

A PROSPECTORS GUIDE TO Epithermal Gold and Silver in Newfoundland and Labrador

Contributed by:

**Matty Mitchell Prospectors Resource Room
Information Circular Number 8**



First Floor • Natural Resources Building
Geological Survey of Newfoundland and Labrador
50 Elizabeth Avenue • PO Box 8700 • A1B 4J6
St. John's • Newfoundland • Canada

Telephone: 709-729-2120, 709-729-6193 • e-mail: matty@gov.nl.ca
Website: http://www.nr.gov.nl.ca/nr/mines/pro prospector/matty_mitchell/index.html



EPITHERMAL GOLD FOR PROSPECTORS

Contents:

What is Epithermal?

What is Epithermal Gold?

Why is the Epithermal Deposit type Important?

Do Epithermal gold prospects occur in Newfoundland and Labrador?

Why should Prospectors be interested in exploring for Epithermal Gold?

Where are Epithermal Gold Deposits formed?

How are Epithermal Gold Deposits Formed?

Types of Epithermal Gold Deposits

LS Gold Deposits

HS Gold Deposits

What are the characteristic textures of Epithermal Gold Deposits?

Alteration

Glossary

Appendix

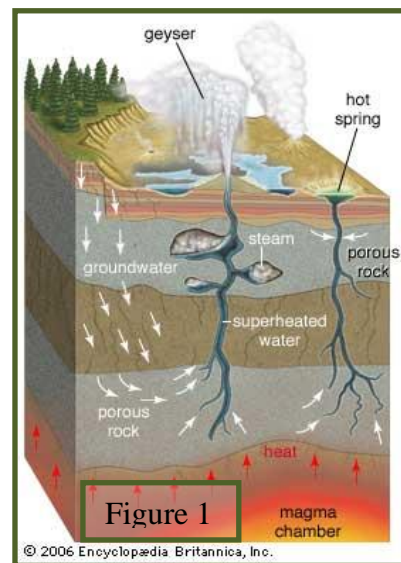
List of Resources

WHAT IS EPITHERMAL?

- **Epi** means shallow.
- **Thermal** refers to heat and to *hydrothermal* or hot, water-rich fluids or *brines*.
So, Epithermal means “shallow heat”.
(Note: words in italics are explained in the Glossary).

WHAT IS EPITHERMAL GOLD?

- **Epithermal Gold** refers to a type of gold deposit formed from hydrothermal fluids at shallow levels in the earth's crust. “Epithermal” is an old term used to classify hydrothermal deposits based on temperature and depth of deposition.
- **Epithermal** is used in field exploration studies to describe $Au \pm Ag \pm Cu$ deposits formed in *magmatic arc* environments.
- **Epithermal Systems** refer to the network of veins and hydrothermal fluids that permeate the crust of the earth between the *magma chamber* and the surface of the earth, and the metal deposits: this is a type of plumbing system (Figure 1) that also includes fractures, faults and other cracks or voids in the crust.
- **Epithermal Alteration**: magma chambers remain in the crust for long periods of time (millions of years) and so do the hydrothermal fluids given off by these magmas. The fluids are hot and salty and can be extremely corrosive thereby causing changes in the chemistry of the rocks that they pass through - this change is called *alteration*. The result is that a whole new suite of alteration minerals is formed.



WHY IS THE EPITHERMAL DEPOSIT TYPE IMPORTANT?

Epithermal Deposits...

- ... contribute significantly to the world's gold supply.
- ... can be extremely high-grade, containing gold values ranging from *10 to more than 200 g/t (grams per tonne)*; the higher grades are called “*bonanza grades*” for obvious reasons (Figure 2). Goldbanks, Nevada, e.g. has high-grade banded veins with gold grades which range up to ~ 8 oz. Au/t (~ 270 g/T).
- ... are commonly found as small vein systems (less than a million tonnes in size which are attractive to small mining companies, providing quick payback at high rates of return on moderate amounts of investment.
- ... may contain significant amounts of silver and/or copper, thereby increasing the value of a deposit.



Figure 2: Banded Bonanza Grade Vein at Hishikari, Japan. Photograph by Mike Porter

DO EPITHERMAL GOLD PROSPECTS OCCUR IN NEWFOUNDLAND AND LABRADOR?

- Yes: only in Newfoundland to date and there has been one gold producer, the Hope Brook Mine. Other epithermal prospects are actively being explored on the island (See Appendix).

WHY SHOULD PROSPECTORS BE INTERESTED IN EXPLORING FOR EPITHERMAL AU?

- The high grade nature of the deposits...
- The price of gold...
- Very distinctive textures in the veins which are easily recognized...
- Potential exists in many different rock types across the Island and in Labrador for these deposit types...

WHERE ARE EPITHERMAL DEPOSITS FORMED?

- Epithermal deposits are typically formed in areas of active *volcanism* called *magmatic arcs* which occur around the margins of continents.
- *Magma*s produce *volcanic* eruptions and *lava* flows and a whole variety of volcanic rocks at the surface of the earth.
- *Magma*s are also a primary source of hydrothermal fluids that transport gold and other metals and may in fact be the source of these metals in various types of epithermal deposits.
- Epithermal gold mineralization typically forms close to *volcanic* and *geothermal* hot spring activity, such as hot springs or geysers (Figure 3): these are the surface expression of hydrothermal systems and also, therefore, of epithermal systems. “Old” epithermal mineral deposits represent the fossilized “roots” of ancient *fumarolic* systems.
- Epithermal deposits are formed at shallow depths, from the surface down to 1000 m and averaging 350 m depth (Figure 4).
- The hot hydrothermal fluids, which are typically under varying amounts of pressure, are so close to the earth’s surface that they bubble up as boiling *hot spring systems* or can form *geysers* like Old Faithful in Yellowstone National Park: so, it’s quite possible that major epithermal gold deposits are forming right now under Yellowstone!
- Epithermal deposits typically form above the level of *Porphyry Cu-Au deposits* (Figure 4).
- Most rock types can host epithermal gold deposits; however, they are most commonly found in igneous and sedimentary rocks.
- Typically, epithermal deposits are younger than their enclosing or host rocks, except where deposits form in active volcanic settings and hot springs.

