

# SEDIMENTARY GEOLOGY AND PALEONTOLOGY

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## Summary

Sedimentary geology is a branch of geology concerned with the study of sedimentary rocks. It comprises the two closely related disciplines of sedimentology and stratigraphy. The main goal of sedimentary geology is to interpret the origin and distribution of sedimentary rocks in terms of the physico-chemical and biological processes that led to their formation. In this way past depositional environments are reconstructed on the basis of facies models elaborated through the comparison between ancient and recent examples.

Sedimentary rocks are the most abundant rocks close to the surface of the earth and contain most of the resources of interest for human society. Efficient management of these resources is heavily dependent on our ability to predict the characters and distribution of sedimentary rocks in the subsurface. Sedimentary rocks are the crucial link between endogenous and exogenous processes and therefore they store a lot of information on the history of our dynamic planet. This information should be our best guide to formulate at least educated guesses on the future evolution of the earth system.

## 1. Introduction

Sedimentary rocks are the products of processes of formation, transport, and deposition of sediments, and of their post-depositional transformation into rocks. The branch of geology concerned with the study of sedimentary rocks is called sedimentary geology. It comprises the two closely related disciplines of sedimentology and stratigraphy. The rationale of sedimentology is that sediments and sedimentary rocks can be interpreted in terms of the processes that led to their formation, provided that the fundamental laws that govern physical, chemical, and biological processes have not changed through time.

Sedimentary processes, acting at or close to the earth surface, involve interactions between the lithosphere, the atmosphere, the hydrosphere, and the biosphere. These processes can be observed at work in natural environments, and some of them can be accurately reproduced in laboratory experiments. Natural environments are characterized by more or less complex sets of physical and chemical conditions, by the organisms that live under those conditions, and by their biological interactions. One of the major goals of sedimentology is therefore to reconstruct the physical, chemical, and biological conditions under which sediments formed and accumulated in past depositional environments by comparing processes and products found in present-day depositional environments with the characters of sedimentary rocks.

Physicochemical and biological conditions at or near the earth's surface obviously change through space and time. As a consequence depositional environments are clearly of limited lateral extent and may grade more or less sharply into one another. The change through time of prevailing physical, chemical, and biological conditions, on a local to global scale, leads to more or less gradual or abrupt changes in the sedimentary processes acting at a particular place. These changes through space and time are more or less faithfully recorded by lateral variations in sedimentary rock bodies and vertical variations in sedimentary successions. In order to reconstruct the picture of the geographic distribution of natural environments at any time, and to unravel the history of changing depositional environments at any place through time, we need to determine space and time relations between rock bodies. This is the object of stratigraphy, a branch of geology that relies on some basic principles and on several different analytical methods to establish relative and absolute ages of rock bodies. By establishing correlations between rock units, based on relative ages, a reference stratigraphic column is constructed. By calculating absolute age in years for rocks whose relative position in the stratigraphic column is known, a geological timescale can be worked out that provides a temporal framework for rocks and events in the history of the earth.

Thick successions of sedimentary rocks accumulate in depressions of the lithosphere called sedimentary basins. Major controls on the nature and evolution of the sedimentary record filling a basin are tectonics, climate, and sea level changes. Sequence stratigraphy (a recent development in sedimentary geology) investigates the role of external controls in shaping the architecture of the depositional sequences.

Fossils, a very important and common component of sedimentary rocks, provide the record of the history of life on earth. This record (going back at least 3.2 billion years) provides evidence for changes of life forms through time on which theories of evolutionary processes are largely based. Major evolutionary trends, as well as events of speciation and extinctions (including mass extinctions), are all more or less accurately preserved. Paleontology is closely related to sedimentary geology since these disciplines share the same record and contribute complementary information to the reconstruction of the earth's history.

