GEOCHEMICAL METHODS OF MINERAL EXPLORATION

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Definition

- The primary role of geochemistry, used to describe the Geological media, in mineral exploration is to find an area *ANOMALOUS* in the product sought, or in elements known to be associated with the type of mineralization sought.

- Geochemical exploration has traditionally involved use of stream sediments to target potentially mineralized catchments
- commonly use soils as the sampling media, possibly via the collection of a grid of samples over the tenement or areas which are amenable to soil geochemistry.
- Areas which are covered by transported soils, alluvium, colluvium or are disturbed too much by human activity (roads, rail, farmland), may need to be drilled to a shallow depth in order to sample undisturbed or unpolluted bedrock

Geochemical anomalies

- Geochemical anomalies may be spurious or related to low-grade or sub-grade mineralisation.
- In order to determine if this is the case, geochemical anomalies must be Drilled in order to test them for the existence of economic concentrations of mineralization.
- The presence of some chemical elements may indicate the presence of a certain mineral.
- Chemical analysis of rocks and plants may indicate the presence of an underground deposit.
- For instance elements like Arsenic and Antimony are associated with gold deposits and hence, are example pathfinder elements.
- Tree buds can be sampled for pathfinder elements in order to help locate deposits.

Geochemical Sampling

- Geochemical sampling methods are methods which involve collecting and analyzing *various* types of geological materials (such as soils, stream sediments, and rocks) or certain biological materials (such as plants).
- Historically these methods have been some of the most productive of any methods used in mineral exploration.
- Sometimes mineralization can be extremely difficult to notice, if not impossible to recognize, by simply looking at a sample.
- Without the use of geochemical sampling methods, many known ore deposits would probably not have been discovered.

- Geochemical sampling plays a key role in the description of mineralization.
- For example, geochemical sampling of soils is often employed to outline the general distribution of mineralization at shallow depths where outcrops of bedrock are minimal or nonexistent
- Numerous samples of different types of rocks and other materials comprising the earth’s crust have been analyzed.
- As a result, the average abundance of trace elements in these materials is fairly well known and established.
- The average value for a specified rock is called the “background” value.
- We are interested in values which are much greater than average or “anomalous” because these values may indicate the presence of an ore body.

- The location of an anomalous value on the map is called an anomaly.
- When values are plotted on a map, a pattern of increasing values may emerge which would give useful information as to the direction to the source.
- For this reason, collection of location data is an extremely important aspect of geochemical sampling in the field.

Dispersion Halos

- Dispersion is the process of dispersing elements outward from a source.
- A dispersion halo is a zone around a mineral deposit where the metal values are less than those of the deposit but significantly higher than background values found in the country rocks around the deposit

Primary Dispersion Halos

- Primary dispersion refers to dispersion which occurs in rocks at or near the time of formation of a mineral deposit.
- It is usually the result of “hydrothermal” (hot aqueous) fluids which are responsible for creating the deposit.
- Fluid movements in rocks are so variable that the halo formed by primary dispersion may or may not reflect the shape of the ore deposit itself.
- The extent of the primary dispersion halo can range from inches to hundreds of feet.
- The extent of the primary halo is dependent on the nature of the rock.
- Rocks which are extremely porous or highly fractured usually develop more extensive primary halos.

Secondary Dispersion Halos

- Secondary dispersion refers to dispersion which occurs in the secondary environment (soils, stream sediments or plants) long after the formation of a mineral deposit.
- This type of dispersion is usually the result of mechanical and/or chemical weathering. Mechanical weathering is caused by physical processes such as breakage due to freezing and thawing.
- Chemical weathering is caused by chemical reactions between minerals and groundwater resulting in chemical decomposition of minerals.
- Chemical decomposition can also be caused by bacteria

