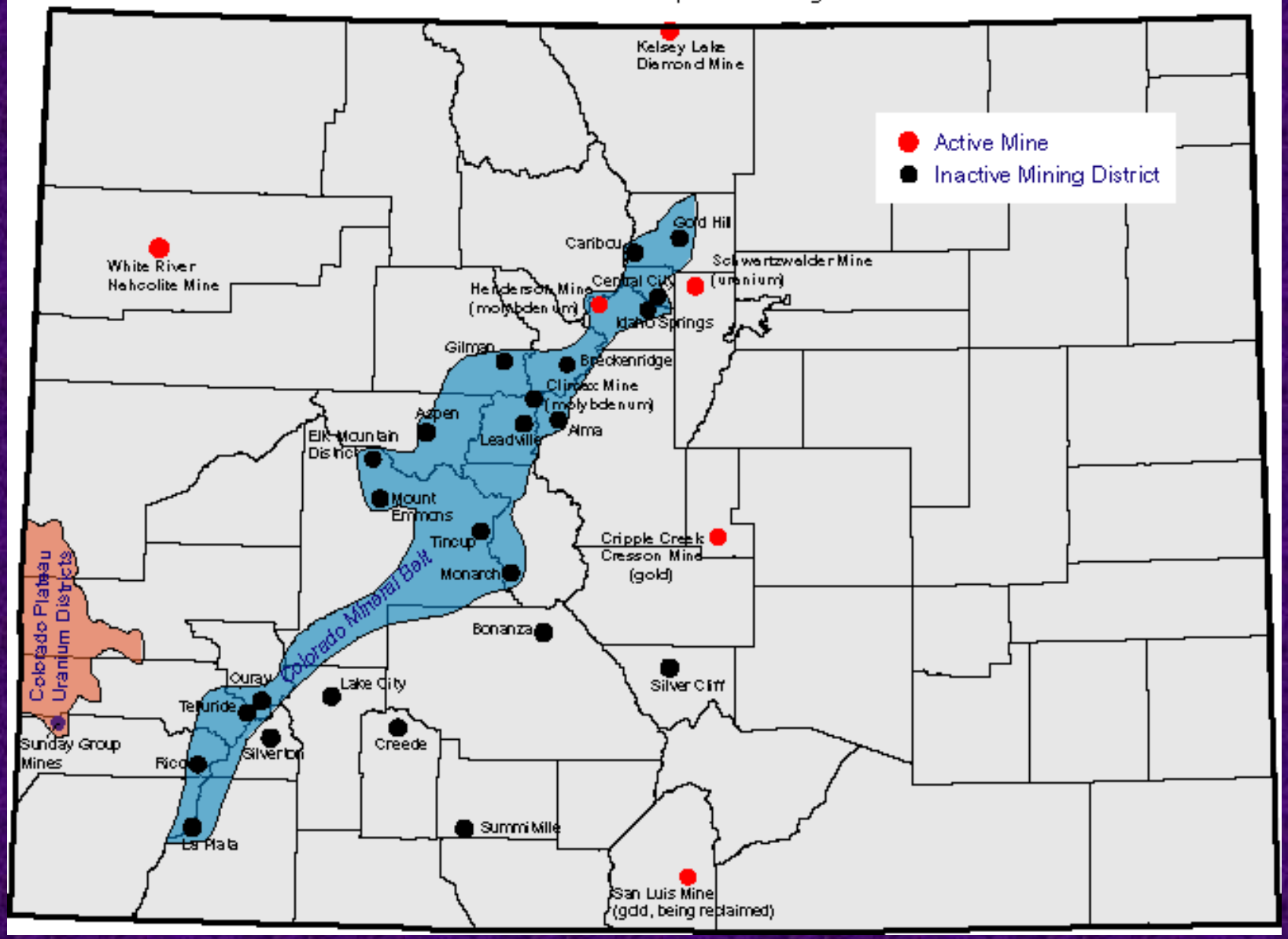
Hydrothermal Ore Systems

Major Mining Districts of Colorado

(Does not include coal or construction material mines)

Click on location for a description of mining district



Hydrothermal Processes

Hot aqueous solutions transport metals and other ions that precipitate to form major ores minerals of the earth.

