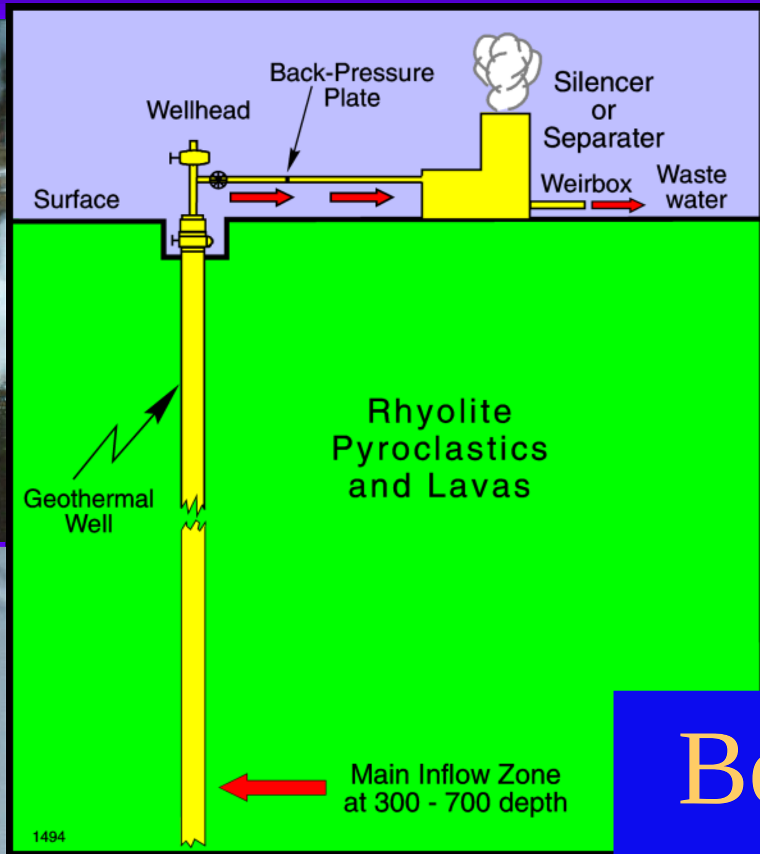
Fluid mixing
as a mechanism for bonanza grade epithermal gold formation

Terry Leach*

&

Greg Corbett

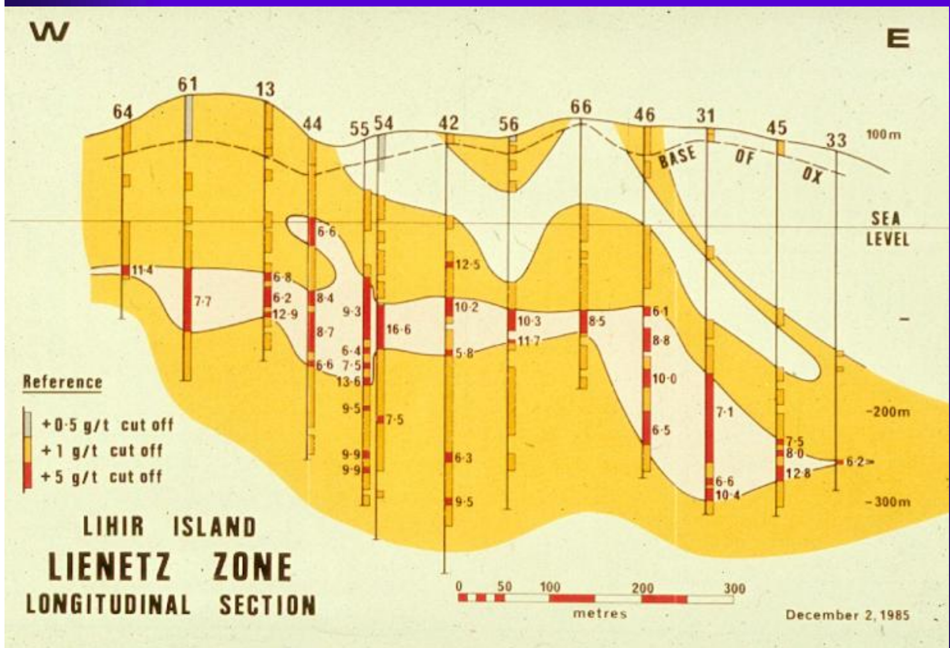


Schematic Diagram of a Geothermal Well and Surface Pipework - Broadlands New Zealand

