ALKALINE ROCKS AND GOLD

24th Symposium of the Geological Society of Iran
Kharazmi University, Tehran
- 16th November 2021 -

Daniel Müller, Consulting Geologist, Santiago, Chile
[danielmuller33@yahoo.com]

Presentation in five parts:

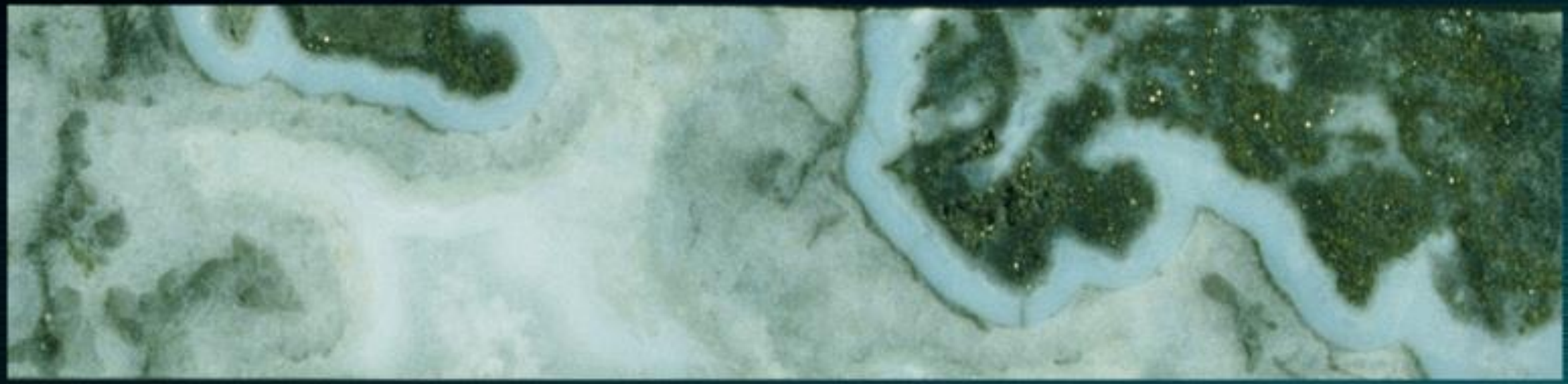
(1 Geochemical fingerprints of potassic igneous rocks in target generation;

(2 Tectonic settings of potassic igneous rocks;

(3 Halogen geochemistry of potassic igneous rocks;

(4 Examples of porphyry Cu-Au and epithermal Au deposits hosted by potassic igneous rocks;

(5 Using magma fertility in target generation.



Alkaline rocks and Gold

Part 1: Geochemical fingerprints of potassic igneous rocks in target generation

Mineral exploration: many challenges

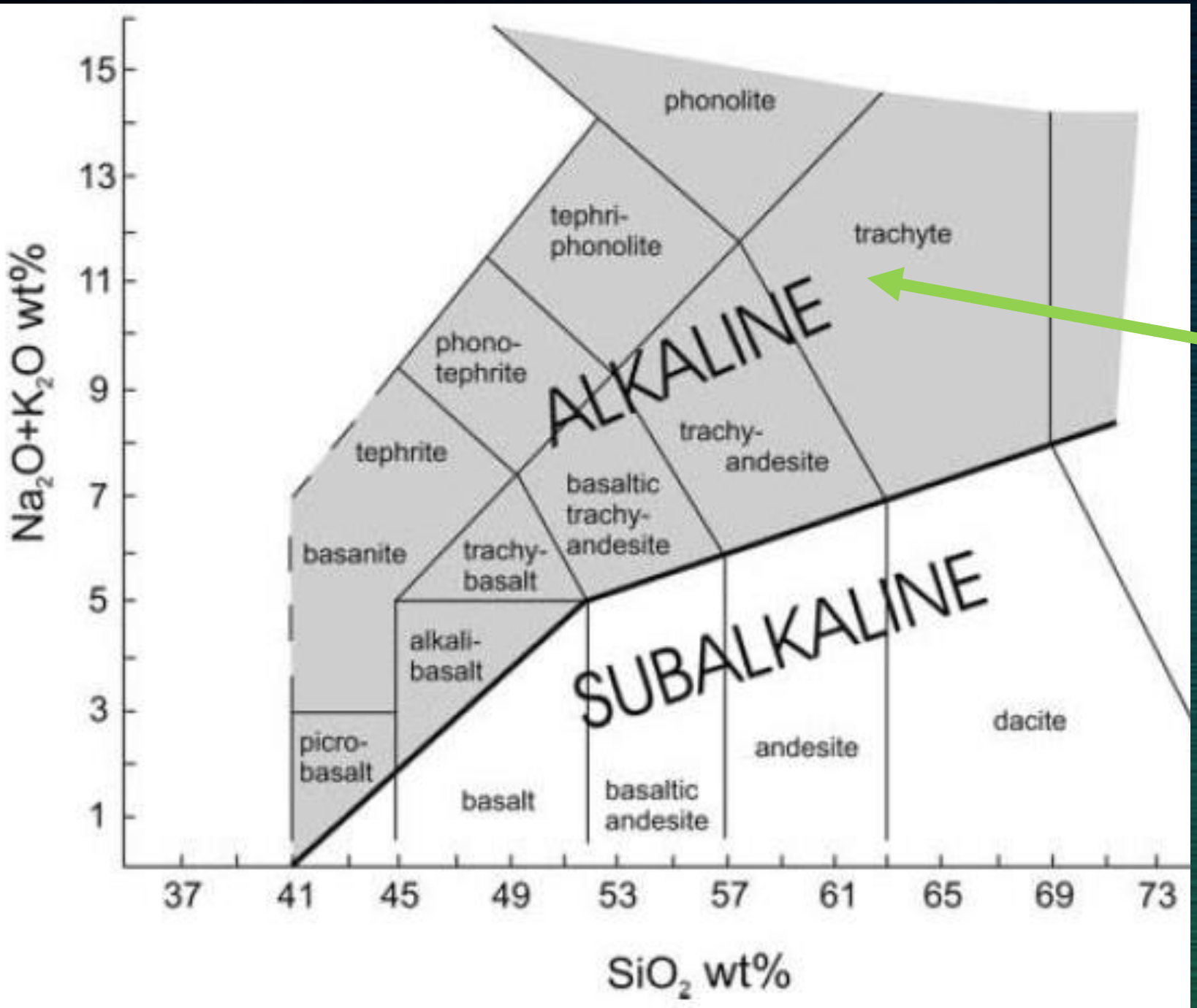
[Photo provided by A. Wurst]

Target Generation in order to tackle these challenges by:

- More efficient and cost-effective exploration
- Systematically select prospective areas/projects
- Ranking of the most prospective areas
- Efficient area size reduction

Target Generation Criteria:

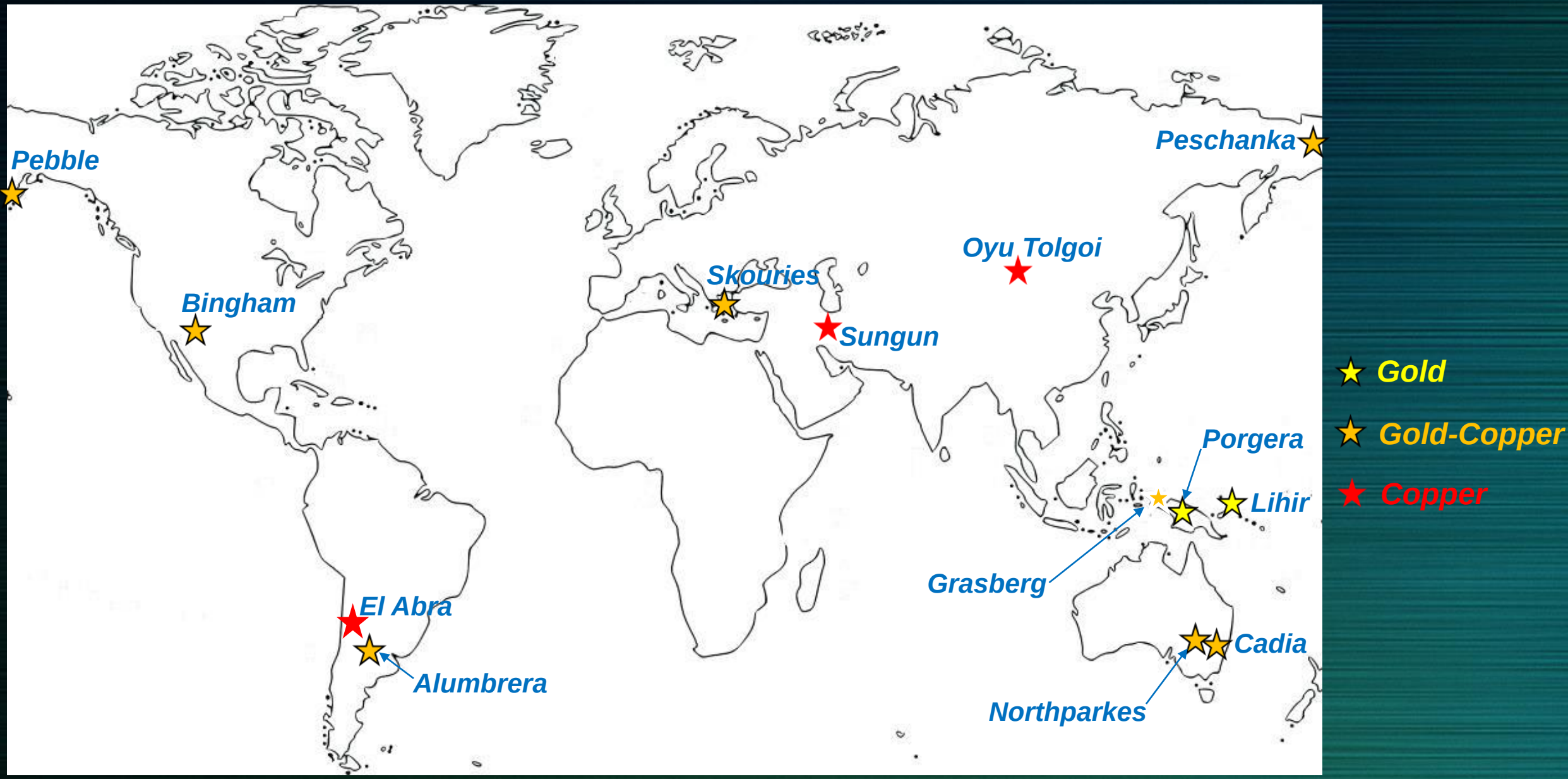
Favorable tectonic setting; (1
Favorable structural framework; (2
Endowment with known mineral deposits; (3
Presence of ancient workings/pirquineros; (4
Fertile intrusive belts. (5

