Effects of fine grains in suspension on fluid viscosity and debris flow mobility

H. Nichols, A. Leonardi & E. Bowman

Contact email: hmnichols1@sheffield.ac.uk

University of Sheffield

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Background:

Debris flows are **saturated high energy mass movements**, as shown in Figure 1.1 [1,2]. These have a **wide distribution of particle sizes**, travel long distances, and are driven by gravity and **internal shearing processes**, shown in Figure 3 [3,4]. The literature divides the hazard components into **two phases**, the solid and fluid. As flow propagates, the driving mechanisms and resulting energy transfers, from frictional contact and collisions, produce the features defined in Figure 1.1.

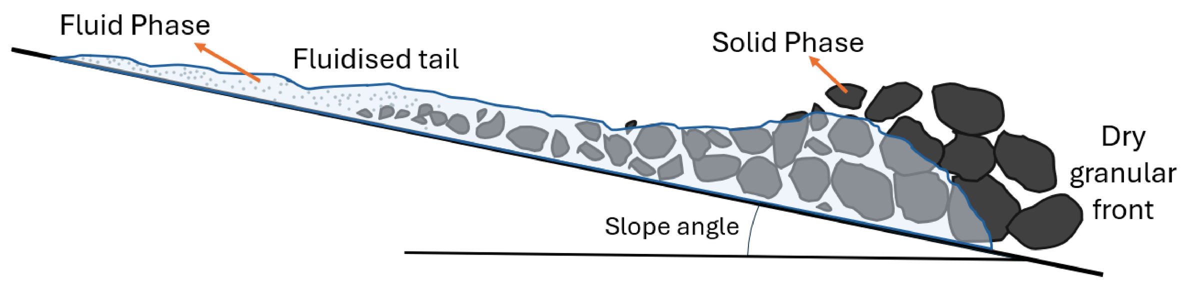


Figure 1.1: Schematic of an idealised debris flow [based on 1 & 2]

Clay particles remain in suspension during a debris flow [1]. Particles carry electrostatic charges, and group (floc) when in suspension [5]. This **increases** the **fluid viscosity**. However, **when sheared** the **viscosity decreases** as flocs are destroyed [5,6]. Therefore, **the fluid phase is shear-thinning**.

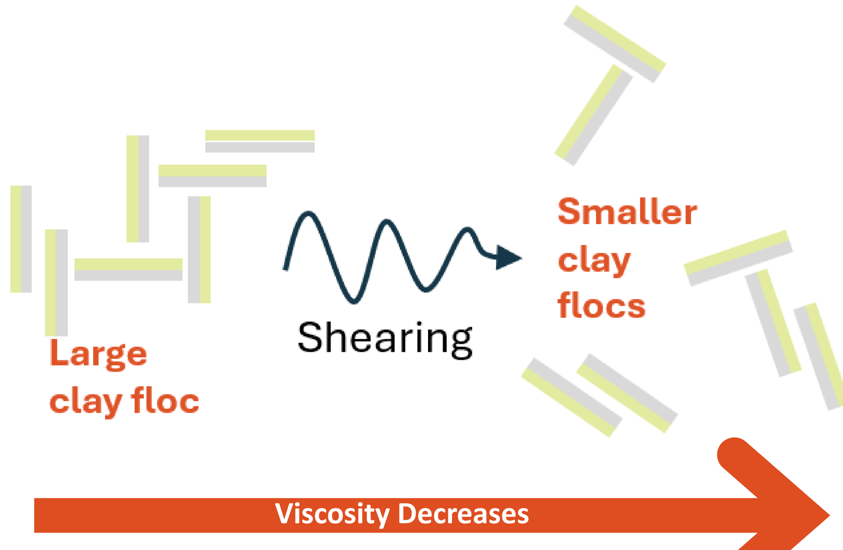


Figure 1.2: Schematic of clay floc break up [based on 5]

As flow **dilates and contracts**, shown in Figures 1.3 & 1.4, the pore spaces change in size and the **interstitial fluid** either **fills or** is **expelled from** the **pore** [8,9]. Currently, it is **unclear how** the **shear-thinning** nature of the **interstitial fluid affects** these **processes** and **particle collisions**.

