

Model Answer Ore microscopy and Ore Petrology Exam

Benha University
Faculty of Science
Geology Department



4th Year Geology / Geology & Chemistry
Time allowed: 2 hours
Date: 15/05/2019

Part A: Ore microscopy 431G (24 Marks)

Question # 1: Write short essay on two from the following **(8 Marks)**

A- The qualitative optical properties studied in plane polarized light only for ore minerals.

The qualitative optical properties studied in PPL are color, reflectance, Bireflectance and Pleochroism.

- Color: A very small number of ore minerals are strongly and distinctively colored (e.g., covellite, bornite, gold), but most are only weakly colored and may appear to the beginner as white through various shades of gray.

Color	Minerals
Blue	Covellite Chalcocite, Digenite
Yellow	Gold, Chalcopyrite, Millerite, Cubanite, Valleriite
Red-brown to brown	Bornite, Pyrite, Violarite

- Reflectance is observed in plane polarized light.

Reflectance is the amount of incident light on a polished surface of a particular mineral that is reflected back to the observer. The reflectance of a phase could be termed as "brightness". It can be accurately measured using equipment added to the standard reflecting microscope and is defined on a percentage scale as

$$\text{Reflectance (R\%)} = (\text{intensity of reflected light} * 100) / \text{intensity of incident light.}$$

- Bireflectance and pleochroism are observed in plane polarized light.

The change of reflectance is a property termed bireflectance.

The change of color (or tint) is a property called reflection pleochroism.

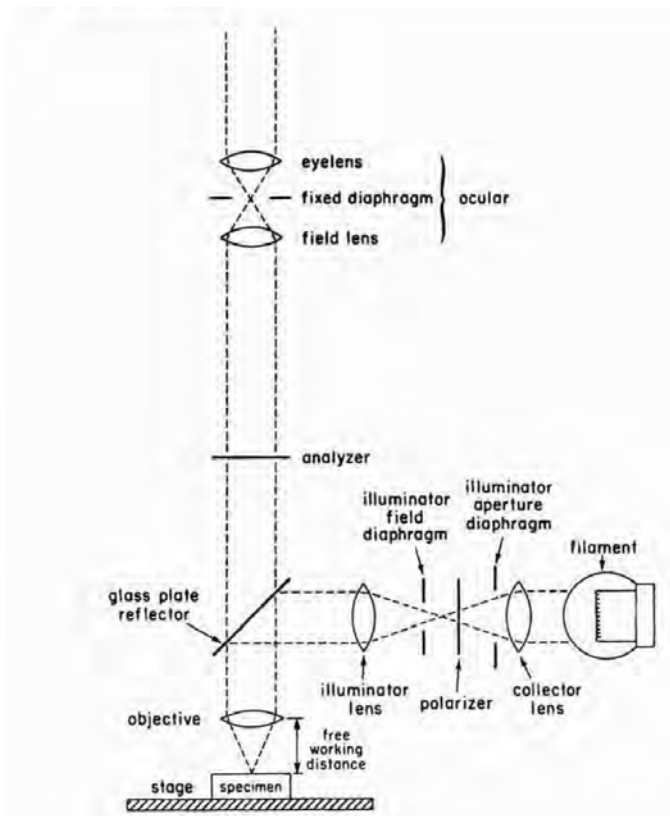
Cubic minerals remain unchanged in reflectance and color on rotation of the stage, whatever the orientation of the grains.

Most minerals of other crystal symmetries show changes in reflectance or color (or both) when sections of certain orientations are rotated.

B- The main difference between reflected- and transmitted- polarized light microscopes. Illustrate your answer with sketches.

The reflected- polarized light microscope differs from the transmitted-polarized light microscope in that it contains a reflector placed in the barrel of the microscope directly above the objective, and light is reflected vertically downward through the objective onto the specimen to be studied.

It differs in that its primary method of illumination is a light source above the sample to allow examination by light reflected from polished surfaces.



C- Grinding and polishing and their importance in preparation of specimens for ore microscopy.

