

Introduction to Epithermal Gold Deposit

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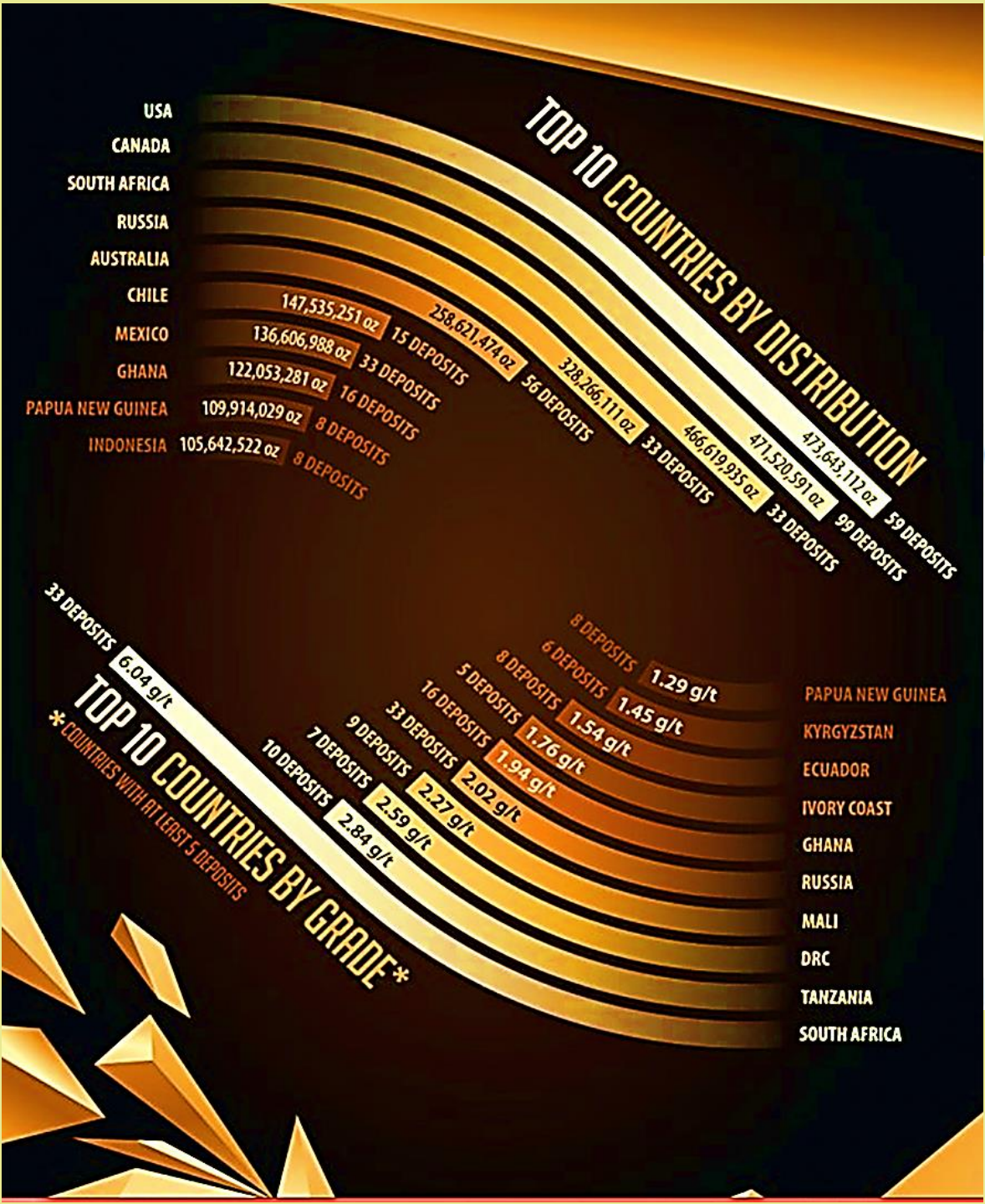
In the name of God



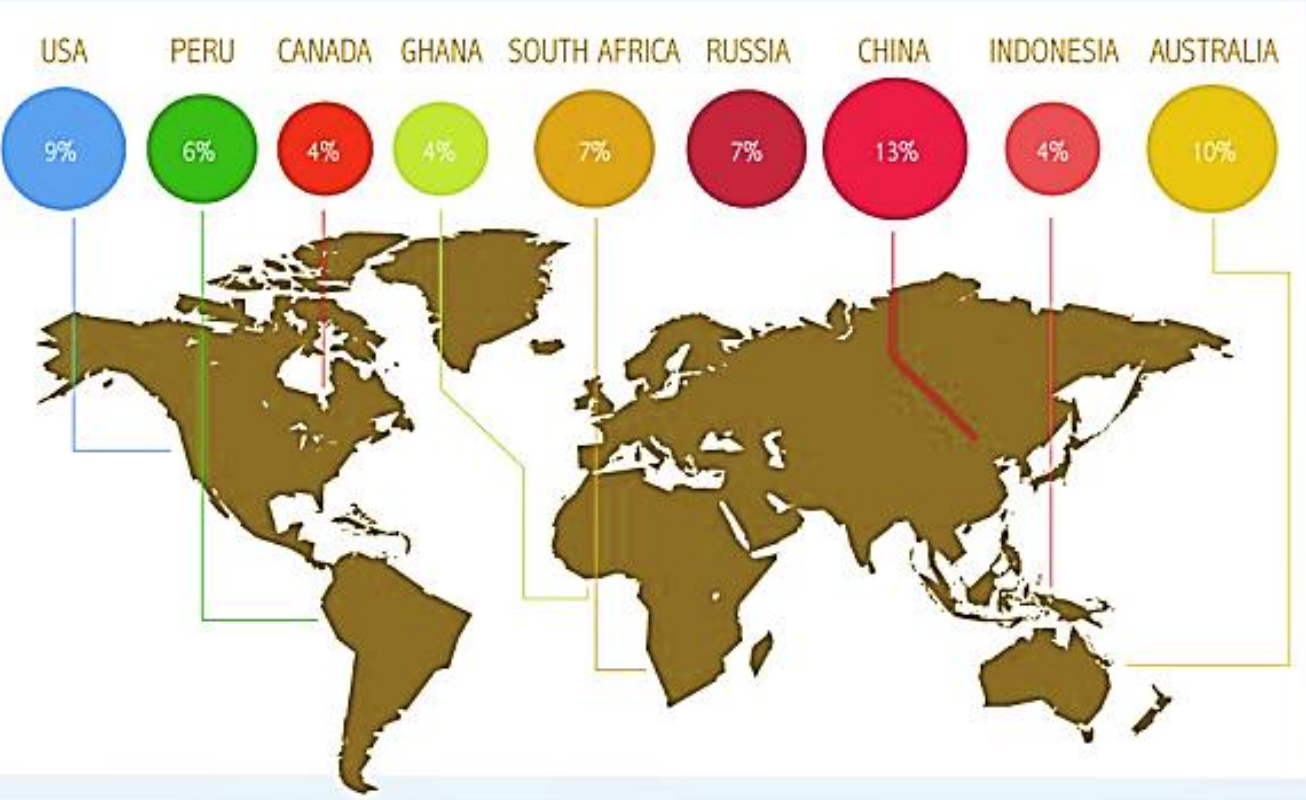
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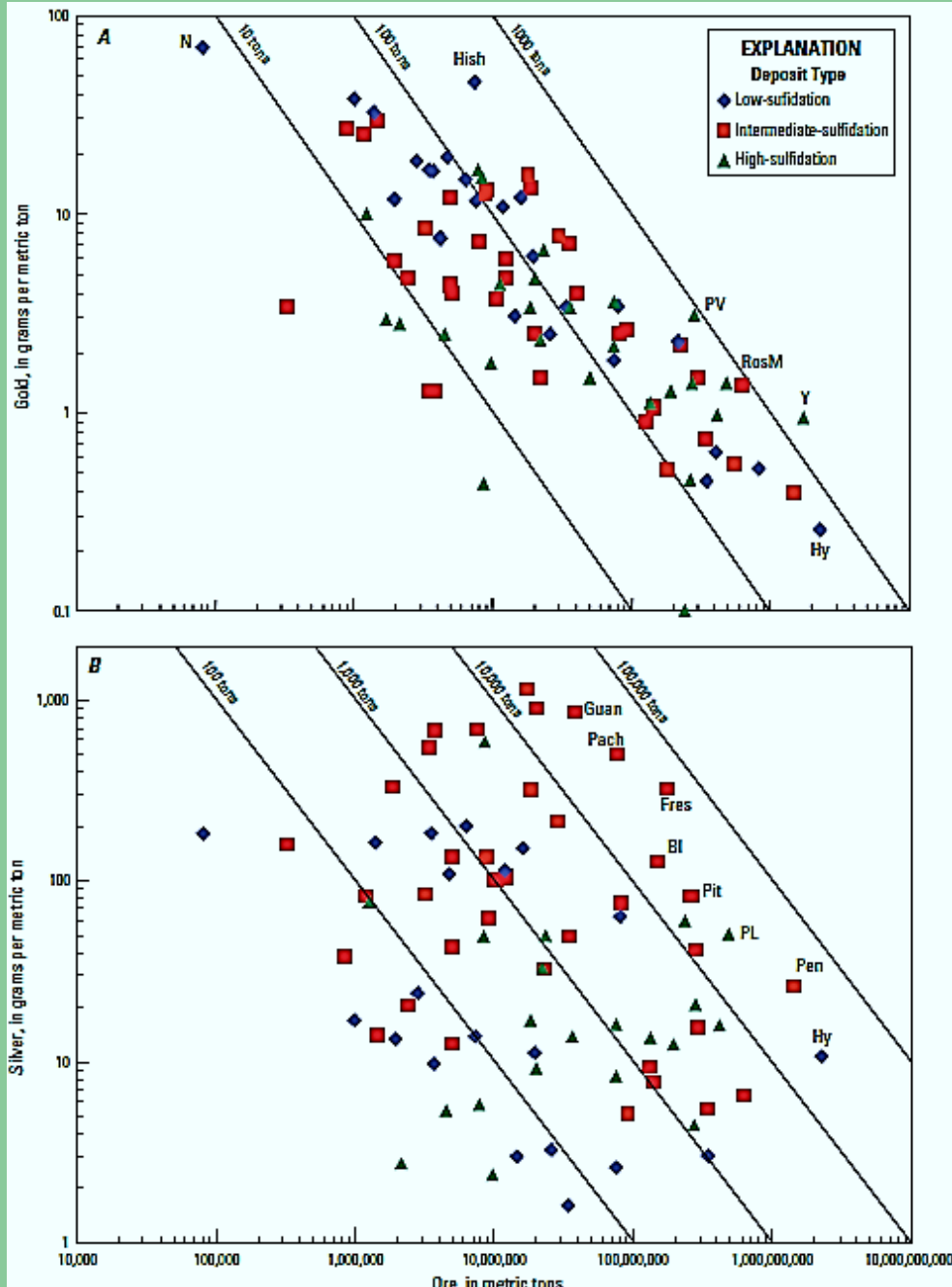
The Map Below Illustrates the Distribution of Gold Production