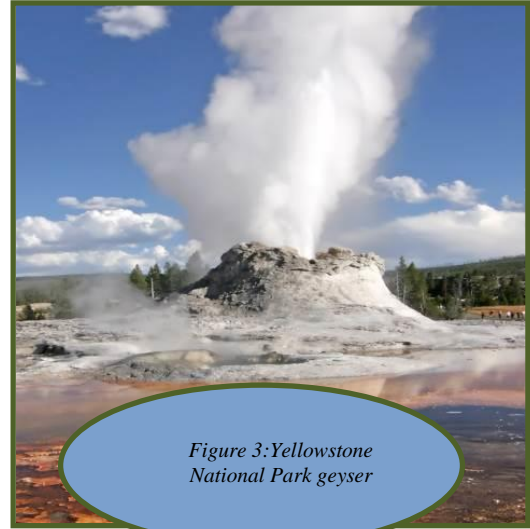
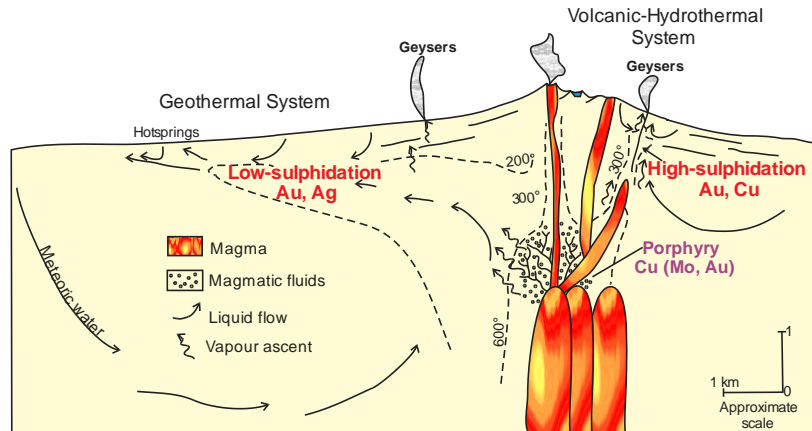


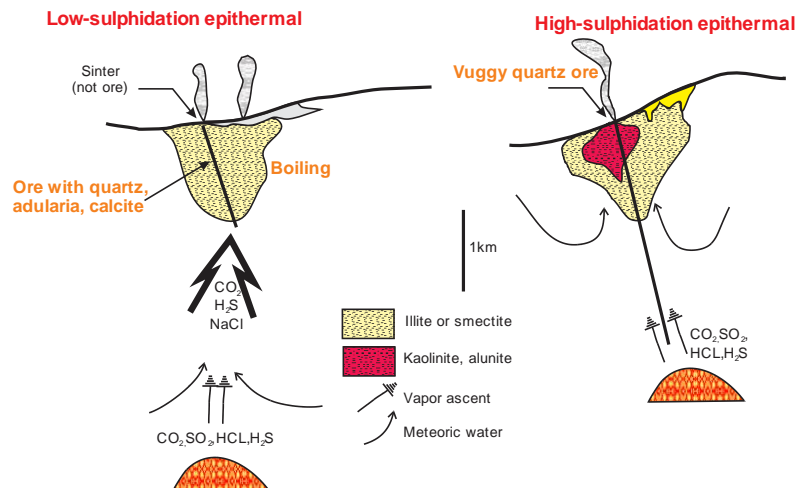
Figure 3: Yellowstone National Park geyser

HOW ARE EPITHERMAL GOLD DEPOSITS FORMED?

- Shallow bodies of magma rise to several km below the surface of the earth and give off or emanate super-hot magmatic fluids (Figure 4).
- As the hot fluids rise toward the surface, through fractures, faults, brecciated rocks, porous layers and other channels (the plumbing system), they react chemically with the country (or host) rocks.



Simplified model for porphyry, LS and HS systems (from Hedenquist and Lowenstern, 1994). See Appendix for more complete model.



Simplified model for fluid types and alteration zoning around LS and HS systems (White and Hedenquist, 1995).

Figure 4: Epithermal Deposits Environments

- Epithermal ore deposits are formed in the crust when the fluids are directed through a structure where the temperature, pressure and chemical conditions are favourable for the deposition of ore minerals, including native gold.

- Gold can also be deposited in a hot spring environment where mineralizing fluids reach the surface and cool, depositing ore.
- In the upper crust, water that has percolated down from the surface is abundant and is called *meteoric water*.
- The magmatic fluids can mix with meteoric fluids to varying degrees and influence ore formation.
- Fluid mixing and *boiling* are the two principal mechanisms that cause ore minerals to be deposited.
- Alteration and mineralization are intimately related in epithermal systems.

TYPES OF EPITHERMAL GOLD DEPOSITS

- There are two principal types of epithermal gold deposits – ***Low Sulphidation (LS)*** and ***High Sulphidation (HS)*** (Figure 4).
- They have different *gangue* and ore mineralogy, formed by the interaction of different hydrothermal fluids with host rocks and ground waters (Figures 4).
- HS and LS systems share some ore, gangue and alteration minerals, but the two systems can be separated based on the presence of several key ore and alteration minerals related to the formation of the mineralization (See tables below).
- LS is also called the *adularia-sericite* system and HS is also called the *alunite-kaolinite* or the acid sulphate system.

(Note: The following represents a simplified overview of the deposit types: more detailed descriptions can be obtained from the web (see list at end of this article) or from numerous research papers available through the Matty Mitchell Resource Room. The most important aspect for prospectors is to be able to recognize vein types as epithermal and therefore worthy of follow-up or ground checking).

LOW SULPHIDATION GOLD DEPOSITS

- Magmatic fluids with metals in solution migrate from the intrusion (magma) to higher crustal levels.
- The fluids interact with the surrounding rock for a long time and become diluted by mixing with meteoric waters (Figure 4).

- As a result, the fluids become dilute with a neutral pH.
- Most LS ore deposition occurs as these mixed fluids interact with the surrounding rocks: *boiling* takes place as a natural part of this process at about 300 m below the surface and may cause some gold to precipitate.
- Boiling causes the ore fluids to “dump” their mineral load into any available open space (fissures and veins).
- Boiling results in brecciation of host rock and *cockade* texture (Figures 5 to 8). Boiling and rapid cooling give rise to very fine-grained ores.
- The fossilized remains of boiling zones are a target for mineral exploration
- Many field-based explorationists show that mixing of rising magmatic fluids with meteoric waters may provide (possibly) the most efficient mechanisms of Au deposition.
- Metal bearing species are deposited first (and very quickly) followed by quartz, calcite and adularia gangue which grow more gradually until all open spaces are filled.
- Quartz continues to be precipitated until the fissures/veins are sealed. When this occurs, the pressure of the gases/fluids underneath the sealed area builds until the seal is ruptured, which leads to boiling and the precipitation of more gold and other metals.
- This vigorous episodic process rips up vein fillings (and, in places, the host rock) deposited in previous stages and covers them with new fillings and gives LS epithermal veins their characteristic repeated banding and breccia textures
- Generally, long-lived LS vein systems display more repetitions and more gold than short-lived systems. The protracted boiling of the fluids in these systems produces high grade gold (greater than one ounce gold per ton) and silver deposits.