- The purpose of grinding is to remove surface irregularities, to remove casting resin that covers the sample, to reduce thickness, to prepare a smooth surface for further work, and to remove any zone of major deformation resulting from initial sample cutting.
- Once a sample has been cut to an appropriate size and cast in a mounting medium, it is ready for grinding and polishing.
- Large research or industrial laboratories commonly employ automated grinding and polishing machines capable of handling large numbers of specimens.
- Adhesive-backed emery paper or diamond embedded in metal or epoxy are preferred to be used and they are better than loose abrasives, because the latter tend to roll and leave irregular depth scratches rather than planing off a uniform surface.

Question # 2: Define FOUR ONLY of the following:

(8 Marks)

A- Isotropism of ore mineral

When a polished surface of a cubic mineral is examined under crossed polars, it is found to remain dark (inextinction) in all positions of the stage, whatever the crystallographic orientation of the polished surface (in some cases, these crystals may not be completely dark but will nevertheless remain unchanged on rotating). Such minerals are termed isotropic.

B- Internal reflection of ore mineral

Some minerals examined in polished section are transparent, and others are completely opaque, with some being intermediate in their "opacity." Transparent phases are, of course, best studied in transmitted light. In polished sections, such phases may allow light to penetrate deep below the surface and to be reflected back to the observer from cracks or flaws within the crystal. Such light will appear as diffuse areas or patches, known as internal reflections.

C- Polishing hardness

Polishing hardness is the resistance of a particular mineral to abrasion during the polishing process. The fact that hard minerals are worn away more slowly than soft minerals means that they may stand slightly above the surfaces of softer grains in the section-an effect known as polishing relief.

Although in the preparation of a polished section every attempt is made to minimize the amount of relief, the presence of some relief enables relative hardness to be estimated rapidly. This determination involves a simple test using the Kalb light line. The procedure is as follows:

- 1- Focus on a clear boundary line between two mineral grains.
2. Lower the stage (or raise the microscope tube) so that the sample begins to go out of focus as the distance between the specimen and the objective increases.
3. Observe a "line" of light that will move toward the softer mineral, provided there is significant relief.

D- Replacement texture

Replacement texture: Replacement of one ore mineral by another or by a mineral formed during weathering is common in many types of ores. However, a major problem in textural interpretation is the recognition of replacement when no remains occur. The easily recognized ores are those replacing wood, fossils and/or minerals of different fabrics. Replacement may result from: (1) dissolution and subsequent reprecipitation, (2) oxidation, and (3) solid state diffusion. The resulting boundary between the replaced and the replacing mineral is commonly either sharp and irregular. The replacement occurs on the Crystal Surface, crystal structure, Chemical composition. Replacement of one ore mineral by another or by a mineral formed during weathering is common in many types of ores. However, a major problem in textural interpretation is the recognition of replacement when no remains occur. The easily recognized ores are those replacing wood, fossils and/or minerals of different fabrics.

A- Open space-filling texture.

The open-space filling texture: is formed where the initial deposition and growth of the ore and gangue minerals in many deposits occurs in open spaces in vugs or fractures developed by dissolution or during faulting. Although the open space may no longer be evident because of subsequent infilling or deformation, the initial formation of the crystals in open space is often still evidenced by presence of well-developed crystal faces, by crystals that exhibit growth-zoning, by colloform or zoned bands. These textures may be developed on a scale ranging from macroscopic to microscopic. Open-space filling is exemplified by the Cu-Pb-Zn -Ag) vein deposits composed of pyrite, sphalerite, galena, chalcopyrite, and silver-bearing sulfosalts, and by some Pb-Zn ores in carbonates.

These textures may be developed on a scale ranging from macroscopic to microscopic. Open-space filling is exemplified by the Cu-Pb-Zn -Ag) vein deposits composed of pyrite, sphalerite, galena, chalcopyrite, and silver-bearing sulfosalts, and by some Pb-Zn ores in carbonates. Pyrite in these ores generally forms as isolated cubes, more rarely as octahedra or as aggregates of interfering crystals along the walls of fractures.