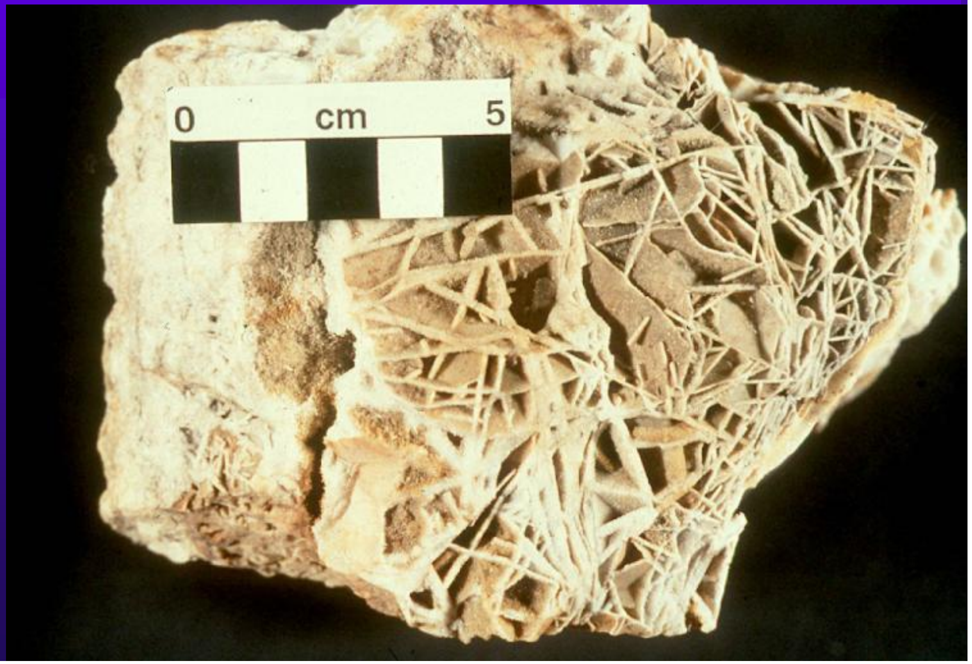
Lea

Boiling

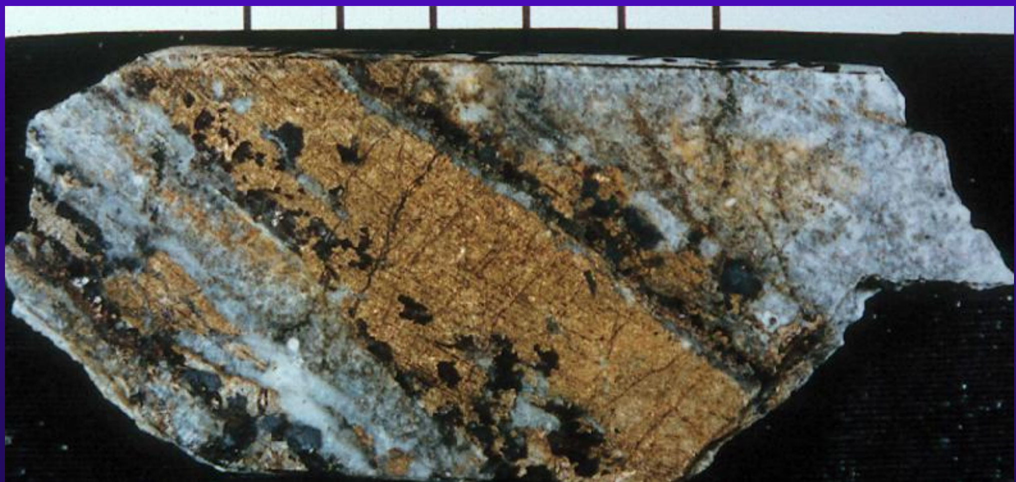
Lihir Island
1984

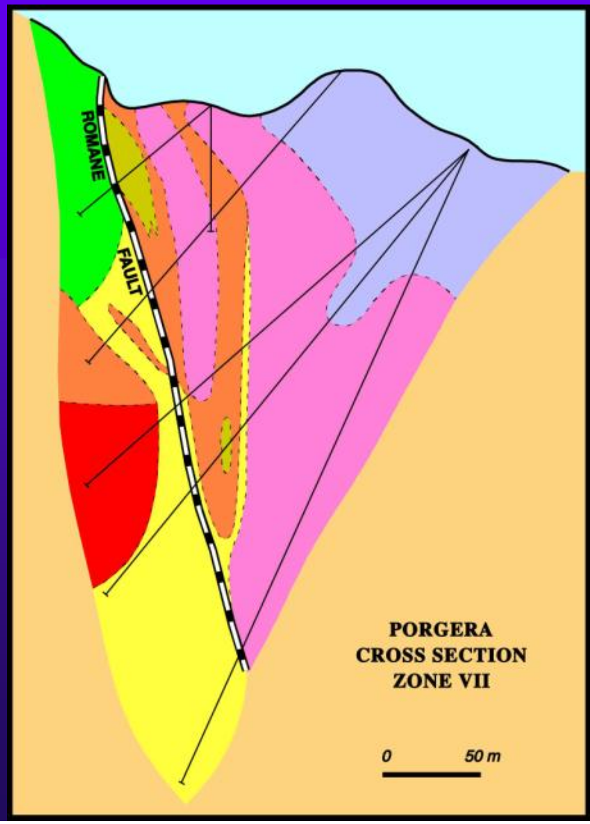


Boiling textures

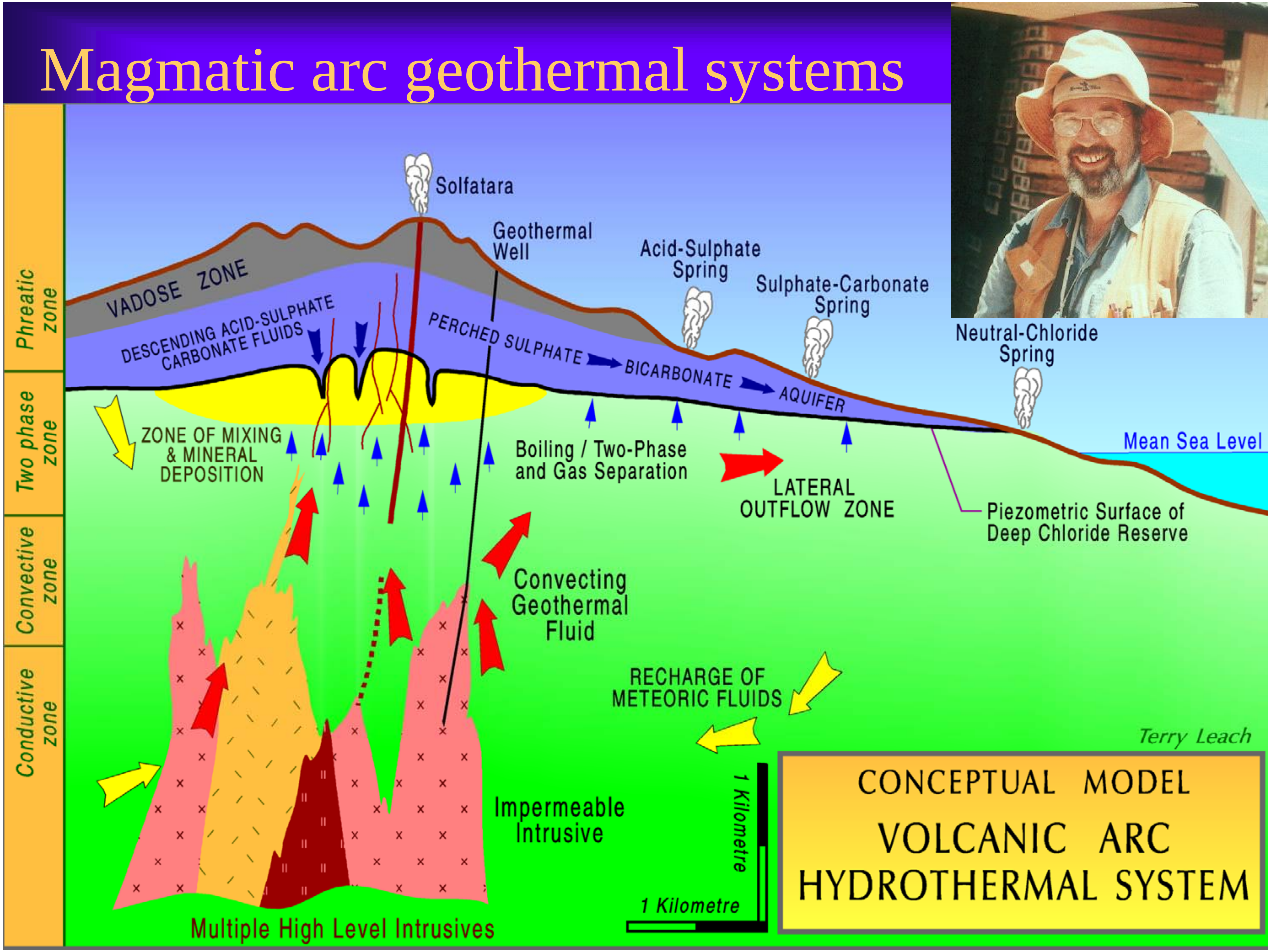


Porgera Zone VII

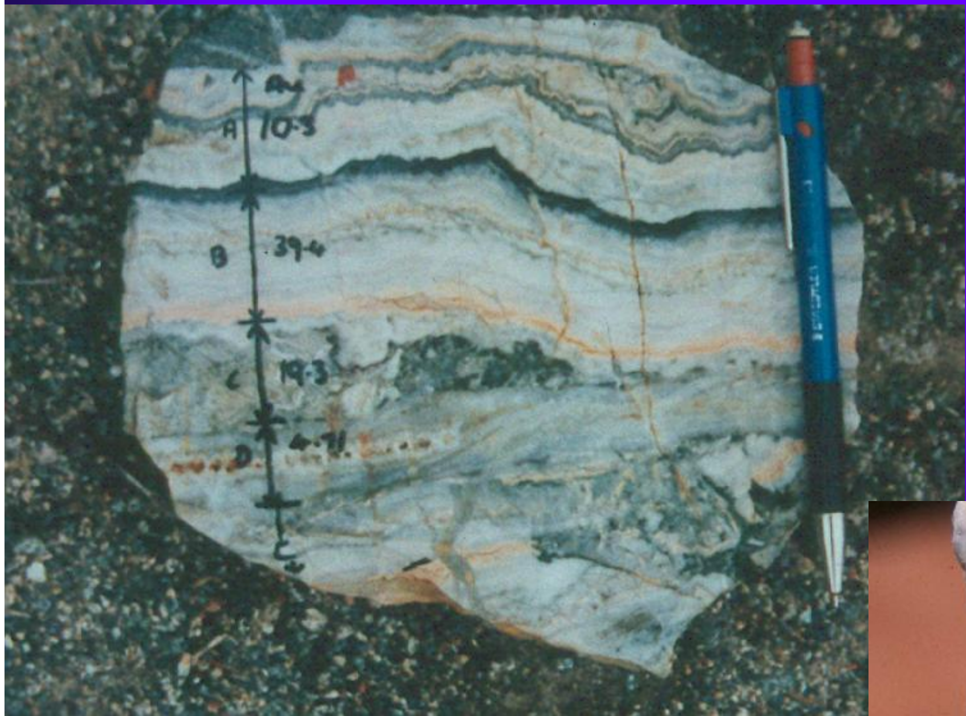




Magmatic arc geothermal systems

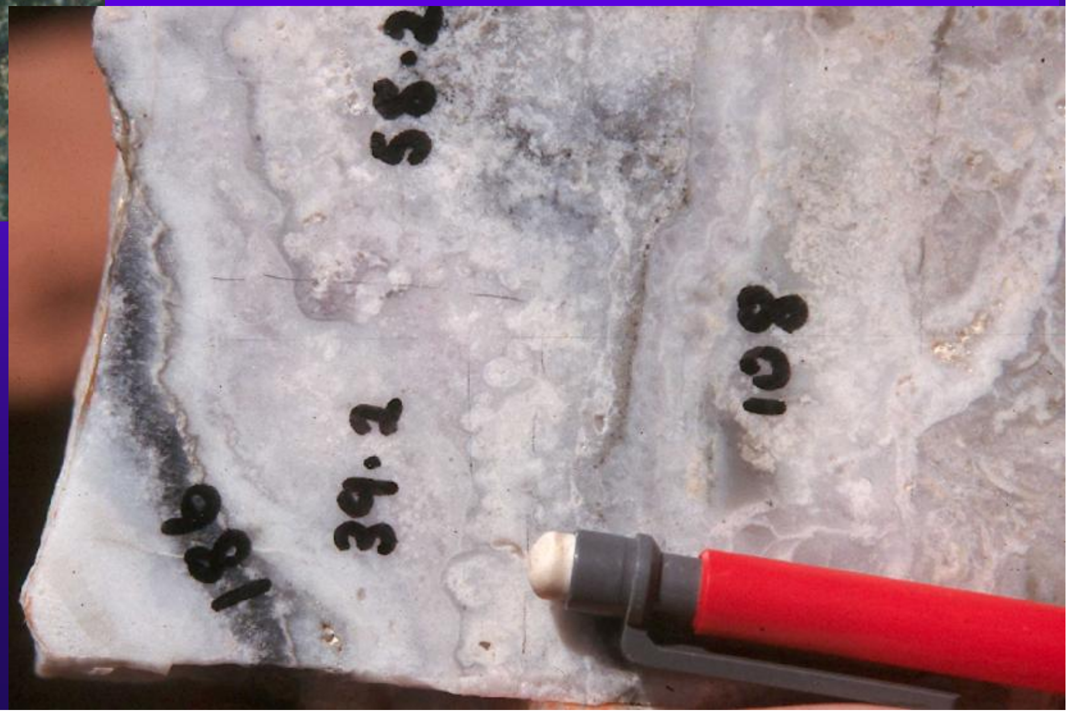


Character sampling

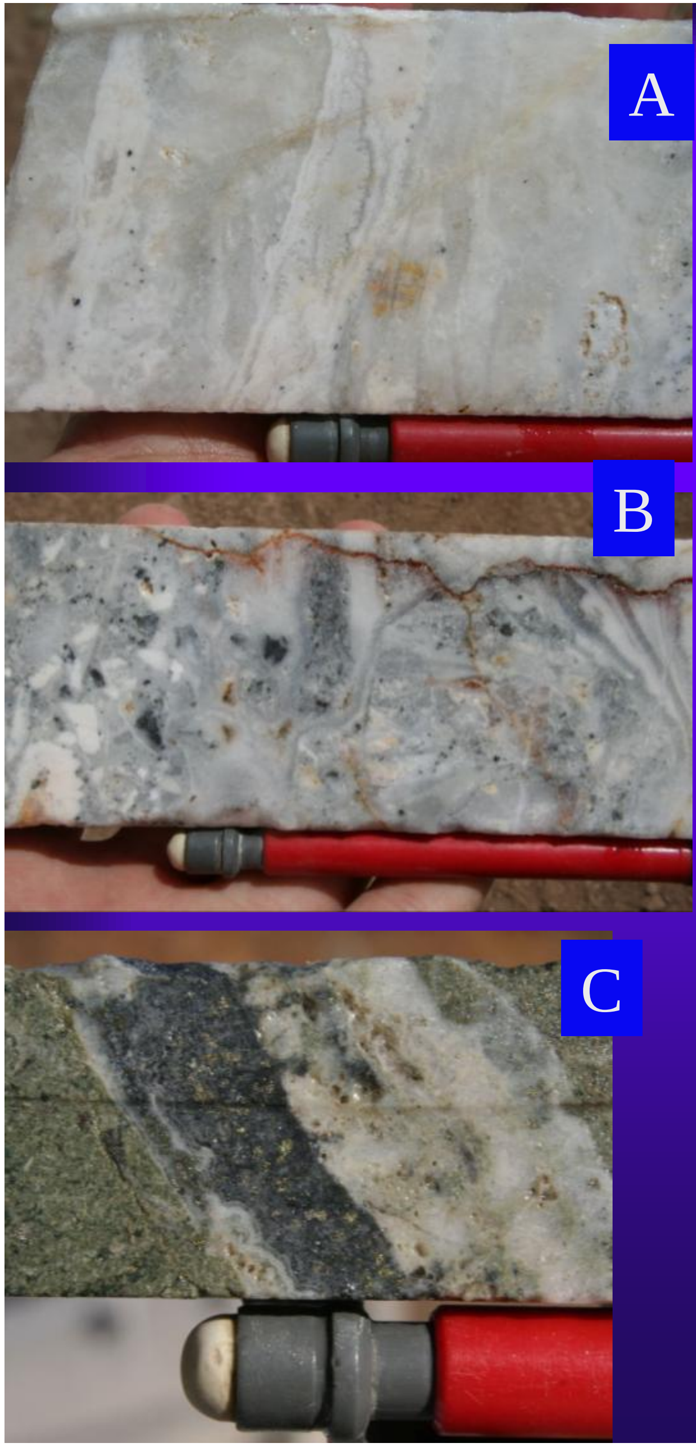


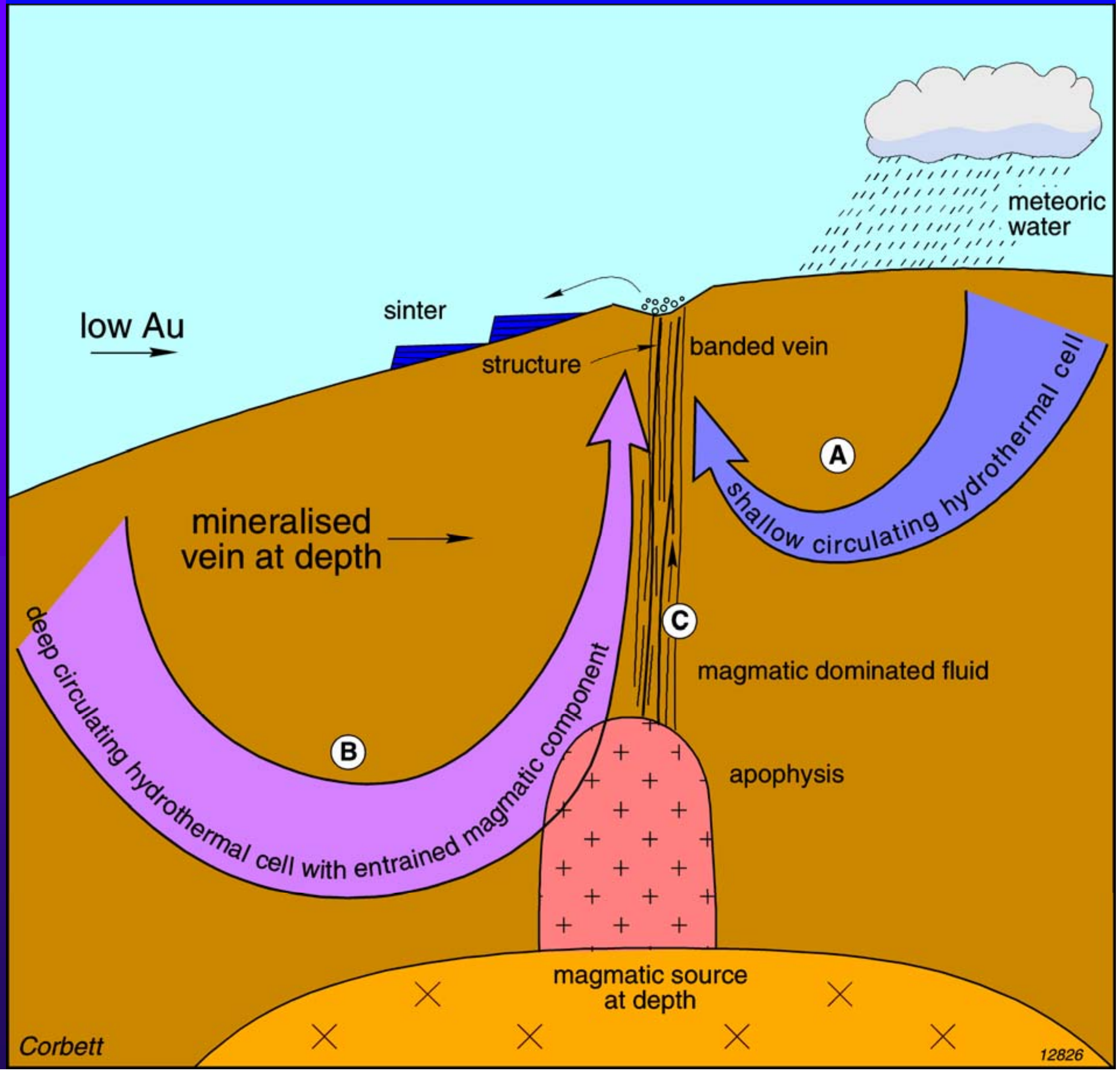
Cracow early 1990's

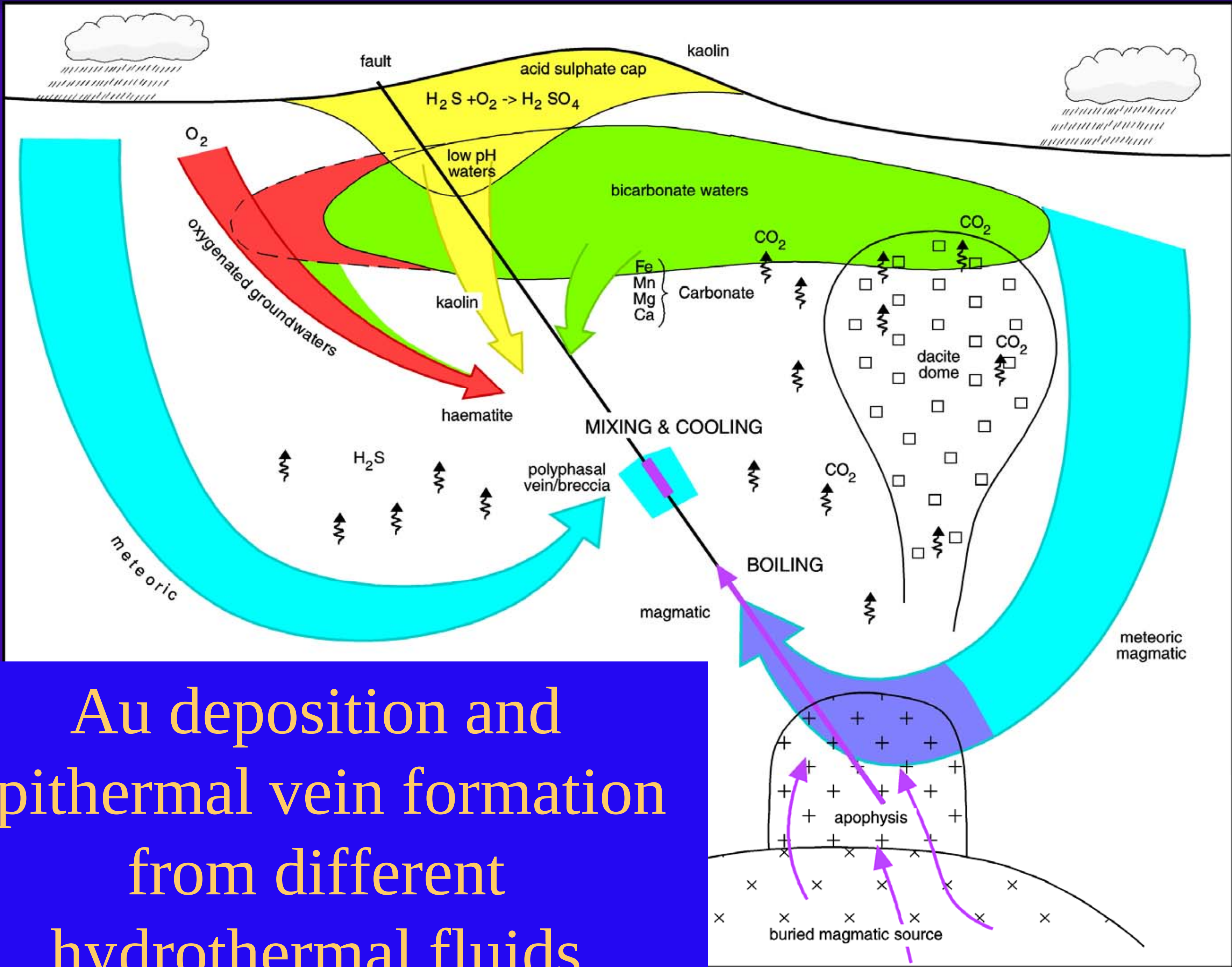
Vera Nancy late 1990's



Banded epithermal veins & Multiple fluid sources







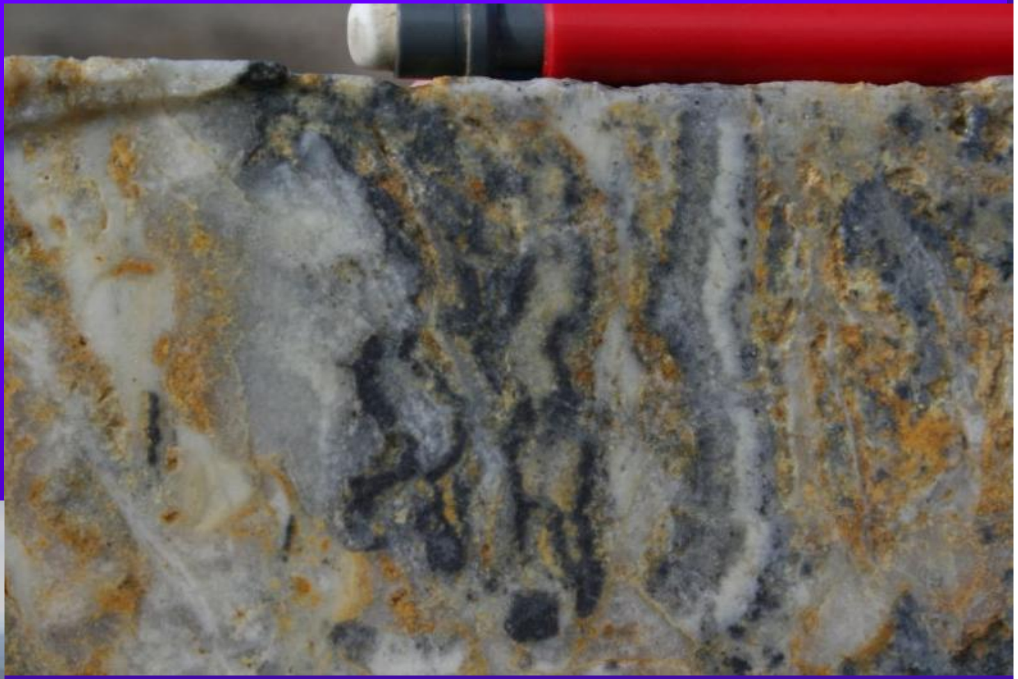
Au deposition and epithermal vein formation from different hydrothermal fluids

Mechanisms of Au deposition

- More efficient mechanisms of Au deposition provide higher Au grades
- Several mechanisms to consider
  - Boiling
  - Cooling
  - Rapid cooling
  - Sulphidation reactions
  - Carbon reactions
  - Mixing with oxygenated groundwaters
  - Mixing with bicarbonate waters
  - Mixing with low pH waters
- Have a minor effect on Ag:Au ratios

Kupol, Russia – chalcedony, ginguro & adularia

58 g/t Au, 1184 g/t Ag



Banded chalcedony-ginguro Au-Ag vein

-El Peñon..

