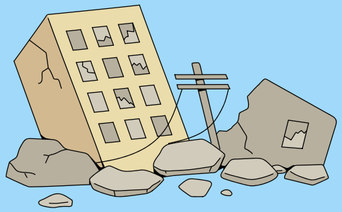
Shake it Off!

Understanding Vibration-induced Friction Reduction in Granular Systems

Mentor: Litong Huang **EPS-01**

Calvin Kan, Derrick Kuang, Gayatri Papagari, Fiona Robertson

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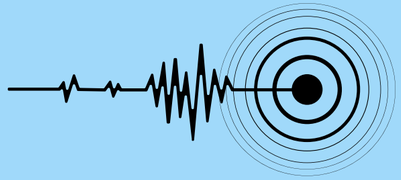
Observations

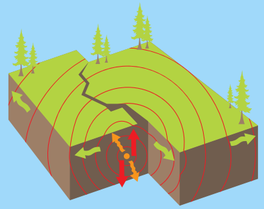
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Acknowledgements









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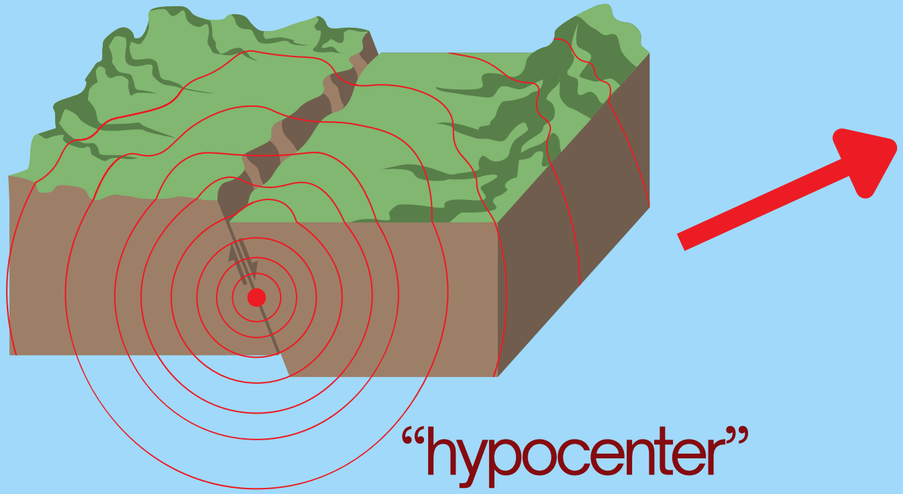
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Seismology Introduction

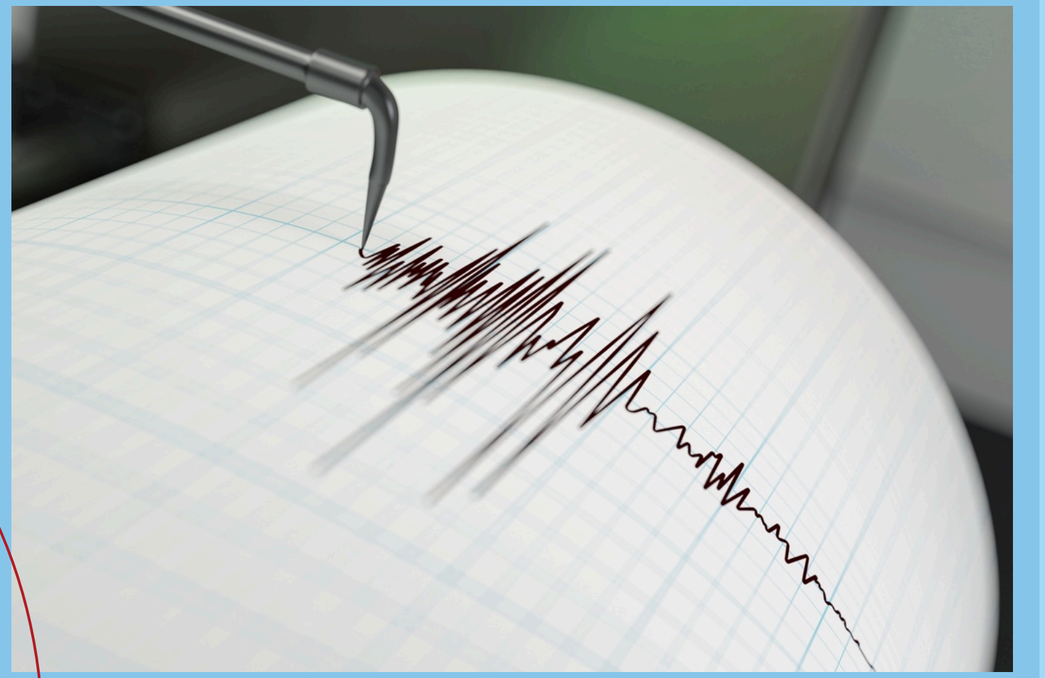
Definition: Scientific study of **earthquakes** and the propagation of elastic **seismic waves** through planetary bodies



Seismic waves propagate outwards, which can be detected at stations called **seismographic stations.**

In November 2002, the Denali fault **magnitude 7.9** earthquake was the **largest in 37 years** in the United States.





Remote earthquakes were triggered and recorded as far as Yellowstone National Park, over **1900 miles away**.

Dynamic Triggering!

Definition: Process where **transient seismic waves** from large earthquakes can trigger **smaller tremors** or **geophysical changes** like landslides.

