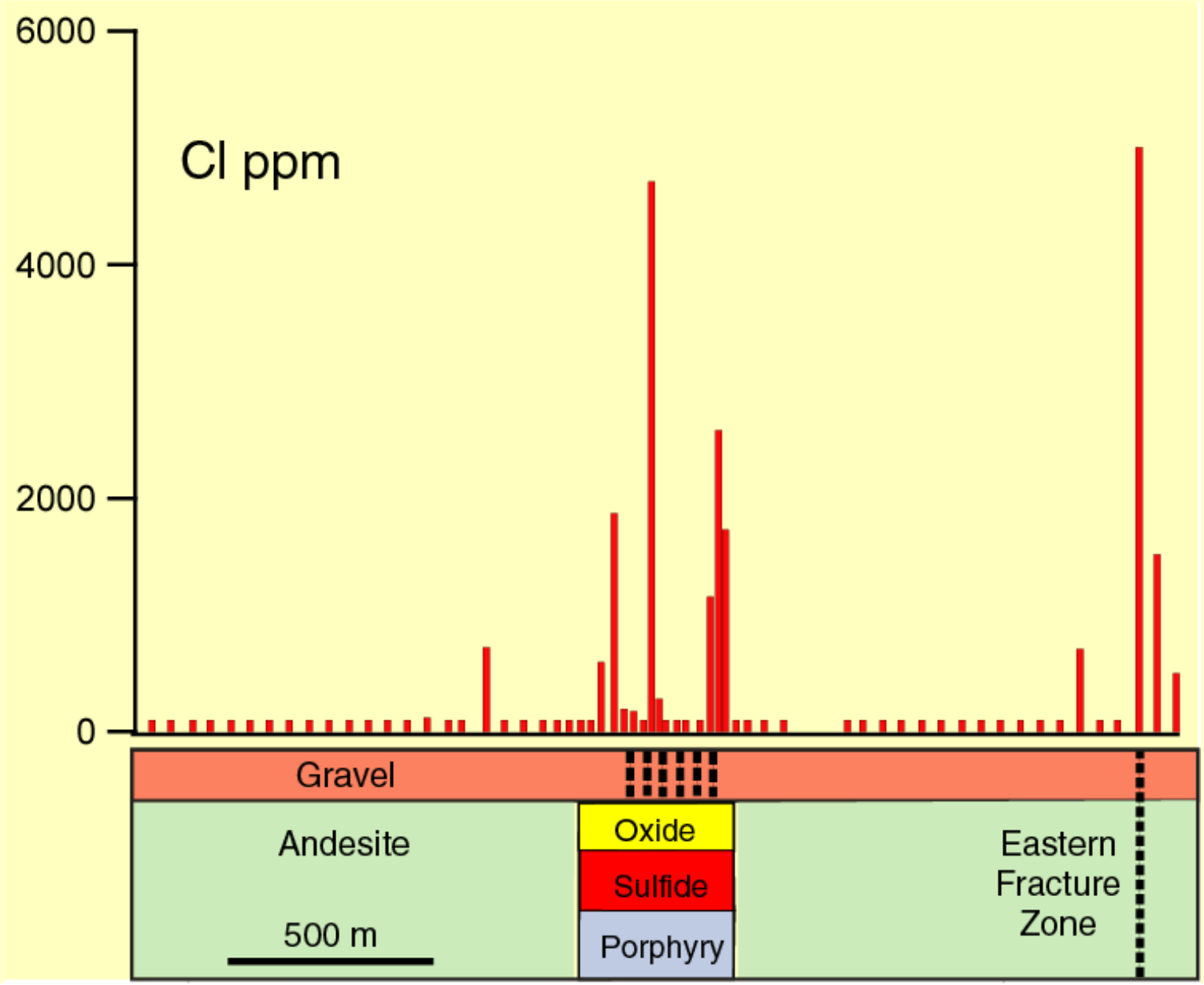


Spence: Gravel Surface Over Ore Zone

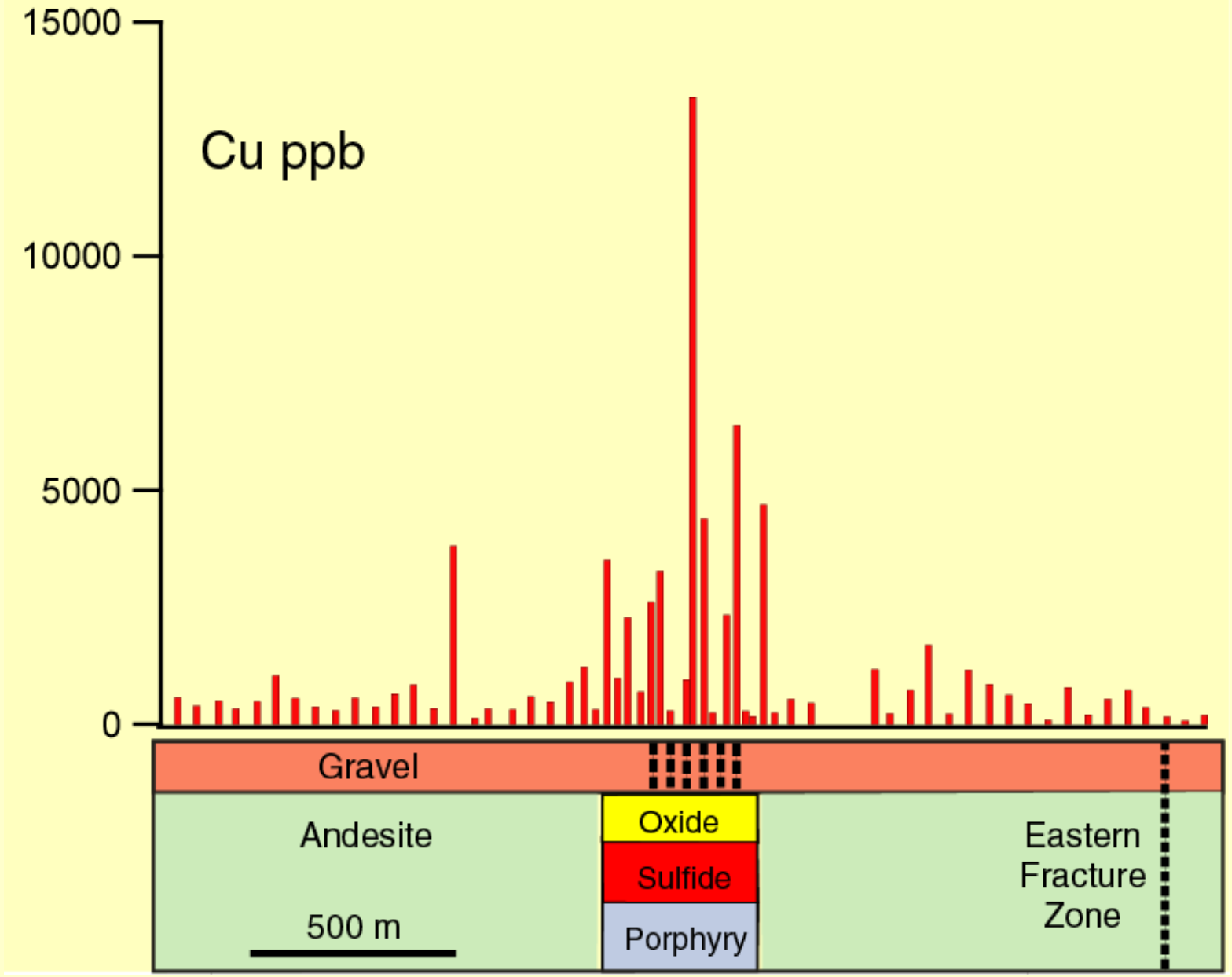
Spence: 400 Mt 1.0% Cu
30-180 m Miocene Gravel Cover



