

# **Exploration Geochemistry**

## **Introduction**

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**Lecture 1**

# Exploration Geochemistry

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- ▶ Geochemical prospecting for minerals defined as any method of mineral exploration based on systematic measurement of one or more chemical properties (measured the trace content of some element or group of elements ) of a naturally occurring material (rock, soil, glacial debris, vegetation, stream or lake sediment, water or vapor).
- ▶ The purpose of the measurements is the discovery of abnormal chemical patterns, or geochemical anomalies, related to mineralization.
- ▶ The goal of every exploration is to find clues that will help in locating hidden ore.



# Exploration Geochemistry

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- ▶ Exploration encompasses almost all data gathering.
  - ▶ Don't limit the geochemical point-of-view to one discipline if others may be relevant. Conclusions must be reasonable in light of other data and information: Geology, Temperature, Well data, Geophysics.
  - ▶ **Objectives (Application):**
    1. **Commercial:** Does the proposed study have a reasonable chance of assisting a project decision (resource assessment, drilling, finance, etc.) in a way that other information could not?
    2. **Academic/Scientific:** articles, thesis, and community service.
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# Scope (Scales) of Exploration

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1. **Reconnaissance survey:** the purpose is to search a relatively large area for indications of ore. The spacing and type of samples are chosen to detect but not necessarily outline favorable orebodies with as **few samples** and at as **low a cost as possible**.
  - ▶ The aim in a reconnaissance survey is to
    1. Determine the mineral possibilities of a relatively large area.
    2. Eliminate the barren ground.
    3. Draw attention to locate areas of interest.
  - ▶ Areas of tens to thousands of square kilometers are evaluated during reconnaissance surveys, often with no more than one sample per 1-100 square kilometers.



# Scope (Scales) of Exploration

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2. **Detailed survey:** the purpose is to outline mineralized ground and to pinpoint the mineralized source with the greatest possible precision, preparatory to physical exploration by trenching, drilling, or underground work.
  - ▶ In order to localize the bedrock source, is usually required a relatively **close sample spacing, normally between 1-100 m.**
  - ▶ The application of detailed surveys is mostly restricted to limited areas of particular interest, selected on the basis of other geochemical, geological, or geophysical information because of **high cost.**
  - ▶ The anomalies should be well defined and should occur in close proximity to the ore.
3. **Orientation survey:** is the key aspects of planning to evaluate which techniques are effective for the commodity sought and in the area of search.



