

SEDIMENTATION AND SEDIMENTARY ROCKS

Alessandro Iannace,

Dipartimento di Scienze della Terra, Universit Federico II, Napoli, Italy.

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Summary

Sedimentary rocks are one component of the modern three-fold classification of rocks. They derive from the lithification of sediments which are produced in basically two ways: by mechanical deposition of grains derived from the alteration of other rocks (detrital or clastic rocks), or as chemical precipitates or grains formed organically or inorganically from an aqueous solution. The whole process of sedimentation is generally considered to comprise weathering of parent rock, transport of grains or ions in solution, and deposition or precipitation. The origin of sediments is thus an exogenic process and is strongly influenced by climate and in most cases also by biological processes. Sediment deposition normally happens in local depressions called "sedimentary basins", the most significant being the marine basins. Lithification take place during burial through a series of transformations called "diagenesis".

Sedimentary rocks are the most abundant rocks near the Earth surface, so they have been and will be in the future the most important resource for Mankind. They provide building materials, energy sources, significant quantities of industrial minerals and metals, and host most water resources. Furthermore, they store the most important record of the Earths history, particularly the evolution of the [?] biosphere and its connections with Litho-, Hydro- and Athmo-sphere evolution.

The modern classification of sedimentary rocks is mainly genetic: four categories of rocks are generally distinguished: detrital, chemical, organic, and residual. Further distinction in rock type is obtained by considering properties such as mineralogic composition, texture and sedimentary structures.

This article describes the most important **sedimentary rock** types and indicates their common usages. Clastic **rocks** are by far the most abundant and are basically formed of silicate minerals including quartz and feldspars as detrital particles, or clay minerals as alteration product. Chemical **rocks** include limestones and cherts, formed through the accumulation of the hard part of protists, invertebrates and algae, or evaporites resulting from the precipitation of salts from supersaturated marine waters. Organic and residual **rocks** are much more rare but are economically very important because they provide most fossil fuels and some significant metal deposits.

1. Introduction



Sedimentary rocks are one component of the three-fold classification of the materials of which the Earth lithosphere consists, the other two being magmatic and metamorphic **rocks**. While the latter pair have their ultimate origin in endogenic processes, **sedimentary rocks** form mainly through exogenic processes, i. e. those taking place at the surface of the Earth. In fact, **sedimentary rocks** are the lithified correspondent of sediments: accumulations of natural **rocky** or mineral grains deposited from a fluid phase (water or air) by physical, chemical or biochemical processes. In a strictly etymological sense, the name "sediment" should be restricted solely to material deposited by gravity from rivers or sea-waters, and consisting of particles coming from the alteration of other **rocks**. In fact, the original Latin word for sediments, *sedimentum*, indicated a material which settled down from a turbid suspension. However, the term is generally extended to include deposits formed through the accumulation of hard parts of organisms or deposited as a chemical precipitate extracted inorganically from a solution. In most of these cases, the resulting deposits are layered because of successive additions, this giving to the **sedimentary rocks** their most distinctive characteristic, stratification.

Sediments accumulation takes place generally in topographic depressions, generically referred to as "**sedimentary basins**", the most important being the epicontinental and oceanic seas. Emergent lands are generally sites of erosion but significant sediments accumulation occur in lakes, alluvial plains and deserts. As a consequence, most **sedimentary rocks** are of marine origin. The word "sedimentation", however, is generally intended not only for the deposition of the sediments themselves but also for the origin of their constituents and their transport to the site of deposition.

The ensemble of phenomena through which loose sediments are transformed into hard **rocks** is generally referred to as "diagenesis", which operates from the earth surface down to several kilometres deep in the Earth crust.

2. Historical perspective



The definition of sediments given above was introduced in the 16th century by the Italian pharmacist Ferrante Imperato, who was one among several

naturalists of the period to understand that many rocks are the hardened equivalent of former sands or mud of marine origin. This conclusion was paralleled in the same epoch by the correct understanding of the origin of fossils, which are a distinctive characteristic of most sedimentary rocks, as the remains of past organisms. The Danish anatomist Niels Stensen (Steno), in the first half of the 17th century, was, however, the first to develop a comprehensive theory on the origin of sedimentary rocks, their fossil content and their stratified structure.

