SEDIMENTATION AND SEDIMENTARY ROCKS

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Summary

Sedimentary rocks are one component of the modern threefold classification of rocks. They derive from the lithification of sediments, which are produced in basically two ways: by the 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 the parent rock, the 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 takes place during burial through a series of transformations called "diagenesis."

Sedimentary rocks are the most abundant rocks near the earth's surface, so they have been, and will be in the future, the most important resource for humankind. They provide building materials, energy sources, significant quantities of industrial minerals and metals, and host most of the earth's freshwater resources. Furthermore, they store the most important record of the earth's history, particularly the evolution of the biosphere and its connections with the evolution of the lithosphere, hydrosphere, andathmosphere.

The modern classification of sedimentary rocks is mainly genetic. Four categories of rocks are generally distinguished: detrital, chemical, organic, and residual. A further

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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 an 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 threefold classification of the materials of which the earth's lithosphere consists, the other two being magmatic and metamorphic rocks. While the last two have their ultimate origin in endogenic processes, sedimentary rocks form mainly through exogenic processes, that is, 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 seawaters, and consisting of particles coming from the alteration of other rocks. In fact, the original Latin word for sediments, *sedimentum*, indicated a material that 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, and this gives sedimentary rocks their most distinctive characteristic: stratification.

Sediment 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 sediment accumulation occurs 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," and operates from the earth's surface down to several kilometers deep in the earth's crust.

2. Historical Perspective

Italian pharmacist Ferrante Imperato introduced the definition of "sediments" in the sixteenth century. He 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

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of fossils (which are a distinctive characteristic of most sedimentary rocks) as the remains of past organisms. In the first half of the seventeenth century the Danish anatomist Niels Stensen (Steno) 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 eighteenth century, all but a few modern volcanic rocks were interpreted as having been 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 threefold classification of 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 reorganization that their sedimentary origin is still perfectly recognizable. Similarly, the pyroclastic rocks, consisting of magmatic fragments but deposited as layered bodies during explosive volcanic eruptions, are intermediate between magmatic and sedimentary rocks (see *Occurrence, Texture, and Classification of Igneous Rocks*).

A significant improvement in the study of sedimentary rocks at the end of nineteenth century was brought about through the introduction of thin-section microscopic analysis by Sorby, complemented by the first deep-sea sediment collections. However, only after the Second World War 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-shale alternations, and opened the way to a more rigorous study of clastic rocks based on the principles of fluid dynamics. In the meantime, systematic worldwide 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 global tectonics in the 1970s, together with the refinement of the geophysical imagery of sedimentary successions during the last 30 years of the twentieth century. In fact, this set the basis for a quantitative approach to the genesis not of a single bed but of entire sedimentary successions, and thus led to the possibility of numerical modeling. This, together with the "global approach" (see *Global Sedimentary Geology*), is certainly the modern frontier in the study of sedimentary rocks and their bearing on the environmental issues of our planet.

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3. Classification of Sedimentary Rocks

At the broadest level, sedimentary rock 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, are chemically precipitated from a solution, either 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.