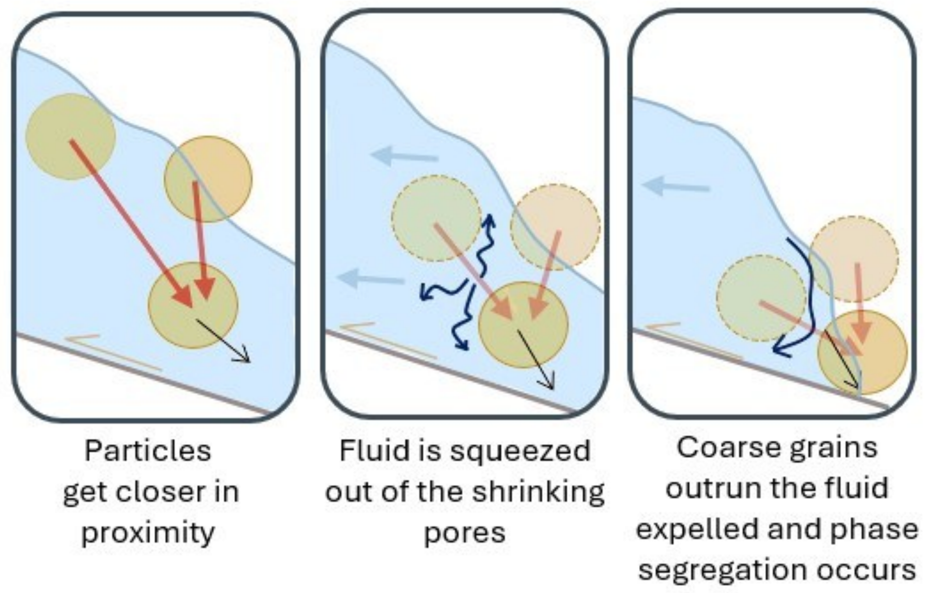


Figure 1.3: Schematic of particle contraction [based on written text in 4,8,9]

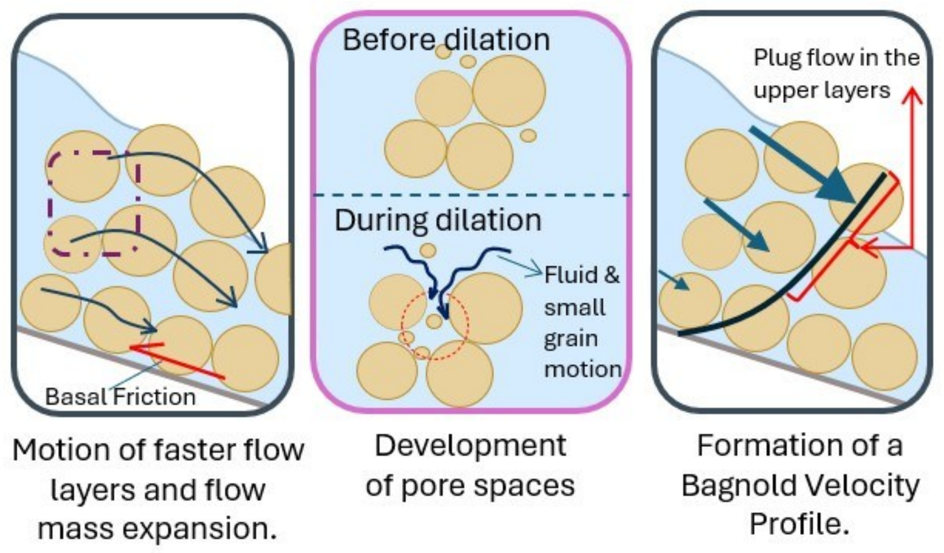


Figure 1.3: Schematic of particle dilation [based on descriptions in 4,8,9]

