SEDIMENTOLOGY&STRATIGRAPHY

COMPOSITION OF SEDIMENTS AND SEDIMENTARY ROCKS

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1.0 Introduction

Sedimentary rocks are types of rock that are formed by the deposition of material at the earth's surface and within bodies of water. Sedimentation is the collective name for processes that cause mineral and/or organic particles (detritus) to settle and accumulate or minerals to precipitate from asolution. Particles that form a sedimentary rock by accumulating are called sediment. Before being deposited, sediment was formed by weathering and erosion in a source area, and then transported to the place of deposition by water, wind, ice, mass movement or glaciers which are called agents of denudation (Sengupta, 2007).

weathering → erosion/transport → deposition/precipitation → lithification.

The science that deals with the properties and origin of sedimentary rocks is called 'Sedimentology'. Sedimentology is both part of geology and physical geography and forms part of paleontology, pedology, geomorphology, geochemistry or structural geology. Composition of sedimentary rocks is defined in terms of mineralogical or chemical constituents. With texture and structure, composition makes aggregate characteristic of a rock. Composition is the basis for grouping of sediments into respective classes. In the classification of sedimentary rock, composition is the first component preceding texture and structure. During the process of transportation significant changes take place in sediments (Fig. 1).

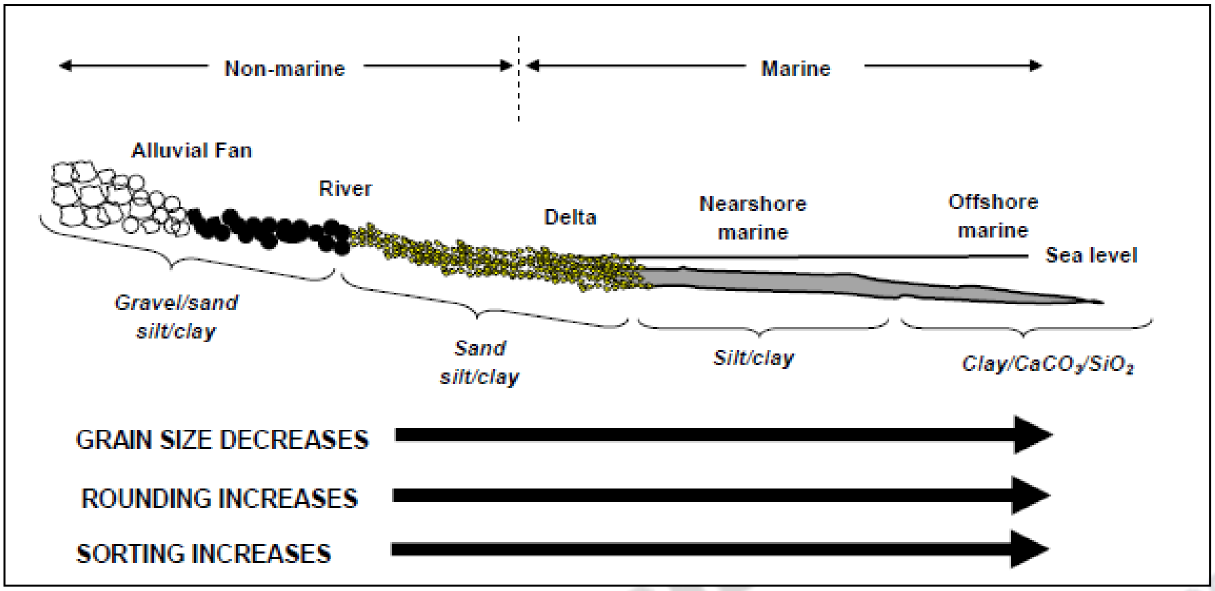

Fig. 1: Change in sediment characteristics with transport

2.0 Mineralogical Composition of Sedimentary Rocks

Sedimentation is basically interaction of atmosphere and hydrosphere on the crust of the earth. Various aspects of sedimentation are discussed in the terms of weathering, erosion, transportation, deposition and diagenesis and none of these processes work in isolation. The original constituents of the crust, minerals of igneous rocks, are unstable to large extent in the atmosphere and hydrosphere as these are formed under higher temperature and pressure conditions. Mainly quartz is the only mineral to resist the weathering process. Other minerals are altered by the action of water, oxygen, carbonic acid and form new minerals which are more stable under the new conditions. Original minerals are break down under the influence of chemical reactions and among the new minerals silicate are the most common as they form more than 90% of earth's crust (Mason and Moore, 1982).