Until the end of the 18th century, all but a few modern volcanic rocks were interpreted as having formed as physical and chemical precipitates from ancient seas. According to this interpretation, taught by the *Neptunists* leader J. G. Werner in Germany but very popular all over Europe, they were all sedimentary in modern terms. The recognition of the magmatic origin of ancient basalts and especially of granitic rocks by J. Hutton and his followers (the *Plutonists*) on the one hand, and the understanding that some crystalline rocks (gneisses and phyllites) are the isochemical transformation of pre-existing rocks on the other hand, led to the modern three-fold classification of the rocks.

However, the boundary between sedimentary and metamorphic rocks is gradational (see, *Metamorphic petrology*). In fact, some metamorphic rocks may have such a low degree of structural and mineralogical reorganisation that their sedimentary origin is still perfectly recognisable. Similarly, the pyroclastic rocks, consisting of magmatic fragments but deposited as layered bodies during explosive volcanic eruptions (see, *Occurrence, texture and classification of igneous rocks*), are intermediate between magmatic and sedimentary rocks.

A significant improvement in the study of sedimentary rocks at the end of 19th century was the introduction of thin section microscopic analysis by Sorby, complemented by the first deep-sea sediment collections. However, only after World War II did the modern study of sediments and sedimentary rocks, Sedimentology, really begin. The introduction of small-scale laboratory experiments led to the recognition of the deep sea origin of many ancient sandstone-shales alternations and opened the way to a more rigorous study of clastic rocks based on the principles of fluid dynamics. In the meantime, systematic world-wide researches in modern carbonate sedimentary environments, often sponsored by oil companies, significantly improved the understanding of limestones and their diagenetic evolution. Finally, the Deep Sea Drilling Project, launched in the 1960s by an international panel of research institutions, completed our knowledge of deep-sea sedimentary dynamics.

These discoveries led to development of *facies models* for every sedimentary environment, a concept that greatly changed the way geologists look at rocks (see, *Stratigraphy and relative Geochronology*). A further development has been the new understanding of the origin of sedimentary basins offered by the Global Tectonics in the 1970s, together with the refinement of the geophysical imagery of sedimentary successions during the last thirty years. In fact, this put the basis for a quantitative approach to

the genesis not of a single bed but of the entire **sedimentary** successions and thus to the possibility of numerical modelling. This, together with the "global approach" (see, *Global Sedimentary Geology*), certainly is the modern frontier in the study of **sedimentary rocks** and its bearing on the environmental issues of our planet.

3. Classification of **sedimentary rocks**



At the broadest level, **sedimentary rocks** classification is mainly genetic and considers two main groups: clastic (or detrital) and chemical. **Clastic rocks** consist of grains derived from the weathering of pre-existing **rocks**, transported in a fluid medium (water or air) and mechanically deposited. The building materials of chemical **rocks**, by contrast, is chemically precipitated from a solution, both inorganically or through a biological catalysis. However, as the role of biological contribution is often debated, it is not worth introducing here a biochemical group of **rocks**. Two minor, but economically significant, groups of **sedimentary rocks** are residual **rocks** and organic **rocks**.

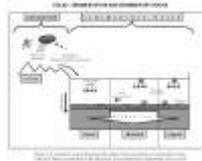


Figure 1 A schematic cartoon depicting the origin of the main group of **sedimentary rocks**. It must be borne in mind that in the origin any given sediment or **sedimentary rock** several of these processes are generally involved at a different degree.

There are three descriptive properties of **sedimentary rocks** which are used to extract a wealth of information about the environments of origin, transport, deposition and lithification experienced by any **rock**. They also allow more detailed classification of **rocks**. These properties are: composition, textures and **sedimentary** structures. Composition refers to the mineralogy of the particles the sediment consists of and reflects the lithology of source area or the specific genetic mechanism; texture is an ensemble of geometrical properties of these particles and their mutual arrangement, which depends mainly on the processes of transport; **sedimentary** structures include many geometrical features of discrete particles packages, the beds, which may result from various depositional or post-depositional phenomena. These properties, together with their mode of origin, provide the base for classification of **sedimentary rocks**.