Hydrothermal Minerals

Includes nearly 600 minerals. Few are abundant, but many have economic value.

General Formula: $M_p X_r$

M = metal or semimetal

Fe, Zn, Cu, Mo, Pb, Ag, Ni, Co, Cd, Sn, Pt, Hg, Tl, Bi

X = nonmetal such as S, Se, As, Sb, Bi, Te

Hydrothermal Minerals

In sulfides X = sulfur .

In sulfosalts M = metal + semimetal (As, Sb, or Bi). Semimetals take the place of sulfur but behave more or less like the metals in the structure.

In arsenides X = arsenic

In sulfarsenides X = sulfur + arsenic

In tellurides X = tellurium

SULFIDES, SULFARSENIDES, AND ARSENIDES

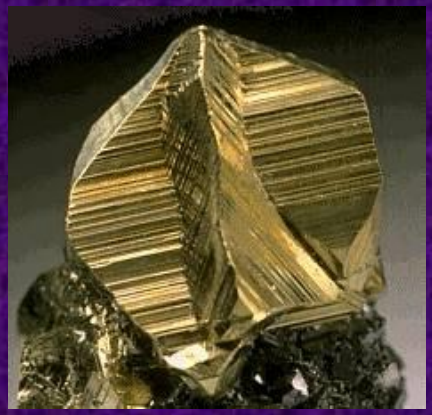
Acanthite = Ag_2S
Cinnabar = HgS
Chalcocite = Cu_2S
Covellite = CuS
Molybdenite = MoS2
Sphalerite = ZnS
Galena = PbS
Stibnite = Sb_2S_3
Pyrite = FeS2
Marcasite = FeS_2
Chalcopyrite = CuFeS2
Bornite = Cu_5FeS_4
Pyrrhotite = $Fe_{1-x}S$
Pentlandite = $(Fe,Ni)_9S_8$
Arsenopyrite = FeAsS

Common Characteristics of Sulfides Minerals:

- metallic luster
- generally opaque to translucent
- relatively high specific gravities
- hardness less than 6 and typically less than 4
- distinctive colors and streaks

galena

pyrite



chalcopyrite

sphalerite

Associated Elemental Minerals

Gold
Silver
Copper

Associated Minerals - Gangue

Some Examples

Quartz
Calcite
Rhodochrosite
Rhodonite
Iron Carbonate – Siderite
Hematite
Barite
Fluorite

Important Factors - Fluids

Solutions to dissolve and transport metals and other ions

Sources hydrothermal fluids include:

1. meteoric waters
2. sea water
3. connate water or formational water
4. metamorphic fluids lost during dehydration
5. fluids associated with magmas

Important Factors - Heat

Sources of Heat:

1. magma
2. prograde metamorphic conditions (>T, >P)
3. geothermal gradient

Temp. at which the minerals generally form ranges from 50 to 650°C

Important Factors - Metals

Sources of metals:

1. magma
2. country rocks that fluids pass through
3. metamorphic reactions

Important Factors - Pathways

Paths to move solutions from depth to areas where conditions are favorable for precipitations of ores

Types of Paths:

1. faults
2. joints
3. breccia zones
4. porous rocks
5. other open spaces

Important Factors - Reactions

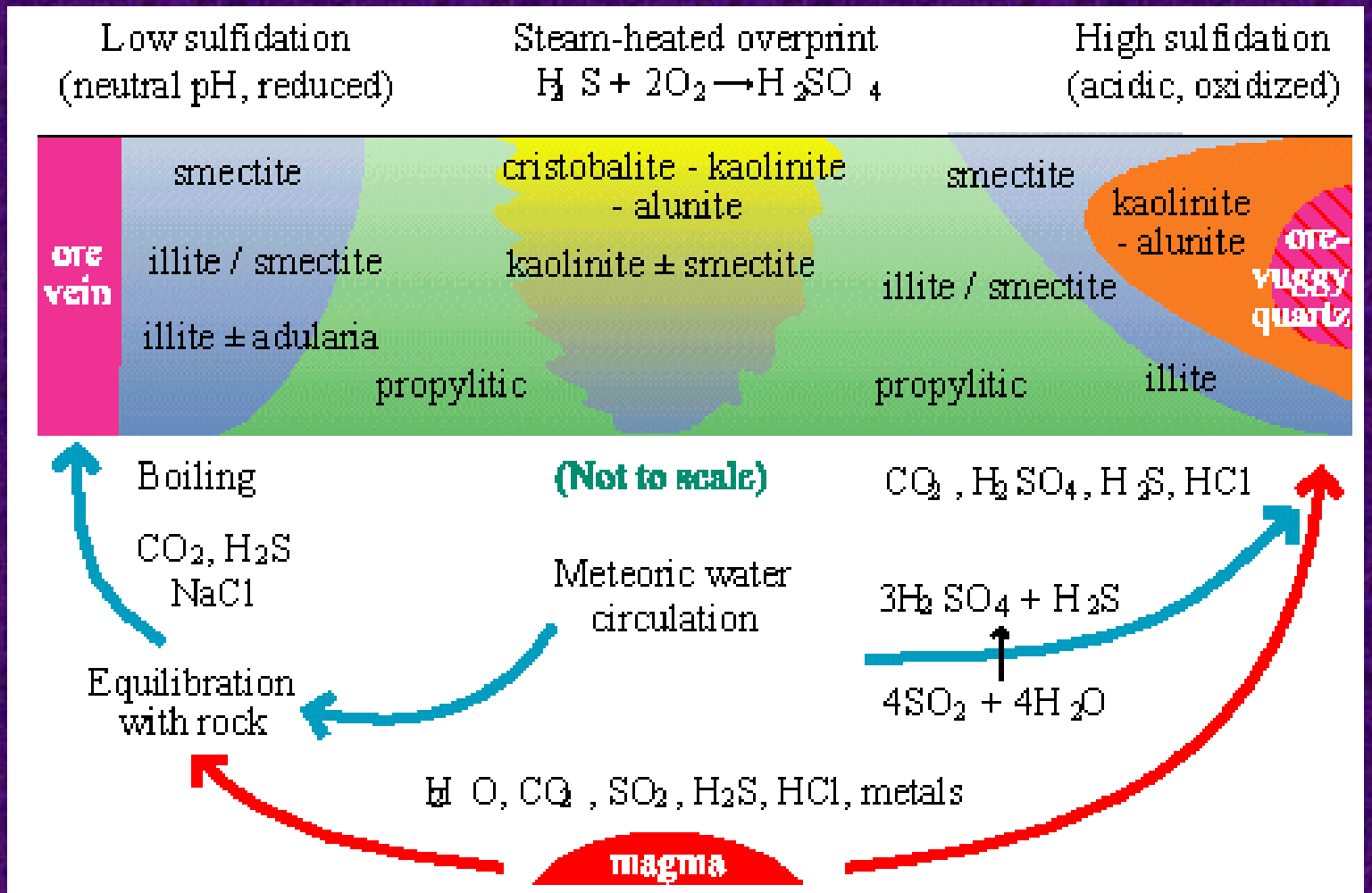
Favorable conditions such as the right acidity (pH), oxygen level (Eh), and temperature to permit chemical reactions that form the minerals.

