GEOCHEMISTRY

"Meteorites: Classification & Composition"

(M.Sc. Sem IV)

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INTRODUCTION

- A ***meteor*** is a piece of solid matter from space which after entering the atmosphere become incandescent (due to atmospheric friction). Outside the Earth's atmosphere, it is known as ***meteoroid***; any part that survives passage through the atmosphere and reaches the earth surface is called ***meteorites***.
- ***Asteroid*** is bigger than a meteoroid and orbits around the sun. An asteroid or meteoroid which glows when close to the Sun is calld ***comets***; it should have a tail like a comma.

METEORITES

- Meteorites are believed to originate in the asteroid belt between the planets of Mars and Jupiter.
- Meteoritic matter is continually falling on Earth, nearly around 30,000 – 150,000 tonnes/year.
- Meteorite consist essentially of:
  - Ni-Fe alloy,
  - crystalline silicates,
  - Fe-S minerals

HISTORICAL BACKGROUND

- In 1974, Ernst Friedrick Chladni summarised his work on meteorites in his book.
- In 1802, Edward Charles Howard was first to chemically analyse stone meteorites.
- Karl Ludwig von Reichenbach (in 1857) was first to study the meteorites under microscope.
- In 1863, Nevil Story Maskelyne studied thin section of meteorite under cross polar light.
- 1863 is marked as the beginning of classification schemes with G. Rose's classification of the meteorite collection at the University Museum of Berlin and Maskelyne's classification of the British Museum collection.

HISTORICAL BACKGROUND

- Rose was the first to split stones into chondrites and non-chondrites.
- Maskelyne classified meteorites into siderites (irons), siderolites (stony-irons), and aerolites (stones).
- In 1833, Tshermak's modified the Rose's classification. It was further modified by Brezina.
- 1907, Farrington classified meteorites on the basis of chemical composition.
- These schemes were further modified by Prior (1920) and Mason (1967), which is still the fundamentals for the meteorite study.

GUSTAV ROSE CLASSIFICATION

GUSTAV ROSE CLASSIFICATION	
Stones	Irons
a. Chondrite (chondrules)	a. Pure Ni-Fe
a. Howardite **a. Shalkites** **(HED groups)** **a. Eucrite**	a. Pallasite (equal proportion of iron-olivine)
a. Chladnite (enstatite)	a. Mesosiderite (equal proportion of iron-silicates)
a. Chassignite (SNC group)	
a. Carbonaceous	

