



Mud and mudstones. Introduction and overview, by Potter, P.E., Maynard, J.B., and Depetris, P.J., 2005, Springer-Verlag, Heidelberg, hardcover, USD 89.95, ISBN 978-3-540-22157-9.

My relationship to the subject of mud and mudstones requires that I digress a little before launching into a point-by-point review of this book. We are at a point in time when the study of fine-grained terrigenous clastics is finally gaining respectability, not the least because it is gradually filtering through: ignorance of these rocks can be costly. The growing interest can be gauged by the fact that several sessions were devoted to these rocks at the American Association of Petroleum Geologists (AAPG) and Geological Society of America (GSA) meetings over the past 3 years, as well as by the scheduling of more mudstone sessions at upcoming meetings (e.g., AAPG in San Antonio in 2008). A quarter century ago, as a freshly minted graduate student, I had started to work on a project that turned out to be mudstones, mudstones, and more mudstones. Standard sedimentary geology texts had plenty to say about sandstones and carbonates, but very little on mudstones—a term that I will use for the remainder of this review, with the understanding that some geologists, myself included, prefer to use shale instead. When I commented about this to one of my professors, I was told that not too long ago a book had been published with the evocative title *Sedimentology of Shale*, with Paul Potter as the lead author. Because our library did not have the book, I decided to get it on my own, even though it was at the time not a cheap buy for a graduate student. When the book arrived in the mail I eagerly opened it, hoping to find answers to the many questions that had piled up since I had started my project. It was a bit of a letdown. Potter et al. had a whole catalog of their own questions, not much to offer in terms of answers, and my questions had, by and large, not even made their list. I admit that I was disappointed at first, but later on it gradually dawned on me that opportunity was knocking. I realized that regarding whichever aspect of mudstone geology I chose to investigate in the future, I would never fail to uncover something new. I might even have a chance to make some serious discoveries. Since that time, I have literally been knee-deep in mud and mudstones and have never been wanting for intellectual stimulation.

Published more than two decades after a long gestation period, *Muds and Mudstones* is the long-awaited sequel to *Sedimentology of Shale*. One has no trouble recognizing that we have made quite a bit of progress since that first catalog

of questions about mudstones was published. Some questions have now been answered to reasonable satisfaction, others are making good progress toward their resolution, and still others have been rephrased and improved upon. With some luck, the first two decades of this century could well become the golden age of mudstone research.

The organization of *Muds and Mudstones* is focused on processes and methodology, posed as a sequence of eight questions.

1. How are mud and silt produced?
2. How are they transported and deposited?
3. What is the role of oxygen at the site of deposition?
4. What is known about mud in modern environments?
5. What are the controlling processes and changes that occur with burial?
6. How do we determine the provenance of mud and mudstone?
7. How do we study ancient mudstone-rich basins?
8. What are the practical aspects of muds and mudstones?

Chapter 2, dealing with the production of mud and silt, is a good overview of the processes that produce fine-grained terrigenous sedimentary materials. Yet, whereas the extrabasinal contribution to mudstones is discussed at some length, the intrabasinal contributions do not receive a similar treatment. For example, Devonian black shales of the eastern United States contain as much as 20% organic matter, as much as 40% quartz silt originating from dissolved radiolarians, and 5–10% pyrite. A rock of such composition might more accurately be called biochemical sediment; let us not forget mudstones with a substantial biogenic carbonate component. Clearly, there are a good many mudstones that do not fit the fine-grained terrigenous clastic label, and, thus, it seems unwarranted to restrict the discussion of mud production to the terrigenous clastic realm. As an aside, the content of Chapter 7, a discussion of provenance issues, might have more profitably been integrated into this chapter dealing with the origin of the materials that comprise mudstones.

In Chapter 3 the authors discuss the processes that transport and deposit muds, providing a useful and compact summary of the processes and their potential impact on mud dispersal. For

the informed reader, however, there are curious inconsistencies in sections of this chapter. For example, much is made of settling velocities of individual particles according to Stokes' Law, only to read on the same page (p. 31) that, "Increasingly, studies indicate that most modern mud is deposited as aggregates—as flocs and as fecal pellets" (a notion with which I fully agree). But then, in the same paragraph (p. 32) we read, "clays are largely separate particles in river water, but are largely in aggregates in seawater." The latter notion, however, though recited commonly and persistently in the literature, is not supported by direct observation. If it were true, there would be no need to add deflocculant when making grain-size measurements of muds via settling tube. Considering that textural features in mudstones have a tendency to be on the subtle side, it would also have been fitting to not only illustrate sedimentary structures that are found in the silty sandy end members, but in the clay-rich portions as well. Likewise, the discussion of bioturbation could have been expanded. It introduced the well-known and easily recognized trace fossils that have been known for decades but left out much of bioturbation in mudstones that does not produce the classical structures indicated, but rather results abundantly in biodeformational textures. It would have been instructive to the novice in mudstone studies to be informed that there are examples of black shales that may appear laminated at first inspection but nonetheless have been completely bioturbated.

In chapter 4 the authors discuss the impact of oxygen availability on the ability of macroorganisms to modify the sediment and on the development of geochemical gradients due to the metabolism of microbes living within the sediment. Various approaches to estimate paleo-oxygenation levels are introduced, including sediment color, biomarkers, paleoecology, degree of pyritization (DOP), redox-sensitive trace metals, and framboid-size distribution. What is missing from the discussion are, for example, results from Mo behavior in modern sediments, indicating that Mo concentrations in shales can not be used to detect and differentiate euxinic, anoxic, or dysoxic conditions. Likewise, the authors may have wanted to include a note that seafloor reworking of sedimentary pyrite can produce abnormally high DOP values and invalidate DOP-based assessments of paleo-oxygenation. Finally, the authors note that the best indicators of paleo-oxygenation levels for the Paleozoic are bioturbation and body fossils. It would have been fitting in this context to point out how much insight about subtle bioturbation features can be gained from careful petrographic study and how detailed study of early diagenetic minerals (e.g., Manganese enrichment in early diagenetic carbonates) can potentially be used to learn about oxygen levels in pore waters near the sediment-water interface.

