Siever, *Sand*, a book report

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Raymond Siever's objective with *Sand* [Siever88] is rather simple, perhaps deceptively so: to expound the major themes of geology for the general reader using one of the most common, prosaic materials on earth as his teaching aid. It's a substance that most people would likely say that they understand implicitly. But in the classroom of an expert like Siever, there's lots to learn. That common grit, of course, is sand, and the book describes how it is created, what it changes into, and what it can tell us about the world now and in the remote past; we learn how geologists study that world and the tools and methods they use.

The book is number 24 in a series (no longer actively published) of science volumes for general readers, of which [Dobson96] is another example: the volumes feature a relatively low page count (ca. 250pp.), generous margins for well-executed figures and illustrations; there are no footnotes, but a further reading section is in the back matter. With such a brief text, there's not much leeway for elementary explanations, so Siever jumps right in to his material.

Stated more carefully, the author does not restrict himself to sand as defined by geologists, that is, particles with a grain size between 1/16 and 2 mm, but rather, as necessary, he discusses the fortunes of the finer silts and clays as well as the coarser pebbles, cobbles, and boulders. Perhaps a more accurate, if less marketable, title for the work would be *Sediment*.

The author's method of presentation is quite effective. Beginning with simple questions—What is sand made of? How does it come to be where we find it? What, in turn, is made of sand?—he proceeds by answering these questions with more questions. Can we determine where this specific sample of sand came from? Given what we now understand about cross-bedding, what does that tell us about conditions in the past? I find it refreshing that Siever defers until the second half of the book a discussion of the big idea of current geological thought, plate tectonics. And it's only in the final chapter that he takes us for a walk along the familiar (to most of us, at some level) geological timeline of eras, periods, and epochs.

However, this approach to the material, the plunging into a field of study with a more structured, definitional explanation to follow, at times works to Siever's disadvantage. Readers a little fuzzy on whether the Pennsylvanian came before or after the Cretaceous may find themselves disoriented. Similarly, the explanation of the fining-upward cycle (a term not in the skimpy index, alas) left me a bit confused. Diagrammed on pp. 70 and 71, the full explanation in words is withheld until p. 80.

Precis

Chapter 1 introduces our sandy subject, what we can say about it, and the tools we use to look at it. The geological partnership between scientists, engineers, and businessmen in the exploration and exploitation of oil and gas resources is introduced.

The next chapter gets more specific about what sand is made of: quartzes and feldspars (i.e., silicon compounds) most commonly, but also calcium carbonates (either chemically precipitated or of biological origin) and calcium sulfates. Both sedimentary rocks (like sandstones) and igneous rocks (like granites) break down under natural processes (physical and chemical weathering) into little bits of sand. Can we take a sample of sand and figure out the chemistry of the rock it came from? Per the discussion capped by the figure on p. 30, the answer turns out to be "it depends on the weathering conditions."

This chapter provides perhaps the most surprising, or at least non-intuitive, information. Sand occurs both in angular grains, like little crystals, and smoothly rounded grains. The source of the rounded grains is but another sandstone that has eroded.

> Quartz sand is so stable that is may be recycled through erosion, sedimentation, burial, and uplift many times and still retain its identity as a grain. Through these cycles it is repeatedly abraded during transport; the final result is a rounded grain that stands as a record of all the cycles of mountain building and erosion that it has gone through.
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> If the average recycling time is 200 million years—a rough guess—a Devonian sand grain deposited about 380 million years ago might have been recycled 10 times since it was first eroded from a granite about 2.4 billion years ago. (pp. 33, 55)

The third chapter puts sand in motion, either driven by wind into dunes or along the bottom of a flowing stream. The author introduces cross-bedding (using a dramatic image on p. 60), a phenomenon described by science long before its cause was understood. Evidence from the field is used to reconstruct flows in the waters that once covered the modern American Midwest; lab experiments with flumes confirm the connection between cross-bedding (observed parallel fine layers of sandstone oblique to the coarser horizontal layers) and sands of various grain sizes moving along the bottom of a river.