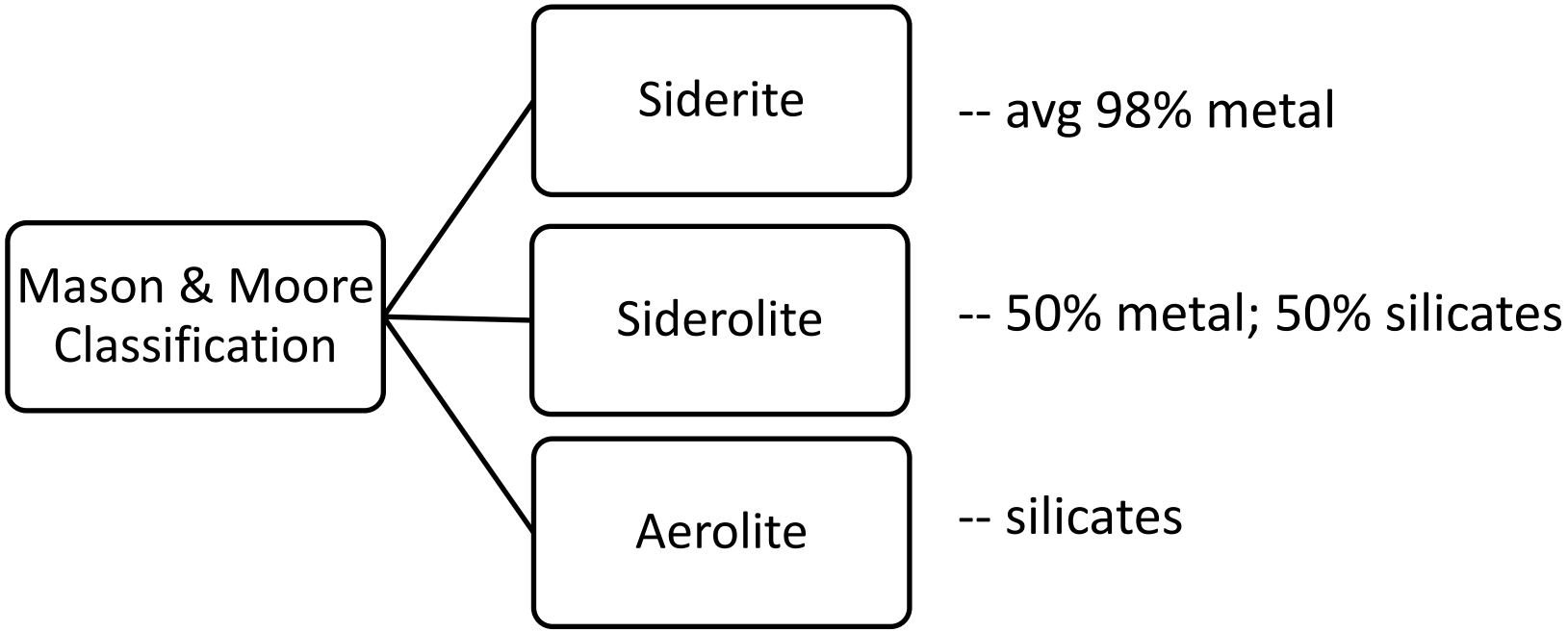
GUSTAV TSCHERMAK CLASSIFICATION

GUSTAV TSCHERMAK CLASSIFICATION	
Stones	Irons
a. Class I - **Largest class** - **Consist of chondrule** - **Further grouped in 9 categories based on mineralogy** **b. Class II** - **Metamorphosed chondrites** - **No chondrules** - **Olivine & pyroxene rich** **c. Class III** - **Achondrites** - **e.g., HED group of meteorites**	a. Class I i) Hexahedrite ii) Octahedrite iii) Ataxite b. Class II i) Pallasite ii) Mesosiderite iii) Siderophyres iv) Grahamites

PRIOR CLASSIFICATION

Group	Class	Major minerals
Chondrite	Enstatite Olivine-bronzite Olivine-hypersthene Olivine-pigeonite Carbonaceous	Enstatite, Iron-nickel Olivine, bronzite, iron-nickel Olivine, hypersthene, iron-nickel Olivine-pigeonite Serpentine
Achondrite (Ca-poor)	Aubrite Diogenites Chassignites Urellites	Enstatite Hypersthene Olivine Olivine, pigeonite, iron-nickel
Achondrite (Ca-rich)	Angrite Nakhlites Eucrites Howardites	Augite Olivine, diopside Pigeonite, plagioclase Hypersthene, plagioclase
Stony irons	Pallasite Siderophyre Lodranites Mesosiderites	Olivine, iro-nickel Bronzite, iron-nickel Bronzite, olivine, iron-nickel Pyroxene, plagioclase, iron-nickel
Irons	Hexahedrites Octahedrites Ataxites	iron-nickel alloy (kamacite) iron-nickel alloy (kamacite, taenite) iron-nickel alloy (Ni rich taenite)

MASON & MOORE CLASSIFICATION



SIDERITES OR IRONS

- Ni-Fe alloy (Ni is 4 - 20%)

- Accesories minerals:

  troilite (FeS),

  schreibersite $(Fe, Ni, Co)_3P$

  graphite,

  Daubreelite $(FeCrS_4)$,

  Cohenite (Fe_3C),

  Chromite $(FeCr_2O_4)$

**These are present as small rounded or lamellar grains scattered through the metal.*

- Widmanstatten figure is displayed normally by the metals.
- The structure is characterised by lamellae of kamacite bordered by taenite.

