Experimental Constraints on Bubble Rise Rates in Magmas During Volcanic Eruptions

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Why it is important to study volcanic eruptions?

- Volcanic eruptions create disasters for life on earth. They are fascinating to watch but can be extremely unpredictable and dangerous. Knowing how and when they erupt is important in keeping life on earth protected. To do so, we must have to understand the underlying physicochemical processes that lead to volcanic eruptions.
- Bubbles exsolved from dissolved volatiles create pressure within the magma driving volcanic eruptions. It is important to understand how bubbles interact with each other in the magma to determine the explosivity of volcanic eruptions.

What Determines How a Volcano Erupts?

- The intensity of an eruption can be determined by the mass of magma that is being erupted and how quickly it comes out.
- How quick the magma comes out can be influenced by the size and number of exsolved bubbles (from dissolved H_2O, CO_2, etc.) in the magma.
- Bubbles provides buoyancy increasing magma ascent rates. However, if bubbles leave magma, this will cause release of the pressurized gas. So, it is important to quantify bubble rise rates as compared to magma ascent rates to determine their affects on explosivity.

Bubbles in magma and why it is important to study them

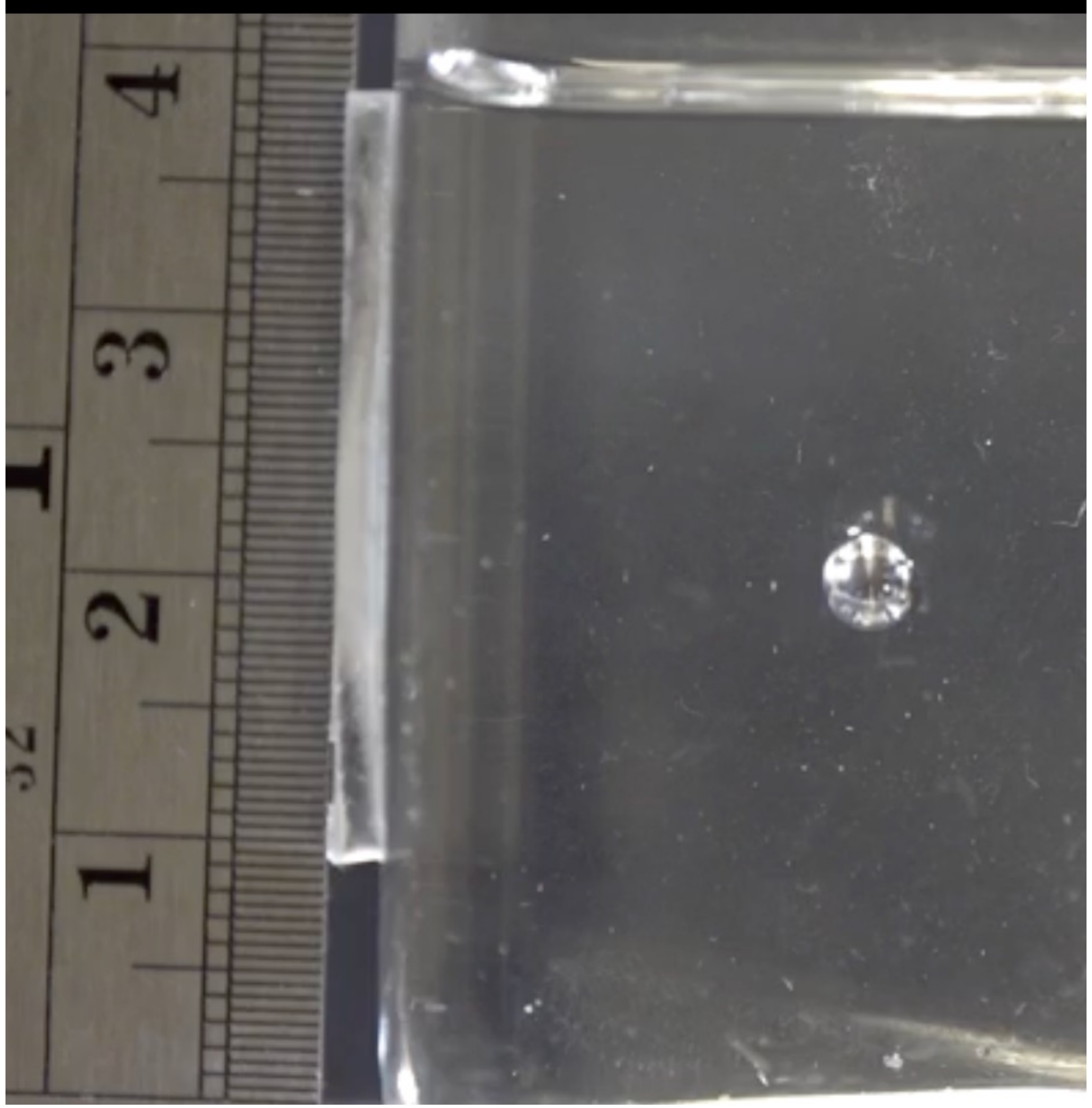
- Bubbles exsolved from dissolved volatiles create pressure within the magma driving volcanic eruptions.
- The dynamics of bubble growth and rise largely depend on magma viscosity.
- The composition, particularly silica content controls magma viscosity. Low silica content means the magma (basalt) has a lower viscosity, while magma with higher silica content (rhyolite) has higher viscosity.
- It is important to understand how bubbles rise within magma to determine the explosivity of volcanic eruptions