The uncertainty on how these processes react together in a debris flow has led to **two main theories**: [1,7,9,10]

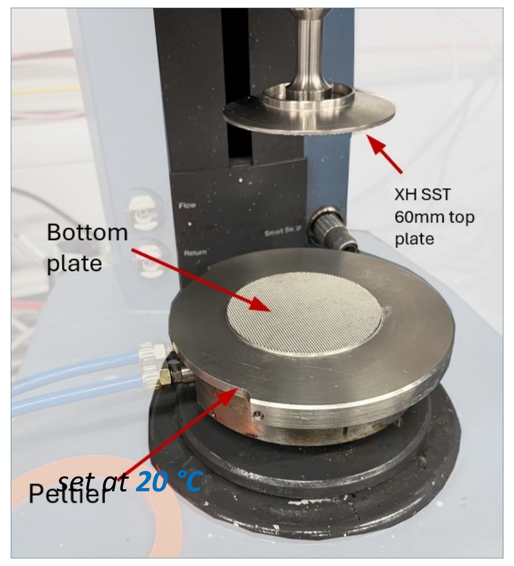
Option 1: Lower mobility	Option 2: Higher mobility
Higher viscosity increases frictional resistance.	Higher viscosity reduces friction between coarser grains & slows collisions.

The **aim of this ongoing research** is to investigate the effects of fine material at **different concentrations** in debris flows at different scales. **Data presented** here shows the **beginning of analysis for the overall effects on debris flow features**, such as runout, with comparison to the viscosity of the interstitial fluid when in shear conditions.

Methods:

A **small-scale instrumented flume**, with a runout channel is used for **scaled debris flow simulation tests**. **Data collected** includes: flow height, **high speed imagery**, and **depositional heights**.

PPT & Basal Total stress data are coming soon!



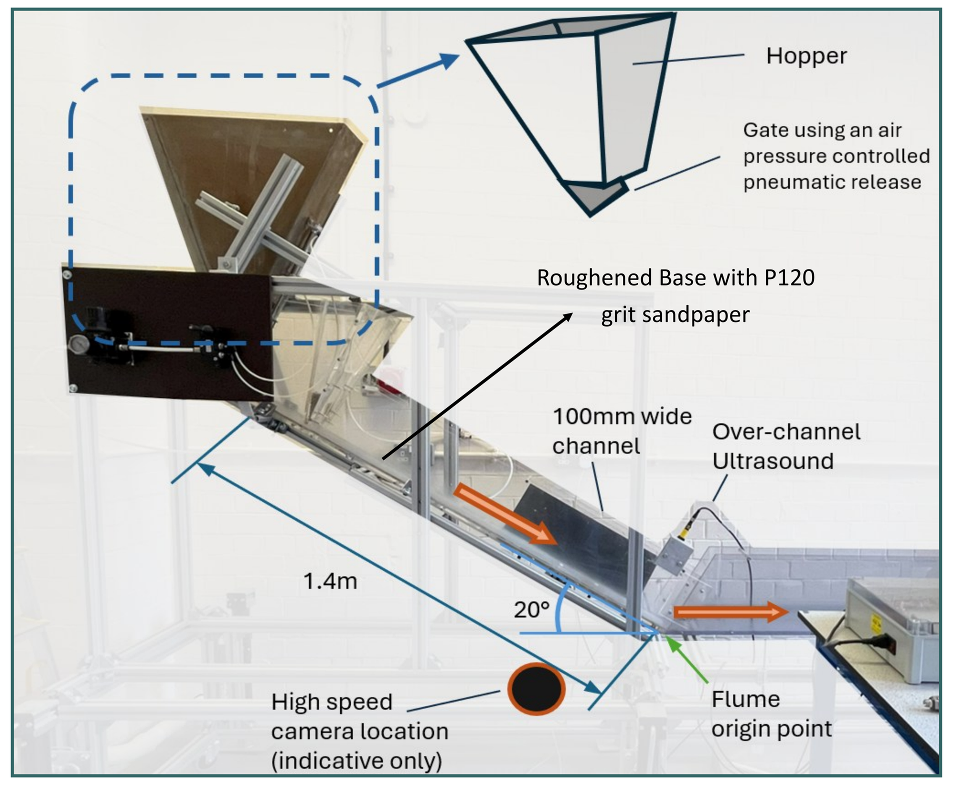


Figure 2.1 (above) - Small-scale instrumented flume.