3.1. **Clastic rocks**

Clastic (from the Greek word for "break down") or detrital **rocks** basically derive from the accumulation of broken pieces of pre-existing **rocks**. In the past they have been named also "derivative" or "aggregate" **rocks**. Their genesis include several processes occurring from the site of the parent **rock** to the **sedimentary** basin where accumulation and lithification take place.

The whole process may require up to several million years but most of this time is represented by burial and diagenesis.

The alteration of a **rock** into smaller fragments or clasts can be accomplished through physical and/or chemical processes. As they are operated mainly by meteoric waters, ice, wind or simply sun heat at or close to the earth surface, **rock** destruction and alteration are generally referred to as "weathering" (see, *Landscape Dynamics*).

The most effective weathering processes are the chemical ones and particularly the hydrolysis of silicates, which are the most abundant minerals on Earth. This break down of the crystalline structure of feldspars and piroxenes produces new minerals (mainly clay minerals and oxides) and free cations (Ca, Na, K, Mg) dissolved in the weathering fluids. The weathering through solution is significant only for **rocks** containing salts, such as carbonates and evaporites. Both processes greatly depend on the degree of acidity of the meteoric waters in the soils, partly provided by the degradation of organic matter. The most effective physical processes able to disintegrate **rocks** are the wedging action of ice and plant roots within fractures.

The grains produced during weathering are then carried away generally within a fluid medium, mostly water or less frequently air, under the action of gravity and/or a current. Transport phenomena include landslides along hill-slopes, river currents, sheet floods on alluvial fans, eolian dusts in deserts, river discharge at deltas, long-shore currents on continental shelves, turbidity currents on submarine fans and slopes, and contour currents in deep sea basins. Moreover, sediments grains, especially bioclasts, may simply settle down through the water column in lakes or seas. A special case of transport media for **sedimentary** grains is represented by ice in glaciers, a process particularly widespread during ancient glacial stages.

All along these phases of transport, grains continue to be chemically altered, and these produce a mineralogical selection with respect to the parent material. Grains of Mg-Fe-silicates are more easily destroyed, whereas quartz, alkaline feldspars, and very tight lithic fragments are less altered and become concentrated together with neo-formed clay minerals. As a consequence, mineralogical composition can be analysed quantitatively (provenance analysis) to retrieve both the nature of the source material and the approximate length of transport, as well as the kind of climate and geotectonic setting, under which it happened.

During transport grains are also continuously abraded and granulometrically selected, according to the laws of fluid dynamics. Finally, they settle down when kinetic energy is unable further to transport them. All this is reflected in texture and **sedimentary** structures. The study bed by bed of grain morphometry, of granulometric distribution, mutual arrangement, and particularly of the kind of lamination and other structures produced just before deposition represents a very specialised field of sedimentology: through the theoretical approach and laboratory experiments of fluid dynamics it is generally possible to attribute a specific depositional

mechanism to every single bed of a **sedimentary** succession. The study of beds association (facies studies, see *Stratigraphy and relative Geochronology*) leads to the reconstruction of the **sedimentary** environment of deposition.



Figure 2 The Drumheller Badlands of Alberta, Canada, consists of **sedimentary** succession of clastic **rocks** (sandstones, siltstones and mudrocks) deposited and buried in a coastal environment during Cretaceous. After uplift, they started to be eroded, renewing the continuous cycle of sedimentation. (Photo courtesy Mariano Parente)

The most current classification of clastic **rocks** is broadly granulometric in that it refers to the size of the largest grains, taken as an index of the maximum kinetic energy during transport. On that basis we divide clastic **sedimentary rock** in conglomerates, sandstones and mudrocks, which correspond, as loose sediments, respectively to gravel, sands and mud. Gravel and conglomerates have grains larger than 2 mm, sands and sandstones larger than 1/16 mm, below which are mud and mudrocks. These granulometric classes are referred to as rudite, arenite and lutite, terms which are often used as a synonym of the corresponding **rock** type. The term breccia is frequently used to indicate a conglomerate with angular clasts whereas the old term puddinga, indicating rounded clasts, is now obsolete. Mudrocks are also referred to as shale, but this term should be restricted to fine-grained **rocks** which split in platy layers. The use of mudstone as a synonym should be abandoned to avoid confusion with a specific term used in carbonate **rocks** classification. A further granulometric class, lime, is often distinguished between arenite and lutite to which correspond silt and siltstones but they are best recognised only with laboratory-based granulometric analysis.



