Diagenesis and Basin Development

*edited by **A. D. Horbury and A. G. Robinson**, published in 1993 by the American Association of Petroleum Geologists, in Tulsa, Oklahoma, USA, ISBN 0-89181-044-7, 274 pages.*

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This text has as its origin a conference which matches the title and was held at the Geological Society of London. Most of the papers in the book were presented at this conference, whose purpose was to show that diagenetic character of the rocks found in petroleum reservoirs is not only directly related to physical compaction but is also a product of subsurface fluid flow. Sequence stratigraphy is promoted as the unifying theme, since both compaction history and fluid flow are determined not only by faulting, changes in the heating or subsidence rates but also relative sea level position. As can be seen in this text, methods for predicting porosity and permeability not only involve correlation between porosity and depth but are related to models that predict fluid water flow through the sediment as a function of its burial history and how water reacts with the various components. The editors point out that water movement is a function of the release of overpressure, eustatic changes in sea level, tectonic elevation of basin margins, faulting and heat flow history and so diagenetic behavior should be predictable. The aim of this text is to trace the various relationships of sediment diagenesis to basin history and build models that predict porosity and permeability. Thus the ultimate goal of the editors is to develop a scheme to predict porosity and permeability from basin analysis based on interpreted seismic sections, but as the editors point out none of the papers presented in this volume contain a single seismic line. A not unreasonable fantasy waiting to be realized!

The book is divided into four parts. The first deals with constraints on diagenetic processes and is composed of three papers. The first paper by Aplin et al. deals with mechanisms of quartz cementation in North Sea Tertiary reservoir sands. It reports on fluid inclusion and oxygen isotope data gathered from the quartz cements and used to characterize the formation waters involved with quartz precipitation. The thought is that the cementation involved is related to water driven by either density convection or diffusion. The next paper deals with geochemical evidence for a temporal control on sandstone cementation in the Halltenbanken and North Sea. In this paper, Gluyas et al. concluded that a single major cementation event occurred causing porosity and permeability loss in reservoirs at different locations. The origin of the cementation appears linked to periods immediately after rapid subsidence and related to loading or thermal events. The thought is that the various stages of cementation are related to regional fluid flow patterns tied to basin subsidence history. The final chapter of this section by Haszeldine and Osborne deals with temperatures of formation water derived from fluid inclusion in diagenetic quartz reset by burial and its implications with response to oil field cementation. This study involved the analysis of fluid inclusions in diagenetic quartz in the hope that the temperatures history associated with quartz growth may be linked to the temperature history of the basin. However there is recognition that diffusion may have taken place in the quartz cements, as it has in carbonates cements of other locations, so leading to a flawed interpretation.

Next is a section on "Diagenesis and Basin Hydrodynamics" which is composed of five chapters which examine fluid flow mechanisms and their relationship to sediment diagenesis. Longstaffe begins by reporting on how movement of meteoric water was probably the major process which drove cementation in the Western Canada sedimentary basin. This meteoric

water is tracked by examining stable isotope data for the various mineral cements. The thought is that an influx of meteoric water drove the cementation in the deeper parts of the basin.

Harrison and Tempel then describe diagenetic pathways in sedimentary basins identifying the diagenetic pathways in sandstones of the Wilcox group and the offshore Fio Group. The authors report that these two rock groups have very different hydrologic histories. Their feeling is that the diagenetic events they see in the rocks are related to periods of greater water flow and so can be understood in terms of the basin history.

Next is a paper by Balen and Cloethingh which discusses stress-induced fluid flow in rifted basins. The authors show how their stress model may explain phases of fluid flow and compaction which can then be tied to diagenetic events. They show how changes in horizontal stress affect fluid flow and feel that this fluid flow may be related to the compressive stresses that leads to overpressuring. They concluded that compressive interplate stress could promote the development of both pressuring and faulting leading to fracturing of strata. The thought is that diagenesis might also be prompted by the increased temperature and heat flow driven by the primary migration of water. Additional diagenesis may be related to the transportation of metallic rich brines. The next paper by Cathles which discusses fluid flow mechanisms responsible for alteration and mineralization in the Cambrian aquifers of the Ouachita-Arkoma basin. The thought is that the either compaction or gas driven dewatering were the most likely causes of dolomitization of these sediments. The presence of associated brines suggests that the system has not been flushed by meteoric recharge and possibly that these brines may explain original diagenesis of the rocks.

Next is a paper by Whitaker and Smart on the circulation of saline ground waters in the carbonate platforms of the Bahamas. Here Whitaker and Smart look at different possible mechanisms associated with carbonate platforms and ramps. They describe a series of modern examples from the Great Bahamas Bank, concentrating particularly on the examples from North Andros Island where they had access to water from wells, caves, and blue holes. The results of the studies are inconclusive, but the authors were able to identify a variety of potential fluid models relating the chemistry of the waters that they found in the caves and wells to these models.

