Geology, Genesis of Gold Deposit and Occurrences in Malaysia

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Classification of Mineral Deposits

- hydrothermal deposits
- magmatic deposits
- syngenetic deposits
- porphyry deposits
- skarn deposits
- vein deposits
- mississippi valley type deposits
- massive volcanogenic deposits
- sedimentary massive sulphide deposits
- layered mafic intrusion type deposits
- placer deposits
Gold is formed in a wide variety of hydrothermal deposits, which may be eroded and the gold concentrated by hydraulic processes in rivers and on the beaches, and deposited as sedimentary placer deposits (*Emas Lanar*).

In hydrothermal deposits, gold is most commonly associated with silver and base metals, copper, lead and zinc.

Most of these deposits are quartz veins deposited from hydrothermal fluids in fault zones at medium (mesothermal) or shallow (epithermal) depths in the crust.
Placer deposits

The high density and chemical stability of gold enables it to be mechanically concentrated in river and beach environments and preserved in placer deposits. These have accounted for more than two-thirds of the total world gold supply. They are grouped into main classes.

- **Quartz pebble conglomerate or pyritic paleoplacer** deposited in braided streams and alluvial fans during the Precambrian.
  - The conglomerates are clast supported with well rounded pebbles of quartz, cherts and locally pyrite, in a matrix of quartz, mica, chlorite, pyrite and fuchsite.
  - They contain native gold, pyrite, uraninite, brannerite and traces of platinium group of mineral.
  - Eg. Witwatersand in South Africa, the largest gold deposits in the world. Ore mined from the witwatersand averages 10g/t Au, 30g/t Ag and 280g/t U

- **Young Placers** consist of gold-bearing gravel and sand, and their consolidated equivalents, deposited in alluvial, beach and fluvioglacial environments during the Late Cenozoic (Quaternary and Tertiary period).
  - These were the deposits worked during the gold rushes.
  - Gravity and hydraulic action concentrate gold and other heavy minerals at locations where the water velocity decreases markedly, such as on the inside of meanders, below rapids and falls, in the boulders, benetah vegetation mates, along strandlines on beaches, and in “traps” such as natural riffles in the river bed formed by fractures or joints in the bedrocks
Rich young placer deposits result from several cycles of erosion.

Transport and deposition.

In some placers, gold may be redistributed and reconcentrated by chemical migration and accretion process.

Native gold occurs along with other heavy minerals such as magnetite, ilmenite, garnet, zircon, rutile, monazite, and locally, cassiterite and platinum group elements.

Grade of median size young placer is less than 0.5g/t.
Detrital gold is insoluble at surface P-T conditions. It becomes caught up in streams which carry it before it drops out due to its weight. It is then sorted - the winnowing process.
Concentrations of gold and heavy minerals often occur at the following places:

1. In the deepest parts of the river
2. Around outcrops of rocks
3. Where two rivers join
4. Where the rivers widens
5. Where the river bends
6. Around boulders and stones
7. In gravel and sand banks
8. Lake and seashores

Dig behind boulders
SLUICE BOX AND TROMMEL

Gold Panning
Hydraulic Gold mining

Cross Section of riffles in sluice

- Water flow
- Fluid bed
- Iron riffle

- Low specific gravity
- Medium specific gravity
- High specific gravity
GOLD DREDGING AND CONCENTRATING ON LINE
Lode gold and mesothermal deposits

These are quartz lode deposits formed in fault and shear system at crustal level within and above the brittle-ductile transition zone, at depths of 3-12km and temperatures from 200-400°C.

Deposits may have a vertical extent of up to 2km, and lack pronounced zoning.

Ribbon banded vein textures are common and were formed by “crack-seal” process involving episodic re-opening of the veins, fluid flow and mineral deposition.

The genesis of the deposits is controversial but most current workers favor a metamorphoehenic-deformational origin, although some deposits may have had a magmatic influence in their genesis.
Tectonic settings of gold-rich epigenetic mineral deposits. Epithermal veins and gold-rich porphyry and skarn deposits, form in the shallow (< 5 km) parts of both island and continental arcs in compressional through extensional regimes. The epithermal veins, as well as the sedimentary rock-hosted type Carlin ores, also are emplaced in shallow regions of back-arc crustal thinning and extension. In contrast, the so-called ‘mesothermal’ gold ores termed *orogenic gold* on this diagram are emplaced during compressional to transpressional regimes and throughout much of the upper crust, in deformed accretionary belts adjacent to continental magmatic arcs. *(after Grove et al., 1998)*
Schematic representation of crustal environments of hydrothermal gold deposits in terms of depth of formation and structural setting within a convergent plate margin. This figure is by necessity stylized to show the deposit styles within a depth framework. There is no implication that all deposit types or depths of formation will be represented in a single ore system. Adapted from Groves (1993), Gebre-Mariam et al. (1995) and Poulsen (1996)
Mesothermal deposits

