GIFT WORKSHOP – 2016

35th INTERNATIONAL GEOLOGICAL CONGRESS

MINERAL DEPOSITS
WHERE DO THEY COME FROM AND HOW DID THEY GET THERE?

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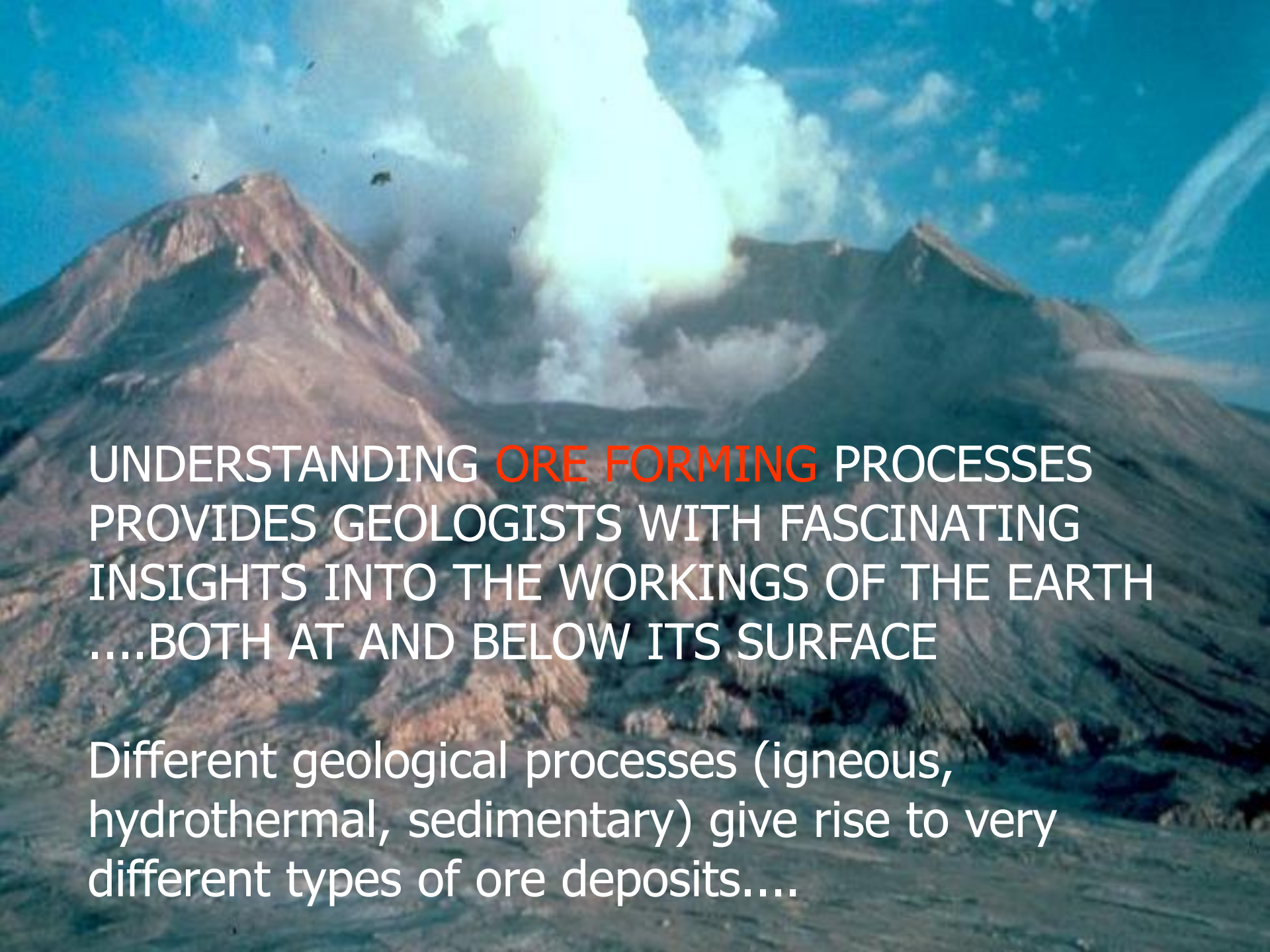
THE UNDERSTANDING OF ORE FORMING PROCESSES IS VITAL FOR THE PROPER AND SUSTAINABLE MANAGEMENT OF GLOBAL METAL RESOURCES...
...it is also key to the environmental remediation that must accompany all mining activity



UNDERSTANDING ORE FORMING PROCESSES PROVIDES GEOLOGISTS WITH FASCINATING INSIGHTS INTO THE WORKINGS OF THE EARTH ....BOTH AT AND BELOW ITS SURFACE

Different geological processes (igneous, hydrothermal, sedimentary) give rise to very different types of ore deposits....

THIS LECTURE WILL DESCRIBE 3 GEOLOGICAL PROCESSES THAT GIVE RISE TO ORE DEPOSITS.....

1. Circulation of sea water through the oceanic crust
   ['black smokers' and Cu-Zn-Pb massive sulphide deposits]

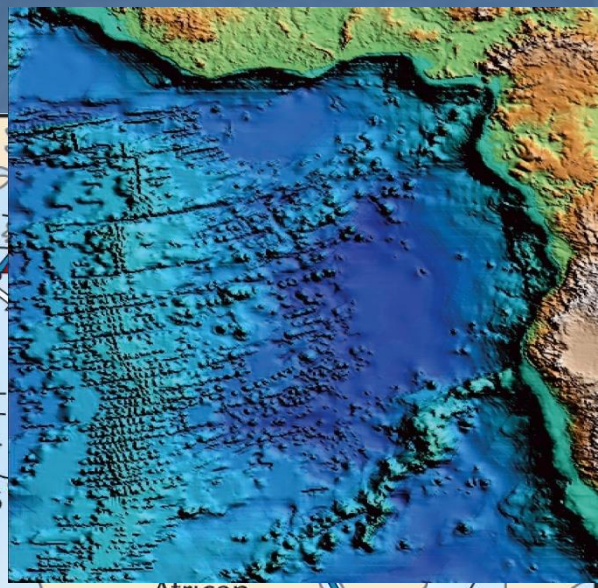
2. Granites and fluids along subducting plate margins
   [the 'porphyry copper' giants of the Andes]

3. Basalt magmatism and fractional crystallization
   [the Cu-Ni-PGE deposits of the Bushveld Complex]

1. OCEAN FLOOR HYDROTHERMAL PROCESSES

exhalative vent or 'black smoker'.....first observed 1977

BLACK SMOKERS HAVE BEEN LOCATED AT 'SPREADING CENTRES' THROUGHOUT THE PACIFIC AND INDIAN OCEANS.....some 370 trillion gallons of sea water pass through vents each year



Eurasian plate
North American plate
Juan de Fuca plate
China subplate
Philippine plate
Hawaiian chain
Pacific plate
Cocos plate
Caribbean plate
African plate
South American plate
Somalian subplate
Nazca plate
Australian-Indian plate
Scotia
Antarctic plate

Spreading ridge & transform faults
Converging plate boundary
Earthquakes
Active volcanoes

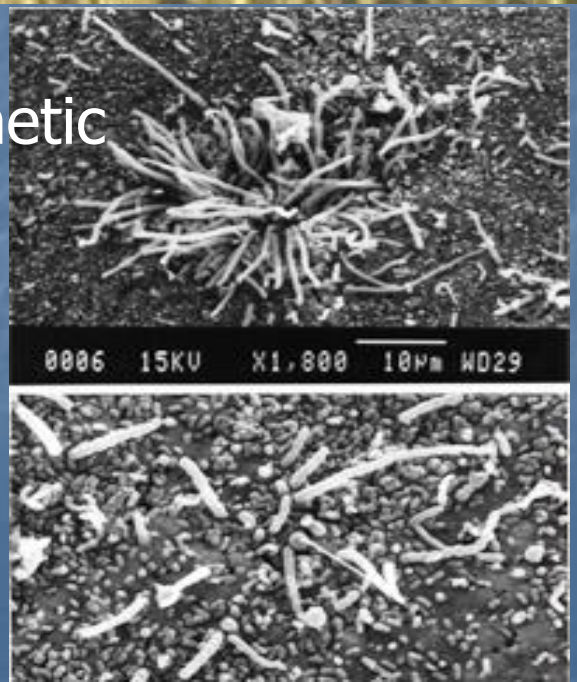
VOLCANOGENIC MASSIVE SULPHIDE (VMS) DEPOSITS.....mainly Cu and Zn

This black smoker, from the East Pacific Rise, consists of a sulfide mound with several actively venting chimneys. (© Woods Hole Oceanographic Institution)