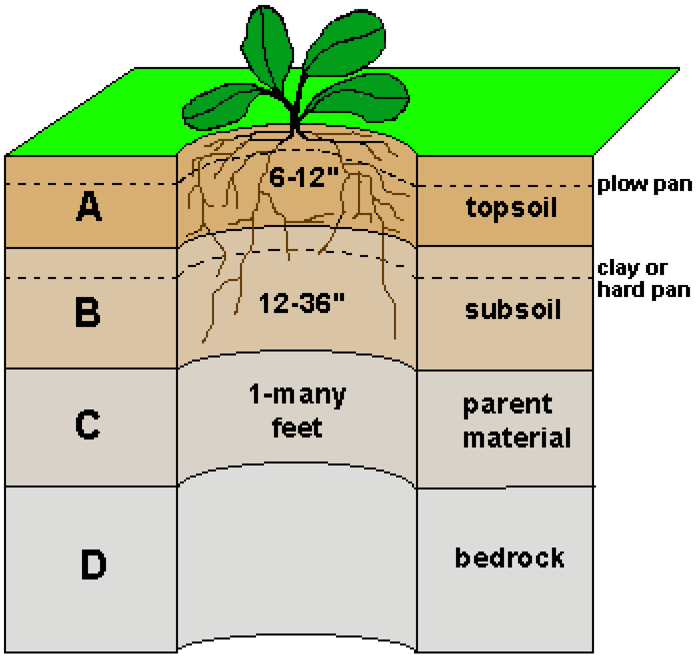
- Halos caused by secondary dispersion are usually much more widespread than those caused by primary dispersion.
- For this reason, sampling of soils, stream sediments or plants can detect the presence of a mineral deposit from a much further distance.

Path finer elements

- Dispersion results in the transport of metallic ions (charged particles) away from a source.
- Some of these ions are precisely the ones sought after, and others are called “pathfinder” metals or elements.
- Pathfinder elements are those which are closely associated with the metal of interest.
- High values of pathfinder elements may be more significant because they have better mobility, resulting in greater dispersion.
- For example, Arsenic and Bismuth are good pathfinders for Gold.

- Another means of dispersion in the stream environment is caused by mechanical erosion.
- Mechanical erosion leads to the breakdown of host rocks containing ore minerals. Consequently, tiny grains of the minerals occur in the suspended load of the stream.
- Turbulence of the water keeps the particles in suspension.
- Turbulence is greatest in steeper areas where the stream water flows faster.
- Downstream where the topography is more gentle, the stream waters move slower, thereby decreasing turbulence
- This causes the suspended load to drop out, resulting in deposition of the mineral grains in the stream sediments.
- Heavy minerals, like ore minerals, tend to drop out first because less turbulence is needed to keep them in suspension.

Soil Sampling



- Soils are the product of weathering of bedrock, decomposition of organic material at the surface, and deposition of other materials which have been transported.
- The soils tend to form certain layers called “horizons”.
- The lowermost horizon consists largely of decomposed bedrock and is called the “C” horizon.
- The uppermost horizon, called the “A” horizon, is variable in composition.
- The “B” horizon is between the “A” and “C” horizons, and is essentially a mixed zone. Dispersion is generally greatest in the “A” and “B” horizons.
- For this reason, soil samples collected from the “B” horizon can detect a mineral deposit from a greater distance.
- In arctic regions, the “B” horizon tends to be poorly developed (if present at all).
- It is best to collect soil samples from the “C” horizon in these regions.

- In India

Later part of Palaeozoic era and the early middle parts of Kainozoic era had been interesting in the mineral formation respectively

1. Bituminous Coal deposits
2. Lignite
3. Petroleum

- In India the more important economic mineral deposits are concentrated in

1. Bihar (Bituminous coal deposit, Zinc, copper, mica and Iron Ore)
2. West Bengal (Bituminous coal deposit)
3. Madhya Pradesh (Iron Ores, Manganese)
4. Orissa (Iron Ores, Manganese)
5. Andhra Pradesh (Mica, Crystolite)
6. Karnataka (Gold, Manganese)
7. Rajasthan (Magnesite, copper, Lead and Zinc)
8. Maharashtra (Bauxite, Manganese)
9. Gujarat (Bauxite)
10. Tamilnadu (Magriesite, Bauxite)
11. Uttar Pradesh (Rock Phosphate)

- There had been some other epochs of Mineralization in some parts of the world

1. Kainozoic - 70 million of years
2. Mesozoic - 155(pluslminus5)million of years
3. Palaeozoic - 600(pluslminus2o)million of years
4. Protrozoic Or Pre-Cambrian - 780 to 1040 million of years
5. Archean - 510 to 2900 million of years

- So far as India is concerned

> The Archean era had been one of the intense Mineral forming activity and most of the major economic Mineral deposits of the major economic Mineral deposits belong to this era of Mineral formation

>In India geologists have been named an important part of this era as Dharwar period

> During which period of most important mineral deposits of this country have been formed. Deposits of Copper, Chromite, Gold, Graphite, on ores, Manganese ores, Mica and Talc etc.