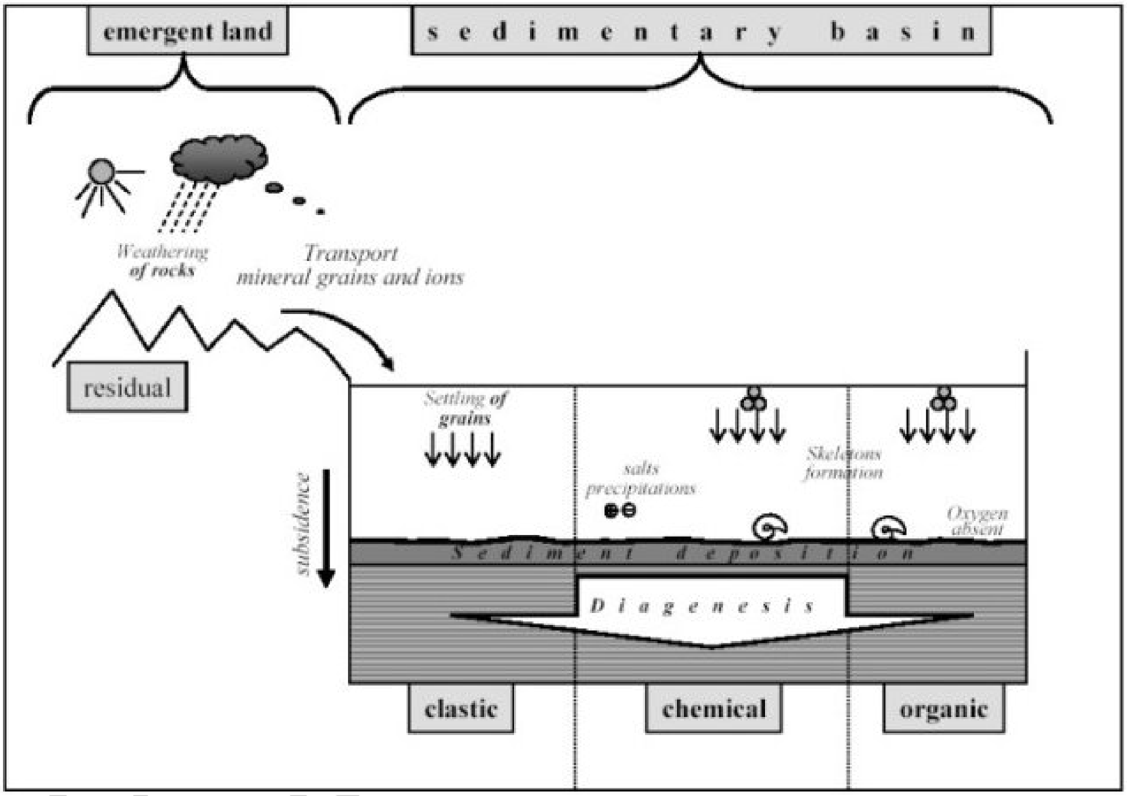

Figure 1. A schematic cartoon depicting the origin of the main group of sedimentary rocks. It must be borne in mind that in the origination of any given sediment or sedimentary rock, several of these processes are generally involved to different degrees.

Three descriptive properties of sedimentary rocks are used to extract a wealth of information about the environments of origin, transport, deposition, and lithification experienced by any rock. They also allow a more detailed classification of rocks. These properties are composition, texture, and sedimentary structures. Composition refers to the mineralogy of the particles the sediment consists of, and reflects the lithology of the 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 particle packages, the beds, which may result from various depositional or postdepositional phenomena. These properties, together with their mode of origin, provide the base for classification of sedimentary rocks.

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Biographical Sketch

Alessandro Iannace graduated in Geological Sciences in 1984. In 1986 he worked with a CNR grant at Pierre and Marie Curie University in Paris to investigate the stable isotope geochemistry of ores and host Cambrian carbonates of Sardinia. While there he also took a DEA in 1987 with a thesis on the oxygen-isotope stratigraphy of Plio-Pleistoecene carbonates drilled by ODP in the western Mediterranean. He took a Ph.D. in Earth Sciences in 1991 at the University of Naples, Italy, where he is presently associate Professor in Sedimentary Geology. His main research interest is the sedimentology and diagenetic evolution of carbonates. Starting with his Ph.D. thesis, he has investigated the Upper Triassic and Lower Liassic dolomites of southern Italy, particularly their paleonvironmental significance, dolomitization processes. and paleogeographic significance in western Tethys. Other research themes include the petrography of Pleistocene carbonates, the hydrothermal dolomitization and mineralization of carbonates in Post-Hercynian Europe, and the protection of the geological heritage of southern Italy.

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