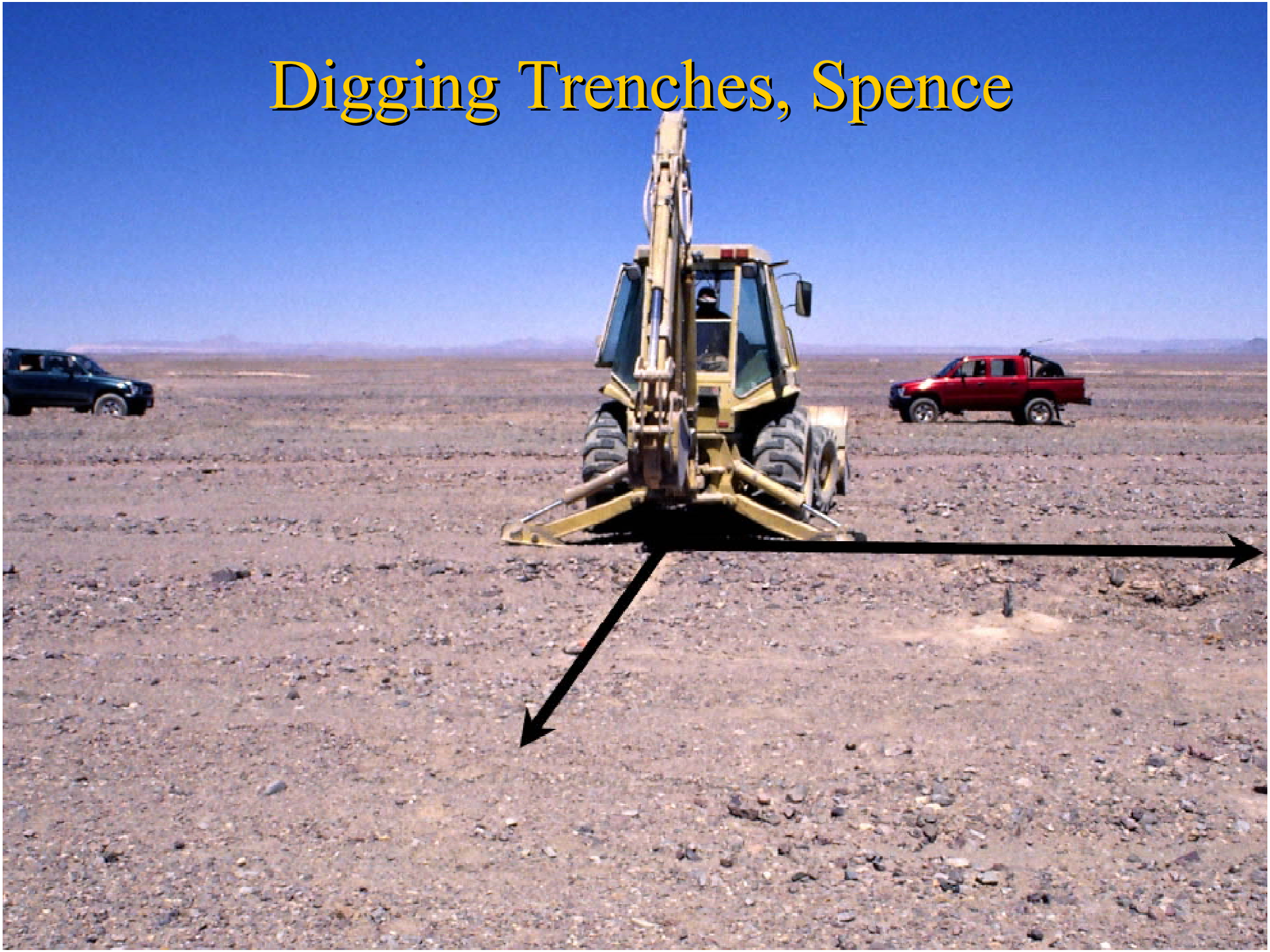
Spence: Chlorine in Soil (Enzyme Leach)



