B.Sc. Sem-V, Paper I (Sedimentology), unit- 1

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Introduction and origin of Sedimentary rocks

The term sedimentology was defined by Wadell (1932) as "the study of sediments." Sediments have been defined as "what settles at the bottom of a liquid; dregs; a deposit" *(Chambers Dictionary*, 1972 edition). Neither definition is wholly satisfactory. Sedimentology is generally deemed to embrace chemical precipitates, like salt, as well as true detrital deposits. Sedimentation takes place not only in liquids, but also in gaseous fluids, such as eolian environments. The boundaries of sedimentology are thus pleasantly diffuse.

Sedimentary rock, rock formed at or near the Earth's surface by the accumulation and lithification of sediment (detrital rock) or by the precipitation from solution at normal surface temperatures (chemical rock). Sedimentary rocks are the most common rocks exposed on the Earth's surface but are only a minor constituent of the entire crust, which is dominated by igneous and metamorphic rocks.

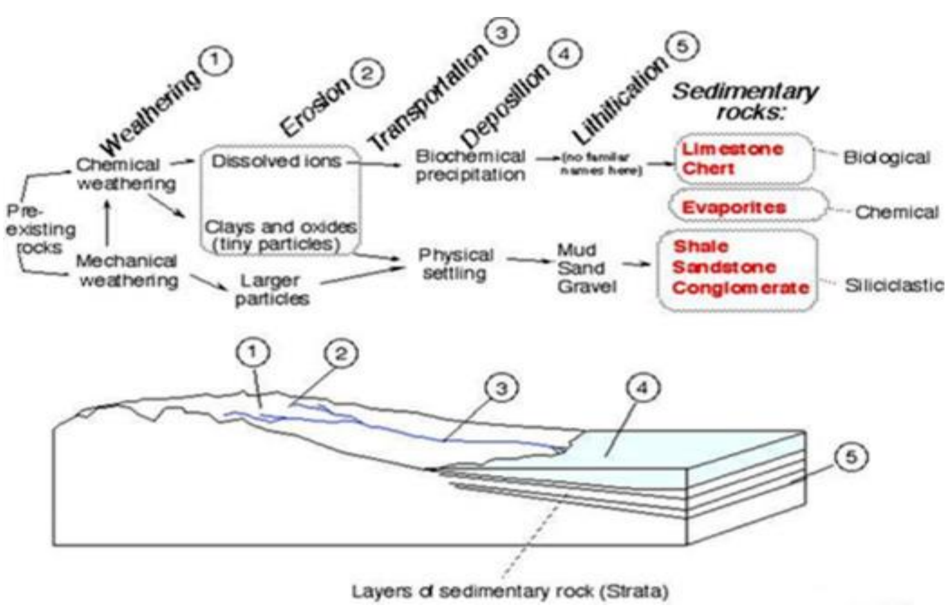

Figure 1 Sedimentary Process

Sedimentary rocks form at low temperatures and pressures at the surface of Earth owing to deposition by water, wind, or ice. By contrast, igneous and metamorphic rocks form mainly below Earth's surface where temperatures and pressures may be orders of magnitude higher than those at the surface, although volcanic rocks eventually cool at the surface. These fundamental differences in the origin of rocks lead to differences in physical and chemical characteristics that distinguish one kind of rock from another. Sedimentary rocks are characterized particularly by the presence of layers, although layers are also present in some volcanic and metamorphic rocks, and by distinctive textures and structures. Many sedimentary rocks are also distinguished from igneous and metamorphic rocks by their minerals, chemical compositions and fossil content.

Sedimentary rocks cover roughly three-fourths of Earth's surface. They have special genetic significance because their textures, structures, composition, and fossil content reveal the nature of past surface environments and life forms on Earth. Thus, they provide our only available clues to evolution of Earth's landscapes and life forms through time. These characteristics of sedimentary rocks are in themselves reason enough to study sedimentary rocks. In addition, many sedimentary rocks contain minerals and fossil fuels that have economic significance. Petroleum, natural gas, coal, salt, phosphorus, sulfur, iron and other metallic ores, and uranium are examples of some of the extremely important economic products that occur in sedimentary rocks.