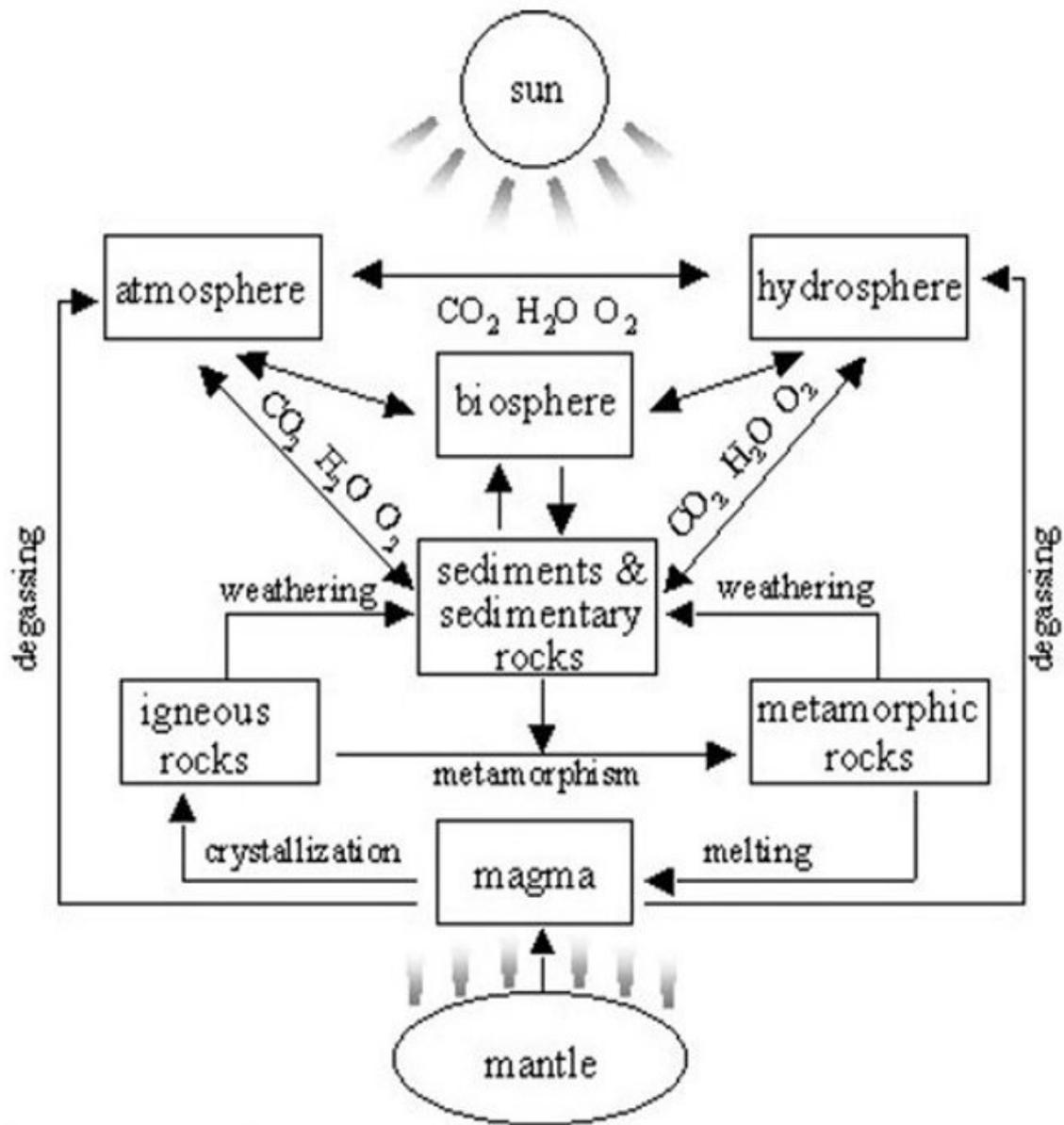


Figure 1. Sediments and sedimentary rocks are the crucial link between exogenous processes, driven by solar heat, and endogenous processes driven by the internal heat of the earth. Therefore they are in the right position to store a lot of information on the history of our dynamic earth.