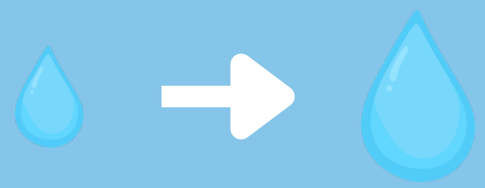
What's Still Unknown / Complexities

❓ **Unclear Physical Mechanisms**

🕐 **Delayed Triggering**

⚠️ **Limited Data Collection**

Factors to Study

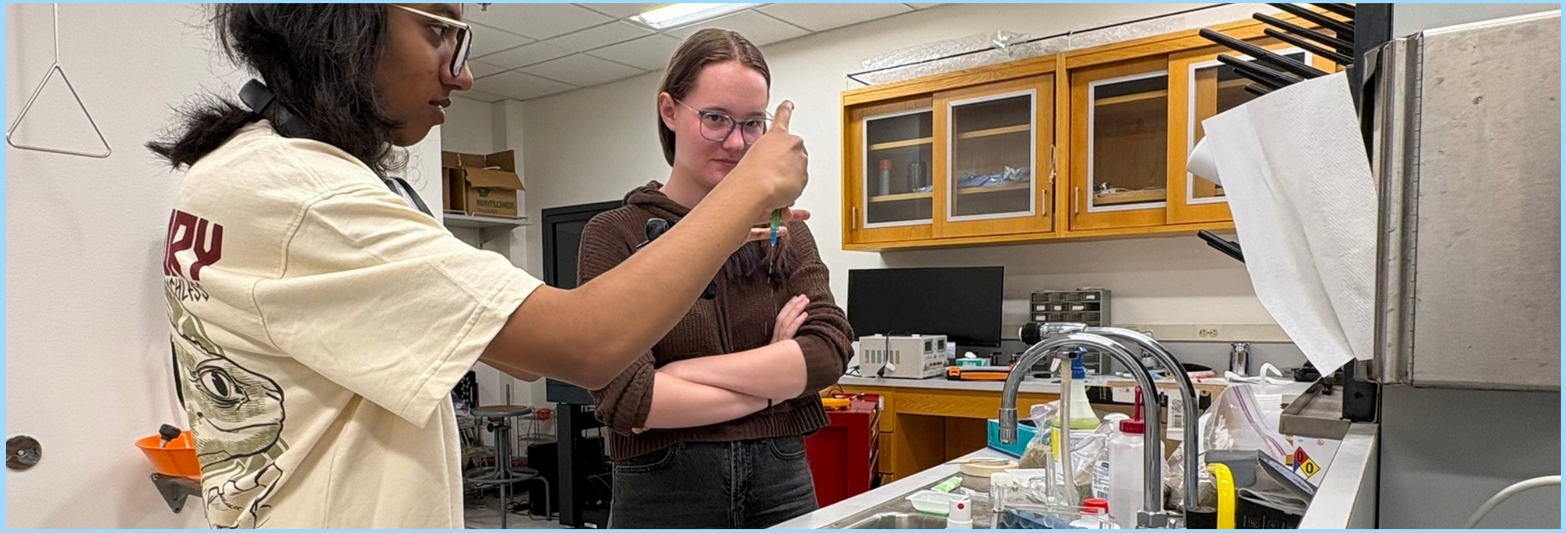


Does some **amount of fluid** at fault lines influence **when** or **how intense** dynamic triggering is?

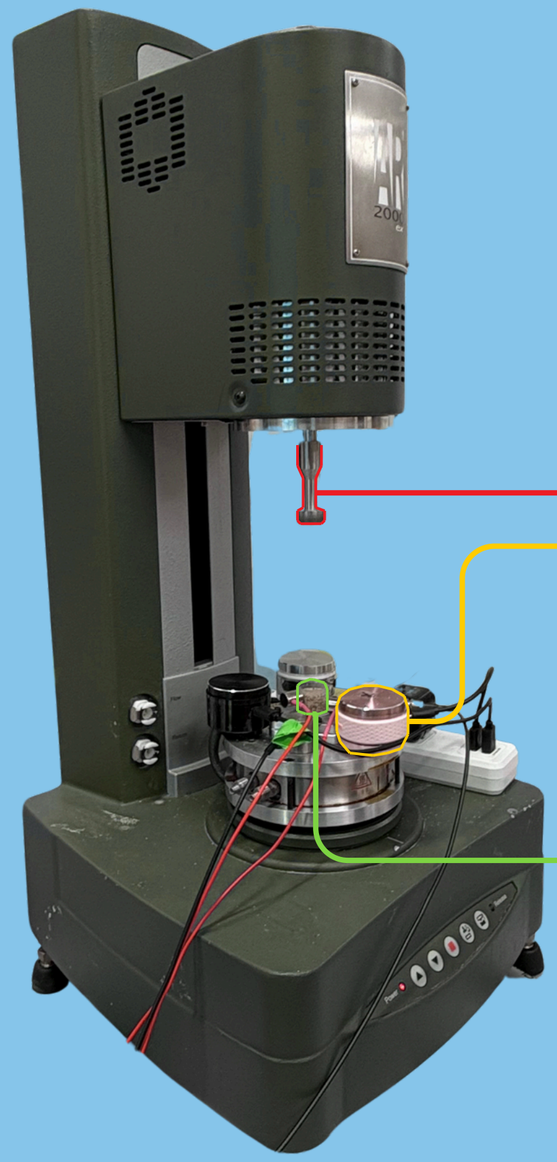


Does the **size of sand grains** within the fault influence **when** or **how intense** dynamic triggering is?

Methodology







Rotor

Main piece that can spin and lower into the sample in the jacket; velocity determined through computer.

Speakers

Sound played that creates vibration for the sample in the jacket; volumes and frequency can be controlled.

Jacket

Contains fluid and sand while experiment is underway; around 2cm tall

Data Collection Procedure

1

Prepare Sample + Rheometer

Sand w/ correct grain size and fluid levels, Center and Lower the rotor using automated procedures

2

Conditioning

2 - 4 hour process that prepares the sample for actual experiment; ensures experiment is reproducible

3

Vibration Test

Speakers play a predetermined frequency + volume that simulate seismic waves, disrupting the sample

4

Wait for Recovery

Gap increases as compaction occurs, resulting in rheometer “reset” and preparation for next vibration test

Data Processing Procedure

1 **Pre-Processing**

Receive data from big ‘.txt’ and ‘.MAT’ files; clip data from vibration tests to reduce size of files

2 **Quality Checks**

Run MATLAB to create plots of torque, normal force, gap, frictional coefficient, and acoustic waves