- **Green lode gold deposits** consists of gold-bearing quartz lodes found in Late Archean and Mesozoic greenstone belts. They are localised along or adjacent to major structural crustal breaks or suture zones, related to terrane collisional boundaries.
- The lodes are hosted in mafic and ultramafic volcanic rocks, banded iron formations, greywacke, and conglomerate, that have been metamorphosed to greenschist and locally amphibolite facies.
- Wallrock alteration is characterised by quartz-pyrite-muscovite assemblages adjacent to the veins (usually within a metre) enclosed within a broader zone of carbonate alteration.
- Mineralogy: The veins contain quartz, carbonate, pyrite, arsenopyrite and minor native gold and base metals.

- In most of today's deposits you can't actually see the gold. Gold is mined at 2 to 5 grams per tonne.
- In the large gold deposits of the past, however, you could see the gold, which was mined at 3 to 4 ounces per tonne! Visible gold is an indication of high grade.
- These high grade deposits are called *lode gold* deposits. They consist of an area of high grade ore surrounded by smaller amounts of gold.
- The small, central, very rich area is called the Bonanza. Malaysia? (sites of the great gold rushes) are / were very good for finding these deposits.
Mesothermal Type Characteristics (orogenic)

Mesothermal type- moderate temperatures (200-300°C) and pressures, (approximately 1-5 km depth).

- Sulphides include chalcopyrite, sphalerite, galena, tetrahedrite, bornite and chalcocite.
- Gangue includes quartz, carbonates (calcite, siderite, rhodochrosite) and pyrite.
- Most show abundant replacement phenomena.
- Some associated with ultramafic rocks including listwanites (fuchsite or mariposite (green mica) bearing altered varieties).
- Ribbon structures parallel to vein walls.
- Includes 'porphyry' copper type deposits.
- Extensive alteration zones with varying amounts of sericite, quartz, calcite, dolomite, pyrite, orthoclase, chlorite and clay minerals.
- Closely related to igneous rocks, both spatially and genetically.
Epigenetic

- If a mineral deposit formed much later than the rocks which enclose it, it is said to be epigenetic.
- An example is a vein. The first step in the formation of a vein is the fracturing or breaking of rock along a fault zone, at a depth ranging from surface to several kilometers below surface.
- The rock must be solid (lithified) and brittle, creating open spaces when it breaks.
- Hydrothermal solutions pass along the fault zone and deposit or precipitate the ore and gangue minerals within the open spaces. Thus, the vein is necessarily younger than the rocks that contain it.
- Since we are fairly certain which deposits are syngenetic and which are epigenetic (although there will always be some degree of uncertainty and overlap), it is convenient to begin the classification with this discrimination.
- Beyond this, the various categories are based on their physical description, including size and shape.
- A third level of subdivision is usually based on the metals contained.
Mesothermal gold deposits form along shear zones in greenstone belts. They have a huge vertical extent but a limited lateral extent.

- **Wall-rock alteration** is very characteristic: ankerite (calcite), albite, sericite (vivid green fuchsite, mariporite - only exist in these settings), quartz, chlorite / talc, pyrite, minor tourmaline.

- Quartz cements the shear zone. Because of this, pressure builds up, then is suddenly released as the rock breaks, silicification occurs again and the cycle is repeated.

- Quartz is dissolved in hot, deep fluids. It can be precipitated just by changing pressure. When pressure drops, quartz is precipitated.

- Pressure is a 'double whammy' because when you drop pressure, volatiles are released, affecting another important factor for gold precipitation - composition.
Pressure and Gold

- Pressure and gold are closely related. At higher pressure (and temperature), gold solubility is higher.
- When pressure is released, H$_2$S (the ligand that makes gold soluble) is driven off, resulting in gold precipitation.
- The precipitated gold is then cemented with silica (quartz) which prevents it being remobilised, even if a lot of faulting occurs.

Gold deposits do not occur below granulite (~5 kbar, 800°C) because at that stage the source fluid does not contain enough gold to saturate. Fluid comes from above and around, above granulite.

