Sedimentation Experiments: Is Extrapolation Appropriate?

WILLIAM HOSKIN

ABSTRACT

*The sedimentation experiments presented on the video **Drama in the Rocks** are critically appraised, and while they are helpful contributions to our understanding of micro- and intra-bed structures in sedimentary rocks, they are merely part of a growing body of previous and ongoing literature. Furthermore, it is shown that it is entirely inappropriate to make extrapolations beyond the experimental conditions to apply the mechanism of non-horizontal layers to the formation of all fossil-bearing rocks during the Noahic Flood. Indeed, a number of unanswered questions and pressing issues make the extrapolations at best misleading, and at worst probably simply wrong.*

The experiments of Berthault[1,2] and Julien et al.[3] represent an appropriate application of experimental techniques to the problems of sedimentary processes. Such experimentation is now recognised as a valuable and necessary contribution to our understanding of the petrology of sedimentary rocks and their structures.[4] The experiments of Julien *et al.*[5] represent a logical research progression from the earlier work of Berthault,[6,7] the results being presented at the 14th International Congress of Sedimentology. These same experiments and results are presented on the video **Drama in the Rocks**[8] (and as a segment in the video **Evolution: Fact or Belief?**[9]) with further conclusions drawn from this work.

EXPERIMENTAL DETAILS AND RESULTS

The experiments investigated the stratification of heterogeneous sand mixtures either in still water or in a unidirectional water flow presumably at room temperature. Initial experiments by Berthault[10,11] found that laminae formed in still water as a function of the segregation of different populations of sand particles as they fell through a small (2-4.7 m) water column. It was noted that segregation of particles through a water depth of 4.7 m was only observed under high sediment flux rates (40 cm^3/min). Julien *et al.*,[12] using a flume, investigated the mechanism of grain segregation that produces lamination, and non-uniform (but still unidirectional) flow that produces graded-beds and desiccation.

In the experiments of Julien *et al.*[13] small amounts of sediment were used producing no lamination thicker than 1.3 cm, with no experiment performed in a water column greater than 84 cm. The physical conditions of experimentation were well monitored and reported with particle lamination and grading being clear in a number of experiments. However, in many more experiments lamination was not clear, or simply not observed. Spectacular cross-laminated and graded beds were produced in the grading experiments. Desiccation along preferential horizontal planes between crusted fine and coarse sands were observed, the experiments being performed on deposits formed under steady flow and continuous supply of sand over a planar bed without bed forms.

A major claim of the investigations of Julien *et al.*[14] was that lamination and grading (on the scale of the performed experiments) was produced by the rolling of different particles on each other producing selective settling of particles of different sizes, forming graded laminae which developed in the downstream direction. The mechanism of this downstream propagation of laminae involves the settling of particles on the foreset slope of the depositional slope (see Figure 6 in Julien *et al.*[15]). The result is the accumulation of many 'layers' of sediment, which when deposited give the illusion of bedding produced by the settling out of sediment from a water column. Each 'layer' therefore consists of a package of heterogenous sediment

and is not deposited horizontally. The mechanism of laminae formation is thus henceforth referred to as the **mechanism of non-horizontal layers.**

SIGNIFICANCE OF THE EXPERIMENTAL RESULTS

The type of experimentation described in the above work is not unique, being a part of a growing body of literature with its roots as far back as the turn of the century.[16] The work is most similar to experimentation performed on aqueous sandy bed forms in unidirectional currents[17-19] and bedding structures observed in shallow tidal environments.[2021] In the context of this body of previous work, it is important to note that as far back as Sorby,[22] sedimentary structures such as produced in the flume experiments of Julien *et al.*[23] were considered to record geologically significant processes operating on time-scales of minutes or hours. In addition to this recognition, great attention has been paid to lamination (and grading) patterns in mixed muddy and sandy sediments accumulated vertically under tidal conditions, these deposits revealing that a single tide can give rise to a variety of complex patterns of lamination. It is also an important recognition to be made, that lamination cannot form in some common marine environments where complex water currents are operating, and/or where the rate of sedimentation is sufficiently high that grain occlusion precludes lamination.

The investigations of Berthault[24,25] and Julien *et al.*[26] are therefore helpful contributions to understanding lamination, grading and possibly desiccation in some situations, on a scale such as in their experiments. The results presented from these investigations would not be ignored by most related researchers, as they also recognise the small time-scales involved in producing such structures under these conditions. However, the controlled supply of the sand mixture to a controlled and non-complex flow regime is not at all typical of the range of natural sediments and conditions, that are observed today and are preserved in sedimentary rocks. The experiments may adequately reproduce the conditions of shallow flood waters, or a shallow aqueous environment experiencing average to strong unidirectional water flow. It would seem clear then that these experimental results are limited in scope to very simple flow regimes in shallow water, with a supply of fairly similar sediment populations. These results appear to be important to our understanding of micro- and intra-bed structures.

IS EXTRAPOLATION APPROPRIATE?