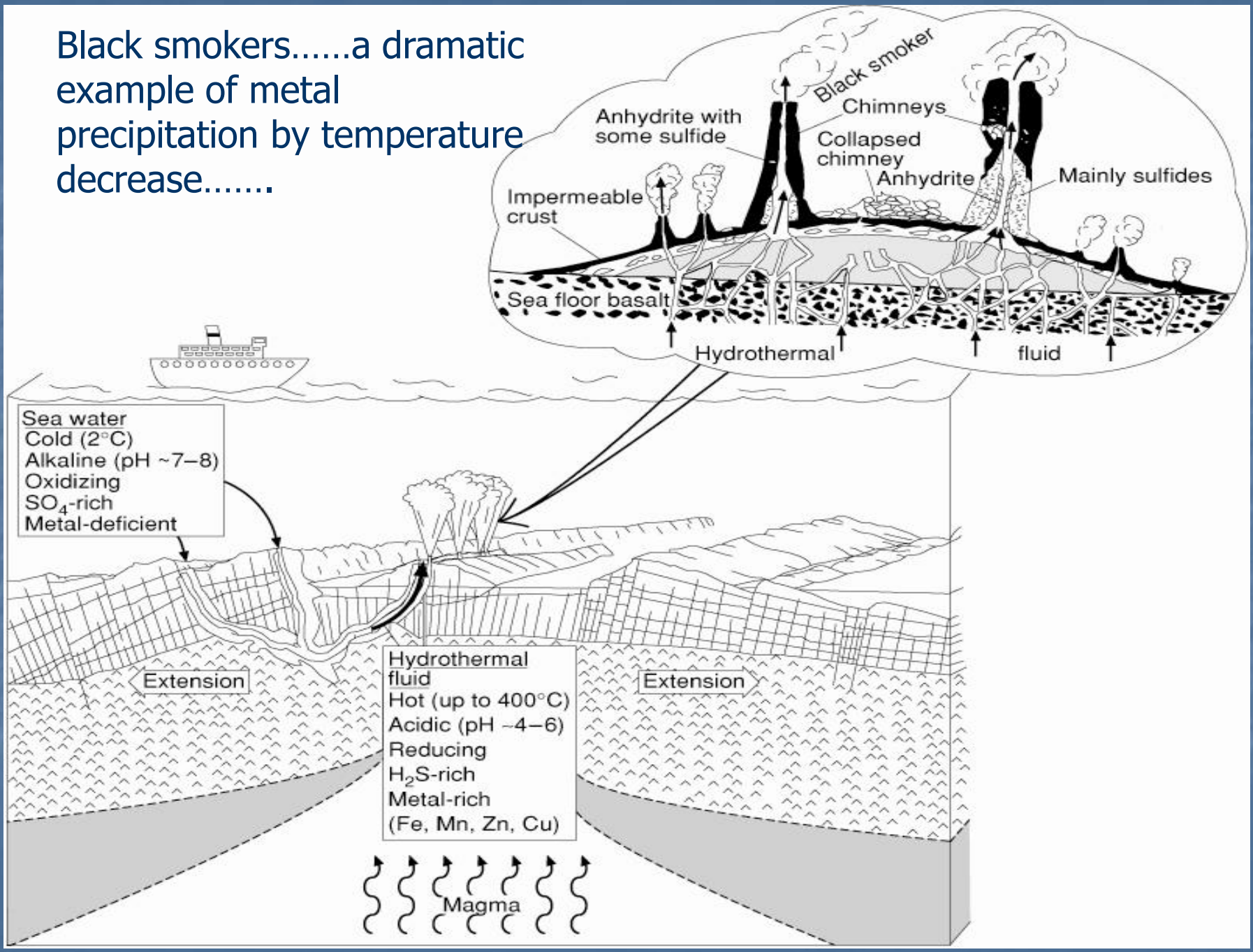
….blind crabs

…..tube worms

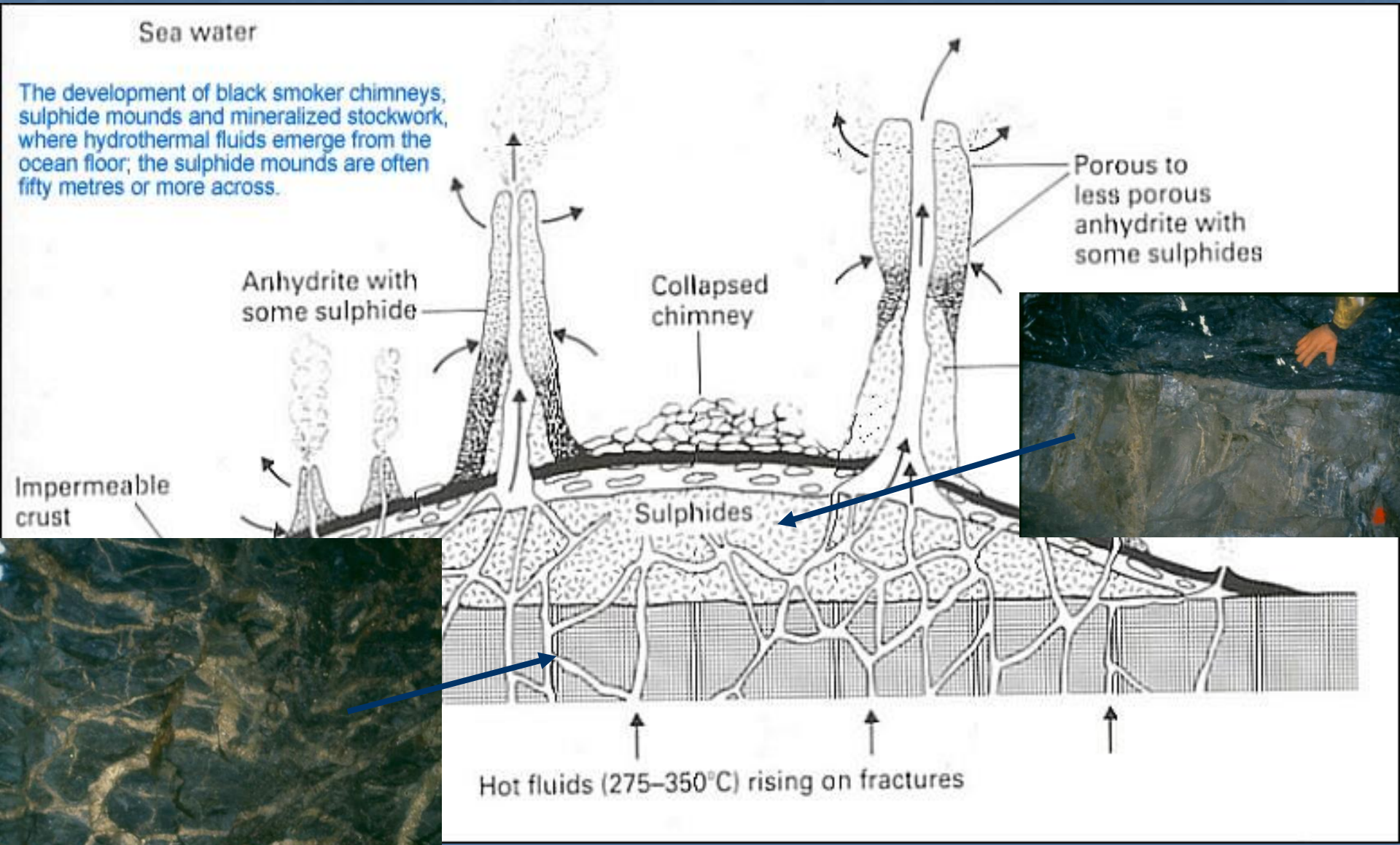
….chemosynthetic bacteria

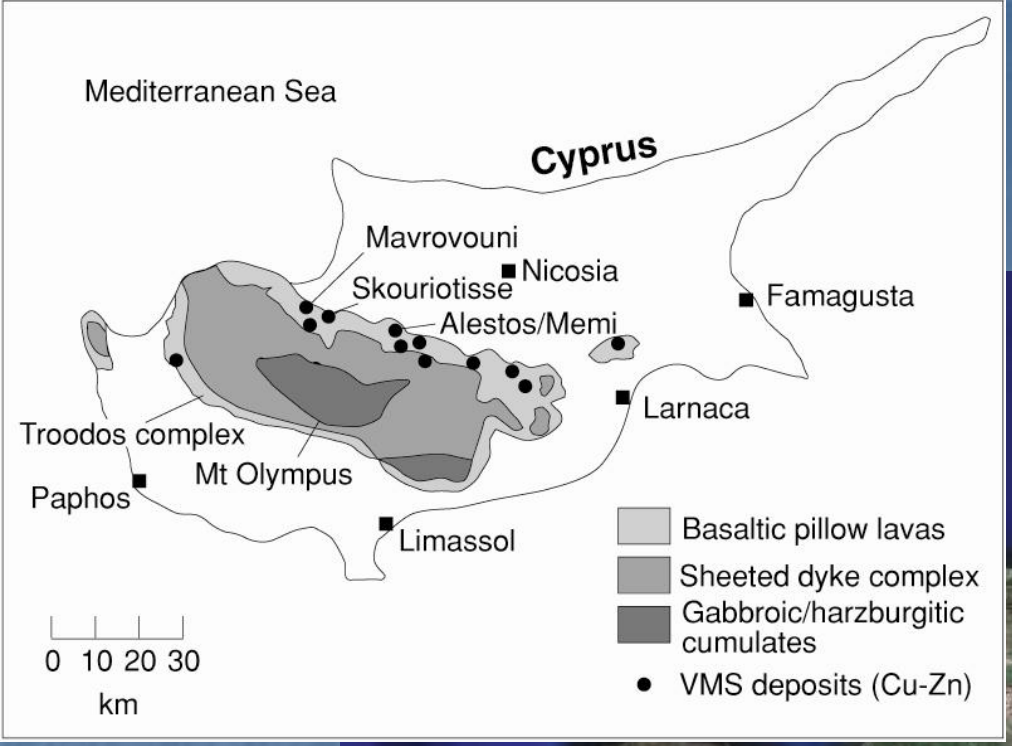


Black smokers……a dramatic example of metal precipitation by temperature decrease…….



....the classic 'massive sulphide' mound model.....





IN THE TROODOS MOUNTAINS OF CYPRUS ONE CAN.....