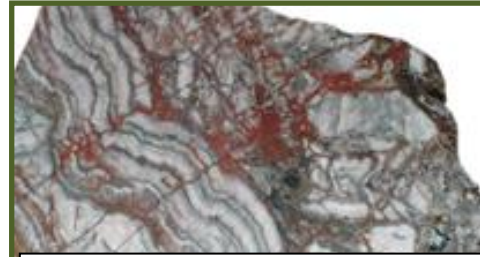


Figure 5: Colloform, crustiform and brecciation textures; Bergs Prospect, Manuels.



Figure 6: Cockade texture in hydrothermal breccia; Stallion Prospect, Central Newfoundland LS veins.

- LS systems are characterized by the minerals quartz-*adularia-sericite*-calcite.
- LS ore deposits are mostly vein or *stockwork* style mineralization which is typically associated with *chalcedonic silica* with or without adularia. These systems are generally sulphide-poor and are dominated by gold and silver mineralization, but may be anomalous in copper, lead and zinc.
- LS systems are mostly associated with very narrow, restricted alteration haloes dominated by clay alteration giving *illite or illite-smectite and adularia*.
- Surficial *sinter* deposits related to the development of these systems are often barren with respect to precious metals, but can be enriched in other elements such as mercury, selenium, antimony, arsenic and locally molybdenum.

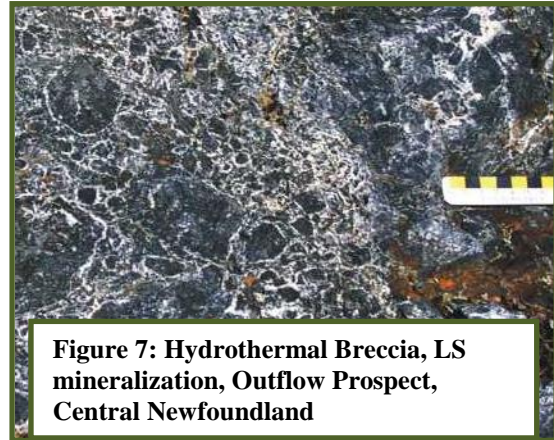


Figure 7: Hydrothermal Breccia, LS mineralization, Outflow Prospect, Central Newfoundland

HIGH SULPHIDATION GOLD DEPOSITS

- Fluids, dominantly magmatic gases such as SO₂, HF and HCl, are channeled directly from a hot magma (Figure 4).
- These hot, strongly acidic fluids undergo limited dilution by ground waters or interaction with host rocks and typically partly dissolve the surrounding rock leaving only silica behind, typically in a sponge-like formation known as *vuggy silica* (Figure 9); this is an important feature seen at the Hope Brook Mine in Southwestern Newfoundland.
- Vuggy silica is a key part of epithermal alteration and commonly occurs at the core of HS ore systems.
- Brines containing gold and sometimes copper that later also ascend from the magma, then precipitate their metals within the vuggy silica bodies and form HS deposits

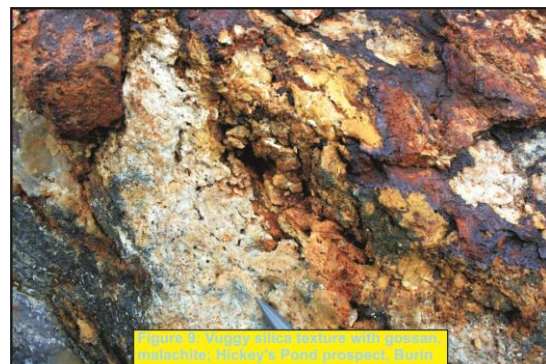


Figure 9: Vuggy silica formation with greenish malachite at Hope Brook Mine

- Veins may be important in HS deposits, but the majority (of deposits) consist of disseminated ores that replace country rock. They are generally dominated by *disseminated or replacement* style ore, which often contain copper minerals such as covellite or enargite, along with gold.

- HS systems are characterized by the development of broad, pervasive alteration haloes of the original host rock (Figure 10), formed as a result of the progressive cooling and neutralization of the hot acidic fluids by reaction with host rocks and ground waters.

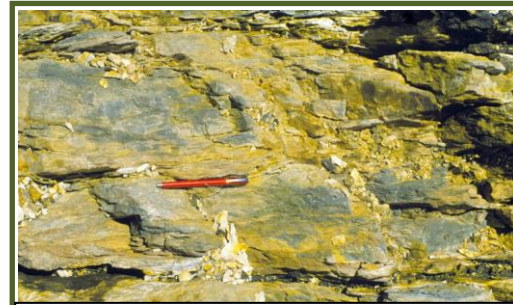


Figure 10: HS alteration – pyrophyllite-sericite at Manuels, Avalon Peninsula

- Mineralization is commonly developed within zones of vuggy silica and alunite alteration which is surrounded by a broader zone of pyrophyllite-illite alteration.
- Hence, HS systems are also known as *quartz-alunite-pyrophyllite-dickite-illite-kaolinite* systems.
- The shape of these mineral deposits is generally determined by the distribution of vuggy silica. Sometimes the vuggy silica can be widespread if the acid fluids encountered a broad permeable geologic unit. In this case it is common to find large bulk-tonnage mines with lower grades.
- One of the challenges in the evaluation of HS alteration/ mineralization is the distinction between ore-bearing systems and zones of non-economic acid alteration which have the potential to distract explorationists and consume precious exploration budgets.

WHAT ARE THE CHARACTERISTIC TEXTURES OF EPITHERMAL GOLD DEPOSITS?

Most epithermal deposits occur in veins, irregular branching fissures, stockworks, or breccia pipes. Colloform and replacement textures are sometimes recognized, but the majority of epithermal deposits are characterized by open space filling textures (crustification, comb structures, symmetrical banding).

Open space filling textures

- Open space filling is common at shallow depths where brittle rocks deform by fracturing rather than by plastic flow.

- At these shallow depths, ore bearing fluids may circulate freely within fractures, depositing ore and gangue minerals when sudden or abrupt changes in pressure and/or temperature take place.

- As such, open space filling textures (common in LS systems) will be different from those resulting from *replacement* (common in HS systems).

- Many hydrothermal ore deposits form by the combined effects of replacement and open space filling, which requires a lot of caution in textural interpretation.



Figure 11: Quart-adularia-hematite LS veins, Steep Nap Prospect, Avalon Peninsula. Boiling texture (stockwork breccia).