There is a limit to how deep you can form Au deposits but there is a huge P-T range at which they can form.
Vein Geochemistry

Fracture filling deposits which often have great lateral and/or depth extent but which are usually very narrow.

A. Hypothermal : Cu (-Au)
B. **Mesothermal** : Cu-Pb-Zn-Ag-Au
C. Epithermal : Au-Ag (-Hg)
Figure 1. Hampton-Boulder (New Caledonia) deposit, cross-section 3440 mN. Alteration and mineralisation (hatched pattern) are hosted in a brittle-ductile shear zone (Boulder-Lefroy Fault) and localised near the margins of competent felsic dykes which intruded parallel to the shear, but predate Au mineralisation (modified from Vanderhor & Groves 1995)
The lithologies associated with epigenetic Au lodes include greenstones, metagreywackes, phyllites, graphitic slates. The best way to reduce a fluid is to add carbon: $\text{H}_2\text{O} + \frac{1}{2}\text{O}_2 + \text{C} \rightarrow \text{CO}_2 + 2\text{H}^+$.

All of the oxygen wants to make carbon dioxide, so you reduce the amount of oxygen in the fluid (and form graphitic slates). The lodes take on highly variable forms:

- **Concordant lodes in carbonate sulfide, schist-bedding plane shear zones.**
- **Discordant quartz-carbonate veins, shear zone vein systems, stockworks - ribbon quartz.**

Schematic NW-SE vertical section through the Pampalo deposit, Ilomantsi, based on computer graphical analysis of drill hole data by J. Parkkinen. (from Nurmi & Sorjonen-Ward 1993)
Pampalo local geology
From Goode (2004)
Hypotheses for the genesis of epigenetic lodes

1. Remobilize dispersed syngenic sulfides and gold during metamorphism, concentrate in shear zones, axial zones of folds, etc.

2. Magmatic-hydrothermal

Evidence for:

1. Host terrains usually intruded by syn- and post-kinematic (deformation) plutons (granites - either not deformed or deformed)

2. Most lodes lie within a few kilometres of intrusives (Lima and Benom)

3. Au mineralisation occasionally found in margins of intrusives (minor)

Evidence against:

1. No plutons exposed in vicinity of some lodes (e.g. none within 20km of Penjom)

2. Wall-rock alteration along veins in plutons usually chlorite-ankerite rich (alteration makes rocks tighter - seals them up with minerals like chlorite, quartz, ankerite - but to make a Au deposit you need to have lots of fluid coming through because there is so little Au in solution!)

3. By far, major hosts to the lodes are mafic volcanics, sediments - not plutons.

3. Lateral secretion accompanying regional / contact metamorphism.
**Dilatants jog**: As a fold goes through a different rock type, it kinks and a hole forms. Because of the created space, a pressure shadow forms i.e. the pressure in the hole is less than the pressure in the rock around it. Fluid is effectively sucked into the whole.

Due to the decompression it undergoes, quartz and gold are precipitated in the hole.

- Fluids in faults are often high in CO₂. When the faults become clogged up, the fluids go outwards into the surrounding **shale units which contain carbon**.
- As carbon is a great reluctant, the fluid is reduced and gold precipitated.
- Some layers are more C-rich than others, which means that more gold is deposited in some layers than in others. On a small scale, these deposits are very Au-rich.

**Pressure shadow**. Pressure shadows occur on every scale

Folding rocks form gaps in the bends. Again pressure shadows are formed and fluid is sucked into the holes to deposit quartz and gold there.
Many of the world's most famous gold deposits are related to subaerial volcanic activity, these are known as epithermal gold deposits. They commonly occur in island arcs and continental arcs associated with subduction.

Epithermal deposits are classified as products of hydrothermal fluids which have a specific depth range.

The deposits are found near the surface and mineralization occurs at a maximum depth of 1 km but it rarely exceeds a depth of 600 m.

It is also considered temperatures to range from 50-300°C under conditions of moderate pressure.

Most of the ore is found in veins. They tend to be irregular branching fissures, vesicle fillings, stock works, breccia pipes and disseminations.

The most common form of emplacement is open space fillings; these include cockscomb textures, crustifications, drusy cavities and symmetrical banding.

Colloform textures are also found, these are typical of a shallow volcanic environment which indicate low temperatures and the free circulation of hydrothermal fluids.

Evidence for repeated mineralization is evident; this includes re-brecciation and multistage banding.
Ore minerals are usually fine grained but have coarse grained well crystallized overgrowths of gangue minerals.

