CHAPTER 17
PLANAR STRATIFICATION

INTRODUCTION

1 Planar stratification is just as common as cross-stratification, if not more so, but the literature on it is not nearly as large. In a sense, the title of this chapter is misleading: it concentrates on the topic of planar lamination, not planar stratification in general.

2 It seems important at the outset to mention the distinction between beds with approximately planar and parallel bases and tops, forming tabular sediment bodies (I tend to call such beds *tabular* beds rather than *planar* beds), on the one hand, and ***planar internal stratification***, within much thicker beds, either planar or not, on the other hand. Such internal stratification might be either technically bedding or lamination, technically, depending on stratum thickness, but the important point is that the relatively thick bed typically comprises a very large number of much thinner internal laminae. This distinction seems to me to be useful and sensible.

3 We need to deal with some more matters of terminology. First of all, the term "parallel" does not need to imply that the existence of straight lines or planes: the laminae might be curved, in three dimensions, but they are parallel in the sense of being *congruent*; that is, adjacent laminae have the same shape, or are at least close to having the same shape. I prefer, however, to reserve the term *parallel* for laminae that are close to being planes, and to use the term *congruent* for laminae that do not form planes but have approximately the same curved shape in a succession of laminae.

4 As far as I can tell, the terms *planar lamination* and *parallel lamination* are essentially identical. Such lamination is sometimes also called *even lamination* or *horizontal lamination*, although the latter term may carry some confusion, because the laminae may have been horizontal when deposited but are not now, or they could have been deposited with a non-negligible initial dip even though they were planar.

5 One could develop a geometrical classification of laminae in a lamina set (also called a laminaset) on the basis of three attributes:

- planar vs. congruent shape of the laminae
- tabular vs. non-tabular shape of the lamina set
- horizontal or non-horizontal orientation of the laminae

Rather than doing that here, however, I will just show the four most common categories that would arise in such a classification (Figure 17-1). What most workers consider planar lamination is the "planar; tabular set; ± horizontal" variety in Figure 17-1. That is the focus of this chapter.

6 With regard to the three other items in Figure 17-1, most sedimentary geologists would call the laminae *cross laminae*, even though, according to the terminology I presented above, they would qualify as parallel (in the sense of *congruent*) laminae. I think most sedimentologists would agree that to a great extent such laminae owe their origin to processes that are specific to the lee regions of ripples or dunes: grain flows down angle-of-repose lee slopes; interleaving of grain-flow deposits and fallout deposits; and/or temporal variation in sediment supply to the lee region as a consequence of arrival of superimposed smaller bed forms to the brink region of the larger form.
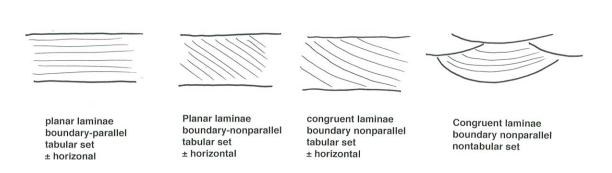

planar laminae
boundary-parallel
tabular set
± horizonal

Planar laminae
boundary-nonparallel
tabular set
± horizontal

congruent laminae
boundary nonparallel
tabular set
± horizontal

Congruent laminae
boundary nonparallel
nontabular set

Figure 17-1. Four common kinds of beds with parallel or congruent internal lamination.

7 In think that, similarly, most sedimentologists would agree that planar lamination in sands and sandstones is somehow associated with the existence of a planar transport surface, in what I called in Chapter 11 the upper-flow-regime plane bed, over which abundant sediment is being transported in traction. Planar lamination is also very common in muds, mudrocks, and shales, and it seems clear that much—probably most—such lamination is formed under conditions of weak currents by fallout without traction. The distinction is usually clear from the overall context of the deposit, aside from the contrast in particle size. After a few comments on the possibilities for paleoflow interpretations, and then a brief section on the characteristic features of planar lamination, the rest of the chapter deals with the origin of planar lamination in sands and in fine sediments.

8 In terms of paleoflow interpretation, in the spirit of Chapter 16, on cross stratification, we might take the approach of trying to identify the entire range of flow conditions under which the bed configuration is a plane bed rather than a bed covered with rugged bed forms—on the theory that planar lamination in sands is associated with plane-bed transport in the upper flow regime. This would, however, give us only a partial idea of how to interpret the environmental significance of planar-stratified beds. The problem is that, in contrast to cross-stratified beds, there are no obvious internal geometrical features that vary with flow and sediment conditions within that overall range, so we cannot try to go on to be more specific about environmental conditions, as we can with much success with cross-stratified beds. Moreover, there is no natural basis for deciding among interpretations involving unidirectional flows, oscillatory flows, or combined flows, all of which feature plane-bed transport in an upper flow regime.