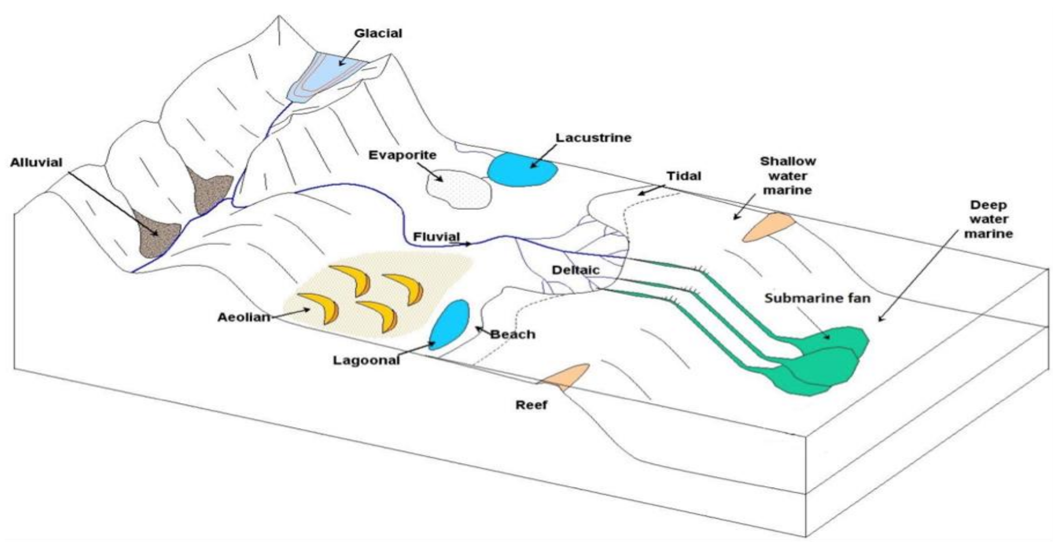

Figure 2 some of the important depositional environments for sediments and sedimentary rocks

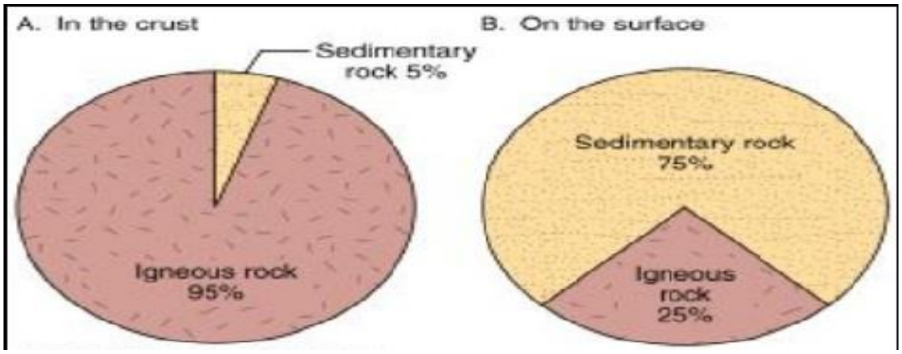

Figure 3 Percentage of Sedimentary rocks

Formation of Sedimentary Rocks

Sedimentary rocks are the product of

1) **Weathering** of preexisting rocks,

2) **Transport** of the weathering products,

3) **Deposition** of the material, followed by

4) **Compaction**

5) **Cementation** of the sediment to form a rock. The latter two steps are called *lithification*.

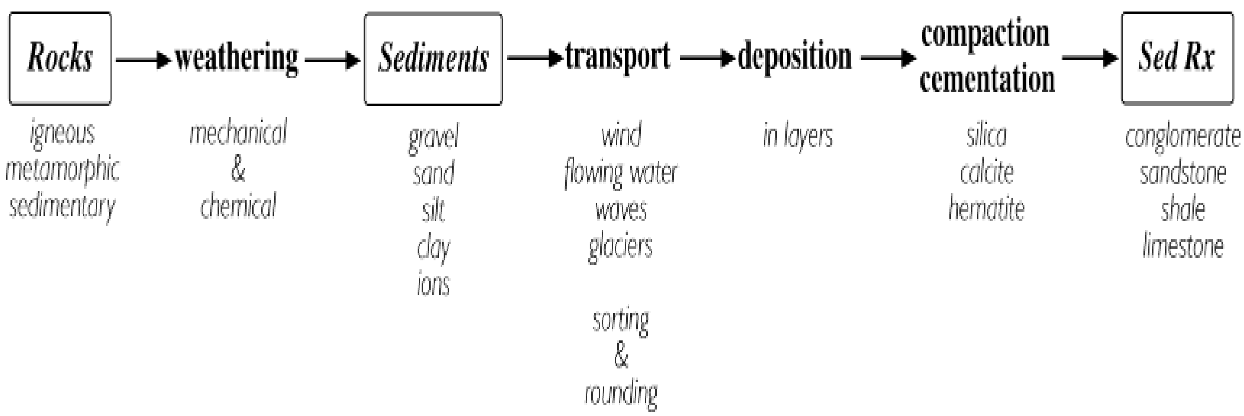

Figure 4 Steps of Formation of Sedimentary Rocks

Weathering

When rocks (igneous, sedimentary, or metamorphic) are at or near the surface of the earth they are exposed to the processes of weathering.