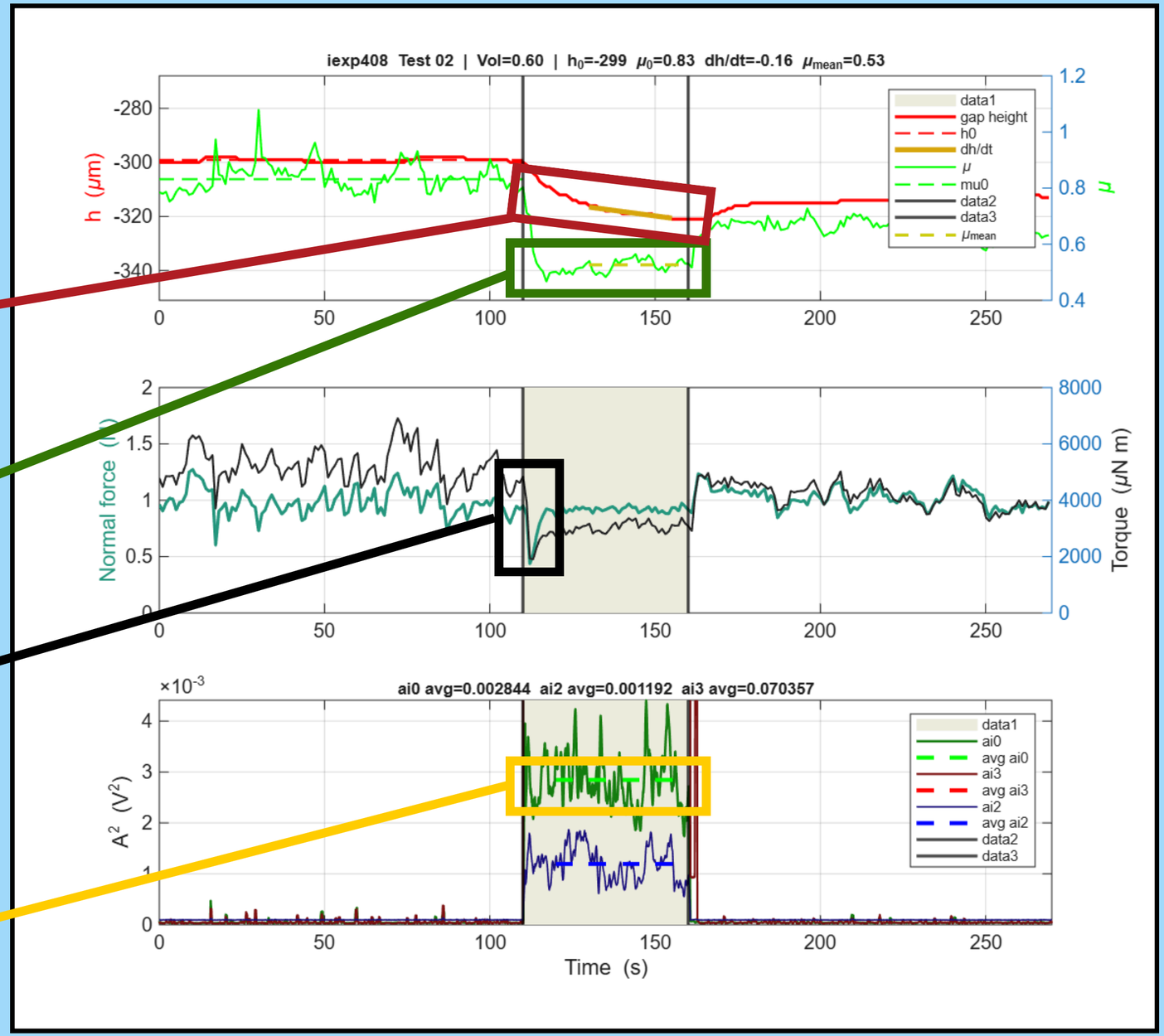
3 “Good” graphs and data are accumulated for analysis.

OR

3 “Bad” graphs and data are discarded from analysis.

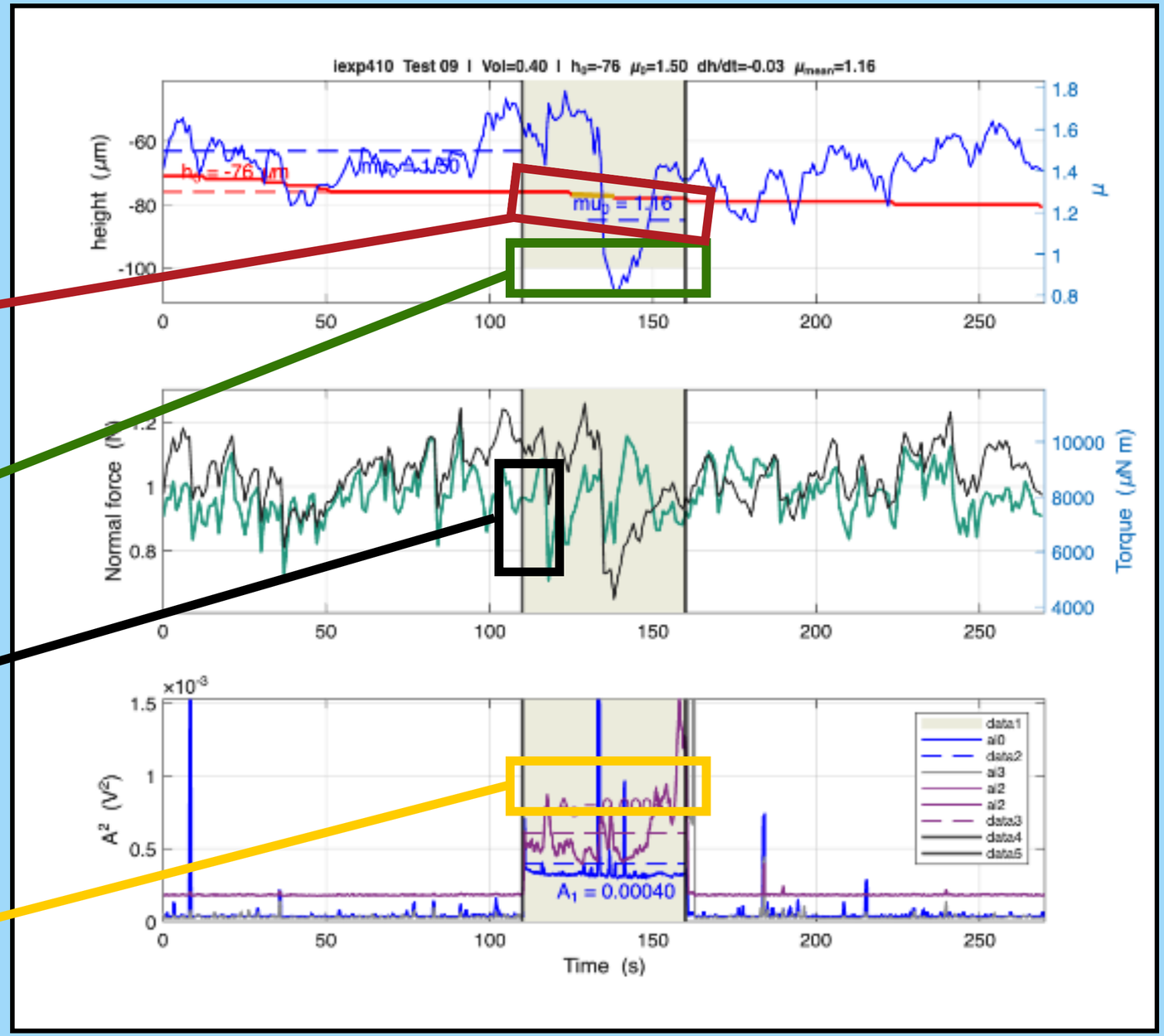
Good Data

- ✅ Decreasing gap height during vibration
- ✅ Stable Coefficient of Friction during vibration
- ✅ Sudden Decrease + Recovery of Normal Force + Torque
- ✅ **Stable Acoustic Data derived from sensors**