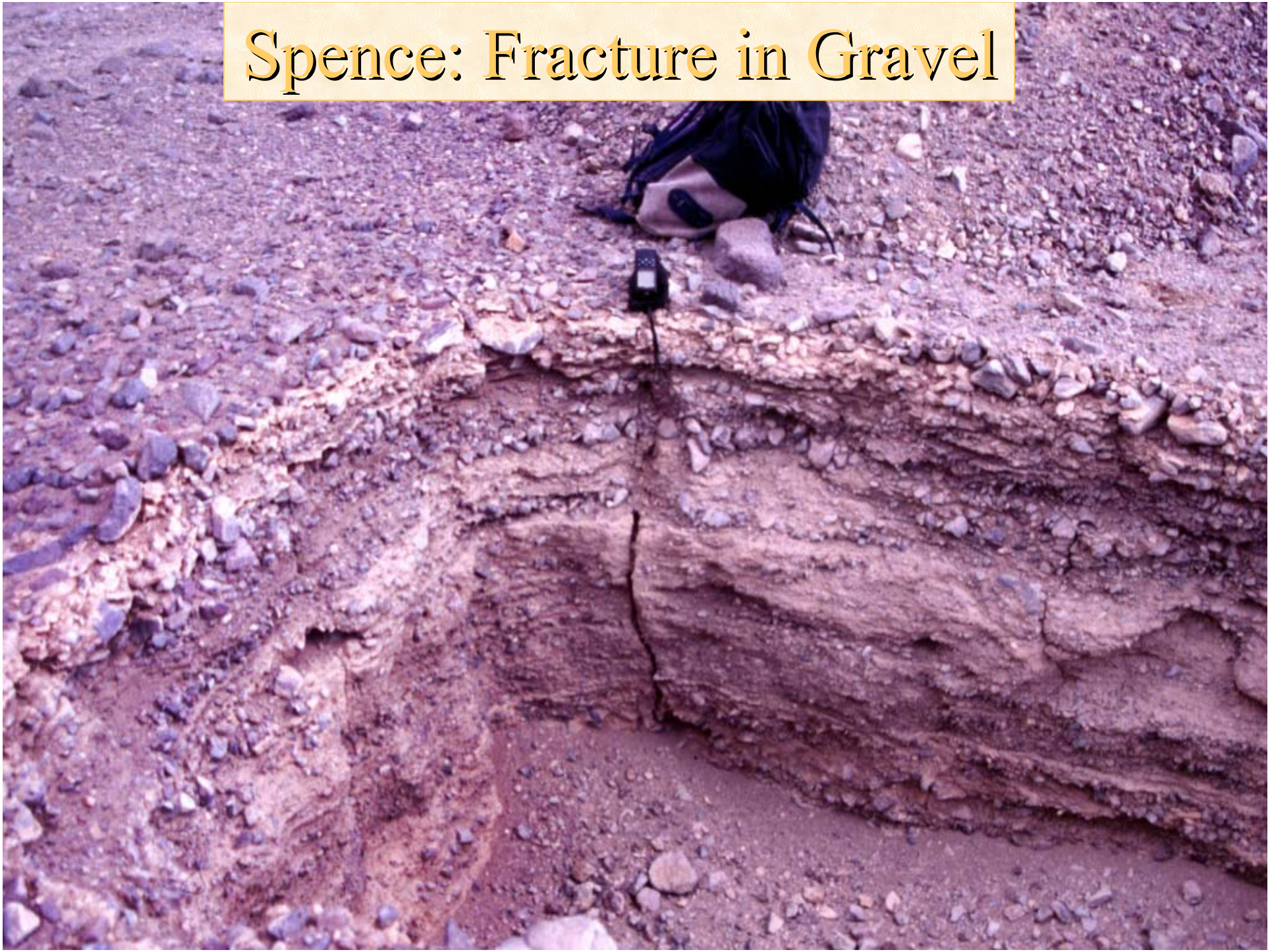
Spence: Copper in Soil (Enzyme Leach)