Most grains in sedimentary rocks are derived from different types of rocks (igneous, metamorphic and sedimentary), the mineralogy and chemical composition of siliciclastics rocks are primarily controlled by parent rock composition. In sedimentary rocks more than 150 different minerals/ mineral species are identified. Most of these are relatively rare and are included as parent rock mineral with altered debris. According to Krynine (1948), some 20 minerals form 99% of the bulk of sedimentary rocks. Sedimentary rocks/ sediments are mixture of several minerals. Sometimes a single mineral dominates the rock composition exceeding even up to 99% like in a case of few sandstone/ quartz arenite. Contrary to this, some may contain variety of minerals like glacial till comprising several different minerals and rock fragments. Most common minerals according to their abundance are mentioned in table 1.

Table 1: Common minerals of sedimentary rocks (after Krumbein and Sloss, 1963)

Type of minerals	**More than 10% of rock**	**Less than 10% of rock**	**Less than 1% of rock (Accessory minerals)**
Detrital minerals	Quartz Clay minerals Mica (Fine)	Detrital chert Coarser mica Feldspar	Zircon, Tourmaline Epidote, Garnet Hornblende, Pyrite
Chemical and authigenic minerals	Calcite, Dolomite	Chert, Gypsum	Anatase, Feldspar,Mica

The siliciclastic sedimentary rocks (like sandstone, conglomerate, shale, and siltstone) make up roughly ¾ of all sedimentary rocks in the geologic record from Precambrian to Present. Textures and structures in the sedimentary rocks provide important clue about transport and depositional conditions. Minerals and rock fragments in the siliciclastic sedimentary rocks lead to understanding of sediment source area and its nature. Petroleum geologists are interested in understanding the siliciclastic sedimentary rocks as sandstones form important reservoir while shales containing organic matter as source for generation of hydrocarbons.

Rock fragments also occur in the composition of siliciclastic sedimentary rocks and are responsible for about 10 - 15 percent of the composition of sandstone. They generally make up most of the gravel size particles in conglomerates but contribute only a very small amount to the composition of mudrocks. Though they sometimes are, rock fragments are not always sedimentary in origin. They can also be metamorphic or igneous. Chemical cements vary in abundance but are predominately found in sandstones. The two major types, are silicate based and carbonate based. The majority of silica cements are composed of quartz but can include chert, opal, feldspars and zeolites. Composition includes the chemical and mineralogicmake-up of the single or varied fragments and the cementing material (matrix) holding the clasts together as a rock. These differences are most commonly used in the framework grains of sandstones. Sandstones rich in quartz are called quartz arenites, those rich in feldspar are called arkoses, and those rich in lithic are called lithic sandstones. Compositional details of common sedimentary rocks are described here.

Sandstones

Sandstones make up 20-25% of all sedimentary rocks and are common rocks to geologists throughout the geologic record across the globe. Sandstone consists of silicate grains ranging in size from 1/16 to 2mm. These particles are known as framework grains. Additionally, sandstone also contains varying amount of cement and very fine material (<0.03mm) as matrix present within interstitial pore space among the framework grains. Framework mineralogy in sandstone can be analysed with reasonable degree of accuracy with standard petrographic microscope or by backscattered electron microscopy. Bulk chemical composition can be determined by techniques like X-ray fluorescence and inductively coupled argon plasma emission spectrometry (ICP). The chemistry of individual grains is determined by use of an electron probe analyser or an energy dispersive X-ray detector (EDX) attached to a scanning electron microscope (SEM) (Boggs, 2006).

Mineralogy of sandstones: Framework particles of sandstones are mainly sand size and coarse silt size silicate minerals and rock fragments. Few principles minerals make bulk of sandstones.

Quartz: Quartz (SiO_2) is the main minerals in the sandstones and make up 50-60% of framework fraction. It is comparatively easy to identify in hand specimens, as well as, in thin sections. Because of its hardness and chemical stability it can survive multiple recycling. Quartz may occur as single (monocrystalline) grain or as composite (polycrystalline) grains. Quartz is derived from plutonic igneous rock, as well as, from metamorphic and older sedimentary rocks.