Cracow

Banded quartz vein - Golden Cross

Quartz pseudomorphing platy carbonate

Adularia

Vera Nancy

Hishikari

Ginguro bands

Visible Au
Asacha, Kamchatka

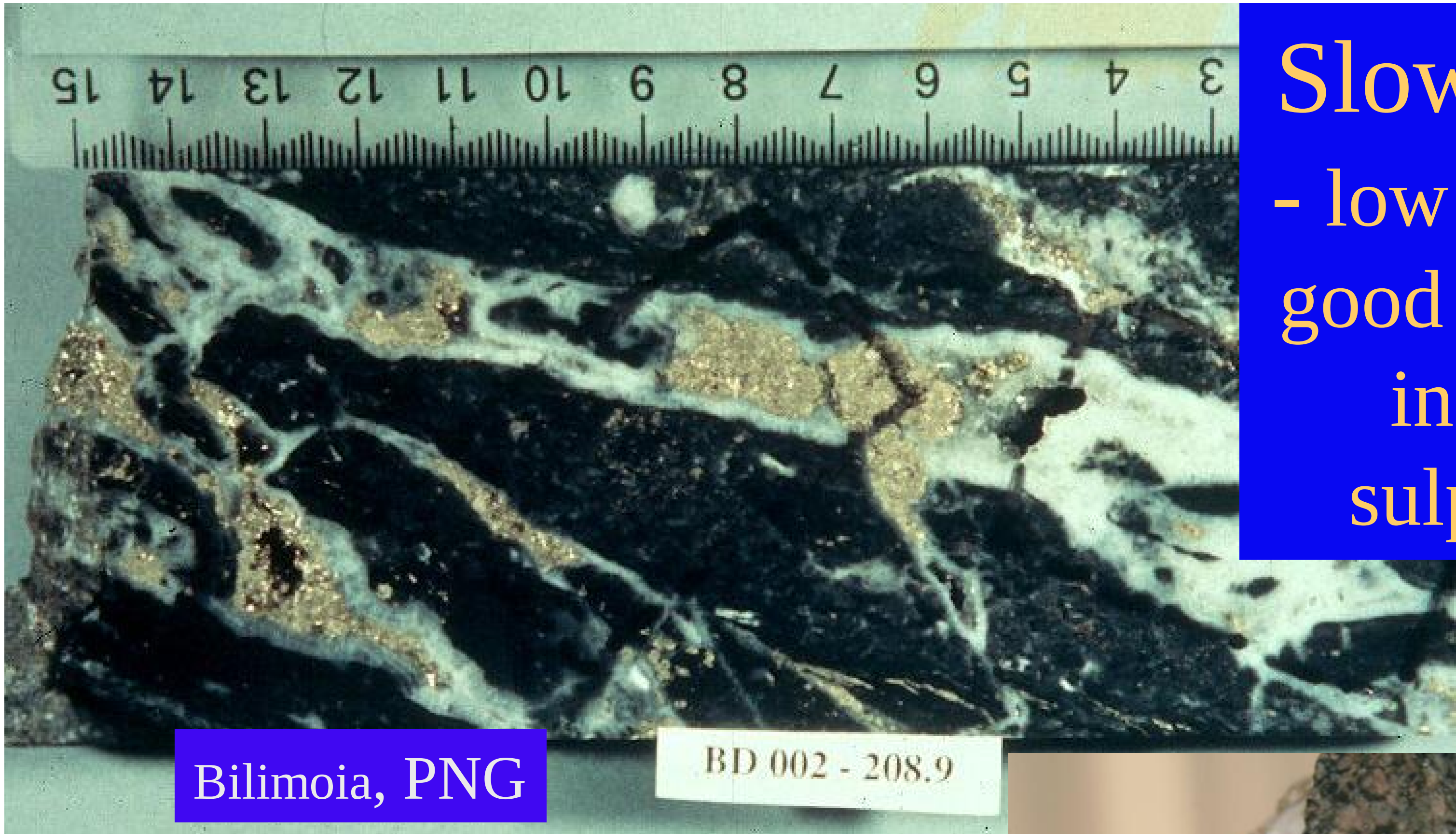
Midas, Nevada

Vera Nancy, Aust

Hishikari, Japan

Patagonia

Slow cooling
- low Au grades, good metallurgy in quartz-sulphide Au

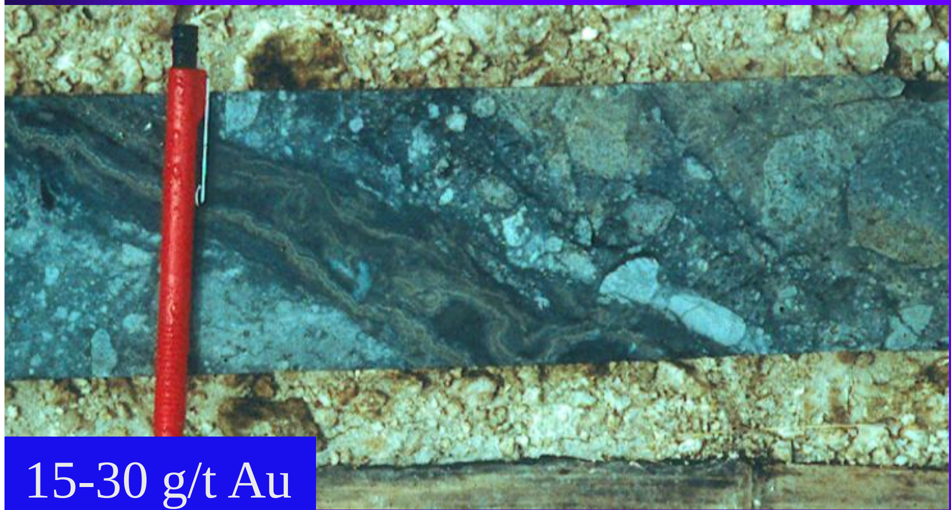


Bilimoia, PNG

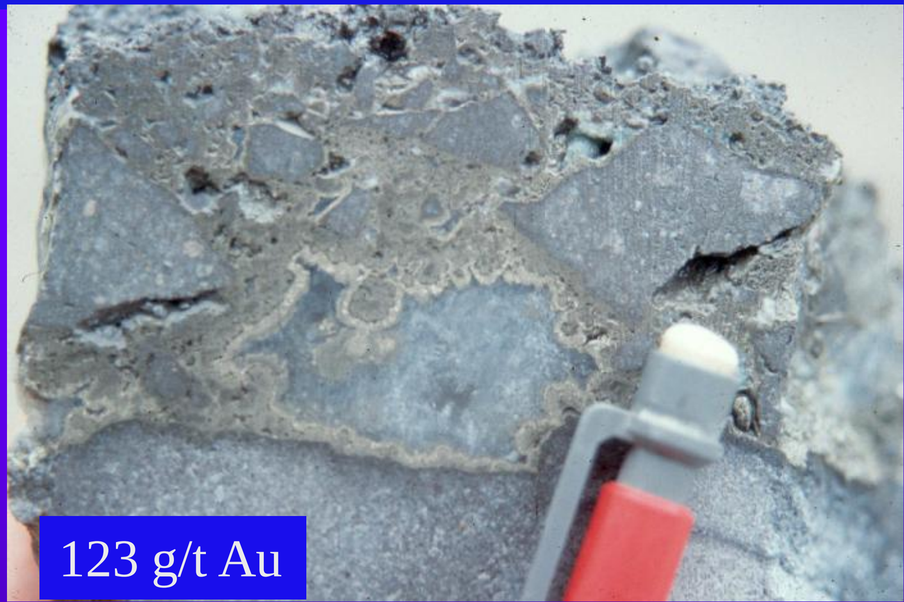
Cowal

Rapid Cooling

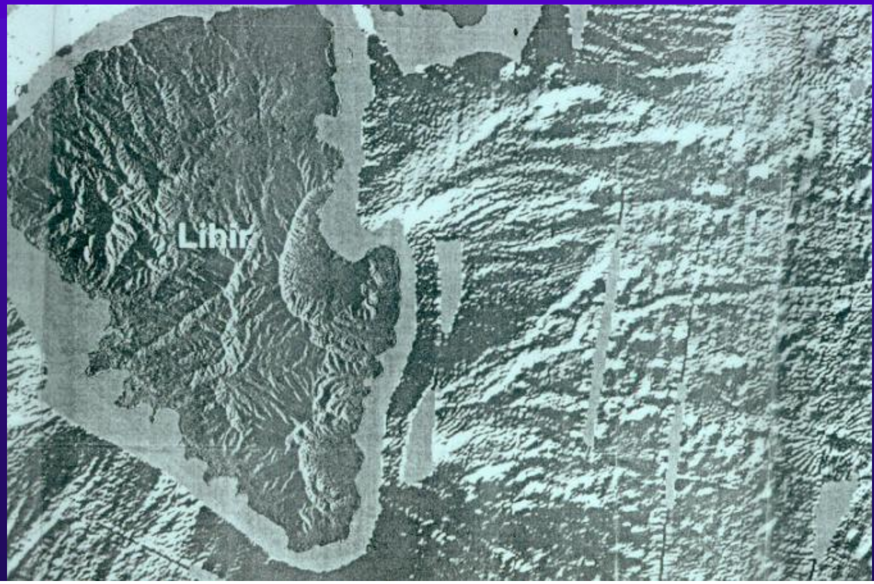
Arsenian Pyrite, Lihir Island, Papua New Guinea



15-30 g/t Au

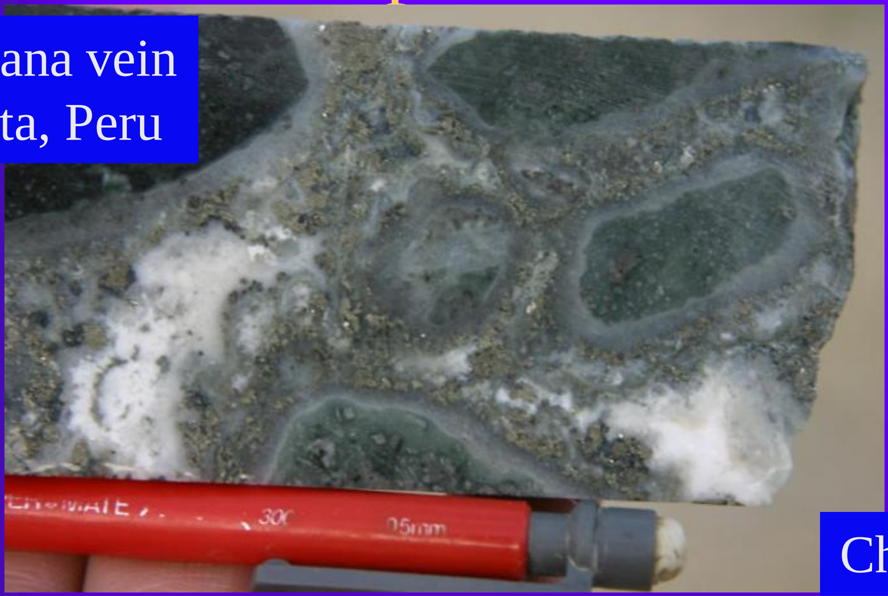


123 g/t Au



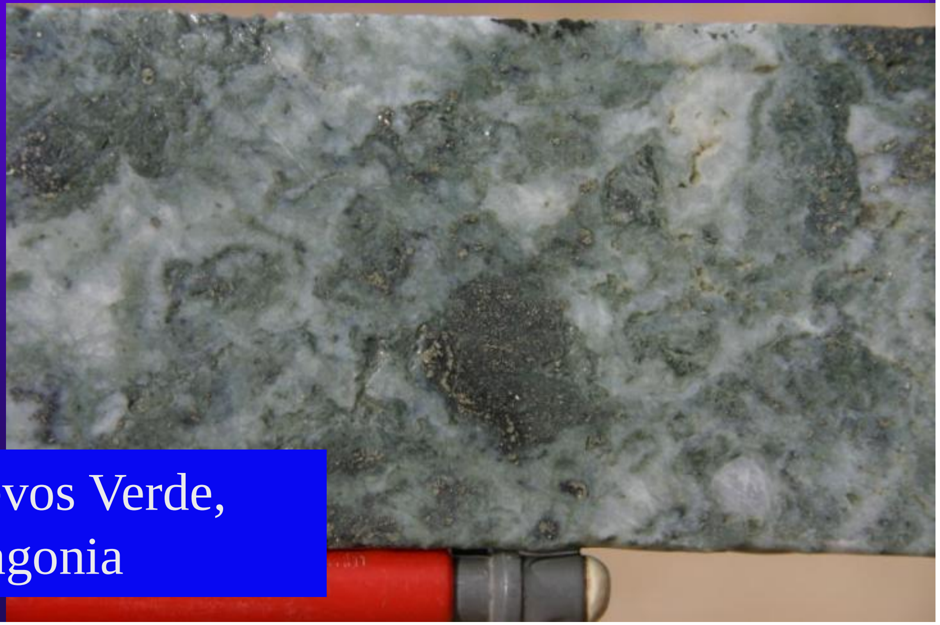
Rapid cooling – opal in contact with sulphides