Sedimentary rocks are the most abundant rocks close to the earth's surface and therefore have been, and will probably be in the future, the most important resource for humankind and for life in general. Oil, gas, and coal are nearly exclusively contained in sedimentary rocks, as are significant amounts of industrial minerals and metals. Sedimentary rocks provide building materials and store most of the earth's freshwater resources. Efficient exploitation and management of these resources is heavily dependent on an accurate knowledge of the nature and distribution of the sedimentary rocks hosting them. This is the field of applied sedimentary geology. Sedimentology and stratigraphy largely developed during the last century under the impulse of research

oriented to the exploration and exploitation of fossil fuels and ore minerals. During the last decades of the 20<sup>th</sup> century the emphasis of applied sedimentary geology has somewhat shifted toward the exploration and management of water resources.

Sedimentary rocks, as a part of the rock cycle (see Figure 1), link endogenous processes working in the earth interior with exogenous processes acting at the earth’s surface. They store information on the interactions between the lithosphere, biosphere, atmosphere and hydrosphere, providing clues to the processes that shapes the solid earth (plate tectonics) and to the evolution of life and climate on earth. Therefore one of the main avenues of sedimentary geology is to disclose the record of history of our planet through geological time and to provide at least educated guesses on its future evolution.

## 2. Sedimentary Rocks

The rocks making up the earth’s lithosphere are classified (according to the lithogenetic process that produced them) into magmatic (see *Occurrence, Texture and Classification of Igneous Rocks*), metamorphic (see *Metamorphic Petrology*), and sedimentary rocks.

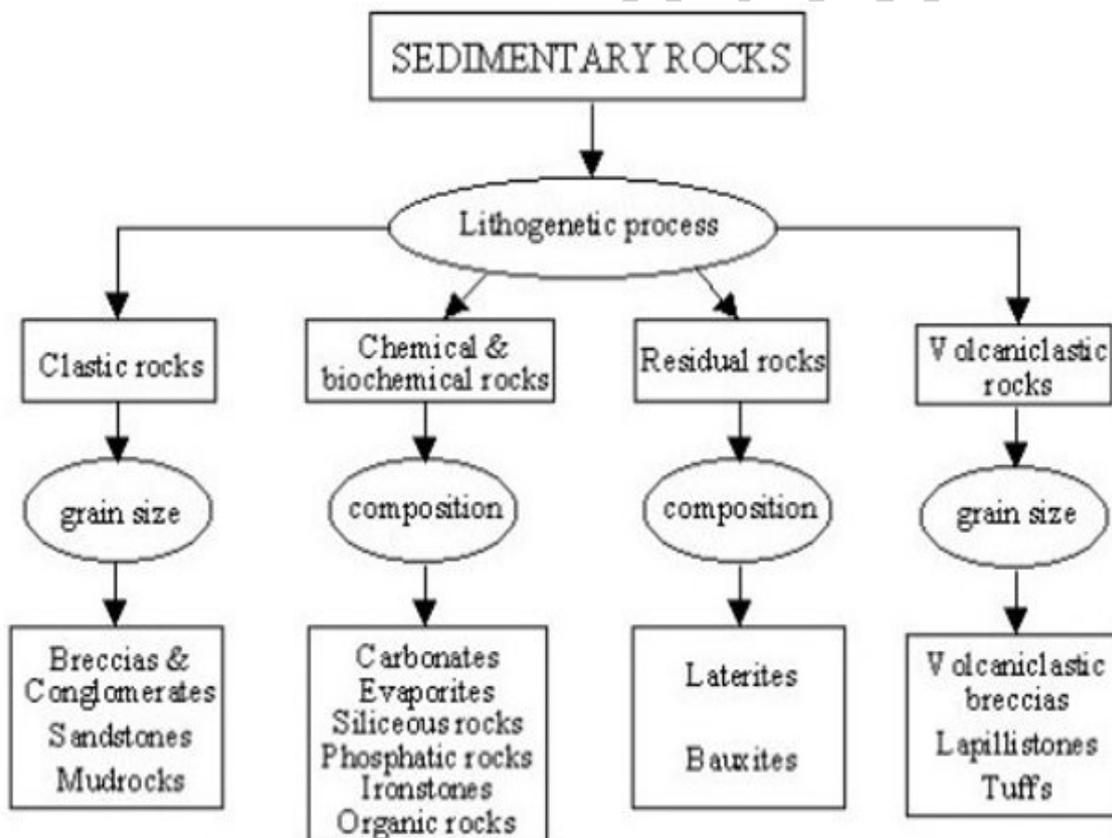


Figure 2. A general scheme of the classification of sedimentary rocks. The broadest categories are based on the lithogenetic process. Further subdivision is based either on the composition or on the grain size.