Figure 3 This sandstone bed show various types of textures and type of lamination from bottom to top, each reflecting the specific type and energy during deposition. Their association allows the **rock** to be interpreted as a turbidite.

A further subdivision of clastic rocks is achieved when the relative proportions of main granulometric classes in a given sample are considered. In fact, in most conglomerates and sandstones it is generally possible to distinguish the grains or clasts with respect to a surrounding much finer material referred to as matrix. The terms clast-supported and mud-supported conglomerates are used respectively when clasts touch each other and when they seem to float in a finer matrix. These terms replaced the older orthoconglomerates and paraconglomerates. Within arenites, when the matrix is more abundant than 15%, the term greywacke is used instead of sandstone.



Figure 4 General classification scheme for clastic rocks considering both composition (triangular diagram) and relative proportion of finer matrix with respect to larger clasts (long axis).

Arenites are also classified according to the composition of their clasts. The most common classification scheme only considers the relative abundance of three components, which are quartz, feldspar and lithic fragments. Based on which one of these components predominates, the terms quartzarenite, arcose and lithic arenites are used respectively. For conglomerates there is no classification based on the composition of the clasts and only the adjectives monomictic and polymictic are used to indicate respectively a clast derived from a single source or from different sources. Nor do mudrocks have a compositional classification, because their mineralogy can only be assessed through careful detailed analysis (X-ray diffraction). They generally consist of clay minerals, a complex group of silicates mainly derived from the weathering of feldspars and volcanic rocks. The most abundant clay minerals are illite, kaolinite, montmorillonite and chlorite.

A peculiar category of clastic rocks is distinguished when most clasts are derived from carbonate rocks. In this case the terms calcirudite, calcarenite and calcilutite are used for each specific granulometric class.

Clastic sediments are an important source of many different building materials. Enormous amounts of gravels and sands are extracted from alluvial plains and shallow seas to be used as aggregate in concrete in most constructions or as loose material in road and railway constructions. The use of mudrocks for the production of bricks and tiles is almost as old as the civilisation and still uses large amounts of mudrocks. A lesser amount of mudrocks is also used in the production of concrete and ceramics and also more specialised industrial applications. Sedimentary rocks, particularly sandstones and conglomerates, have been largely used as building stones for centuries, up to the modern introduction of concrete. However, many sedimentary rocks are still largely quarried as ornamental stones due to the aesthetic value of many sedimentary structures and fossils.

Some metals are extracted in significant amount from clastic **rocks**. Some copper deposits, and minor lead and zinc, are contained within fine grained, organic rich shales. Fluvial sandstones and conglomerates may contain important concentration of gold, such as in the giant deposits of South Africa of Proterozoic age.



Figure 5 An image of a quartz-conglomerate of the Witwatersrand formation taken in the gold mines of South Africa (photo courtesy of Maria Boni)

3.2 Chemical **rocks**

Sedimentary rocks formed through chemical processes represent a very complex assemblage comprising **rocks** very different in terms of composition and genesis. The most significant groups are carbonates, siliceous **rocks** and evaporites.

Carbonate **rocks** are characterised by a very simple mineralogical composition, dominated by calcite and dolomite, calcium and calcium-magnesium carbonates respectively. Calcite is the main constituent of limestones, dolomite of dolostones. Dolostones form as a diagenetic replacement of pre-existing calcareous sediments, soon after deposition or during burial (early and late diagenetic dolostones) and even after lithification into limestone **rocks** (epigenetic dolostones). Other carbonate minerals, such as aragonite or siderite, are far less common.

Despite their simple mineralogy, carbonate **rocks** may form in different ways, always related to the precipitation of calcium carbonate from water. This is due to the fact that calcite and aragonite are very close to saturation in sea-water and in some meteoric waters. However, purely inorganic precipitation of calcium carbonate is quantitatively a quite limited process, the calcite of most limestones being extracted metabolically from organisms. For that reason carbonate **rocks** are often referred to as biochemical or organogenic.