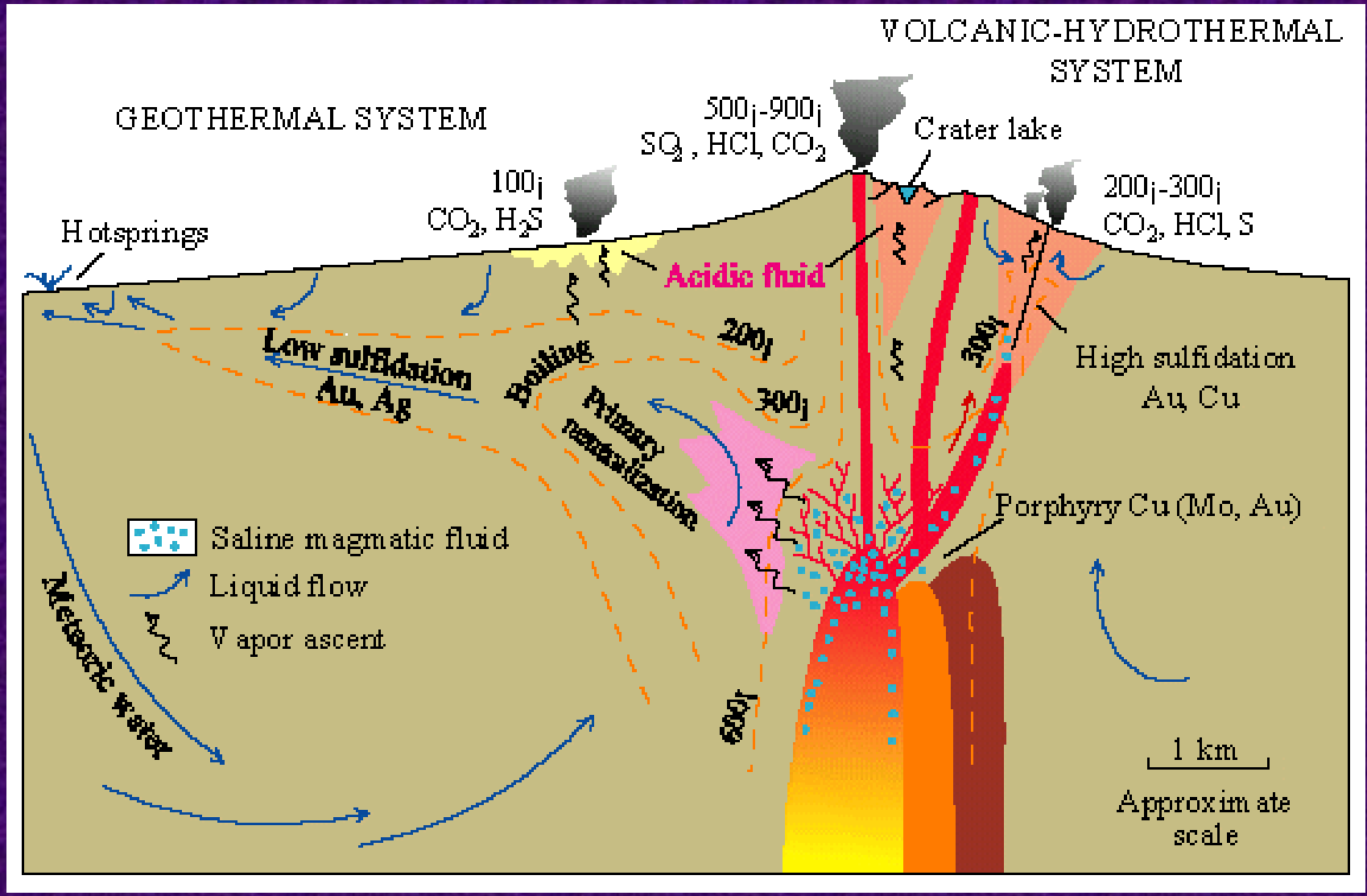
Boiling, rapid pressure decrease, reactions with adjacent rock types, and mixing with seawater can cause rapid precipitation and the concentration of mineral deposits.

Important Factors - Time

Time to create sufficient concentrations of precipitated minerals to constitute an economic deposit of minerals.