# Scope (Scales) of Exploration

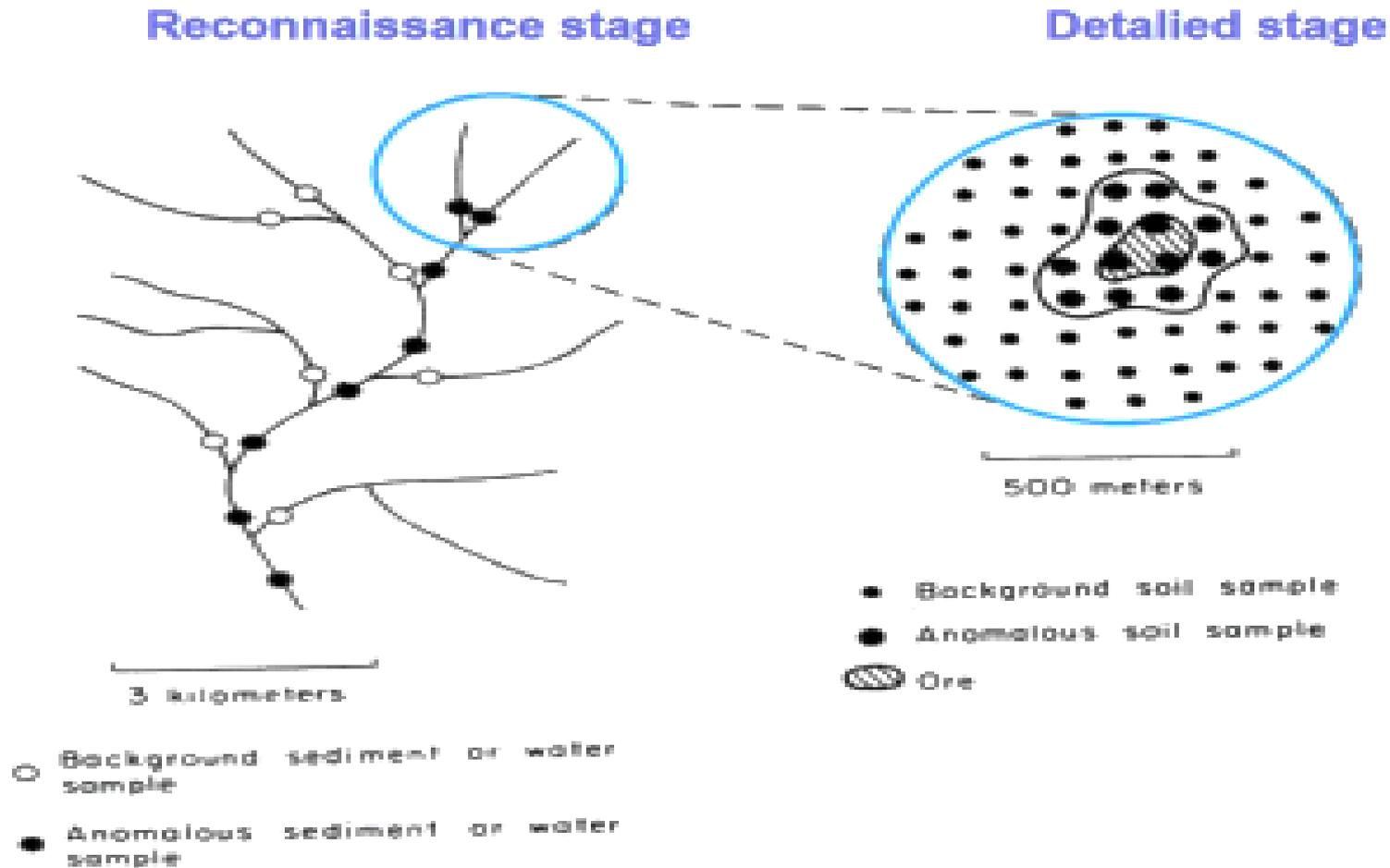


Fig: Reconnaissance exploration using stream sediment or water, as contrasted to detailed exploration using soils.

# Techniques: Data Basics

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- ▶ Too much data rarely the problem
- ▶ Wrong data can be a problem
- ▶ Thorough and disciplined record-keeping
- ▶ Location: GPS
- ▶ Maps of results and synthesis of data at common scale
- ▶ Generation data: during data gathering and during data analysis
- ▶ Data management



# Geochemical Program

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- ▶ A geochemical program can be divided into the following phases:
    1. Planning: The choice of the field survey technique and the analytical methods depends on the commodity sought and its location.
    2. Sampling: Samples should be collected in nonmetallic containers to avoid contamination.
    3. Chemical analysis: Most analysis is aimed at the determination of the elemental concentrations in a sample and usually of trace metals.
    4. Interpretation: this will involve the use of statistical analysis on a computer.
    5. Follow-up: the application of various geochemical techniques.
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# The Geochemical Environment

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- ▶ The earth is a dynamic system in which materials are moved from place to place and changed in form and composition by a variety of processes, including melting, crystallization, erosion, dissolution, precipitation, vaporization and radioactive decay.
- ▶ The behavior of matter in this system is extremely complex. The geochemical environment defined by pressure, temperature, and availability of the most abundant chemical components, determines the stability of mineral and fluid phases at any given point.
- ▶ On the basis of differences in pressure, temperature, and chemistry, the geochemical environments of the earth can be classified into major groups:
  1. **Deep-seated environment**
  2. **Surficial environment**



# The Geochemical Environment

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1. **The Deep-seated environment** extends downward from the lowest levels reached by circulating surface water to the deepest level at which normal rocks can be formed. Magmatic and metamorphic processes predominate in this zone.
    - ▶ It is an environment of **high temperature and pressure, restricted circulation of fluids, and relatively low free-oxygen content. Most ore formed.**
    - ▶ Volcanic phenomena, hot springs, and similar features can generally be included with the deep-seated environment.
    - ▶ The terms “**hypogene, primary, and endogenic**” have been used by some workers to refer to phenomena in this environment.
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# The Geochemical Environment

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2. **The Surficial environment** is the environment of weathering, erosion, and sedimentation at the surface of the earth.
- ▶ It is characterized by **low temperatures, nearly constant low pressure, free movement of solutions, and abundant free oxygen, water, and CO<sub>2</sub>. Most ore destroyed.**
  - ▶ The terms “**supergene, secondary, and exogenic**” have also been used to refer to processes in this environment.