Feldspar: Feldspar grains make up 10-20% of framework grains of average sandstones. After quartz, feldspars are second most abundant minerals. Several varieties of feldspars are distinguished on the basis of chemical composition and optical properties.

Alkali feldspars constitute a group of minerals ranging in chemical composition from $KAlSi_3O_8$ through (K, Na)$AlSi_3O_8$ to $NaAlSi_3O_8$. Because of dominance of potassium rich feldspars, alkali feldspars are generally also called potassium feldspars (K- feldspar). Important member of this group are orthoclase, microcline and sanidine.

Plagioclase feldspars form a complex solid solution series ranging in composition from $NaAlSi_3O_8$ (albite) to $CaAlSi_3O_8$(anorthite). General formula for this series is (Na, Ca) (Al, Si) Si_2O_8. Plagioclase feldspars can be distinguished from alkali on the basis of optical properties. In general, alkali feldspars are more common in sedimentary rocks and plagioclase is more common in sandstones derived from volcanic rocks. Feldspars are chemically less stable than quartz and more susceptible to chemical alteration during weathering and diagenesis owing to their softer nature, prone to mechanical shattering and cleavage. It is difficult on the part of feldspars to survive multiple cycle and hence if feldspar content of the rock is around 25% then it can be deduced that particular rock is derived directly from the crystalline source rocks.

Accessory minerals: Minerals with an average abundance of 1-2% in sedimentary rocks are referred as accessory minerals. These include common micas (muscovite, biotite) and heavy minerals which are denser than quartz. Average abundance of coarser mica in siliciclastic rocks is less than 0.5%. Muscovite is chemically more stable than biotite and also more abundant in sandstones. Micas are generally derived from metamorphic source rocks, as well as, from plutonic igneous rocks.

Minerals having specific gravity more than 2.9 are categorised as heavy minerals. These include both chemically stable and unstable varieties. Zircon and rutile are widely studied heavy minerals and can survive multiple recycling episodes. If zircon and rutile are rounded then it indicates that last source was sedimentary. Relatively less stable minerals are magnetite, pyroxenes and amphiboles and less likely to survive recycling. These are generally first cycle sediments and reflect composition of proximate source rocks. Heavy minerals are derived from a variety of igneous, metamorphic and sedimentary rocks.

Rock fragments: Part of source rocks, yet not disintegrated, form individual grain in the rock are called rock fragments. Rock fragments, highly variable in composition, range from zero to sometimes 80% of rock. Fragments of any kind igneous, metamorphic or sedimentary rock may occur as rock fragments in sandstones. Most common rock fragments in sandstone are clasts of volcanic rock, volcanic glass, fine grained metamorphic rocks such as slate, phyllite, schist and quartzite. Sand size fragments of siltstone, shale, chert and chert nodules are also common. Clasts of limestone and other carbonate rocks are also found as rock fragments in sandstones. Rock fragments are particularly important to understand the sediment source rocks and more reliable indicators.

Mineral Cements: Framework grains in siliciclastic sedimentary rocks are bound together by some type of mineral cement. Cementing material may be silicate minerals such as quartz, opal or non-silicate minerals such as calcite or dolomite. Quartz is the most common mineral to act as cement in sandstones. In many ancient sandstones quartz cement is chemically attached to the crystal lattice of existing quartz grains forming rims of cement called quartz overgrowth. When silica cement is deposited as microcrystalline quartz, it fills interstitial spaces among framework grains. Carbonate minerals also commonly found as cement in siliciclastic sedimentary rocks. Calcite is most common and precipitates in the pore spaces of framework grains. Dolomite and siderite (iron carbonate) also found as cement. Other less commonly found cement in sandstones includes hematite, limonite, feldspars, anhydrite, gypsum, barite, clay minerals and zeolite minerals. All cements are secondary minerals from after deposition of sandstones and during burial.

Matrix minerals: Grains smaller than 0.03mm which form interstitial spaces in sandstones are called matrix minerals. It may include clay minerals, fine size mica and feldspar. Clay minerals may be studied by X-ray diffraction and scanning electron microscopy. Most common clay minerals are illite, montmorillonite, kaolinite and chlorite. Clay minerals are formed during sub-aerial weathering and hydrolysis as secondary minerals and also by subaqueous weathering in marine environment and during diagenesis.