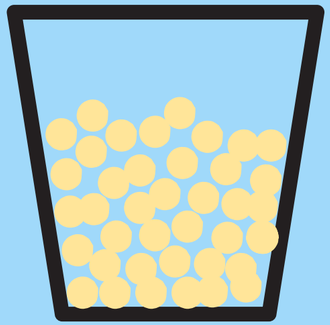
Bad Data

- ✗ Decreasing gap height during vibration
- ✗ Stable Coefficient of Friction during vibration
- ✗ Sudden Decrease + Recovery of Normal Force + Torque
- ✗ **Stable Acoustic Data derived from sensors**



Final Experiment Plan

1

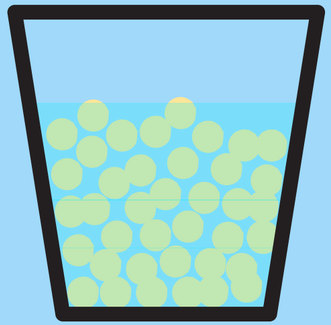


DRY SAMPLE

Grain Size

417 - 500 µm

2

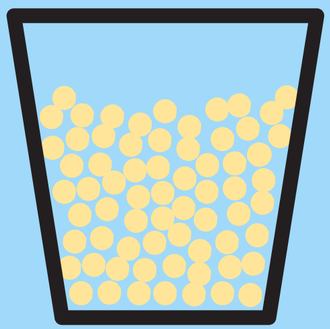


WET SAMPLE

Grain Size

417 - 500 µm

3

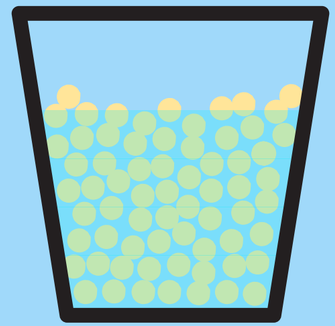


DRY SAMPLE

Grain Size

355 - 417 µm

4



WET SAMPLE

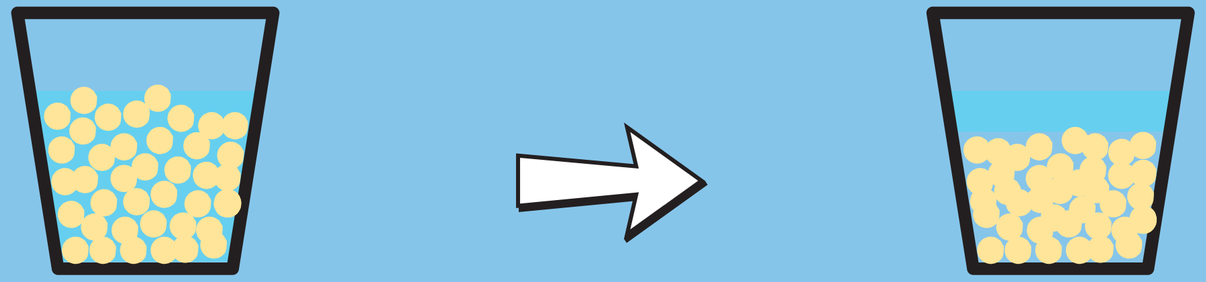
Grain Size

355 - 417 µm

Observations and **Results**

WET SAND

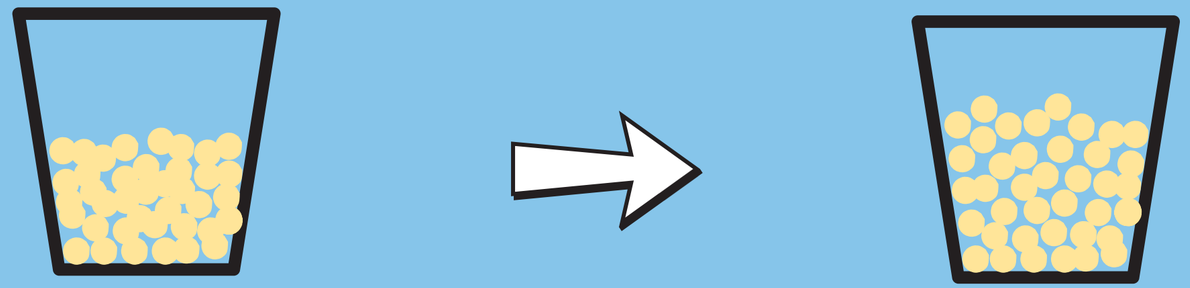
As velocity of rotor increases...



...the sample of sand **compacts.**

DRY SAND

As velocity of rotor increases...