The marine domain is by far the main environment where carbonate sediments accumulate, from the supratidal flats to the deep oceanic floors. Most of these sediments consist of the skeleton fragments of a big variety of invertebrates, algae and protists living both on the sea-floor or at the sea surface as phyto- and zoo-plankton. Inorganic precipitation of calcite may be significant only in specialised environments like in shallow sand bars formed by oolites, sand-sized spherical particles of calcite concretions. An

organic origin has been proposed also for some thick accumulations of carbonate mud, generally believed to be very fine detritus of calcareous shells.

Carbonate production is generally favoured at relatively low latitude, even though carbonate sands can be found also in the very cold waters surrounding Antarctica. The thickest accumulations are found on continental shelves, shallow oceanic platforms and reefs of the subtropical domains in areas with clear waters, i.e. with very low clastic input from rivers. Significant accumulation of carbonates also forms in the deep seas through the accumulation of test of planktonic organisms such as foraminifers, coccolithophorides and pteropodes.

As carbonate sediments are mostly accumulation of biogenic material, the composition and relative abundance of carbonate rocks have varied considerably through time. The development of metazoans with calcareous shells, in fact, closely coincides with the so-called Cambrian Explosion of life on Earth. Precambrian carbonate rocks of marine origin, in fact, mostly consists of stromatolites, laminated rocks formed as purely inorganic or biologically-mediated concretions on microbial mats, the only life form on Earth in those times. In the deep seas, the accumulation of calcareous plankton started with the Jurassic era, more ancient carbonate rocks of deep marine origin being dominated by detrital sediments formed in shallower areas. Reefal rocks, i.e. those rocks deriving from the organic build-ups standing on the sea floor at the transition between continental shelves and deeper basins, exhibit the strongest compositional correlation with age. In fact, as they consist of the remains of rich and diverse biotic assemblages, their ecological composition, and hence their internal structures and size, has changed significantly throughout the life evolution.



Figure 6 A superb exposure of fossil corals from the Adnet quarries, Austria, exploiting Triassic reef carbonates as ornamental stones.

The peculiar origin of carbonate rocks is reflected in their classification schemes. In carbonate sediments the size of the largest particle is generally not an index of the kinetic energy in the depositional environment because it depends only on the biology of the organism producing it. The most common classification schemes are thus based on classification of larger grains and on the relative abundance sparite in the matrix of micrite and sparite. In micrite crystals are smaller than 4 microns, in sparite larger. It is generally assumed that micrite-rich carbonates formed in a very quiet environment, whereas sparite-rich (or micrite-free) ones formed in

environments with agitated waters. It must be observed, however, that despite the widespread use of these classifications, it has been recently demonstrated that in some carbonate **rocks** mud formed during diagenesis or as a chemical precipitate, and hence its abundance has no hydrodynamic meaning.

The most significant carbonate **rocks** formed in terrestrial environments are tufa, travertine, and speleothemes. Travertines are generally layered limestone formed by inorganic precipitation of calcium carbonates in areas close to the discharge of hydrothermal waters, such as Yellowstone. Tufa is a highly porous variety of travertine and is generally deposited from meteoric waters at low temperature as an encrustation around vegetal matter. Both for travertine and tufa sudden physico-chemical variation in carbonate-rich water is responsible for the precipitation of calcite and aragonite. For travertine, there is increasing evidence that the process is directly linked to plant and/or fungi metabolic activity.

As sandstones and conglomerates, limestone has been largely used as building stone especially in the past. Today limestones are extensively quarried, especially as raw material for cement production and as aggregates. This very active mining industry has produced tremendous injuries to the landscape of many countries before the modern concept of visual impact assessment was current with local governments. Many limestones are also quarried in big pieces as ornamental stones. The most important deposits of lead and zinc, together with some silver, are hosted in carbonate succession as a consequence of late-diagenetic introduction of sulphur and metals by hydrothermal waters.