B- Exsolution texture.

Is a secondary textures resulting from cooling where many ores form at elevated temperatures and have undergone cooling over temperature ranges. In exsolution, one phase is expelled from another. The form of exsolved phase varies with the minerals involved, their relative proportions, and the postdepositional cooling history of the ore. The exsolution process result from diffusion of metal atoms, nucleation of of crystallites, and growth of crystals.

In case of Pb-Zn ores in carbonates, cooling is less than 100°C whereas in the case of Fe-Ni-Cu ores in ultramafic rocks, cooling is as much as 1000°C. Refractory minerals such as magnetite, chromite, pyrite, sphalerite often retain their original composition and texture through the cooling episode, whereas many sulfides, sulfosalts, and native metals re-equilibrate during cooling. Re-equilibration of ores on cooling is accompanied to some degree by recrystallization of primary minerals. The textural effects resulting from cooling are varied. Most ores undergo compositional or structural adjustments in the form of exsolution or inversion as they cool from the

temperatures of initial crystallization or the maximum temperature of metamorphic recrystallization.

Exsolution itself is a form of decomposition, because the original high temperature composition no longer exists as a single homogeneous phase.

Question # 3: Compare between the following minerals according to their optical properties and chemical formulas: (8 Marks)

A- Pyrite and Chalcopyrite

Pyrite

FeS₂, Cubic, Cream white, Reflectivity: High, Isotropic, Cube or octahedron shape.

Chalcopyrite

CuFeS₂, Brass yellow, Trigonal, Reflectivity: Medium, Very weak Anisotropic

Two sets of Cleavage, Birefringence: Present, Lamellar twins

B- Covellite and Galena

- Covellite
- CuS
- Hexagonal
- Ink Blue
- Reflectivity: low
- Anisotropic
- Birefringence may be present
- Intense pleochroism

- Galena
- PbS
- Cubic
- White
- Reflectivity: high
- Isotropic
- Three sets of cleavage
- Habitat: Triangular pit

C- Magnetite and Hematite

Magnetite

Fe₃O₄, Cubic, Isotropic, Pale" faint" brown, Reflectivity: medium, Crystal habit: equant, Crystal form: euhedral, two sets of cleavage, BIF (Banded Iron Formation)

Hematite

Fe₂O₃, Trigonal, Anisotropic, White, Reflectivity: high, Crystal habit: Bladed, Internal Reflection "reddish brown", BIF (Banded Iron Formation), Moderate birefringence.

D- Goethite and Chromite

- Goethite
- Fe₂O₃.H₂O
- Orthorhombic
- Grey
- Crystal habit: colloform
-
- Chromite
- FeCr₂O₄
- Cubic
- Isotropic
- White with brown tint
- Reflectivity: high
- Internal Reflection: brown or reddish brown

Part B: Ore petrology (24 Marks)

Answer the following questions (Draw if possible)

Question # 1: Define g from the following: (8 Marks)

1. *Gangue minerals*

Gangue mineral, in mining, is the commercially worthless material that surrounds, or is closely mixed with, a wanted mineral in an ore deposit. It is thus distinct from overburden, which is the waste rock or materials overlying an ore or mineral body that are displaced during mining without being processed.

2. *Greisenization*

Greisenization: is a process of hydrothermal alteration in which feldspar and muscovite are altered to quartz, topaz, tourmaline, and lepidolite by the action of water vapour containing fluorine.

3. *Laterites*

Laterites are red colored iron-rich soils that have been leached through tropical weathering processes.

They can host important mineral deposits including Iron, Nickel, Bauxite (Aluminum) and REE's.