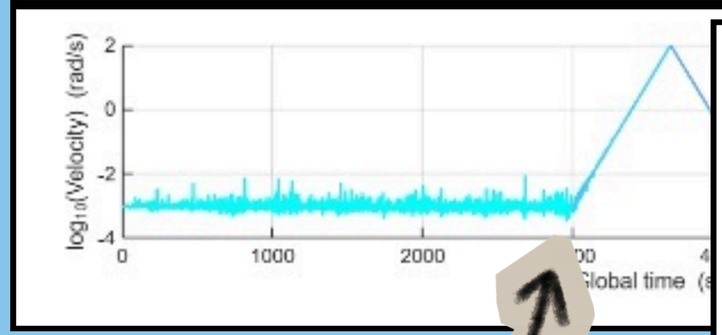


...the sample of sand **expands.**

RAW DATA

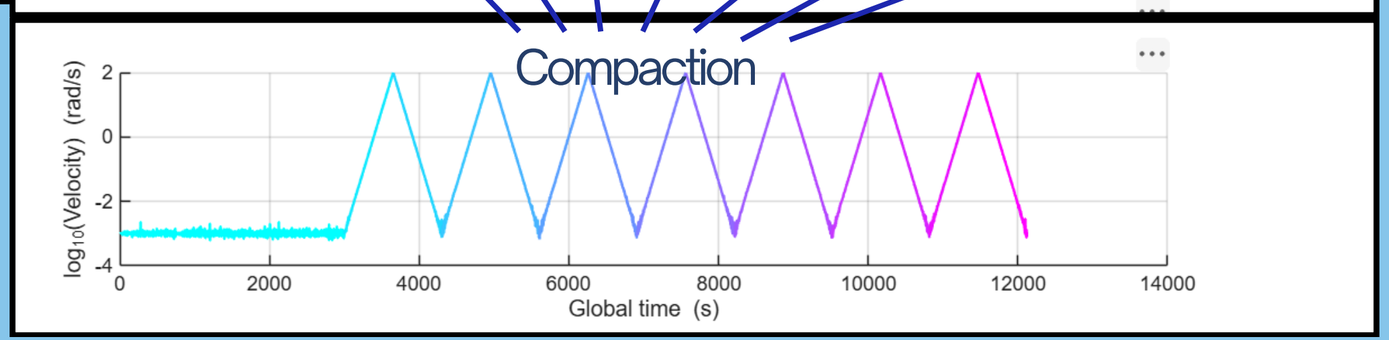


WET SAND

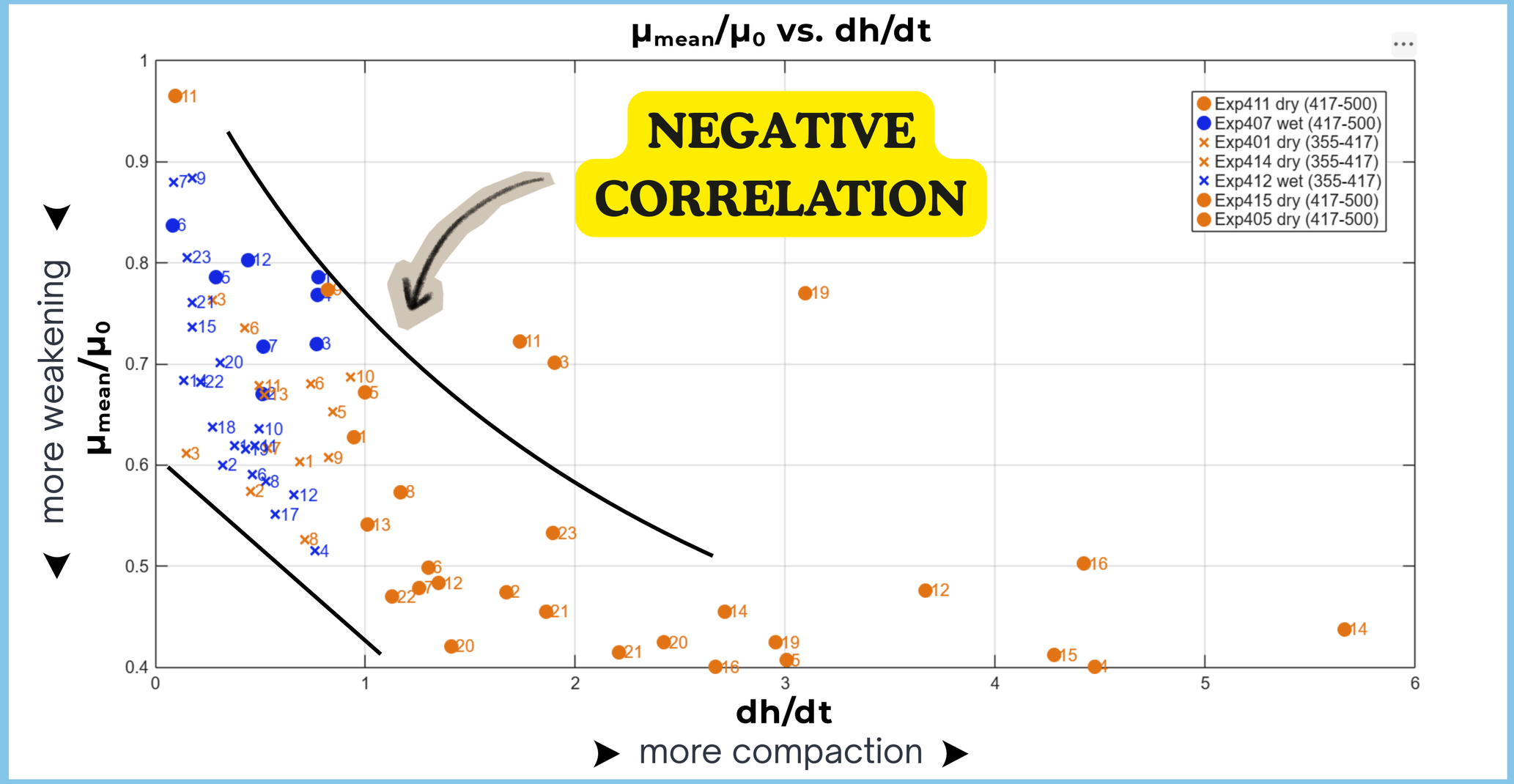


DRY SAND





RAW DATA - ALL DATA



Summarized Results



Long-term conditioning process is necessary for acceptable data and a reproducible experiment.