Conglomerate

Sedimentary rocks containing substantial proportion (>30%) of gravel size (>2mm) particles are categorised as conglomerates. Breccia is also similar to conglomerate but contain angular, gravel size particles contrary to rounded particles of conglomerate. Conglomerates are common in the entire geological record but make less than 1% of total sedimentary rocks. Conglomerates are similar to sandstones in origin and depositional mechanisms (Boggs, 2006).

Compositionally, conglomerates are very diverse and contain different types of rock fragments/ clasts. Sand size or mud size grains are present as matrix. Depending upon the source and depositional regime conglomerate may contain fragments of igneous, metamorphic or sedimentary rocks. Stable conglomerates containing single type of clasts (like quartz, chert) is known as oligomict conglomerate. Polymict conglomerates contain different types of rock clasts.

Shales/ Mud Rocks

Shale is fine grained siliciclastic sedimentary rocks containing more than 50% of silicate grains in size less than 0.062mm. Generally, term shale is used for laminated rock and mud rock for non-laminated rock. Shales primarily composed of clay minerals and fine size quartz and feldspars. Other minerals like calcite, dolomite, siderite, pyrite, iron oxides, heavy minerals and organic matter are also commonly found. Using XRD analysis, different minerals of shale can be computed.

Non-siliciclastic Rocks/ Carbonate Rocks

By definition, carbonate rock must contain more than 50% carbonate minerals. The elemental chemistry of carbonate rocks are dominated by calcium, magnesium and carbonate ions. Calcium and magnesium are present in both limestone and dolomite but magnesium is important constituents of dolomite. Other elements present in minor amount are Si, Al, K, Na and Fe. Trace elements in carbonate rocks are B, Be, Ba, Sr, Br, Cl, Co, Cr, Cu, Ga, Ge and Li. Relative presence of trace elements are controlled by mineralogy of rock and fossil contents. Chief carbonate minerals are-

- Calcite group: Calcite, Magnesite, Rhodochrosite, Siderite and Smithsonite
- Dolomite group: Dolomite, Ankerite
- Aragonite group: Aragonite, Cerussite, Strontionite, Witherite

Aragonite is dominantly present in modern shallow marine carbonate but rocks older than Cretaceous contain little aragonite as it is metastable polymorph (same chemical composition but different crystal structure). Aragonite present in geologically older rocks has been subsequently dissolved and replaced by calcite. Similarly, in ancient carbonate rocks enrichment of dolomite is more than calcite as $CaCO_3$ exposed to magnesium rich interstitial water converted to dolomite during burial and diagenesis. Stable isotope composition of carbonate rocks (particularly of oxygen and carbon) is important to understand paleoenvironmental conditions and chronostratigraphic correlations.

2.1 *Detrital and non-detrital minerals*

The mineralogy of sedimentary rocks has two components- first resistant minerals by the breakdown of the parent rocks and second newly formed minerals as the product of chemical decomposition.

Detrital minerals consist of broken and abraded particles transported to site of deposition by physical/ mechanical processes. Most common detrital minerals are quartz, clay minerals and fine grained micas and relatively less common are chert, feldspar and coarser micas. Accessory minerals constitute less than 1% of the total rock and are particles of higher density derived from parent rock (Table 2).

Table 2: Detrital minerals with source rock types (after Krumbein and Sloss, 1963)

Silicic & intermediate Igneous rocks	**Pegmatites**	**Mafic and ultra Mafic igneous rocks**	**Metamorphic rocks**	**Reworked sediments**
Apatite Biotite Hornblende Monazite Muscovite Titanite Zircon	Cassiterite Fluorite Topaz Tourmaline Wolframite	Anatase Augite Brookite Chromite Hypersthene Ilmenite Leucoxene Olivine Rutile	Andalusite Garnet Glaucophane Hornblende Kyanite Sillimanite Staurolite	Glauconite Iron ores Quartz Rutile Tourmaline Zircon

Among the detrital minerals, quartz is very resistant to chemical attack under surface conditions. Feldspars are less resistant but remain in sedimentary rocks and are chemically decomposed due to prolong weathering. Alkali feldspars may be formed in sediments under surface or near surface conditions as authigenic calcite, orthoclase and microcline are studied. Kaolinite, montmorilonite, illite and chlorite are common clay minerals.

Clay minerals, having layer-lattice structures, are stable secondary products formed by the decomposition of aluminosilicates. Clay minerals are very small in size, generally less than 0.002mm in diameter.