- Veins are the most common ore host (Figure 8), and breccia zones, *stockwork* and fine grained bedding replacement also occur (Figure 11).
- Fracture systems are commonly, but not necessarily, associated with large-scale volcanic collapse structures (*calderas*).
- There is a close association between the deposits and subaerial *pyroclastic* rocks and sub-volcanic intrusions.

- Hot spring and fumarolic material may be present in deposits that are not deeply eroded.

- Ore and associated minerals are deposited mainly in open space filling with *banded*, *crustiform*, *drusy*, *colloform* and *cockscomb* textures.



Figure 12: Sample of crustiform and colloform banded chalcedonic quartz vein material from the Geib pit, Nevada. Gangue minerals are mainly quartz and calcite with lesser fluorite, barite and pyrite.

- Gold and silver are the main economic minerals with lesser Hg, As and Sb.
- Hydrothermal alteration is pronounced, with *argillic* - *phyllic* alteration within a larger *pyroclitic* envelope.

FORM OF DEPOSITS

	LS (Adularia-sericite)	HS (Acid sulfate)
Open-space veins:	Dominant	Minor, locally dominant
Disseminated ore:	Minor	Dominant
Replacement ore:	Minor	Common
Stockwork ore:	Common	Minor

ALTERATION

Hydrothermal fluids react with the minerals in the rocks they are passing through to produce distinctive, new minerals which define alteration zones.

Characteristics of LS epithermal Au-Ag deposits

- Pyrite-sphalerite-galena-chalcopyrite typically within quartz veins with local carbonate.
- Associated with illite clays.
- Deposited from dilute hydrothermal fluids.
- Many LS veins are well banded and each band represents a separate episode of mineral deposition.

Characteristics of HS epithermal Au-Ag deposits

- The alteration suite of minerals formed in low pH, acidic conditions include, e.g., kaolinite, dickite, alunite and pyrophyllite.
- Barren areas of HS alteration described as lithocaps or barren shoulders are a common source of difficulty for explorationists, especially as these may crop out in the vicinity of low and HS epithermal Au and also porphyry Cu-Au mineralization.
- Barren shoulders are non-mineralized silica-alunite- pyrophyllite alteration. A good local example would be the High Alumina Belt well exposed at Mine Hill in Manuels.
- These alteration zones are characterized by high temperature minerals such as pyrophyllite-diaspore but may also include corundum.

- Lithocaps may locally conceal epithermal or porphyry mineralization.
- These alteration zones are distinguished from mineralized HS systems in the field by the lack of vuggy silica and generally coarse grained and higher temperature layered silicates (e.g., alunite, pyrophyllite, dickite).
- The presence of high temperature alteration minerals such as alunite or corundum is distinctive.

GUIDES TO DISCOVERING EPITHERMAL TYPE GOLD

- The presence of intrusive rocks and associated alteration provide important guides to prospecting for epithermal deposits.
- Deposits are often controlled by the physical characteristics of the country rocks. For example, in some gold camps, good fissure veins occur in igneous rocks whereas they are poorly developed in sedimentary rocks and serpentine. In other gold camps, large quartz veins exist in quartzite, whereas in argillite the veins are very narrow. The igneous rocks and quartzite fracture readily while the other "softer" rocks do not tend to hold open spaces.
- In addition to Au, anomalous Se values in lake sediments (about 6 to 10 ppm and up) have been useful in tracking down epithermal prospects on the island as well.
- The important thing for prospectors is to be able to recognize that certain textures in the rocks they are examining indicate epithermal systems and not to worry about whether they are Low Sulphidation or High Sulphidation.

PRESENT DAY FORMATION OF EPITHERMAL DEPOSITS IN JAPAN

- High temperature geothermal activity is currently observable close to active volcanoes on the islands of Japan: the fluids are mostly water dominated and controlled by fractures, such as those that are presently forming epithermal veins.
- It is possible to observe currently active epithermal systems precipitating both HS and LS epithermal gold mineralization at different locations and to study the conditions and processes that are responsible for their formation in drill holes testing for geothermal power generation stations.

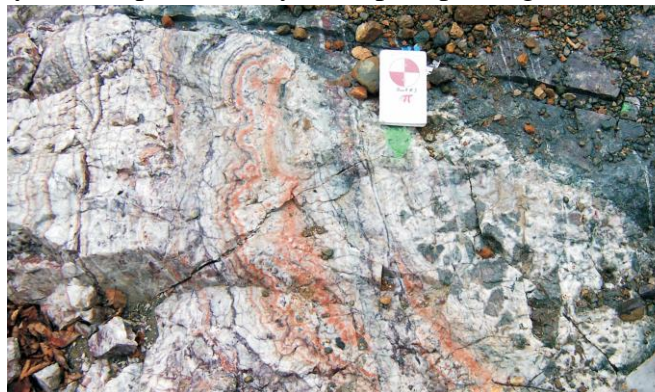


Figure 13: Crustiform, colloform and cockade textures – Steep Nap Prospect, Manuels

Some notable areas include the Kyushu Field which includes

- i) The Kuju Iwo-yama high temperature fumarolic area which is an active HS field,
- ii) The Hatchobaru geothermal power plant where gold mineralisation is currently being deposited, and magmatic hydrothermal activity (HS) occurs in a LS hydrothermal field,
- iii) The Komatsu Jigoku LS steaming ground
- iv) The Aso volcano and museum/volcanic observatory,
- v) The Onoyama sinter near Hishikari,
- vi) The Hishikari LS bonanza gold mine,
- vii) The Fuke Gold Mine, an intermediate type between the LS Hishikari and HS Kasuga mines.

Quartz Textures in Epithermal Systems

Chalcedonic Silica

This texture is characterized by cryptocrystalline quartz with a waxy luster (Figure 12) that indicates low temperature silica (120°C - 200°C) usually at shallow depths above an up flow zone and possibly overlying mineralization.

Cockade

This texture (Figure 6) occurs in breccias where concentric crustiform bands formed around isolated fragments of wall rock or earlier vein material.

Colloform

The external surface of mineral or mineral aggregate shows combined spherical, botryoidal, and reniform or mammillary forms. These are rounded, globular textures. It is a characteristic form in fine rhythmic bands with kidney-like surface of chalcedonic silica such as in Figures 5, 12 and 13.

Comb structure

Euhedral prismatic crystals growing from opposite sides of a fissure symmetrically towards its centre develop an inter-digitated vuggy zone similar in appearance to that of the teeth of a comb (lower right, Fig. 6).



Figure 14: McLaughlin Mine: multistage vein filling of extensional fractures; at least 5 possible stages of veinfilling.