Mariana vein
Arcata, Peru

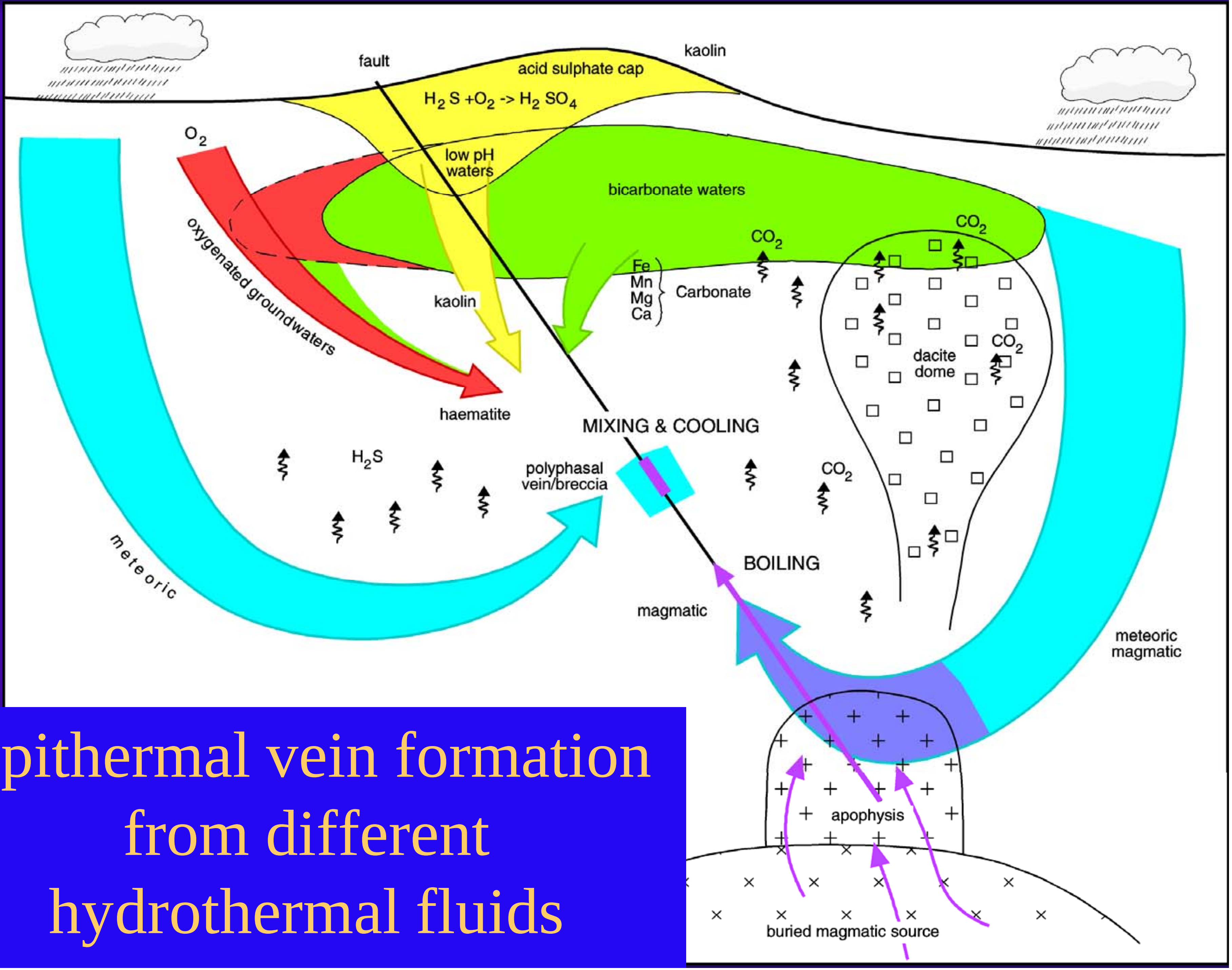


Chatree, Thailand

Fresnillo



Huevos Verde,
Patagonia



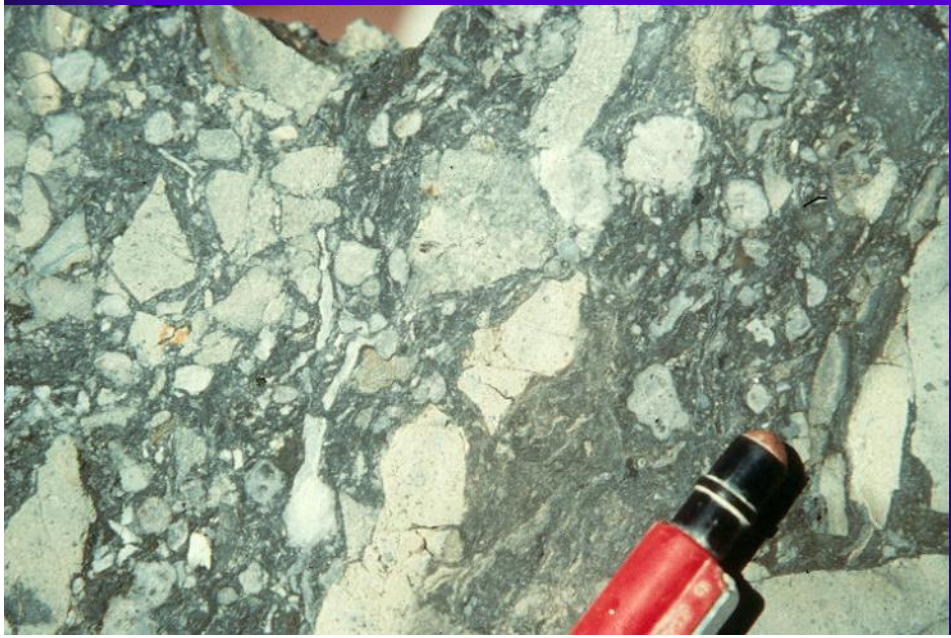
Epithermal vein formation from different hydrothermal fluids

Sulphidation

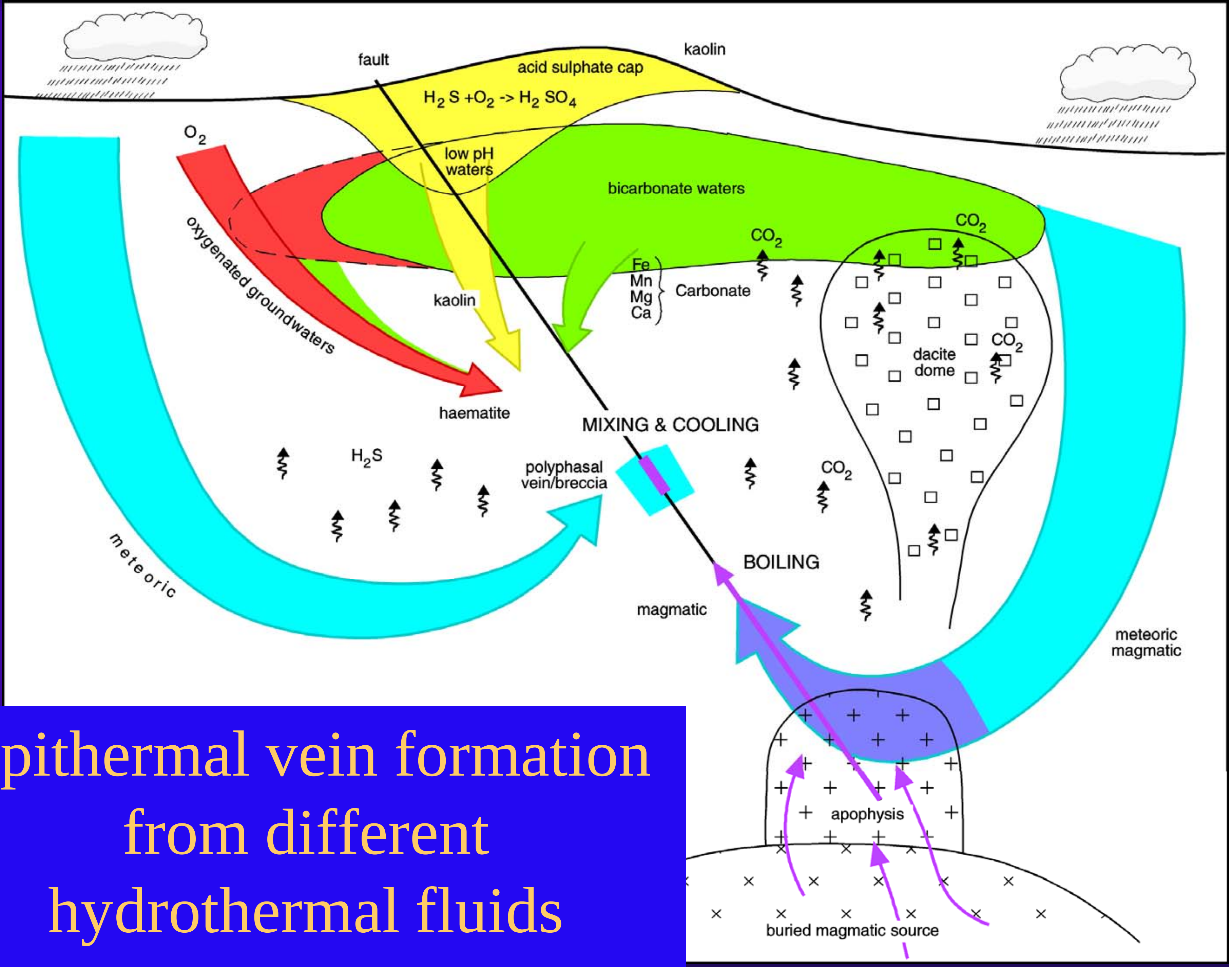
Lihir, arsenian pyrite 13.1 g/t

CARLIN TREND

Meikel 15 g/t Au

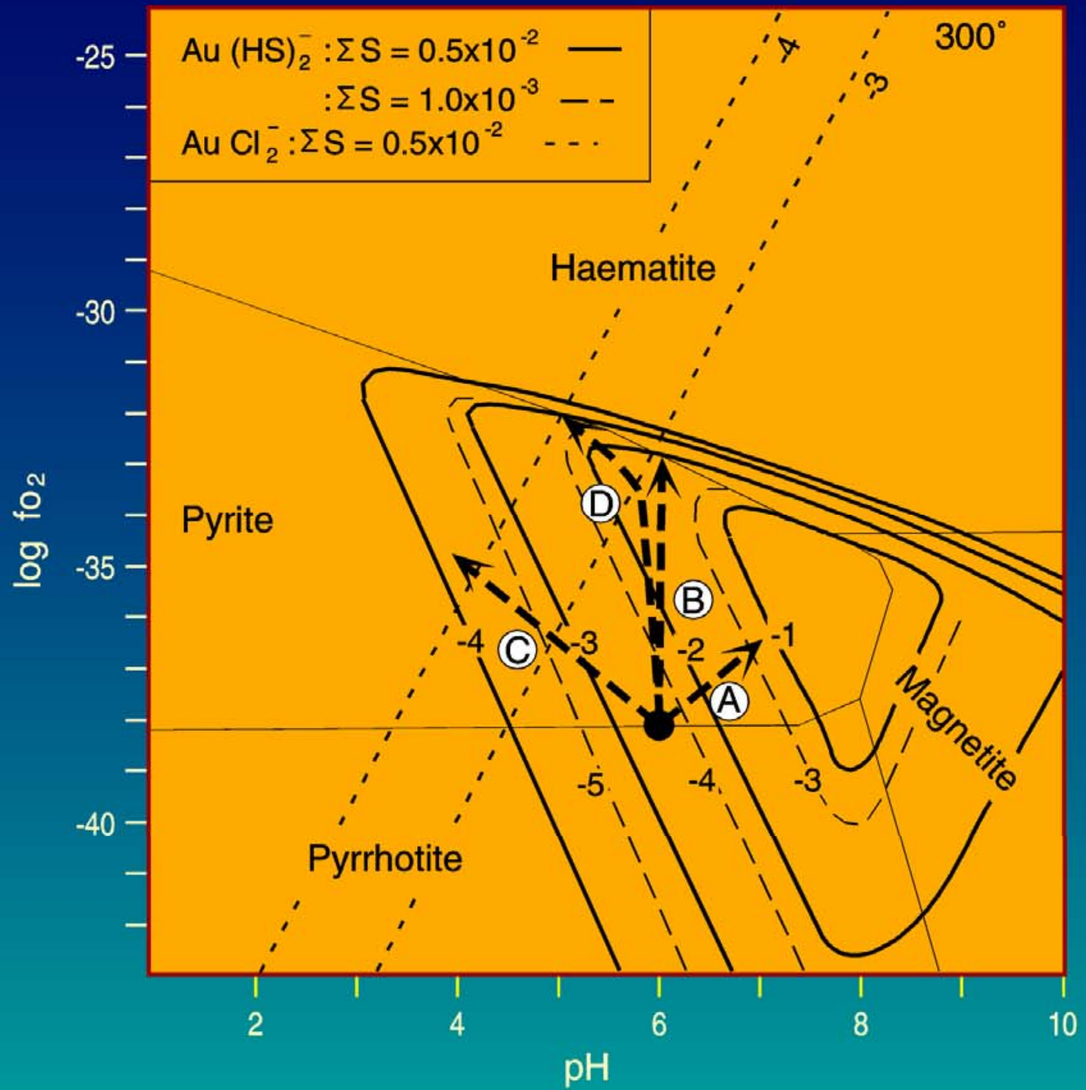


Goldstrike 2-3 g/t Au



Epithermal vein formation from different hydrothermal fluids

Gold Solubility



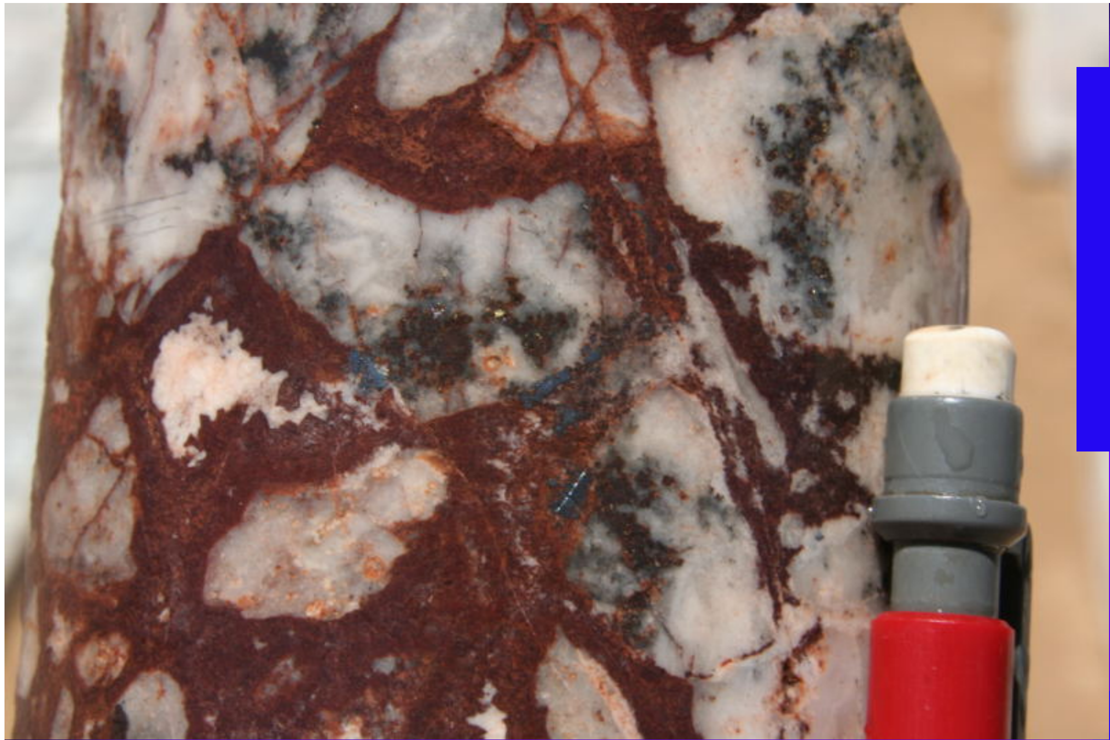
Gold solubility as HS$^-$ and Cl$^-$ complexes as a function of pH, fo$_2$ and ΣS (modified from Seward 1982; Brown 1986).