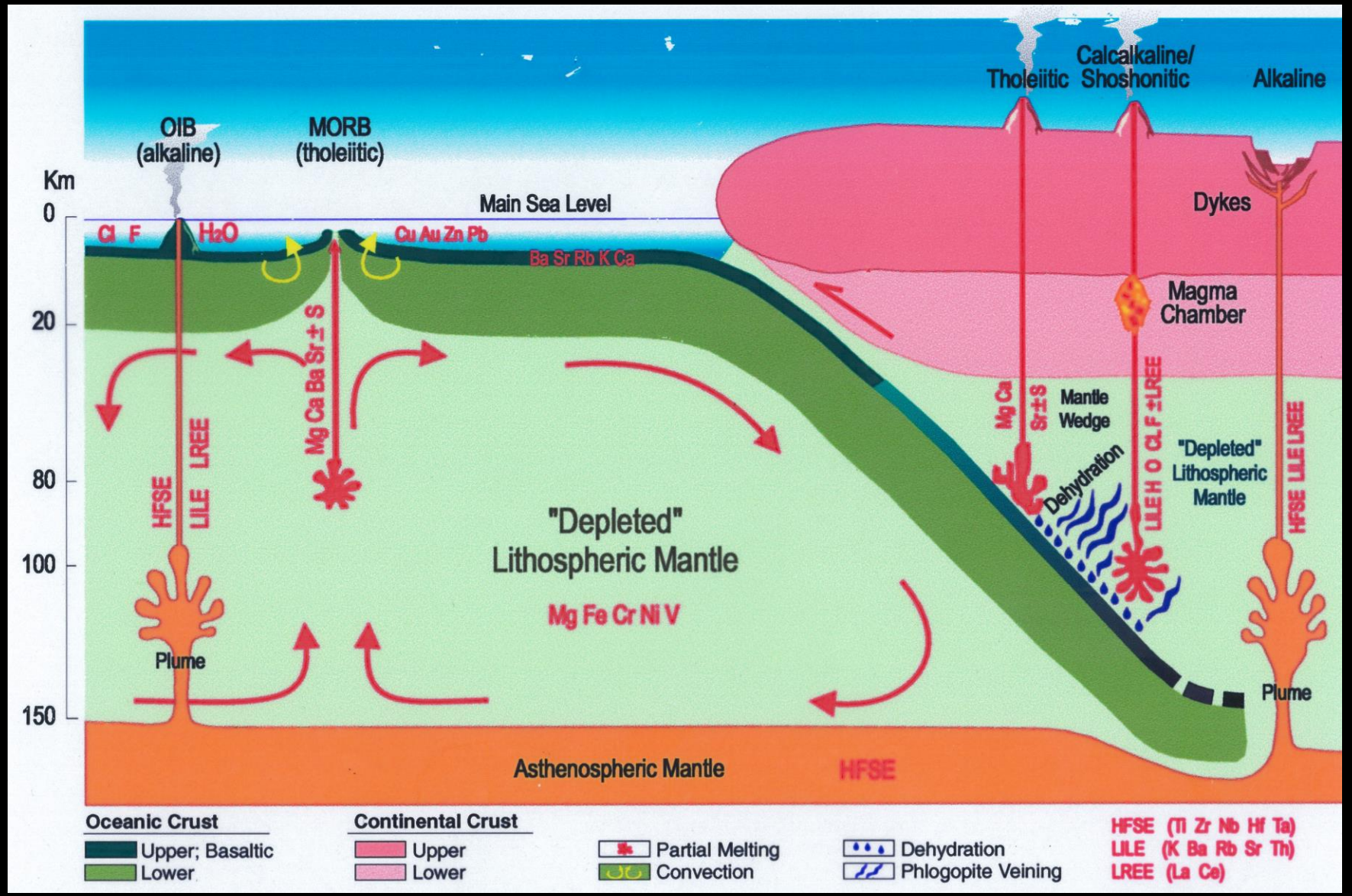


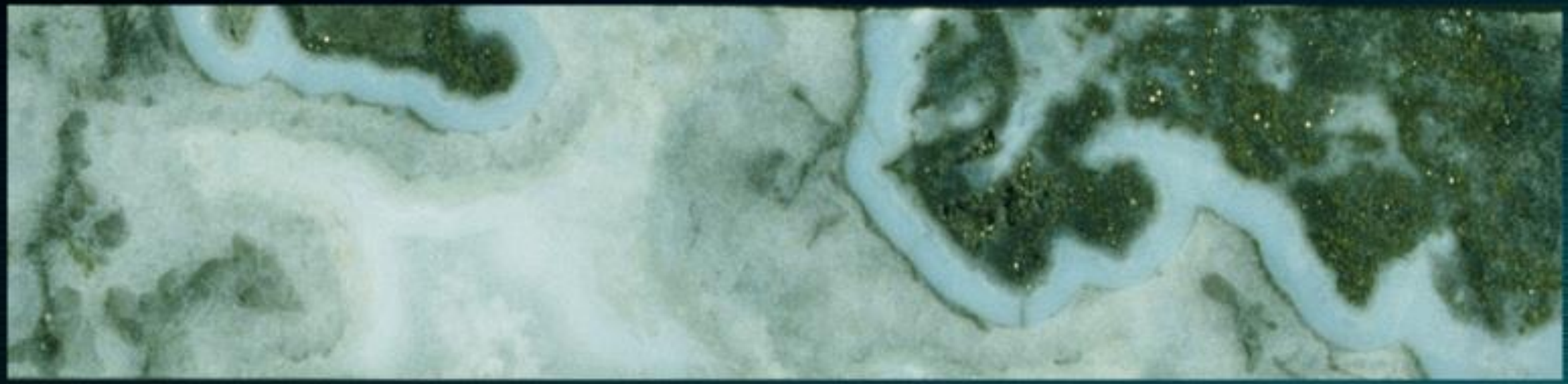
Alkaline **rocks are defined by *both* high K_2O and Na_2O**

[Le Maitre 1989]

Major gold and copper deposits hosted by high-K igneous rocks



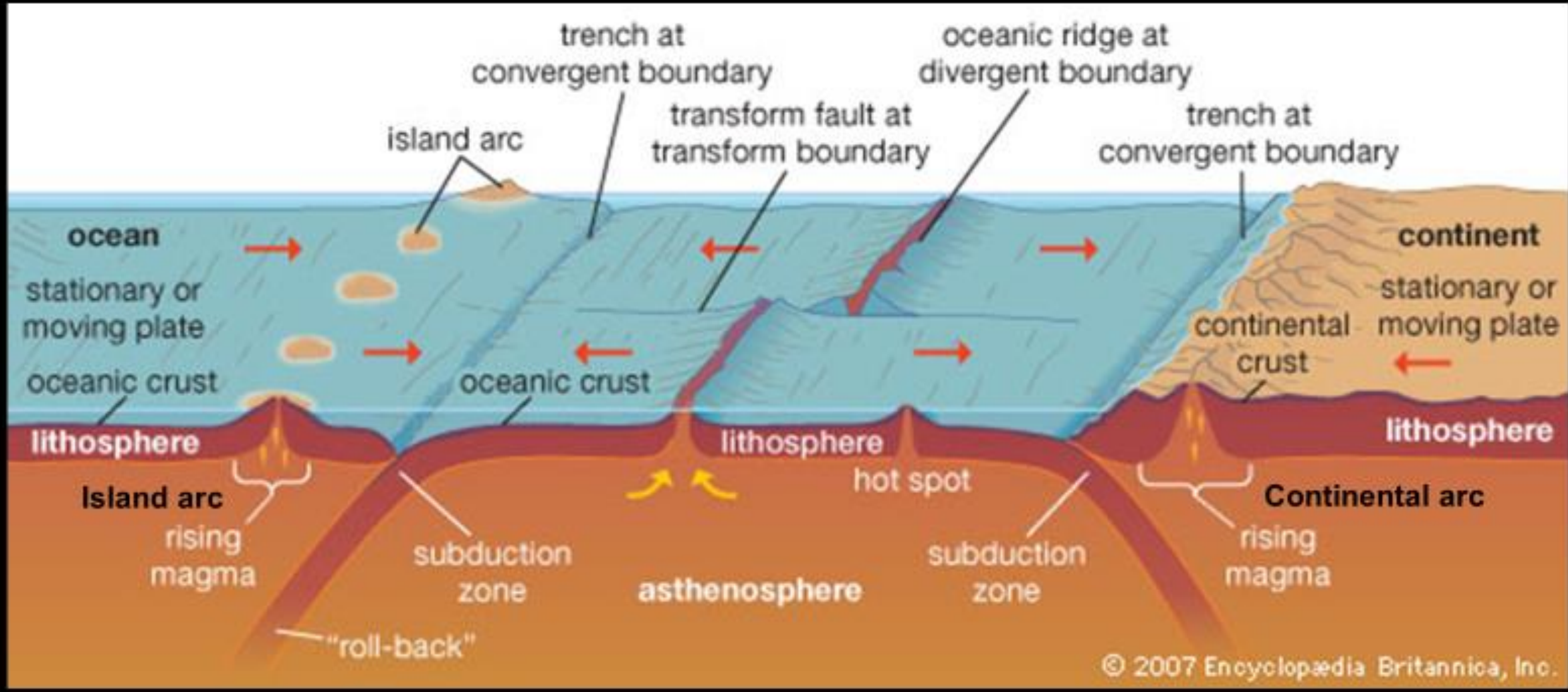

Km
0
20
80
100
150
OIB
(alkaline)
MORB
(tholeiitic)
Main Sea Level
Cl F
H2O
Cu Au Zn Pb
Ba Sr Rb K Ca
Mg Ca Ba Sr ± S
HFSE LILE LREE
"Depleted"
Lithospheric Mantle
Mg Fe Cr Ni V
Plume
Asthenospheric Mantle
HFSE
Tholeiitic
Calcalkaline/
Shoshonitic
Alkaline
Dykes
Magma
Chamber
Mg Ca
Sr±S
Mantle
Wedge
Dehydration
LILE H O Cl F ±LREE
"Depleted"
Lithospheric
Mantle
HFSE LILE LREE
Plume
Oceanic Crust
Upper; Basaltic
Lower
Continental Crust
Upper
Lower
Partial Melting
Convection
Dehydration
Phlogopite Veining
HFSE (Ti Zr Nb Hf Ta)
LILE (K Ba Rb Sr Th)
LREE (La Ce)

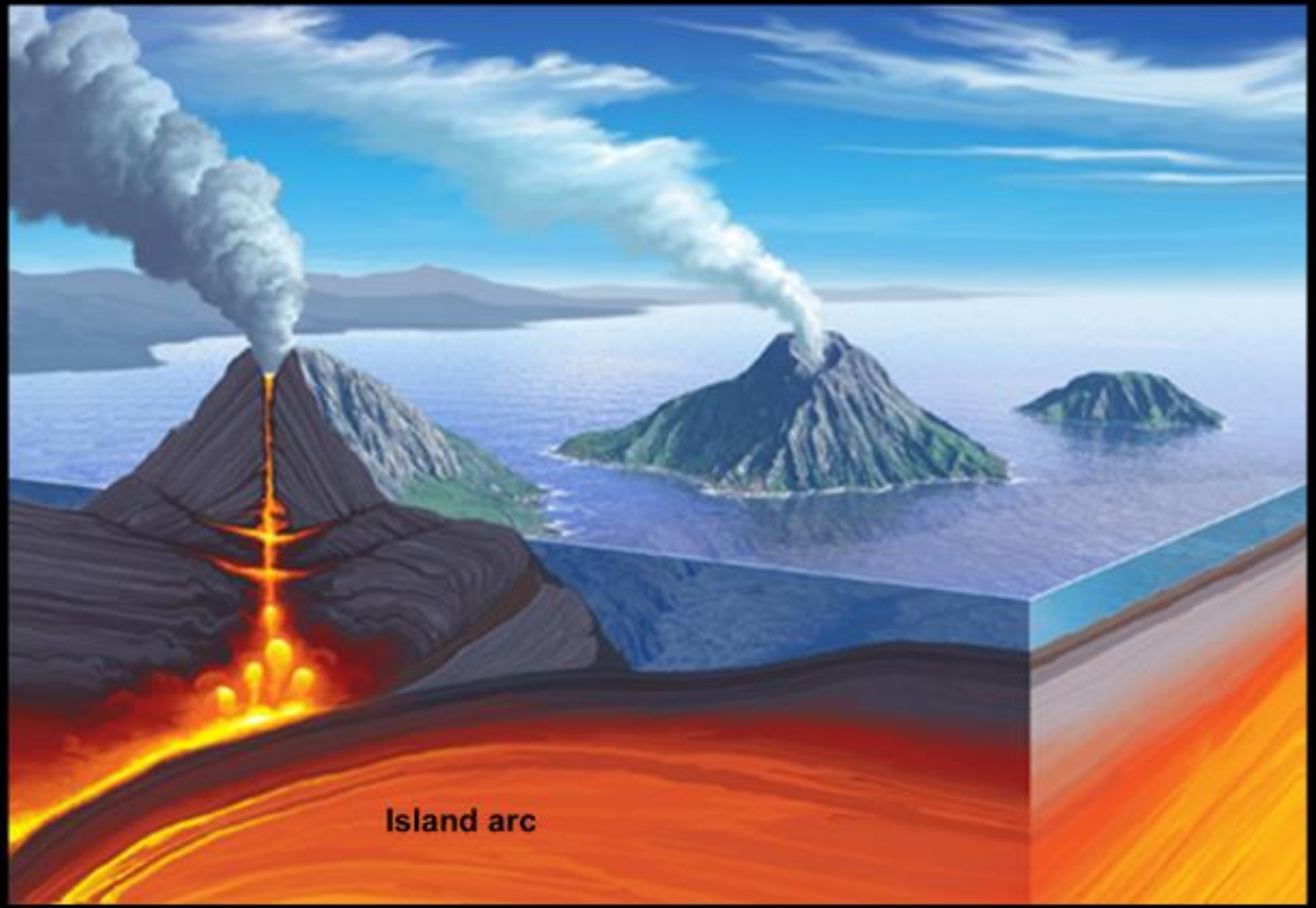


Alkaline rocks and Gold

Part 2: Tectonic settings of potassic igneous rocks

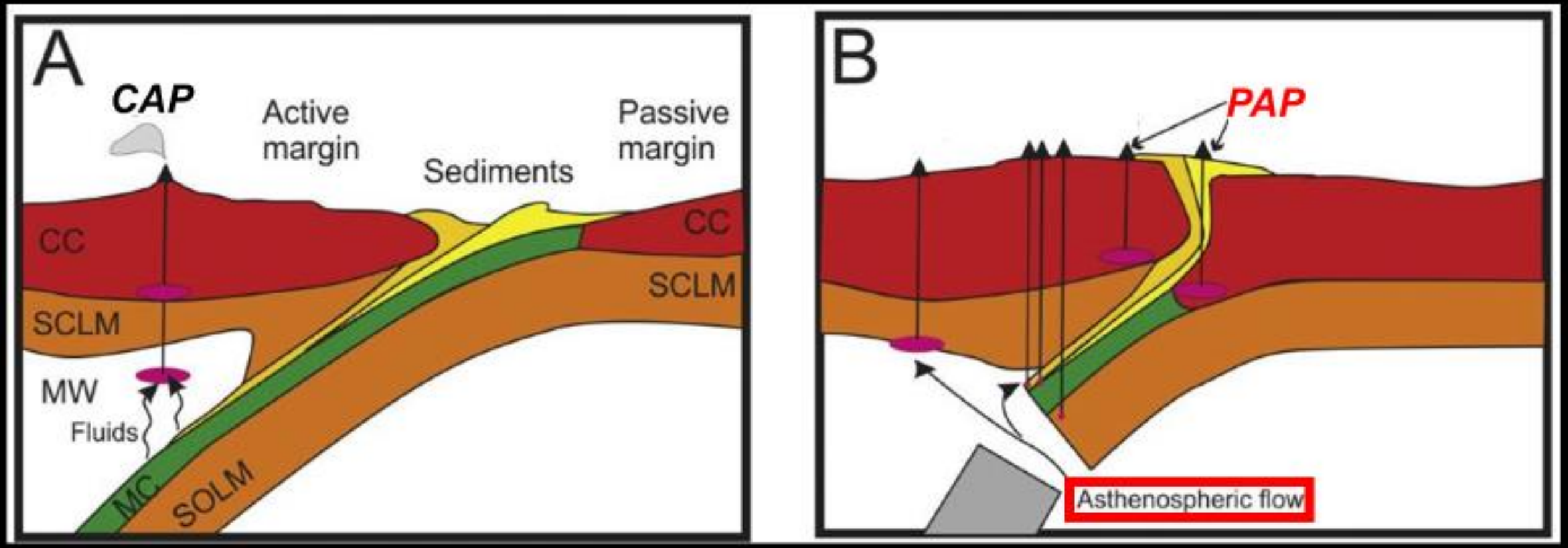
Continental arc versus oceanic island arc