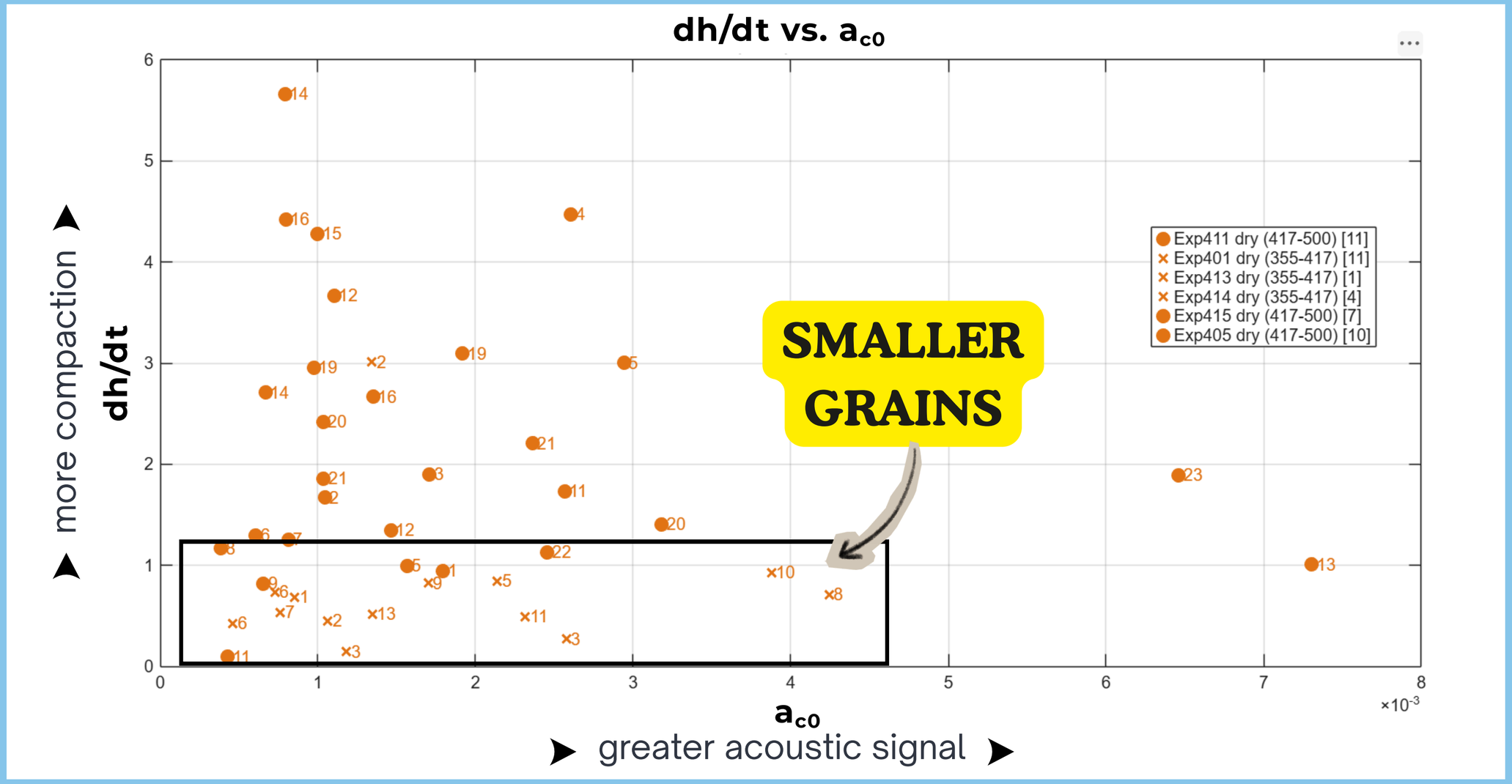


Smaller grain sand samples show less frictional weakening and a slower rate of compaction

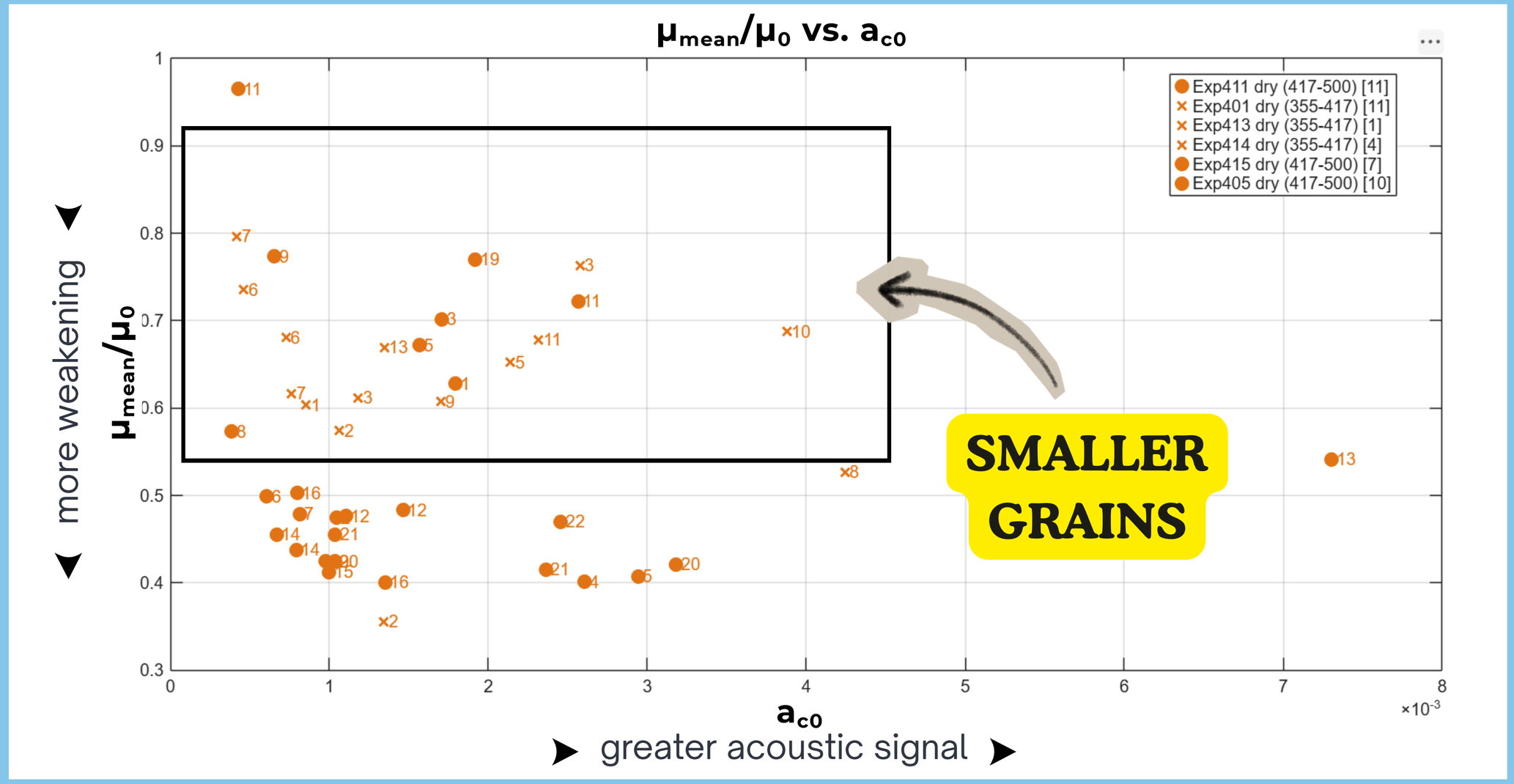


“Dry samples show more frictional weakening and a faster rate of compaction.”