WHO'S STILL PRODUCING GOLD? (PERCENTAGE OF WORLD PRODUCTION)

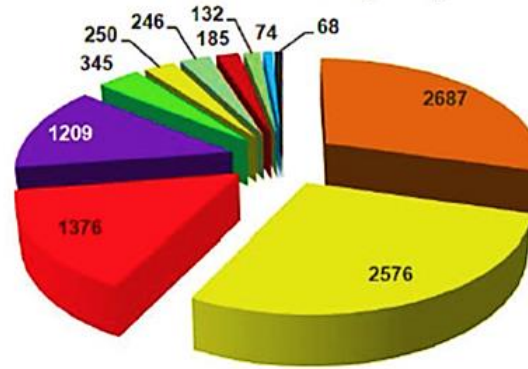


Graphs showing gold (A) and silver (B) grades and tonnages for most epithermal gold-silver deposits



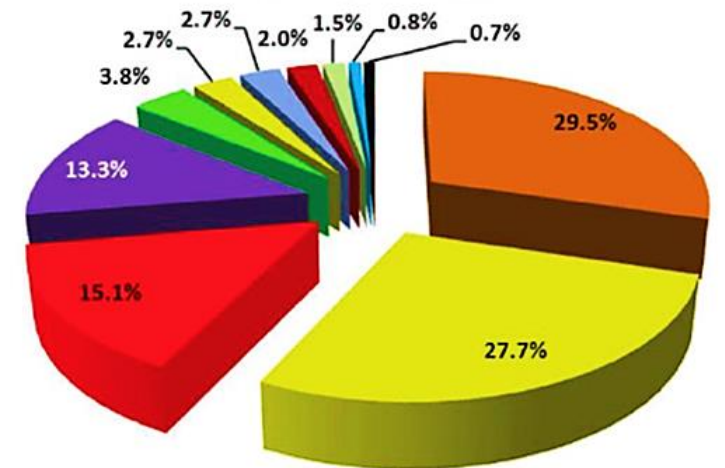
Relative Importance of the different types of gold deposit in overall production between 1984 and 2012

Au endowment by deposit type - Moz



- Orogenic
- VMS
- Paleoplacer
- Intrusive-related
- Cu-Au porphyry
- IOCG
- Epithermal
- Skarn
- Carlin
- PGE-related

Au endowment by deposit type - %



Total known gold endowment = 9149 Moz



Introduction:

Epithermal mineralization usually at 50 to 250 ° C at the surface and depth of 1000 meters are formed. Groundwater and magma have a fundamental role in this process.

Types of epithermal gold deposit:

3 endmember types:

a: High sulfidation bodies: Cu-Au-As, sulfide rich, andesite arcs.
Hosted by lithocaps: advanced argillic zones over porphyry system.

b: Low sulfidation bodies: Au-Ag bonanzas, sulfide poor.
Ls veins: Au-Ag-Te, sulfide poor; extensional, bimodal.

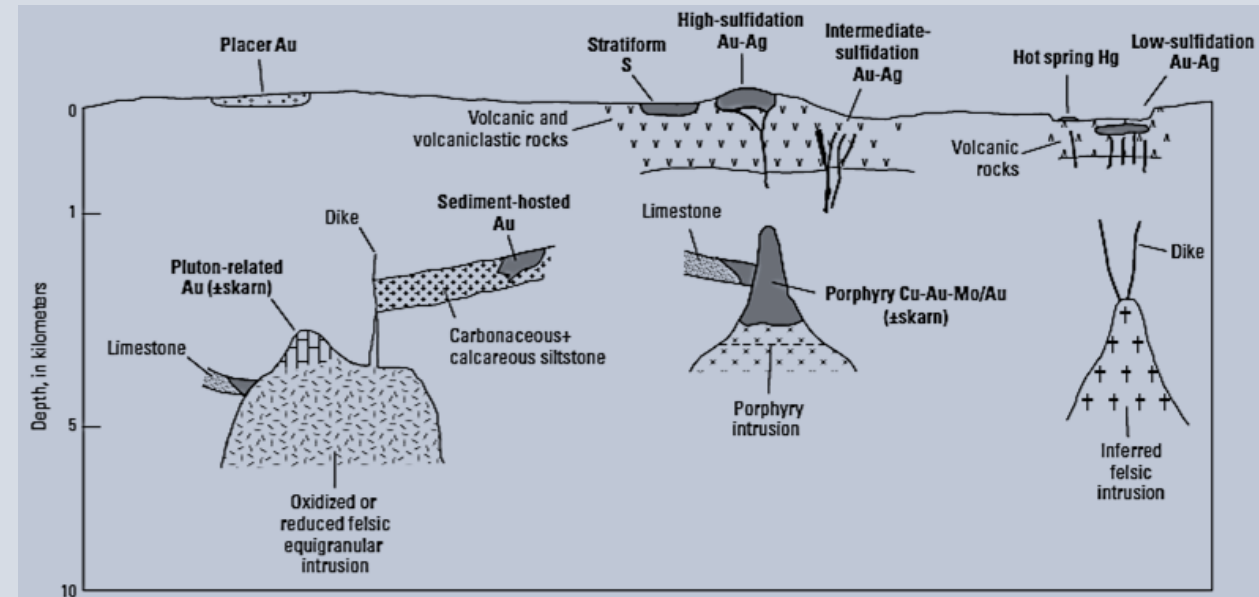
c: Intermediate sulfidation bodies: Ag-Au(Zn-Pb), sulfide rich.
Zoned and/or complex mineralogy (intrusion related, diatreme)

Epithermal gold deposits resources:

High sulfidation ores: small reserve

Low sulfidation ores: big reserve

Intermediate sulfidation ores: medium reserve



Schematic cross section showing epithermal gold-silver deposits and other related or proximal deposit types. Figure based on Sillitoe (2008). Abbreviations: Ag, silver; Au, gold; Cu, copper; Hg, mercury; Mo, molybdenum; S, sulfur.