A: boiling
B: Mixing with oxygenated fluids
C: Mixing with low pH fluids
D: Mixing with bicarbonate-sulphate water

A - C Leach in Corbett & Leach 1998
D by D. Cooke May 1998 & Leach 2008

Leach
94487LIT

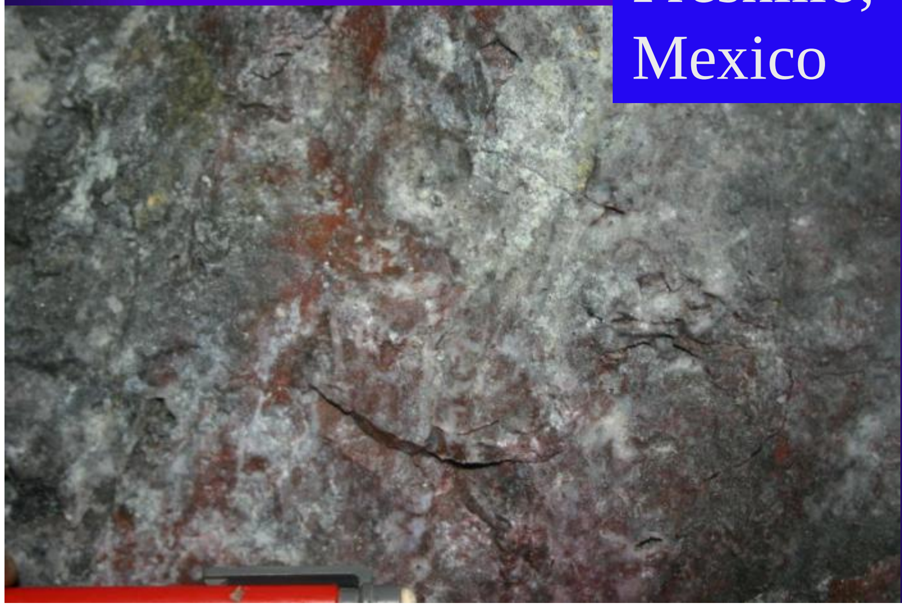
Mixing with oxygenated waters – hypogene haematite



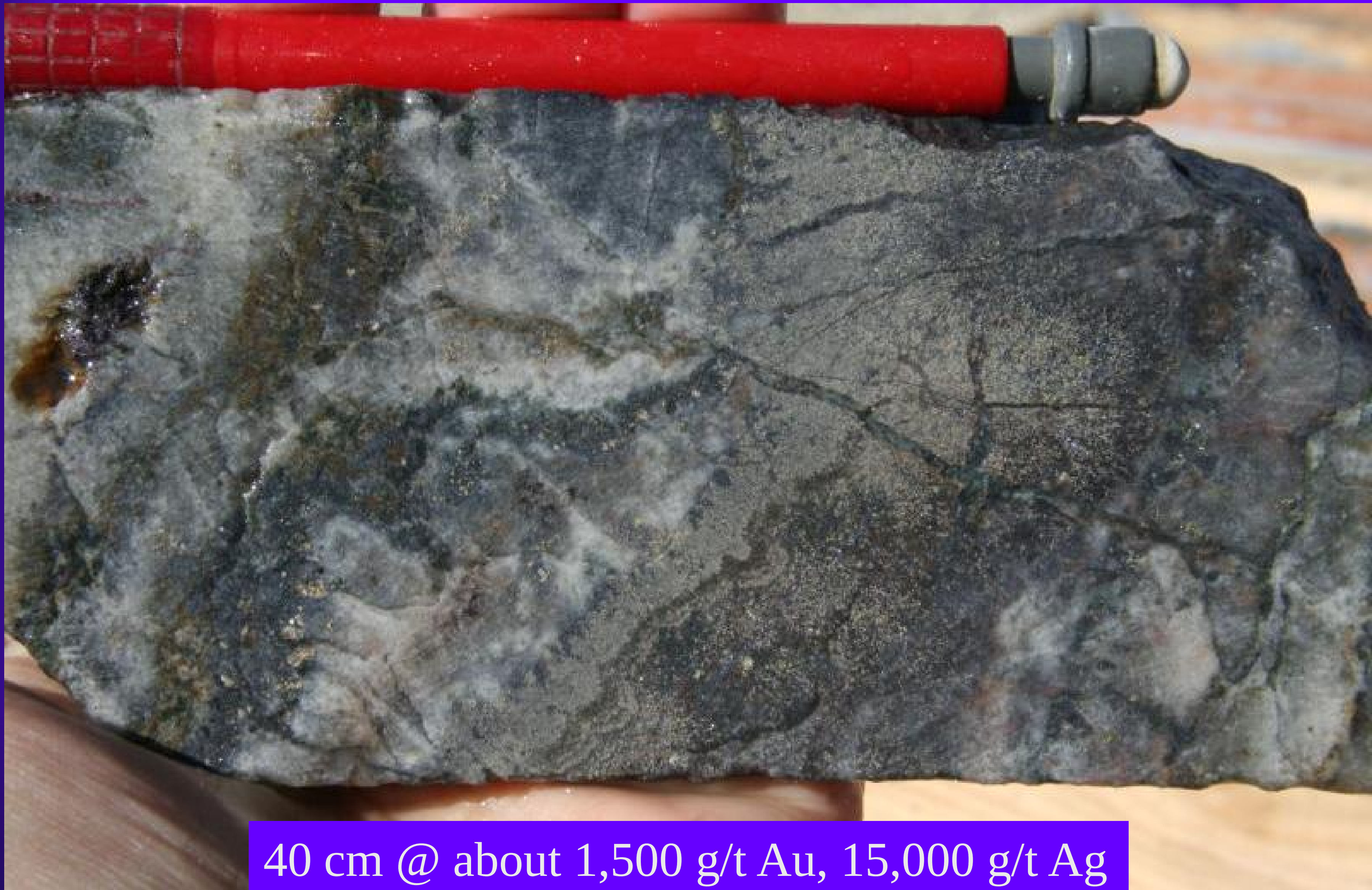
Palmarejo Mexico

Kupol, Russia
86 g/t Au 1370 g/t Ag

Fresnillo,
Mexico

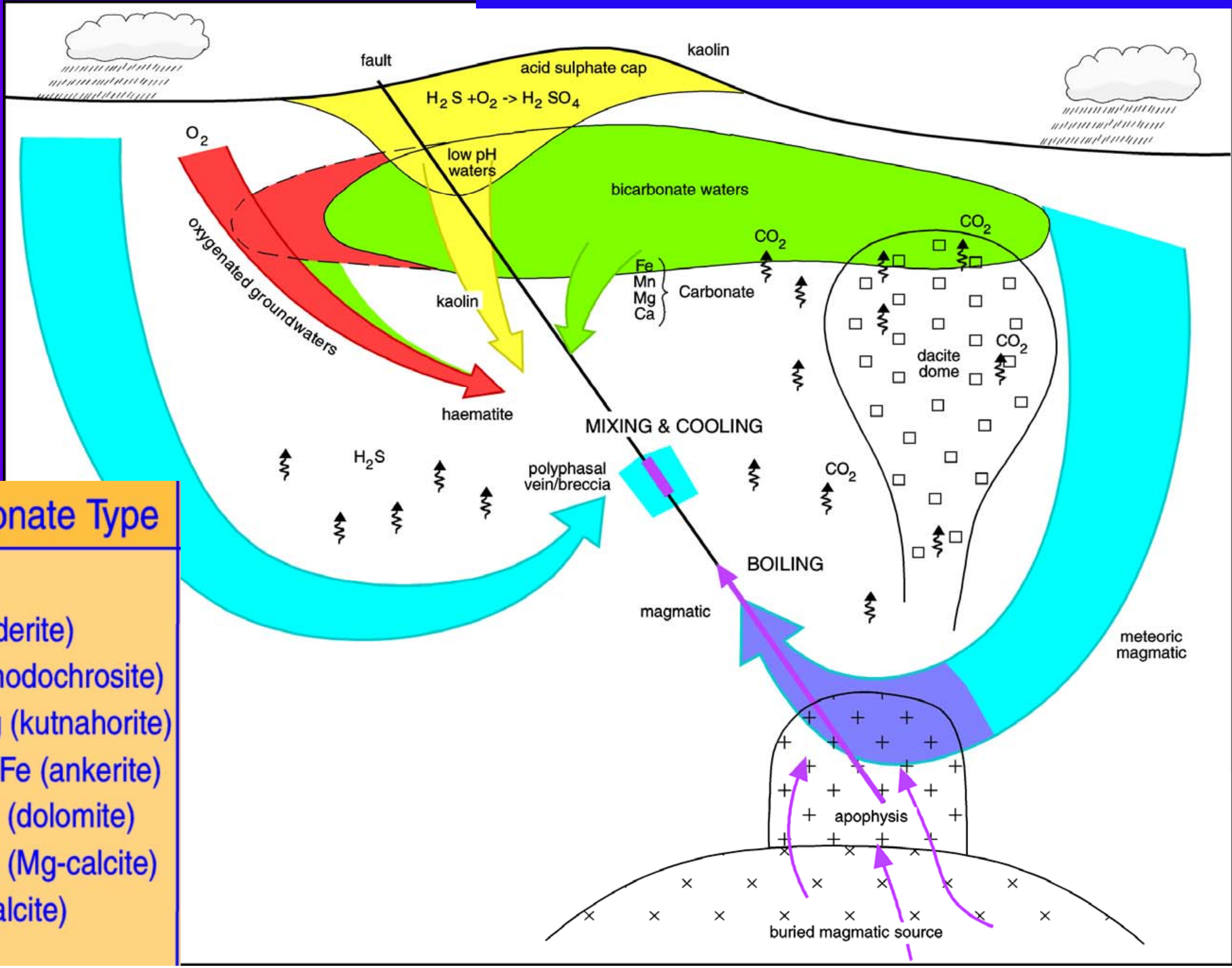


Kupol polymetallic Ag-Ag



40 cm @ about 1,500 g/t Au, 15,000 g/t Ag

Bicarbonate waters

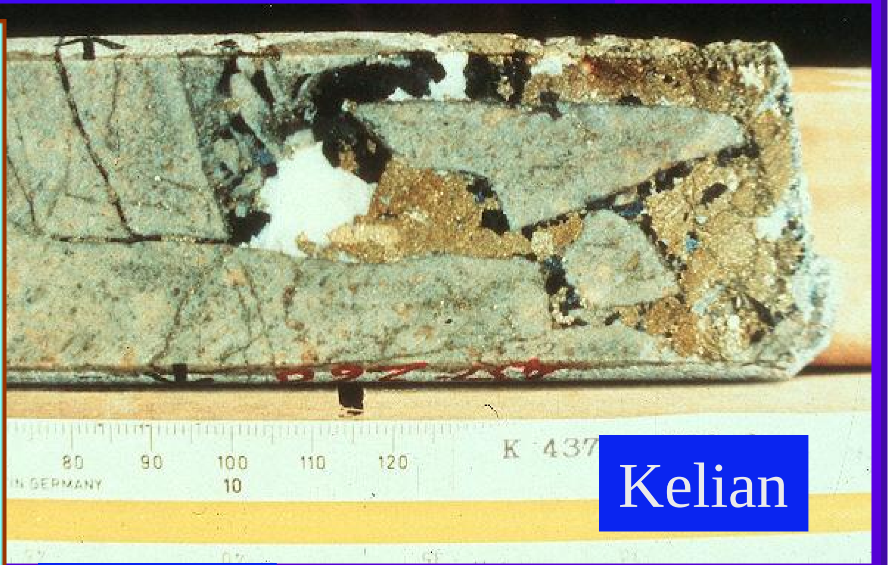


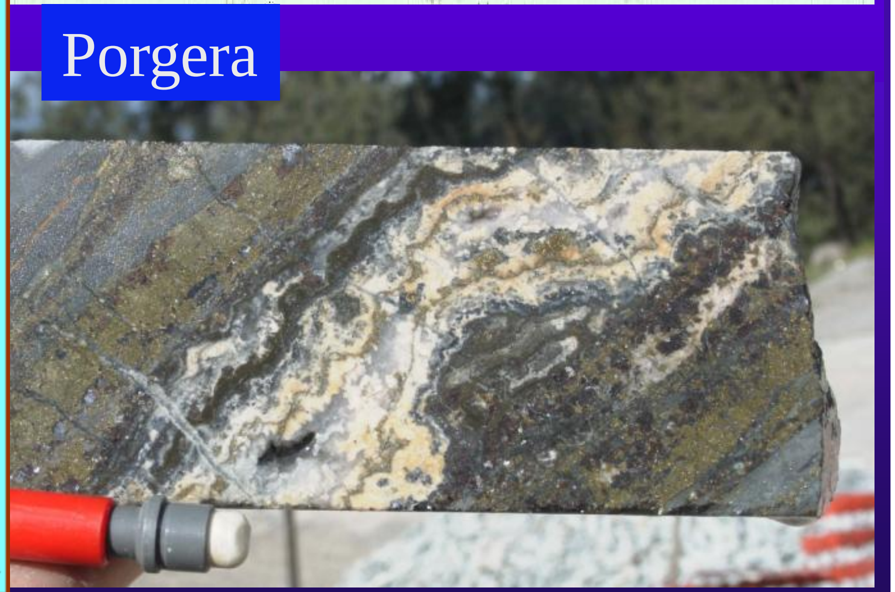
Carbonate Type

Fe (siderite)
Mn (rhodochrosite)
MnMg (kutnahorite)
MgCaFe (ankerite)
MgCa (dolomite)
CaMg (Mg-calcite)
Ca (calcite)