> The rocks in which- they found are naturally very old and metamorphic rocks belongs to Dharwar period

> Other eras — early part of Cainozoic or Tertiary period also been of universal interest and rich mineralization in many parts of the world. (e.g. Copper and Molybdenum ore deposits in USA)

- METALLOGENIC EPOCHS AND PROVINCES

  - 4500 Million of Years Old Earth

  - A statistical analysis of the major one deposits of the world shows

> Most mineral deposits of magmatic origin corresponds in Age, generally with the major periods of crustal disturbance and Mountain-building movements.

> The Proterozoic Era (or) Precambrian period appears to have been a period of great and varied mineral formation the world over this period belong the worlds leading deposits of Gold, Iron, Chromium, Manganese and Copper.

> In general Pre-Cambrian stable land-mass are the scenes of the greatest mining activity in the world (780- 1040 MILLION OF YEARS).

>Another important and interesting mineral forming epochs was the Kainozoic era (or) Tertiary era (70 million of years)

- Copper Province of Khetri-Pur-Banera-Binder:
- Two main zones of copper mineralisation in the province: Khetri zone and Pur-Banera Binder zone. The potential areas are Madhan Kudan, Kalihan and Chanmari in Ketri zone and Dariba in Pur-Banera-Binder zone.
- Pre-Aravalli, Aravalli and Delhi are found in the area and the Copper mineralisation are along different favourable structural zones related to different orogenic movements.
- The province shows basic volcanics of earlier stage and acidic magmatism of the intermediate-late stage of mobile belt. Found along three zones

1. Singhana-Khetri-Babai zone
2. Anjari-Dariba-Bairat-Jadawas zone
3. Kishangarh-Ajitgarh-Ambamara zone

- Lead and Zinc Province of Hesatu - Belbathan Bihar:
- Important occurrence are at Baraganda, Chandio, Jhalakdiha, Ganganpur, Toolsitanr, Baghmari etc.,
- Mineralisation associated with tremolite-actinolite schist, amphibolites and caic-granulite occur as pockets within chotanagpur granite gneiss.

- Iron Ore Province of Singhbhum - Keonjhar- Sundargarh- Mayurbanj:
- Found in Precambrian meta sediments along with chotanagpur gneiss and singhbhum granite
- Important occurrence at south of Singhbhum, Keonjhar, Sundargarh, Mayurbhanj, Cuttaack & Koraput.
- Developed in the interior areas of mobile belt as banded hematite iron ore deposits.
- Found along the zones

1. Cuttack-Keonjhar-Singhbhum-Mayurbhanj zone
2. Singhbhum- Keonjhar zone
3. Mayurbhanj-Sambalpur-Koraput-Sundargarh zone

- The Singhbhum metallogenic zone is of sedimentary - metamorphic nature containing iron and manganese. Where as Mayurbhanj is liquid magmatic deposit which formed during early crystallization of basic plutonic rocks.

METALLOGENIC EPOCHS:

- The geological periods during which mineral deposits were formed in abundance in certain sectors of the globe.
- In India three major metallogenic epochs
- Precambrian epoch
- Late Palaeozoic epoch
- Late Mesozoic to Early Tertiary epoch

- **PRECAMBRIAN EPOCH:** Minerals were formed due to various geological process like igneous activity, sedimentation, metamorphism, weathering etc.,

Important minerals:

1. Iron ore :- Singhbhum (Bihar); Keonjhar,Mayurbunjh & Sundargarh (Orissa); Bastar & Durg (Madhya Pradesh); Shimoga & Chickmanglore (Karnataka) etc.,
2. Chromite:-Singhbhum (Bihar); Keonjhar & Cuttack (Orissa); Mysore & Hassan (Karnataka) etc.,
3. Gold :-Kolar, Hutti & Gadag (Karnataka); Ramgiri & Anantpur (Andhra Pradesh); Wyanad (Tamil Nadu) etc.,

4.Copper :- Singhbhum (Bihar); Ketri (Rajasthan); Malanjkhand (Madhya Pradesh); Agnikundala (Andhra Pradesh) etc.,

5.Manganese:- Balagha (MP); Bhandra & Nagpur (Maharashtra); Karnataka & Gujarat etc.,

6. Lead & Zinc:- Zawar (Rajasthan); Orissa & Gujarat etc.,

- **LATE PALAEOZOIC EPOCH:** Hercynian movement introduce great changes which is marked by mountain building and initiation of sedimentary era.