Calcium is precipitated from solution (non-detrital) either by physiochemical changes or by the vital processes of organisms. Dolomite is believed to be formed by metasomatic actions of limestone by magnesium bearing water.

Figure 2 shows the size range of detrital particles in clastic sediments. Quartz and mica extend through most of the size range while the clay minerals are typically associated with shale.

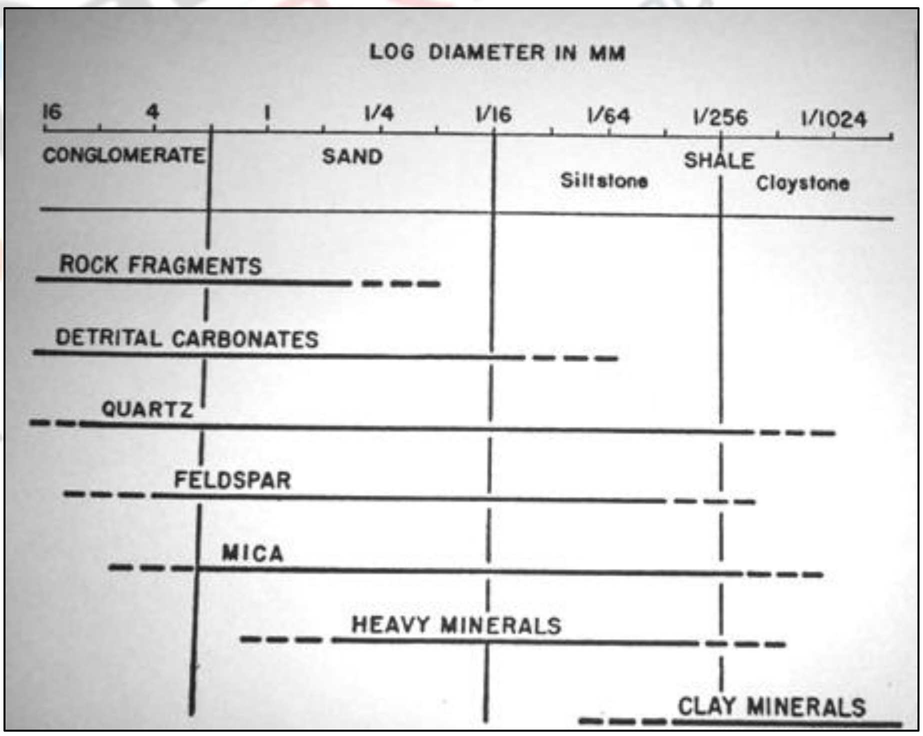

Fig. 2: Size range of detrital particles in clastic sediments (Krumbein and Sloss, 1963)

In non-clastic/ non-detrital rocks most common minerals are calcite and dolomite. Chert, secondary quartz and gypsum/ anhydrite are relatively less common. Rare occurrence of accessory minerals is also found in non-clastic rocks.

Different components of minerals in sedimentary rocks may be mixed in any proportions in specific sediment. For example sandstone will have quartz as the main constituent while limestone consists of calcite and dolomite. If limestone has enough detrital clay minerals then it may be classified into argillaceous limestone. Classification of different sediments is a separate subject and discussed in other module in detail.

Sandstones are mixtures of mineral grains and rock fragments coming from naturally disaggregated products of erosion of rocks of all kinds. Minerals may be lost/ modified by weathering in the source area, by transportation and by diagenesis. Study of minerals in sandstone is important to understand provenance, tectonics and climate, as well as, for history of transportation, changes during sedimentation and diagenesis (Pettijohn et al., 1972).

In any sediment/ sedimentary rock, composition of detrital component depends upon the source rock, degree of weathering of source rock material and distance and mechanism of transport while in non-detrital/ non-clastic composition depends upon the physical and chemical processes dominating at the site of deposition (Fig. 3).