Geochemical Features:

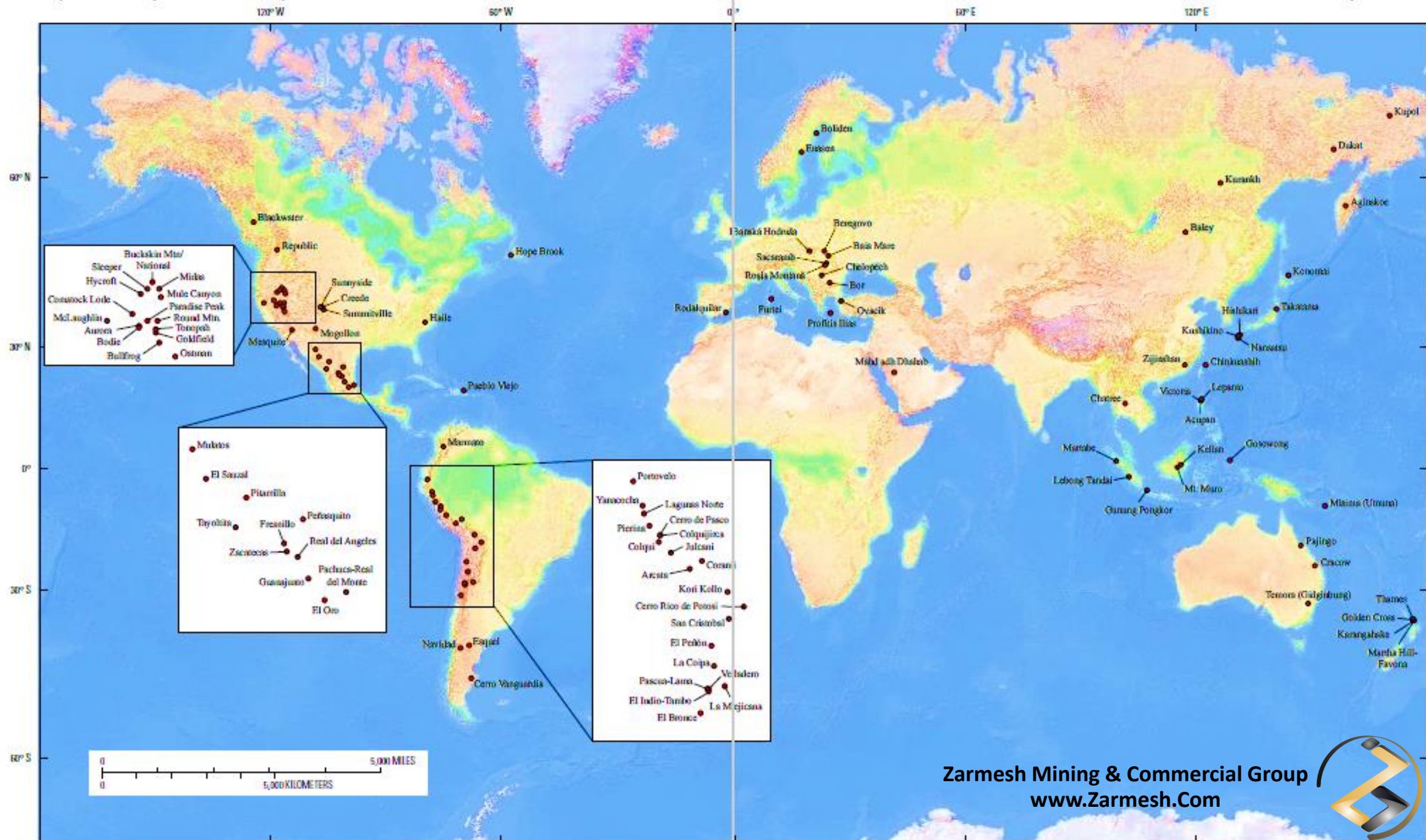
High sulfidation ores: high copper and low Ag/Au

Low sulfidation ores: high zinc, lead and high Ag/Au

Intermediate sulfidation ores: high zinc, lead and copper ?
Ag/Au

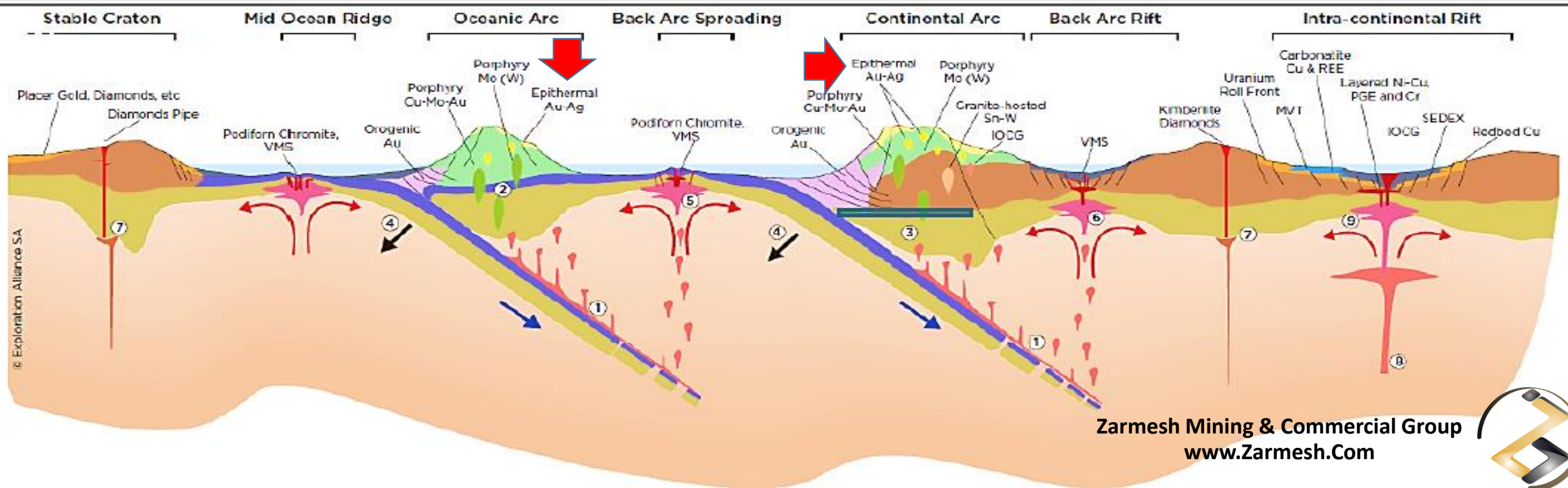


Map showing locations of epithermal gold-silver in the world



Geodynamic settings in terms of the supercontinent cycle mineral deposits

Sulfidation state	Igneous rock composition ¹	Tectonic setting
High	Calc-alkaline, andesite-dacite	Magmatic arc in a neutral to mildly extensional stress state; compressive stress state uncommon but serves to suppress volcanic activity
Intermediate	Calc-alkaline, andesite-rhyolite	Magmatic arc in a neutral to mildly extensional stress state; compressive stress state rare
Low	Calc-alkaline, alkaline, tholeiitic bimodal basalt-rhyolite	Magmatic arc undergoing extension leading to rifting; postcollisional rifting



TYPES OF GOLD DEPOSITS

PLACER
Deposits are formed when erosion exposes veins of gold. The gold, because of its density, eventually is moved by Earth's forces such as water and gravity. Gold nuggets found with gold panning are created in this manner.

VOLCANOGENIC MASSIVE SULPHIDE (VMS)

(VMS) deposits are formed at or near the **SEA FLOOR** by underwater volcanic activity. They can be a significant source of copper, zinc, lead, gold, and silver.

EPITHERMAL

Deposits are created close to surface and are deposited by hot fluids. These occur typically in areas where **MAGMA** is able to move high in the Earth's crust. Gold, silver, copper, and other metals are found in epithermal deposits.

PORPHYRY

Deposits are the single most important source of **COPPER** and molybdenum today. Also sometimes containing gold, they form when a column of magma rises and cools in two stages, trapping rich localized zones of minerals.