Carbonate-base metal Au –

Leach and Corbett, 1993, 1994, 1995; Corbett and Leach, 1998

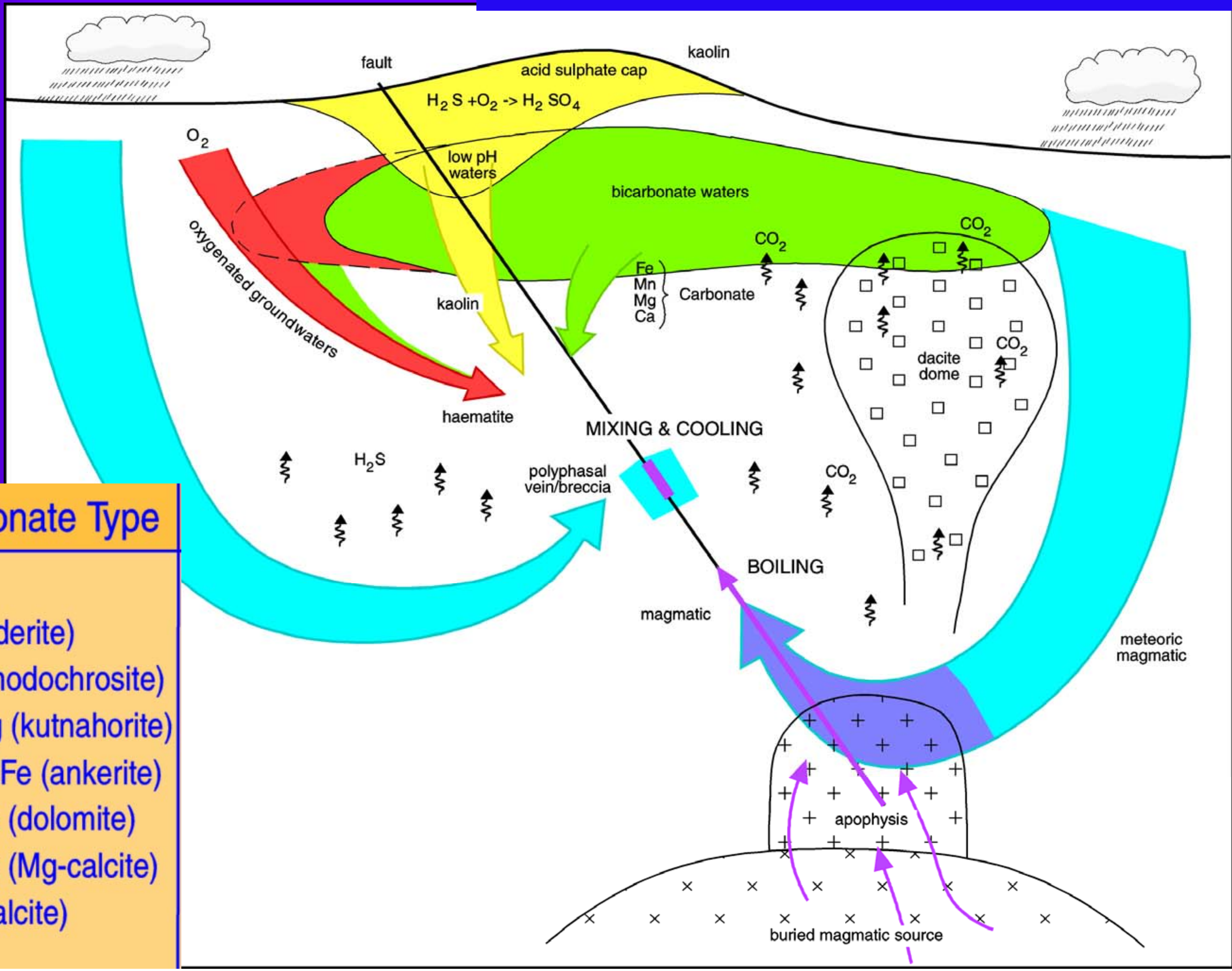




Mixing with bicarbonate waters in polymetallic Ag-Ag vein systems

Santa Ana, Peru

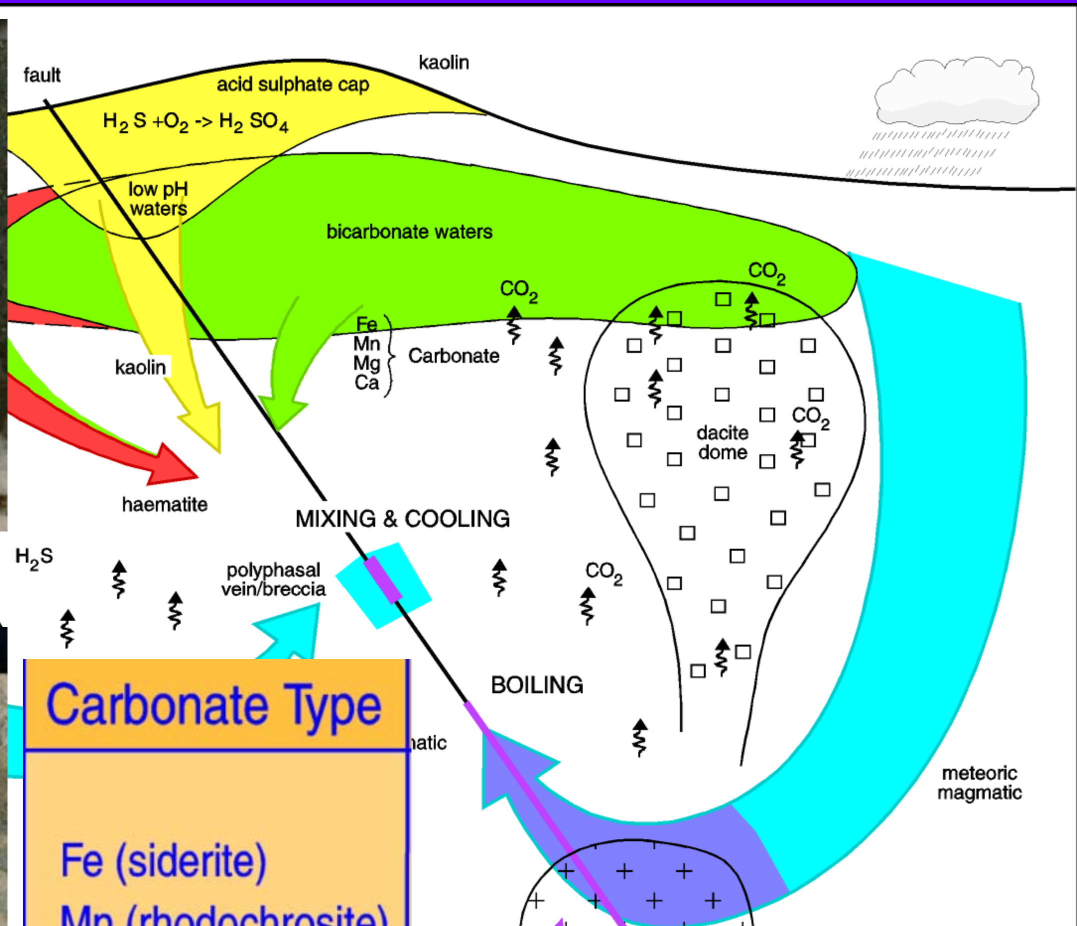
Bicarbonate waters



Carbonate Type

- Fe (siderite)
- Mn (rhodochrosite)
- MnMg (kutnahorite)
- MgCaFe (ankerite)
- MgCa (dolomite)
- CaMg (Mg-calcite)
- Ca (calcite)

Mixing with with bicarbonate waters



Rhodochrosite
69 g/t Au, 42 g/t Ag

Dolomite
7.93 gt/ Au, 19 g/t Ag

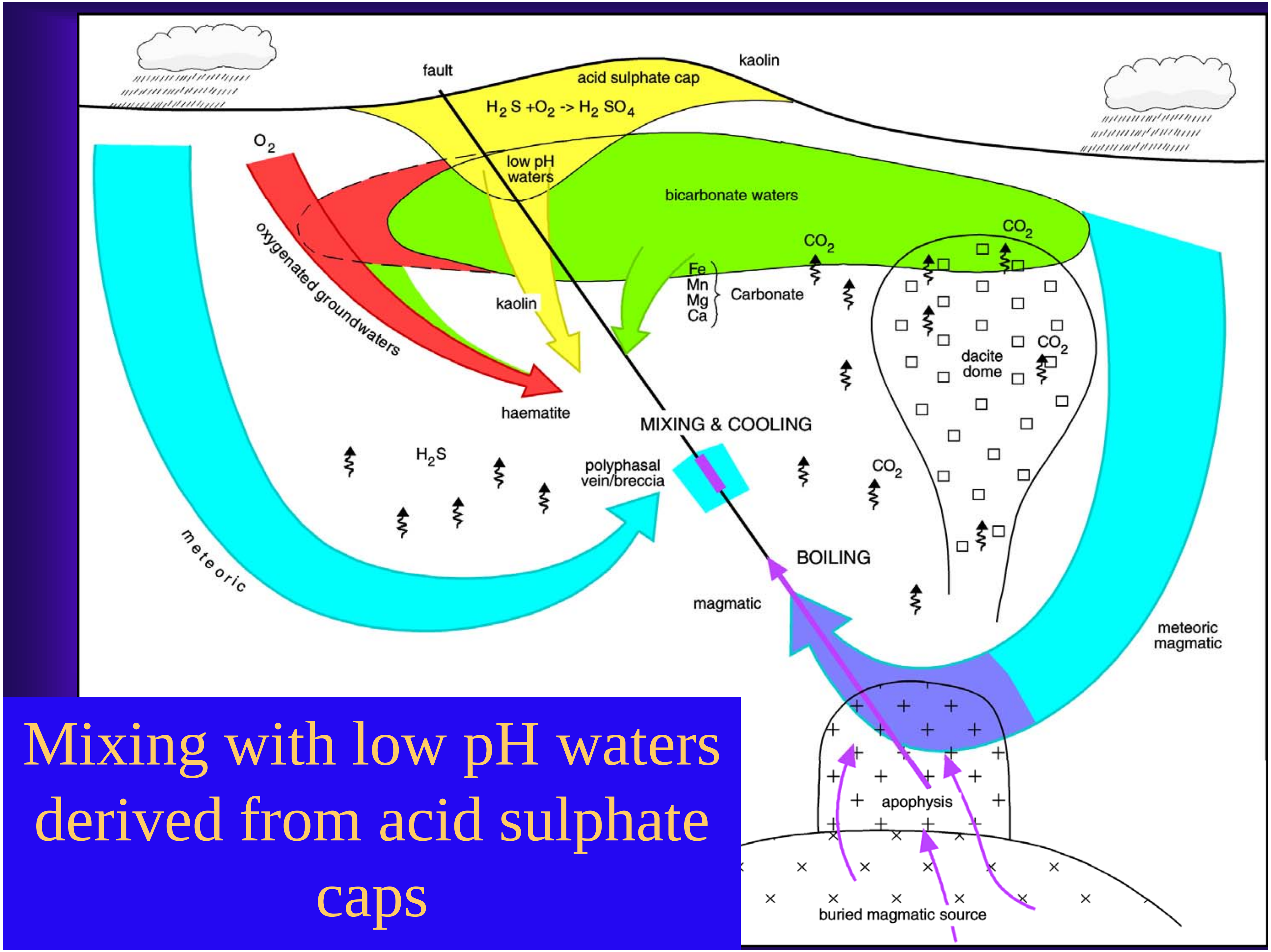
Carbonate Type

- Fe (siderite)
- Mn (rhodochrosite)
- MnMg (kutnahorite)
- MgCaFe (ankerite)
- MgCa (dolomite)
- CaMg (Mg-calcite)
- Ca (calcite)