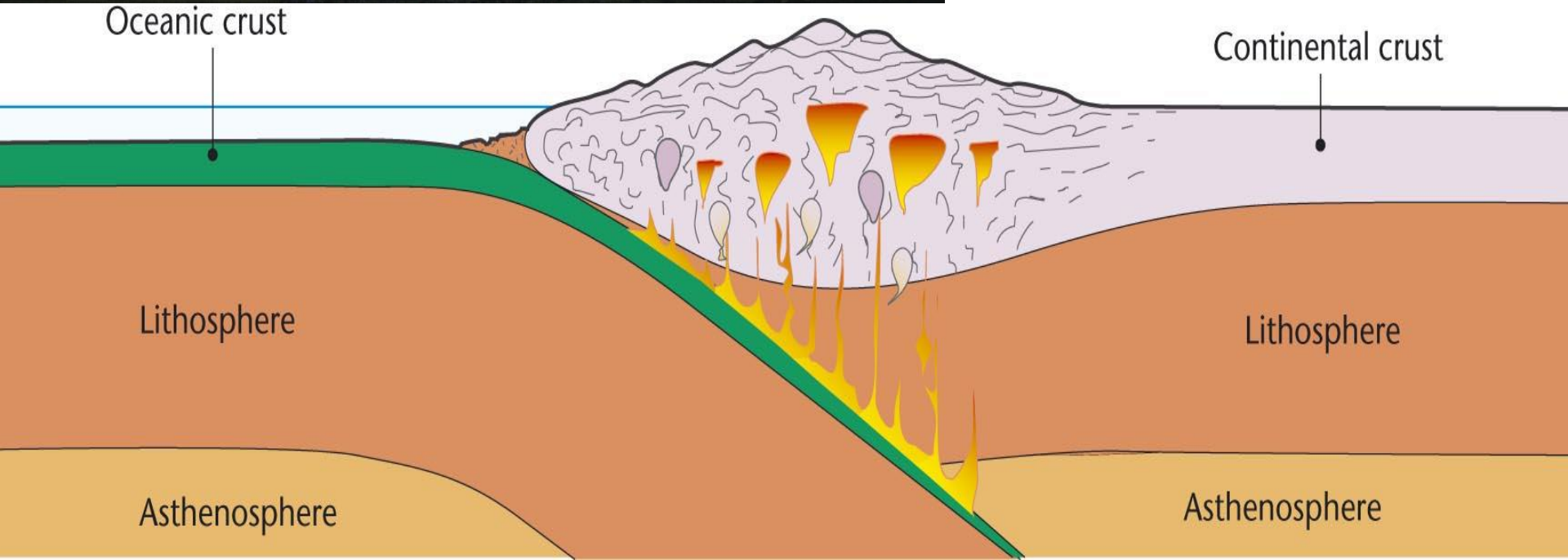
...see the pillowed ocean floor basalts.....

....and the sheeted dykes that feed magma into the spreading centre....


....as well as the remnants of mined out Cu-Zn VMS deposits

2. SUBDUCTION RELATED GRANITE MAGMATISM AND VOLCANIC FLUIDS….

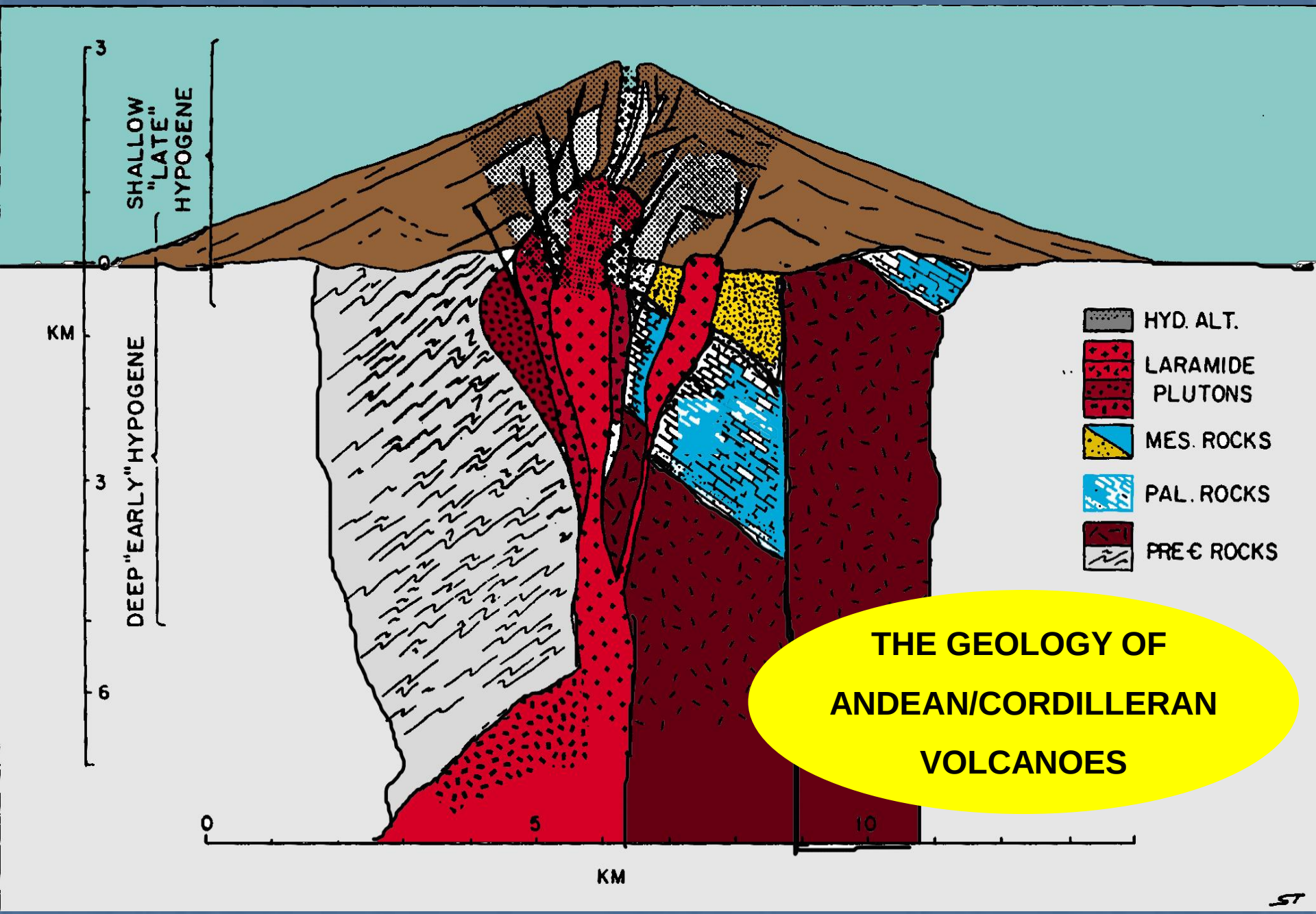
…..THE 'PORPHYRY' Cu-Mo GIANTS OF THE CHILEAN ANDES