In **mechanical weathering** rocks are broken up into smaller pieces by frost-wedging (the freezing and thawing of water inside cracks in the rock), root-wedging (tree and other plant roots growing into cracks), and abrasion caused by, for example, sand-blasting of a cliff face by blowing sands in the dessert, or the scouring of water transported sand, gravel, and boulders on the bedrock of a mountain stream. Mechanical weathering breaks rocks into smaller and smaller pieces but without otherwise altering the minerals.

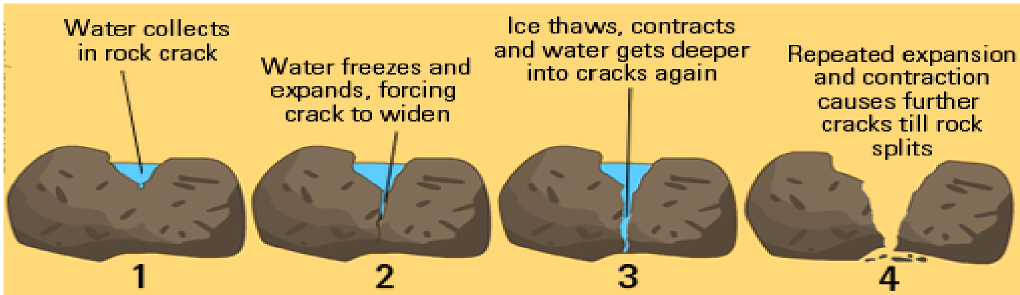

Figure 5 Physical weathering

In **chemical weathering** minerals are changed into new minerals and mineral byproducts. Some minerals like halite and calcite may dissolve completely. Others, especially silicate minerals, are altered by a chemical process called ***hydrolysis***. Hydrolysis is the reaction of minerals in weakly acidic waters. Most natural surface waters are slightly acidic because carbon dioxide from the air dissolves in the water. Some of the dissolved CO2 reacts with the water forming the chemical compound ***carbonic acid.***

Figure 6 Chemical weathering

Complete weathering of silicate rocks will yield:

solid materials	1) **clays**

	2) **quartz sand** (if the rock originally contained quartz)
dissolved materials	3) **soluble silica**
	4) **metal cations**

Stability of Minerals	Rate of Weathering
MOST STABLE	Slowest
Iron oxides (hematite)	↓
Aluminum hydroxides (gibbsite)	
Quartz	
Clay minerals	
Muscovite mica	
Potassium feldspar (orthoclase)	
Biotite mica	
Sodium-rich feldspar (albite)	
Amphiboles	
Pyroxene	
Calcium-rich feldspar (anorthite)	
Olivine	
Calcite	
Halite	
LEAST STABLE	Fastest

Figure 7 Relative stabilities of Common Minerals Under weathering

Rock fragments will also remain where the rocks are not completely weathered.

Not only is quartz the most stable of the common rock forming minerals in chemical weathering, its high hardness and lack of cleavage make it quite resistant to mechanical weathering. Quartz is itself an agent of mechanical weathering in the form of blowing dessert sand.

Transport

As the process of weathering proceeds the products are carried off. The most important transporting agent is water. Water carries or rolls particles in rivers, from the smallest suspended clay particles to the largest boulders. Boulders and smaller rock fragments continue to be broken up and chemically altered as they tumble downstream. Water also carries dissolved minerals, such as silica and cations downstream as well as in the groundwater. Other transporting agents include wind which blows dust and sand, glaciers, which carry large amounts of gravel and huge boulders in addition to smaller particles, and mass wasting on hill slopes. In addition to decreasing the particle size, as sedimentary material is transported it is also **sorted** into similar sized particles as a result of changing energy (velocity) in the transporting medium (water or wind), and **rounded** by continued abrasion**.**