Clastic Sedimentary Rocks			
Texture (grain size)		**Sediment Name**	**Rock Name**
Coarse (over 2 mm)		Gravel (rounded fragments)	Conglomerate
		Gravel (angular fragments)	Breccia
Medium (1/16 to 2 mm)		Sand	Sandstone
Fine (1/16 to 1/256 mm)		Mud	Siltstone
Very Fine (less than 1/256)		Mud	Shale

Chemical Sedimentary Rocks			
Composition	**Texture (grain size)**	**Rock Name**	
Calcite	Fine to coarse crystalline	Crystalline Limestone	
		Travertine	
	Shells and cemented shell fragments	Coquina	Biochemical Limestone
	Shells and shell fragments cemented with calcite cement	Fossiliferous Limestone	
	Microscopic shells and clay	Chalk	
Quartz	Very fine crystalline	Chert (light color) Flint (dark color)	
Gypsum	Fine to coarse crystalline	Rock Gypsum	
Halite	Fine to coarse crystalline	Rock Salt	
Altered plant fragments	Fine-grained organic matter	Bituminous Coal	

Fig. 3: Texture and composition of clastic and non-clastic rocks

2.2 ***Authigenic minerals***

Authigenic minerals are formed in place within sediment. These minerals are introduced in the system after deposition and make part of the rock apart from detrital and non-detrital minerals. Among the more common, chert is formed in limestone after deposition, calcite cement in sandstone, pyrite in shales, feldspar crystals in limestone, gypsum crystals in clay. Glauconite occurs in some sandstones and shale. It forms on the sea bottom in reducing environment in shallow water condition (Krumbein and Sloss, 1963). it is difficult to distinguish between authigenic and detrital minerals. Like calcite may form simultaneously with deposition of clean quartz sands to form calcareous sandstone or it may precipitate later in the system to form cement. In the similar way, dolomitisation process may occur simultaneously with the depostion of limestone or it may start later. Authigenic minerals, in general, make part of post depositional changes i.e. diagenesis.

2.3 *Accessory minerals*

Accessory minerals form less than one percent of total rock composition and are least abundant in the clastic rocks. Despite their negligible proportion, accessory minerals provide important information about the source rocks of the sediments (Table 1). These minerals are derived from the parent rock, which has been source of sediments, survived of weathering and transportation. Accessory minerals have higher density than more commonly found minerals like quartz and feldspar and also called heavy minerals. Since heavy minerals provide important information about provenance (source area of the detrital material), their study is crucial in sedimentary petrology. Heavy minerals may be separated from lighter minerals by various physical and chemical methods. Table 2 shows the list of heavy minerals and their source/ parent rocks from which they are derived.

2.4 *The End-member concept*

End-member concept was developed by Krynine (1948) and extended by Pettijohn (1949). According to this concept it is possibel to express the composition of any rock in terms of particular end members (such as quartz, calcite etc.) or group of end members (like quartz and feldspar, calcite and dolomite etc.) to understand systematic variations among classes of sediments. It provides important tool to interpret and classify sedimentary rocks.

Sedimentary rocks may be classified according to percentage of end member of detrital or chemical fractions. If rock consists of 50 percent or more of detrital end members then rock is called detrital/ clastic rock while if end member (50% or more) is chemical in origin then rock is called chemical or non-clastic.

3.0 *Chemical Composition of Sediments*

In coarse grained sediments identification of minerals give gross chemical composition but in fine grained rocks like shale, identification of minerals need special studies like X-ray diffractometry (XRD) analysis. Additionally, identification of trace elements and organic matter require separate studies like that of thermoluminescence.

In the chemical analysis of sandstone, shale and limestone following composition in variable proportions is commonly observed.

SiO_2; TiO_2; Al_2O_3; Fe_2O_3; FeO; MgO; Cao; Na_2O; K_2O; P_2O_5; S; CO_2

The average sedimentary rock contains about 58% SiO_2, 13% Al_2O_3, 6% CaO, 5% FeO and Fe_2O_3 in addition to minor amount of TiO_2, MgO, Na_2O, K_2O, P_2O_5, S and CO_2. Similarly, this composition suggests mixture of sandstone (mainly SiO_2), shale (mainly $Al_2O_3$and SiO_2) and limestone (mainly Cao and CO_2), (Fig. 4).