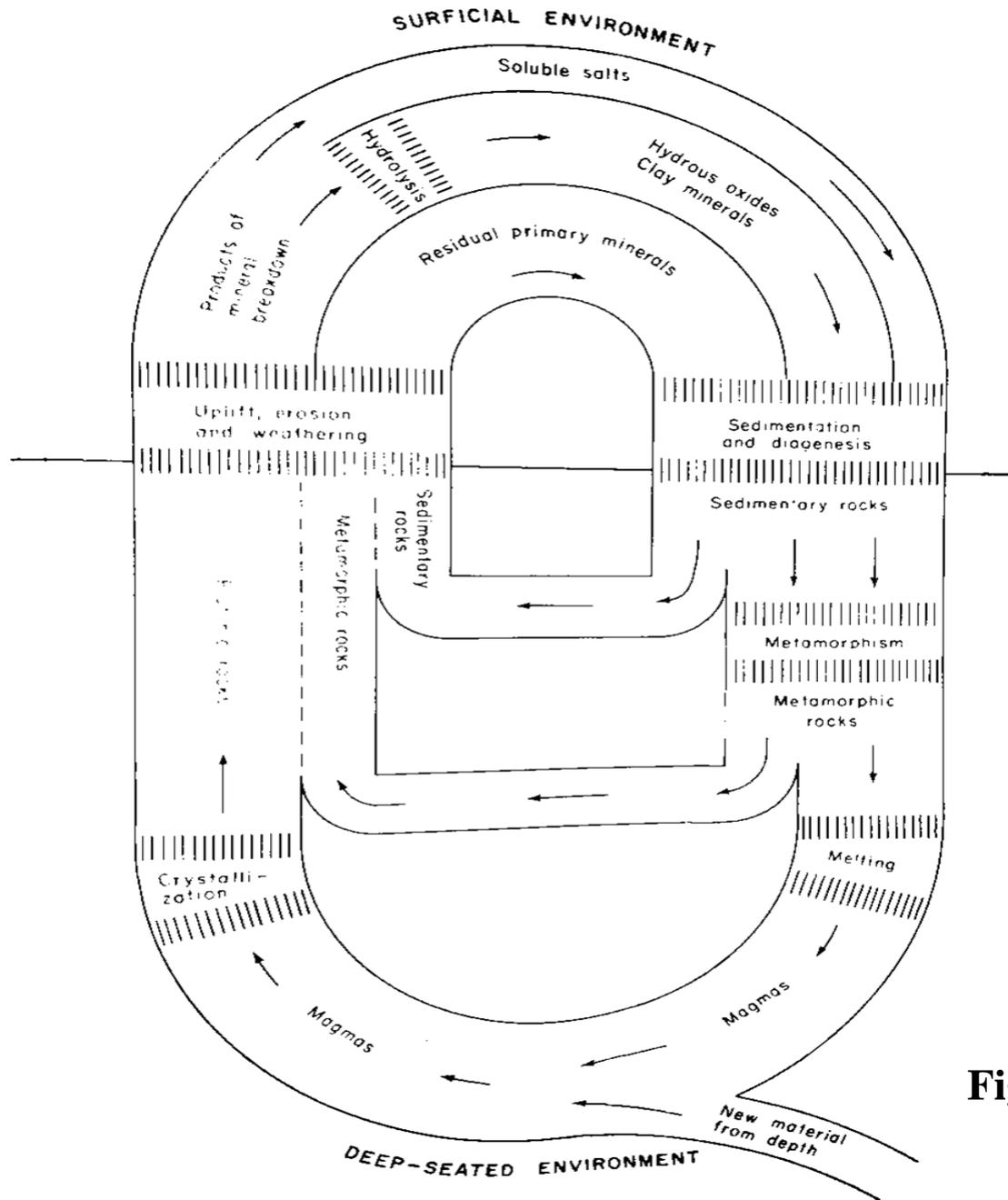


# The Geochemical Cycle

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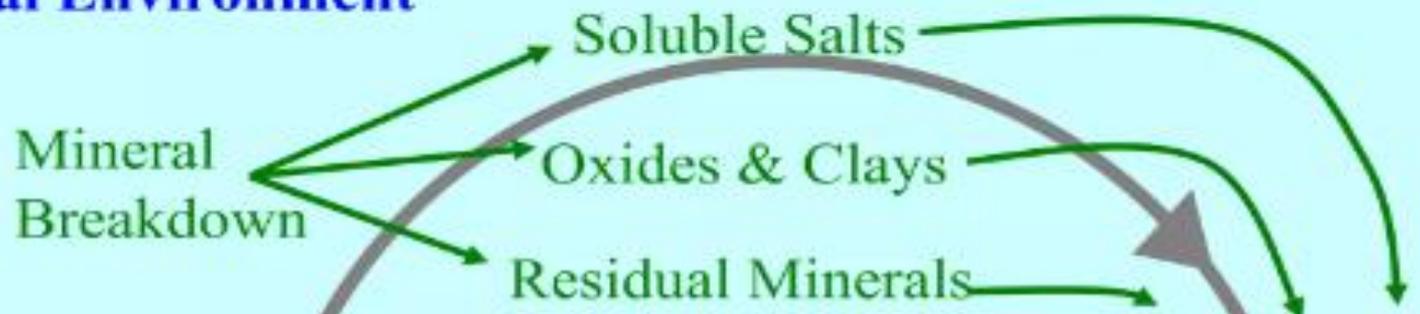
- ▶ The movement of earth materials from one environment to another can be conveniently visualized in terms of a closed cycle defined as geochemical cycle.
- ▶ This cycle starting on the right-hand side of the diagram and moving clockwise, sedimentary rocks are progressively metamorphosed as they are subjected to increasing temperature, pressure, and increments of new materials from outside the system.
- ▶ They may eventually attain a state of fluidity such that on recrystallization they can differentiate into various kinds of igneous rocks and hydrothermal extracts.
- ▶ When erosion brings the resulting suits of rocks into the surficial environment again, the component elements are redistributed by weathering agencies. A new series of sedimentary rocks is then deposited, and the cycle is closed.





**Fig: The Geochemical Cycle**

**Surficial Environment**



Uplift  
Erosion

Sedimentation  
Diagenesis

Hydrothermal Ores  
Igneous Rocks  
Magmatic Ores

Sedimentary Rocks  
Sedimentary Ores

Crystallization

Metamorphism

Metamorphic Rocks  
Metamorphic Ores

Magma

Melting

Mantle  
Material

**Deep-Seated Environment**



**Fig: The Geochemical Cycle**

# The Geochemical Cycle

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- ▶ This figure is highly simplified, as in reality large parts of the cycle may be missing in any given case, as suggested by arrows in the center of the diagram.
  - ▶ For example, for sedimentary sandstone and shale to be exposed to weathering and erosion without remelting or even significant metamorphism.
  - ▶ Furthermore, this major cycle incorporates several important minor cycles, such as the circulation of carbon from the air into living plants, animals, organic deposits, and back into the air again.
  - ▶ The geochemical cycle embraces both the deep-seated and the surficial processes. The horizontal division in the diagram indicates the boundary between these two sectors of the geochemical cycle.
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# The Geochemical Dispersion

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- ▶ A given small mass of material in the earth normally does not maintain its identity as it passes through the major transformations of a geochemical cycle, but rather **tends to be redistributed, fractionated, and mixed with other masses of material**. This process, in which **atoms and particles move to new locations and geochemical environments**, is called **geochemical dispersion**.
- ▶ Nearly all dispersion occurs in dynamic systems in which earth materials are undergoing changes in chemical environment, temperature, pressure, mechanical strain, or other physical conditions.
- ▶ The rocks or minerals stable in one environment and the grains or atoms contained in them are released to be dispersed by either chemical or mechanical processes. Generally decreasing the concentration by spreading it over a large volume.