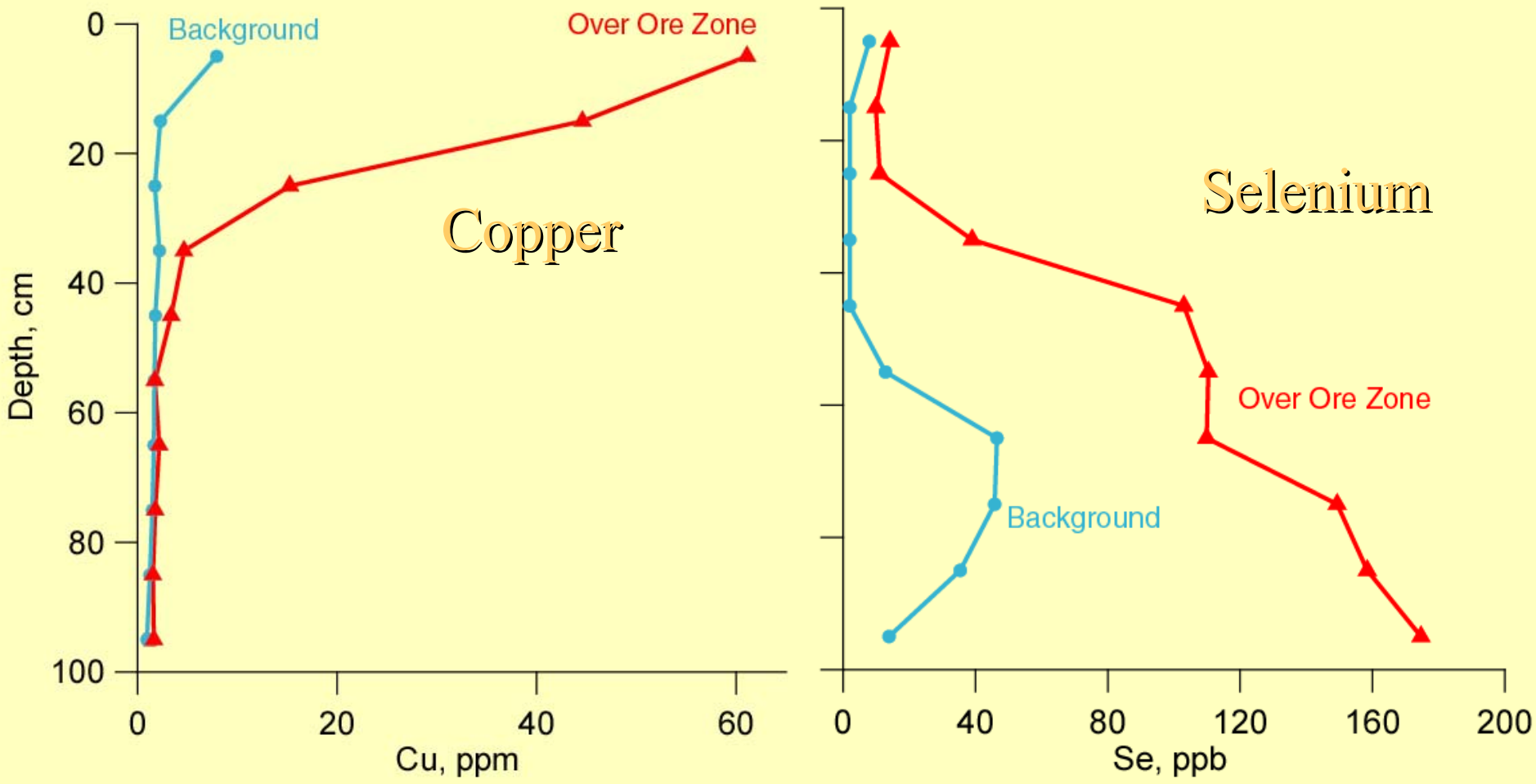
Digging Trenches, Spence



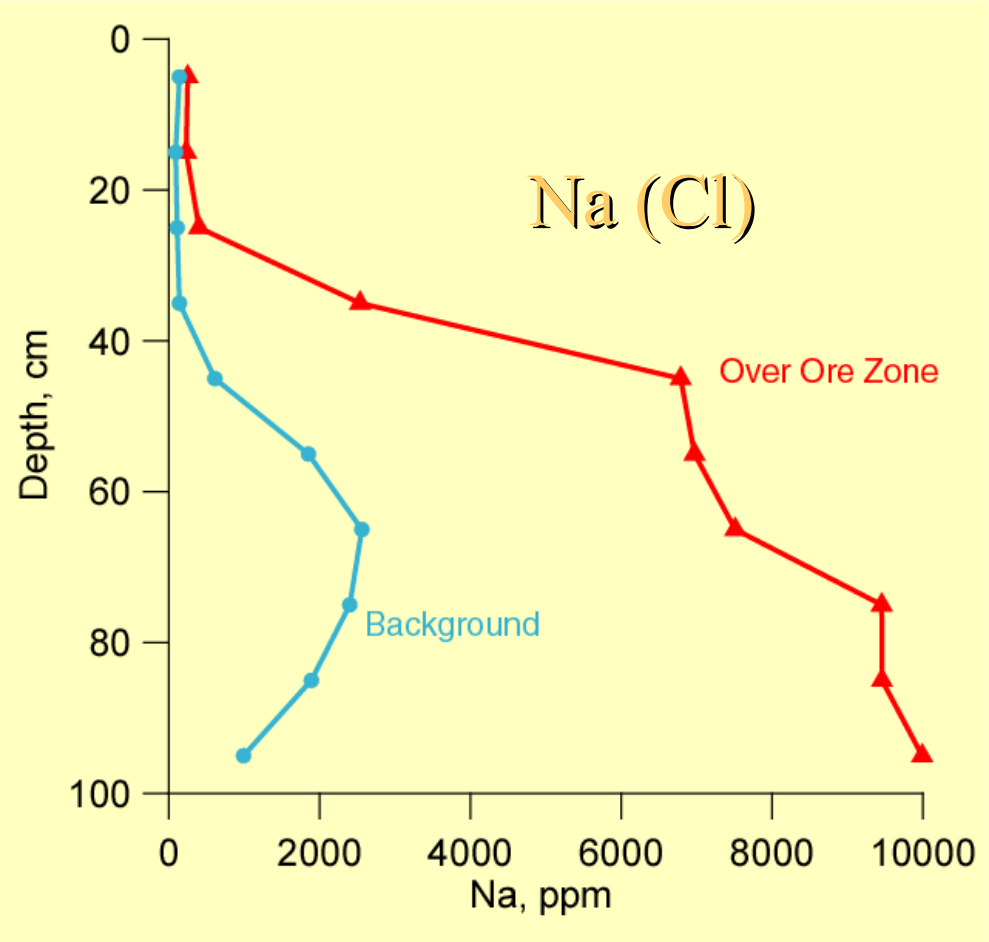
Spence: Fracture in Gravel