Important minerals:

1. Rich in coal deposits of lower Gondwana age:- Jharia, Bokaro, Rajhmahal (Bihar);Raniganj (Bengal); Godavari (AP) etc.,

   Intruded by Hypabyssal basic Dolerites, Basalts, Mica rich Ultra basics etc.,

2. Gives other mineral deposits like :- Fire Clay, Iron stone, Ochre etc., in the Gondwana formations

- LATE MESOZOIC TO EARLY TERTIARY: Fissure eruption of Basaltic Lava (Deccan Traps)

Important minerals:

1. Semi precious stones:- rock crystal, Amethyst, Agate, Onyx, Chalcedony etc.,
2. Mineral deposits:- Fluorite, Copper, Lead & Zinc, Chromite, Magnesite, Clay Asbestos etc., (Due to Igneous activity)

- METALLOGENIC PROVINCE:

>A region containing particular type of mineral deposit that has been produced due to mineralisation during one or more metallogenic epochs.

- Gold Province of Karnataka, Andhra Pradesh & Tamil Nadu:
- It covers Gold fields of Kolar, Hutti & Gadag of Karnataka; Ramgiri, Gooty, Bisanatham & Gavanikonda of Andhra Pradesh; Wynad, Cherambadi & Bensibetta of Tamil Nadu.
- Province is occupied by Dharwars, represented by metamorphosed mafic volcanic rocks altered to schistose and Amphibolites later intruded by Dolerite dykes and Pegmatite.
- Characterised by mineralisation of intermediate-late-final stages of development of the mobile belt along the zones

1. Gadag - Chitaldurg - Mysore zone
2. Ramgiri - East Bangalore zone
3. Hutti - Kolar-Mamandur-Vellore-Tirupatti zone

- The Gold is associated with Quartz lodes or Quartz Veins and Sulphide bearing reefs within schist and belongs to high temperature hydrothermal class.

- Copper Province of Singhbhum:
- It is localised in the shear zone, which extends from Duarpuram in west to Barahagora in the southeast.
- Found in margins of Singhbhum Granite massif which intrude the schist, occur as veins in granite and the neighbouring mica-schist, quartz schist and hornblende schist or epidorite.
- Characterised by mineralisation of intermediate-late-final stages of development of the mobile belt along the zones
- The province represent hydrothermal and pegmatitic mineralisation in metamorphosed sedimentary of greywacke suite and associated metavolcanics.

>Iron Province of Chanda - Durg - Bastar:

- This represent metamorphosed flysch type association with banded-hematite-quartzite of early stage of development of mobile belt.

>Iron Province of Karnataka - Goa:

- This represents sedimentary metamorphic deposits formed during the early stage of development of mobile belt
- Important occurrence are found at Bellary-Hospet, Shimoga, Chitradurga, Chickmanglur, Kudramukh and Bhabudan Hills
- Banded - Hematite - Quartzite type of iron ores found predominantly
- Magnetite iron ore is found in Tumkur area, which is of magmatic deposit formed during early crystallization of basic plutonic rocks.

>Manganese Province of Balaghat - Bhandara - Nagpur:

- This province falls in Madhya Pradesh and Maharashtra
- Represent gondite type of deposit associated with metamorphosed Dharwar rocks.

CASSIFICATION OF MINERAL DEPOSITS

- Mineral deposits are generally classified on the basis of their origin

1. Primary or Hypogene deposits: Formed at depth due to magmatic action, assending solution etc under heat and pressure
2. Secondary or Supergene deposits: Formed at or near the surface due to weathering, descending solutions and surface waters

- Classification appeared during middle of 19th century
- Based on the Vein : Von Wissenbach, Von Cotta and Le Conte.
- Based on the Form : Von Cotta, Prime, Koheler, Cailon and Lottner-Serlo.
- Based on the Origin: Grim, Von Groddeck, Pumpelly etc.,
- Around beginning of 20th century more logical classification on the basis of origin was proposed by various authors.

BECK (1904)

>Primary

A. Syngenetic

- Magmatic
- Sedimentary

B. Epigenetic

- Veins
- Not Veins

>Secondary

- Residual
- Placers.

BERGEAT-STELZNER (1904)

> Prototype

A. Syngenetic

- with erruptive rocks
- with sedimentary rocks

B. Epigenetic

- Cavity fillings
- Replacements

> Secondary

- Residual
- Placers

- IRVING (1908)

> Bed Rock Deposits

A. Syngenetic

- Igneous
- Sedimentary

B. Epigenetic

- Cavity fillings
- Replacements
- Contact metamorphic

> Disintegration Deposits

- Mechanical
- Chemical

- Lindgren in 1911 proposed genetic classification.

