

## Clast imbrication in coarse-grained mountain streams and stratigraphic archives as indicator of deposition in upper flow regime

### Abstract

Clast imbrication is one of the most conspicuous sedimentary structures in coarse grained clastic deposits of modern rivers but also in the stratigraphic record. In this paper, we test whether the formation of this fabric can be related to the occurrence of upper flow regime conditions in streams. To this end, we calculated the Froude number at incipient motion of coarse-grained bedload for various values of relative bed roughness and stream gradient as these are the first order variables that can practically be extracted from preserved deposits. We found that a steeper energy gradient, or slope, and a larger bed roughness tend to favour the occurrence of supercritical flows. We also found that at the onset of grain motion, the ratio  $\phi$  of the critical shear stress for the entrainment of a sediment particle and its inertial force critically controls whether flows tend to be super- or subcritical during entrainment. We then mapped the occurrence of clast imbrication in Swiss streams and compared these data with hydrologic calculations. Results indicate that imbrication may record supercritical flow provided that (i)  $\phi$ -values are larger than c. 0.05, which is appropriate for streams in the Swiss Alps; (ii) average stream gradients exceed c.  $0.5 \pm 0.1^\circ$ ; and (iii) relative bed roughness values, i.e. the ratio of water depth and bed sediment  $D_{84}$ , are larger than  $\sim 0.06 \pm 0.01$ . We cannot rule out that imbrication can arise under subcritical flows with  $\phi$ -values as low as 0.03, as demonstrated in a large number of flume experiments. However, our results from Alpine streams suggest that clast imbrication likely reflects upper flow regime conditions where clasts form well sorted and densely packed clusters. We consider that these differences may be rooted in a misfit between the observational and experimental scales.