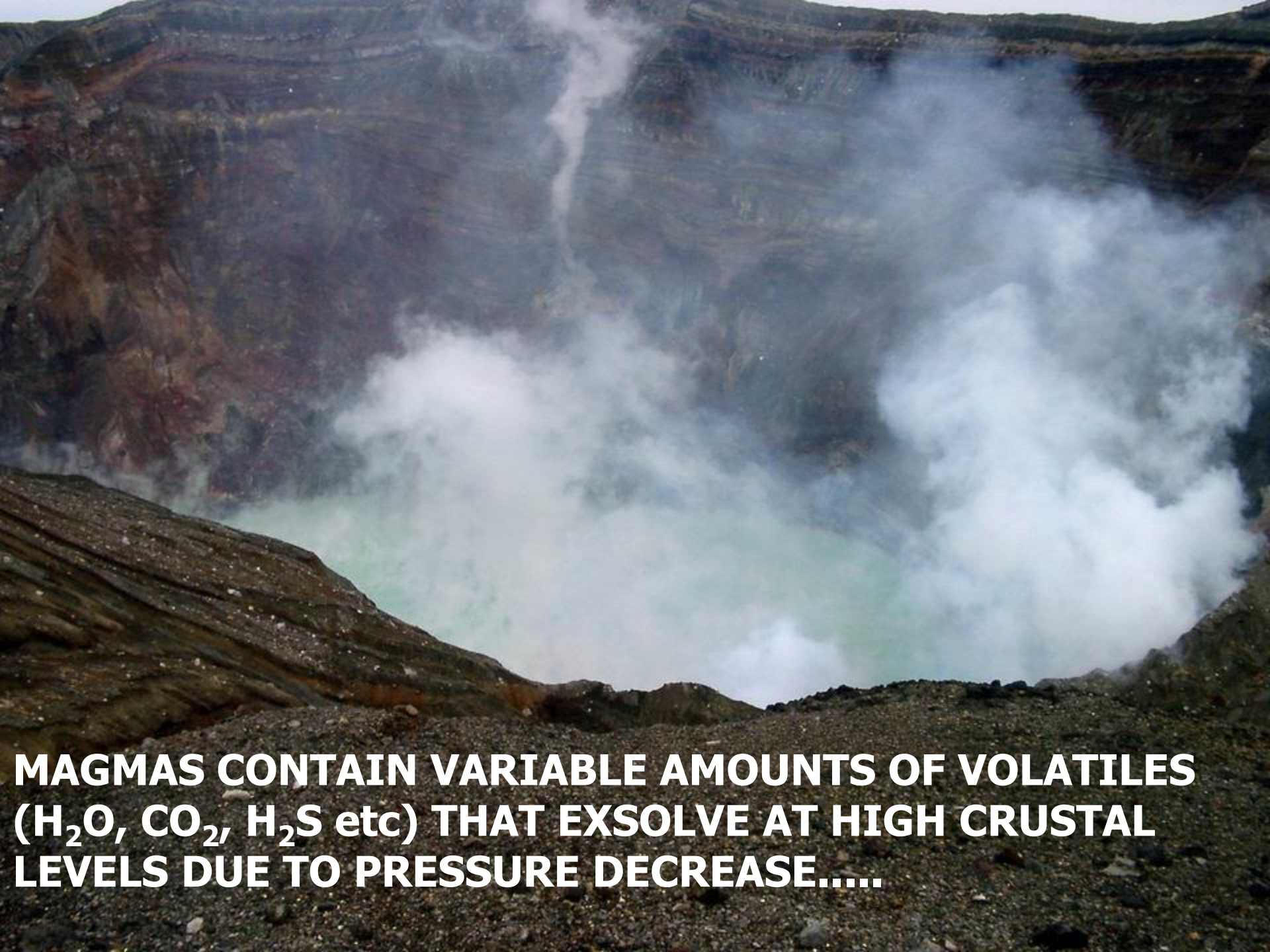

THE HIGH ANDES IS CONSTRUCTED BY LARGE VOLCANOES AND GRANITE INTRUSIONS.....

….and on top of them sit some of the great porphyry copper deposits of the world…….


El Teniente, Chile



THE GEOLOGY OF ANDEAN/CORDILLERAN VOLCANOES

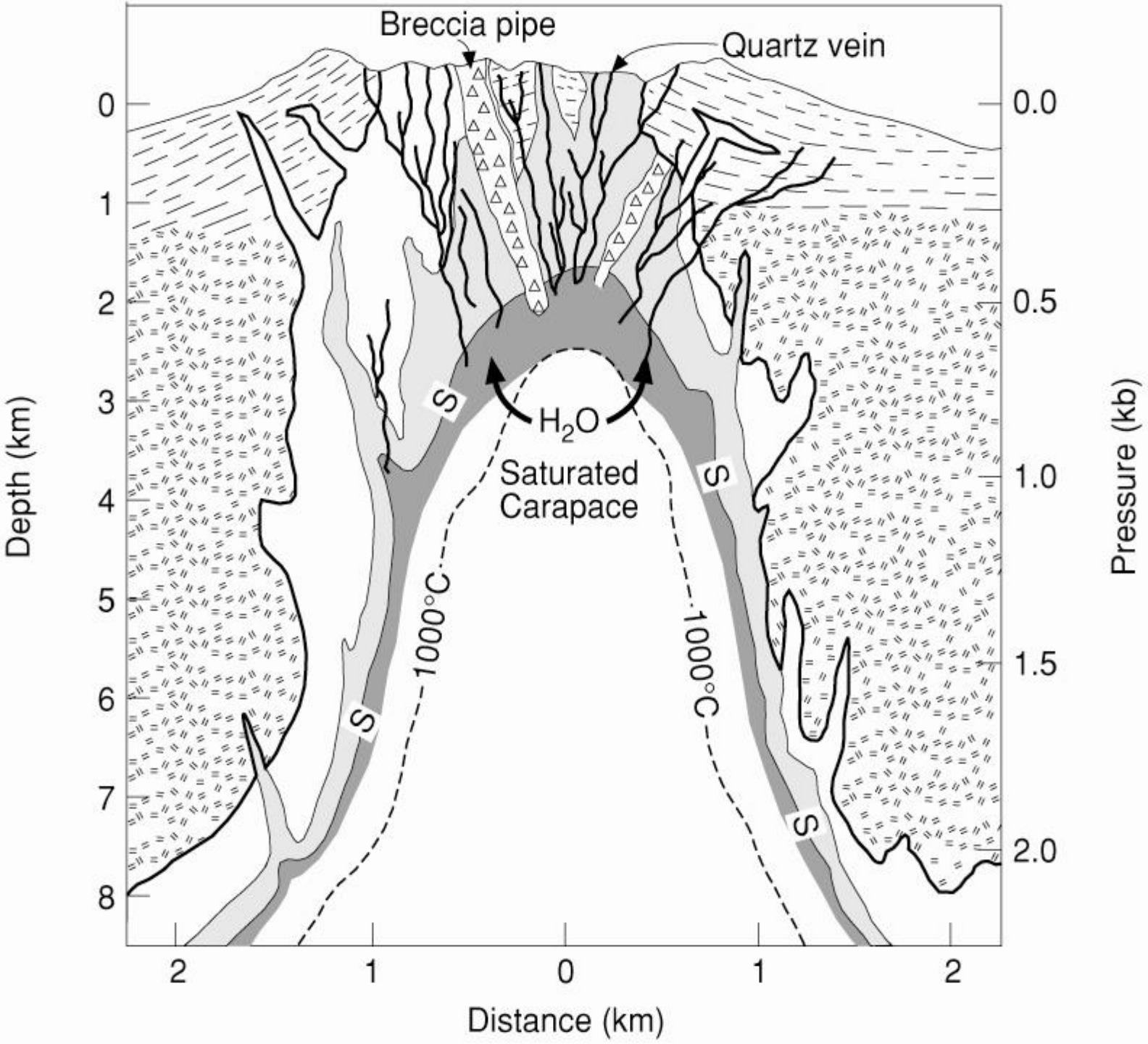


MAGMAS CONTAIN VARIABLE AMOUNTS OF VOLATILES (H_2O, CO_2, H_2S etc) THAT EXSOLVE AT HIGH CRUSTAL LEVELS DUE TO PRESSURE DECREASE.....