I made heavy weather of the discussion of shear stress in this chapter (pp. 39ff.): it's easy to confuse forces acting within a fluid with forces acting between a fluid and the sand it is flowing over. However, in the subsequent passages, I discovered the intriguing statement that the increased viscosity of cold, early spring meltwater increases its ability to transport sediment.

Sand and other sediments in a meandering riverbed, now frozen into distinctive profiles, is the basis for chapter 4. The facies of a vertical sequence of sediments constitutes a geologic signature that can be used to infer the conditions under which they were laid down—that is, its sedimentary environment, be it continental alluvial fan, coastal delta, or abyssal plain.

Chapters 5 and 6 take up sand in motion at the seashore and under the ocean. A pair of maps of Cape Cod's Wellfleet area (pp. 106-107), one each from the 19th and 20th centuries, does a good job of illustrating the comings and goings of sedimentary coastlines. The idea of turbidity currents—massive undersea flows of sediment along the continental slope—was an eye-opener for me, as apparently it was to the geological community in the 1940s and 1950s. Again, the analysis of turbidites (rocks formed as a result of turbidity currents) depends on following the sequence of sediments by grain size, from coarse pebbles at the base to fine clays at the top.

The following chapter rolls out an explanation of what is known about the movements of crustal plates and how observations of sedimentary rocks contribute to that knowledge. The figure on p. 143 correlates the ways in which sand can be deposited—as turbidites, in deserts, on alluvial plains and fans, in deltas, and at continental shelves and rises—with the major features of tectonic movement—subduction zones, active and passive margins, rift valleys. Sandstones under the southern Midwest help geologists understand the failed rifting in that area, and contribute to an explanation of the great earthquake of 1812 in New Madrid, Missouri.

Chapter 8 takes up the topic of diagenesis, that is, all postdepositional processes that operate on a bed of sediments—in other words, what happens to sand to make it sandstone? It turns out that any number of precipitates from the water suffusing the bed can cement sand grains together: calcium carbonate, sulfates, phosphates, silicates, and iron oxides among them. Temperature and pressure, of course, have observable effects on the porosity and permeability of a sandstone, as well as how individual grains come into contact with one another. How well a sedimentary rock can be penetrated by a fluid is of high importance to geologists and engineers searching for deposits of oil and natural gas, as chapter 9 discusses.

Finally, the grand sweep of sands across geologic time is described in chapter 10. Under Archaean and Proterozoic low-oxygen conditions, sand forms banded iron formations, consisting of alternating layers of quartz and hematite (Fe_2O_3). The appearance of streamside vegetation in the Phanerozoic means that meandering rivers can develop.

Remarks

Fortunately for readers interested in the mid-Atlantic region, it's specifically called out as an example of rifting along a continental margin (pp. 158-159).

Siever does a good job of demonstrating the scientific approach. He makes it evident that geology is an active science, working its way from uncertain knowledge to better, clearer, more precise certainty. He's not one to glamorize the profession, but rather to emphasize its quirks:

> Geologists, like spies sifting through cans of garbage, looking for revealing bits of information, search for the properties that are clues to Earth's patterns of behavior now and in the past. (p.17)

I was entertained by his tongue-in-cheek description of the Society for Long-Term Experiments, to which he gained membership by measuring the room-temperature solubility of quartz in distilled water, observing a change of 1 ppm over a period of two years. (p. 21)

The book is a worthwhile, fairly quick read. I would recommend it to a general reader, curious about geology in general and sedimentology in particular—one who is equipped with a geological dictionary and not shy about encountering a few chemical formulae or a smidgen of math along the way.

I picked up this title out of sheer caprice. The performance artist and musician Laurie Anderson has used sand in her works and has referred to Tibetan sand paintings in interviews. Several years ago, in the wild and woolly days of online communities, she used to tell a story about making the acquaintance of someone who shared her interest in sand. It turns out that her new electronic pen pal was a boy who was most interested in the material in his own sandbox. If sand was that interesting to Anderson and her friend, then that was reason enough for me.

References

[Dobson96] Dobson, Andrew P., *Conservation and Biodiversity*, Scientific American Library, New York, 1996.

[Siever88] Siever, Raymond, *Sand*, Scientific American Library, New York, 1988.