RAW DATA - DRY DATA



RAW DATA - DRY DATA

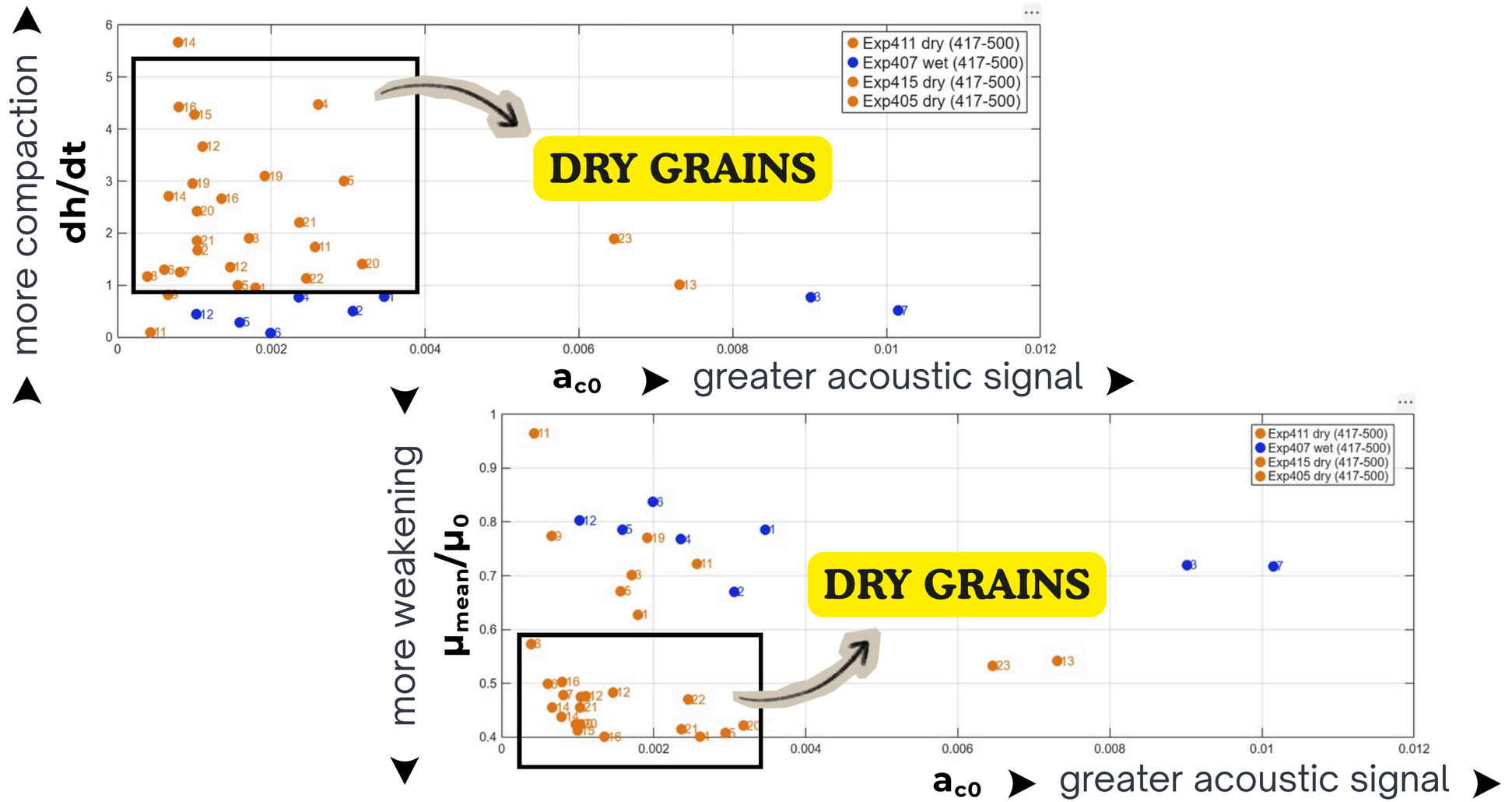




Potential Reason?