SIDERITES OR IRONS

Siderite are grouped into 3 class:

i. Octahedrite:

Lamellae are parallel to octahedral faces (exsolution due to very slow cooling).
characterised by widmanstatten structure.

ii. Hexahedrite:

Lamellae are parallel to hexahedral faces.
Iron-Nickel alloy, consisting entirely of Kamacite.

iii. Ataxites:

Iron-nickel alloy
Nickel > 14%, and consist largely of taenite.

SIDEROLITES OR STONY IRONS

- Consist of *Fe-Ni alloy and silicates* in approximately equal proportions.
- *Siderolite are grouped into 2 class:*

i) Pallasites:

Made of continuous base of Ni-Fe enclosing olivine grains of euhedral forms.

ii) Mesosiderites

It shows a discontinuous base (metallic phase) and silicates are plagioclase and pyroxene with accessory olivine.

AEROLITES OR STONES

Essentially consists of silicates.

- Includes two group:

i) Chondrites (undifferentiated or unmelted)
- characterised by the presence of chondrule which are small rounded bodies made of olivine and pyroxene.
- further categorised in different groups based on composition.

ii) Achondrites (differentiated or melted)
- composed of: Olivine~40%, pyroxene~30%, nickel-iron~10-20%, plagioclase~10% and troilite~ 6% .
- coarsely crystalline than chondrules.
- resemble terrestrial silicate rocks and hence probably crystallized from a silicate melt.

e.g., similar to basalts and gabbros.

GENERALISED CLASSIFICATION SCHEME

- I) **Stony meteorites**
  - a. Chondrites
    - i) Carbonaceous chondrite class
      - CI chondrite (Ivuna-like) group
      - CM-CO chondrite clan
      - CV-CK chondrite clan
      - CR chondrite clan
    - ii) Ordinary chondrite class
      - H chondrite group
      - L chondrite group
      - LL chondrite group
    - iii) Enstatite chondrite class
      - EH chondrite group
      - EL chondrite group

b. Achondrites

i) Primitive achondrites

- Acapulcoite-lodranite clan
- Brachinite group
- Winonaite group
- Ureilite group

ii) HED meteorite clan

- Howardite group
- Eucrite group
- Diogenite group

iii) Lunar meteorite group

iv) Martian meteorite group ("SNC meteorites")

- Shergottites
- Nakhlites
- Chassignites

Other Martian meteorites

v) Angrite group

vi) Aubrite group (enstatite achondrites)

- II) **Stony-iron meteorites**
    - a) Pallasites group
        - i) Main group pallasites
        - ii)Eagle station pallasite grouplet
        - iii) Pyroxene pallasite grouplet
    - b) Mesosiderite group
- III) **Iron meteorites**
    - a) Magmatic iron meteorite groups
        - i) IC iron meteorite group
        - ii) IIAB iron meteorite group
        - iii) IIC iron meteorite group
        - iv) IID iron meteorite group
        - v) IIF iron meteorite group
        - vi) IIG iron meteorite group
        - vii) IIIAB iron meteorite group
        - viii) IIIE iron meteorite group
        - ix) IIIF iron meteorite group
        - x) IVA iron meteorite group
        - xi) IVB iron meteorite group

b) Non-magmatic or primitive iron meteorite groups

i) IAB iron meteorite "complex" or clan

- IAB main group
- Udei Station grouplet
- Pitts grouplet
- sLL (low Au, Low Ni) subgroup
- sLM (low Au, Medium Ni) subgroup
- sLH (low Au, high Ni) subgroup
- sHL (high Au, Low Ni) subgroup
- sHH (high Au, high Ni) subgroup

ii) IIE iron meteorite group

PICTURE GALLERY OF DIFFERENT METEORITES

Stony iron meteorites

Stony meteorites chondrites

Stony meteorites Achondrites

Iron meteorite

REFERENCES AND FOR FURTHER STUDIES

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