# The Geochemical Dispersion

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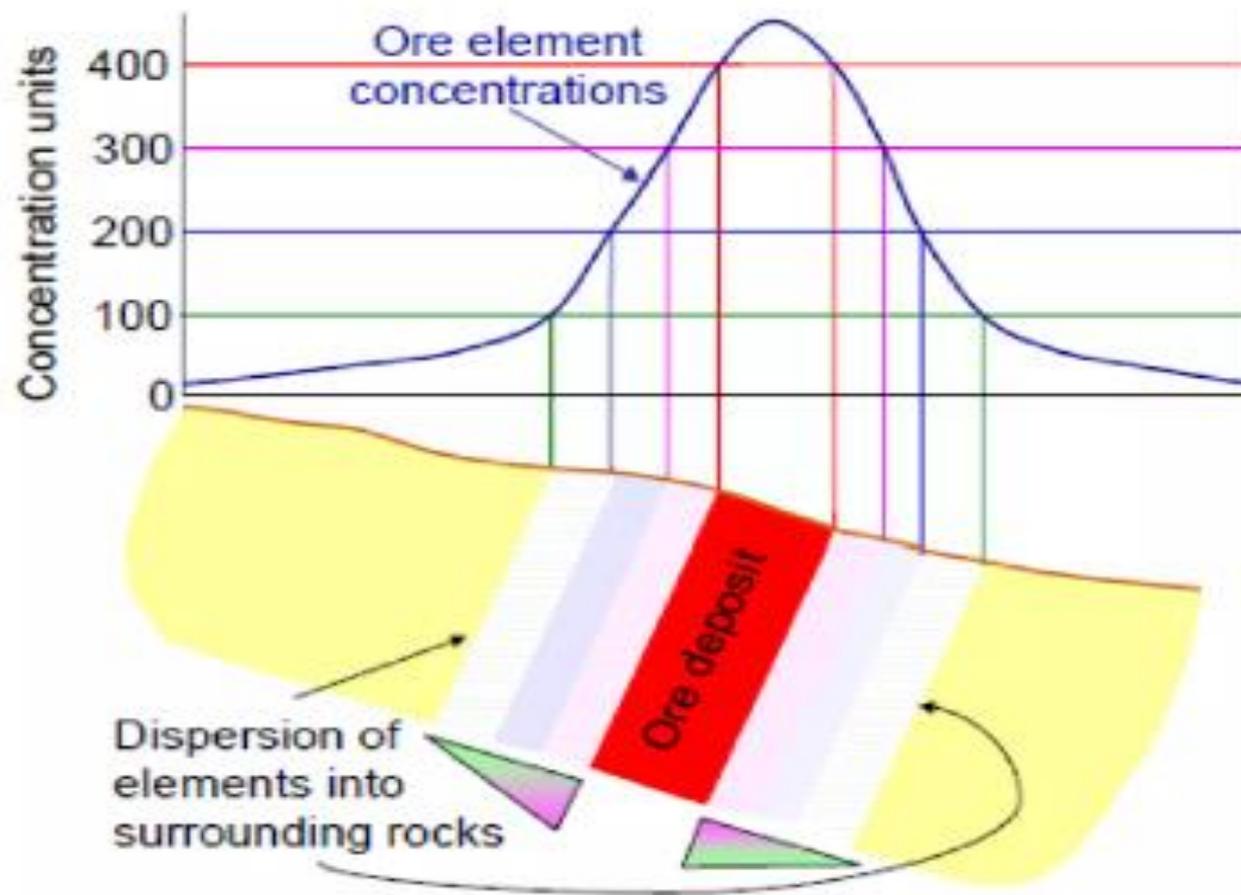


