Geoscience Canada

Facies Models 4

David L. Kidder

Volume 38, Number 3, September 2011

URI: https://id.erudit.org/iderudit/geocan38_3rv01

See table of contents

Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

Cite this review

Kidder, D. L. (2011). Review of [Facies Models 4]. *Geoscience Canada*, *38*(3), 141–144.

REVIEW

Facies Models 4

Edited by Noel P. James and Robert W. Dalrymple
Geological Association of Canada (2010) St. John's, NL, Canada, 586 p. ISBN-13: 978-1-897095-50-8; ISSN: 1208-2260
Member Price: $55

Reviewed by David L. Kidder
Department of Geological Sciences
Ohio University
Athens, Ohio, USA, 45701
E-mail: kidder@ohio.edu

Constructing a facies model is an ingenious way of examining the complexities of sedimentary systems. These systems are challenging to visualize, given that the rock outcrops, cores, and well logs that reveal them represent a miniscule component of a package of sedimentary rocks that can extend laterally for hundreds to thousands of square kilometres and may be thousands of metres thick.

Facies Models 4 assembles a substantial volume of new and established knowledge that has accumulated since 1992, when the third version of the *Facies Models* series came out. The authors, reviewers, and editors have taken great pains to keep the style of presentation at a level between textbooks and more detailed primary literature. The chapters are clearly written and easy to understand. The illustrations are a wonderfully choreographed blend of cartoons, field photographs, line diagrams, seismic sections, well logs, and more. The volume keeps to the three-part format of the 1992 version. As in the predecessor, the first two parts are entitled "Principles, Tools and Concepts" and "Terrigenous Clastic Facies Models." Part Three, "Chemical and Biochemical Facies Models" has a broader coverage of facies than the previous edition, hence the title change.

Following an introduction to the volume by Noel James and Robert Dalrymple, Robert Dalrymple's overview chapter on interpreting sedimentary successions defines the facies model concept and explains how to apply such models in a sequence-stratigraphic context. Although facies models can be quite useful, areas in which individual deposits vary from a given model often provide critical perspective of the processes governing that individual deposit.

In the chapter on ichnology and facies models, authors James MacEachern, George Pemberton, Murray Gingras, and Kerrie Bann integrate the biological and sedimentological interplay that results in distinct marine ichnofacies. Distinct ichnofacies types in softground marine settings, substrate-controlled situations, and softground continental environments are discussed, and a facies model for the ichnofacies paradigm leads to an explanation of settings, such as the progradational wave-storm dominated coast in which the authors integrate ichnology with facies analysis and genetic stratigraphy.

Robert Dalrymple kicks off Part II by introducing siliciclastic facies models. Controlling factors on sediment accumulation, such as sediment supply, grain transport processes, preservational factors, and accommodation space, all contribute to the ultimate accumulation of a given facies. Important factors such as tectonics, climate, and biological influences through time are also addressed.

Carolyn Eyles and Nick Eyles have very much modernized the glacial deposits chapter to include considerations of glacial flow over soft and/or wet sediments. New information on rates of glacial erosion, the flux of glacial sediment, and glaciomarine depositional systems attests to the vast increase in knowledge of how glacial systems work and how the glacial record is interpreted. Glaciomarine settings are subdivided into ice-proximal and ice-distal regimes, and effects such as changing water depths and the role of floating ice are incorporated into the discussion. Glaciofluvial and glaciolacustrine settings as well as periglacial deposits and supraglacial situations are also covered. Sequence stratigraphy in glaciated basins is explored before the predominantly marine pre-Pleistocene record and the snowball Earth debate provide a long-term perspective on these fascinating deposits.

Andrew Miall's chapter on alluvial deposits deconstructs river systems into the essential architectural elements of channels, bedforms, and overbank deposits, such as levees and crevasse splays. Each element is composed of distinct facies; the geometry of, and spatial relationships among these facies help to distinguish these critical components as developed in meandering, anastamosing, and braided rivers. Schematic cartoons, field photographs, well logs, and seismic and ground-penetrating radar imagery illustrate the essential features of these systems from the conceptual to the applied.

Michael Brookfield and Simone Silvestro use modern processes to identify the features of modern desert systems. Erosional features and depositional elements ranging from fine-scale surface structures and lami-

nae, to wind ripples, dunes, and draas (large-scale eolian bedforms), provide a spectral view of the complexity of these systems. Soils, paleosols, and sand seas are presented before facies models for these deposits are developed. In addition to the traditional desert-belt settings, the authors extend their coverage to eolian deposits in Arctic deserts and on Mars.

Guy Plint reviews the history of approaches to understanding storm deposits and the processes that form them, from flume studies of hummocky cross-stratification, to stratigraphic approaches, to a more holistic approach that embraces not only the sands, but the muds, which constitute the largest component of shelf sediments. From there, he examines morphological elements and physical processes on the beach and upper shoreface. A well-illustrated overview of the sedimentary structures found in storm deposits is integrated into their patterns of occurrence in facies successions across a spectrum of sandy-to-conglomeratic settings.