Calcite 2.8 g/t Au 11 g/t Ag

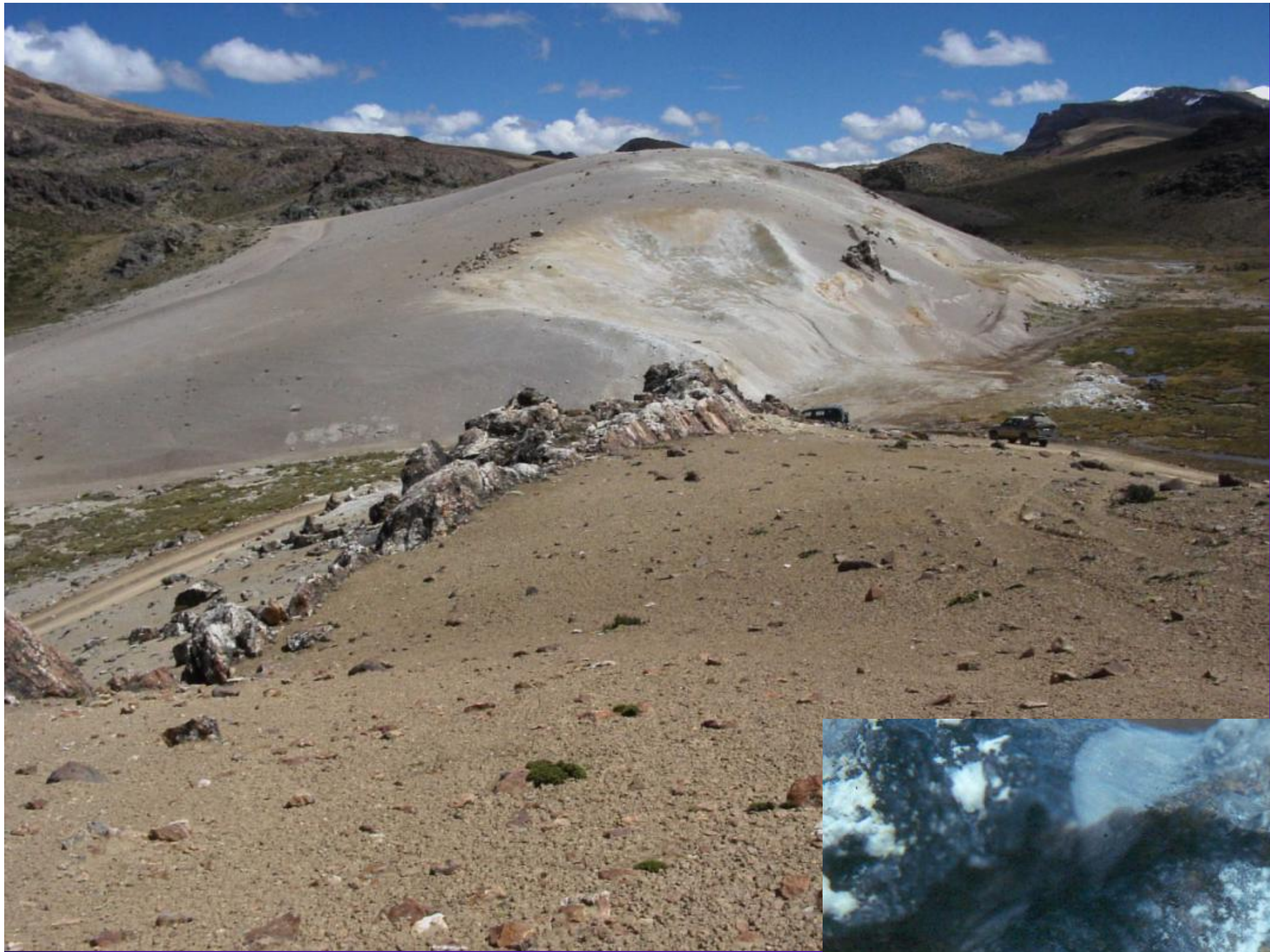
Manganese wad

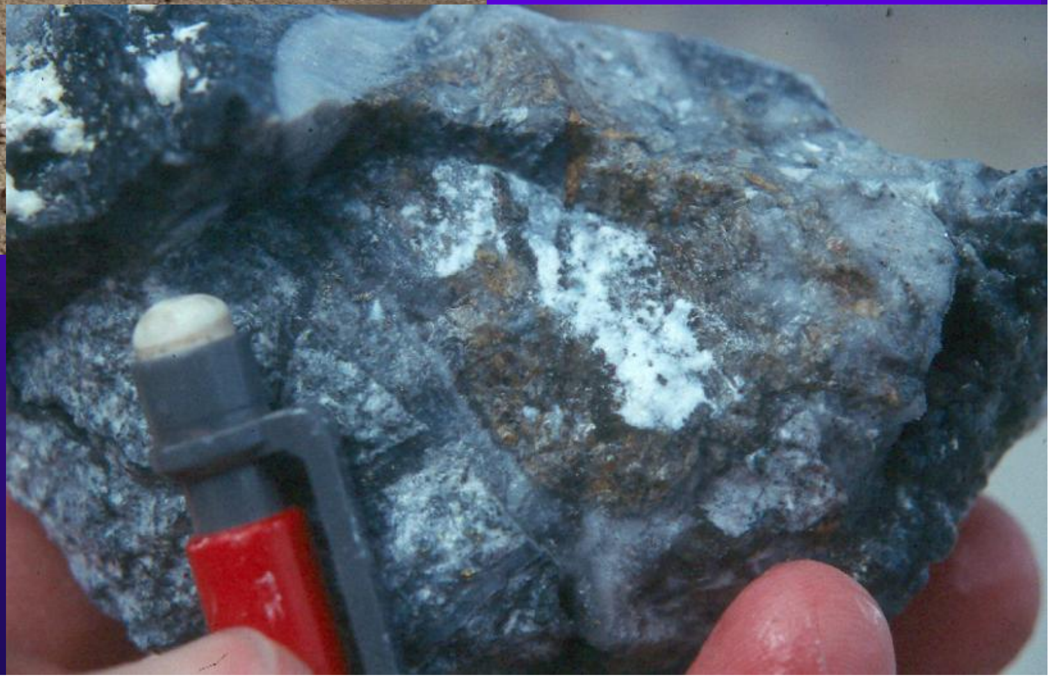
Mt Kare
Papua New Guinea



Mixing with low pH waters derived from acid sulphate caps

Arcata – Acid cap

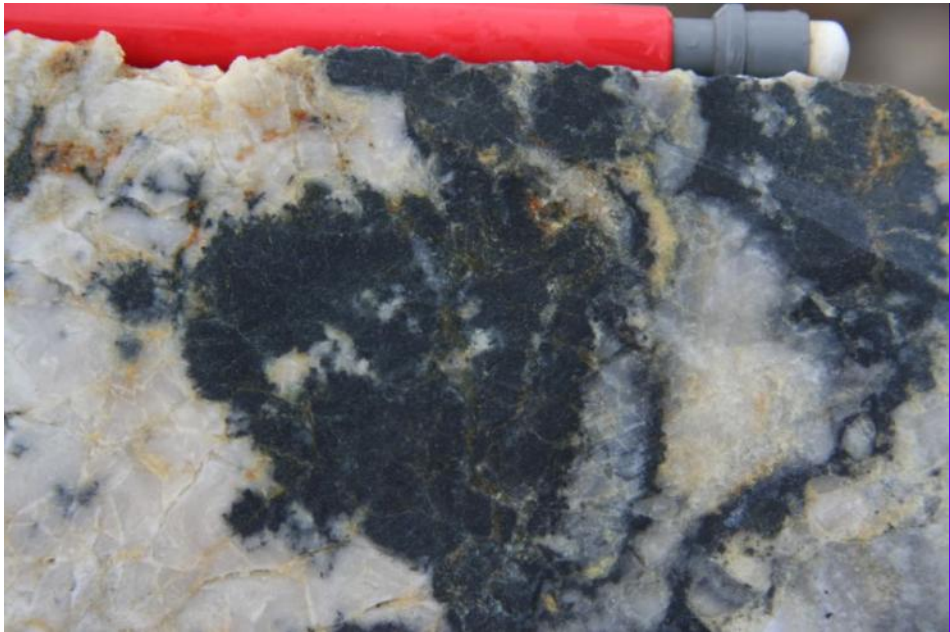




Ares - Kaolin

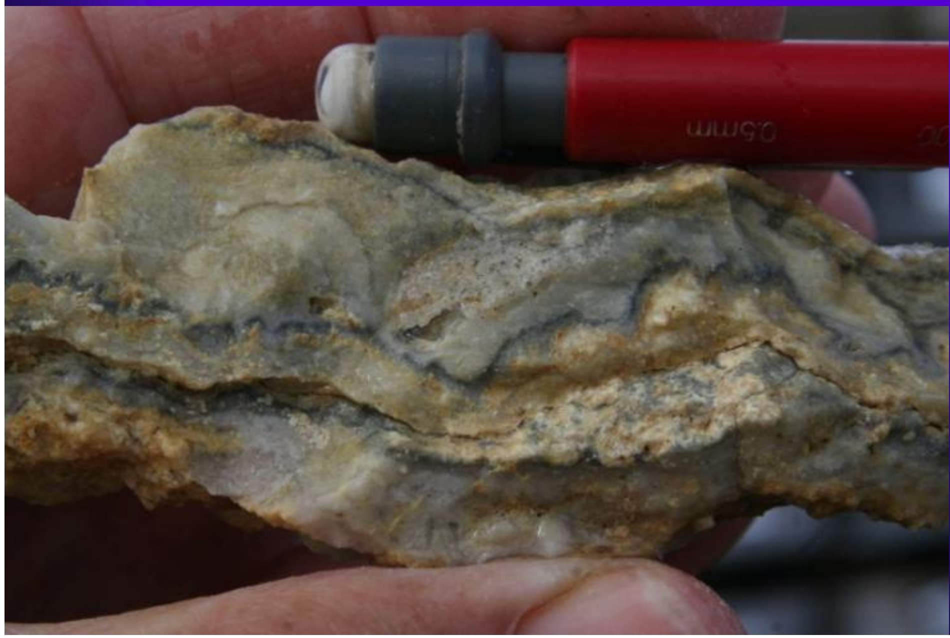
Kupol - kaolin

602 g/t Au, 2082 g/t Ag



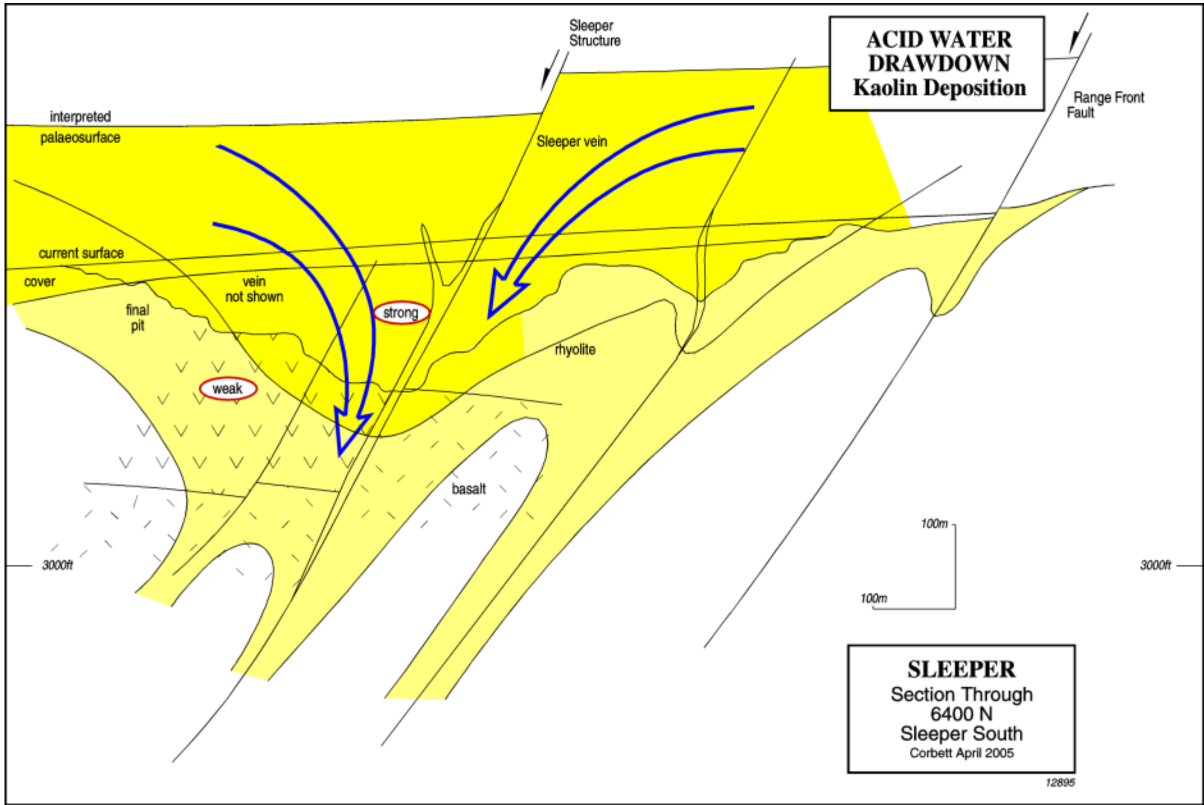
Kaolin intergrown with ginguro

45 g/t Au, 117 g/t Ag



55 g/t Au, 355 g/t Ag

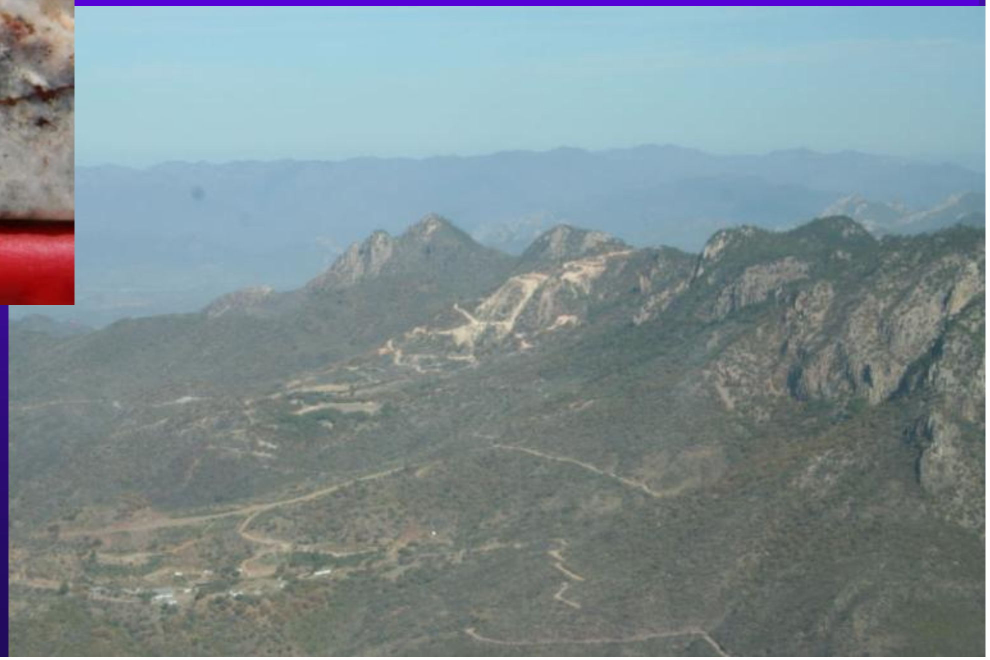
Sleeper Gold Mine, Nevada



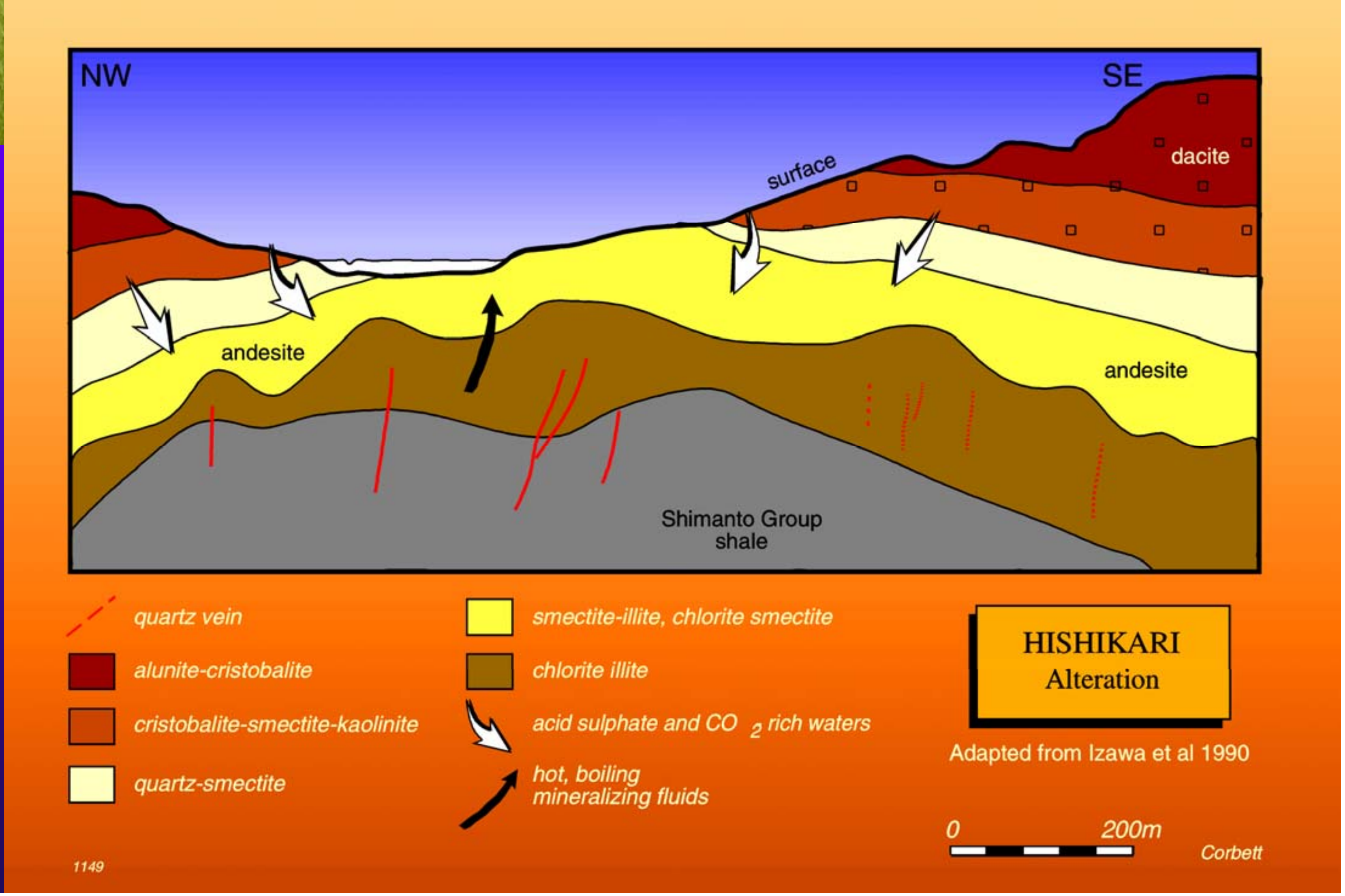
Kaolin-pyrite intergrown

Fine black silica-sulphide Palmarejo Mexico

186 g/t Au, 3720 g/t Ag

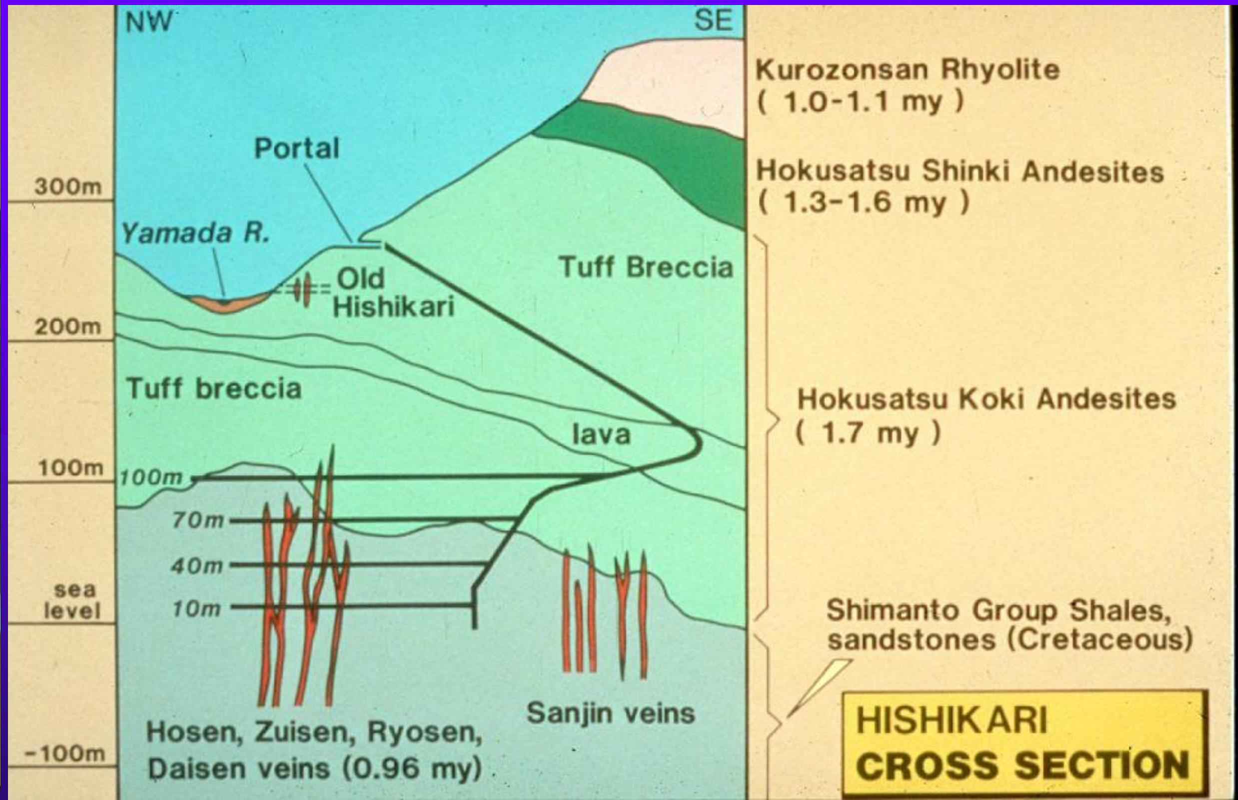


Hishikari Japan

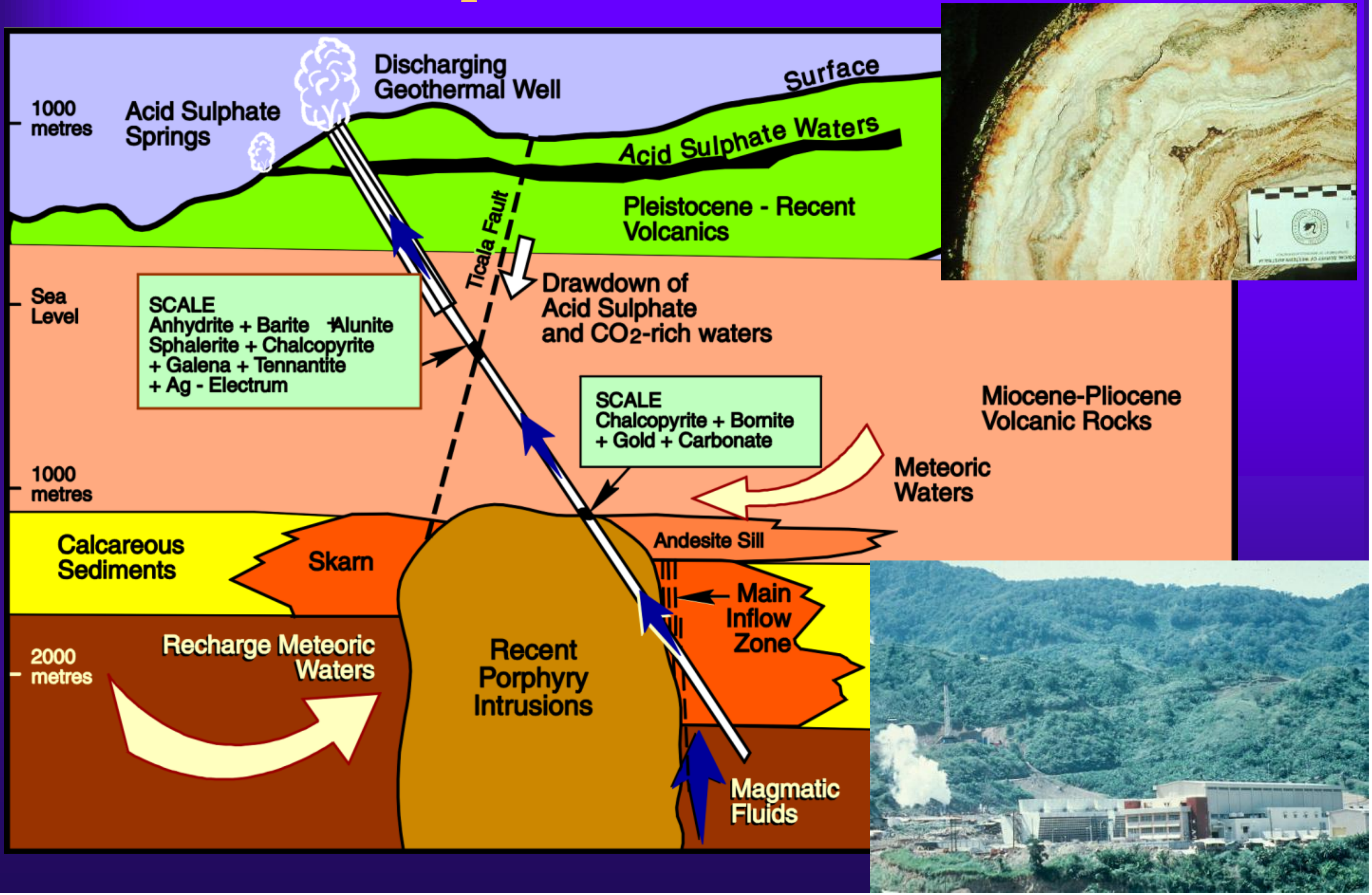


Hishikari Japan

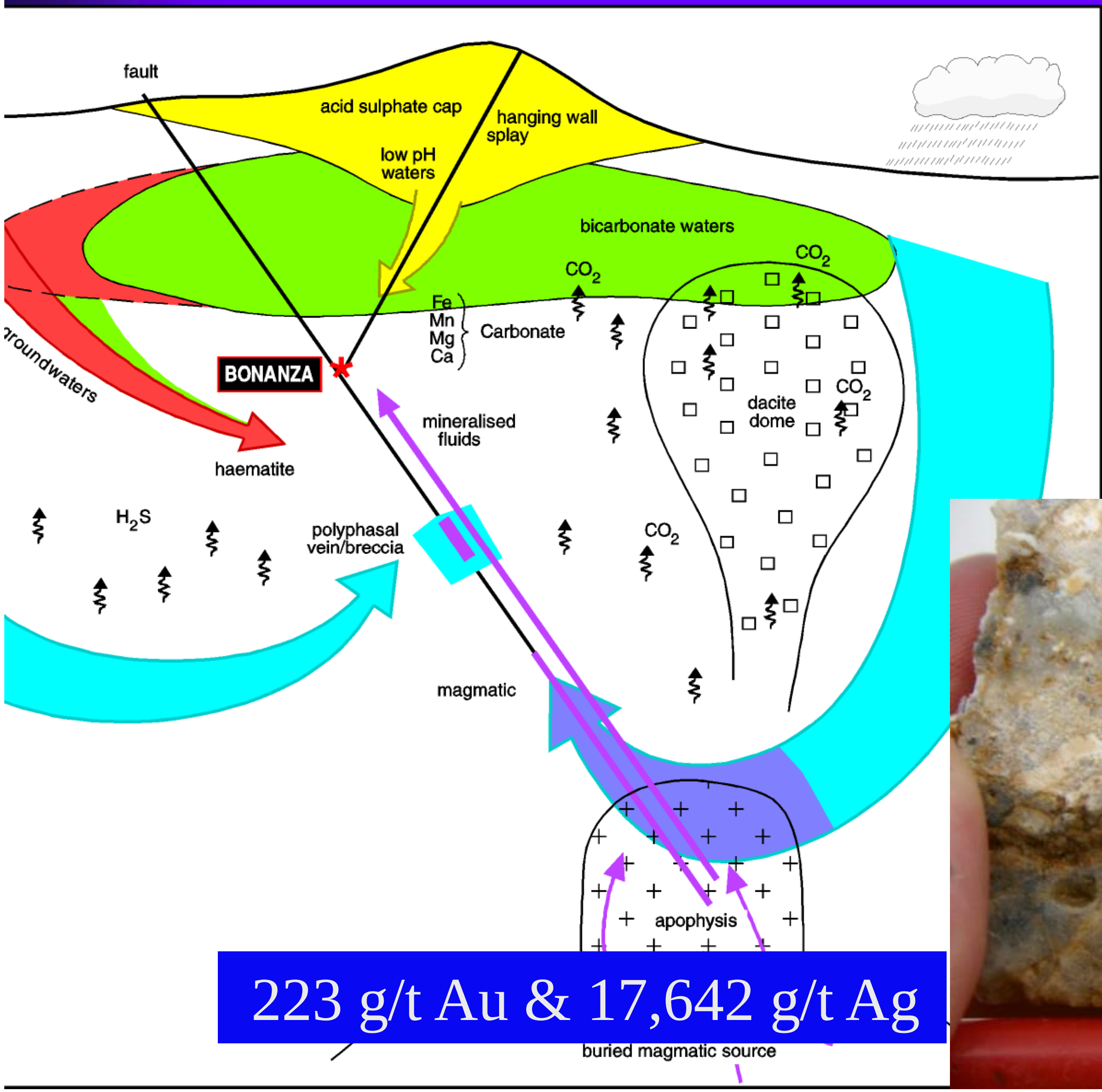
50,000 g/t Au

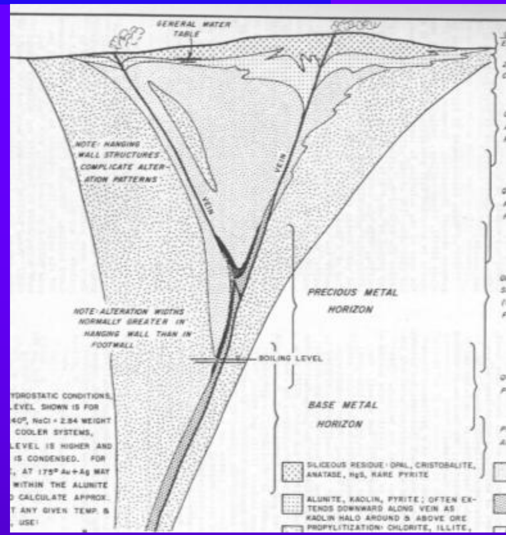