Magmatic-hydrothermal fluid….
90°C, pH=2

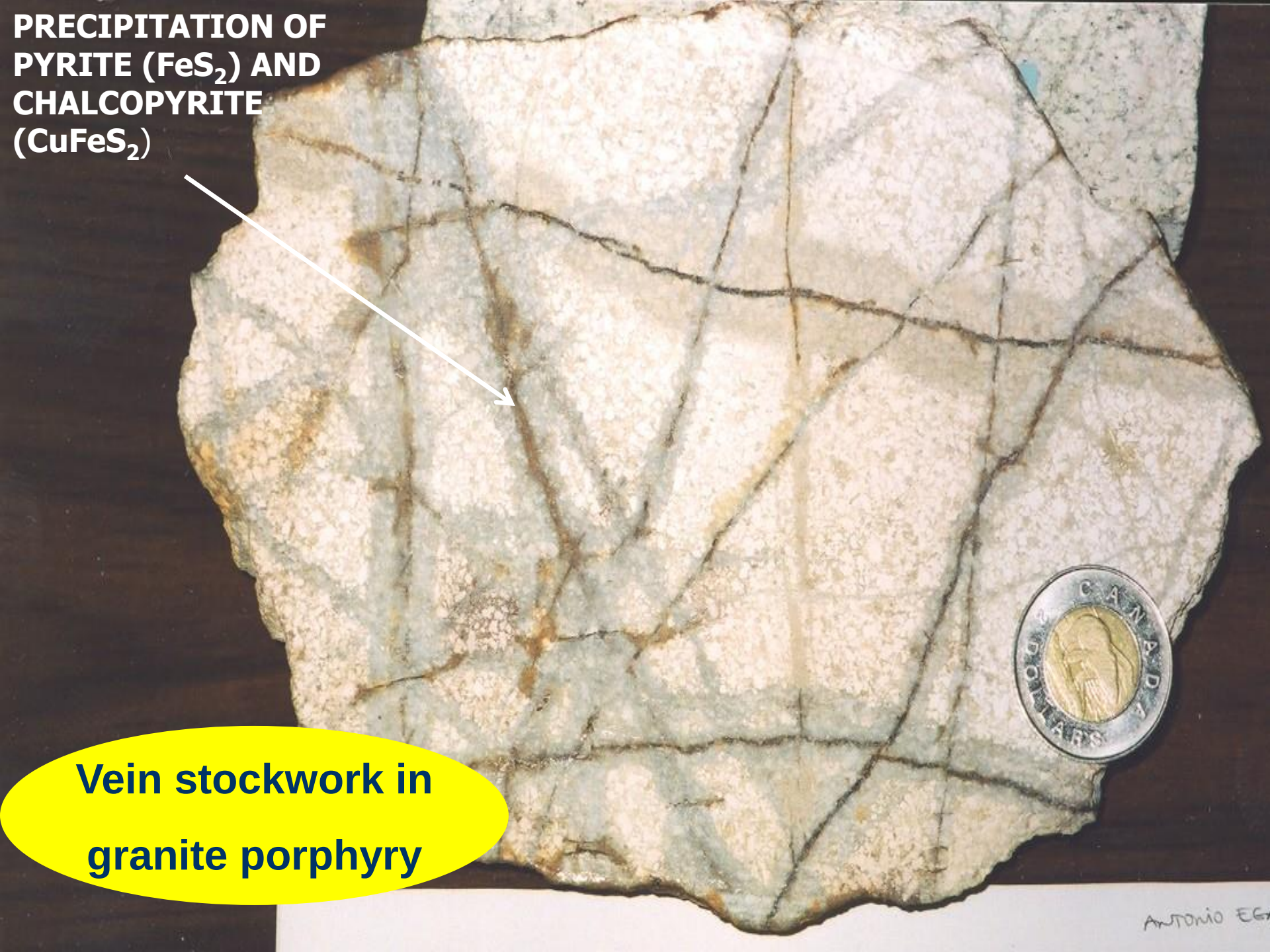
KASUGA GOLD MINE
Kyushu, Japan

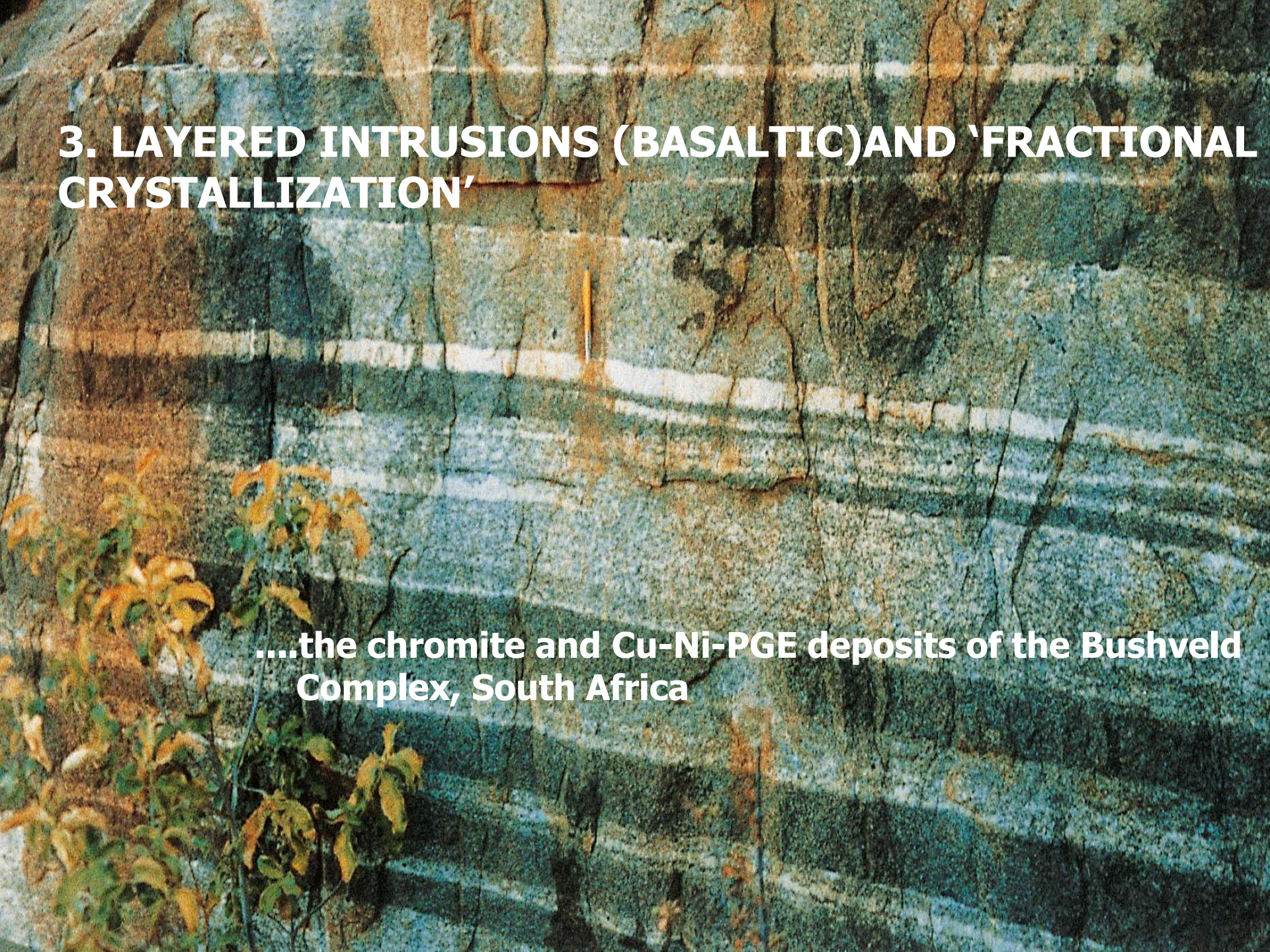
Weairakei, North Island,
New Zealand


Breccia pipe
Quartz vein
Depth (km)
Pressure (kb)
0
1
2
3
4
5
6
7
8
0.0
0.5
1.0
1.5
2.0
S
S
S
S
H_2O
Saturated
Carapace
1000°C
1000°C
2
1
0
1
2
Distance (km)