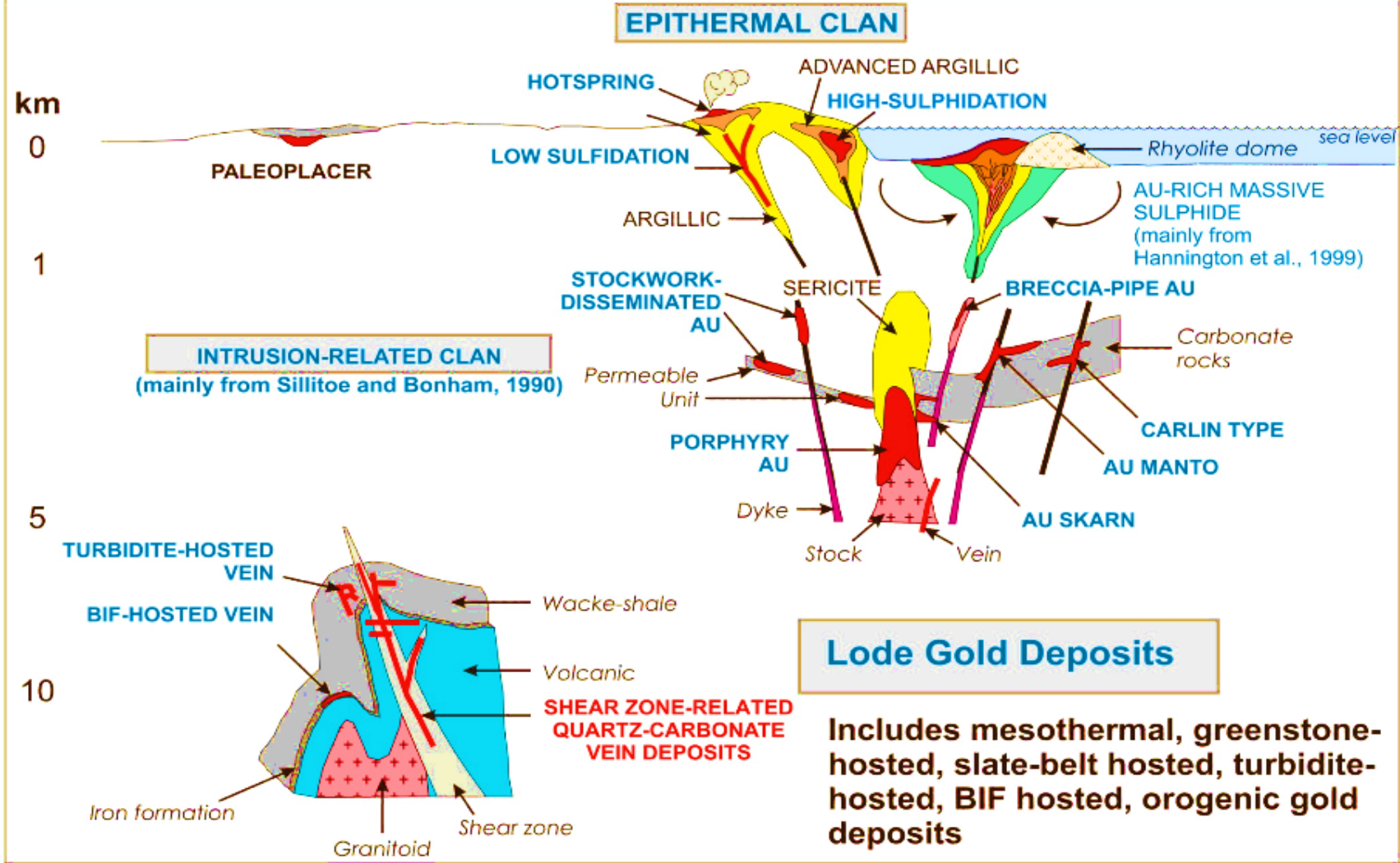
CARLIN-TYPE

Deposits occur chiefly in Nevada, where the gold is "invisible" to the naked eye by being disseminated throughout the sedimentary rock. Almost always, these are hosted in **CARBONATE** rocks.

OROGENIC

Deposits form during "mountain forming" events when tectonic plates collide. The gold, along with other minerals, is often precipitated in quartz.

Inferred Crustal Levels of Deposition



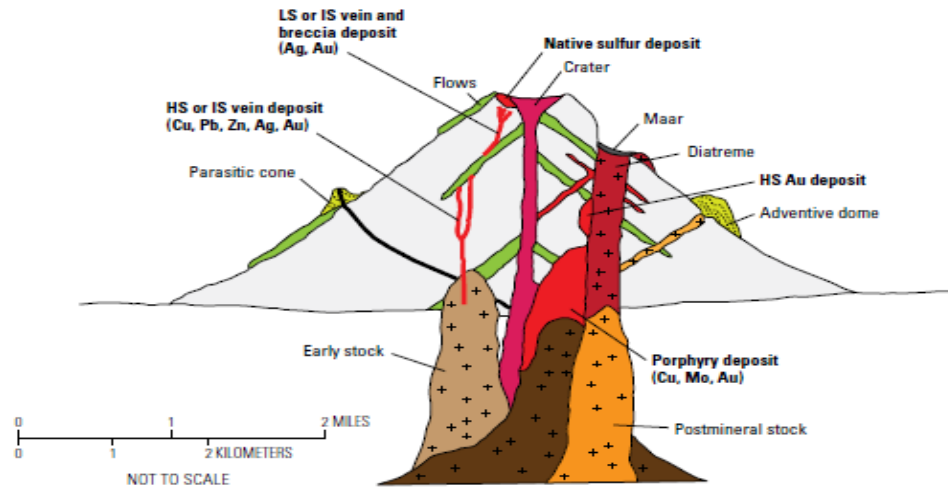
Modified after Dubé and Gosselin (2007)



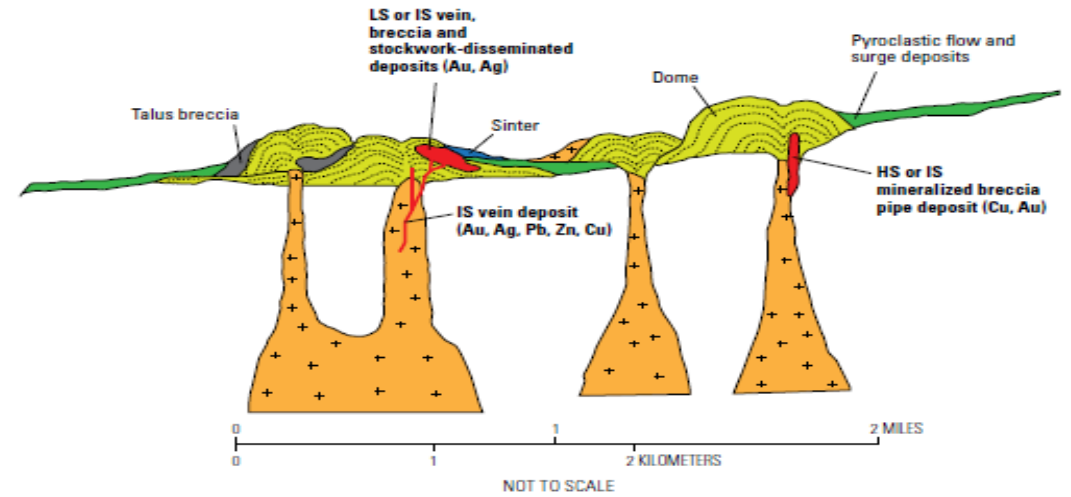


Schematic cross sections showing volcanic landforms that commonly host epithermal gold-silver and related deposits and principal metals. *A*, Stratovolcano; *B*, Lava dome field; *C*, Ignimbrite (ash-flow) caldera; *D*, Maar-diatreme complex. Figure modified from Sillitoe and Bonham (1984).