Active Hanging Wall Splay
Palinpinon Geothermal



Intersection of collapsing acid sulphate waters and rising mineralised fluids





223 g/t Au & 17,642 g/t Ag

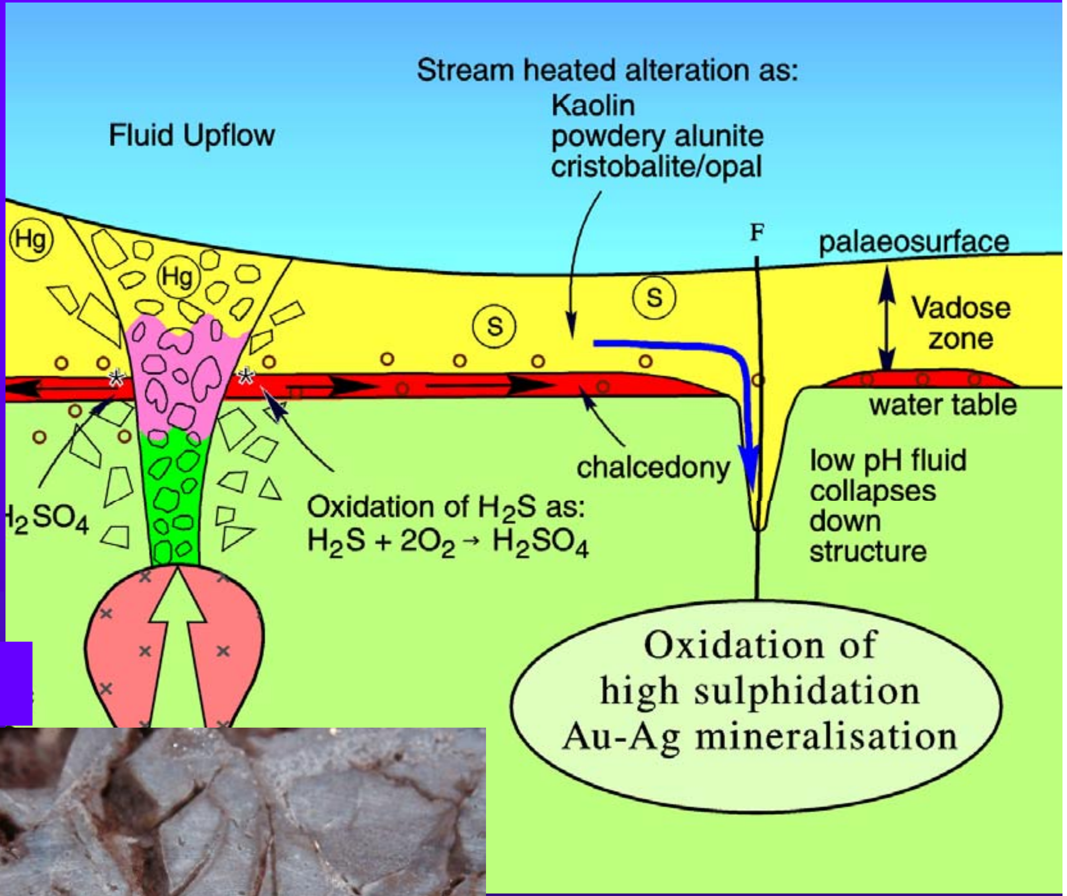
Champagne Pool, Waitapu, New Zealand

Orange precipitate in ppm or %
Au 80, Ag 170, 170 Hg, 2% As, 2% Sb

Hypogene oxidation in high sulphidation epithermal systems

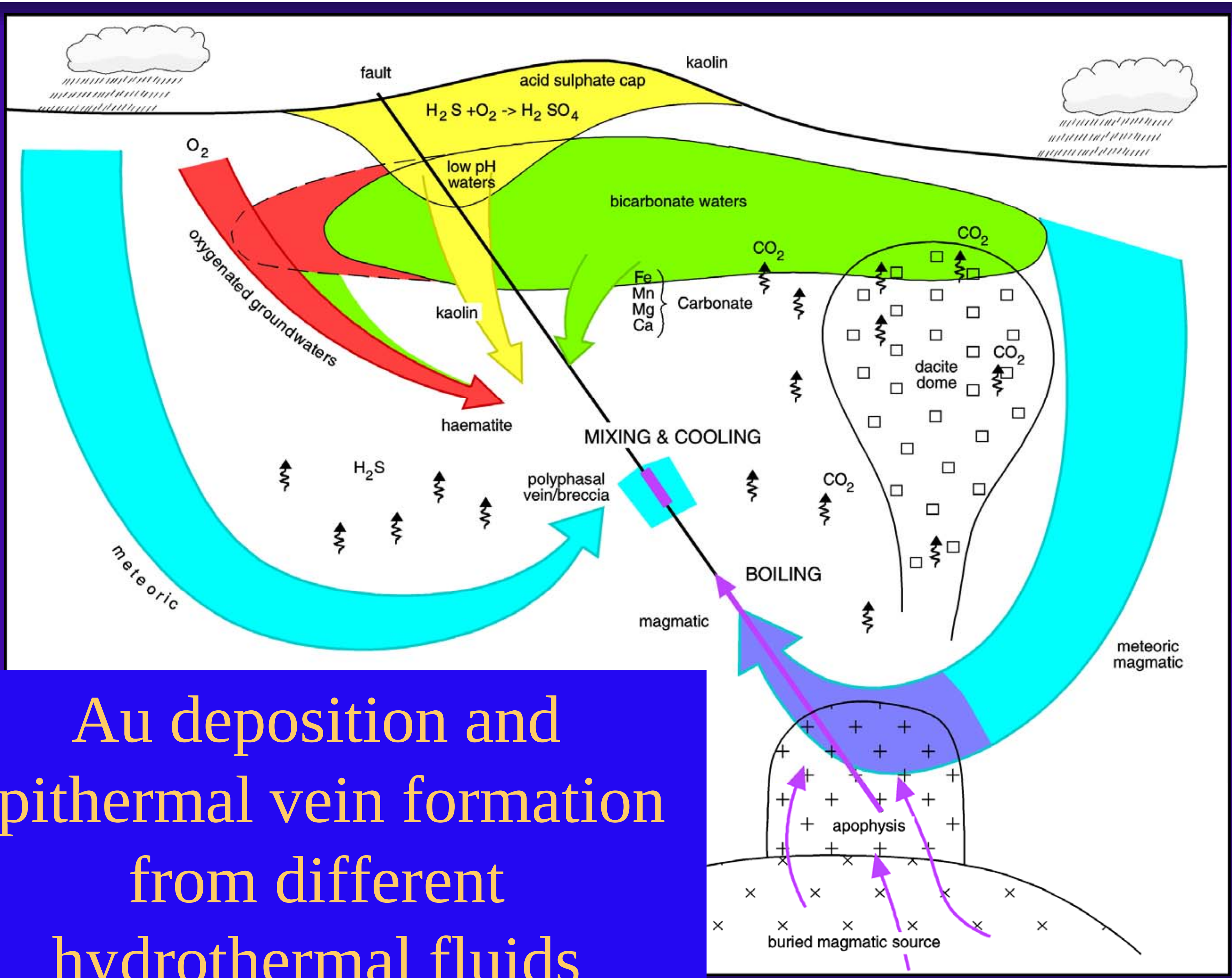
Pierina, Peru

Veladero, Argentina



Conclusion

- Several mechanisms may account for the deposition of Au in low sulphidation epithermal Au systems
- While boiling does deposit Au, this is not always the case
- Several different mixing reactions may account for elevated Au grades with increased efficiency and hence higher Au grade involving:
  - Oxygenated groundwaters
  - Bicarbonate waters
  - Low pH acid sulphate waters



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