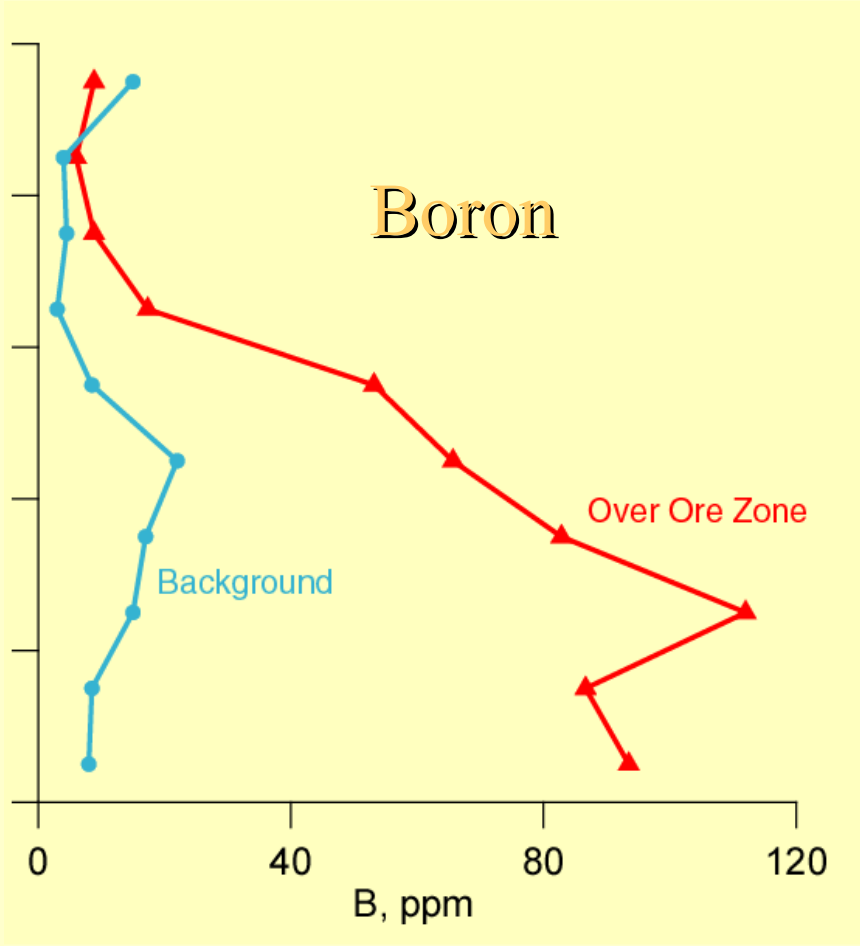


Trench Profiles – Cu (Cation) vs. Se (Anion) Cold Hydroxylamine



Trench Profiles – Na(Cl) and