A. Stratovolcano



B. Lava dome field



C. Ignimbrite ash-flow

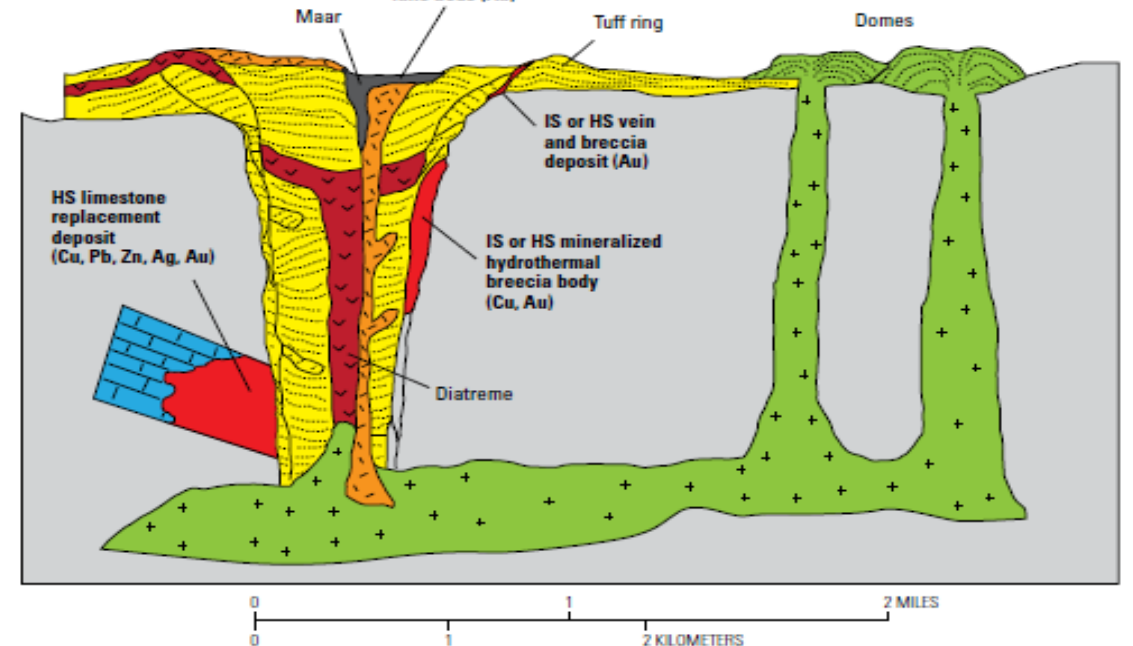
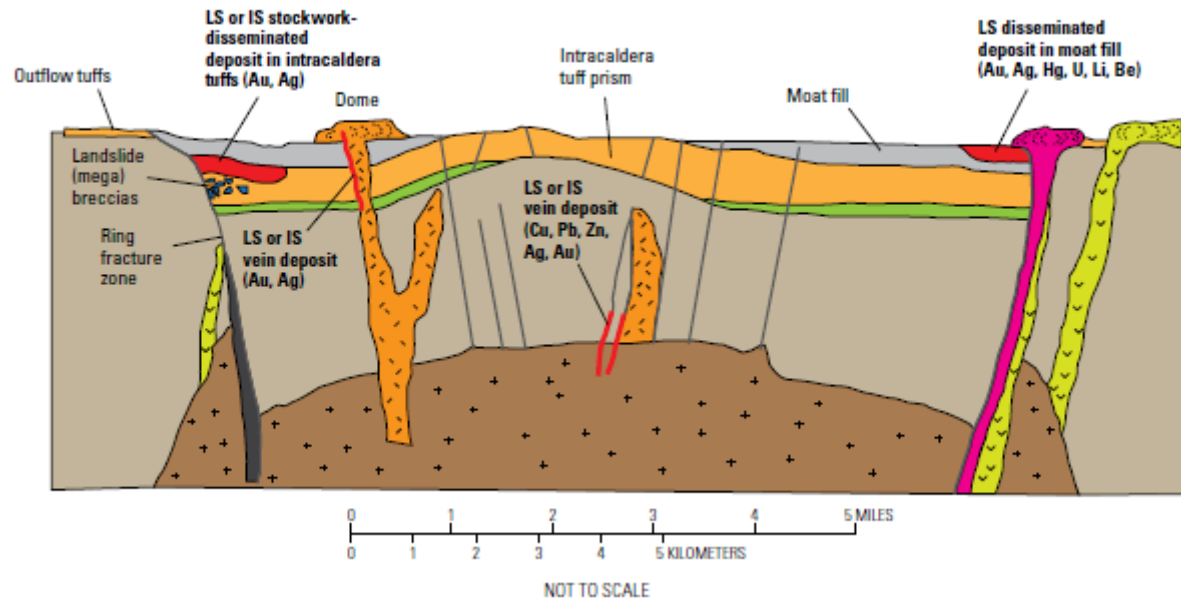
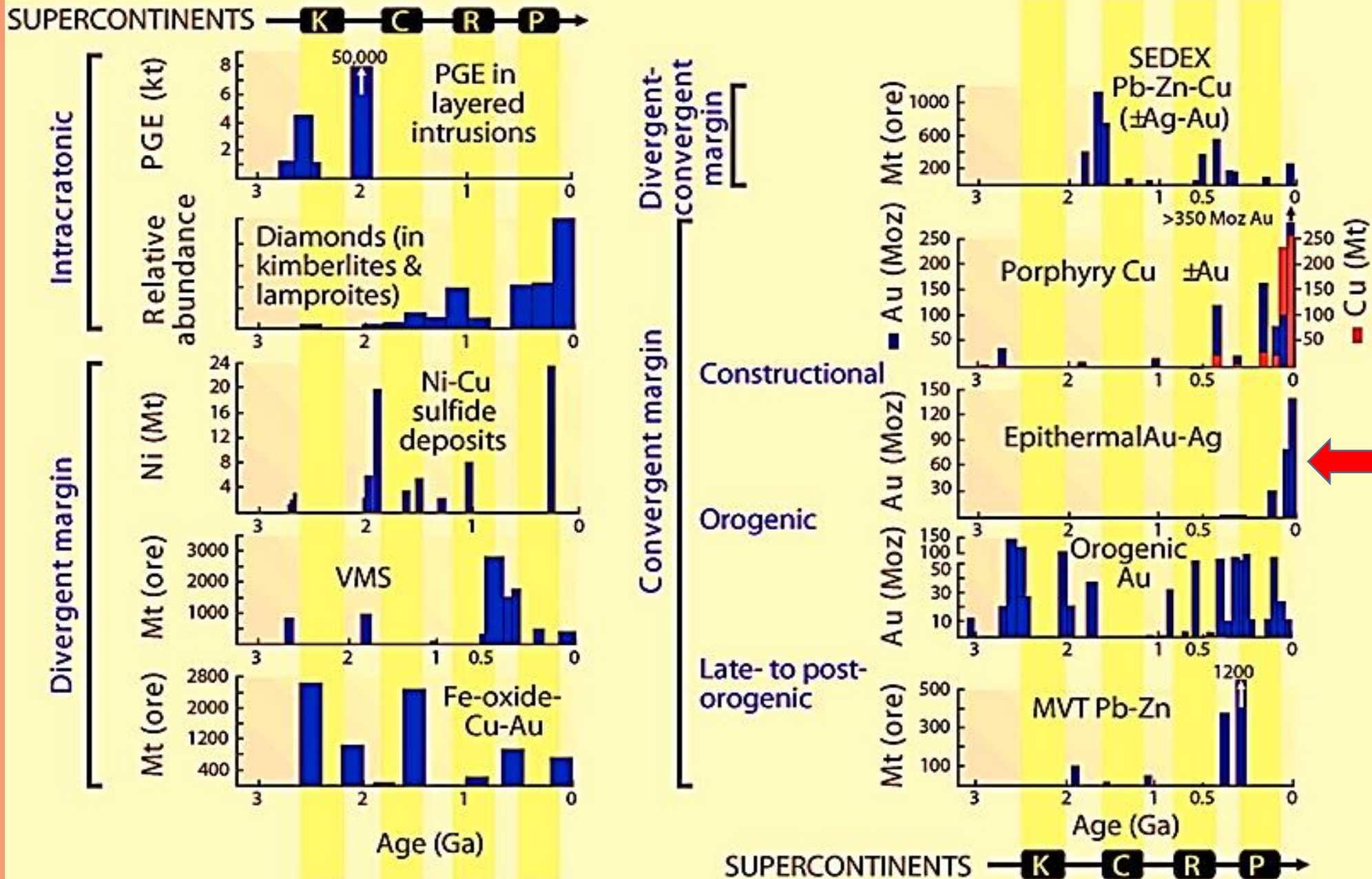


Diagram showing the temporal distribution of deposit types ascribed to broad geodynamic settings in terms of the supercontinent cycle, as summarized from Figure 1. Temporal distributions are from Groves et al. (2005b) and references therein. K, Kenorland; C, Columbia; R, Rodinia; P, Pangaea



Epithermal gold deposit main characteristic

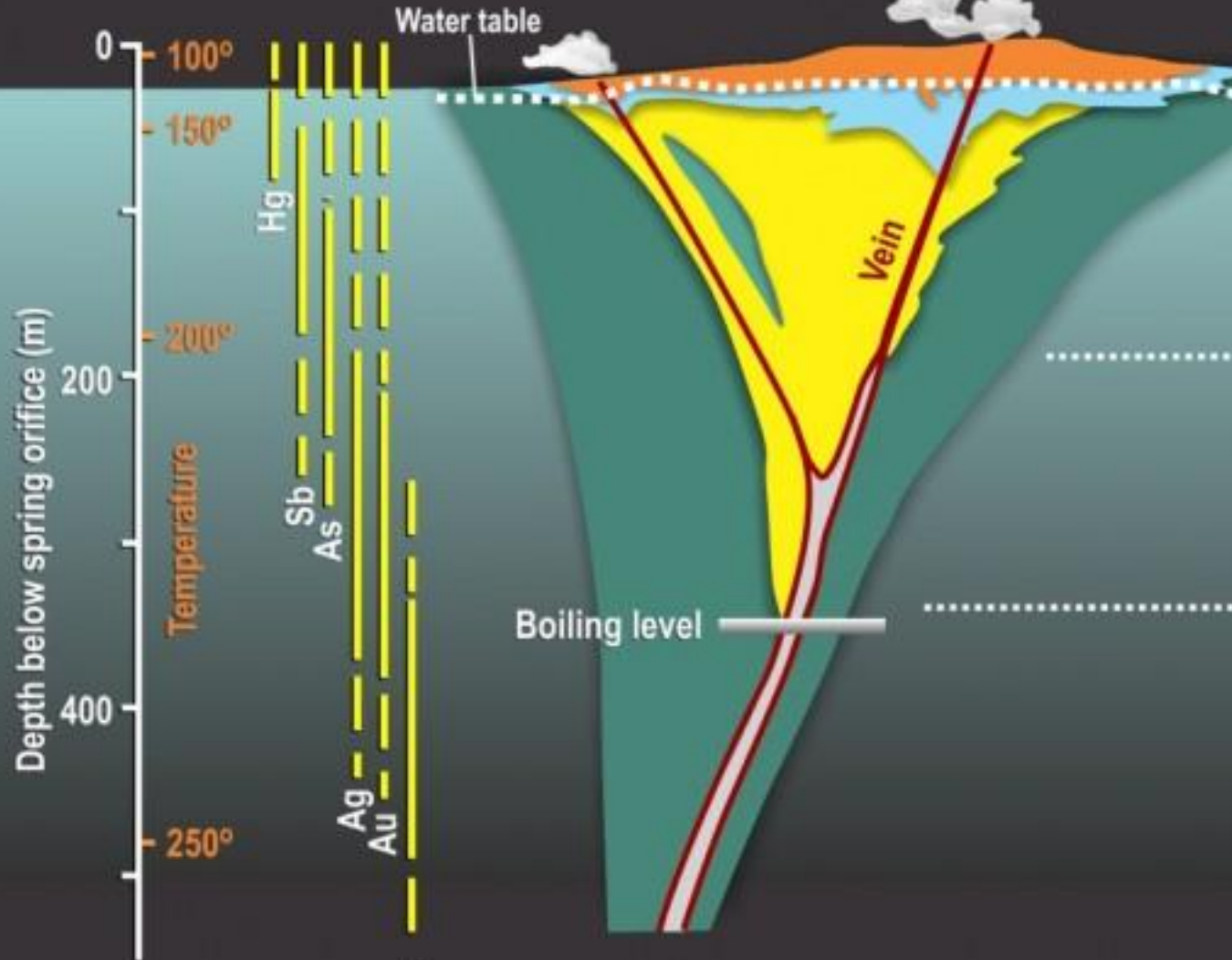
Parameter	Low Sulphur deposit	High Sulphur deposit
Ore minerals Gold	Gold, pyrite, electrum, sphalerite, galena	Gold, chalcopyrite, pyrite, tellurides, covellite
Gangue minerals	Quartz, Calcite, adularia, illite, carbonates	Quartz, alunite, barite, kaolinite, pyrophyllite
Textures	Veins, and open space filling druse cavities, symmetrical banding and Colloform	Wall rock replacement, breccias, veins
Deposit characteristics	Cavity veins and stockworks ore common	Disseminated ores and replacement ores common
Main metals	Au, Ag, Zn, Pb, and minor Cu, Sb, As, Hg, Se	Au, Ag, Cu, As, and minor Pb, Hg, Sb, Te, Mo, Bi