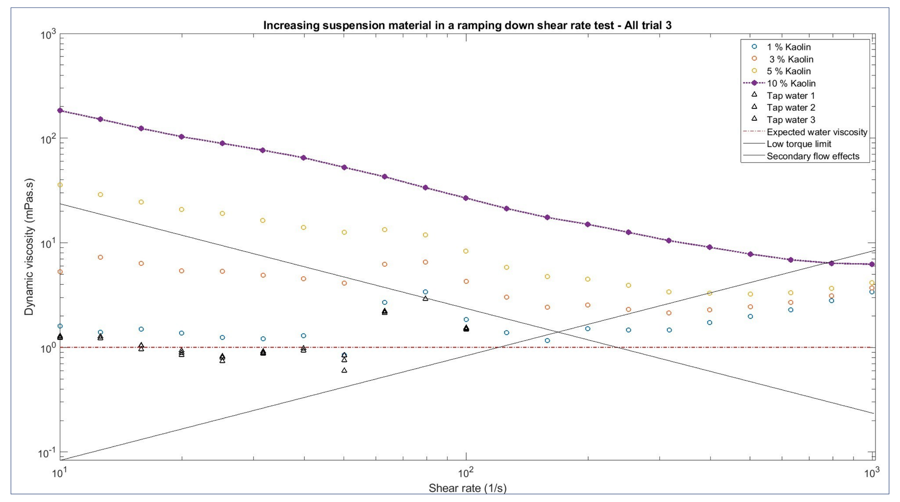
Figure 2.2 (left) - AR2000 Rheometer with cross-hatched parallel plate geometry.

A **rheometer, AR2000**, is used to **measure the viscosity** and shear stress-strain relationship of the **interstitial fluid** with a **variable shear rate**. The gap size is set to 1 mm for all tests. Each trial uses a ramp UP in shear rate which is immediately followed by a ramp DOWN program.

Sample properties: Model debris flows used a **bulk solid phase of uniform coarse grains**, Denstone® 2000 [11], **3.85mm diameter** average and a **gravimetric water content** of **45%** [4]. The solid phase of these samples had increasing percentages of the Denstone replaced with powdered kaolin to change the interstitial fluid viscosity. Samples tested had **fines contents** of **0%, 3%, 5%** and **10%.** Suspensions are vibrated prior to testing.

Results:

Figure 3.1 (right) shows the viscosity of all kaolin suspensions with a decreasing shear rate. The figure shows **all suspensions produce a shear-thinning trend** and **viscosity** is shown to **increase with clay content**. Some anomalies are seen between 60-100rpm and post-400rpm for some tests. This is due to the limits of the rheometer and likely secondary flow effects [12].



Key takeaways from small-scale flume test data:

1. Figures 3.2 - 3.4 (right column) show the in-motion and depositional features of the small-scale flume tests are both influenced by the presence of fines. Figure 3.2 shows the **runout length is always increased** when the grading curve includes any fines. However, the **magnitude of the increase is near identical** regardless of if the d_{10} is all or partially kaolin.
2. Figure 3.3 shows the flow height of the primary surge is only significantly increased by a 10% fines content and which is also seen for the second surge in the 5% test.
3. Figure 3.4 - Surprisingly, both the 3% and 5% dry granular fronts have higher velocities compared to that of the 10% and the control. In the latter flow stages the 10% develops to the highest velocities observed, although the 3% test still remains the next fastest flow in these sections.