Boron (anion) Cold Hydroxylamine





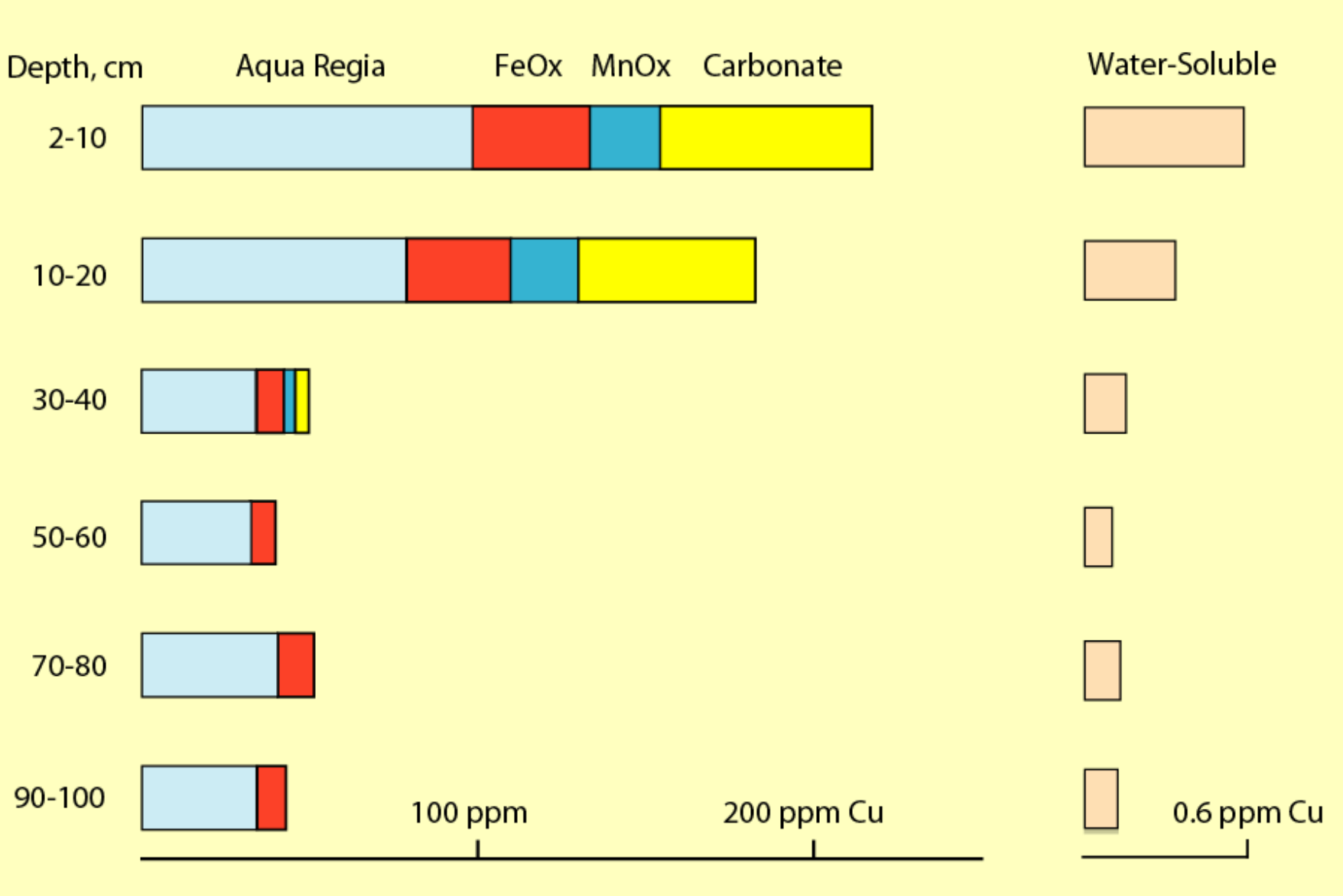
Interpretation of Distribution of Elements in Soil Profiles