Crustiform

Successive, parallel bands, ranging from mm-thin to several cm thick that are distinguished by their colour, texture or mineral proportions. Crustification results from a change in composition and/or physicochemical conditions of the hydrothermal solution, and is represented by layers of different mineralogies one on top of the other. Crustiform texture shows successive bands oriented parallel to vein walls

Geyserites

At right (Figure 15) is a peculiar texture of hot springs sinter (McLaughlin mine, Nevada). The spherical forms are called "geyser pearls" or "geyser eggs." These structures formed as concentric bands of precipitate built up on constantly agitated sand grains on the floor of the hot spring pool. Each "pearl" contains a nucleus of rock (Photo: D. Enderlin).

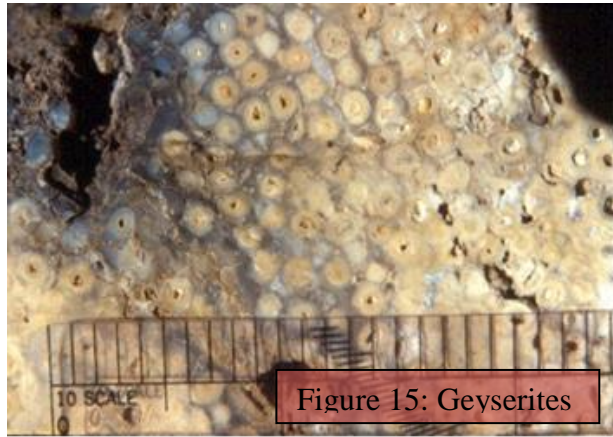


Figure 15: Geyserites

Lattice-bladed

A network of intersecting quartz blades which have replaced calcite (Figure 13).

Massive

Quartz veins that have a homogenous appearance with no banding or fractures.

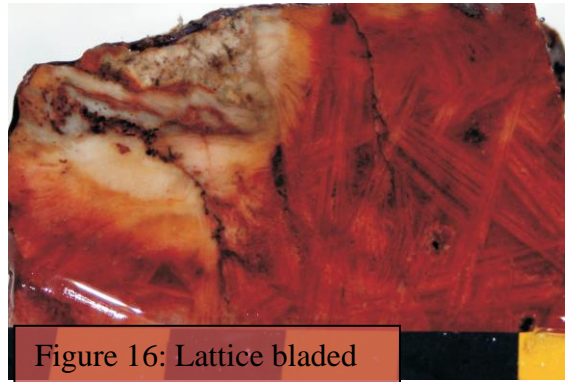


Figure 16: Lattice bladed

Sinter

As water cascades down slope from the emerging hot springs, mineral deposits build up through time. Calcareous spring deposits are called "tufa," while siliceous spring deposits are called "sinter." Unlike veins, which grow from opposing walls of a cavity, sinter forms in only one direction (upward and outward from the surface on which it is depositing). Textures such as the "eggshell" layer pattern shown at right are seen in modern hot springs as well (Figure 17). McLaughlin Mine – Nevada (Photo: D. Enderlin).



Figure 17: Sinter - McLaughlin Mine, Nevada
Photo D. Enderlin

Vugs

Small cavities developed in a rock or vein resulting in a spongy appearance.

Wall rock alteration

Alteration that is developed marginal to a secondary feature such as a vein.

GANGUE MINERALS IN EPITHERMAL SYSTEMS

	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	common
Hematite	common	

ORE MINERALS IN EPITHERMAL SYSTEMS

	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)

GLOSSARY

Acidic

Fluids having a pH of < 7 , commonly around 0 - 2 in acidic hydrothermal fluids related to HS systems: this pH is similar to that of battery acid.

Adularia

Chemical formula $(K, Na) AlSi_3O_8$; this is a low-temperature ($< 200^\circ C$) potassium feldspar, commonly light pink in color, but can also be white.

Advanced Argillic

An alteration assemblage formed under low pH and high temperatures; common minerals include alunite, diaspore, pyrophyllite, dickite, tourmaline, topaz, zunyite and white mica.

Alunite

Chemical formula $KAl_3(SO_4)_2(OH)_6$; this is a sulfate mineral, related to acidic alteration within epithermal systems.

Argillic

An alteration assemblage characterized by the minerals illite, illite-smectite, smectite and carbonate.

Alteration

Alteration is a process that occurs in rocks when hydrothermal fluids pass through and cause the original minerals to become unstable and change to new minerals that are stable in the new set of temperature, pressure and chemical conditions.

Alteration Overprint

The first set of alteration minerals can again be changed if hydrothermal fluids at different temperatures and pressures and chemistry pass through causing a second set of new minerals to form. The second set of alteration minerals is called an overprint.

Alteration Haloes

As these hydrothermal fluids interact with the rocks they pass through, their chemistry changes continually as well as temperature and pressure and therefore the alteration minerals will change too. As a result, alteration minerals commonly form in shell-like layers or haloes (Figure 18). A typical sequence might be from vuggy silica (at the centre) progressing through quartz-alunite, kaolinite-dickite, illite rich rock, and finally chlorite rich rock at the outer reaches of alteration. The clay and sulphate alteration (referred to as acid-sulphate alteration) in HS systems can leave huge areas (sometimes up to 100 square kilometers) of visually impressive coloured rocks. The boundaries between the altered rocks and the original rocks and between the different alteration zones are usually gradational.

Alteration (Clay) Minerals:

Dickite

Dickite's chemical formula is $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$; this is a clay mineral, formed at high temperature ($\sim 200\text{--}225^\circ\text{C}$) and associated with acidic alteration in epithermal systems.

Illite

Illite's chemical formula is $\text{KAl}_4\text{Si}_6\text{Al}_{1.5}\text{O}_{20}(\text{OH})_4$; it's a clay mineral indicative of temperatures $>200^\circ\text{C}$.

Illite-smectite

Clay mixture indicative of temperatures between $150\text{--}200^\circ\text{C}$, and a near-neutral pH.

Kaolinite

Chemical formula is $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$; this is a clay mineral, related to lower temperature ($<200^\circ\text{C}$) acidic alteration within epithermal systems.

Pyrophyllite

Pyrophyllite's chemical formula is $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$; it is a hydrous aluminum silicate mineral, related to high temperature ($200\text{--}250^\circ\text{C}$) acidic alteration within epithermal systems

Sericite

Chemical formula $(\text{K},\text{Na})_2\text{Si}_6\text{Al}_2\text{O}_{20}(\text{OH})_4$; sericite is a fine-grained version of muscovite - white mica.

