

## Diagenesis

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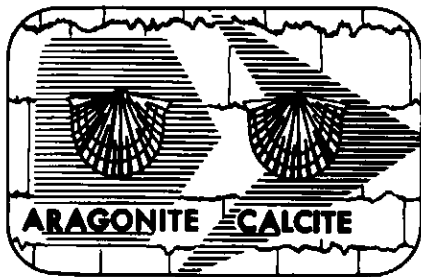
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# Articles



## Diagenesis

### Introduction by the Series Editor

In Volumes 3 to 6, the readers of *Geoscience Canada* were exposed, through an excellent series of articles, to the concept of sedimentary facies models. Common aspects of depositional processes, styles of accumulation and their resulting deposits for a particular environment were stressed. Given the success of that series it would only seem natural to continue with the story of how sediments evolve into the rocks which we observe today. Much of the transition from sediment to rock is accomplished by diagenesis. In the series to follow, the term 'diagenesis' refers to the process or sum of processes which alters the composition and texture of a sediment after deposition. This includes deep burial processes but excludes more extensive high temperature or pressure metamorphic processes.

The study of diagenesis is basically a study of relative mineral stabilities reacting to mechanical (physical) and/or chemical processes. The range of physical and chemical conditions included in diagenesis is 0 to 200°C, 1 to 2000 Kg/cm<sup>2</sup> and water salinities from fresh to concentrated brines. Thus the range of diagenetic environments is potentially large. Actual values of the preceding parameters can vary not only with depth but aurally at any single depth. Therefore, diagenesis can occur in any depositional or post-depositional setting in which a sediment or rock may be placed by sedimentary or tectonic processes.

For example, a carbonate sediment could conceivably undergo early diagenesis in the meteoric vadose, meteoric phreatic, marine vadose, marine phreatic (submarine) environments, or zone of mixing (meteoric and marine) phreatic (all of which are essentially in the depositional realm!); late diagenesis in intermediate to deep burial depths; and again diagenesis in the near surface environment because of subsequent uplift and erosion. Furthermore, with time and depending on the tectonic history of setting in which this carbonate occurs, it could be returned repeatedly to any one of these diagenetic environments.

Physical processes of diagenesis are primarily the result of compaction due to burial. Chemical processes of diagenesis include such diverse processes as solution and cementation due to the movement of water within the sediment. Physicochemical processes result from pressure solution. As diagenesis proceeds these processes affect not only the constituents of a sediment/rock but also modify its porosity and permeability.

Diagenetic processes are controlled by physical and chemical factors such as the nature of the sediment. For example, in sandstones these controls include the composition of detrital grains, content of non-conductive materials in the pores, porosity and permeability, sediment fabric, and overall sediment geometry; environmental factors - pressure and temperature; and the nature of pore water including its composition, the content of any non-conductive fluid and the rate of fluid movement through pore systems. These factors have been long recognized although their actual affect is still poorly understood.

Another factor affecting diagenesis, and one which is not usually properly acknowledged, is the overall tectonic framework in which strata evolve. Perhaps the most important factor is time. A relatively old sedimentary rock may have been involved many times in the geologic cycle of deposition, burial, uplift, and erosion, passing through numerous diagenetic environments. These expe-

riences may be recorded in diagenetic sequences, although in reality much of what the rock may have experienced may not be preserved or can be later destroyed. Another aspect of the time factor is the probability of significant changes in pore fluid chemistry. What would be the affect on diagenetic processes if the earth's hydrosphere has evolved through geologic time?

Diagenesis affects not only the sediment but also modifies porosity and permeability. This aspect of diagenesis is very important to the development of reservoir porosity for hydrocarbons, minerals or potable water. For example, in petroleum geology it has been long recognized that primary intergranular porosity and permeability of a sand is greatly reduced and maybe even totally destroyed in the early stages of burial diagenesis. However, recent studies of diagenesis indicate that this scenerio can be altered at even greater depths by the development of secondary porosity through dissolution of detrital and authigenic minerals. In fact, in many basins the volume of secondary porosity in sandstones equals or exceeds that of primary porosity, as in the Alaskan Prudhoe Bay Field.

Not all diagenetic products are the result of processes which acted for a considerable time. Diagenesis can also happen almost instantly such as occurs when a petroleum borehole being drilled with fresh water penetrates a sandstone having smectite within its pore system. The clay swells and permeability is substantially reduced. In later completion practices, perforation and acidizing operations can also reduce formation permeability. If authigenic chlorite is present within the pore system, acidization can lead to the formation of hydroxide gels. Additional damage to the reservoir can occur during stimulation and even more so during the application of thermal and chemical techniques in enhanced recovery. These instantaneous problems are not only common to many sandstone reservoirs in Canada but elsewhere in the world.

Research on diagenesis has so far focussed on explaining the results of diagenesis in terms of a response to physical and chemical processes. What is still greatly lacking is the development of models for most of these processes, especially those which properly incorporate geologic time and tectonic styles. In the series of articles to follow emphasis will be given to a review of the state of the art relative to diagenesis in major sedimentary rock types. Main processes of diagenesis in various diagenetic environments and the resulting products will be presented (i.e., what is actually present in the rocks, interpreted processes and where feasible general models will be presented). This approach has been taken because even now we have only a very limited knowledge of the actual mechanics of any one types of diagenesis. In fact, our present techniques for establishing values of controlling factors such as burial temperatures is at best semi-quantitative.

The first two articles in the series, written by D. Morrow, deal with one of the best recognized (but least understood) diagenetic processes - dolomitization of carbonate rocks. The chemistry of dolomitization is outlined in Part A. The apparent complexity of this chemistry is not meant to frighten anyone, rather it serves to underline the actual controls on any one particular diagenetic process. Part B, to follow in the next issue, is a more typical article and will focus on proposed models of dolomitization and ancient dolostones. As with the earlier series of Facies Models, these articles will be supplemented with applicable Canadian examples and appropriately selected reference lists.

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