Fresh rock
Altered rock

Morenci Cu-Mo mine, Arizona

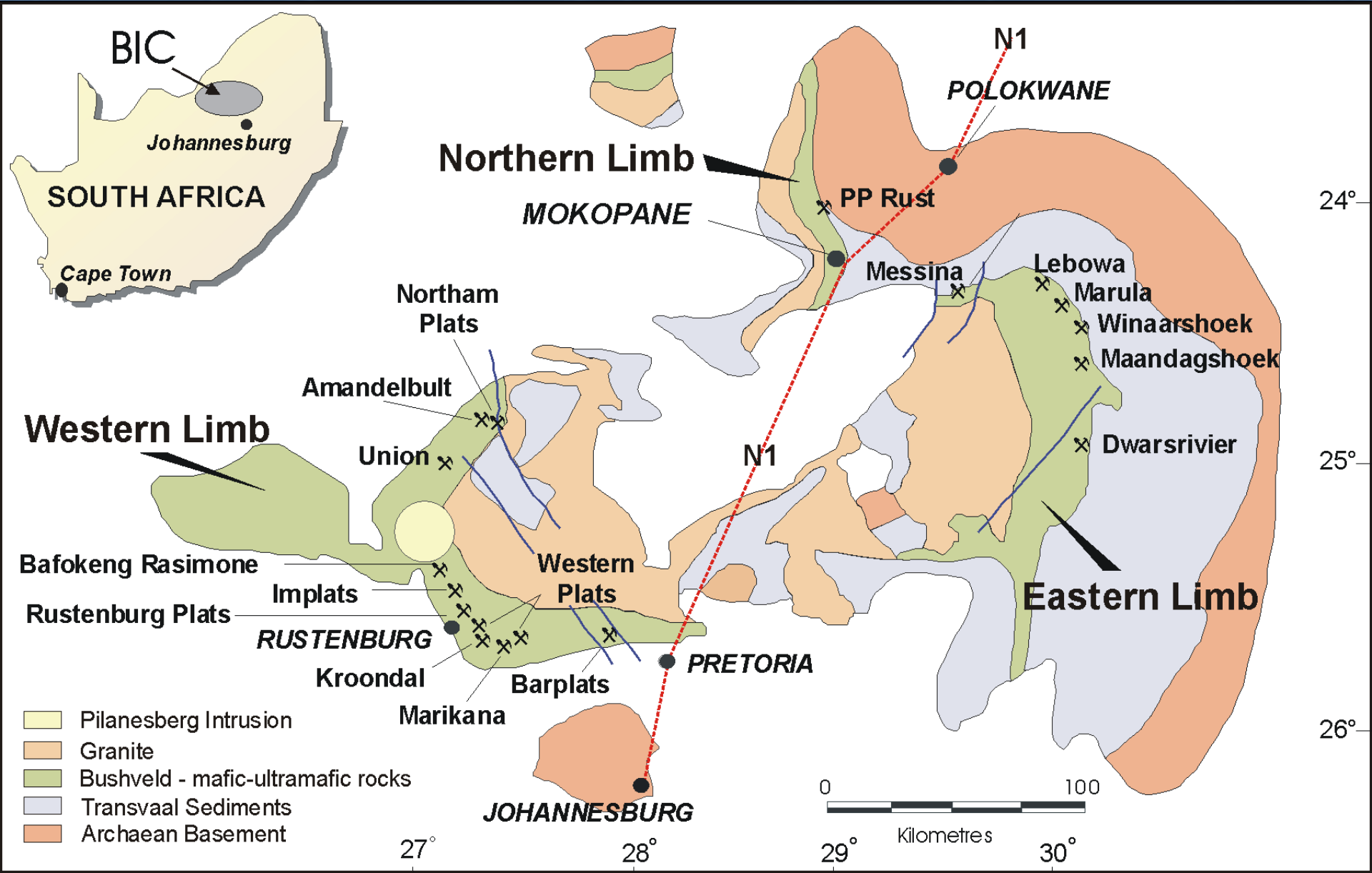

PRECIPITATION OF PYRITE (FeS_2) AND CHALCOPYRITE ($CuFeS_2$)
Vein stockwork in granite porphyry
CANADA
DOLLARS