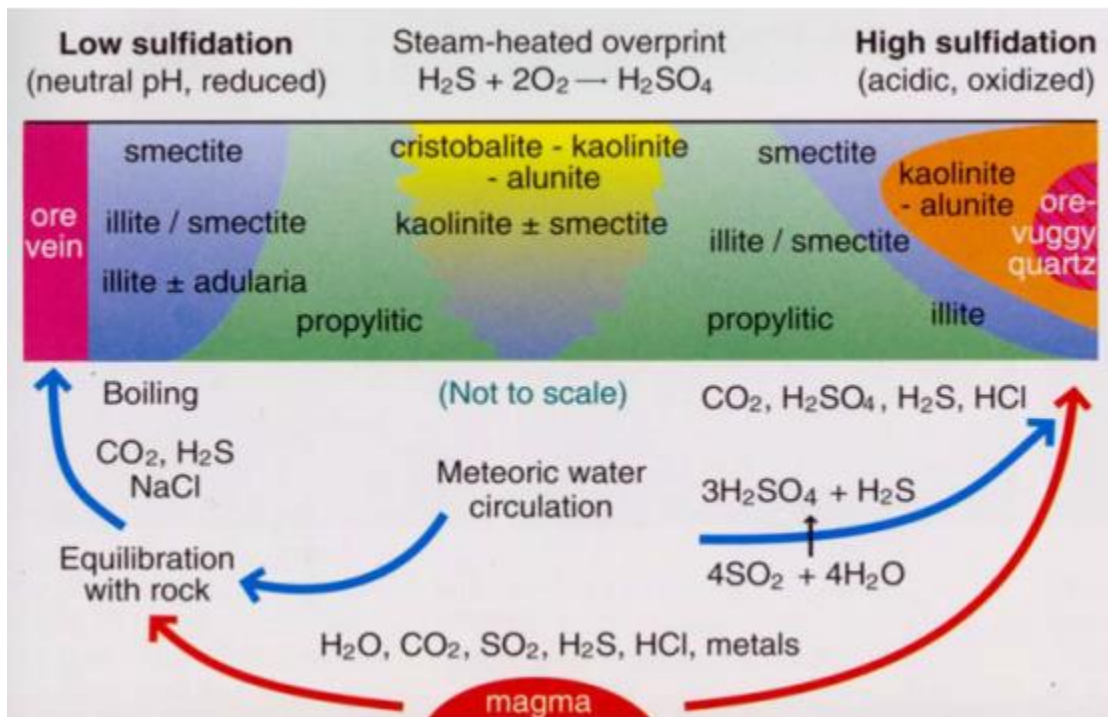


Figure 18: Alteration haloes associated with epithermal deposits Source -

Boiling

Boiling happens when trapped gases in the fluids are suddenly released due to rapid decrease in temperature and pressure as the fluids rise towards the surface. Water at temperatures in excess of 100°C can remain liquid under high pressure but as it nears a low-pressure environment it boils suddenly and often explosively. The epithermal ore fluids, which rise from depth along structural pathways at high temperatures (>200°C) are under enough pressure to prevent boiling. Mineralization occurs when the pressure drops abruptly (through faulting or other rupture), which instantly triggers boiling (“flashing”) and causes the ore fluids to “dump” their mineral load into any available open space. Pseudoblasted texture (calcite replaced by silica) along with the development of colloform-crustiform banding and brecciation (Figure 19) in chalcedonic silica veins indicate boiling of the hydrothermal fluids.

Brines

Brine refers to a salty solution like seawater, rich in various salts, for example, NaCl or sodium chloride – common table salt – or KCl, potassium chloride, depending on the rocks that they pass through; brines can be acidic, neutral or alkaline and can contain lots of dissolved metals.

Caldera

Caldera volcanoes are the most catastrophic types of volcanoes in a category by themselves because of the unique way in which they form. This type of volcano is shaped more like an inverse volcano. An enormous magma chamber bulges up beneath the ground from the extremely high pressures of the trapped gases within. Ring-shaped cracks form outward from the magma chamber toward the surface and these act as relief valves for the magma to escape. Once the accumulated pressure has been sufficiently released through a series of extremely powerful pyroclastic and plinian eruptions, the ground above the magma chamber subsides or caves in, leaving a large depression. Caldera volcanoes are the largest on earth, with some calderas measuring from 15 to 100 kilometers wide.

<http://www.extremescience.com/calderas.htm>

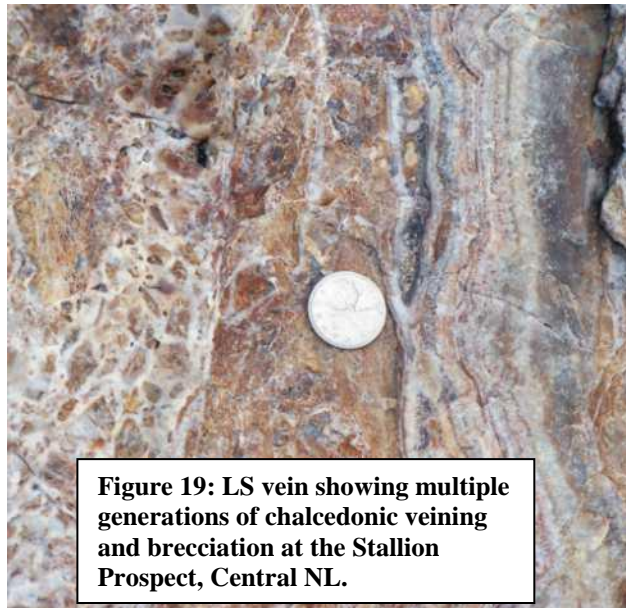


Figure 19: LS vein showing multiple generations of chalcedonic veining and brecciation at the Stallion Prospect, Central NL.

Chalcedonic recrystallization

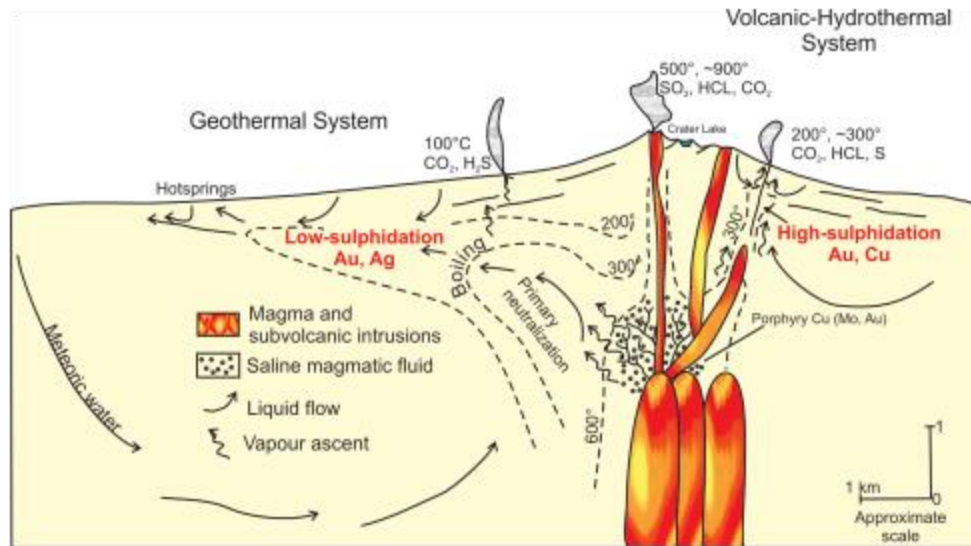
Silica minerals, except quartz, are unstable and convert to quartz after deposition.