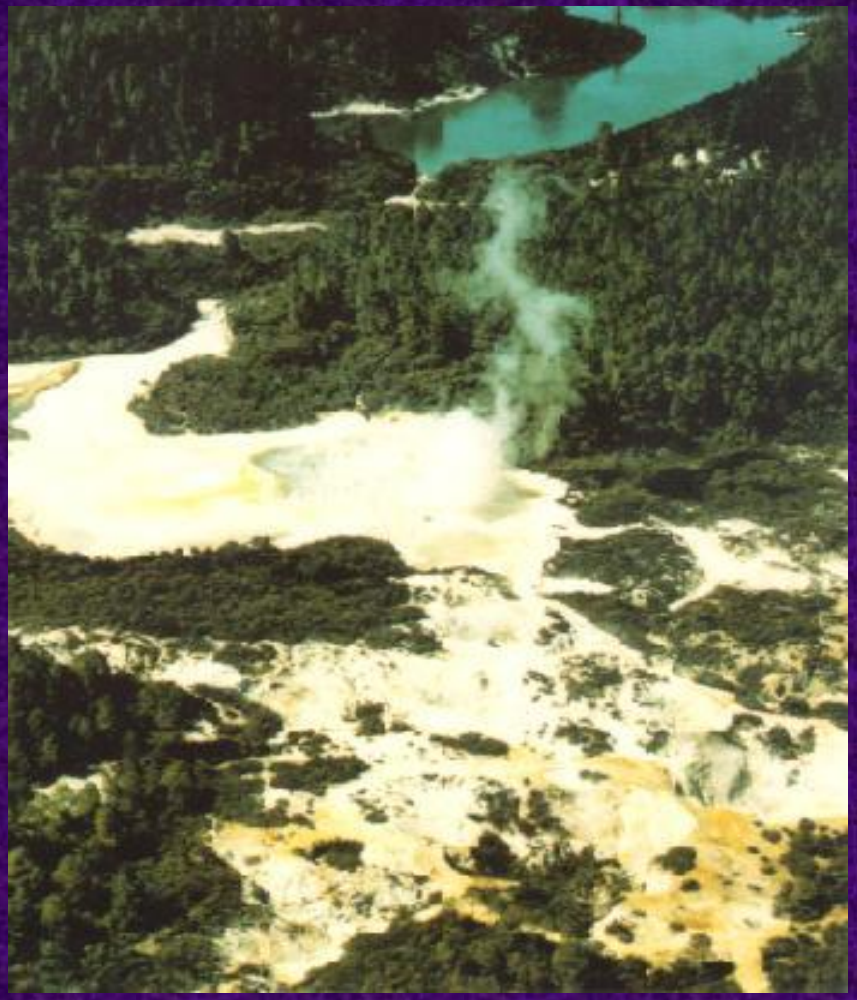
Main driving force: geothermal cell where cold water moves down through fractures in rocks and is heated at depth by hot rocks or magma.


Low sulfidation
(neutral pH, reduced)
Steam-heated overprint
$H_2S + 2O_2 \rightarrow H_2SO_4$
High sulfidation
(acidic, oxidized)
ore vein
smectite
illite / smectite
illite ± adularia
propylitic
cristobalite - kaolinite - alunite
kaolinite ± smectite
smectite
illite / smectite
propylitic
kaolinite - alunite
ore-vuggy quartz
illite
Boiling
CO_2, H_2S
NaCl
(Not to scale)
CO_2, H_2SO_4, H_2S, HCl
Meteoric water circulation
$3H_2SO_4 + H_2S$
$4SO_2 + 4H_2O$
Equilibration with rock
H_2O, CO_2, SO_2, H_2S, HCl, metals
magma


VOLCANIC-HYDROTHERMAL SYSTEM
GEOTHERMAL SYSTEM
500¡-900¡
SO2 , HCl, CO2
Crater lake
100¡
CO2, H2S
200¡-300¡
CO2, HCl, S
Hotsprings
Acidic fluid
Low sulfidation
Au, Ag
Boiling
200¡
300¡
Primary remagnetization
High sulfidation
Au, Cu
Porphyry Cu (Mo, Au)
Saline magmatic fluid
Liquid flow
Vapor ascent
Meteoric water
600¡
1 km
Approximate scale

Yellowstone

Modern System in New Zealand



As the fluids pass through the country rock metal ions and other elements are dissolved out. The hot fluids are less dense than cold water and move upwards through fractures, pores, and other open space and precipitate when conditions are favorable.