4. Immiscible separations

Immiscible separations

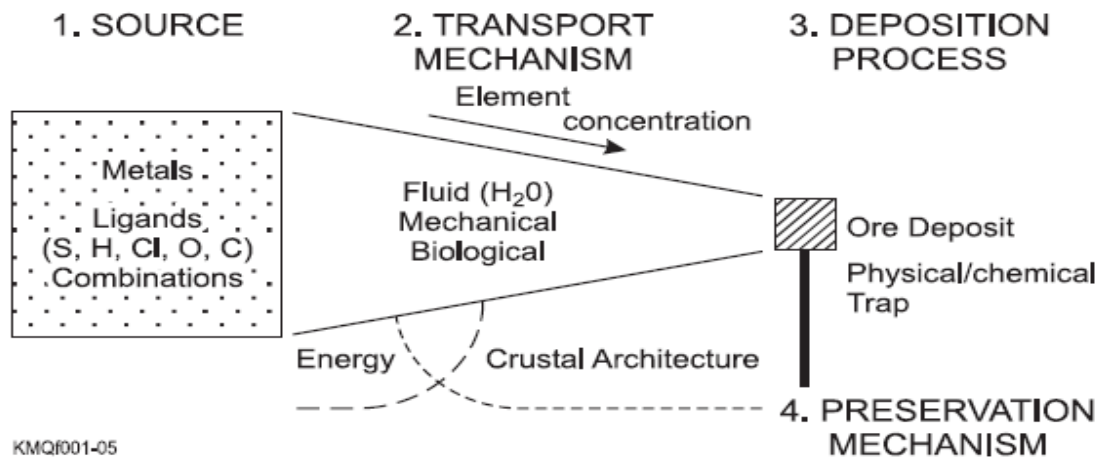
- As magmas cool, they can split into two liquids of different composition and density.
- One of these liquids is the silica-rich melt. It has the most volume.
- The other, typically much smaller in volume, can be rich in metal oxides, sulfides or carbonates.

Types of Immiscible Melts

- Oxide melts can be rich in Fe (Fe_2O_3 , hematite) and Ti (FeTiO_3 , ilmenite).
- Sulfide melts can be rich in Ni, Cu, and the platinum-group elements, in addition to iron sulfur (FeS , -pyrrhotite).
- Carbonate melts can be rich in niobium, tantalum, rare earths, copper, thorium, and phosphorous.

5. Ore-genesis theories

- Ore-genesis theories vary depending on the mineral or commodity examined. They generally involve three components: source, transport or conduit, and trap.
- Source is required because metal must come from somewhere, and be liberated by some process.
- Transport is required first to move the metal-bearing fluids or solid minerals into their current position, and refers to the act of physically moving the metal, as well as to chemical or physical phenomenon which encourage movement.
- Trapping is required to concentrate the metal via some physical, chemical, or geological mechanism into a concentration which forms mineable ore.



6. *Pneumatolytic deposits*

They are mineral deposits formed by the action of the hot mineralized vapors and gases released by solidifying magma in the interior of the earth as a consequence of pneumatolysis at high temperature 400-600°C (based on Niggli diagram).

7. *Miarolitic class*

This is the class of pegmatite deposit based on P-T condition. It is characterized by the presence of open cavities in the pegmatite. The cavities may remain open, be filled with clays, or lined with crystals. These pegmatites were probably emplaced

8. *Pegmatite Deposits*

- Pegmatites are often defined as very coarse-grained igneous rocks, usually of granitic composition, that tend to be enriched in normally rare elements such as lithium, beryllium, tantalum, and others.
- Indeed, most pegmatites have granitic composition but pegmatites of basic, intermediate or alkaline rocks are also well known. Therefore, it is recommended that a modifier such as “granitic” is used to state clearly what is the composition of the pegmatite under consideration.
- In addition, ore-grade pegmatite bodies may contain very essential amounts of minerals (e.g., minerals of Li, Cs, Be, etc.)

9. *Placer Deposits*

They are mineral deposits formed by the concentration of moving particles through wind or water action are called placer deposits.