3. LAYERED INTRUSIONS (BASALTIC)AND 'FRACTIONAL CRYSTALLIZATION'

....the chromite and Cu-Ni-PGE deposits of the Bushveld Complex, South Africa

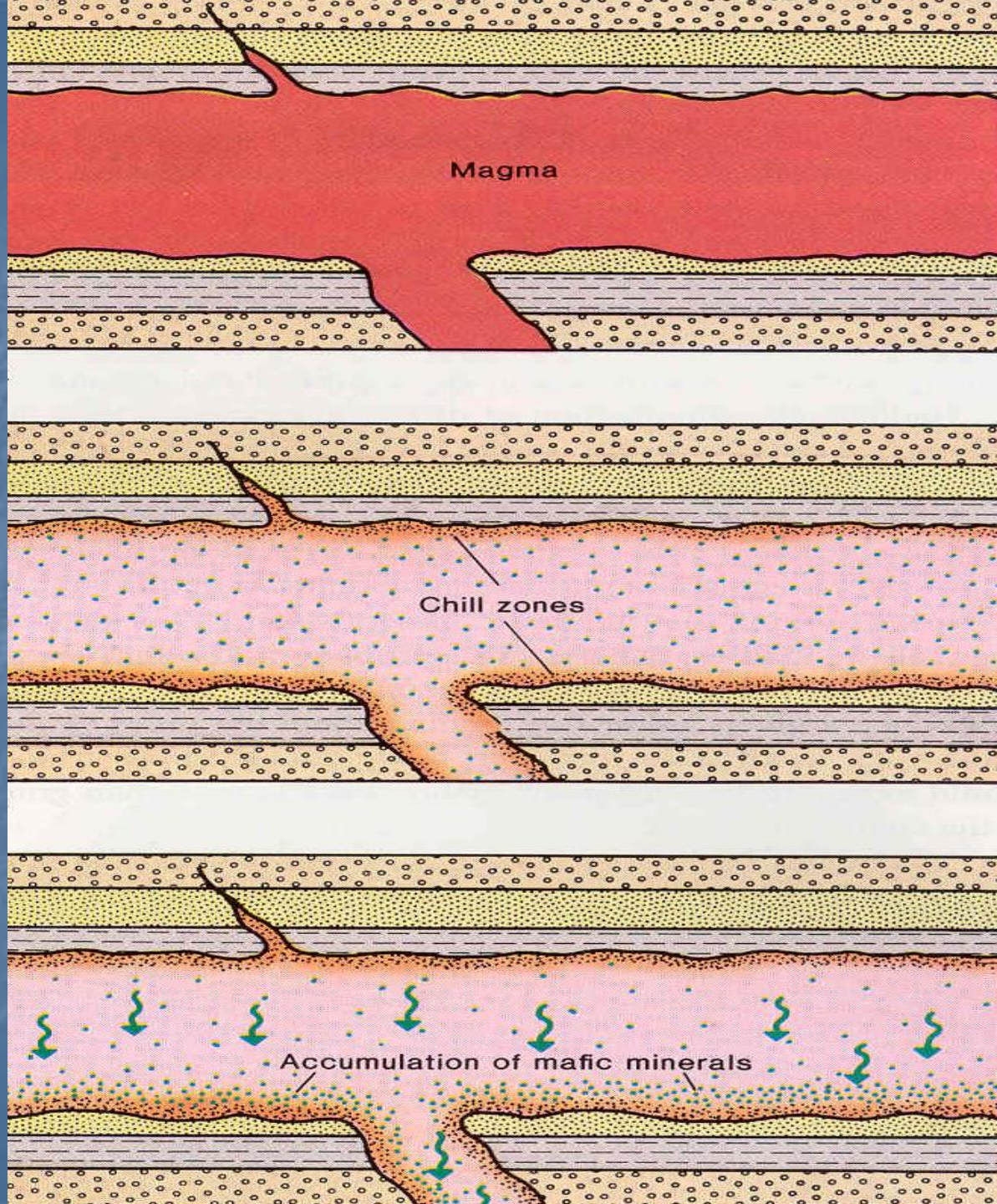
The Bushveld Complex



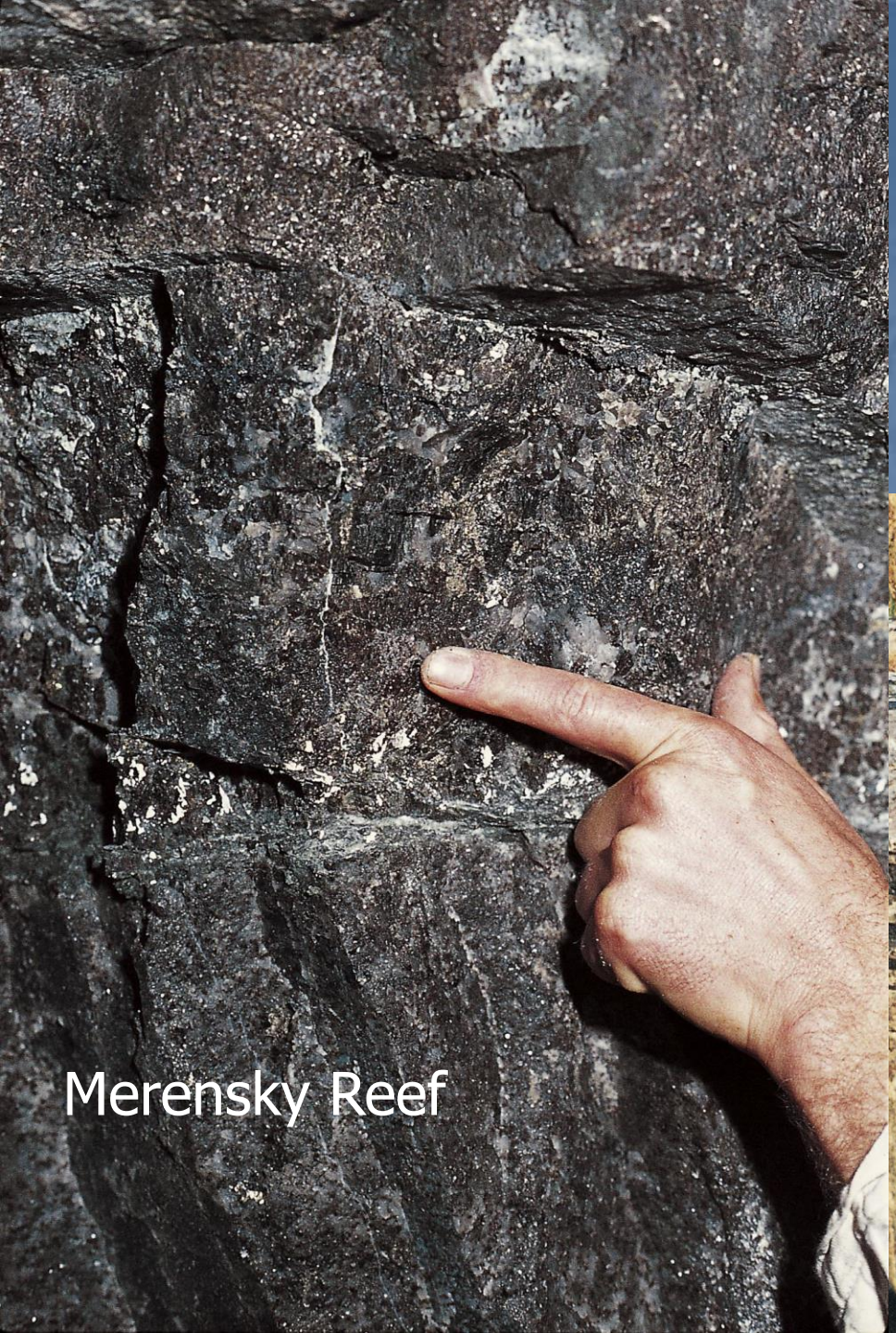
WHAT IS CRYSTAL FRACTIONATION?

...as early crystals form and settle to the floor of the magma chamber, the residual magma changes composition....

...so later crystals also change composition, ultimately forming a 'layered intrusion'



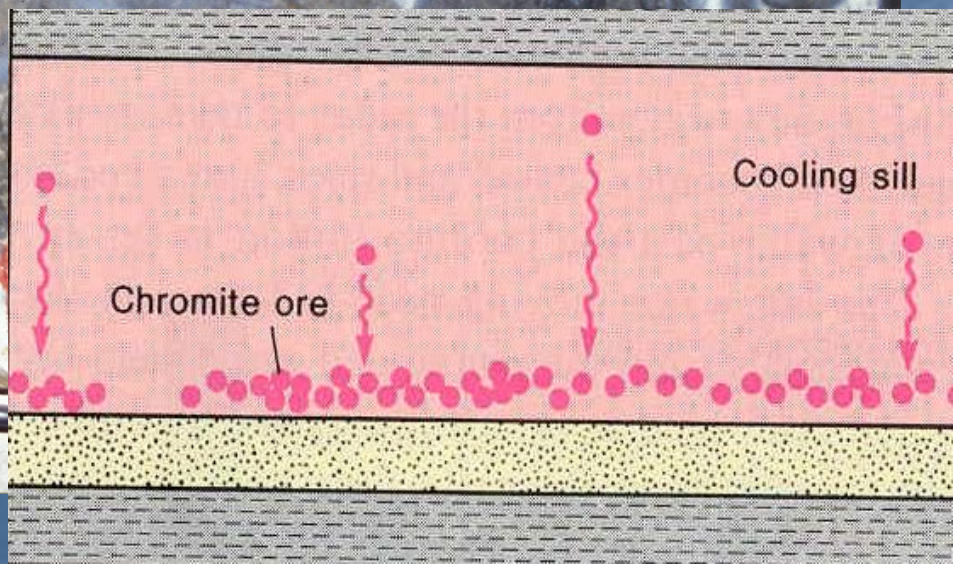
THE BUSHVELD COMPLEX CONTAINS >80% OF THE WORLD'S PGE RESERVES AND A SUBSTANTIAL PORTION OF ITS CHROMIUM RESERVES....