Chapter 5 is a comprehensive review of the various factors that determine where muds are likely to accumulate in modern environments (fluvial, lacustrine, deltas, glacial, and shallow and deep marine). This section also includes an overview of the processes that are involved in transport and deposition of mud in these environments. At the end of the chapter (p. 122) the authors pose the following question: "How well, if at all, do sedimentary structures and textures of muds and mudstones of different environments distinguish one environment from another...", and that is followed with, "This has rarely been attempted." The statement, as such, is puzzling, because as far

as I know this question can be answered in the affirmative. There are several studies of Precambrian and Phanerozoic mudstones that demonstrate that, when examined in sufficient detail, the sedimentary structures and textures of mudstones can indeed be used to differentiate depositional environments.

Chapter 6 deals with the effects of burial on mudstones and provides an overview of mechanical compaction and its effect on mudstones and mudstone successions, which is followed by an overview of chemical processes during shallow burial. The section on deeper burial deals mainly with the transformation of clay minerals and biogenic silica and with the maturation of organic matter and hydrocarbon generation. The literature on burial diagenesis (both physical and chemical) is extensive, and I noticed that a good many statements in this section were clearly referring to certain scholarly papers, however no references were provided. This general observation also applies, to varying degrees, to other chapters in this book. One would also think that if the authors feel the need to use illustrations from older literature, they would not repeat in their captions outdated views of geological relationships or processes. For example, in Fig. 6.22 the statement is made that the Carboniferous Borden Formation and the New Albany Shale of western Kentucky are genetically related mudstone formations. Yet, it has been known for some time that they are separated by an unconformity.

The chapter on provenance, Chapter 7, is to a large degree a survey of the various methodologies (e.g., architecture of basin fill, petrographic, mineralogical, major and trace element chemistry, isotopes) that have been used to investigate mudstone provenance. About two-thirds of the methods section is devoted to geochemical approaches, although the authors are aware of the limitations that recycling imposes on largely bulk rock geochemical studies. On the other hand, such petrographic approaches as cathodoluminescence, by which provenance information from stable grains like quartz can be extracted, are not mentioned at all. In Table 7.2 it is stated that the quartz content of mudstones is independent of diagenesis. Yet, in the previous chapter, as well as in Chapter 2, they mention the production of authigenic quartz silt during diagenesis. While by necessity the various chapters of this book were compiled over multiple years, one has the impression that the final edit did not succeed in producing full coherence and uniform updates. Also, as already mentioned in the discussion of Chapter 2, intrabasinal contributions to mudstones cannot be neglected. The latter can have a big impact on mudstone variability and complicate especially the geochemical provenance approaches. The intertwined nature of provenance issues also makes one wonder (again) whether this chapter should not have been integrated into chapter 2.

In Chapter 8, muddy basins, the authors discuss the accumulation of mud under a range of tectonic settings, and the various factors that may determine whether a basin will be dominated by mudstones or by other lithologies. This chapter also contains a review of the principles of sequence stratigraphy and how sea-level change may impact variability and distribution of mudstones at the basin scale. The chapter concludes with an overview of Milankovitch cyclicity and how it can, over a range of scales, imprint a cyclic character on mudstone successions.

The ninth chapter of the book, Practicalities, is a review of the multifaceted economic importance of mudstones. The

topics touched upon include mudstones as seals and aquitards, as a source of mineralizing fluids, as trap environments for metal-bearing fluids and host rocks of sedimentary ore deposits, as sources of industrial minerals (ceramics, brick, and tile manufacture), as the principal source of hydrocarbons, and mudstones and mudstone weathering as an impediment and hazard to construction projects.

The final portion of the book consists of a collection of appendices that give examples of how mudstones might be described in the field and in drill cores, general comments on terminology and classification, an overview of clay minerals and soils, some mention of petrographic techniques, organic matter and its maturation and study, and a brief overview of the uses of light stable isotopes. While brevity is commonly considered a virtue, I felt that this section was overly brief. A more expansive treatment of techniques would, in my opinion, be very helpful to newcomers to this area of research. What I would have liked to see in particular is a good demonstration of the powers of straightforward petrographic study. I consider this to be a regrettable shortcoming because there is a tremendous amount of information that can be gleaned from careful examination of petrographic thin sections. Somebody just starting the study of mudstones would never get that impression by reading this book.

Obviously, my take on mudstones is not wholly congruent with that espoused by the authors of this book. Yet, mudstones are a most varied lithology, cover a much greater

chemical, compositional, and textural spectrum than either sandstones or carbonates, and in spite of steady progress, are still comparatively poorly known. Relevant research is spread out over many technical disciplines and difficult to keep up with consistently. Would I have written this book differently? Absolutely! Would it have been a better book? Perhaps, but not with any degree of certainty. It would probably have been stronger in some points, but weaker in others. Mudstones are a complex topic, and it is very challenging to cover every aspect comprehensively. The authors have succeeded in giving the reader a broad review that is not available from any other source, and they give an introduction to many interesting aspects of mudstones and mudstone sedimentology. The book provides a very helpful summary of the processes that determine mudstone variability and mudstone properties, and it should be a great help to those who wish to engage themselves more deeply in this exciting area of research. In spite of above noted omissions and inconsistencies, this book is the best single source of information on mudstones currently available. As such it should be considered an essential addition to the library of any serious sedimentary geologist.

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