Question # 2: Answer just two questions from the following: (8 Marks)

1. *What is the mechanism of the cooling stage in the concentration of metals?*

- Magma, like most liquids, contains dissolved volatiles (water, CO₂, SO₂) in varying amounts.
- When the magma rises, pressure drops, the magma cools and volatiles separate and rise to the top of the magma chamber.
- This separation changes pH (acidity), Eh (oxidation) and viscosity.....
- When the pressure drops and magma cool, it begins to crystallize
- At this point the magma chamber has 4 different phases at least:

1- Volatiles

2- Gas and aqueous liquid,

3- Remnant Melt (Molten magma),

4- Solid (crystals)

- Metals partition preferentially into each of the phases
 - Examples:
 - ***Cr and C (diamond) go into early crystals,***
 - ***Ni and Pt combine with S to form dense sulfide melt,***
 - ***Cu may go into brine solutions,***
 - ***Au tends to go into the gas and aqueous liquid***

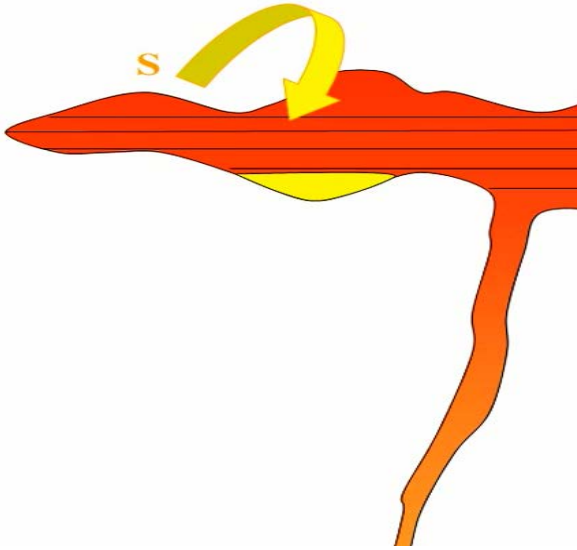
2. Describe how to form the Cu-Ni Massive Sulfide deposits (Draw if possible).

Formation process

- Intruding mafic magma rich in Cu and Ni.
- Magma absorbs sulfur "S" from the surrounding rocks.
- Sulfur combine with Ni and Cu in magma to produce Ni-Cu sulfide melt.
- Sulfide melt separates from magma (immiscibility) and collects as puddles at the bottom of the magma chamber.
- Cooling to produce massive sulfide.
- Main sulfide minerals:

Pentlandite (Fe, Ni)₉S₈

Chalcopyrite CuFeS₂

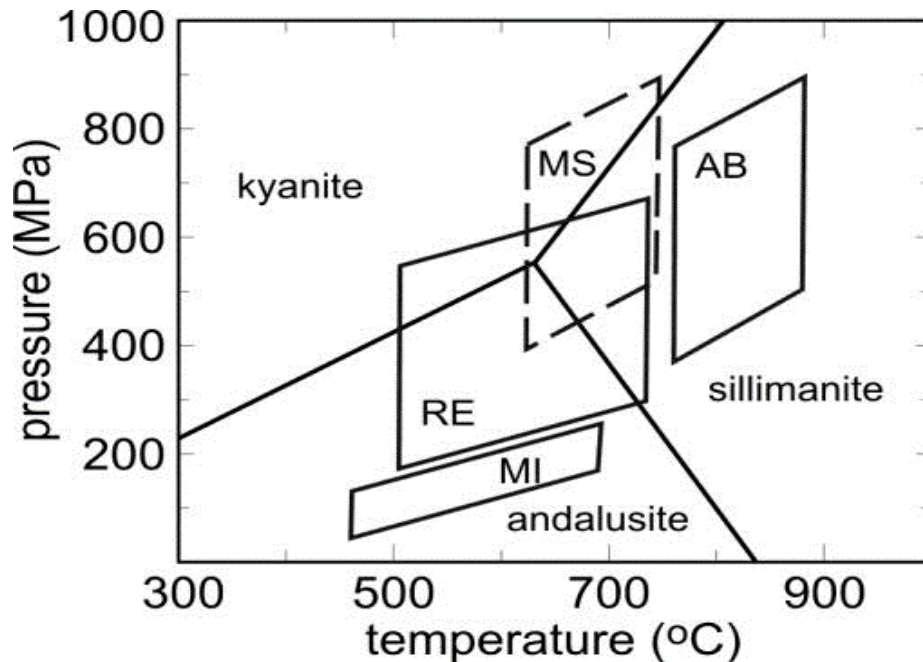


**3. Pegmatites are separated into different classes with distinct P-T conditions.
(Discuss and draw if possible).**

A classification widely used today can be found in Černý and Ercit (2005) (see the following Figure). Pegmatites are separated into classes with distinct formation P-T conditions and other features:

- a) **Abyssal class.** Pegmatites of this class are found in rocks of high metamorphic grade (amphibolite to granulite facies). Their textures are variable and may include some of the complex pegmatitic textures (e.g., graphic granite).
- b) **Muscovite class.** Pegmatites of this class are typical for rocks with slightly lower P-T conditions than the abyssal class. Other than that, it is not quite clear what should be the clear separating point between the two classes. Pegmatites of this class are conformable with the host rocks and are thought to be generated locally by the anatexis (partial melting) of the high-grade metamorphic rocks.
- c) **Muscovite – rare-element class.** The pegmatites of this class are intrusive bodies which form a continuum from granite to rare-element pegmatites.
- d) **Rare-element class.** These pegmatites intrude host rocks with the peak metamorphic conditions falling in the low-pressure portion of greenschist facies or amphibolite facies. This class is the most diverse in composition and the most important in terms of the economic usage of these rocks.

e) **Miarolitic class.** This class is characterized by the presence of open cavities in the pegmatite. The cavities may remain open, be filled with clays, or lined with crystals. These pegmatites were probably emplaced



Question # 3: Answer just two questions from the following:

(8 Marks)

1. Write on the different pegmatite families based on the commodity?

Two pegmatite families are distinguished based on the commodity as following:

a) **LCT family,**

- where LCT stands for lithium (Li), cesium (Ce), and tantalum (Ta).
- This assemblage of elements is found in highly evolved pegmatites in S-type granites (S-type granites are thought to originate by melting of sedimentary rocks rich in illite/muscovite).
- Additional elements which these pegmatites may contain are Be, B, F, P, Mn, Ga, Rb, Nb, Sn, and Hf.

b) **NYF family,**

- where NYF stands for niobium (Nb), yttrium (Y), and fluorine (F).
- These elements are typical for pegmatites evolved from A-type granites (that is, anorogenic or “within-plate” granites).

- Additional elements in these pegmatites are heavy-rare earth elements, Be, Ti, Sc, and Zr.
- A common feature is the occurrence of amazonite (green variety of Pb-bearing microcline feldspar).

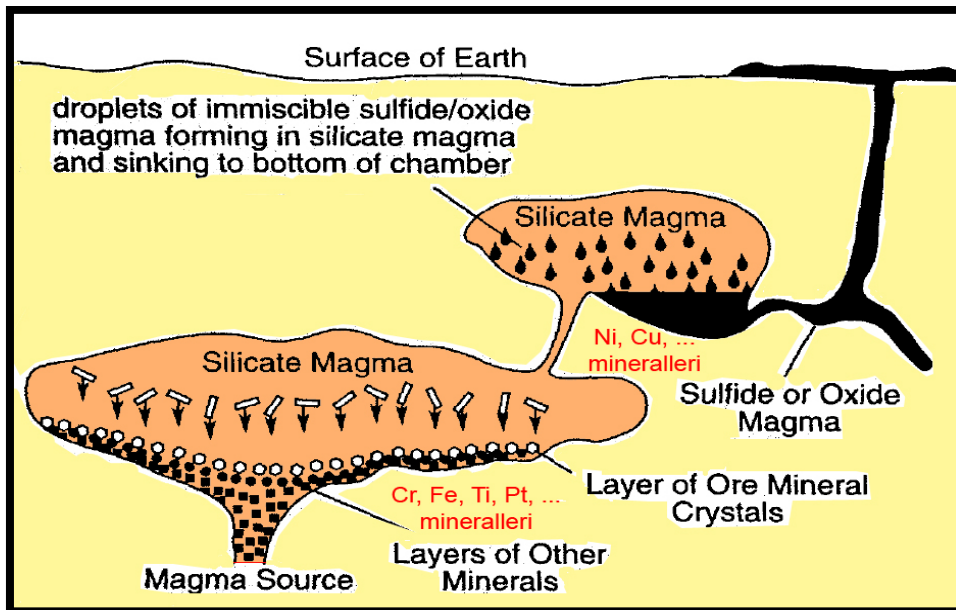
2. Write on Chromite and Platinum-group elements (PGE) deposits.