Hydrothermal Alteration

Wall rock alteration results from the passage of hot fluids through the rocks changing the conditions of stability which causes existing minerals to react with surrounding minerals or fluids and alter or recrystallize to new, more stable minerals.

Gossans are an example.

Hydrothermal Alteration

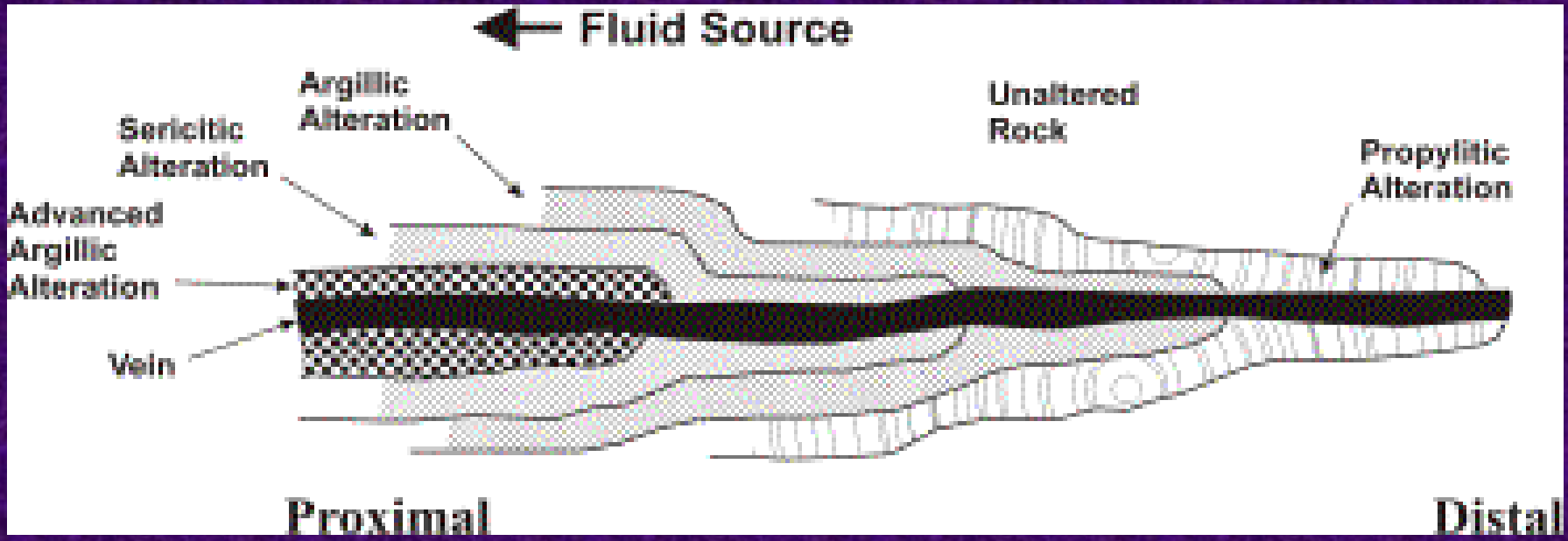
Degree and distribution of the alteration is controlled by:

1. properties and composition of the solution
2. properties and composition of the host rocks
3. temperature and pressure
4. changes in the constituents

Hydrothermal Alteration

Types of alteration commonly associated with hydrothermal deposits include:

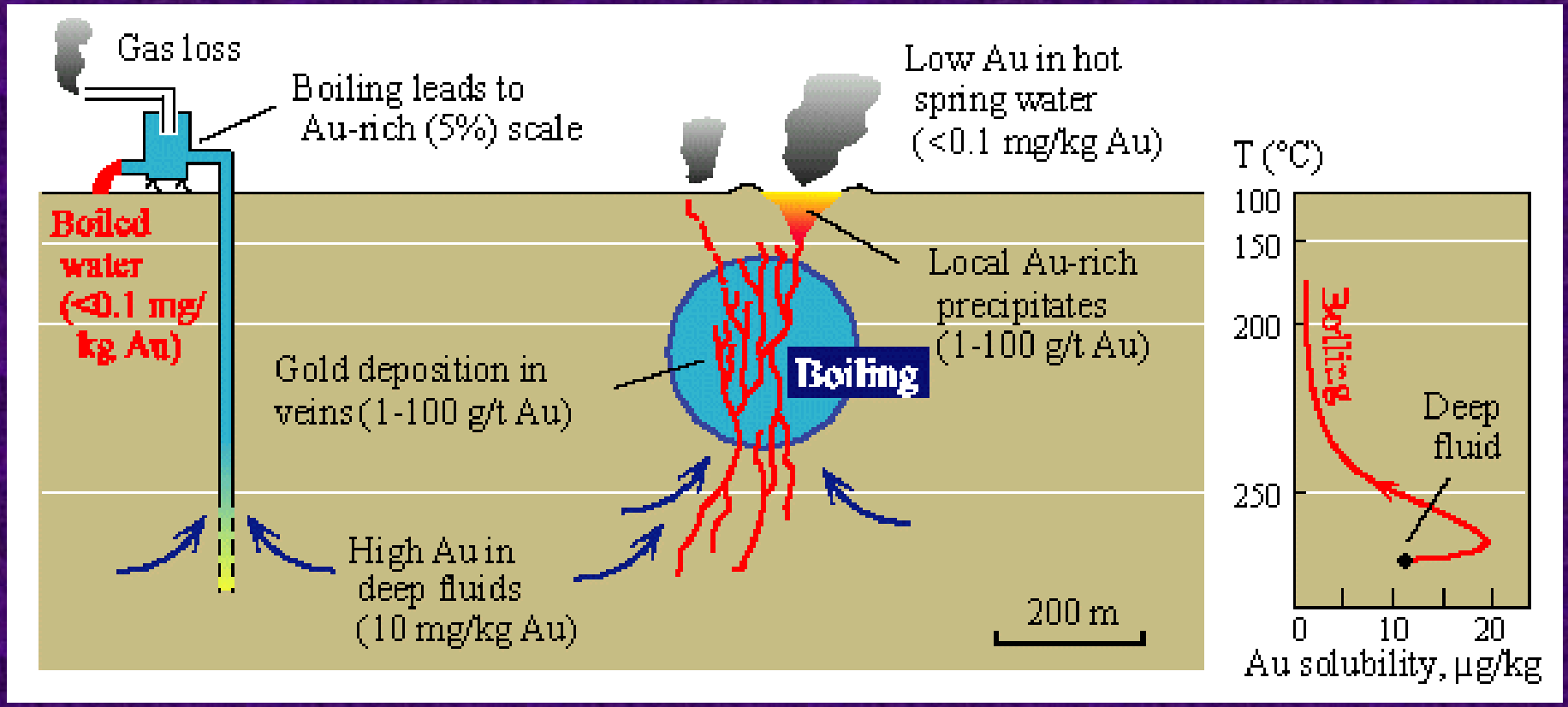
dolomitization: dolomite
silicification: quartz
argillic alteration: clays such as kaolinite
propylitic alteration: epidote + chlorite
sericitization: pyrite + fibrous muscovite
potassic alteration: low temp K feldspar - adularia