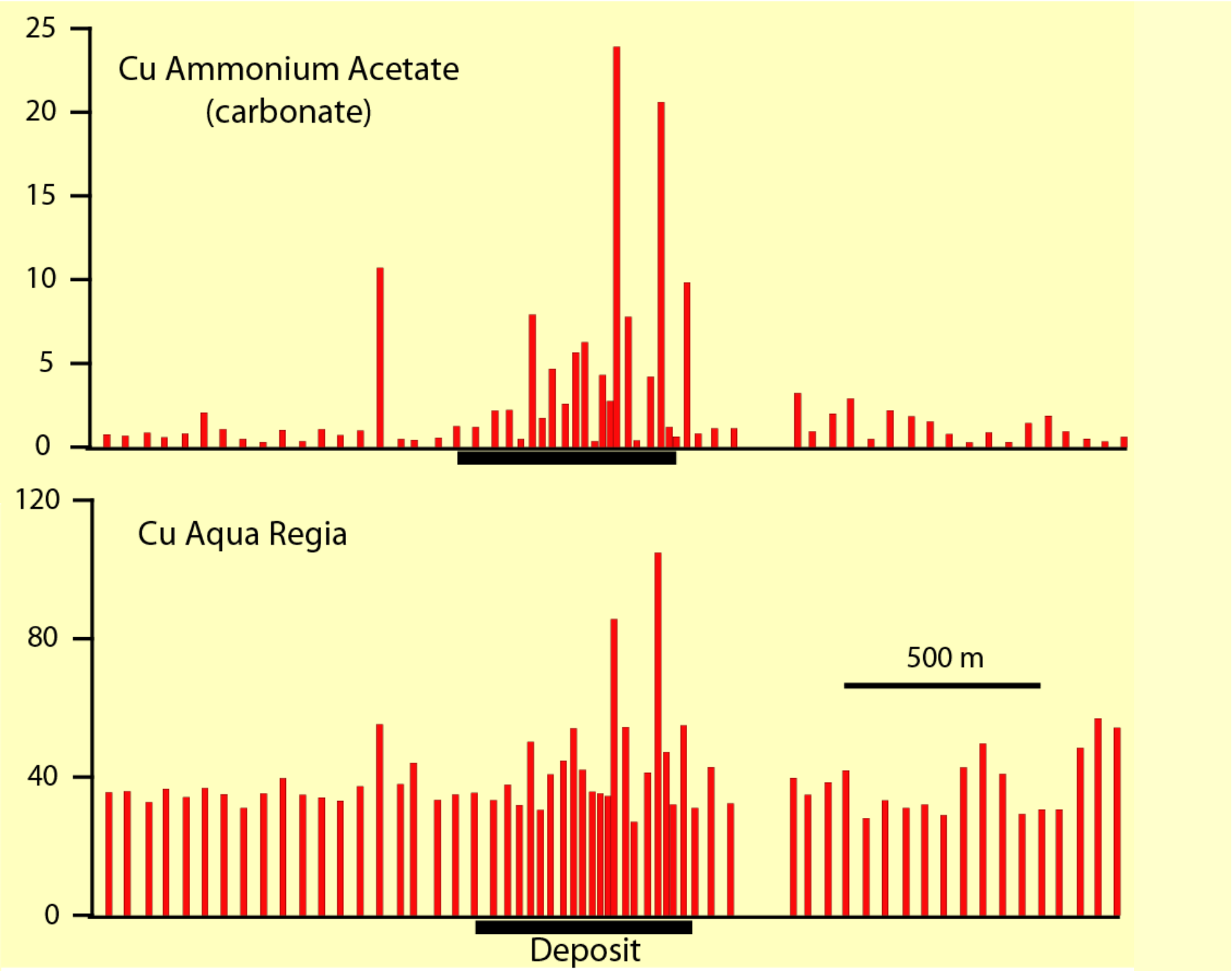
- After seismic pumping of mineralized groundwater to the surface and evaporation, elements are redistributed by the rare rainfall of the Atacama Desert.