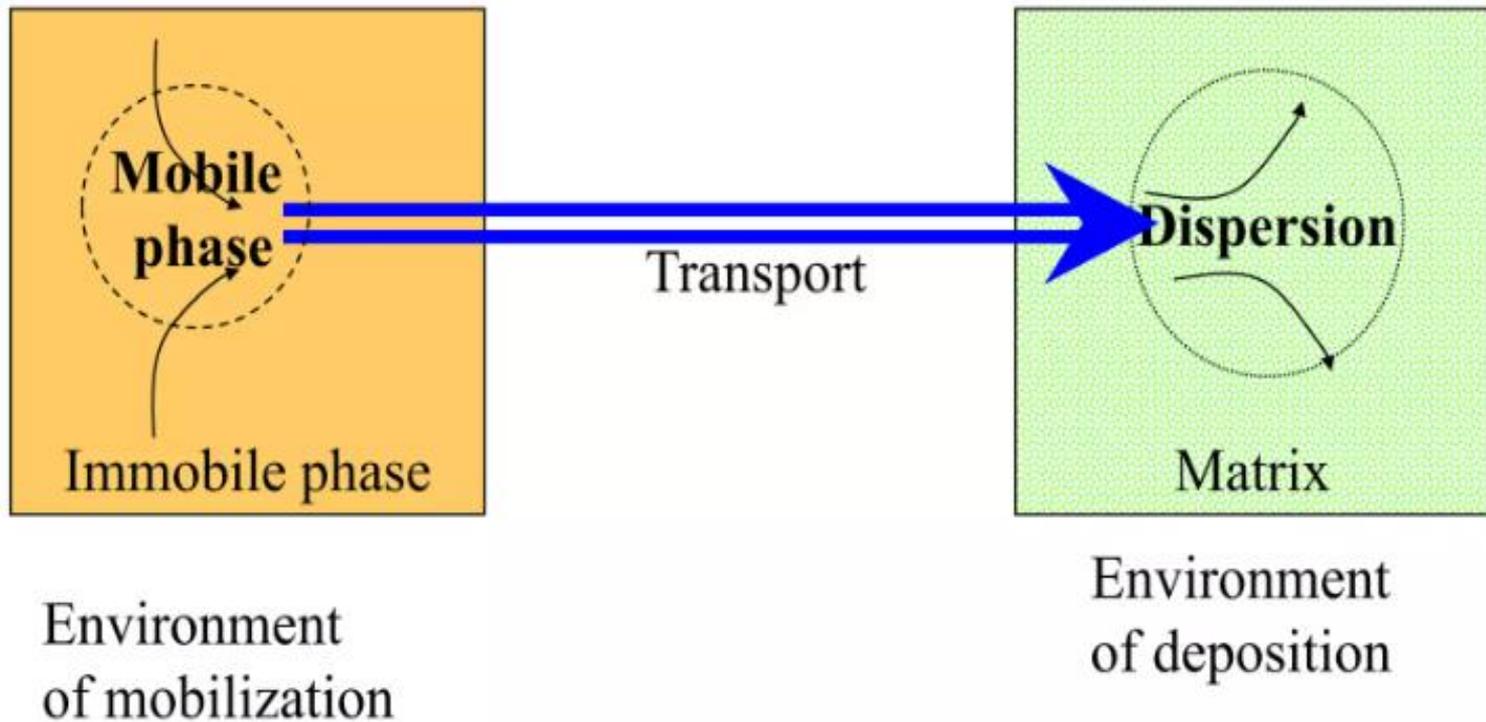
Fig: Concentration of elements distribution by dispersion

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# The Dispersion process

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# Agents of Dispersion

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## Mechanical

Examples:  
Magma injection,  
glacial transport,  
alluvial sorting

Results:  
Mixing  
Fractionation  
not common

## Chemical- biochemical

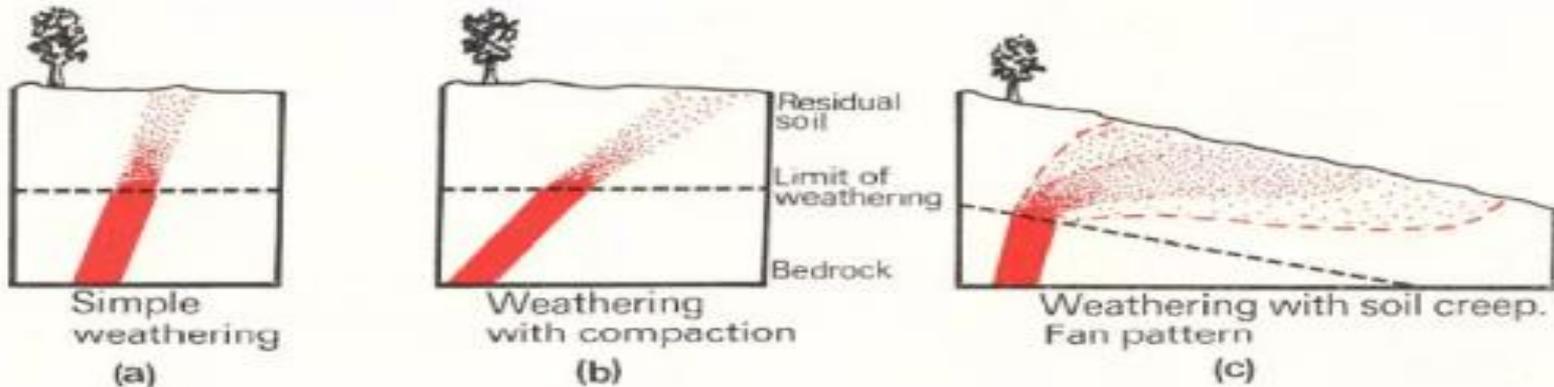
Examples:  
dissolution/dep  
osition,  
melting/crystall  
ization