Characteristics

- Usually well layered
- Host rock: mafic to ultramafic in composition
 - Usually Peridotite rocks (especially Dunite) in case of Chromite deposits
 - Usually Pyroxenite in case of PGEs.
- Chromite (FeO.Cr₂O₃) appears as sediment-like layers or possibly disseminated.
- PGEs are six metals are ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), and platinum (Pt) usually occurred with chromite or with Fe / Cu / Ni sulfides (ex pyrrhotite in sulfide rich layers).

Formation process

- The deposition of Cr and PGEs at critical chemical balance in magma.
- Formed by magmatic differentiation (Early crystal fractionations and precipitation by gravity (Gravitational precipitations))
- Mafic melt are very fluid, and heavy crystals settle on the floor of the magma chamber by gravity.
- After that repeated injection of magma into the magma chamber result layers of different composition.



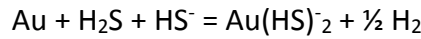
3. What are the Role of Complex Ions and Ligands in hydrothermal fluids?

- The complex ions and ligands have in general played a role in defining the mechanism of dissolution, transport, and deposition of metals as well as the solubility of these metals in hydrothermal fluids (Pirajno 2009).
- Cl^- (chloride) and HS^- (sulfide) complexes are the most efficient and common ligands for the dissolution and transport of metals. At high temperature, Cl^- complex is dominant in high salinity fluids and is likely appropriate for complexing base metals and Ag. While, HS^- complex, which is less dependent on temperature, is dominant in low salinity fluids and is principally suitable for complexing Au (Pirajno 2009).
- Also, this complex depends on the physicochemical conditions. These conditions which are responsible for destabilization of metal complexes have many factors, e.g.
 - (1) *pressure loss and/or boiling;*
 - (2) *temperature decrease;*
 - (3) *reduced activity of complexing ions (S or Cl);*
 - (4) *changes in the redox state of the solution.*
- This destabilization plays an important role in the precipitation of metals from hydrothermal solutions (Pirajno 2009).

- The ore-carrying capacity of the fluids is largely determined by the activity of these ligands, rather than the abundance of the metals to which they are bonded. This activity is a function of concentration temperature, ionic strength, pH and Eh. Very important complexes for the solubility of metal sulphides in hydrothermal fluids are H₂S and the hydrosulphide ion HS⁻ (Rickard and Luther 2006).

Example:

- Studies of active hydrothermal systems and epithermal Au deposits indicate that thio-sulfide (*Thio means means that an oxygen atom in the compound has been replaced by a sulfur atom*) complexing (HS)⁻ is one of the dominant mechanisms of transport for Au.
- Here, Au⁺ is complexed by the sulfur ligand HS, which was shown by Seward (1979 a,b) at Broadlands, New Zealand, to predominate over chloride complexes at near neutral pH.
- Furthermore, Pope et al. (2005) in their study of Au abundances in the Waiotapu springs (also in New Zealand) have shown that Au-HS complexes are several orders of magnitude more abundant than any other complexing ligands.
- Thio-complexes of Au⁺ up to 300°C and 1500 bar, with pH 3–10 are found to be stable. Gold thio-complexing at near neutral pH is defined thus:



نموذج اجابة استرشادى لمادة ميكروسكوبية وبتروولوجية الخامات 431G

استاذ المادة د/ عمرو عبدالناصر علي

د/ عادل ماضي عفيفي

المستوي الرابع

جيولوجيا وكيمياء

With our best wishes

Dr. Amr Abdelwasser

Dr. Adel Afify