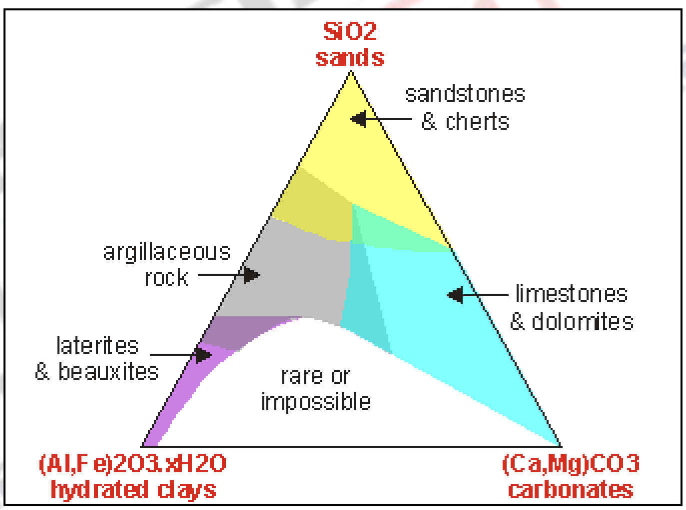

Fig. 4: Sediment composition triangle

Chemical composition of sedimentary rocks is exceedingly variable since sedimentation leads to further diversification. In terms of oxides SiO_2 may exceed 99% in some sandstones, Al_2O_3 may constitute 70% in bauxite, Fe_2O_3upto 75% in limonite, FeO up to 60% in siderite, MgO to 20% in dolomite, CaO up to 60% in limestone and so on (Fig. 5).

Origin	Composition	Texture/Description	Rock Name (link)	Origin
Inorganic Chemical	Calcium Carbonate $CaCO_3$	Crystalline (interlocking crystals)	Limestone	Precipitated directly from sea water, surface water (lakes) or groundwater (caves/springs).
	Calcium Magnesium Carbonate $CaMg(CO_3)_2$	Crystalline (interlocking crystals)	Dolostone	Alteration of limestone by magnesium-rich solutions.
	Silica SiO_2	Microcrystalline (interlocking microscopic crystals); well-cemented	Chert	Precipitation from silica-rich fluids.
	Sodium Chloride NaCl	Crystalline (interlocking crystals)	Rock Salt	Evaporation of saline lakes or sea water.
	Calcium Sulfate $CaSO_4$-2H20	Crystalline (interlocking crystals)	Rock Gypsum	Evaporation of saline lakes or sea water.
Bio-chemical	Calcium Carbonate $CaCO_3$	Visible shells/shell fragments, loosely cemented	Coquina (limestone)	Cementation of shells, shell fragments.
		Microscopic marine organisms, loosely cemented	Chalk (limestone)	Cementation of skeletal material.
		Shell fragments, cemented with calcite cement	Fossiliferous limestone	Cementation of shells, shell fragments.
	Silica SiO_2	Microscopic marine organisms, well cemented	Chert	Cementation of skeletal material.
	Organic Matter	Fine-grained	Coal	Compressed plant matter.

Fig. 5: Composition of chemical rocks

4.0 *Evaporites*

Although all water bodies on the surface and in aquifers contain dissolved salts, the water must evaporate into the atmosphere for the minerals to precipitate. For this to happen, the water body must enter a restricted environment where water input into this environment remains below the net rate of evaporation. This is usually an arid environment with a small basin fed by a limited input of water. When evaporation occurs, the remaining water is enriched in salts, and they precipitate when the water becomes supersaturated (Fig. 6).

Non-marine evaporates are usually composed of minerals that are not common in marine environments, because in general the water from which non-marine evaporite precipitates has proportions of chemical elements different from those found in the marine environments. Non-marine deposits may also contain halite, gypsum, and anhydrite, and may in some cases even be dominated by these minerals, although they did not come from ocean deposits. Some particular deposits even show important tectonic and climatic changes.