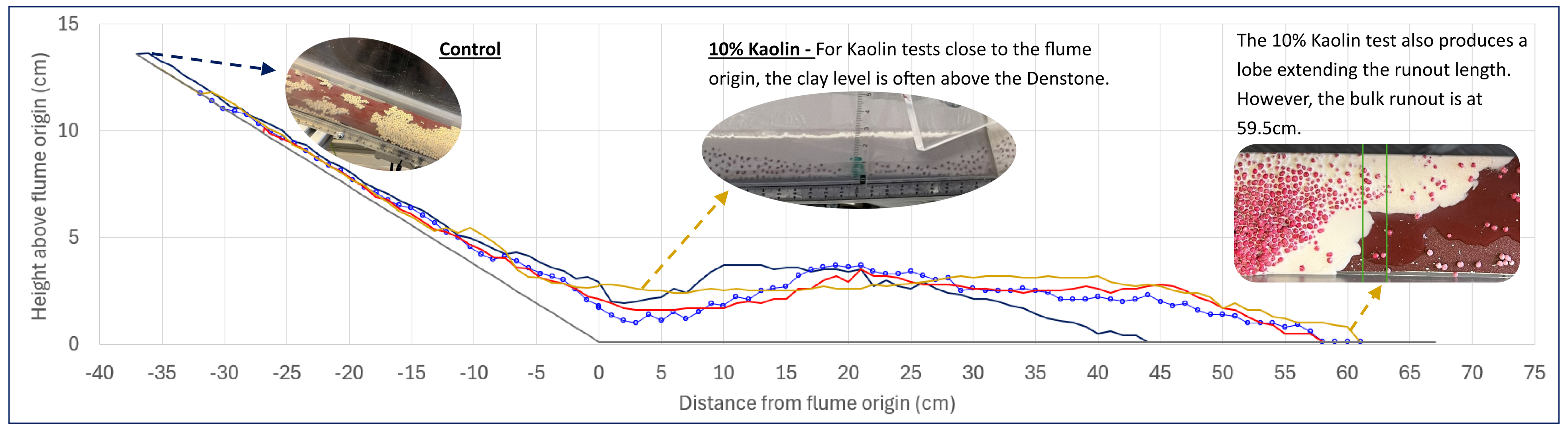
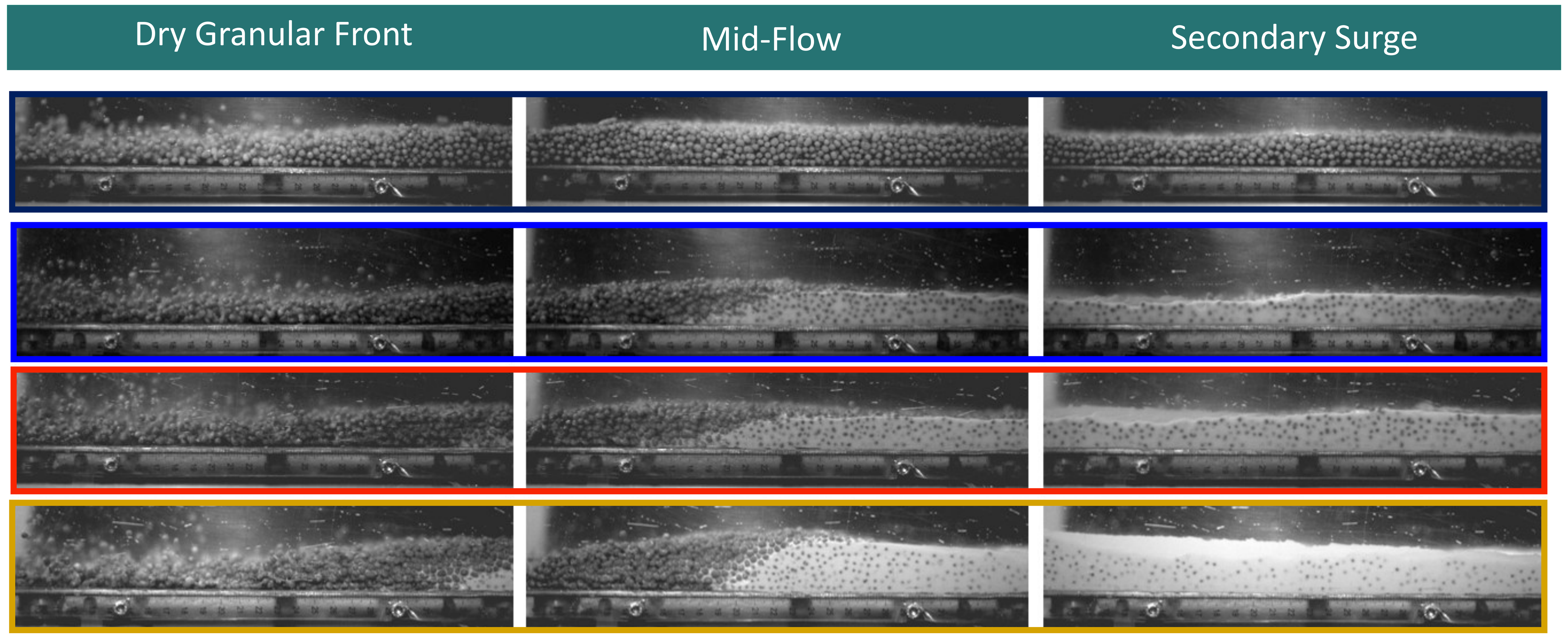