Covellite

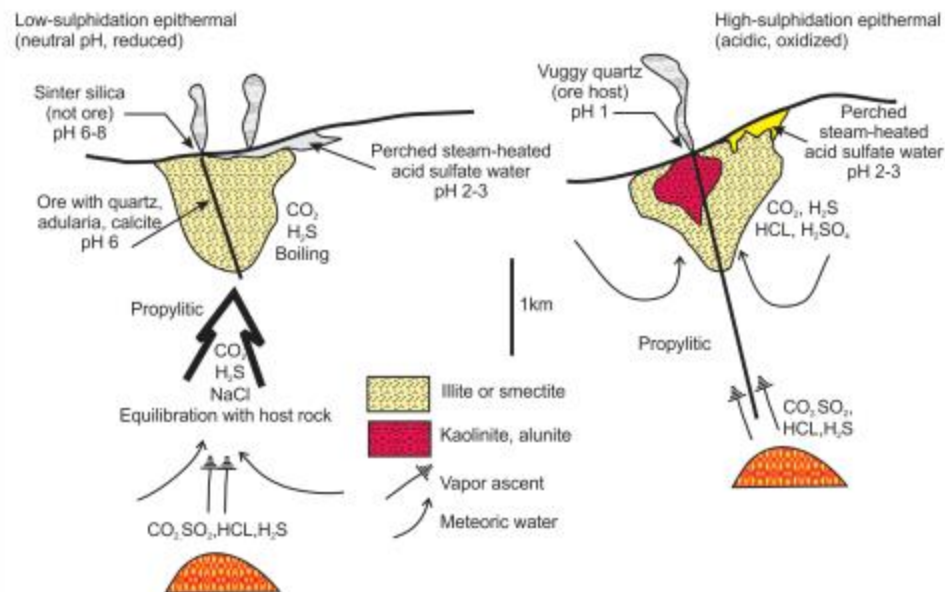
Covellite is CuS, a copper sulphide mineral, often displaying an indigo-blue coloration.

Disseminated

Disseminated mineralization is that which occurs sprinkled throughout the host rock as individual crystals or as clusters of crystals.



Schematic cross section through an intrusive centered hydrothermal system outlining the environments of porphyry, high-sulphidation and low-sulphidation systems (Hedenquist and Lowenstern, 1994).



Schematic diagram of the fluid types and alteration zoning around high- and low-sulphidation epithermal systems (from White and Hedenquist, 1995).

Figure 20: Epithermal Deposits Environments

Enargite

Chemical formula is Cu_3AsS_4 ; generally it is black or iron-grey and has a black streak.

Fumaroles

These are volcanic vents or holes in the earth's surface through which hot liquids, steam and volcanic gases escape from the earth's interior. The liquids can form hot springs. A fumarole rich in sulfur gases is called a solfatara; a fumarole rich in carbon dioxide is called a mofette; these can be quite dangerous if you get too close and one would need breathing apparatus

Gangue

Gangue refers to the useless part of the material mined for extracting ore metals: for example, silica is the predominant mineral in much of the epithermal systems and is the main gangue mineral.

Geothermal

This refers to the heat of the Earth's interior: "geo" means earth and "thermal" means heat. The temperature of the ground beneath our feet is about 10^0 to 15^0 C. For every 100 m you go below ground, the temperature of the rock increases by about 3^0 C (or in technical terms, a geothermal gradient of about 30^0C per Km).

Geysers

A geyser is a type of fumarole, a vent in the Earth's surface that periodically ejects a column of hot water and steam. Some geysers have eruptions that blast thousands of gallons of hot water hundreds of feet in the air, for example, Old Faithful, the world's best known geyser. It is located in Yellowstone National Park (USA) and erupts every 60 to 90 minutes and blasts a few thousand gallons of boiling hot water up to 60 m into the air.

Hot Springs

The water issuing from a hot spring is heated by geothermal heat. Note that hot springs in volcanic areas are often at or near the boiling point. The hot springs can hold high concentrations of dissolved solids: they often have a very high mineral content, containing everything from simple calcium to lithium, and even radium. Because of folklore and the therapeutic value some of these springs have, they are often popular tourist destinations, and locations for rehabilitation clinics for those with disabilities.

Hydrothermal Fluids

Hydrothermal Fluids are also called Hydrothermal Solutions or Aqueous Solutions. The main ingredient of hydrothermal fluids is water and they are always brines, which means they have dissolved salts for instance NaCl , KCl , CaSO_4 and CaCl_2 . The amount of salinity in these brines varies from close to 3.5 weight percent (wt %) (close to that of seawater) to around 35 wt %. These brines are so salty that they have the capacity to dissolve large quantities of metals, for example, Au, Ag, Cu, Pb and Zn. High brine temperatures add to the efficiency of the brines in dissolving the metals. The hydrothermal fluids can range in Ph from neutral to highly acid or alkaline.

Magma

Magma is molten rock in the earth's crust where it can collect into vast magma chambers. Magma is more buoyant than the surrounding rock and makes its way upwards through weaknesses in the Earth's crust until it reaches the surface, where it comes out quietly as lava, forming vast lava fields or volcanic edifices. The temperature of magma can range between 700 and 1300 degrees Celsius depending on its chemical composition.

Magmatic Arc

Magmatic arcs involve huge volumes of magma rising to the surface in an arc-like shape. Most of the epithermal deposits of the world can be found in the "Ring of Fire" which is the area of volcanism that rims the Pacific Ocean from eastern Asia to the western Americas

Magmatic Fluids

Magma is a silicate melt in which water has only very limited solubility. As magma rises through the earth's crust, it cools and the pressure drops, causing a water-rich fluid to separate from the magma. This fluid will be enriched in metals such as copper, lead, zinc, silver, gold, lithium, beryllium, boron, rubidium and volatiles like fluorine, chlorine and carbon dioxide. [

Meteoric Water

Meteoric water is mostly ground water derived from rain and snow falling on the surface of the earth and filtering down through the crust of the earth. The word "meteoric" has the same root as "meteorology".