Figure 7 Quarry exposure at Portland, UK showing a thick bed of Jurassic limestone covered by a stratified conglomerate representing a raised gravel beach of Pleistocene age. The Portland limestone has been extensively quarried in the past because of its excellent technical properties, and its name has been extended to the most largely used cement in modern times.

Evaporites are purely chemical **rocks** which form through the accumulation of salts precipitated from a highly concentrated solution as a consequence of evaporation. Today this happens generally in relatively limited coastal environments where small water-bodies become isolated or semi-isolated from the open sea or in inland lakes. In both cases, an arid climate with very limited precipitation is required to deposit significant amounts of evaporite minerals because meteoric waters would have the effect of diluting water and stopping mineral precipitation. In the past, there have been times, such as Permian or Upper Triassic, when evaporite deposition was a much larger-scale phenomena, taking place over wide areas in the marine domain, both in shallow and deep waters. It has been suggested by several authors that widespread evaporite deposition in those times was favoured because of a

higher salt concentration in the global Ocean as contrasted with its present value of 3.4%.



Figure 8 A laminated gypsum bed from the Miocene of Calabria, Italy. Evaporites formed extensively at the end of miocene in the almost dried Mediterranean basin. The vertical grooves are due to dissolution by present-day meteoric waters.

If a given volume of ocean water is concentrated by continued evaporation, several salts will precipitate one after the other according to their solubility products: first carbonates (calcite) will precipitate, followed by calcium sulphate (gypsum), sodium chloride (halite) and potassium chloride (potash). In terms of the amounts of deposit, halite should be far the most abundant, followed by potash salts. However, the conditions for the precipitation of the most soluble salts, and especially for their preservation in the **sedimentary** environment and during burial, are more rarely encountered; as a consequence gypsum, and its dehydrated variety anhydrite, is the most common mineral of ancient evaporite deposits, followed by halite.

The salt we use in cooking comes both from salinas and from fossil deposits of halite. Gypsum has been used since antiquity as a construction material. Potash evaporite, albeit rare, is economically important in the fertilisers industry.

Chert is another important category of chemical **rocks** which form mainly by biological accumulation. In fact, some marine planktonic organisms, namely radiolarians and diatoms, as well as some benthic sponges, are able to extract silica from seawater to make their tests and skeletons. The accumulation of these hard parts within the sediments may form significant deposits. Radiolarian ooze is particularly abundant in modern oceans and is the source of many ancient thick successions of banded cherts or radiolarites



Figure 9. Folded beds of cherty limestones of Cretaceous age in Greece.

The original biogenic silica is generally hydrated (opal) and transforms progressively in chalcedony and quartz with diagenesis. The siliceous sediment may be more or less mixed with some detrital clays, resulting after diagenesis in variously silicified mudrocks. When silica is mixed with other **sedimentary** material, such as carbonate, it may concentrate in nodules or single beds during these diagenetic transformations, resulting in typical

lithologies such as cherty limestones. Chert was a strategic material for Mankind before the discovery of metals. Today it has no economic interest.

A special case of chemical **rock** is represented by cherts interlayered with iron oxides (hematite, goethite). These are found as discrete cm-thick layers in the so-called *banded iron formations*. These uncommon **rocks** formed in many parts of the world almost exclusively during Precambrian time. The alternation of silica and iron mineral is considered to be attributable to alternating chemical conditions in the **sedimentary** environments, leading alternatively to solution and precipitation of iron. In more recent times, during Phanerozoic, similar iron-rich **sedimentary rocks** only formed in very limited **sedimentary** environments. These deposits, however, represented a significant source of iron which has been, for example, a long-lasting cause of controversy and war in Europe.



Figure 10. A banded ironstone from the Proterozoic of South Africa (photo courtesy of Maria Boni)

Quite limited in occurrence also are phosphate-rich **rocks**, known as phosphorites. Phosphate minerals form and concentrate in the **sedimentary** environments as chemical precipitate only in special conditions, namely when there is an high productivity associated with slow sediment accumulation. In these cases, phosphorous present in the environment precipitate as apatite nodules which may form significant enrichments. Generally these are limited to thin beds both in clastic and carbonate successions and are associated with abundant remains of fish bones and teeth. Phosphorites are mainly exploited for the production of fertilisers.