Results:  
Fractionation  
common  
Mixing  
dilution

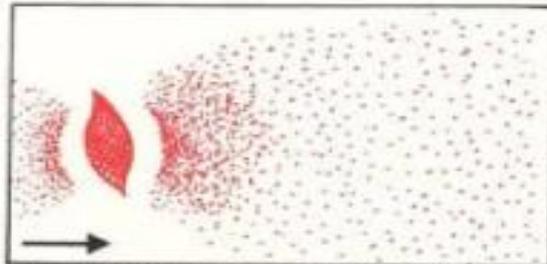
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# Types of Dispersion

1. **Clastic dispersion** : solid particles moved physically.  
Prevailing agents are soil creep and wind.



Plan



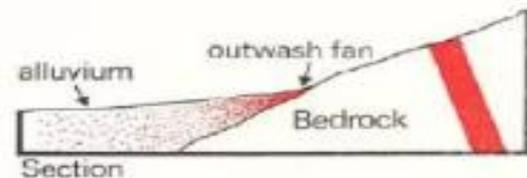
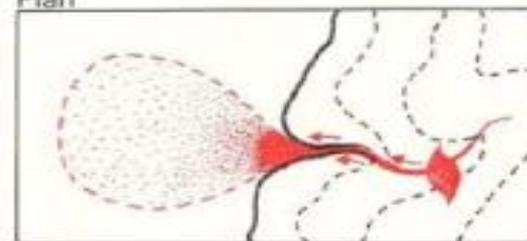
Prevailing wind direction