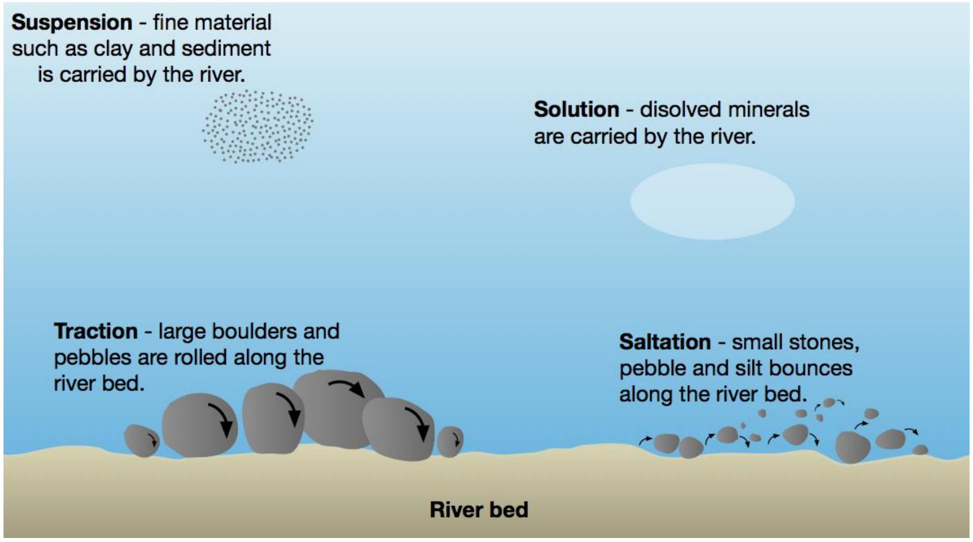

Figure 8 Transportation

Deposition

Sediments are transported only when there is enough energy in the transporting medium, for example, when a stream is flowing rapidly enough to carry a given size of sedimentary particle. Steep mountain streams can move large boulders during spring flood but these boulders will never be transported out into a placid lowland river. So the largest sediments (boulders, cobbles, and pebbles) which survive the weathering process tend to be deposited near to their source, for example at the point where a mountain stream flows out onto a valley floor. Sediments of a given size are deposited whenever they move into an environment with insufficient energy to transport them. For example, silt carried by a flooding river will settle out in the quiet backwaters outside the river banks (perhaps enriching someone's farmland - while wrecking their home).

Sediments are deposited layer upon layer. The layers are deposited horizontally.

Sorting: When a river encounters the ocean it begins to deposit its suspended sediments. Progressively finer sediments are deposited moving away from the shoreline. All fine materials are winnowed out leaving sands in the wave-dominated beach and near shore environment. The sands remain in this high energy environment. In deeper/calmer water silt settles out. In water deep enough not to be affected by surface wave action the clay fraction begins to settle out.

The dissolved load in water will precipitate out (crystallize) if it encounters a supersaturated environment. Gypsum, halite, and other salts, precipitate out of seawater in arid areas, like the eastern Mediterranean, where evaporation is high (thus increasing the salinity) and influx of fresh seawater is low.

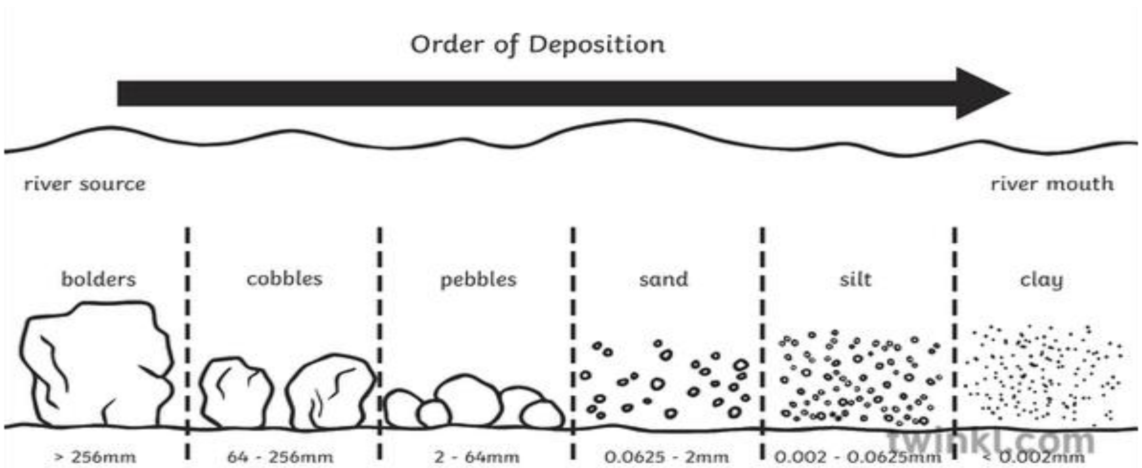

Figure 9 Deposition

DIAGENESIS

Diagenesis is the term used for all of the changes that sediment undergoes after deposition and before the transition to metamorphism. The multifarious processes that come under the term diagenesis are chemical, physical, and biological. They include compaction, deformation, dissolution, cementation, authigenesis, replacement, recrystallization, hydration, bacterial action, and development of concretions. (Soft-sediment deformation can be included in diagenesis, but not hard-rock folding and faulting.)