Figure 3.2 (top) - The depositional profiles of each test composition.

Figure 3.3 (middle) - Frames depicting key flow features, taken from high speed video recordings.

Figure 3.4 (bottom) - The velocity of a tracked particle at the base, middle and top of the flow for each test producing a velocity profile across the flow.

Figure 3.2 (above) & Figure 3.3 (below)



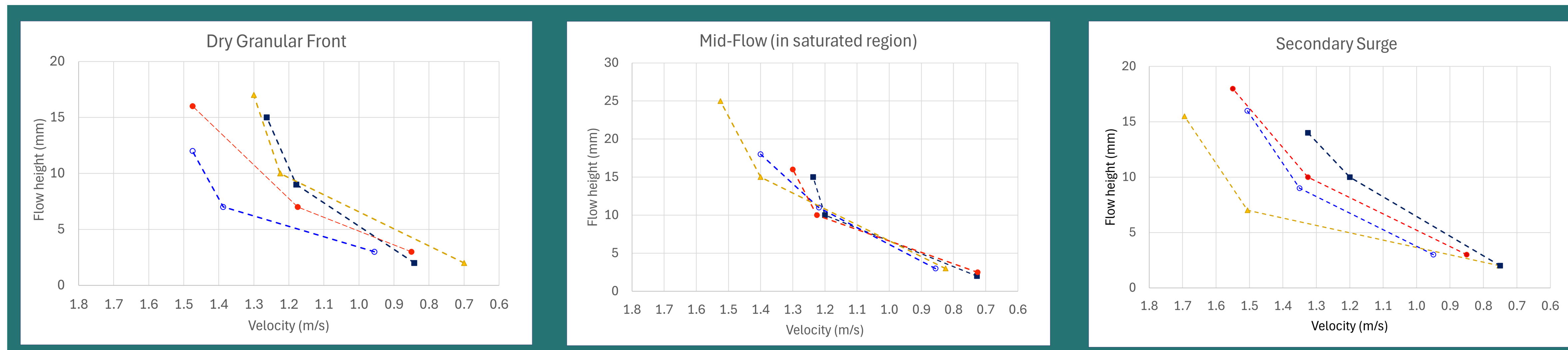


Figure 3.4 (above)

Fines in debris flow:

Always increase mobility

Sometimes increase velocity.

Future Work: (1) Investigate the balance between water pressure & total basal stress. (2) Further velocity analysis - Continuation using PIV and possibly use of granular temperature. (3) Identify if this mobility change is isolated to clays.

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ABSTRACT QR CODE !