Porphyry Cu-Au

Porphyry Cu \pm Au \pm Mo deposits form in the higher levels of magmatic intrusions – specifically those intrusions that are the so-called porphyry type i.e. large crystals in fine-grained matrix. Porphyry Cu-Au and epithermal Au \pm Cu deposit types may grade into one another or may be telescoped together because of later faulting and folding. Most modern scholars consider epithermal deposits to form above deep Porphyry Cu-Au systems which constitute the magmatic roots of epithermal gold systems

Propylitic

The result of low-pressure-temperature alteration around many orebodies. The propylitic assemblage consists of epidote, chlorite, Mg-Fe-Ca carbonates, and sometimes albite-orthoclase.

Protolith

The original rock prior to it being affected by alteration or deformation.

Replacement

Replacement occurs when hydrothermal fluids pass through rocks and replace the original mineralogy with a new set of minerals. The new minerals can include ore. Alteration and replacement are all part of one process.

Stockwork

A stockwork is a complex system of structurally controlled, or randomly oriented, network-style veinlets some of which may be mineralized and some may be gangue.

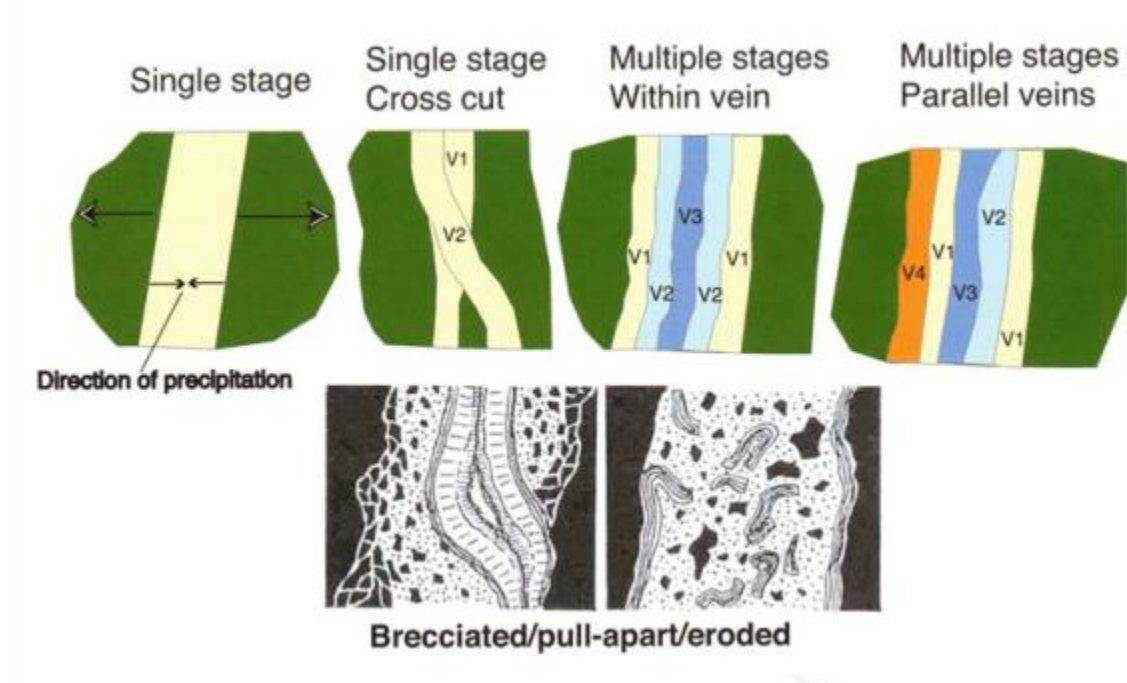


Figure 21: Development of a pull-apart (or dilational) fissure showing successive veins filling the open spaces: V1 would be the first infill followed by V2 etc. Subsequently, the veins can be brecciated by hydrothermal fracturing, faulting or volcanic activity.

Volcanoes

When magma reaches the surface, its name changes to lava! Lava can extrude quietly as, for example, the Hawaiian type of volcano, or as a violent eruption throwing up volcanic debris ranging in size from ash to large boulders, for example, Mount Etna in Italy.

Vuggy Silica

Characteristic style of alteration in HS systems where hot acids have “eaten” the rock, creating a sponge-like mass of holes or vugs.

Appendix

Selected Epithermal Gold Showings or Prospects in Newfoundland:

for more details on these research the MODS (Mineral Occurrence Data System) in the Geoscience Resource Atlas at <http://gis.geosurv.gov.nl.ca/>

**Abbot's Brook No. 1
Aztec / Glenwood
Braxton-Bradley
Calvin's Landing**

**AT Vein
Bergs
Brent's Cove
Country Pond East Vein**

**Avalon Trend
Bluefin North
Burin**

Farmers' Fields	Freshwater Pond	Grog Pond
Hickey's Pond Prospect	High Beach	Hope Brook
Hope Brook South	Hornet	Island Pond
Kelstone	Lamaline	Lazyman
Holyrood Pyritized Zone	Long Harbour	Merasheen
Moosehead	Mustang / Outflow /	Piper
New Fortune / Deer Pond South	O'Reilly	Paradise Lake
Point Rosie	Rip Van Winkle	Santana
Spanish Room	Stallion / West Tower	
Steep Nap	Stewart Au	Strouds Pond
Tug Pond East		

List of Resources

<http://www.gabargold.com/texture.html>

<http://www.asianow.ca/i/noelwhite/work/SEG%20Newsletter%201995%20-%20Epithermal.pdf>

http://www.corazongold.com/s/hog_ranch.asp?ReportID=547463& Type=Hog-Ranch& Title=Photos

http://earthsci.org/mineral/mindep/depfile/vei_dep.htm

http://www.miningandmetallurgy.com/gold/html/epithermal_gold_deposits.html

http://www.northernminer.com/resources/Tools/Geology101/#Epithermal_deposits, Part1

<http://www.korearth.net/down/doc/Corbett.pdf>

http://corbettgeology.com/leach_and_corbett_2008_mixing_and_bonanza_au.pdf

http://www.foldtan.ro/files/Hedenquist_2000.PDF

<http://www.portergeo.com.au/tours/epithermalgold2005/epithermal2005deposits.asp>

<http://www.almadenminerals.com/geoskool/vein-systems.html>

<http://it.geol.science.cmu.ac.th/gs/courseware/205363/WWW/Mineral%20Deposits.htm>

http://wolfweb.unr.edu/homepage/arehart/courses/471-671x/Epithermal_handout.pdf

http://wolfweb.unr.edu/homepage/arehart/courses/471-671x/Epithermal_handout.pdf