The two most important diagenetic processes are compaction (the topic of a later section), and lithification, the term used for the complex of processes— including compaction—by which a loose sediment is converted into a solid sedimentary rock. A variety of processes mentioned or described in later sections of this chapter contribute to the general process of lithification.

Compaction and Cementation

As sedimentation continues, the earlier deposited sediments are laden with an increasing overburden. They are compacted, reducing the available pore space and expelling much of the pore-water.

Dissolved minerals in the ground water precipitate (crystallize) from water in the pore spaces forming mineral crusts on the sedimentary grains, gradually cementing the sediments, thus forming a rock. **Calcite** (calcium carbonate), **silica**, and **hematite** (red iron oxide) are the most common cementing agents. You may be familiar with calcite (or lime) encrustation on old plumbing fixtures, showerheads, and inside hot water heaters.

Cementation by calcite cements commonly occurs in the deeper parts of freshwater aquifers in the phreatic zone. Saturation is achieved with respect to calcite as a result of dissolution of more soluble aragonite and magnesian calcite in more up dip locations, closer to the recharge area of the aquifer. As fluids move progressively downdip, they dissolve more and more aragonite and magnesian calcite until the fluid approaches saturation with respect to those phases. Because the solubility of pure calcite is lower than that of Mg-calcite or aragonite, however, the fluid at that point is supersaturated with respect to calcite and precipitates calcite rim cements. Rim cements (that is, those that encrust all exposed grain surfaces) are characteristic of cementation in the phreatic zone. Rim cements generally have a blocky habit.

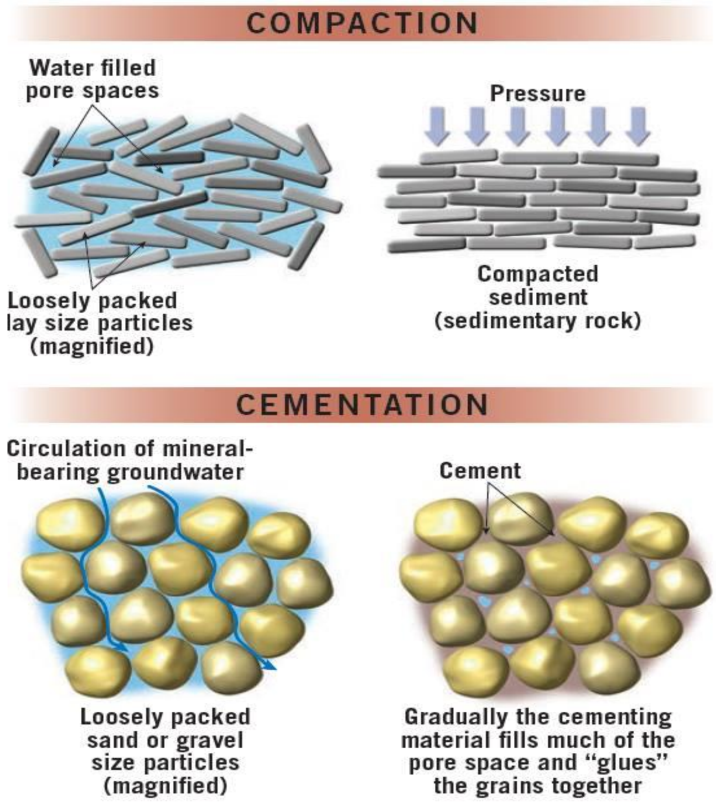

Figure 10 Compaction and Cementation

Replacement

Carbonate petrologists have long recognized that some carbonate particles. like ooids or shells, or unstable marine cements that were originally sediments, are now different in both crystal size and mineralogy. This realization follows from recognition of ghosts of the primary mineral, represented by inclusions, pseudomorphs, or reproduction of an original outline. (A pseudomorph is a mineral whose outward crystal form is that of another mineral, owing to some process that changed the mineral composition without changing the crystal geometry).

This process of replacement is commonly called neomorphism. Neomorphism includes the diagenetic processes in which older crystals, whether abiotic or biogenic in origin, are consumed and in their place simultaneously occupied by new crystals of the same mineral or a polymorph.