Robert Dalrymple returns to present the current state of knowledge of tidal depositional systems. Basic principles of tides and tidal currents set up a summary of the sedimentary structures used to distinguish and interpret tidal facies. From that foundation, tide-dominated environments are then discussed in terms of processes, channels, bedforms, shelf ridges, and tidal flats. Modern examples spice up that discussion as do examples of facies successions and seismic sections. A review of the manner in which tidal facies vary among tidal depositional systems in settings such as deltas, estuaries, transgressive shelves, and seaways and straits provides a sense as to how facies and their spatial relations change from one system to another. The discussion of stratigraphic organization of tidal successions highlights the complexity of tidal deposits.

Janok Bhattacharya tackles the challenging topic of deltas by first classifying these highly variable systems, and then addressing issues of sediment dispersal, wave reworking, and tidal reworking. Map and cross-section perspectives are used to explore aspects of the subaerial delta plain, distributary channels and mouth bars, as well as the delta front and prodelta components. Vertical facies successions are then examined for various components of delta systems. Analysis of facies architecture reveals the stratigraphic packaging of delta systems and helps pave the way toward interpreting such architecture from seismic sections and well-log data. Discussion of the sequence stratigraphy of deltas provides a larger view as it examines the interplay of sea-level change with delta systems.

Ron Boyd, in his portrayal of transgressive, wave-dominated coasts, notes that while we understand the post-Pleistocene transgression through the modern analogue in which we exist, surprisingly few ancient transgressive coastlines have been studied. His discussion of coastal organization and classification helps tie together concepts from some of the preceding chapters, and his emphasis on a clear definition of transgression and regression as opposed to simple sea-level changes is a good reminder to those who may tend to blur this distinction at times. From there, he illustrates transgressive coastal geomorphology, and follows with a discussion of the processes controlling transgressive wave-dominated coasts, exploring facets, such as shoaling waves and their impact on the seabed. A brief side trip into the value of new technology, such as sidescan sonar, ground-penetrating radar, and LIDAR (Light Detection and Ranging) promises ever-improving resolution for viewing coastal sedimentary systems.

William Arnott's chapter on deep marine sediments and sedimentary systems are the final terrigenous clastic facies model. After briefly reviewing the history of some key events contributing to human understanding of this often elusive facies, the author discusses sediment transport via different types of flows such as sediment-gravity flows. From there he moves into deep marine architectural elements, emphasizing that changes in sea level, tectonics, and sediment supply influence the 'turbidite system'. In addition to the classical point-source fans, he explains that multiple-source ramps and line-source aprons are significant contributors to the family of turbiditic sediments. Channels, levees, overbank deposits, and depositional lobes are among the chief architectural elements covered. The chapter concludes with an examination of deep marine facies associations in light of sequence stratigraphy.

Noel James, Alan Kendall, and Peir Pufahl join forces to present an introduction to biological and chemical facies models. This introduction to Part III (Chemical and Biological Facies Models) unites the non-siliciclastic facies discussed in this book, which are mostly marine. A new chapter on lakes broadens the perspective; otherwise, Part III addresses the mostly biochemically formed carbonates, the mostly chemically produced evaporites, and a new association called bioelemental sediments, which form via biological/chemical/oceanographic processes in the water column and include phosphate, chert, and iron-rich sediments. Discussion of carbonate, evaporite, and bioelemental factories compare and contrast the modes of sediment production in these three realms. The scope of the chapter broadens toward the end as the authors explore how biology, oceanography, tectonics, biological evolution, and global evolution all affect the manner in which biochemical and chemical sediments accumulate.

Warm-water neritic carbonates are discussed by Brian Jones. Topics include sediment production in the carbonate factory, warm-water depositional systems and facies models, and consideration of how eustatic, climatic and tectonic factors influence carbonate facies in neritic settings. Facies models in modern systems are well portrayed and clearly explained for shelves, ramps, atolls, isolated oceanic islands, and epeiric seas. However, the author emphasizes that extending modern models into the ancient environment is not always successful, given that, among other things, many ancient carbonate deposits have no modern analogue. The importance of changes in sea level and the resulting formation of sequence boundaries that serve as bounding surfaces among sediment packages conclude this chapter.

Noel James and Jeff Lukasik shift the discussion of carbonate facies from warm- to cool- and cold-water neritic settings. After long receiving far less attention in the literature than

their warm-water counterparts, these cooler water carbonates have been gaining recognition of late. Within the cool-water carbonate realm, warm-temperate and cold-temperate carbonates can be distinguished; in modern systems, a temperature of about 15° C divides the two types. The carbonate producers are chiefly filter-feeding organisms that rely heavily on particulate food that settles from overlying surface waters. Coralline algae are the only carbonate-secreting phototrophs in this depositional system, and can sometimes produce carbonate banks up to a few metres in height. Facies models from open oceans, interior basins, and seaways are discussed. Paleozoic and possible Neoproterozoic examples are considered before a discussion of depositional dynamics and sequence stratigraphy of these deposits brings the chapter to a close.