The ore assemblages include sulfantimonides, gold and silver tellurides, stibnite, cinnabar, native mercury, electrum, native gold, native silver, selenides and to a lesser extent galena, sphalerite and chalcopyrite.

Typical gangue minerals found are quartz, calcite, fluorite, barite and pyrite. Dolomite, hematite, chlorite, rhodonite are sometimes found.

Gold can also be deposited in a hot spring environment (mineralizing fluids reach the surface and cool, depositing ore) and in a placer environment (erosion of an ore body, heavy metals redeposited in sedimentary environment).
There are two types of mineralizing fluids which are responsible for forming epithermal gold deposits, they have a different chemical composition and are from contrasting volcanic environments (Fig. A).

The first is a low sulphidation (LS) fluid which is reduced and has a near neutral pH. It is a mixture of magmatic and meteoric waters.

The geochemical composition is similar to waters found when drilling hot springs in geothermal systems.

Gold is carried in solution and is precipitated out in veins near the surface at the zone of boiling.

Some of the features which are characteristic of this type of setting are Colloform and brecciated quartz which is cemented by adularia and bladed calcite.

The second type of mineralizing fluid is a high sulphidation (HS) fluid.

This is an oxidized and acidic fluid which dominantly originates from a magmatic source. It deposits gold near the surface when the fluid cools or is diluted by meteoric waters.

The gold in this type of deposit is hosted by leached silicic rock from acidic fluids which are generated in a volcanic hydrothermal environment.
Conceptual Model for Styles of Epithermal Gold-Silver and Porphyry Copper Mineralisation

FLUIDS
- Oxidizing ground water
- CO₂ - rich acid sulfate waters
- Evolving gases
- Meteoric recharge
- Magmatic mineralized fluids

MINERALIZATION
- Tension vein
- Banded vein
- Sheeted vein
- Bonanza
- Breccia infill/structural control
- Lithological control
- Stockwork vein
- Breccia
- Dissolved
- Jasper
With both LS and HS deposits, the mineralizing fluids ascend to the surface via fracture networks.

Mineralization often occurs within these conduits. LS fluids usually deposit ore in large cavity filling veins, or in a series of finer veins known as stockworks.

The more acidic HS fluids penetrate farther into the surrounding country rocks, which deposit ore in veins which may be scattered throughout the host rock.
Erosion has a very important part to play in the occurrence of epithermal gold deposits. Very few epithermal deposits can be related directly to deep seated intrusive bodies, but this relationship can be seen where deep erosion has occurred.

Most deposits have no visible relationship with plutonic rocks.

As these ore deposits are found at or near the surface and in tectonically active areas, they are susceptible to immediate erosion.

Subsequently this type of deposit is dominantly found in areas of Tertiary volcanism, and is almost unknown in pre Cenozoic lithologies.

The alteration in country rocks around hydrothermal veins is usually extensive. High porosity and permeability values in wall rocks allow deep migration of the mineralization fluids.

The difference in temperature between the cool country rocks and the hot invading fluids causes reactions which results in a new assemblage of minerals.
The main products of this mineralization are chlorite, alunite, sericite, zeolites, clays, adularia, silica and pyrite.

Propylitization is the main zone of alteration in which chlorite is the main mineral.

Silica, chlorite, sericite and pyrite of the alteration halos are usually fine grained. Near the surface it is not uncommon to find a broad argillic zone of alteration often containing alunite.

Some deposits are found to have an aluminous advanced argillic alteration zone in which kaolinite, sericite, pyrophyllite and andalusite with minor corundum, topaz and diaspore is found.

Carbonate minerals such as calcite, dolomite, ankerite and rhodochrosite are also products of alteration. Montmorillonite and kaolinite clays may be abundant forming zones parallel to the walls of veins.

Often supergene gossans are found above epithermal ore deposits.
This is a weathering process in which an iron oxide cap is formed above the deposit. Also pyrite within the altered wall rock is oxidized to limonite, goethite and hematite.