METALS

ALTERATION

VEINING



Chalcedonic superzone	Crystalline carbonate	Agate, bladed, molds
	Bladed carbonate	Agate, amethyst
	Massive chalcedonic	Lattice, moss, agate
Crustiform - colloform superzone	Moss + chalcedonic > crystalline	Lattice bladed, sulphide bands, moss adularia
	Crystalline > moss + chalcedonic	Needle adularia sulphide bands dissem. sulphides
Crystalline superzone	Crystalline quartz + adularia + sulphide	Crustiform
	Crystalline quartz + carbonate	Crustiform

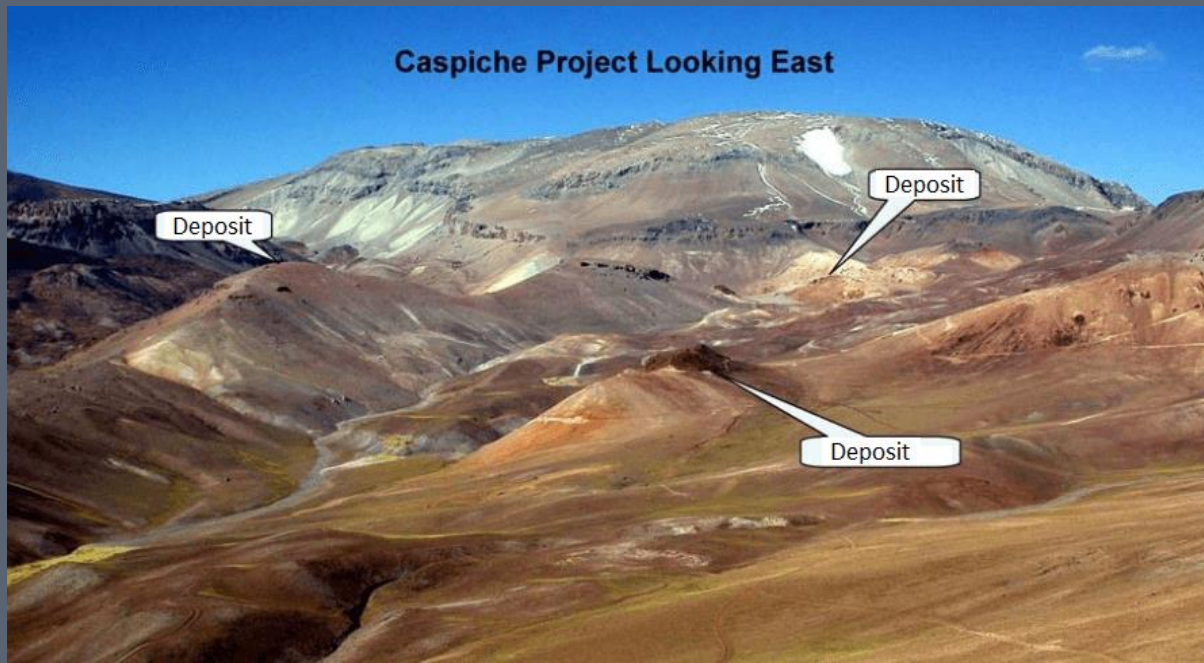


After Buchanan (1981), Morrison et al. (1990) and Corbett & Leach (1997).

High sulfidation outcrop



Low sulfidation outcrop



Caspiche Project Looking East

Deposit

Deposit

Deposit



Ore minerals

High sulfidation ore



Gold ore high sulfide

High Sulphide vein hosted in advanced argillic altered volcanic.

Intermediate sulfidation ore



Gold& Silver ore

High grade gold and silver ore consisting of lustrous GALENA, CHALCOPYRITE, SPHALERITE from the only operating...

Low sulfidation ore



High-grade gold ore (bonanza-grade gold ore)

Auriferous quartz-adularia rhyolite Native gold (Au) occurs in this rock as colloform bands, partially replaces breccia clasts, and also disseminated in the matrix



Ore Textures



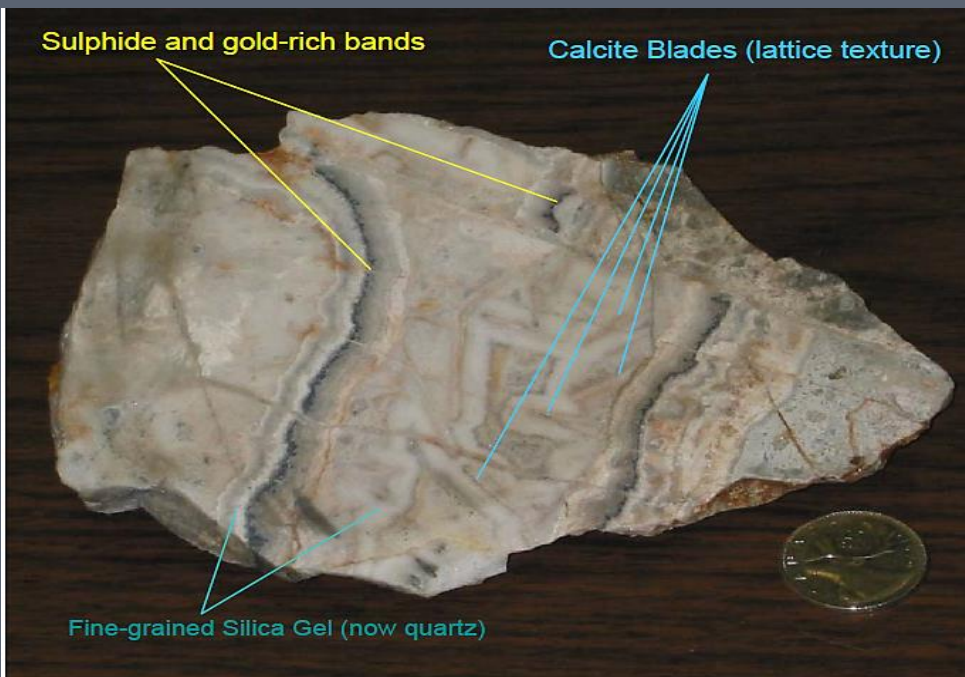
Colloform-banded quartz



Urumalqui Crustiform Banding



Vuggy silica



Sulphide and gold-rich bands

Calcite Blades (lattice texture)

Fine-grained Silica Gel (now quartz)



Epithermal boiling texture of bladed quartz-carbonate in gold-bearing quartz vein, Danbo Property

Alteration	Mineralogy	Occurrence and origin
Propylitic	Quartz, K-feldspar (adularia), albite, illite, chlorite, calcite, epidote, pyrite	Develops at >240°C deep in the epithermal environment through alteration by near-neutral pH waters
Argillic	Illite, smectite, chlorite, inter-layered clays, Develops at <180°C on the periphery and in the shallow epithermal pyrite, calcite (siderite), chalcedony	environment through alteration by steam-heated CO ₂ -rich waters
Adv. Argillic (steam-heated)	Opal, alunite (white, powdery, fine-grained, pseudocubic), kaolinite, pyrite, marcasite	Develops at <120°C near the water table and in the shallowest epithermal environment through alteration by steam-heated acid-sulfate waters; locally associated with silica sinter but only in geothermal systems
Adv. Argillic (magmatic hydrothermal)	Quartz, alunite (tabular), dickite, pyrophyllite, (diaspore, zunyite)	Develops at >200°C within the epithermal environment through alteration by magmatic-derived acidic waters
Adv. Argillic (supergene)	Alunite, kaolinite, halloysite, jarosite, Fe oxides	Develops at <40°C through weathering and oxidation of sulfide-bearing rocks