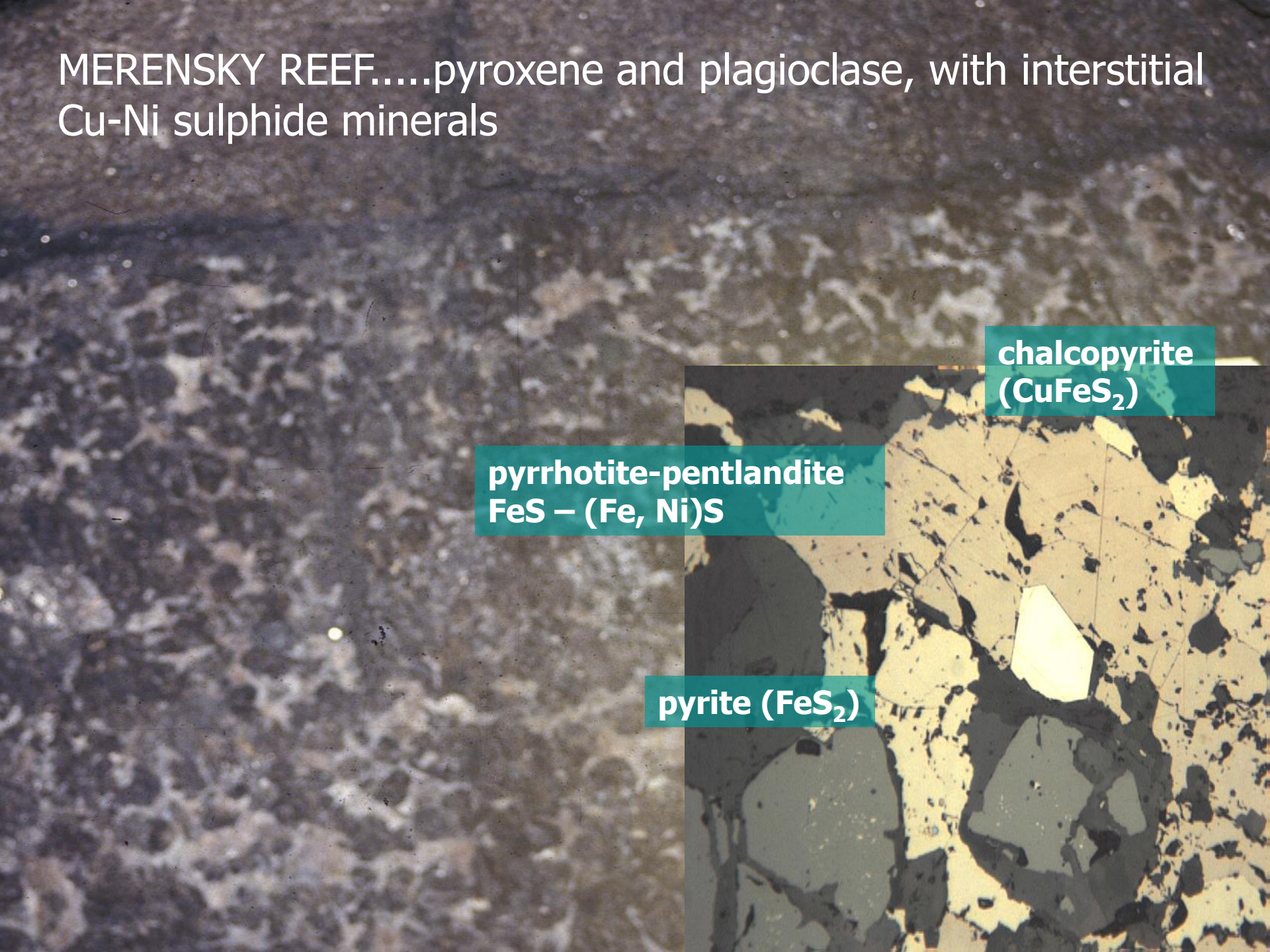
Merensky Reef

UG1 chromitite seams

UG2 chromitite seam…an interval of crystallization dominated by chromite



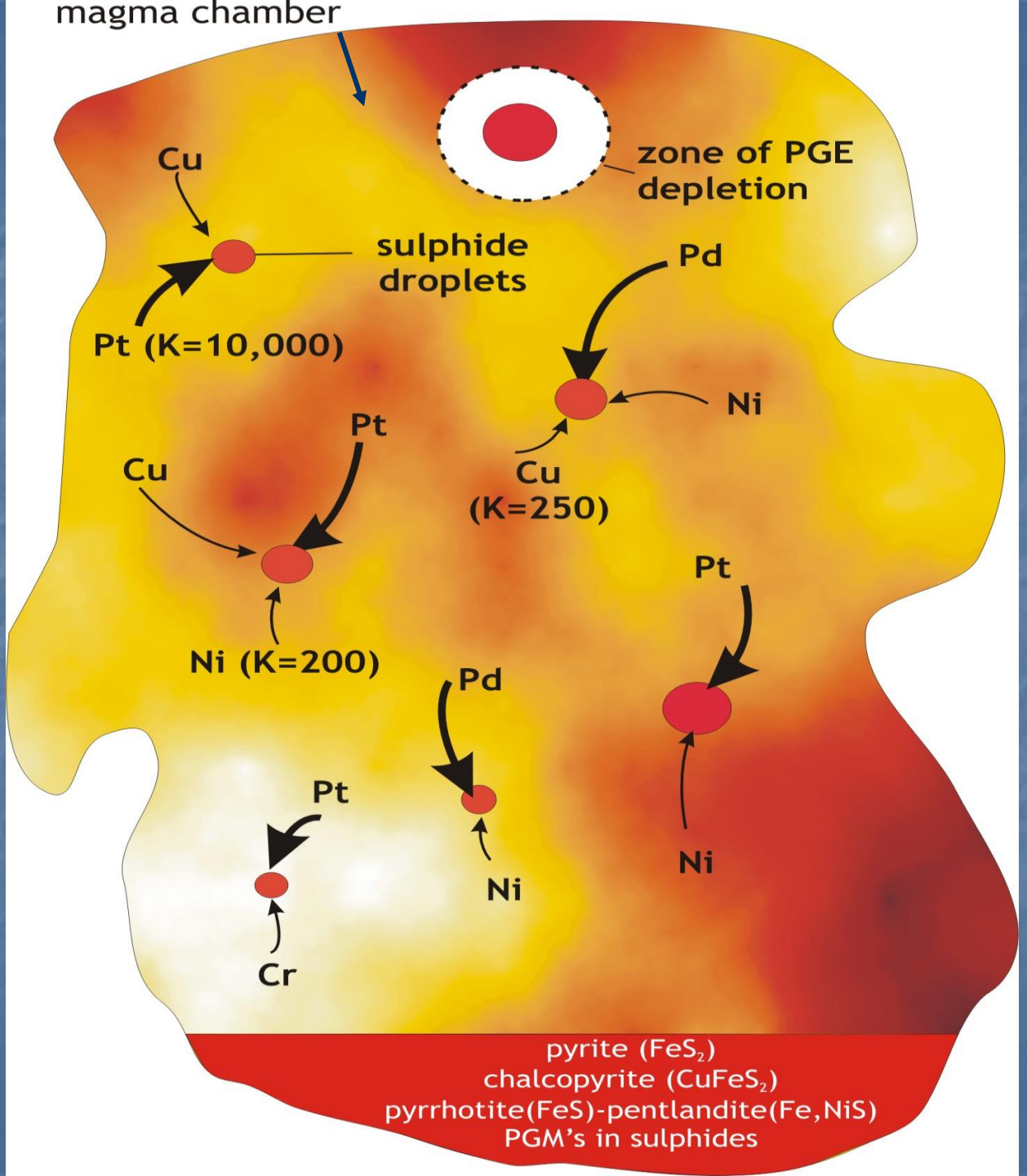
MERENSKY REEF.....pyroxene and plagioclase, with interstitial Cu-Ni sulphide minerals

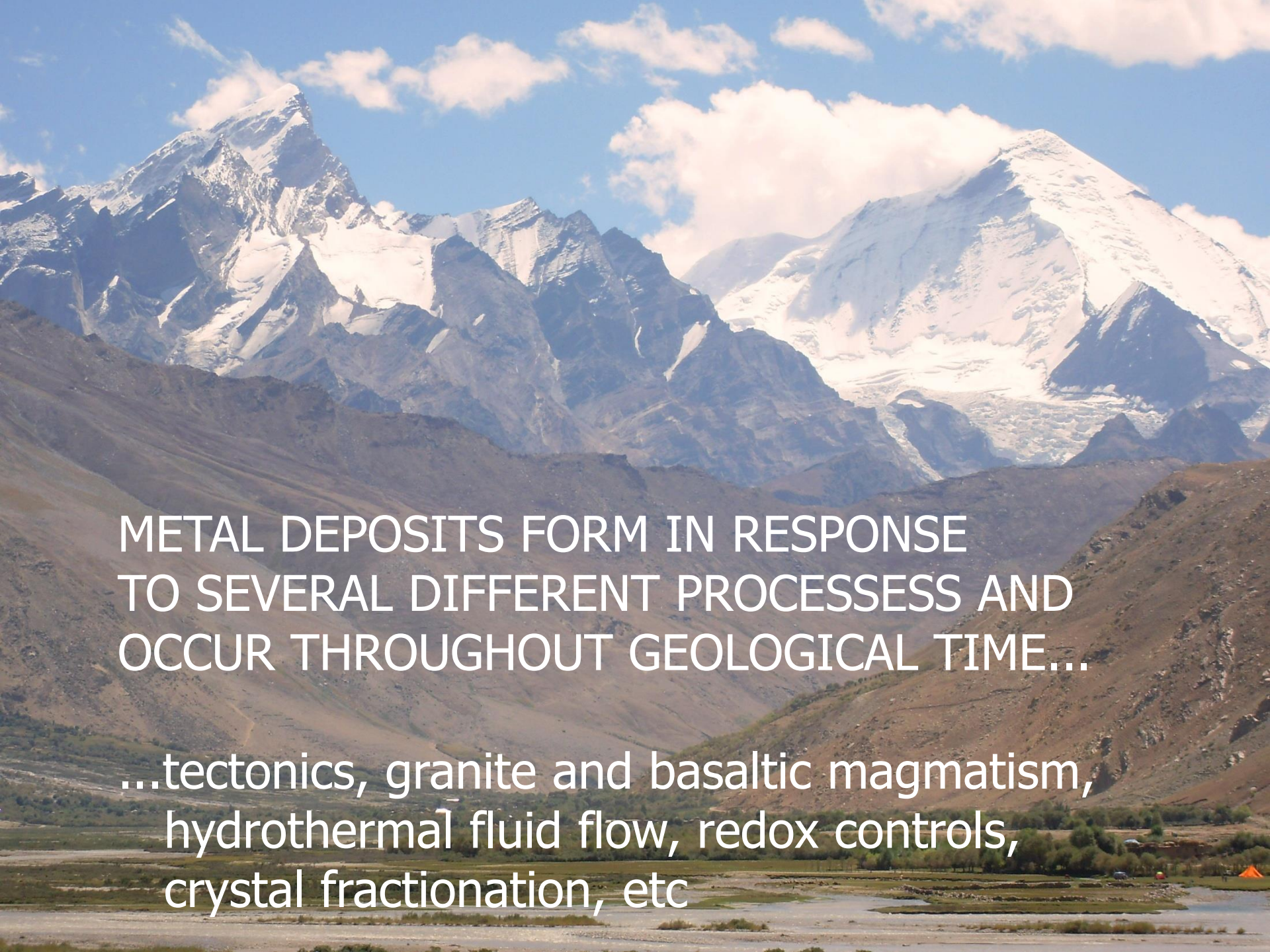


…sulphide immiscibility and partitioning of siderophilic metals (Cu, Ni, PGE) into the sulphide globules which tend to coalesce at the base of the magma chamber……

…a potentially very important ore-forming process…

eg. Merensky reef (PGE)
Sudbury (Ni-Cu)
Kambalda (Ni-Cu)
Norilsk (Ni-Cu)





METAL DEPOSITS FORM IN RESPONSE TO SEVERAL DIFFERENT PROCESSESS AND OCCUR THROUGHOUT GEOLOGICAL TIME...

...tectonics, granite and basaltic magmatism, hydrothermal fluid flow, redox controls, crystal fractionation, etc