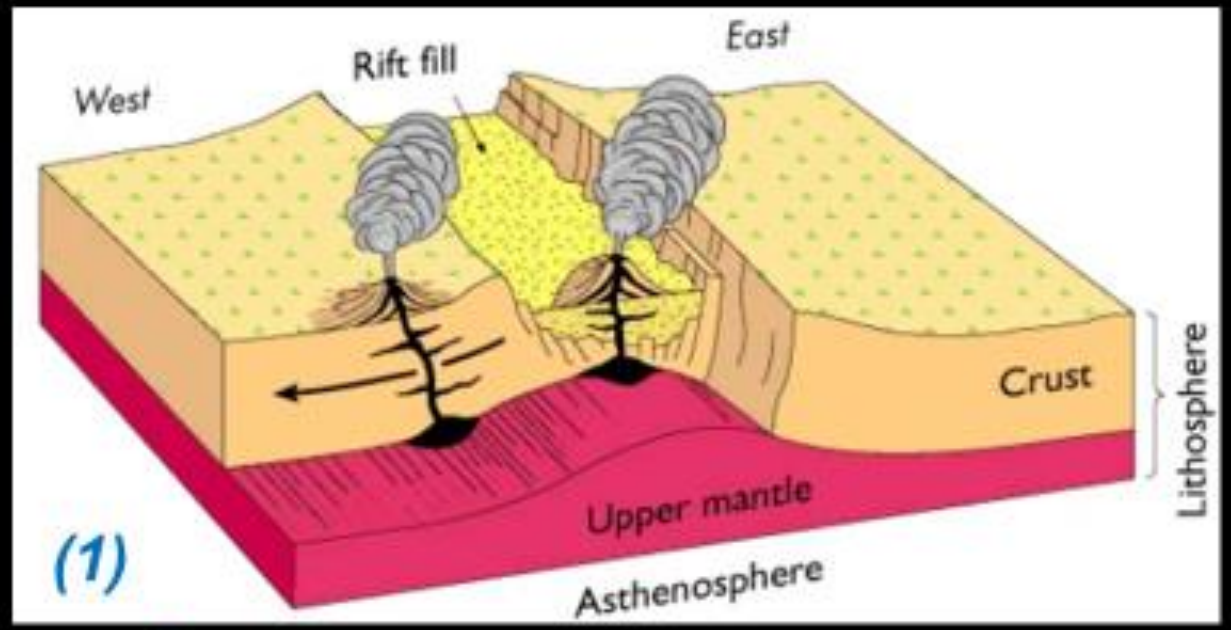
Oceanic
island arc

Post-collisional arc (PAP)

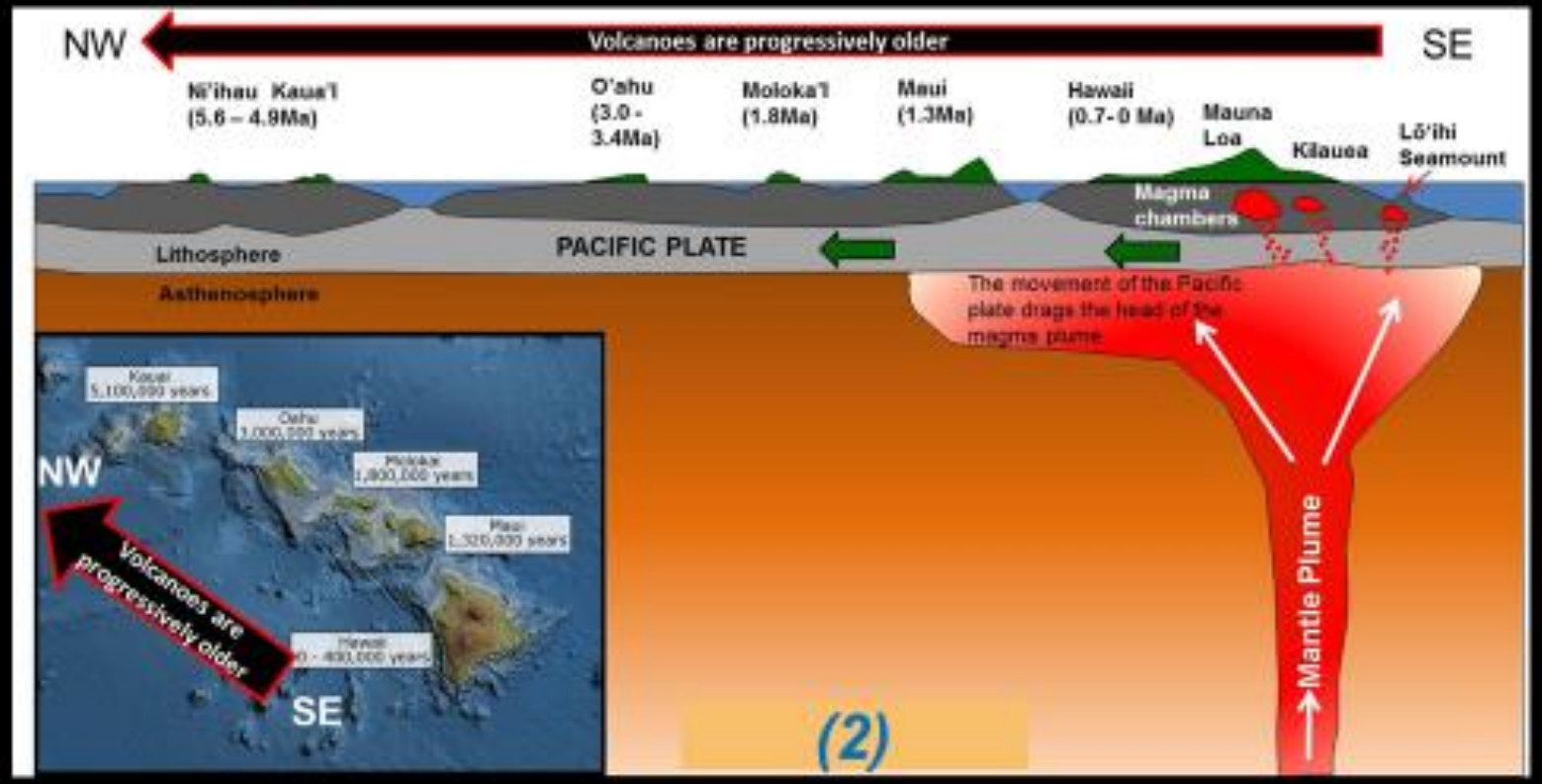


[Ivanov et al. 2019]

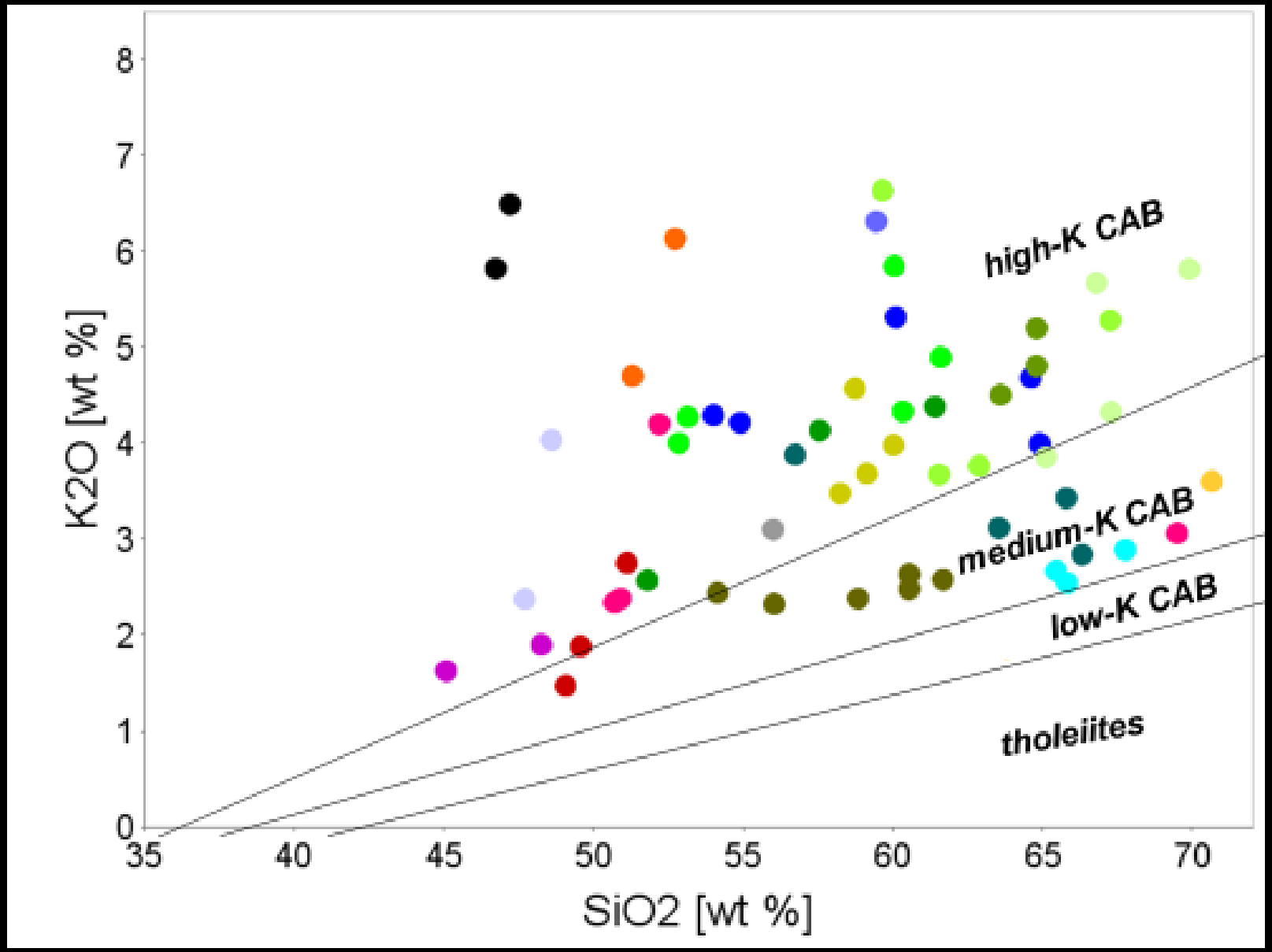
Within-plate tectonic settings:



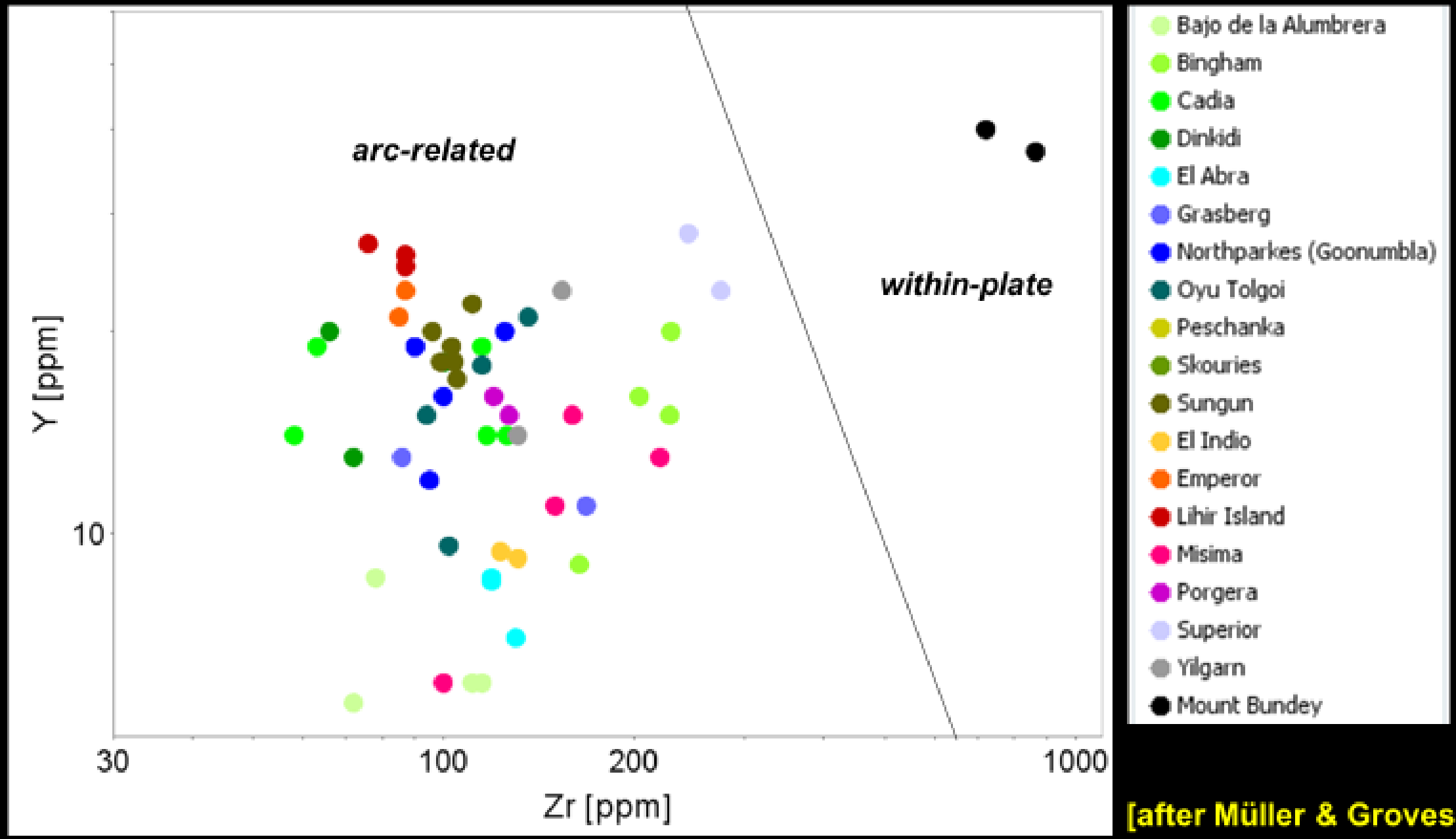
(1) Rifting (e.g. East-African Rift)



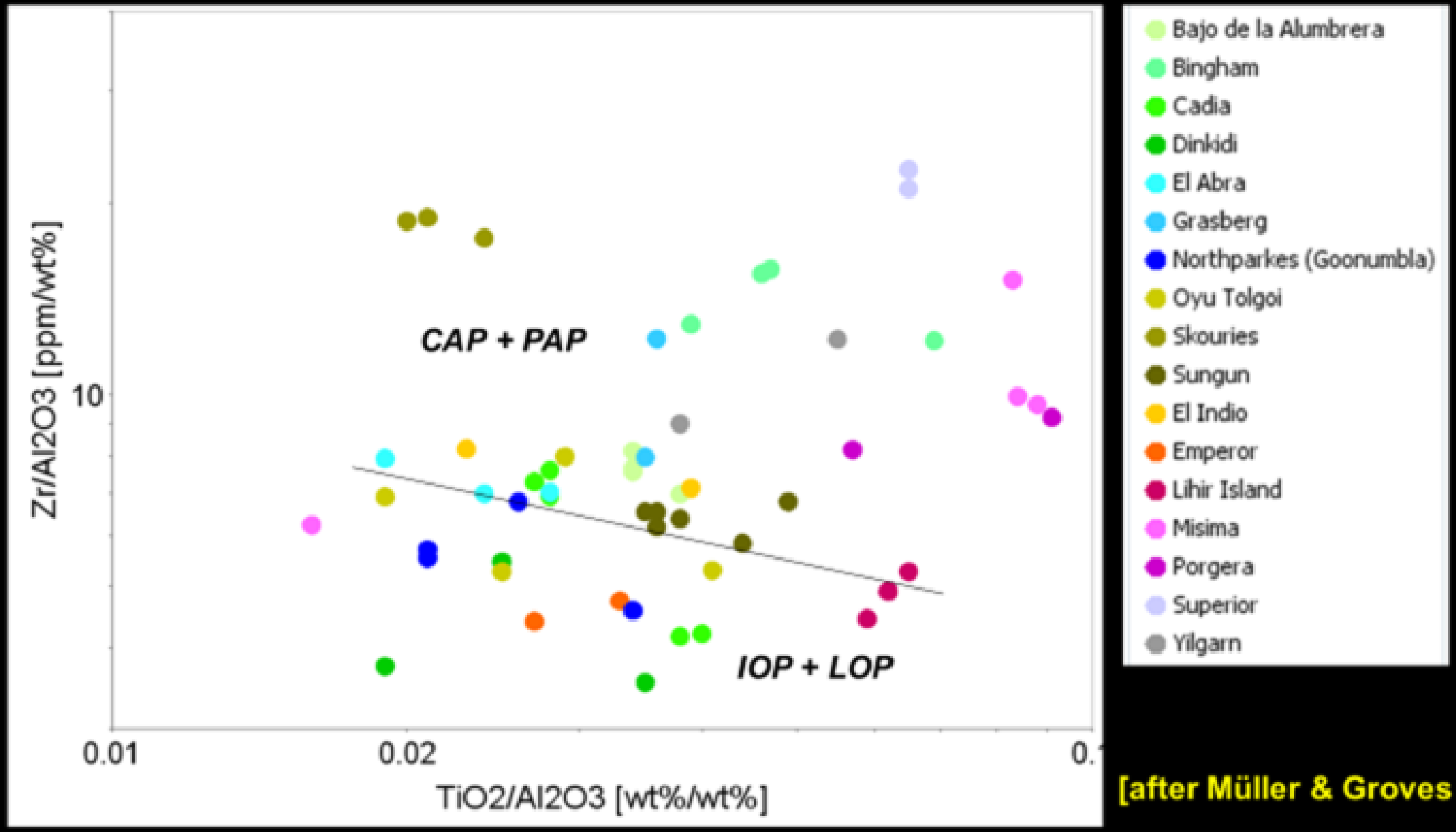
(2) Hotspot or plume magmatism (e.g. Hawaii)



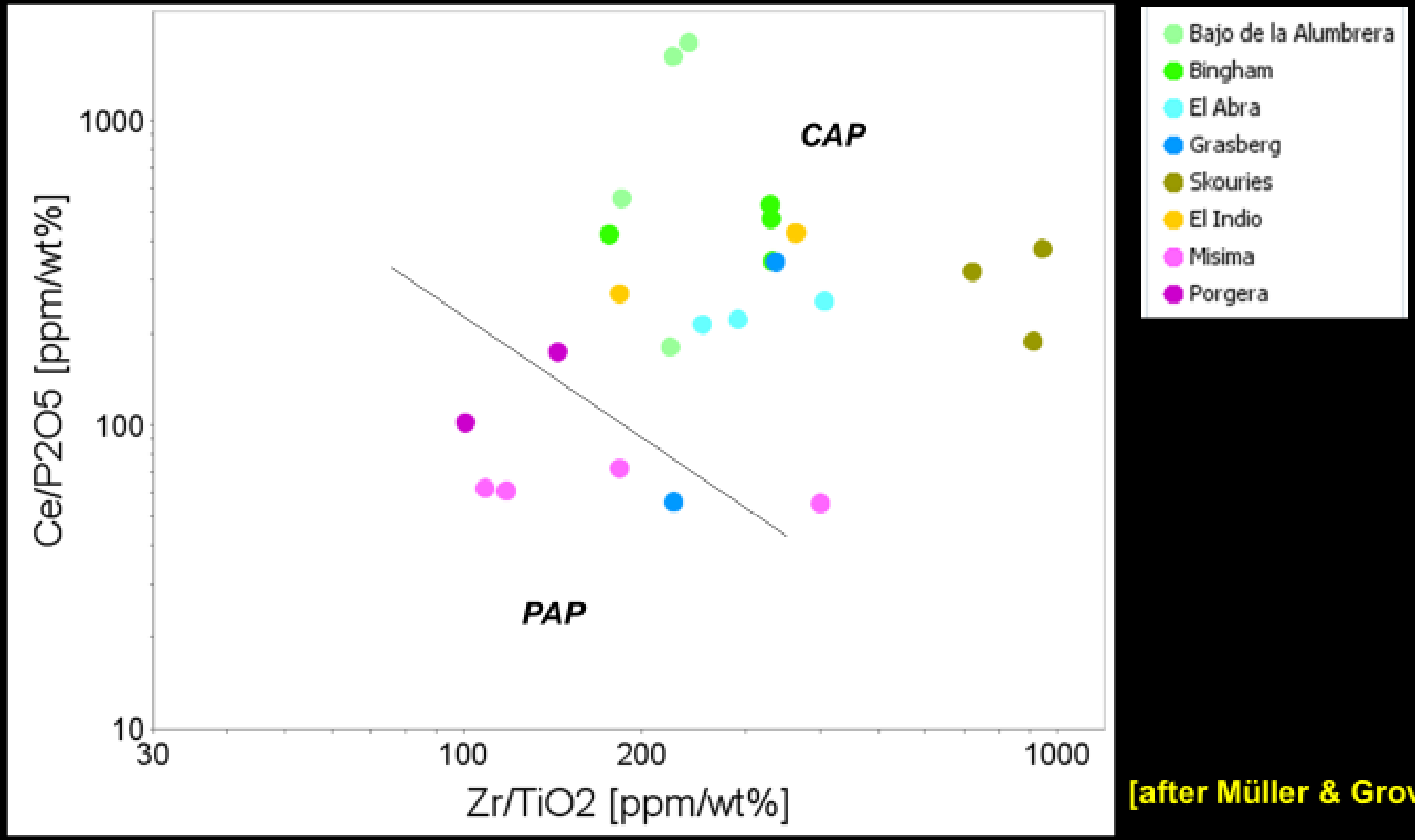
[after Müller & Groves 2019]



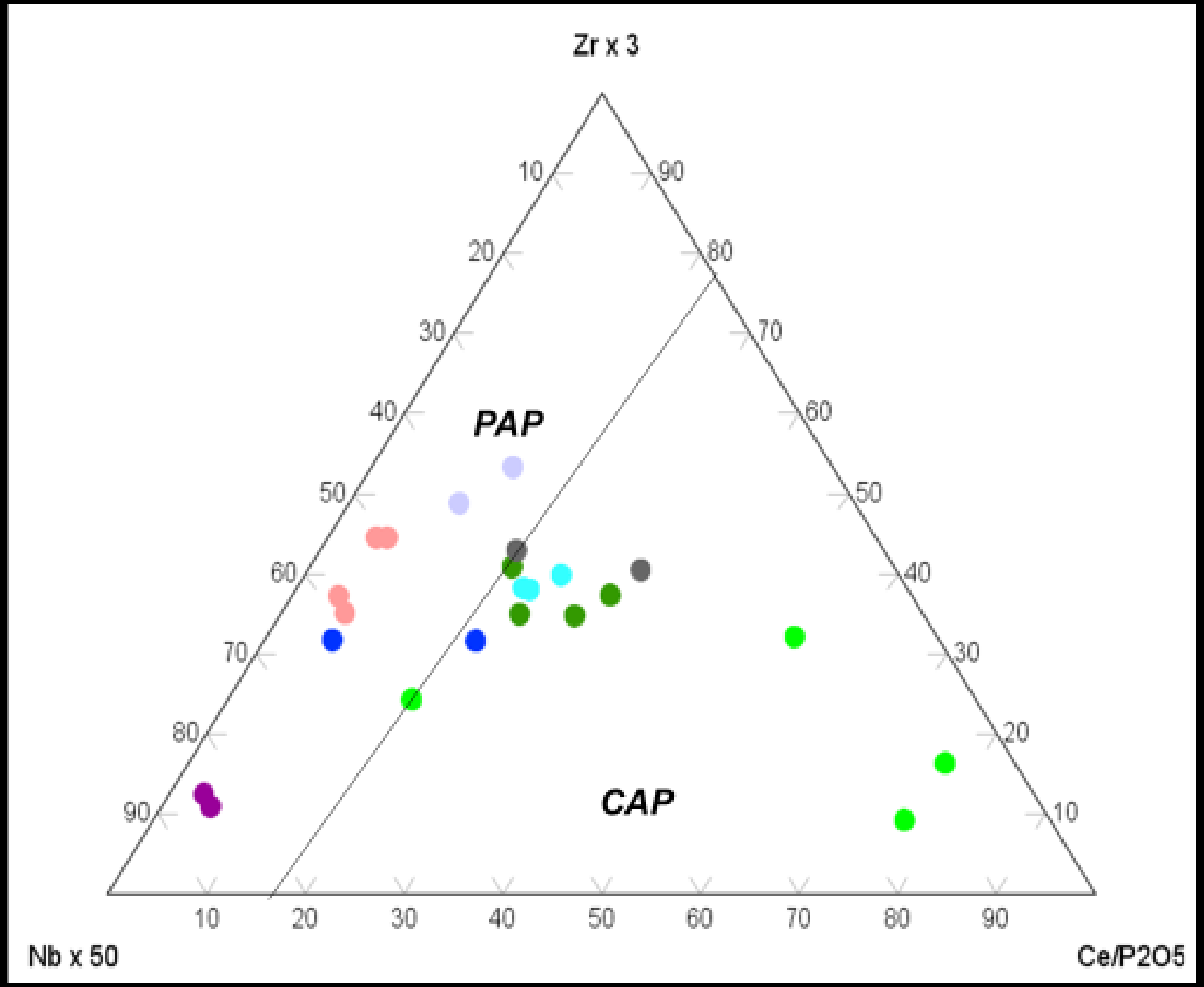
[after Müller & Groves 2019]