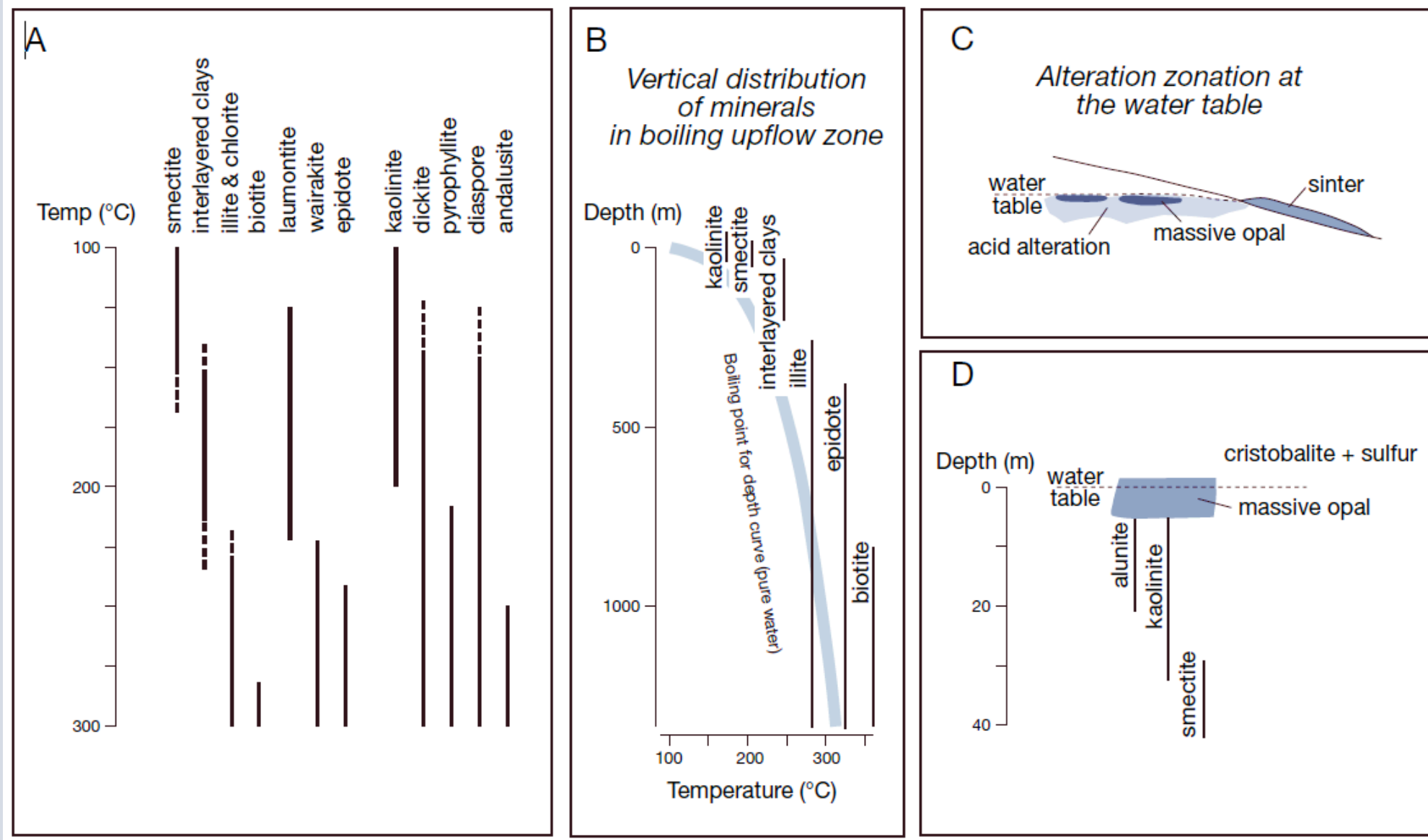
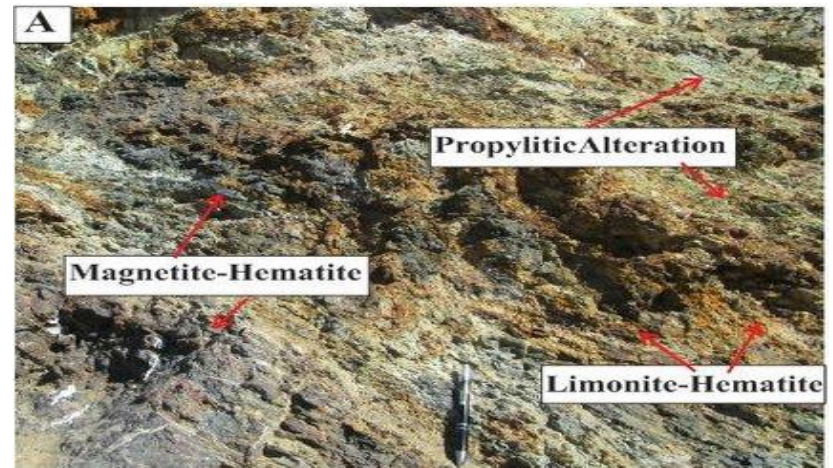
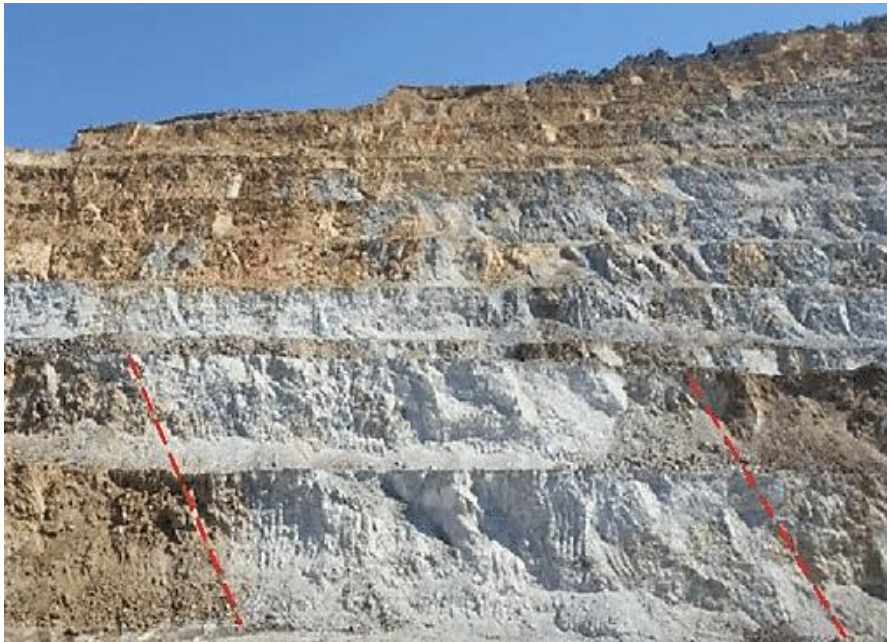


FIG.. Key indicator minerals in epithermal environments. A. Stability range of temperature-sensitive clays, phyllosilicates and zeolites (Henley and Ellis, 1983; Reyes, 1990). B. Vertical distribution of some of the same minerals plotted according to depth, using the hydrostatic boiling curve as the reference temperature gradient. C. Diagnostic hydrothermal minerals forming at the water table, comprising silica sinter where near-neutral pH waters discharge around boiling hot springs and vertically zoned acid alteration (modified from Sillitoe, 1993b). D. Magnification of vertically zoned steamheated acid alteration at the water table (Schoen et al., 1974; Immons and Browne, 2000a): cristobalite and sulfur form at and above the water table; tabular massive opal forms at and below the water table; alunite and kaolinite form at and below the water table and the zone of massive opal.