3.3 Organic **rocks**

Organic **rocks** represents quantitatively a minor fraction of **sedimentary rocks** but they are certainly the most important economically. They comprise coal and oil-shales, which have been the most important energy sources of the last two centuries. To them we should add petroleum and natural gas because these are organic-rich natural constituents of the earth crust, thus **rocks** by definition. However, they are generally found as fluid infilling of pores within host **rocks** far away from the place where they actually formed.

Organic matter is normally present in every sediment and **sedimentary rocks**. However, its content is normally well below 1%, rising to 2% in some mudrocks. But organic **rocks** are characterised by a much higher content in organic carbon, which is a consequence of very special conditions in the **sedimentary** and diagenetic environments.

Coal is the name given to several carbon-rich **rocks** deriving from the diagenetic transformation of peat-like material deposited in swamps. According to the degree of diagenetic evolution, we distinguish lignite, litanthrace and anthracite, which correspond also to increase in carbon, and hence energetic power, enrichment.

Oil-shales are mudrocks with a high content of more or less altered organic matter, which is referred to as kerogen. Organic matter is often marine in origin and derives from the accumulation of bacterial and algal organisms. Its high concentration is generally interpreted as the result of poor oxygen concentration in bottom waters and in pore waters of sediments, which prevents organic matter oxidation during sedimentation and diagenesis. However, modern studies also emphasize the importance of high organic productivity in the surface waters to produce organic-rich sediments.

Hydrocarbons are extracted from oil shales upon heating, but the economic value of these **rocks** stems mainly from their being the main source of petroleum. During burial, temperature increase induces chemical reactions in the kerogen leading to the formation of many different hydrocarbons; these then are expelled from the fine-grained source **rock** and migrate toward a coarser-grained and more permeable **rock** which become the reservoir of petroleum and gas. A basic condition to have a valuable deposit is that the reservoir has to be buried beneath a seal represented by a **sedimentary** formation which prevents petroleum degradation by surface derived fluids. One of the biggest accumulations of hydrocarbons on Earth, the Tar Sands of Athabasca, corresponds to an exposed reservoir in which the oil has been oxidised to asphalt.

3.4 Residual **rocks**

Residual **sedimentary rocks** could actually be considered a special category of soils in that they form as weathering products of pre-existing **rocks**. However, while soils are a mixture of minerals and organic matter, residual **rocks** consist only of inorganic mineral matter.

The two most common types are laterites and bauxite, both formed by very intense weathering in a subtropical environment. Laterite forms when a silicate **rock** is deeply attacked by acid waters under a thick vegetal cover. The hydrolisis of silicate liberates the cations present in the mineral lattices which are readily removed in solution together with the silica. The most insoluble cations, namely iron and aluminium, are locally reprecipitated as oxide and hydroxide, forming a thick crust, the lateritic crust. If the processes are more intense, even iron is put into solution and only aluminium stays behind, forming the economically interesting deposit called bauxite.

4. Environmental significance of **sedimentary rocks**



Sediments and **sedimentary rocks** represent only a small portion by volume (5%) of the whole Earth crust but they are the most abundant near the Earth

surface (75%). As a consequence, they have been a fundamental resource for Mankind: strategic materials, such as chert and clays in the past, and coal and hydrocarbons today, are in fact **sedimentary rocks**, as well as the constituents of most building materials. **Sedimentary rocks** yields big amounts of the important base metals such as iron, aluminium, lead and **industrial minerals**. Finally, the largest aquifers are found within **sedimentary** successions.

The economic importance of **sedimentary rocks** is mirrored by their profound scientific interest. As they are formed through processes related to the exogenic cycle and contain the remnants of past living organisms, they represent the most sensitive recorder of the Earth's history: their study, revealing fundamental details of past climates, oceanic and continental environments and life evolution, has been fundamental in the modern understanding of the Earth as a complex system based on the dynamic equilibrium among Hydro-, Athmo, Litho- and Biosphere, the "Gaia hypothesis" of J. Lovelock.

For that reason, when the exploitation of **sedimentary rocks** as a resource is seen in a perspective of sustainable development, the "natural heritage" value has to be considered. Indeed, by analogy with archaeological monuments, some special outcrops of **sedimentary rocks** may be such a good record of pages of the Earth's history that they should be protected against destruction to become "Geosites" offered for the education of future generations.