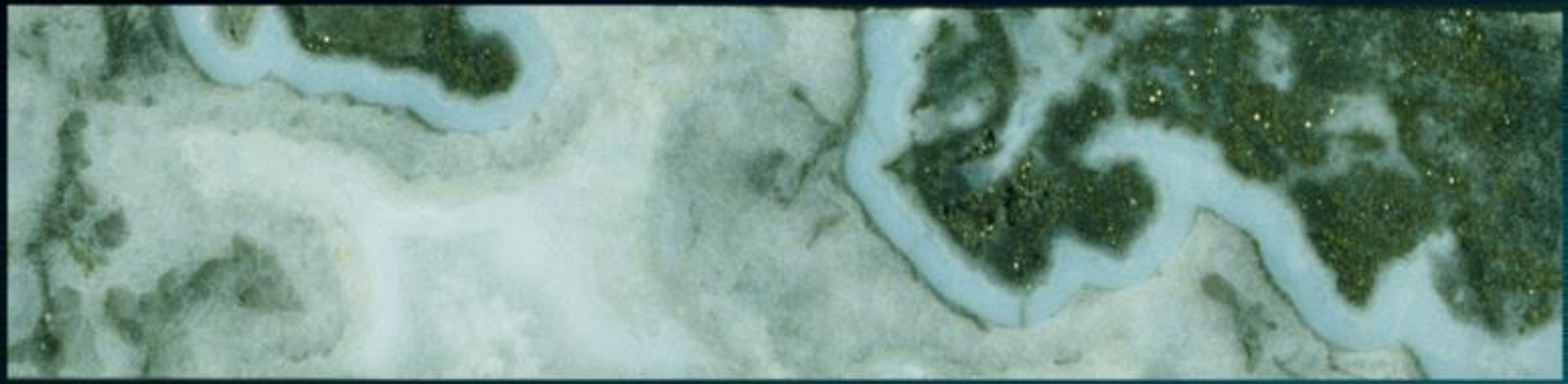
[after Müller & Groves 2019]



[after Müller & Groves 2019]



[after Müller & Groves 2019]



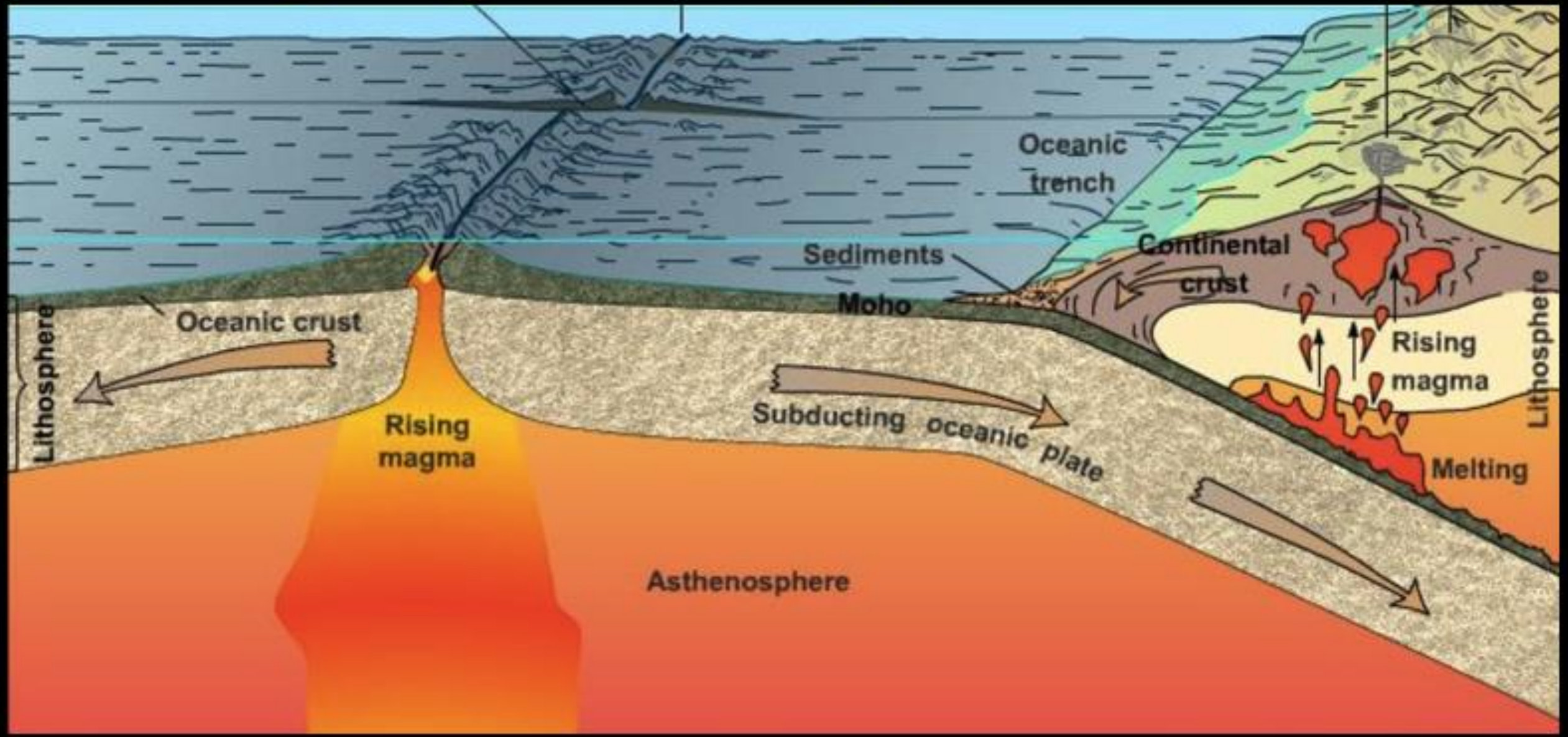
Alkaline rocks and Gold

Part 3: Halogen geochemistry of potassic igneous rocks

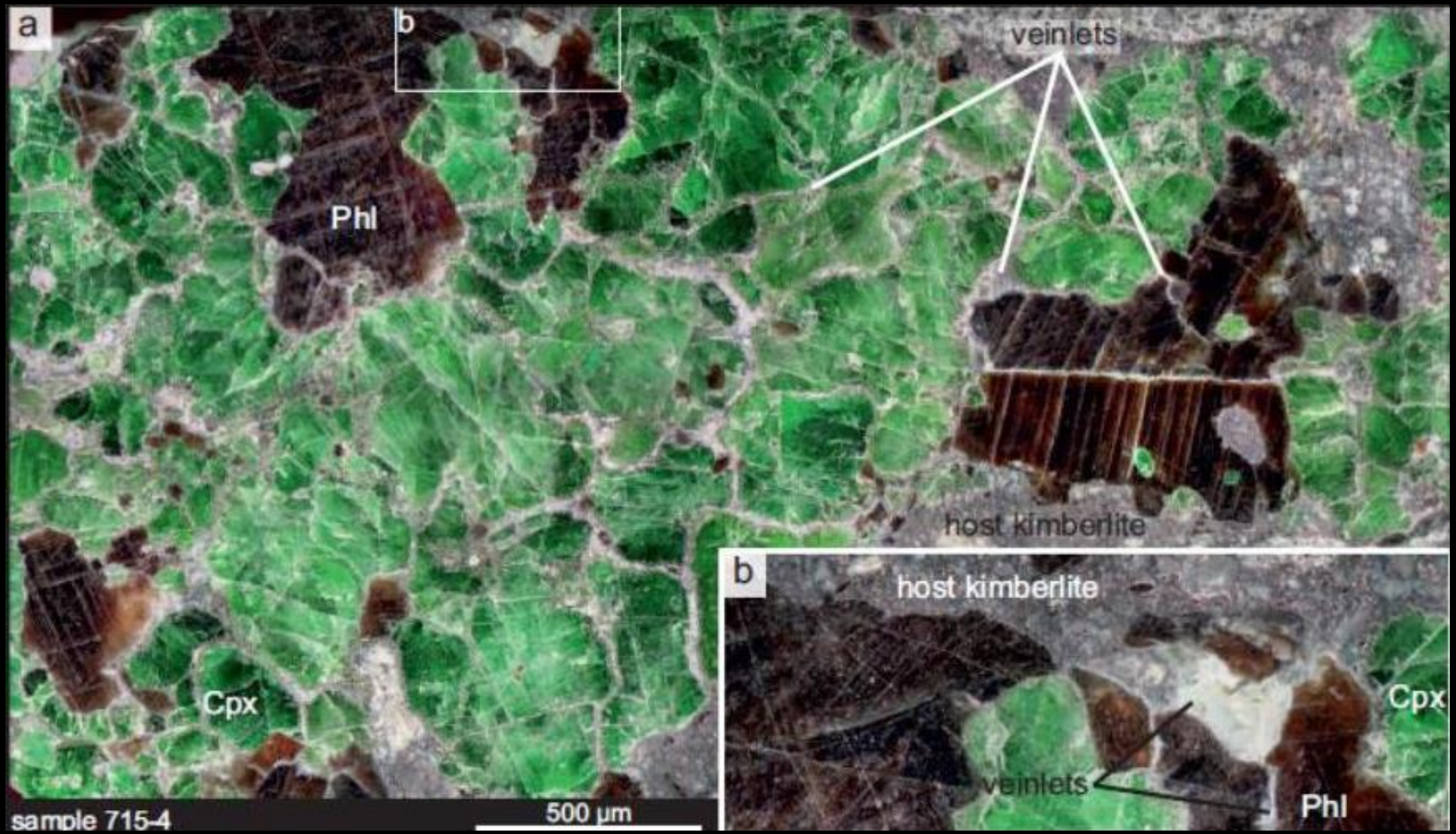
Formation of hydrothermal Au deposits critically depends on:

- Availability of water and other volatiles (H_2O, Cl)
- Availability of sulfur (S)
- Availability of metals (Au)

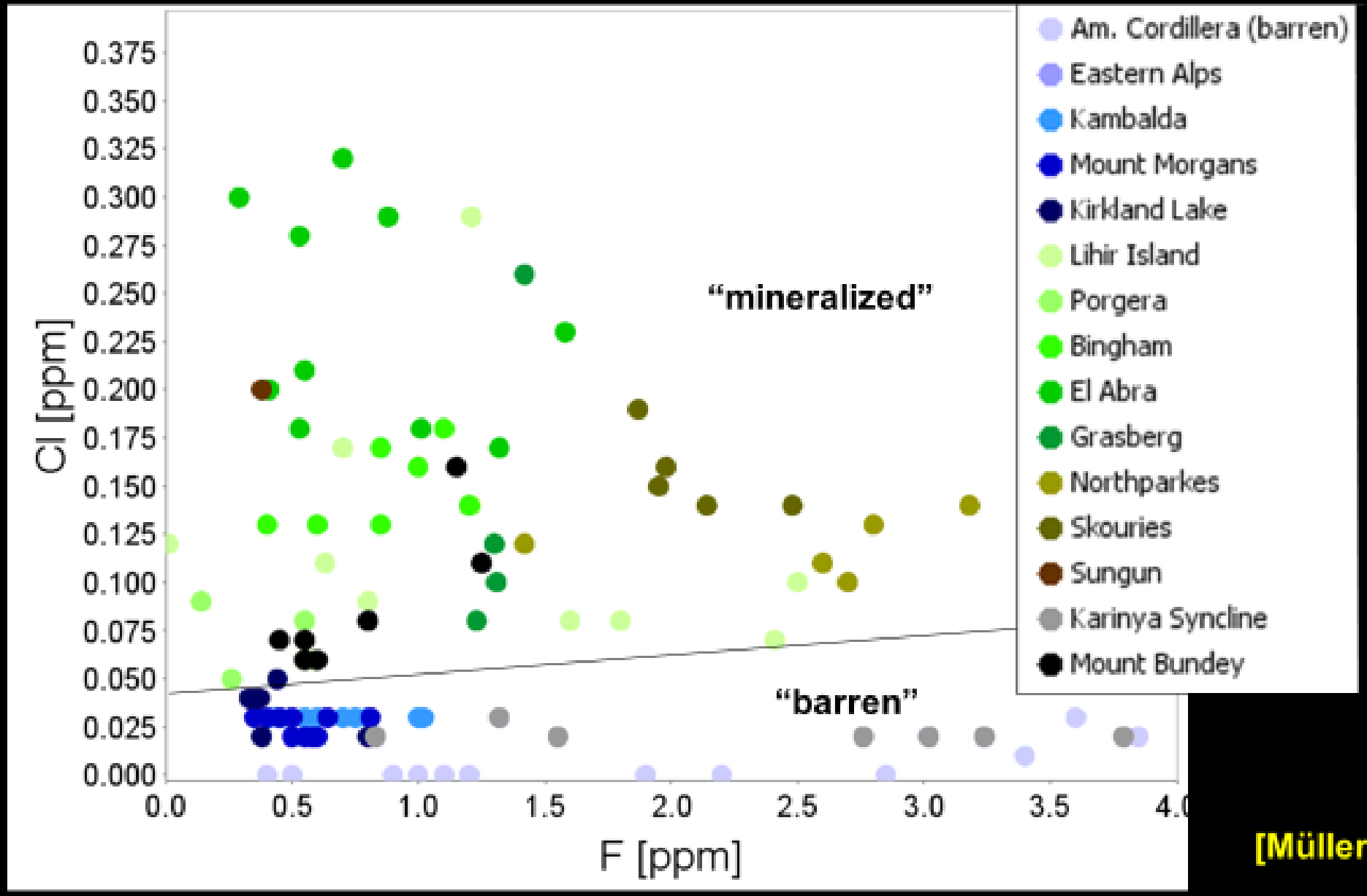
Subducted serpentinites and altered oceanic crust are responsible for transporting the largest amount of halogens into the mantle wedge