Fluid Source
Argillic Alteration
Sericitic Alteration
Advanced Argillic Alteration
Vein
Unaltered Rock
Propylitic Alteration
Proximal
Distal

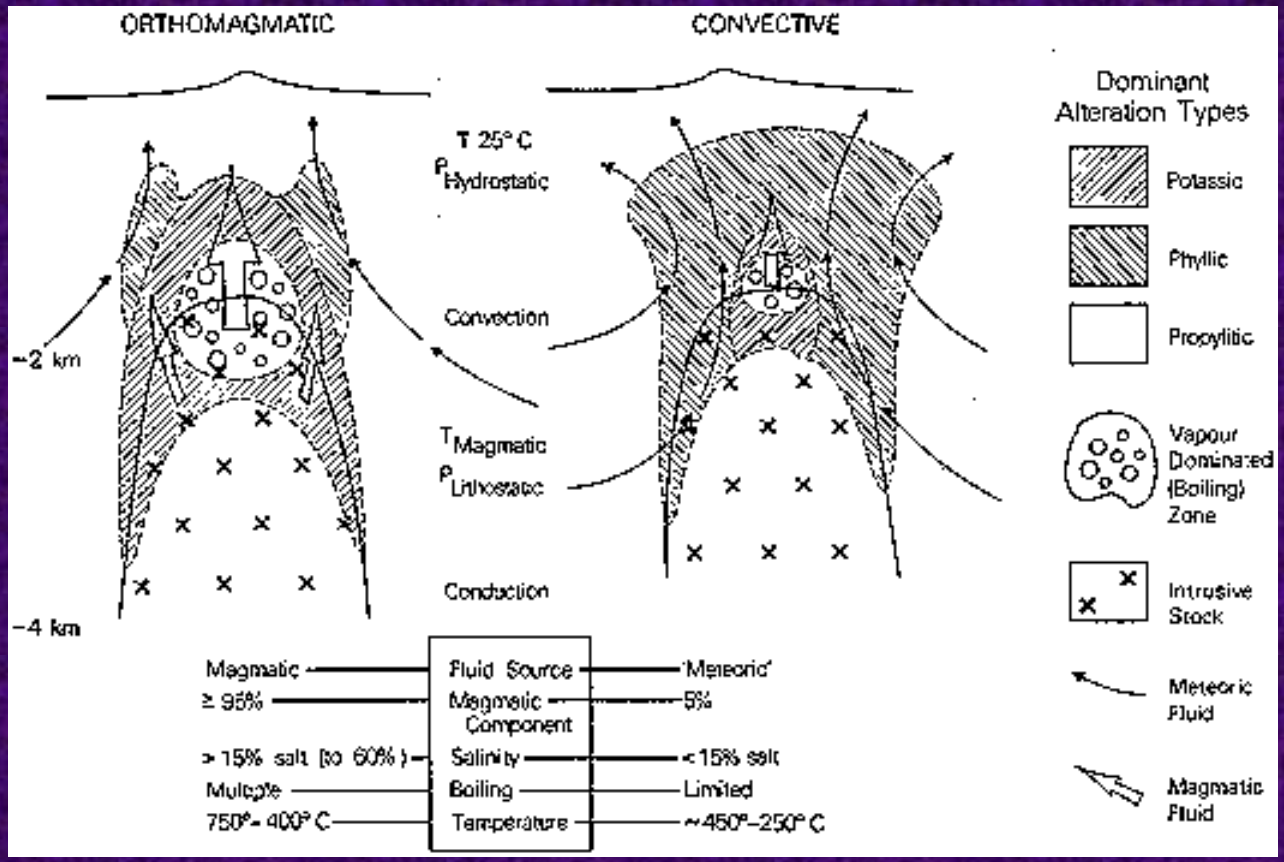
Types of Hydrothermal Deposits

1. veins or lode deposits
2. replacement deposits
3. disseminated deposits: porphyry copper/moly
4. massive sulfide deposits

Vein Deposits



Porphyry Deposits



Massive Sulfide Deposits