Propylitic Alteration



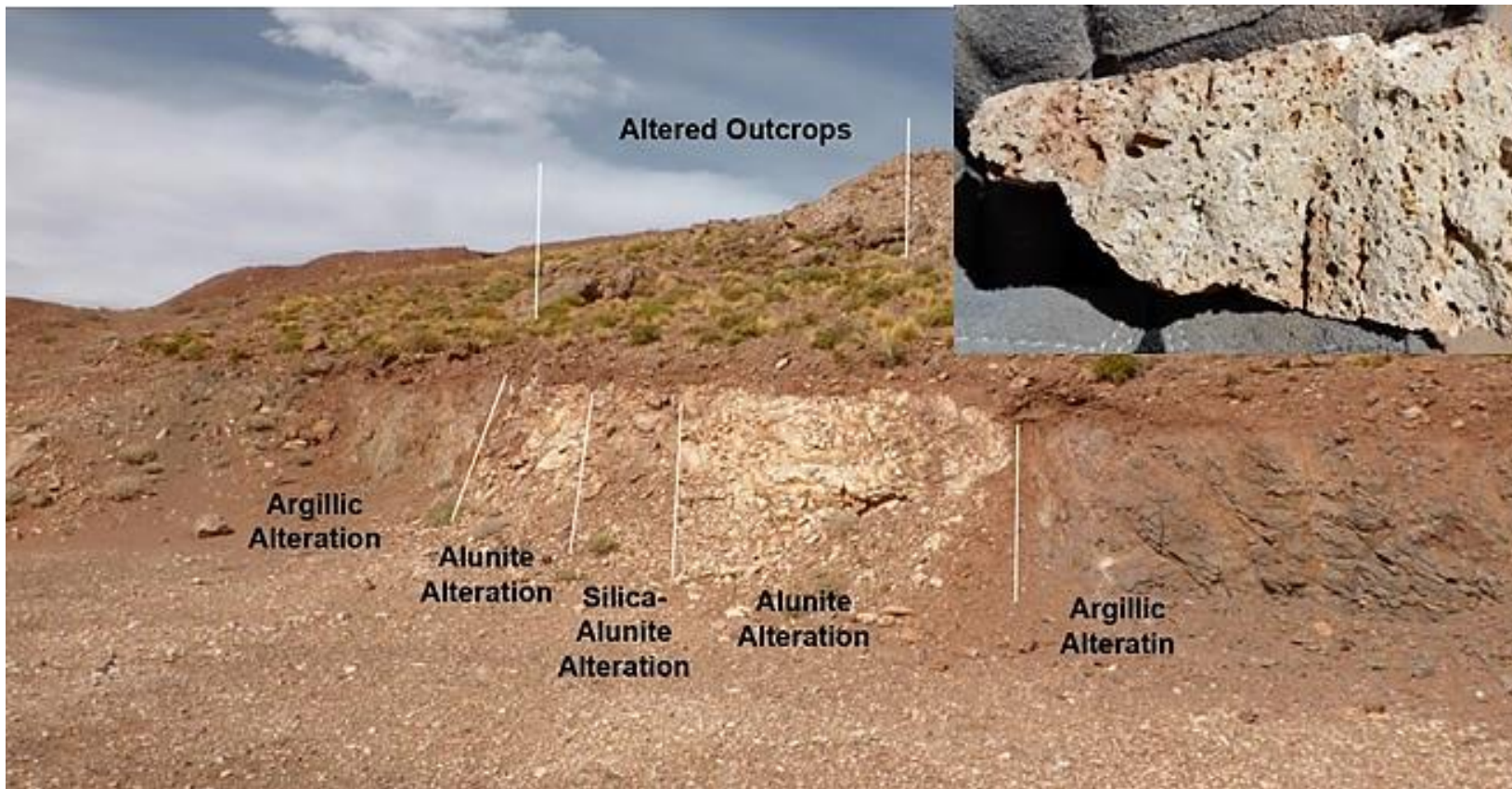
Advanced Argillic Alteration



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advanced argillic alteration in an arid setting at Pascua-Lama. from publication: High Sulphidation Gold Deposits.

Alunite Alteration



Jarosite Alteration



Alteration crust rich in jarosite and other sulfates at El Jaroso Ravine, Sierra Almagrera (SE Spain)

Jarosite samples

Alteration crust rich in jarosite

Jarosite in New Zealand. Credit: Michelle Kotler



Epithermal Au Mineralization and Associated Hydrothermal Alteration in Southern Kyushu



414m (2.54 g/t Au & 1.1 g/t Ag), "Yellow" polymict hydrothermal breccia jarosite-alunita-barite-filled matrix with sub angular vuggy silica altered fragments



silica sinter





Gangue Minerals In Epithermal Systems

Minerals	LS	HS
Quartz	abundant	abundant
Chalcedony	common (variable)	common (minor)
Calcite	common (variable)	absent (except as overprint)
Adularia	common (variable)	absent
Illite	common (abundant)	uncommon (minor)
Kaolinite	rare (except as overprint)	common (minor)
Pyrophyllite-diaspore	absent (except as overprint)	common (variable)
Alunite	absent (except as overprint)	common (minor)
Barite	common (very minor)	common (minor)
Sericite		common
Hematite	common	



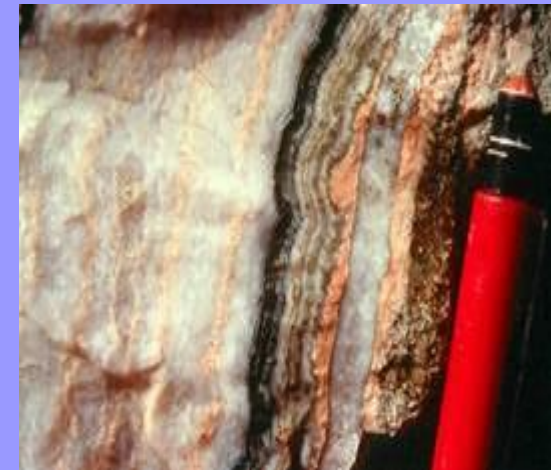
Bladed Calcite



bladed Barite



Illite



Adularia



Minerals

LS

HS

Pyrite	ubiquitous (abundant)	ubiquitous (abundant)
Sphalerite	common (variable)	common (very minor)
Galena	common (variable)	common (very minor)
Chalcopyrite	common (very minor)	common (minor)
Enargite-Luzonite rare	(very minor)	ubiquitous (variable)
Tennantite-Tetrahedrite	common (very minor)	common (variable)
Covellite	uncommon (very minor)	common (minor)
Stibnite	uncommon (very minor)	rare (very minor)
Orpiment	rare (very minor)	rare (very minor)
Realgar	rare (very minor)	rare (very minor)
Arsenopyrite	common (minor)	rare (very minor)
Cinnabar	uncommon (minor)	rare (very minor)
Electrum	uncommon (variable)	common (minor)
Native Gold	common (very minor)	common (minor)
Tellurides-Selenides	common (very minor)	uncommon (variable)



Native Gold



Enargite



Cinnabar



Argentite (Silver sulphide)
Native Gold and Electrum

RM06-A01



Dakota Matrix

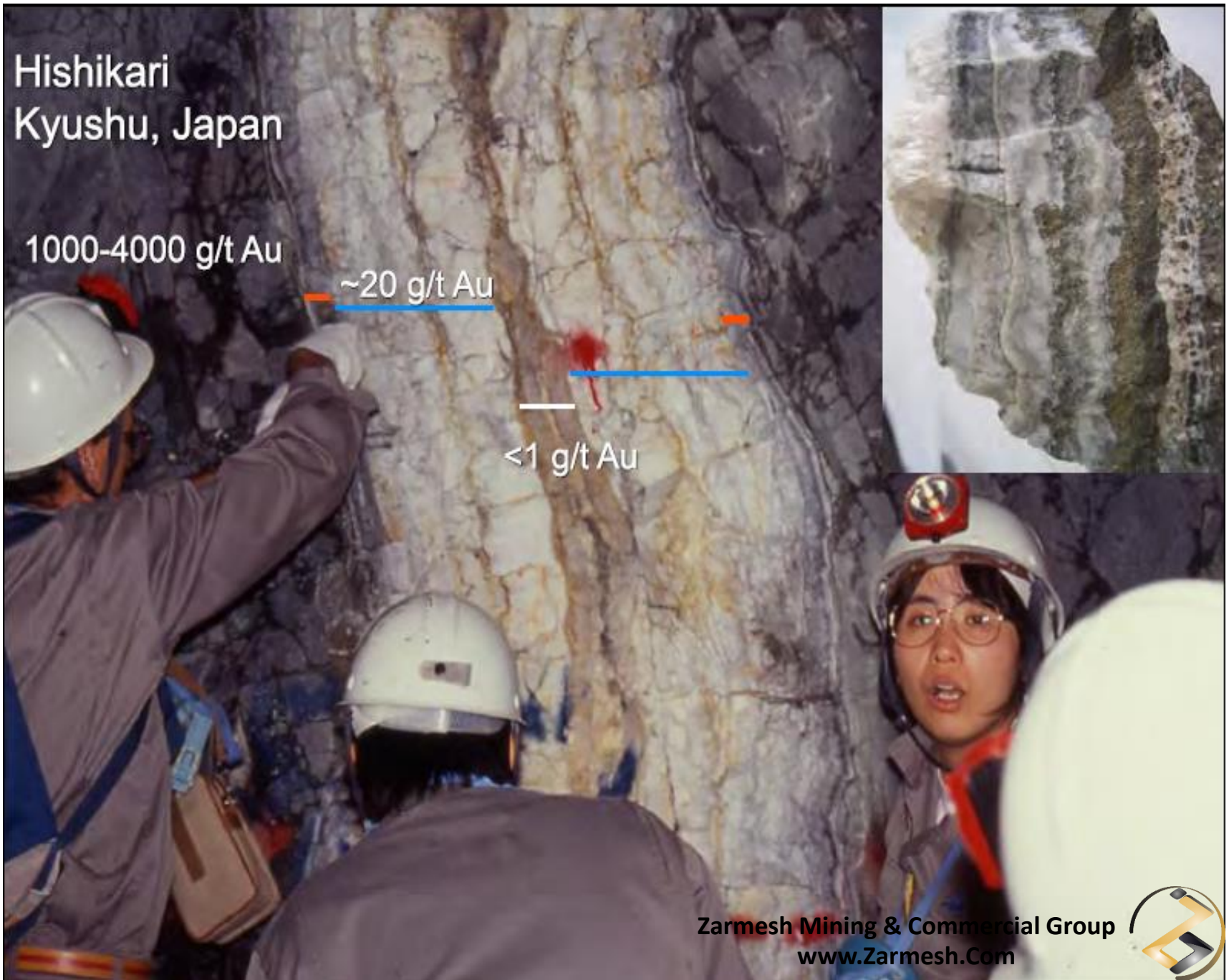


Hishikari Kyushu, Japan

1000-4000 g/t Au

~20 g/t Au

<1 g/t Au



Thank you for your attention!