Extrapolation of these results beyond the conditions of experimentation would lead to incorrect conclusions, due to the typical complexity of the physical conditions and the sediment load that is observed contemporaneously in nature and sedimentary piles. Based on the work of Julien *et al.*[27] in particular, Berthault[28] in the video **Drama in the Rocks** draws the conclusion that all fossil-bearing rocks were probably formed during the Noahic Flood by the **mechanism of non-horizontal layers** as observed under the well-constrained conditions of flume experimentation. This conclusion represents a gross over-interpretation of the experimental results of Julien *et al.*,[29] as with respect to the supposed prevailing conditions during the Noahic Flood these experiments were performed using an extremely narrow range of geologically possible sediment sizes and types in relatively very shallow water, in relatively uniform and controlled physical and chemical conditions. If we are to agree with Berthault[30] that all fossil-bearing rocks were deposited during the Noahic Flood, then we must also accept a scenario where the whole Earth was experiencing intense turmoil and undergoing catastrophic processes that we can hardly hope to understand, let alone reconstruct in a small flume under extremely well-controlled conditions. Berthault[31] admits

> *These experiments in calm and running water, confirm that the deposit of a heterogranular sediment can give rise to horizontal and cross lamination,* ***provided that a minimum disturbance of water is involved'*** (emphasis added).

It is clearly dismissible on these bases that the **mechanism of non-horizontal layers** was a dominant mechanism operating during the formation of the Noahic Flood deposits.

UNANSWERED QUESTIONS AND PRESSING ISSUES

In order to clarify the conclusions made on **Drama in the Rocks** it would be helpful to address the experiments and conclusions in the context of other researchers and experimentalists, and to answer the following statements and questions.

(1) For the **mechanism of non-horizontal layers** to be operatable a vertical sloped step (deltaic foreset slope) between one height of sediment and another is necessary. The vertical height of this step will approximate the thickness (before diagenesis) of the deposited sequence resulting from the continuous introduction of sediment (see Figure 6 of Julien *et al.*[32]). If the implication that all fossil-bearing sediments (and those non-fossil bearing deposits forming a part of the same sequence) formed during the Noahic Flood by the **mechanism of non-horizontal layers** is true, then we must accept, for the case of the Grand Canyon (say a 1.6 km thick sequence), a vertical sloped step of a height in excess of 1.6 km, if the sediments formed at the same time. It is of course not reasonable to assume this situation, but if it is accepted that the **mechanism of non-horizontal layers** was operating, then it is sensible to assert that it operated many times on small 'packages' of sediments, building successively on top of already deposited sediments. However, if this is the

case then each package of deposited sediments relates to the underlying one in a strictly younger chronological sense.

This consideration of sedimentation during the Noahic Flood confronts the broad conclusion of the **Drama in the Rocks** video, where it is said that the discovery of the operation of the **mechanism of non-horizontal layers** is *'the most important discovery in sedimentation'* because by such a mechanism *'strata provide no indication of age'*. This is not true however, at the very least (assuming the proposed mechanism operates in all conditions) there is a broad chronological progression up a large sedimentary deposit, even if it isn't as finely divided on a bed by bed basis. We either accept that packages of sediments overlying other packages of sediments are younger, or we accept a physically unreasonably high vertical sloped step by which progressive lateral deposition is occurring.

(2) There are many examples in the geological column of juxtaposed rocks having differing oxidation states. In some cases oxidised sediments are overlain by highly reduced rocks, which may in turn be overlain by oxidised sediments. How can this situation arise by the **mechanism of non-horizontal layers?**

(3) If large amounts of marine-borne sediments were laid down at the same time (by any mechanism), and all experienced dewatering at the same time, we would expect to see in the sediment cement some evidence of chemical exchange tending toward chemical homogeneity in cements of different sediment packages. Furthermore, in the geological column, we observe pure carbonate cements in limestones for example, and pure siliceous cements in sediments conformable to the limestones. By the **mechanism of non-horizontal layers,** how is such a situation obtained?

(4) Large thicknesses of marine evaporitic salts occur in some regions of the world and are bounded by sediments. How is it possible for these salts to have formed in an open subaqueous environment in a relatively instantaneous flood event as is envisaged for the Noahic Flood, unless by massive-scale, rapid precipitation? And if so, how would such salt layers have formed by the **mechanism of non-horizontal** layers?

(5) Within the sedimentary record there are strong evidences for the formation of different sediments at widely varying temperatures. For example, high latitude regions with a water temperature near 0°C, and some salt deposits that probably formed at a temperature only 17° below the boiling point of water.[33] Costello and Southard[34] and Boguchwal and Southard[35] present experimental sedimentation results, stressing the effect of temperature (and thus viscosity) on controlling the positions of boundaries between the stability fields of aqueous sandy bed forms in unidirectional currents. How reasonable is it then to extrapolate Berthault's experimental results to far beyond the temperature conditions of his Experiments, when other workers have already stressed that temperature is an important factor? Also, a large thermal gradient was more than likely in the oceans during the Noahic Flood, a physical condition outside of Berthault's experimentation and therefore of unknown effect on sediment lamination.

(6) If what we understand to be bedding planes are really only desiccation cracks, why for example are the large majority of graptolite fossils found on these desiccation cracks and not disseminated throughout the sediment itself?