Next is a section on "Diagenesis and Faults" which is composed of a paper on fault processes and diagenesis and the effect of fluid flow by Knipe. This paper shows that there appears to be an interaction between the faulting process and fluid flow and diagenesis. There is no doubt that faults do act as both high permeability pathways and barriers to fluid flow. The author emphasizes the importance of integrating studies of the timing of faults and the presence or absence of various diagenetic events. This paper is followed by five papers forming a section on diagenesis, sequence stratigraphy and changes in relative sea level. This section begins with a paper by Read and Horbury on the relationship between eustatic and tectonic controls on porosity evolution beneath sequence-bounding unconformities and parasequence disconformities of carbonate platforms. This paper reviews numerous examples from a variety of settings, in terms of their aquifers and diagenetic history. Settings range from tidal flat/sabkha settings, to unconformities and aquifers, marine-meteoric mixing zones, diffuse flow vs. conduit flow aquifers, carbonate aquifers and calcite cementation. It considers parasequences and their diagenesis as it is associated with small high frequency sea level changes from both arid and temperate climates for different geological times and locals. They consider, for instance, the Cambrian Ordovician cycles of the USA, the early Silurian Interlake Formation of the Williston basin, the upper Permian San Andres-Grayburg formation of USA,

the upper Yates formation of Permian basin in USA, the Triassic cycles of Syria and Iraq, the lower Jurassic of North Africa, the upper Jurassic of Middle East and so on. The paper also considers diagenesis associated with moderate and high amplitude, 4th and 5th order sea level changes in various settings, focusing on key features and cataloging various geographic locations. The paper considers diagenesis associated with long term sea level changes and the development of Paleokarst formation in locations stretching from Britain to Russia to Western Mediterranean, Middle East, Cretaceous Gulf of Mexico and so on. This paper is probably one if the most significant of the book since it covers so many examples and includes very clear summary diagrams of the diagenesis and porosity evolution associated with the various scales of sea level fluctuation. The authors track porosity and diagenetic trends and their relationship to deposition and the rate of lateration.

This article is followed by a paper by Stemmerik and Larssen which examines the diagenesis and porosity evolution of the lower Permian palaeoaplysina buidups of Bjornoya, in the Barents Sea. These authors examine the effects of high amplitude sea level fluctuations on the diagenesis of these rocks and attempt to predict reservoir quality for time equivalent buildups of the offshore. They conclude that an arid climate was responsible for the cementation and diagenesis of these rocks. Next is a paper by Moore and Heydari which deals with burial diagenesis and hydrocarbon migration of platform limestones.

The authors provide a conceptual model based on the upper Jurassic of the Gulf Coast of the USA which relates the carbonate diagenesis of these rocks directly to the Haq et al. 1987 sea level chart and is related to Moore's earlier studies of the Smackover Formation. It emphasizes the importance of early diagenesis on the development of diagenetic pathways.

Next is a paper by Hendry in which he discusses geological controls on regional subsurface carbonate cementation of Middle Jurassic limestones in Central England, using isotopes to investigate the paleohydrology of these rocks. The paper considers the effects of third order tectonic sequence boundaries overprinting fourth order sequence boundaries. It tracks what the effects of the early Cretaceous paleohydrology had on Bathonian rocks which in turn had already experienced the effects of hydrological change during the deposition of the various late Jurassic units. The final paper of this text is by Bjorkum et al., which considers how important the late Cimmerian unconformity is in controlling formation of kaolinite in sandstones of the North Sea. The general conclusion of this paper is that the diagenetic effects of the Cimmerian unconformity on the underlying sandstones has been overestimated and the kaolin distribution is not especially related to the unconformity.

This book is well illustrated and most of the illustrations are clear. Care has been taken in the editing of the papers and focusing on the theme of the text. This text is certainly not the final answer to our understanding of the diagenesis of sediments but it does deal with the state of art as of this time. Probably the most important paper in the text is the one by Read and Horbury. This provides a most complete synthesis of the diagenesis associated with many different depositional environments from different geological periods and times, with different frequencies of deposition as related to sea level variation. The other papers deal more specifically with particular regions and particular problems. Each paper is in itself is a valuable contribution, pointing up the importance of detailed stratigraphy and the relationship of the diagenesis to depositional environment and later tectonic and sea level events. If you have an interest in sedimentary stratigraphy and are faced with diagenetic problems associated with that stratigraphy, the book should help you track down the understanding of diagenesis of a particular unit or may point out techniques you may want to use to investigate diagenesis of that unit further. However, if you have no special interest in this topic, this book will be more

use to you on the shelves of your company or local university library. I felt that the book could have been included more papers like that of Read and Horbury, but the text largely reflects the state of the art rather than the ability of the editors or the authors. I am certainly pleased to have the book available to me and will undoubtedly refer to it in the future, since it matches my interest in carbonates and sedimentary diagenesis.