(see, *Global **Sedimentary Geology***)

Related Chapters



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Glossary



Exogenic: said of a process taking place at or very close to the Earth surface.

Endogenic: said of a process taking place within the solid Earth.

Magmatic rocks: **rocks** formed by the cooling and solidification of a molten material originating within the Earth, mainly silicatic in composition, called magma.

Metamorphic rocks: **rocks** formed from the solid state, mineralogical recrystallization of pre-existing **rocks** with (almost) no gain or loss of material.

Diagenesis: ensemble of phenomena affecting sediments after deposition and during burial and transforming of them into a solid **sedimentary rock**. They may include compaction, cementation, solution, recrystallization, replacement, hydratation, bacterial reduction etc.

Texture: in **sedimentary rocks**, indicating several collective geometrical attributes of the grains composing a sediment or **sedimentary rocks**, such as roundness, sphericity, granulometric sorting, packing.

Sedimentary structures: macroscopic features of a **sedimentary rock** or bed formed during deposition (primary s.) or diagenesis (secondary s.) deposition through physical, biological and chemical processes.

Weathering: The physico-chemical alteration of **rocks** under the action of atmospheric phenomena,

Turbidite current: A density current consisting of a mixture of sediment and water flowing generally along the slopes of marine or lacustrine basins and producing a characteristic association of clastic lithologies referred to as turbidite.

Contour current: Oceanic currents flowing at the base of the continental rise and generally along the bathimetric contours, producing fine sands (and sandstones) known as contourites.

Sheet floods: A flat body of running water, more or less charged with sediments, expanding over large areas with great kinetic energy, often as short-duration rare events in arid regions.

Sedimentary succession: A number of superposed **sedimentary** beds.

Feldspar: Group of aluminosilicate minerals containing variable amounts of K, Na, Ca, widespread especially in magmatic, metamorphic and as detrital component in clastic **sedimentary rocks**. Minor amounts may form during diagenesis.

Quartz: The crystalline silica (SiO_2), representing the second most common mineral of magmatic and metamorphic **rocks** and, because of its resistance to weathering, one of the main constituents of detrital **sedimentary rocks**. Chert are **rocks** consisting of microcrystalline variety of quartz.

Supratidal: Part of the shore area immediately above the high-tide limit.

Intertidal: Part of the shore area comprised between high- and low tide limits.

Supratidal: Part of the shore area immediately below the high-tide limit.

Cambrian Explosion: The apparently sudden diversification of life recorded at the Proterozoic- Cambrian boundary in almost every **sedimentary** succession.

Solubility product: At a given temperature and pressure, indicates the product of ion concentrations in a solution in equilibrium with their solid salt.

Benthonic: Also benthic, said of marine organisms living at the sea bottom.

Planktonic: Also planktic, said of organisms living close to the sea surfaces, generally passively drifting.

Soil: Mixture of weathered **rock** material and organic substance, interface between the **rock** substrate and the atmosphere and natural medium for most plant growth.

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Biographical Sketch



Alessandro Iannace graduated in Geological Sciences in 1984. In 1986 he was at Pierre and Marie Curie University in Paris with a CNR grant to investigate the stable isotope geochemistry of ores and host Cambrian carbonates of Sardinia. There he also took a DEA in 1987 with a thesis on the oxygen-isotope stratigraphy of Plio-Pleistocene carbonates drilled by ODP in Western Mediterranean. He took a PhD in Earth Sciences in 1991 at the University of Napoli, Italy, where he is presently associate Professor in Stratigraphy and Sedimentology. Its main research interest is the sedimentology and the diagenetic evolution of carbonates. Starting with his PhD thesis, he has investigated the Upper Triassic and Lower Liassic dolomites of Southern Italy, particularly their paleoenvironmental significance, dolomitization processes and paleogeographic significance in Western Tethys. Other research themes include petrography of Pleistocene carbonates, the hydrothermal dolomitization and mineralization of carbonates in the Post-Hercynian Europe and the protection of Geological Heritage of Southern Italy.