The **Drama in the Rocks** video would lead us to believe that every bedding plane or lithological contact is in fact a simple desiccation joint. How then do these 'desiccation joints' form in large deposits of monotonous and uniform sediments where we do observe horizontal lithological contacts? Furthermore, if these planar bedding surfaces between monotonous sediments do not represent breaks in sedimentation, how do they represent a preferred plane of weakness in otherwise uniform and isotropic sediments (how does this 'joint' know where to propagate?).

CONCLUSIONS

These experiments, although valuable for the conditions in which they were performed, fall far short of the physico-chemical conditions that would have conceivably been present across the face of the Earth during the Noahic Flood. Therefore, because the materials and the conditions of the experiments do not at all approximate those of the Noahic Flood, the conclusions of Berthault[36] drawn from the experiments extending to the Flood as a whole are inappropriate and are most probably simply wrong. These conclusions need to be refined or abandoned, because as they stand they are misleading to the majority of the viewers of this video who are not in a position to critically appraise the experiments and conclusions.

REFERENCES

1. Berthault, G., 1986. Experiences sur la lamination des sediments par granolcassement periodique posterieur au depot. Contribution a 1'explication de la lamination dans nombre de sediments et de roches sedimentaires. **Compte Rendus Academie des Sciences Paris,** 303:1569-1574. English translation published as: Experiments on lamination in sediments, **CEN Tech. J.,** 3:25-29 (1988).
2. Berthault, G., 1988. Sedimentation d'un melange heterogranulaire. Lamination experimental en eau calme et en eau courante. **Compte Rendus Academie des Sciences Paris,** 306:717-724. English translation published as: Sedimentation of a heterogranular mixture: experimental lamination in still and running water, **CEN Tech. J.,** 4:95-102 (1990).
3. Julien, P. Y., Lan,Y. and Berthault, G., 1993. Experiments on stratification of heterogeneous sand mixtures. **Bulletin of the Geological Society of France, 164:649-660** and **CEN Tech. J., 8(1):**37-50 (1994).
4. Allen, J. R. L., 1995. Sedimentary structures: Sorby and the last decade. **Journal of the Geological Society (London), 150:417-425.**
5. Julien *et al*., Ref. 3.

6. Berthault, Ref. 1.
7. Berthault, Ref. 2.
8. Berthault, G., 1995. **Drama in the Rocks.** Video, Creation Science Foundation Ltd, Australia.
9. Wilders, P., 1992. **Evolution: Fact or Belief?** Video, Creation Science Foundation Ltd, Australia.
10. Berthault, Ref. 1.
11. Berthault, Ref. 2.
12. Julien *et al*., Ref. 3.
13. Julien *et al*., Ref. 3.
14. Julien *et al*., Ref. 3.
15. Julien *et al*., Ref. 3.
16. Sorby, H. C, 1908. On the application of quantitative methods to the study of the structure and history of rocks. **Quarterly Journal of the Geological Society (London),** 64:171-232.
17. Sorby, Ref. 16.
18. Allen, J. R. L., 1991. The Bouma Division A and the possible duration of turbidity currents. **Journal of the Sedimentary Petrology,** 61:291-295.
19. Mantz, P. A., 1992. Cohesionless, fine-sediment bed forms in shallow flows. **Journal of Hydraulic Engineering, 118:743-764.**
20. Allen, J. R. L., 1982. Mud drapes in sand-wave deposits: a physical model with application to the Folkestone Beds (early Cretaceous, southeast England). **Philosophical Transactions of the Royal** Society, A306-.291-345.
21. Dalrymple, R. W., Makino, Y. and Zaitlin, B. A., 1991. Temporal and spatial patterns of rhythmite deposition in the macrotidal Cobequid Bay-Salmon River Estuary, Bay of Funday, Canada. **Memoirs of the Canadian Society of Petroleum Geologists,** 16:137-160.
22. Sorby, Ref. 16.
23. Julien *et al*., Ref. 3.
24. Berthault, Ref. 1.
25. Berthault, Ref. 2.
26. Julien *et al*., Ref. 3.
27. Julien *et al*., Ref. 3.
28. Berthault, Ref. 8.
29. Julien *et al*., Ref. 3.
30. Berthault, Ref. 8.
31. Berthault, Ref. 2.
32. Julien *et al.*, Ref. 3.
33. Krauskopf, K. B., 1989. **Introduction to Geochemistry,** McGraw-Hill, Singapore, 2nd edition, 617p.
34. Costello, W. R. and Southard, J. B., 1981. Flume experiments on low-flow regime bed forms in coarse sand. **Journal of Sedimentary Petrology,** 51:849-864.
35. Boguchwal, L. A. and Southard, J. B., 1990. Bed configurations in steady unidirectional water flows. Part I. Scale model study using fine sand. **Journal of Sedimentary Petrology,** 60:649-657.
36. Berthault, Ref. 8.

William Hoskin is a geologist with brief experience in the mining industry. His broad interest is the chemical evolution of the continental lithosphere with specific interests, and current research, being the stability/chemistry of accessory minerals and the provenance of sediments.