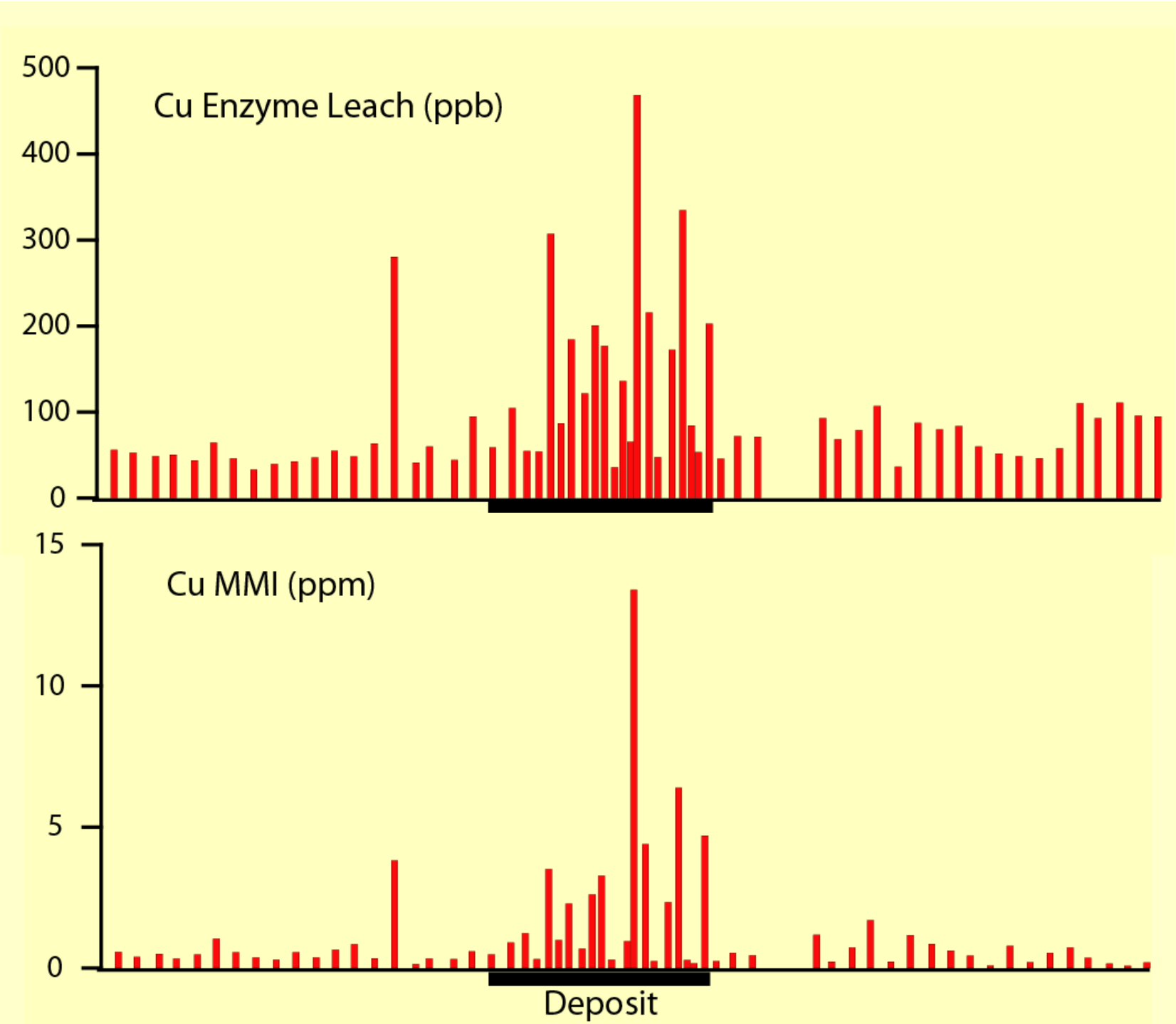
- Copper as a cation is surface-active and is readily adsorbed by negatively-charged colloids and surfaces near the surface, then incorporated into secondary minerals.

- NaCl plus elements dissolving as anions: Boron, Selenium, Arsenic and Gold, are not easily adsorbed and migrate to depth.

Sequential Leach, Spence Soil Profile: Copper




25
20
15
10
5
0
Cu Ammonium Acetate
(carbonate)
120
80
40
0
Cu Aqua Regia
500 m
Deposit


500
400
300
200
100
0
Cu Enzyme Leach (ppb)
15
10
5
0
Cu MMI (ppm)
Deposit

Conclusions

1. Porphyry Deposits in Basement Covered by 10 My Miocene Gravels
2. Basement Faults Propagate up through Gravels as Fracture Zones
3. Seismic Pumping of Mineralized Groundwaters to Surface
4. Rainfall Redistributes Elements in Soil: Cations (Cu) Remain Near Surface while NaCl and Anions Removed to Depth
5. Elements Incorporated into Soil Minerals: Carbonate, Fe and Mn Oxides, which can be Extracted by Selective Leaches.