I. Deposits by mechanical processes.

II. Deposits by chemical processes.

	TEMP	PRES
A. In surface waters		Med
By reaction	0 - 70	to
evaporation		High
B. In bodies of rocks		
1. concentration of substance contained within rocks.		
By weathering	0 - 100	Med
By ground water	0 - 100	Med
By metamorphism	0- 400	High

2. By introduced substances

without igneous activity	0- 100	Med
related to igneous activity	0 – 100	Med
>By ascending waters		
Epithermal deposits	50 - 100	Med
Mesotherrmal deposits	200 - 500	+ High
Hypothermal deposits	500 - 600	+ High
>By direct igneous emanations		
Pyrometasomatic	500 - 800	High +
Sublimates	100-600	Low -Med

C. In Magmas by defferentation

Magamtic deposits	700 - 1500	High +
Pegmatites	575 +	High

- Niggli in 1925 introduced a new major classification

> Plutonic

A. Hydrothermal

B. Pegmatitic-Pneumatolyic

C. Orthomagmatic

>Volcanic

A. Exhalative to hydrothermal

B. Pneumatolytic

C. orthomagmatic

- Schneiderhohn in 1932 introduced his classification

A. Magmatic rocks and ore deposits

(a) Intrusive magmatic

- Intrusive rocks and liquid magmatic deposits
- Pneumatolytic
- Pegmatite veins
- Pneumatolytic veins and impergnations
- contact Pneumatolytic
- Pneumatolytic - hydrothermal
- Hydrothermal

(b) Extrusive magmatic

- Extrusive hydrothermal
- Exhalation

B. Sedimentary deposits

- Weathered zone (oxidation and enrichment)
- Placers
- Residuals
- Biochemical
- Salts
- Fuels
- Descending groundwater deposits

C. Metamorphic deposits

- Thermal contact metamorphism
- Metamorphic rock
- Metamorphosed ore deposits
- Rarely formed metamorphic deposits

- Bateman (1942, 1950) and modified by Jensen (1981) proposed a simple classification.

PROCESS	DEPOSITS	EXAMPLE
1. Magmatic concentration		
High P and T	I. Early magmatic	
	Disseminated crystallisation	Diamond pipes
	Segregation	Chromite
	Injection	
	II.Late Magmatic	
	Residual liquid segretation	magnetite
	Residual liquid injection	magnetite& pegmatite
	Immiscible liquid segregation	Sulphides
	Immiscible liquidinjection	Sulphides
2.Sublimation Low T & P	Sublimates	Sulphur

3.Contact Metasomatism

Int, Low, High T & P	Contact metasomatic	Iron, Copper, Gold

4. Hydrothermal

Low to High T & P

Telethermal

Epithermal

Leptothermal

Mesothermal Xenothermal

Hypothermal

A Cavity filling	a. Fissure Veins	Gold,Silver,Copper, Lead & Zinc
	b. Shear-Zone deposits	Gold with Pyrite
	c. Stock works	Gold,Silver,Tin
	d. Ladder Veins	Gold
	e. Saddle-reefs	Gold
	f. Tension crack fillings (pitches & flats)	
	g. Breccia fihlings,volcanic,tectonic collaps	Zinc
	h. Solution cavity fiuings,caves & channels, gash veins	Lead & Zinc
	i. Pore space fillings	
	j. Vesicular fillings	Copper
B. Replacement	a. massive	Copper
Low to High T & P	b. Lode fissure	Gold
c. Disseminated		Copper

5. Sedimentation (Exclusive of evaporation)Low T&P	Sedimentary	Iron, Manganese, Ph
6. Bacteriogenic	Bacterial products or Reduction	Sulphur
7.Submarineexhalative volcanism Low to High T & P	Submarine Volcanic	Manganese nodules
8. Evaporation Low T & P	Evaporates	
	a. Marine	Gypsum, salt, potash
	b. Lake	sodium carbonate, borate
	c. Ground water	Nitrates
9.Residual & mechanical con Low T & P		
A. Residual concentration	Residual deposits	Iron,Manganese,Bauxite
B. Mechanical concentration	Placers	
	Stream	
	Beach	Gold
	Fluvial	Tin
	Aeolian	Gold
1O.Surficial Oxidation & Supergene enrichment Low T&P	Oxidized supergene	sulphide Copper
11.Metamorphism	a. Metamorphosed deposits	Graphite, Asbestos
Int. to High P & T	b. Metamorphic deposits	Garnet, Sillimanite