Materials that will eventually form sedimentary rocks originate through the weathering of pre-existing rocks, are transported either as particulate matter or as ions in solution, and are finally deposited through physical, chemical, or biochemical processes. After the deposition diagenetic processes may more or less profoundly alter the characters of sediments and sedimentary rocks.

The classification of sedimentary rocks at the broadest level is genetic, insofar as it is largely based on the lithogenetic process (see Figure 2). Clastic rocks consist of grains deposited mechanically after a more or less lengthy transport in a fluid medium (water or air). The material building chemical/biochemical rocks is transported as ions in solutions and is precipitated either inorganically or with the intervention of biological activity. Residual rocks result from *in situ* accumulation of the weathering residue. Volcaniclastic rocks are the products of the sedimentation of material ejected during explosive eruptions.

Sedimentary rocks are further characterized and subdivided on the basis of composition and texture (see *Sedimentation and Sedimentary Rocks*).

## 2.1. Clastic Rocks

Clastic rocks are classified on the basis of grain size into breccia and conglomerates, sandstones, and mudrocks. Grain size is visually estimated in the field and more properly assessed in the laboratory, through sieving of loose sediments and thin section analyses of hard rocks. When more than one grain-size class is present, different terms are combined.

Clastic sediments can be accumulated in a large spectrum of depositional environments from a continental alluvial plain to a deep sea fan. Their mineralogical composition is largely independent from processes of transport and deposition, and therefore the environment of deposition cannot be interpreted satisfactorily on the basis of composition.

On the other hand sorting, shape, roundness, and fabric are other textural characters of clastic rocks that together with grain size provide information on the process(es) of transport and deposition. For instance a matrix-poor sandstone with well sorted and rounded grains will be defined as texturally mature, and a long transport by high energy and persistent wind and currents will be inferred.

Sedimentary structures of clastic rocks contribute other pieces of evidence enabling us to make inferences about the processes of transport and deposition. For instance, a sand or sandstone showing wave ripple marks can be interpreted as a near-shore marine deposit, whereas other types of cross-stratification may suggest deposition by currents.

The mineralogical composition of sandstones is not only used as a convenient method of classification (see *Sedimentation and Sedimentary Rocks*) but also gives us information on such important aspects as the lithology, tectonic setting, and climate of the source area, as well as the duration and intensity of transport experienced by the sediment before deposition. When the composition of sandstone is related to the

lithology of its source area it must be considered that instable grains are selectively removed by intense weathering or by reworking and long-distance transport. This consideration is the basis of the concept of mineralogical maturity. Sandstone is said to be mineralogically mature if it contains an high proportion of highly resistant and chemically stable clasts (quartz and chert grains). Vice versa, it is said to be mineralogically immature if it contains large amounts of more labile grains (feldspars and lithic fragments other than cherts). So mature sandstones are the result of intense weathering and/or intense abrasion and sediment reworking. At the other end immature sandstones result from limited weathering and/or rapid transport and deposition.

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### **Biographical Sketch**

**Mariano Parente** graduated with honors in Geological Sciences in 1986. He took a Ph.D. in Sedimentary Geology in 1993 at the University of Naples (Italy), working on the stratigraphy of the Upper Cretaceous to Oligocene shallow water carbonates of Salento Peninsula (Southern Italy). After holding a postdoctoral position at the University of Naples he spent three years as a lecturer at the University of Basilicata (Italy). Since May 2000 he has held a permanent position as a researcher in stratigraphy and sedimentology at the University Federico II of Naples, where he teaches field geology. His main research interests are the stratigraphy and sedimentology of the shallow water carbonate facies of Southern Italy.

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