Phlogopite-rich mantle nodule in kimberlite, Arkhangelsk, Russia

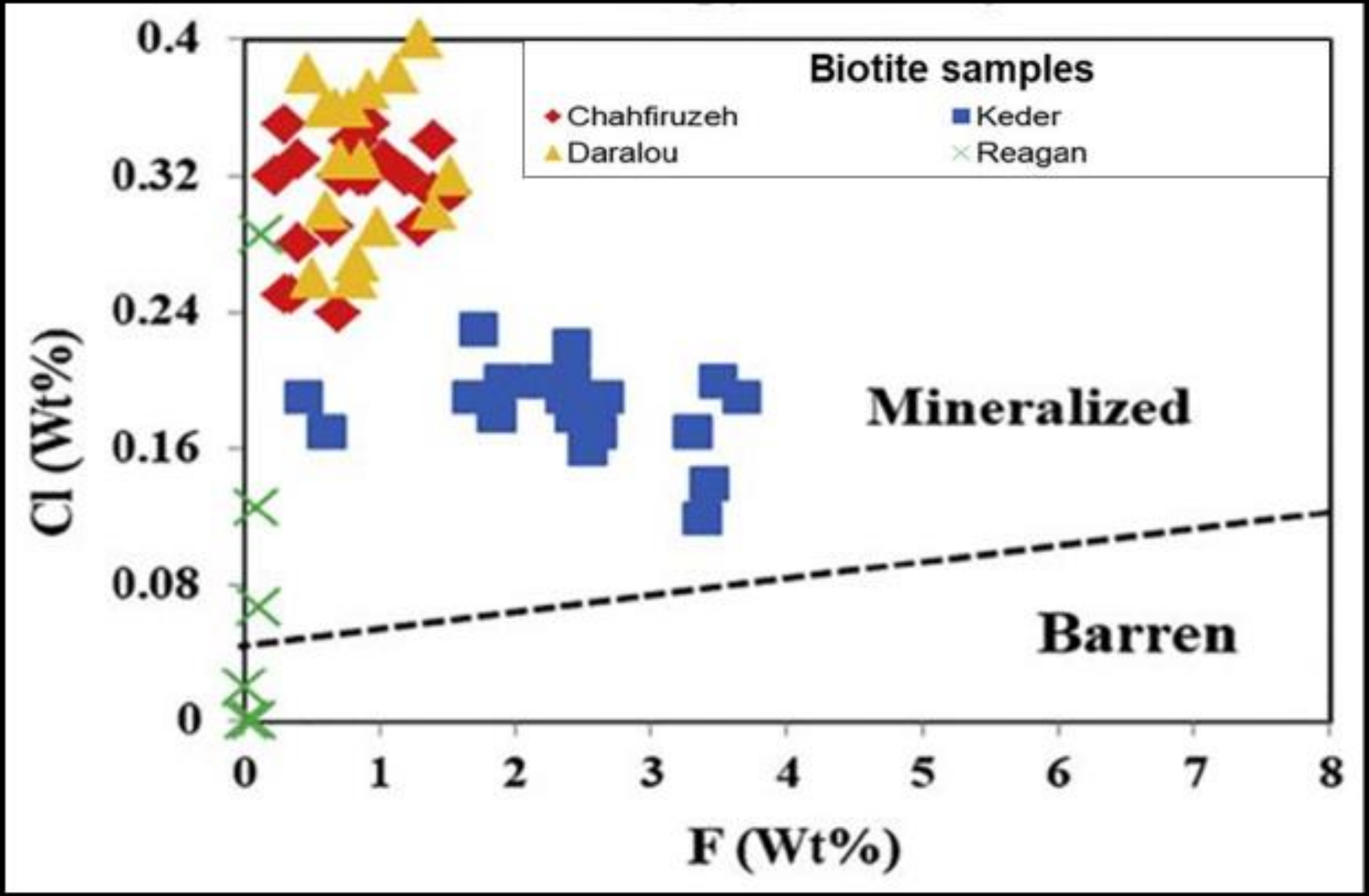


[Kargin et al. 2018]



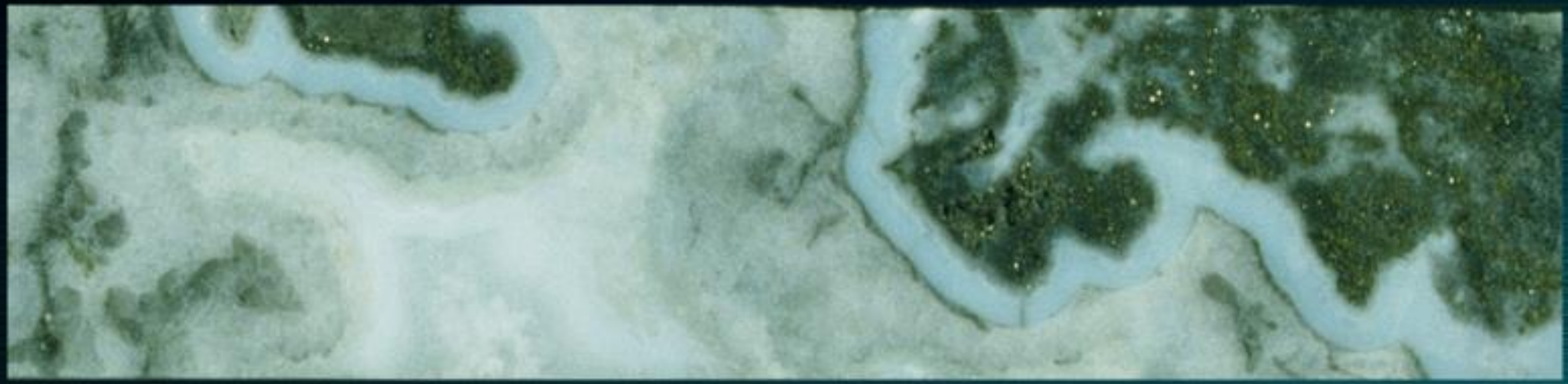
Biotite halogen contents from mineralized and barren intrusions

[Müller & Groves 2019]



Recent case study on porphyry Cu deposits in southern Iran
(Chahfiruzeh contains about 100 Mt @ 0.7 wt% Cu)

[after Zarasvandi et al. 2019]

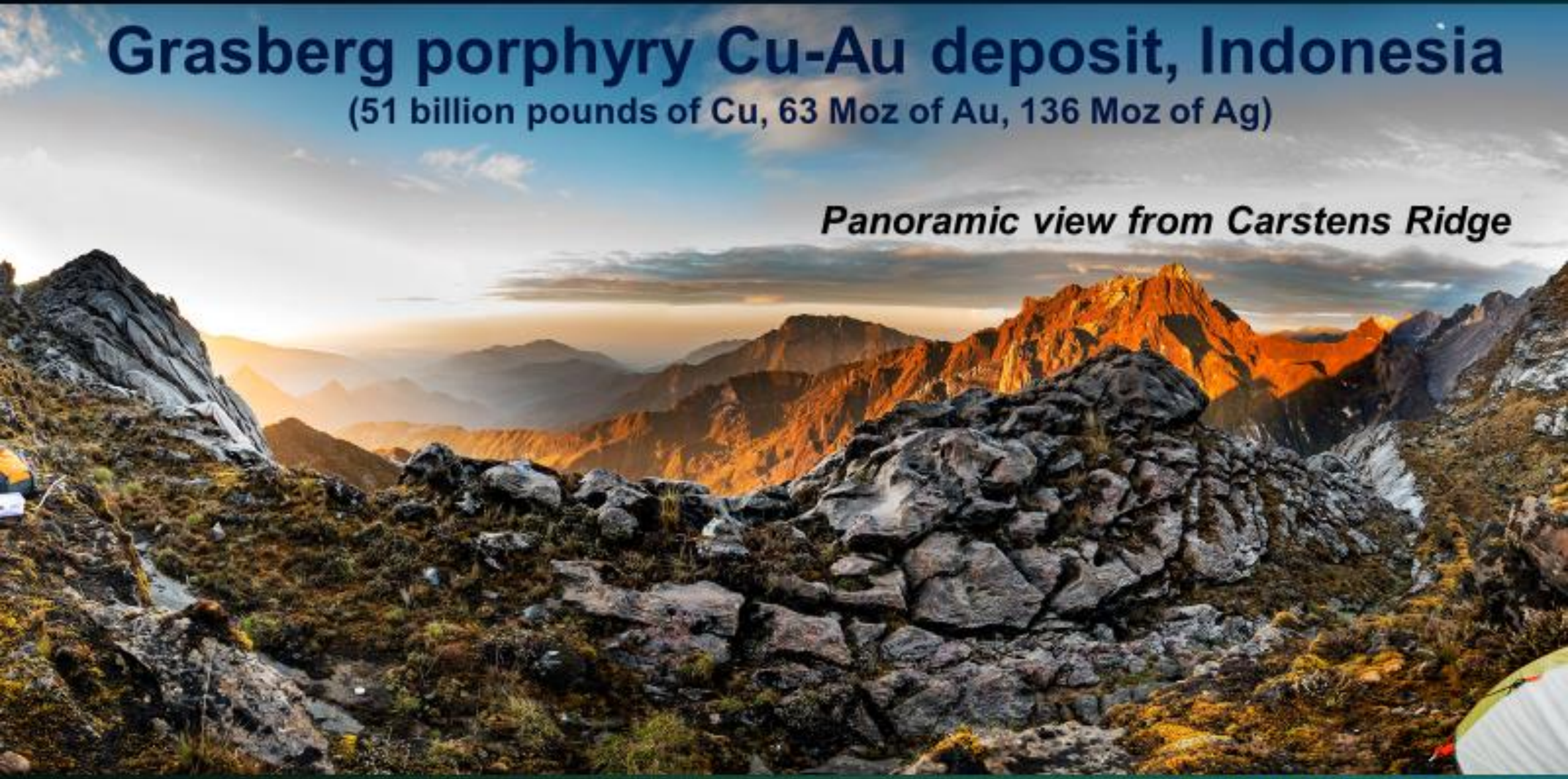


Alkaline rocks and Gold

Part 4: Examples of porphyry Cu-Au and epithermal Au deposits hosted by potassic igneous rocks

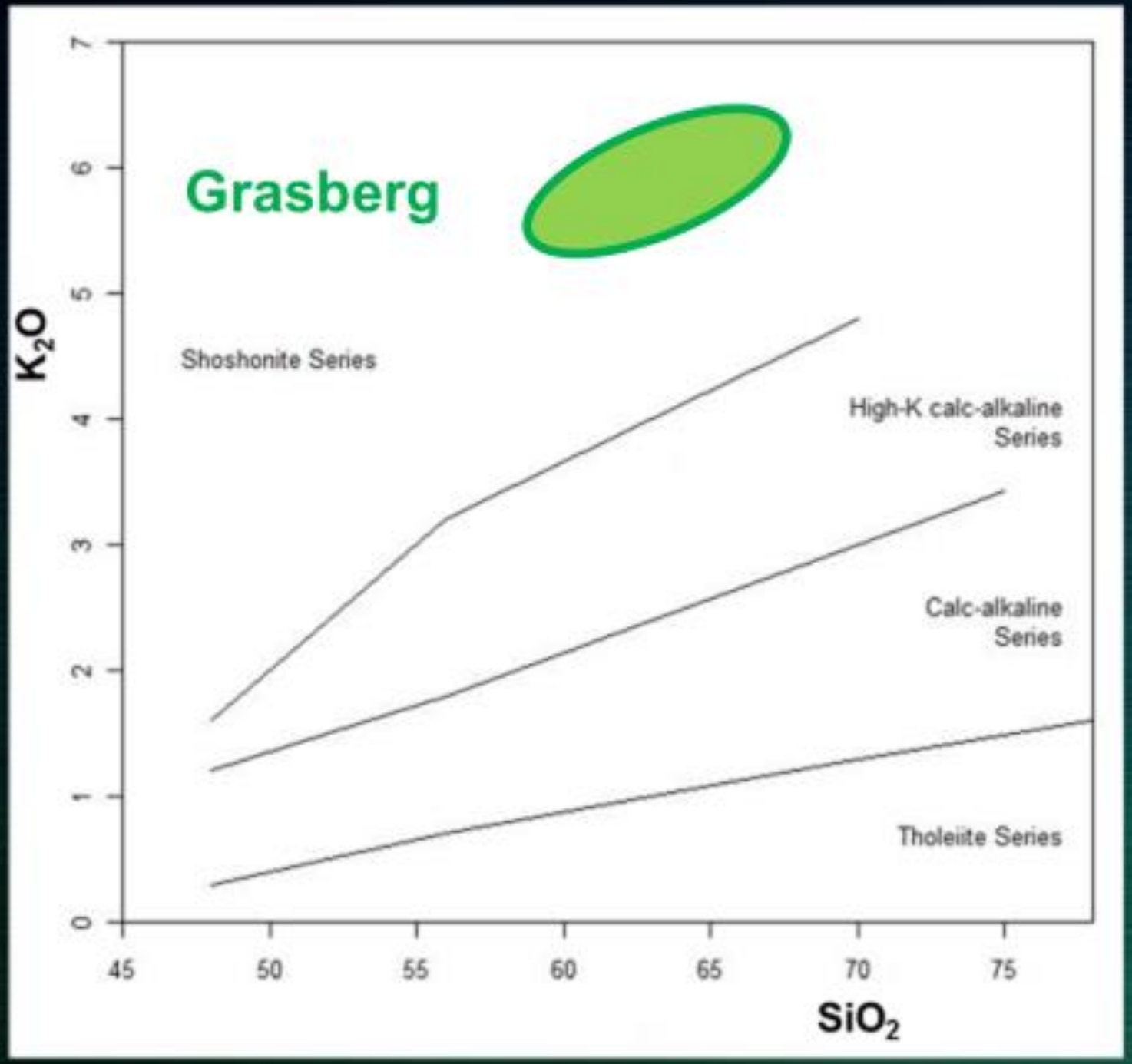
Grasberg porphyry Cu-Au deposit, Indonesia