Section



Fan pattern by wind action

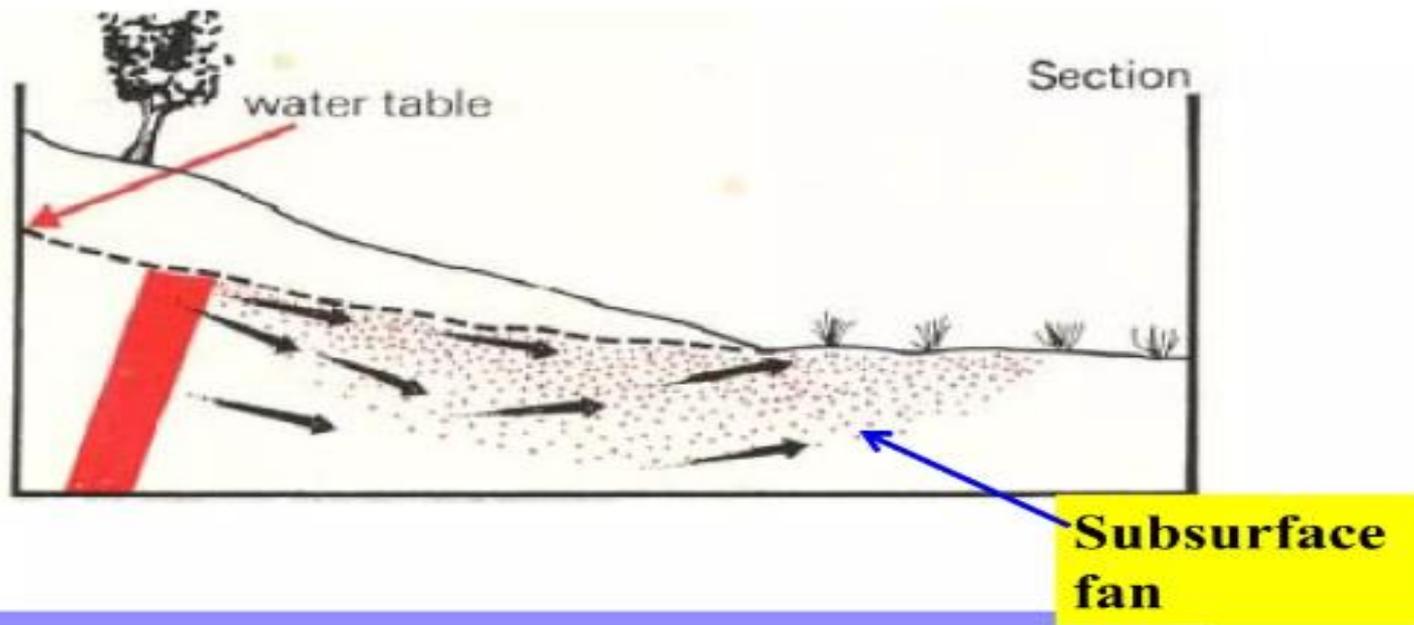
Plan



Section

# Types of Dispersion

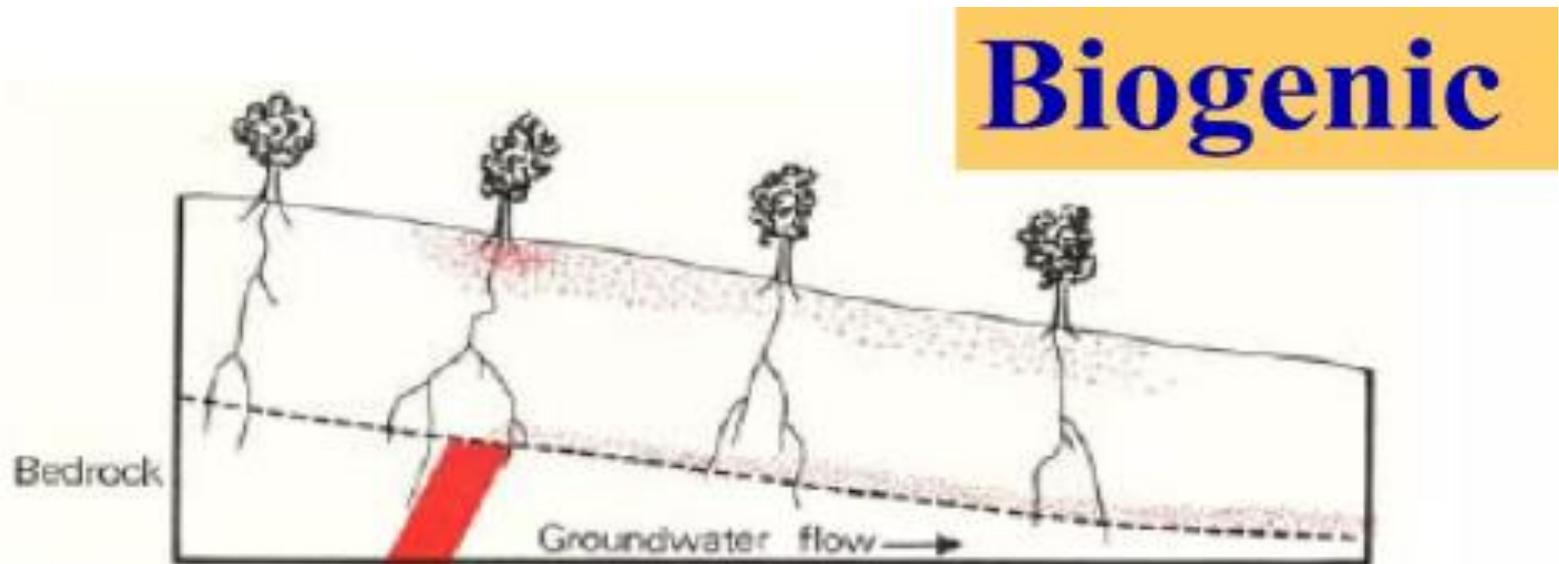
2. **Hydromorphic dispersion:** solid particles dissolved in water and transported in chemical solution.



Dispersion by lateral groundwater flow- hydromorphic

# Types of Dispersion

3. **Biogenic dispersion:** solid particles moved by biological activities. Elements are dissolved by groundwater in contact with the ore vein; and are transported in solution in the direction of groundwater flow. Plant roots take up nutrients from the water solution.



# Stages of Dispersion

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1. **Primary dispersion:** includes all processes leading to emplacement of elements during the formation of an ore deposit, no matter how the orebody was formed. Examples; diffusion of metals into wallrock around hydrothermal deposit during ore deposition in deep-seated environment, and precipitation of traces of metals on sea floor near a volcanogenic deposit in surficial environment. The main media of survey are rocks.
2. **Secondary dispersion:** applies to the redistribution of the primary patterns by any later process, usually in the surface environment. Examples; diffusion of metals from ore deposit undergoing metamorphism in deep-seated environment, and weathering of ore deposit in surficial environment. Media of survey are soil, stream, sediments, water, air, plants and animals.