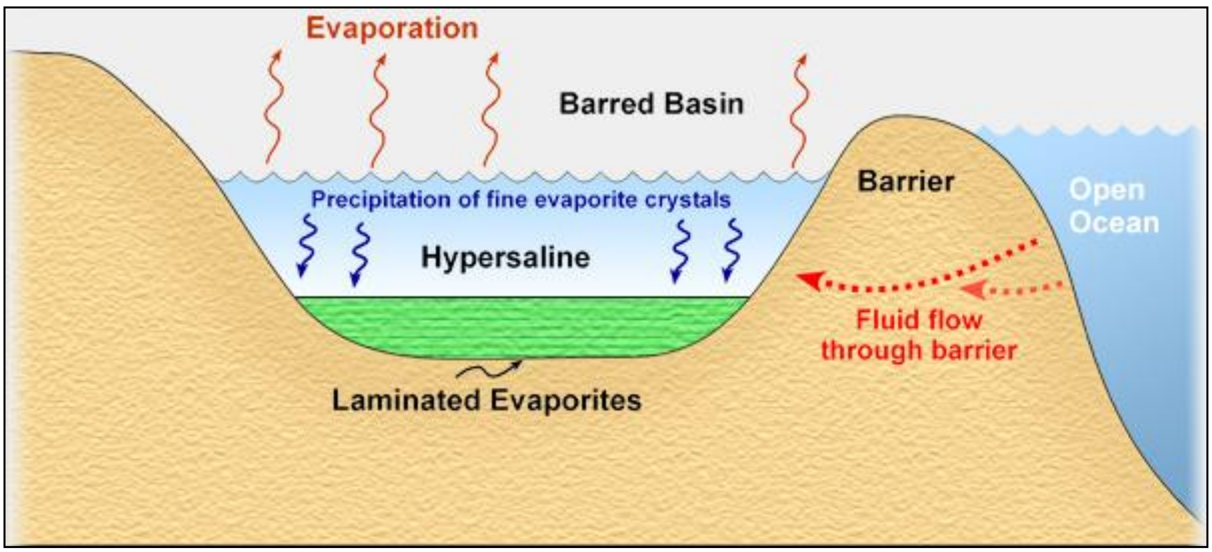

Fig. 6: Formation of evaporates

Evaporate formations need not be composed entirely of halite salt. In fact, most evaporite formations do not contain more than a few percent of evaporite minerals, the remainder being composed of the more typical detrital clastic rocks and carbonates. Major evaporite minerals and their chemical composition are given in table 3.

Table 3: Major evaporite minerals

Mineral class	**Mineral name**	**Chemical Composition**
Chlorides	Halite Sylvite Carnallite Langbeinite Polyhalite Kainite	$NaCl$ KCl $KMgCl_3 * 6H_2O$ $K_2Mg_2(SO_4)_3$ $K_2Ca_2Mg(SO_4)_6 * H_2O$ $KMg(SO_4)Cl * 3H_2O$
Sulfates	Anhydrite Gypsum Kieserite	$CaSO_4$ $CaSO_4 * 2H_2O$ $MgSO_4 * H_2O$
Carbonates	Dolomite Calcite Magnesite	$CaMg(CO_3)_2$ $CaCO_3$ $MgCO_3$

5.0 *Conclusions*

With texture and structure, composition is in important component to make total characteristic of a rock. Composition is the basis for grouping of sediments into respective classes. During the process of transportation significant changes take place in sediments and in the process many minerals alter to form new ones. In the composition of sedimentary rocks, mineralogy has two categories- first resistant minerals by the breakdown of the parent rocks and second newly formed minerals as the product of chemical decomposition.

The composition of siliciclastic sedimentary rocks includes the chemical and mineralogical components of the framework as well as the cementing material that make up these rocks. Major minerals can be categorized into subdivisions based on their resistance to chemical decomposition. Those that possess a great resistance to decomposition are categorized as stable, while those that do not are considered less stable. The most common stable mineral in siliciclastic sedimentary rocks is quartz. Quartz makes up approximately 65 percent of framework grains present in sandstones and about 30%of minerals in the average shale. Less stable minerals present in this type of rocks are feldspars, including both potassium and plagioclase feldspars. Feldspars comprise a considerably lesser portion of framework grains and minerals. They only make up about 15 percent of framework grains in sandstones and 5% of minerals in shales. Clay mineral groups are mostly present in mudrocks (comprising more than 60% of the minerals) but can be found in other siliciclastic sedimentary rocks at considerably lower levels.

Accessory minerals are associated with those whose presence in the rock is not directly important to the classification of the specimen. These generally occur in smaller amounts in comparison to the quartz, and feldspars.

The average sedimentary rock contains about 58% SiO_2, 13% Al_2O_3, 6% CaO, 5% FeO and Fe_2O_3 in addition to minor amount of TiO_2, MgO, Na_2O, K_2O, P_2O_5, S and CO_2. Similarly, this composition suggests mixture of sandstone (mainly SiO_2), shale (mainly Al_2O_3 and SiO_2) and limestone (mainly Cao and CO_2). In terms of oxides SiO_2 may exceed 99% in some sandstones, Al_2O_3 may constitute 70% in bauxite, Fe_2O_3upto 75% in limonite, FeO up to 60% in siderite, MgO to 20% in dolomite, CaO up to 60% in limestone.