Higher Inertia +
Reduced Mobility
due to Size

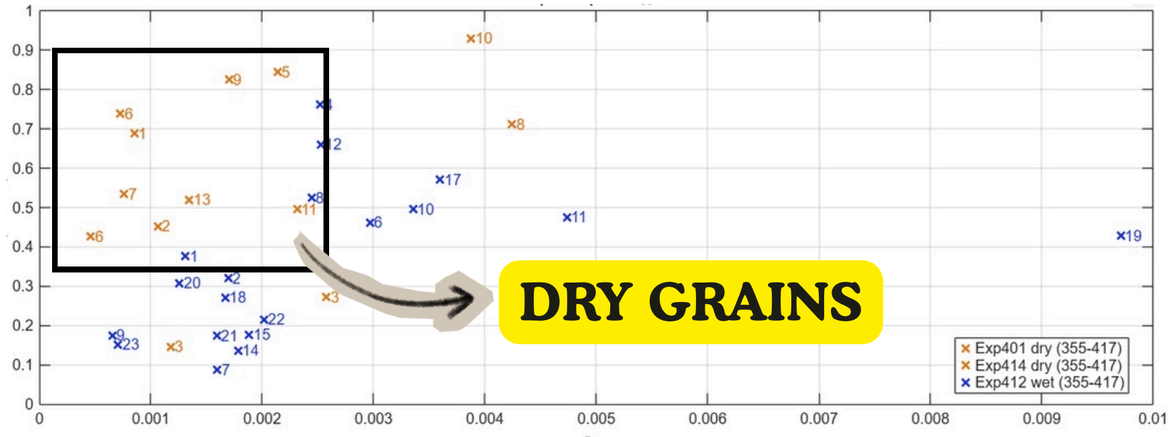
RAW DATA - BIG (🟡) DATA



RAW DATA - SMALL (❌) DATA

more compaction ▲

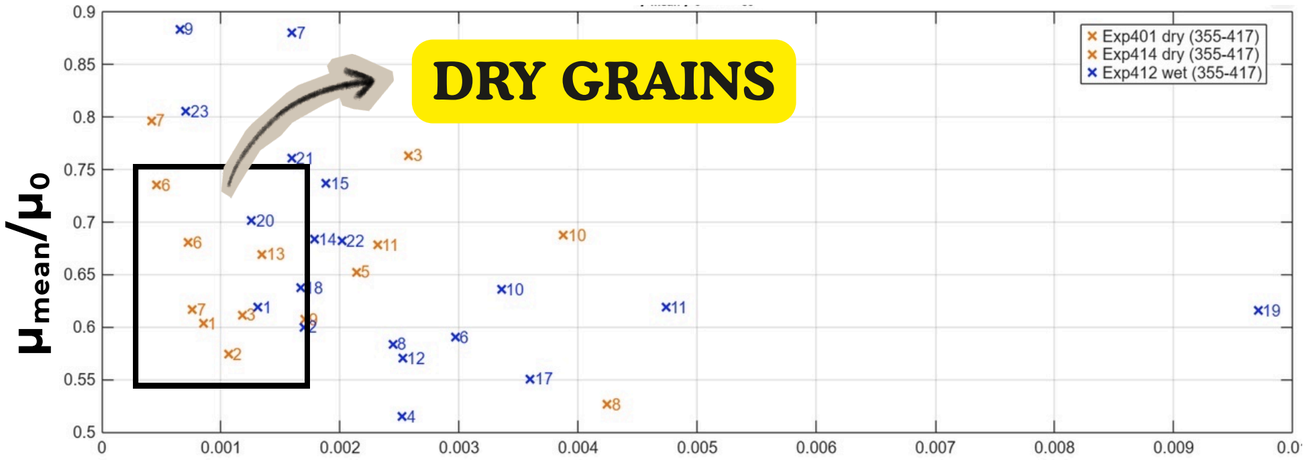
dh/dt



a_{c0} ➤ greater acoustic signal ➤

▼ more weakening

μ_{mean}/μ_0

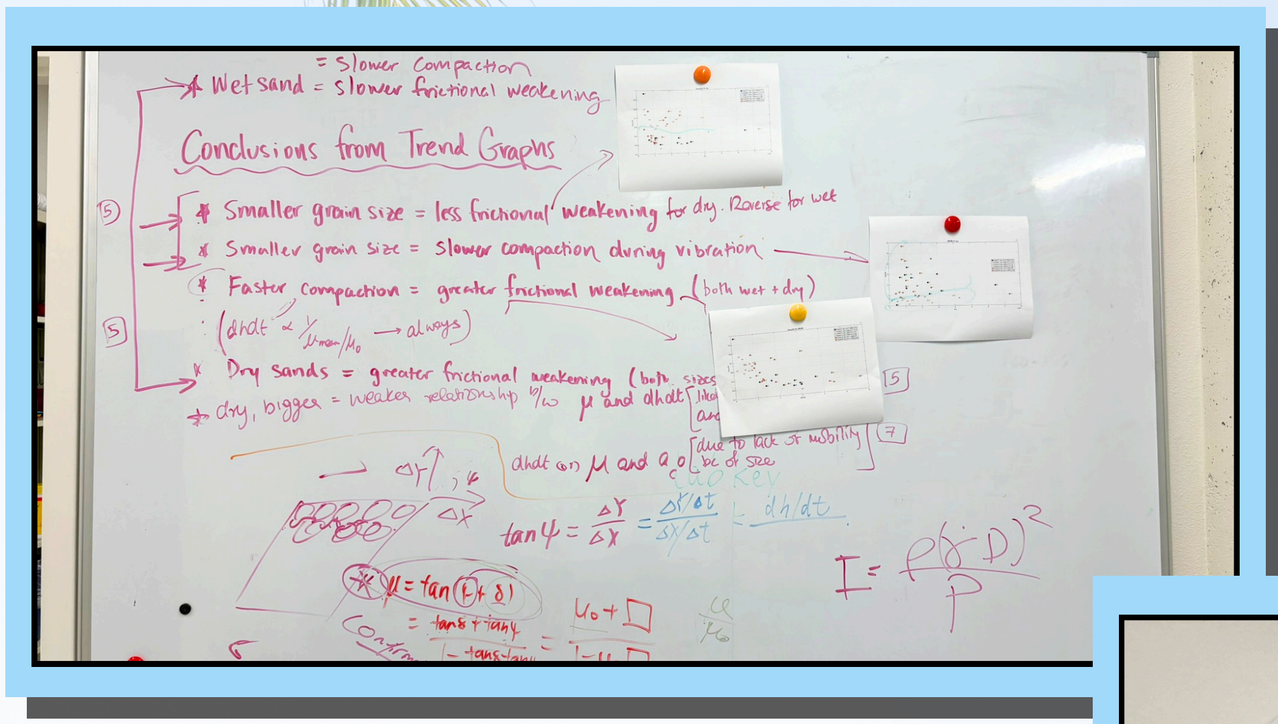


a_{c0} ➤ greater acoustic signal ➤



Potential Reason?

Cohesion and our
Conditioning Procedure


= slower compaction
Wet sand = slower frictional weakening
Conclusions from Trend Graphs
Smaller grain size = less frictional weakening for dry. Reverse for wet
Smaller grain size = slower compaction during vibration
Faster compaction = greater frictional weakening (both wet + dry)
Dry sands = greater frictional weakening (both sizes
dry, bigger = weaker relationship b/w μ and dh/dt
dh/dt ∝ 1/μ
always
dh/dt on μ and a
due to lack of mobility
tan ψ = Δy/Δx = Δy/Δt / Δx/Δt = dh/dt
μ = tan(ψ + δ)
I = ρ(ẏ D)² / P


ANULAR
EDIA
Fluid and Solid
Yoël Forterre
Pouliquen

Research Conclusion

Drier, larger grain-size sand demonstrate more frictional weakening and compaction.

Challenges and Limitations

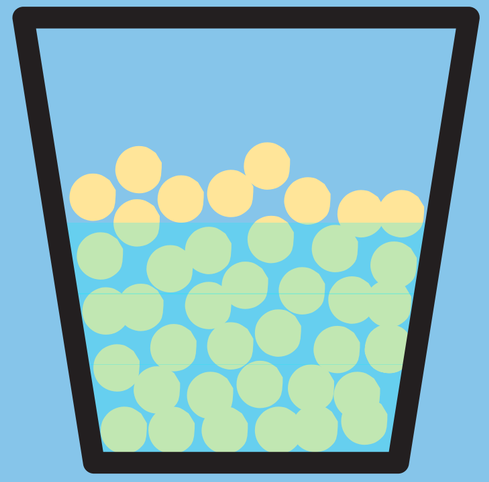
Hurdle: Wetness of Sample

Original Plan

4 Fluid Increments
4 Grain Sizes

= 16 Experiments

❌ **Too much in too little time!**



Sample Dries Before Tests Are Complete

Final Plan

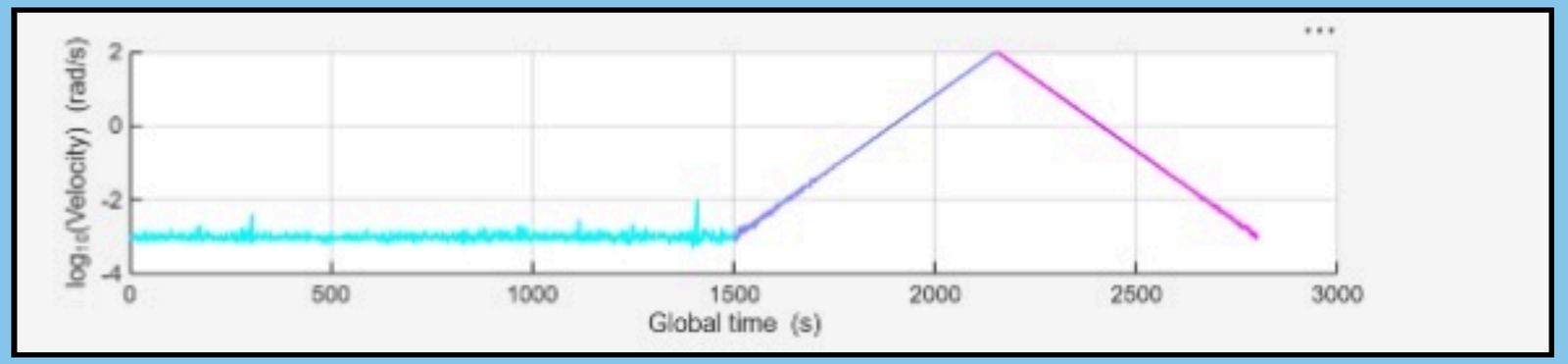
2 Fluid Increments
2 Grain Sizes

= 4 Experiments

✅ **Repeatable, simple, realistic!**

Hurdle: Long Conditioning

We tried shortening conditioning to **under 1 hour...**



...but ended up with **poor data** and **inconsistent results**.

Implications of Conclusion

With some types of grains displaying
greater frictional weakening and compaction...

...Areas of greater grain size and drier sands may be
more susceptible
to remote triggering like landslides.

Acknowledgements

Many thanks to our mentor **Litong** and advisor **Emily** for assisting us on our journey here at SIP!





Thank You!

Questions?