(51 billion pounds of Cu, 63 Moz of Au, 136 Moz of Ag)



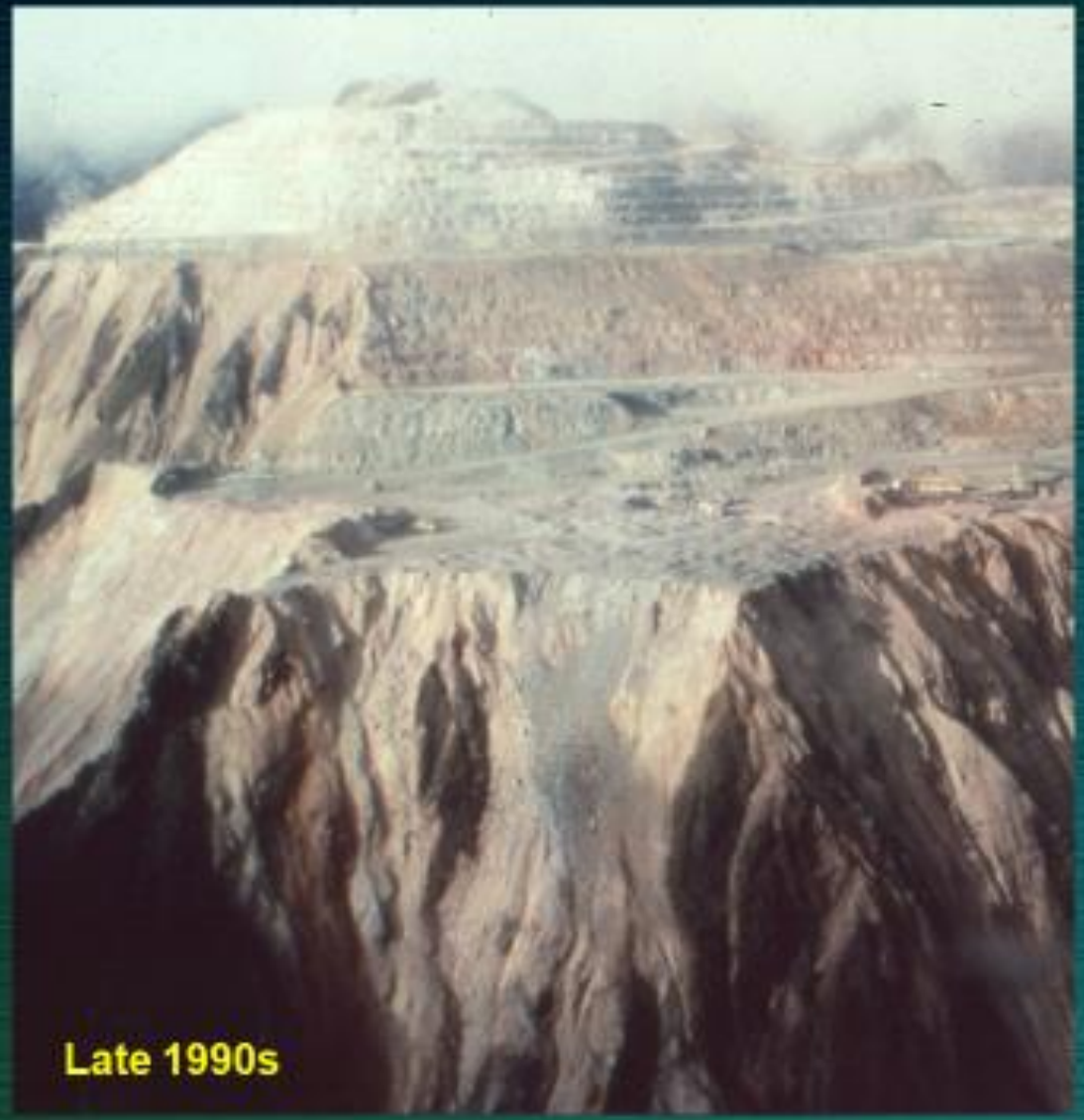
Panoramic view from Carstens Ridge

[photo taken by P. Warren]



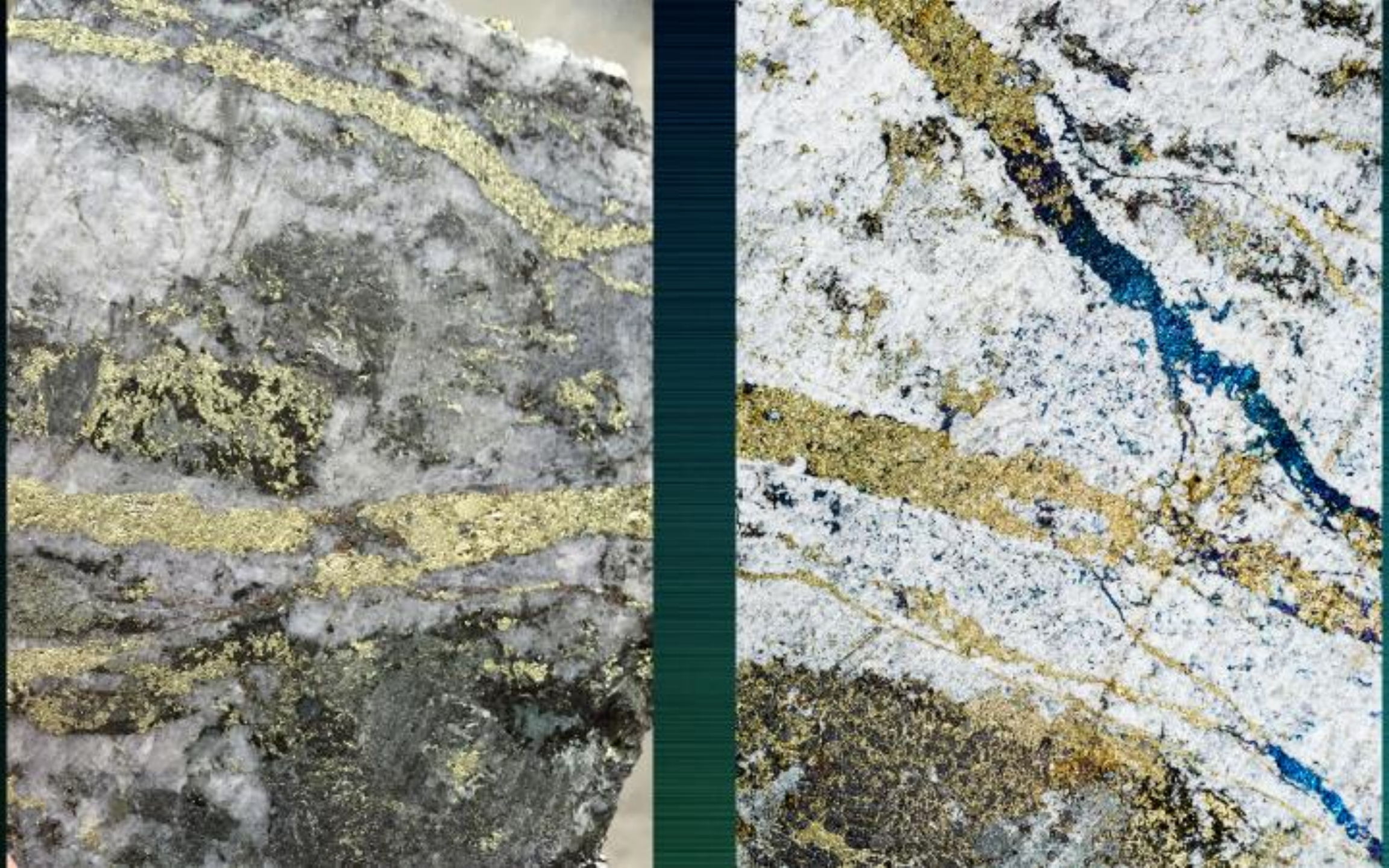
[data from Freeport 1993]

Grasberg porphyry Cu-Au deposit, Irian Jaya, Indonesia



Grasberg porphyry Cu-Au deposit, Irian Jaya, Indonesia

[Photos taken by P. Warren]

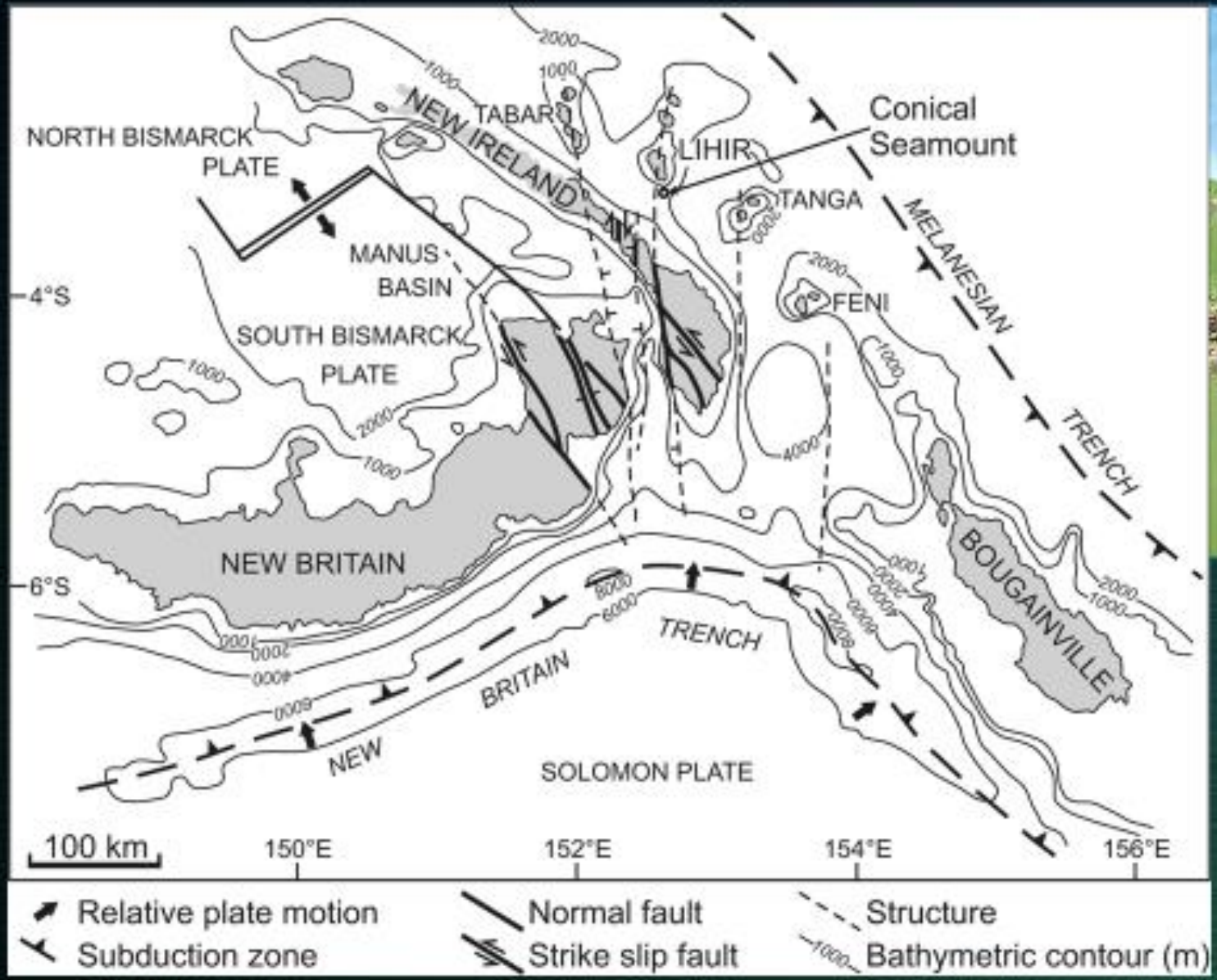


Grasberg copper-gold deposit, Indonesia:

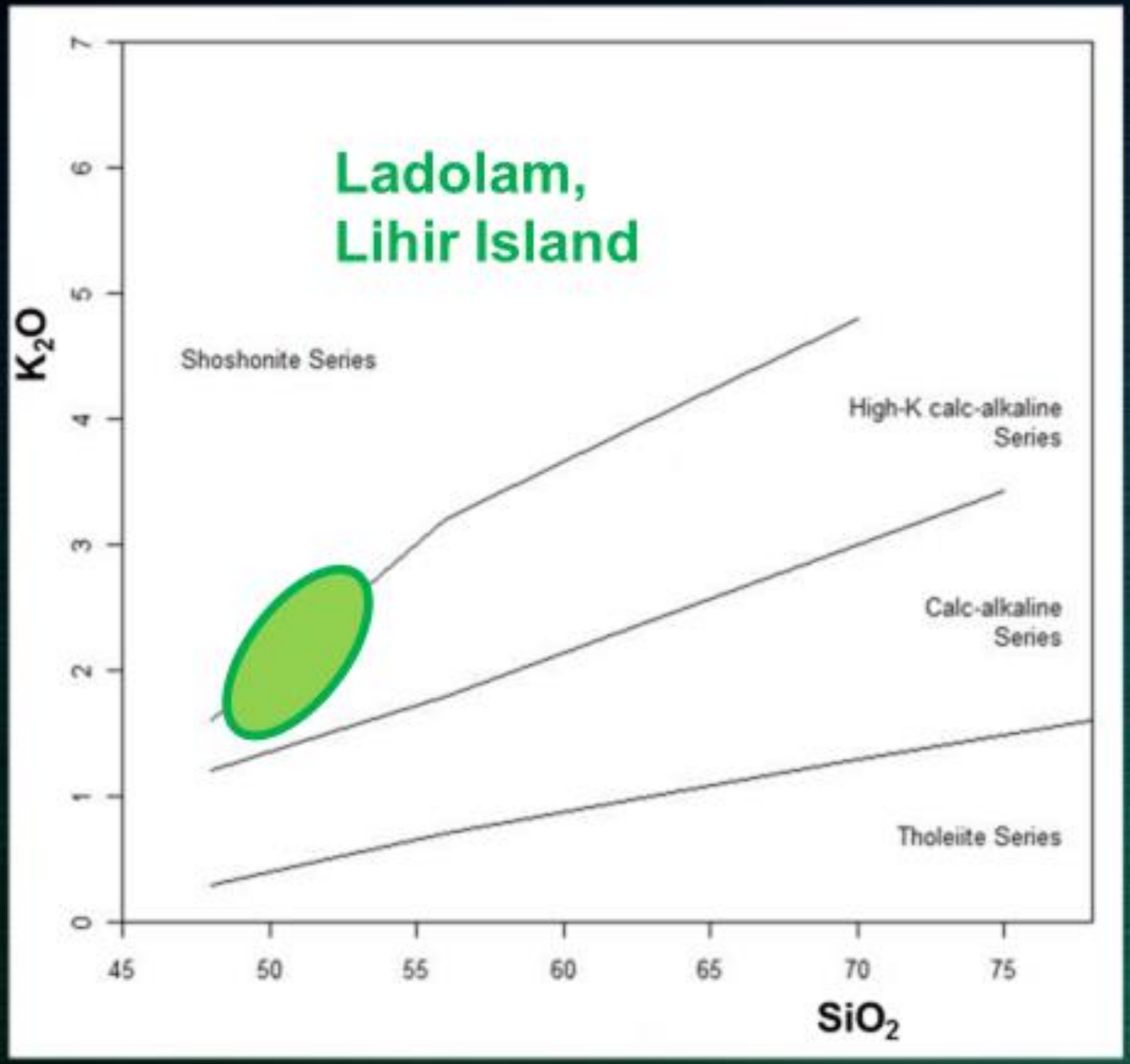
1. Age: 3.33-3.01 Ma (Pliocene)
2. Wall rocks: andesites and limestones
3. Intrusions: high-K calc-alkaline Mnzdio
4. Mineralization: porphyry Cu-Au and skarn
5. Resource: 51 Mio pounds Cu, 63 Moz Au, 136 Moz Ag

Ladolam gold deposit, Lihir Island, P.N.G.

(total resource of 56 Moz of Au)



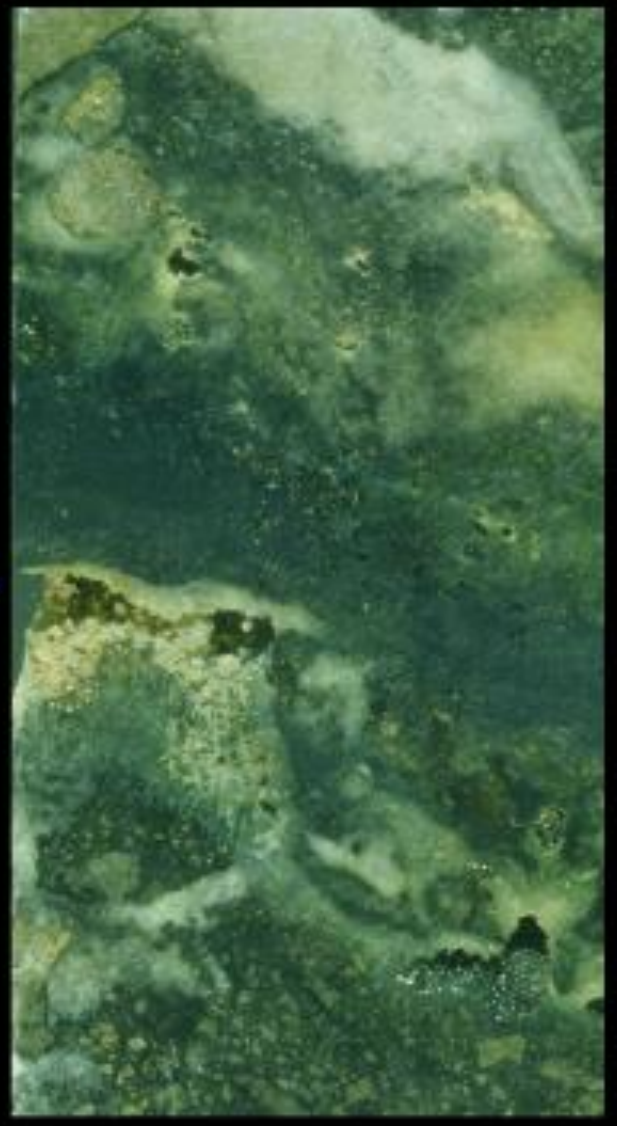
[modified after Lindley 2016]



[data from Müller et al. 2001]

Ladolam gold deposit, Lihir Island, P.N.G.

Transition from porphyry Cu to epithermal Au mineralization

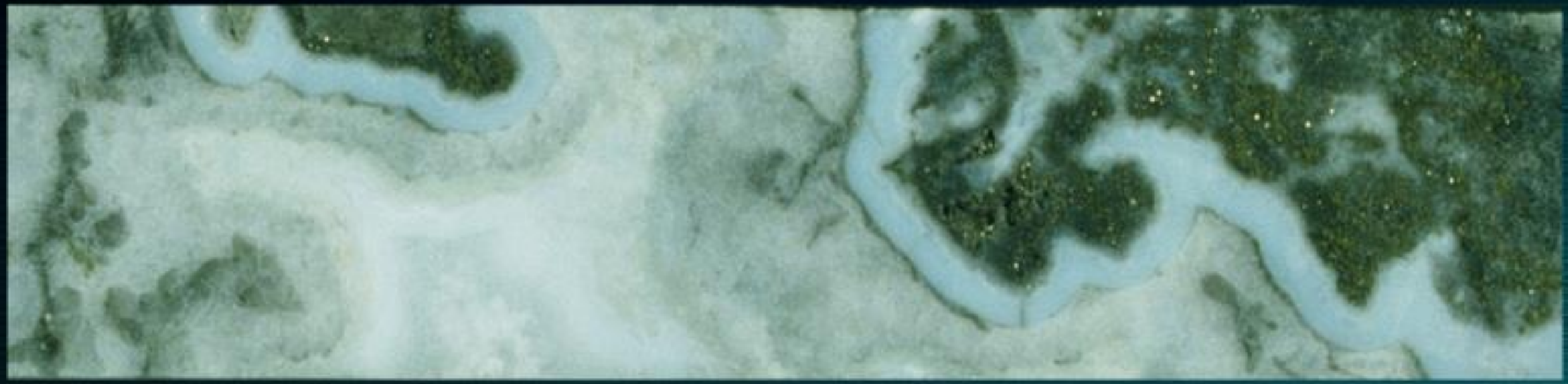


Ladolam Au deposit, Lihir Island, P.N.G.

[Photos taken by D. Müller]

Ladolam gold deposit, Lihir Island, PNG:

1. Age: 0.10-0.35 Ma (Pleistocene)
2. Wall rocks: trachyandesites
3. Intrusions: high-K calc-alkaline Mnzdio
4. Mineralization: epithermal Au
5. Resource: >56 Moz Au

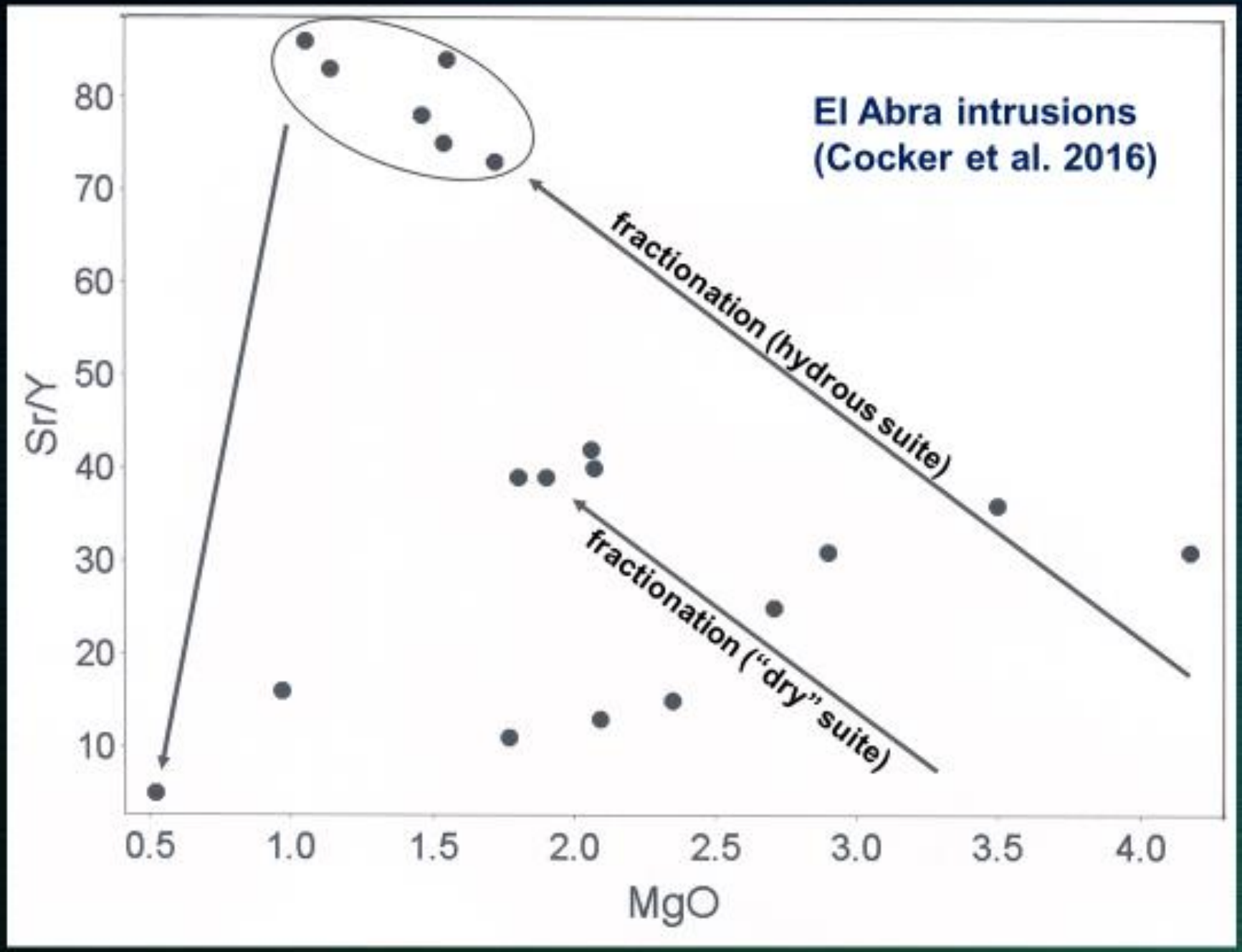


Alkaline rocks and Gold

Part 5: Using magma fertility in target generation

Selection criteria for *fertile* intrusive belts in target generation:

- Sr/Y
- La/Yb
- Eu/Eu*
- V/Sc
- Fe_2O_3/FeO



Sr/Y

Proxy for the volatile content (H_2O, Cl)


END
This presentation is also available at Youtube:
https://www.youtube.com/watch?v=3VWk2gnn6-I