9 Owing to these problems, the observational fodder for interpretation of planar lamination would have to lie in textural attributes like particle size distribution and particle orientation, or in subtle variations in lamina thickness and spatial continuity. There is an offsetting advantage, however: the scale of planar lamination is so small that its features can be studied in even small laboratory flumes.

FEATURES OF PLANAR LAMINATION

• Laminae range in thickness from just a few particle diameters to over a centimeter (in which case they should not technically be called laminae any more!), equivalent to as much as hundreds of particle diameters.

• The essential feature of planar laminae is that their extent is much greater than their thickness. At a minimum, the lateral extent is an order of magnitude greater than the thickness, and it can range up to many meters, which is at least three orders of magnitude grater than the thickness.

• Laminae, almost by definition, vary in their textural features (particle size, sorting, and shape); they are commonly graded, either normally or inversely.

• On parting surfaces through planar-laminated sandstones, *parting lineation* (also called, somewhat more precisely, *parting-step lineation*) is characteristic, presumably reflecting a tendency for flow-parallel orientation of slightly elongated particles under upper-flow-regime conditions.

THE ORIGIN OF PLANAR LAMINATION IN SANDS AND SANDSTONES

10 Up until the late 1980s, the origin of planar lamination was an unsettled issue; a number of hypothesis had been proposed but none seems to have been widely accepted. Perhaps surprisingly, from the vantage point of the present, there were no reports of attempts to reproduce planar lamination experimentally

in laboratory flumes, with the exception of the study by McBride et al. (1975). McBride et al. (1975), in shallow flow in a small flume, demonstrated that a variety of parallel lamination could be generated by the downstream movement of very low, depth-limited current ripples during slow overall aggradation of the sediment bed. They did not succeed, however, in producing parallel lamination under upper-flow regime plane-bed conditions—the flow condition under which it might be most natural to expect planar lamination to develop.

11 Early ideas on the development of planar lamination developed along two lines: downstream movement of very low-amplitude bed forms or bed waves under plane-bed conditions in the upper flow regime under conditions of slow aggradation of the bed, or the effect of features of the turbulence structure on sand transport. In a field study of a shallow sand-bed river, Smith (1971) was the first to report on development of planar lamination caused by downstream movement of low-amplitude bed forms. Models that invoke turbulence structure of the flow date back to that of Allen (1964).

12 The first attempt to develop a model that involves both of the effects describe above was that of Allen (1984). Later, on the basis of similar flume studies made at about the same time, Bridge and Best (1988) and Paola et al. (1989) (see also Best and Bridge, 1992, and Bridge and Best, 1997) developed a satisfying model in which the laminae are accounted for by downstream movement of very low-amplitude bed forms under upper-regime plane bed conditions, with the internal features of the laminae accounted for by the nature of the turbulence felt by the bed.

PLANAR LAMINATION IN FINE SEDIMENTS

13 Planar lamination an develop wherever there is fallout of suspended sediment onto a planar sediment surface in the presence of currents that are too weak to transport the newly arriving sediment over the bed. This is what was called fallout without traction in Chapter 14. Planar lamination of this kind is at once the easiest to understand and philosophically the most natural. Whenever there is a planar bed surface with particles raining down from above, from a fluid that is not moving fast enough to transport the particles once they land, planar lamination is formed, provided only that the nature of the sediment that is raining out fluctuates in one or more ways with time. Such planar lamination is usually found in fine sediments—muds and silts—for the obvious reason that it is not easy to imagine scenarios in which sediment with substantial fall velocities can be carried for long distances by near-bed currents too weak to transport that sediment as bed load.

14 The floor of the deep ocean is exposed to bottom currents that in most (but not all) places and at most (but not all) times are well below the threshold for sediment entrainment. Slow settling of fine sediment onto the sea floor under those conditions leads to planar lamination if the nature of the settling sediment varies in some way with time—and also provided that bioturbation does not

disrupt the lamination. I suspect that most marine sedimentologists would assert that by far the most planar lamination in the sedimentary record was formed in just such a way!

15 Most shales, if you inspect them closely enough, have planar lamination. The study of such planar lamination goes far beyond the scope of these notes, because it involves consideration of the physicochemical interactions among fine clay particles, as well as the microbiological setting.

16 One way of producing fallout-without-traction planar lamination in coarser sediments, like fine to medium sands, is to appeal to strong and sediment-laden hypopycnal flows in the ocean (or in saline lakes), from which sediment rains down into quieter water below. Such hypopycnal flows develop wherever the river flow that disgorges into the water body has bulk density lower than that of the water body. Provided that the concentration of suspended sediment is not so high as to make the bulk density of the river flow even grater than that of the saline water body—in which case a bottom-hugging density underflow develops—the river flow spreads out across the surface of the water body, from which it is largely uncoupled dynamically because of the tendency for the strong vertical density gradient to damp turbulent mixing.

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