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Earth Surface Dynamics Discussions

Interactive comment on "Clast imbrications in coarse-grained sediments suggest changes from upper to lower flow regime conditions" *by* Fritz Schlunegger and Philippos Garefalakis

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This paper considers whether the imbrication of coarse grains can be considered to represent the position of a local flow transition from sub- to super-critical flow. The paper uses some simple calculations to demonstrate under what conditions the entrainment of D84 grains is associated with super-critical flow conditions. Data are also presented to show the range of conditions under which imbricated grains are observed in the field. The idea that imbrication can say something about flow conditions is an attractive one, as it is easier to observe in sedimentary rocks that other channel properties.

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Discussion paper

Having read the previous two reviews, I agree with the points that they raise. I've also looked at the authors' responses. However, I'm still unconvinced by the argument that imbricated fabrics only form under super-critical flows, and less convinced that strong imbrication will only occur at the specific location of the transition between sub- and super-critical regimes. I agree with Carling that it is not clear from the paper whether you are claiming that imbrication occurs when Fr > 1, or only at the locations where flow is transitioning at a hydraulic jump. If it is the latter case, then how do you reconcile the widespread occurrence of imbrication across bars with the limited spatial extent of hydraulic jumps? Could you predict the spatial occurrence of hydraulic jumps and see whether that matched the spatial occurrence of imbrication?

There are some flume studies that are relevant to your work which demonstrate imbricated fabrics forming in subcritical flows. Burtin and Friedrich (2018) demonstrate imbrication in flows with Fr = 0.54 and 0.55 (calculated from their Table 2). Powell et al (2016) demonstrate imbrication in flows with Fr = $\sim$0.60 to $\sim$0.94, with the amount of imbrication not varying with Fr. (Fr is calculated using their stated slopes, depth and roughness ratio, and your equations 6 and 8). Are these data consistent with your argument?

I think that Figure 3 could be clearer, and is potentially misleading. Panels A/B and C/D show different things; Fr values in A/B and imbrication in C/D. By using the same colour scheme across all panels you are equating imbrication with Fr > 1, but it's hard to tell whether the data support this. I can see that as slope increases, Fr is likely to be > 1 and more imbrication is observed. The pattern with bed roughness is less clear. In B Fr > 1 is most likely at intermediate roughness, however the imbrication all occurs at high roughness. The sites with no imbrication occur at the sort of roughness values that correspond to the highest Fr values; therefore the two patterns don't look similar to me. Why not calculate the Fr values for entrainment of D84 in the field and rock deposits, and see whether you get a consistent pattern between the Fr value and whether imbrication is observed?

I would have liked to see some attempt to quantify the amount of imbrication that is observed in the field and rocks. In your response to Carling you refer to shallow and strongly dipping grains, and suggest that the former might form under sub-critical flows. If this is the case, then your argument is not as simple as imbrication equals super-critical flows. You would need a more robust method to quantify the amount of imbrication, and a dataset to determine the relationship between imbrication amount and flow regime.

As with Carling, I'm also unconvinced by the argument that grain rolling is necessary for imbrication to occur. I would have thought it possible for a grain to be entrained by sliding, and to slide or flip into an imbricated position on deposition. There is also evidence that beds can undergo some restructuring at sub-critical flows, which has potential to include imbrication.

Comments by line:

19: I'm not convinced that this description of a threshold is consistent with Fig 3 and later parts of the paper, in which you describe Fr values decreasing again at high slopes and roughness values.

119: I agree with Wickert that you need to consider hiding effects. The stated Shield's criterion values of 0.03 to 0.06 normally refer to D50, and in the case of hiding effects (i.e. in most gravel beds) then the Shields value of D84 would be less than for D50. In your response you argue that imbricated grains would be harder to move, and therefore a higher value is appropriate; however, if you are considering how grains become imbricated from a non-imbricated bed, then you don't need to make this adjustment. It's important to address this issue, because the dimensionless critical shear stress that you use affects whether you reach super-critical flows in Fig 3. If a value less than 0.047 is most appropriate, then it doesn't support your argument about the importance of super-critical flows.

122: Don't include 0.047 in eq. 3; use φ instead as this is consistent with what you show later on when this equation gets combined with others in equations 9 and 10.

225: You do refer here to the idea of sorting, and therefore hiding, effects affecting the value of φ, but this would be better explained earlier on when you are considering the appropriate value of φ.

305: I assume that you are looking at exposures that are parallel to the flow direction, but you don't state whether this is the case. The amount of imbrication that you observe is likely to be affected by the direction of the exposure with respect to the flow direction.

350: It might be useful to have a summary of which exposures shows imbrication and which didn't.

373: It's not obvious to me how eq. 1 explains the decrease in Fr at high slopes and high roughness. This could be more clearly explained. See Lamb et al. (2017) for analysis of the relationships between flow resistance, flow depth and slope.

423: Changes with slope depend on whether flow depth and hence relative roughness also changes.

449: I don't follow the argument here. I think that you're arguing that because of the pivot angle, then φ should be greater than the typical 0.03 to 0.06? You don't need imbrication to get pivot angles greater than 5 to 10° though. Most gravel grains have higher pivot angles; see Kirchner et al. (1990), Buffington et al. (1992) and Johnston et al. (1998) among others.

583: Where or how are the data available?

References:

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