Peritidal carbonates are covered by Brian Pratt. His initial overview of these low-relief, often dolomitic systems, examines the processes and settings in which tidal flats form. He emphasizes that the nature of these systems has evolved considerably, from dominance by microbes prior to the Cambrian to more diversified biotas in the Phanerozoic. After briefly discussing diagenesis in tidal-flat deposits, the author examines peritidal sediments and facies in shallow subtidal, intertidal, and supratidal zones. The pitfalls in recognizing peritidal facies are pointed out before moving on to peritidal stratigraphy, cyclic vs. non-cyclic successions, and causes of cyclicity for both autocycles and allocycles.

In their chapter on reefs, Noel James and Rachel Wood point out that direct application of modern reef analogues to ancient systems is very challenging because of the considerable biological and oceanographic contrasts involved. Despite this variability, reefs of a number of ages are significant hydrocarbon reservoirs. James and Wood review facies associations among skeletal reefs, skeletal-microbial reefs, microbial reefs, and mud mounds. Reef growth strategies as a response to various influences such as relative sea-level change, tectonics, carbonate saturation, evolving ocean chemistry, and climate are reviewed. All these factors affect the geological history of reefs, which is summarized and illustrated at the end of the chapter.

Ted Playton, Xavier Janson, and Charles Kerans team up to describe and interpret carbonate slopes. Comparison of carbonate slopes with siliciclastic ones reveals a number of interesting differences; carbonate slopes, for example, undergo considerable submarine cementation and biological binding, leading to greater potential for brittle failure than in sandy counterparts. Key breakthroughs in carbonate slope research have come in the areas of deposits and processes, margin and slope morphology, and sequence stratigraphy. The authors classify the deposits into debris-dominated, grain-dominated, and mud-dominated slope systems, and describe the features that characterize each system. Models for the three slope types noted above take this chapter to the next level, followed by a discussion on the controls on these sedimentary systems.

Bioelemental sediments are discussed by Peir Pufahl. Concentrations of dissolved iron, silica, and phosphate are low in modern oceans, and yet enrichments in these elements form conspicuous deposits that are often economically significant. Life plays a pivotal role in concentrating many of these sediments. For example, iron-precipitating bacteria are now recognized as an important part of the genesis of Precambrian iron formations. Most Precambrian chert is abiogenic, whereas silica-secreting organisms have controlled the accumulation of most cherty deposits since the Cambrian. In addition to his overview of iron formation genesis and classification of chert types, the author discusses how these sediments vary in shallow- and deep-water environments. Pufahl discusses the manner in which phosphorus is concentrated in insular, seamount, and continental margin phosphorites, and compares phosphorites in upwelling vs. non-upwelling settings. After reviewing each bioelemental sediment type, the author generalizes bioelemental systems, emphasizing iron and phosphorus. Lateral and facies relations are examined, as is their long-term evolution in the geologic record.

Alan Kendall introduces marine evaporites by noting that evaporite mineral crystallization from subaqueous settings is most prevalent at the top or bottom of the water column. However, evaporites can form in a diverse array of settings. He addresses controls on evaporite formation, such as the concentration and composition of brines, basin hydrology, influx of water or salts, basin restriction, and brine reflux. Evaporite facies are subdivided into mud-flat or sabkha facies, shallow-water facies, and deep-water facies, and the inherent processes and characteristics of each of these facies are reviewed. From there, the author describes the facies models that have been developed for evaporites, mainly focusing on basin-margin settings and basin-central situations. In summarizing evaporite facies, Kendall indicates that they are best defined by "internal sedimentary and diagenetic characters" rather than by particular geographic environments. Although much has been learned about evaporites in recent decades, sequence-stratigraphic applications are not, as yet, greatly successful in evaporite facies.

In their chapter on lakes, Robin Renaut and Elizabeth Gierlowski-Kordesch rise to the challenge of summarizing the complexities and substantial variability of lacustrine systems and facies in a single chapter. Lakes can be dominated by carbonate, evaporitic, siliciclastic, volcaniclastic or organic sedimentation, and combinations of more than one sediment type can occur. After reviewing physical, chemical and biological processes in lakes, the authors enter into a discussion of lacustrine facies models for lakes with siliciclastic shorelines and carbonate shorelines. The many topics discussed include an examination of deltas, sublacustrine fans, the influence of pelagic biotas, organic-rich lake deposits, and saline lakes. Renaut and Gierlowski-Kordesch move from here to classification of lakes and sequence stratigraphy in lakes, describing the facies associations found in overfilled lakes, underfilled lake basins, and balanced-fill basins. As a parting thought, the reader is reminded that in addition to the complexities noted throughout their chapter, a given lake, during its lifetime, may shallow, deepen or under-

go other changes that will noticeably change the character of the sediment record.

I have used the 1992 (3rd Edition) version of *Facies Models* for many years in my graduate and upper-level undergraduate course on depositional environments. As part of the course, the students read and present the chapters to their classmates. This not only updates and augments their memories of the aspects of depositional environments to which they were introduced anywhere from two to four years previously, but positions them ideally to delve into the primary literature for the rest of the term. I am delighted to report that *Facies Models 4* can serve even more effectively in this role. The book is not only a wonderful gateway to the literature on sedimentary geology, but it will now be one of the first resources I reach for when I need quick access to information on depositional sedimentary systems.