What often occurs in copper deposits when supergene enrichment takes place is very minimal in an epithermal deposit, only minor enrichment of gold and silver takes place.
**Epithermal gold Deposit main characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low Sulphur deposit</th>
<th>High sulphur deposit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore minerals</td>
<td>Gold, pyrite, electrum, sphalerite, galena</td>
<td>Gold, chalcopyrite, pyrite, tellurides, covellite</td>
</tr>
<tr>
<td>Gangue minerals</td>
<td>Quartz, calcite, <strong>adularia</strong>, illite, carbonates</td>
<td>Quartz, alunite, barite, kaolinite, pyrophyllite</td>
</tr>
<tr>
<td>Textures</td>
<td>Veins, and open space filling drusy cavities, symmetrical banding and Colloform.</td>
<td>Wall rock replacement, breccias, veins</td>
</tr>
<tr>
<td>Deposit characteristics</td>
<td>Cavity veins and stockworks ore common</td>
<td>Disseminated ores and replacement ores common</td>
</tr>
<tr>
<td>Main metals</td>
<td>Au, Ag, Zn, Pb, and minor Cu, Sb, As, Hg, Se</td>
<td>Au, Ag, Cu, As, and minor Pb, Hg, Sb, Te, Mo, Bi</td>
</tr>
</tbody>
</table>

Some geologists believe that the epithermal deposits may have been formed entirely by the circulation of meteoric fluids, with no part played by a magmatic source. The area is situated in a U-shaped valley which has many geothermal springs; these have been used to demonstrate a relationship between hot springs and epithermal deposits. Studies of these springs mainly by the use of fluid inclusions and stable isotope studies has shown that the fluids are dilute, weakly alkaline chloride water which has undergone boiling, fluid mixing and oxidation at temperatures around 250°C (LS). It can be said that in many areas the ore minerals are deposited by magmatic fluids with a certain amount of dilution by meteoric waters (HS).
Other gold mineralisation types

• Porphyries
  Gold is deposited with copper in porphyry copper deposits, for example. Usually neither metal is present in sufficient quantities to warrant a mine, however, together they form a good deposit.

• Other
  Gold is also found in supergene (enriched) deposits, exhalative (VMS) deposits and at places (Cu, Au, U) and (Cu, Au).
Gold Mineralization

• **Four Belt** – Namely 1-4 (Style/Genetic/Occurrence)

• Type I : (Gold Belt II) – Consist Significant large vein Traversing Granite and Metasediment.

• Known as Gold Chemical Zone.

• BUFFULO REEF, RUBBER HILL (Felda Sg. Koyan), SELINGSING AND KUALA TUI

• Type II (East of Type I) – Gold Dessiminated within Quartz vein Stockworks of Quartz vein Related to Granitoid.

• Volcanic Exalative-Carrying Sulphide and Other Au-Ag Massive

• Known as Zinc-Copper-Lead Zone
Regional Structure

- Dominated by strong NW-SE Tranding Fault
- Raub-Bentong is Significant Structure
- A Linear Pattern of Intrusive Emplacement
- Parallel With Bentong Suture (BS)
- Distric Scale Fault System
- Plays a Major Role and Closely Related to The Zone of Gold Mineralization
Gold Mineralization and Occurrence in Malaysia

- Paleozoic and Triassic
- Deep to Shallow Marine Sediment
- Limestone
- Acid Volcanic and Volcaniclastics
- Deposited in the Back Paleo Arc Basin
- Stratigraphically Belong to Bentong and Raub Group and Pahang Volcanic Series
- Calc-alkali series granitic rock
Calc-alkaline intrusion complex and district structural features of Kuala Lipis Raub area
Penjom area, part of the Block 7 concession (1990)
The Penjom gold mine occurs in the Central Gold Belt of Malaysia, which is an eroded fold and thrust belt accreted onto a continental terrain in the west.

The stratigraphy consists of foreland basin sedimentary rocks with a high volcanogenic component metamorphosed to lower greenschist facies.

Felsic intrusions accompany the main orogenic event.

Gold mineralisation at Penjom is associated with quartz-carbonate veins with a low sulphide content. These occur in local dilatational settings within the folded carbonaceous and calcareous shale and sandstone sequence beneath the Penjom Thrust.

Favourable mineralised settings are provided by N-S and N-W striking steep-dipping faults and syn-folding tonalite intrusions.

Orogenic gold deposits in the mine area and surrounding district.

Perhaps the most significant unit in the mine area is the tonalite intrusion complex. This is a series of competent, narrow sills (typically less than 5 metres thick) that are folded along with the host stratigraphy. They also have minimal thermal aureoles and chilled margins (< 20 cm). These observations suggest that the tonalitic magma intruded under near-equilibrium conditions (400°C at 5-10km depth) prior to the peak structural deformation event.
Concordant quartz-(carbonate) veins in carbonaceous shale stratigraphy

Padang Tengku formation and Pahang Volcanic series (Permo-Triassic)
And the name of Lipis is derived from a local folklore about a white crocodile named Pis was 'ditegur' by Sang Gedembai or Kelembai. From "Cis Pis!" slowly after years it turned into Lipis.