Approach: Laboratory Experiments

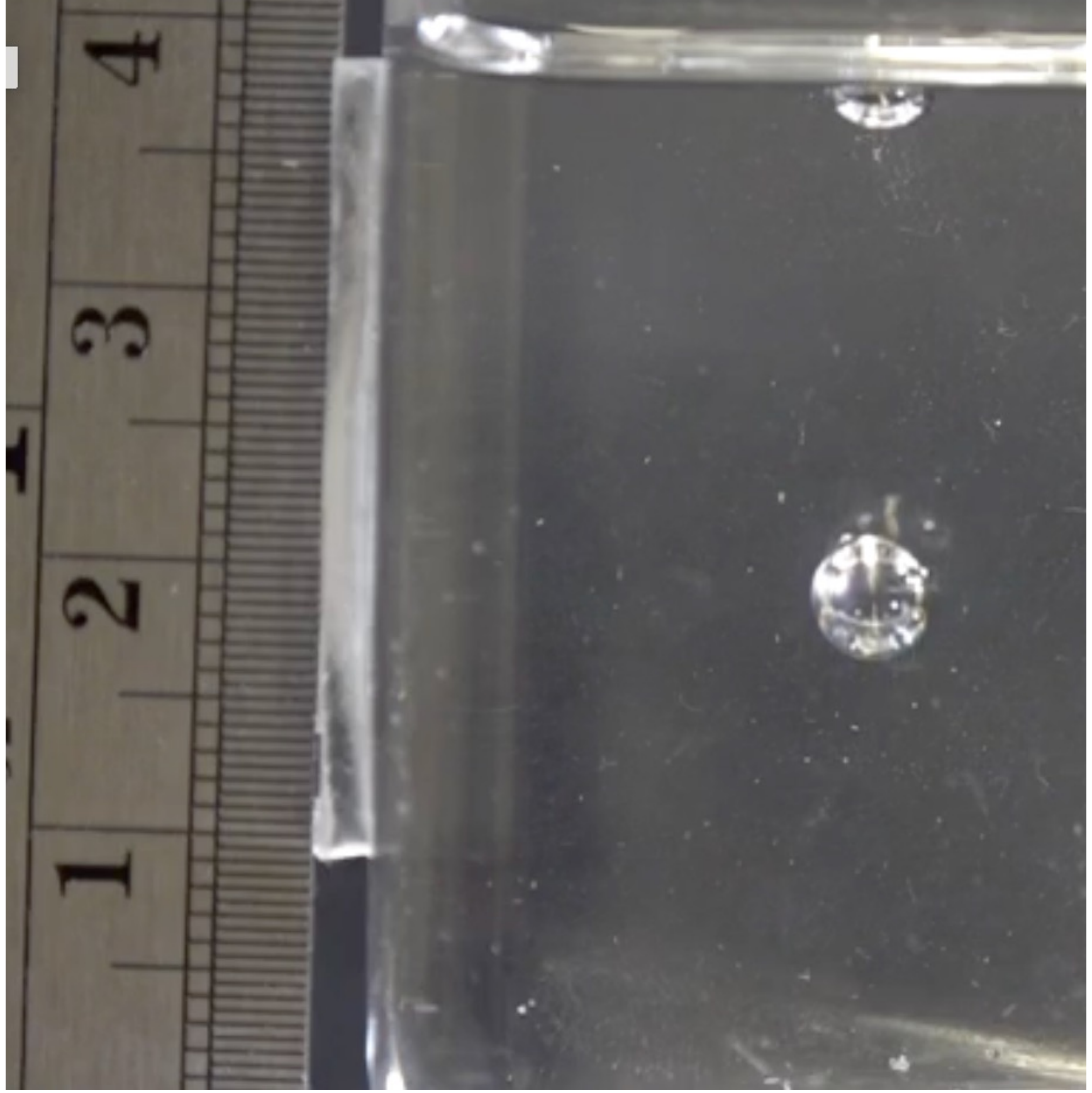
- In this study, I investigate the rise rate of bubble rise in silicone fluid, which is used as an analog for silicate melt.

Single bubble: Small vs. Big

- In the first experiment, I injected a single bubble into a high viscosity silicon oil (60 Pa s) and recorded the bubble traveling upwards to the surface. I then repeated the same experiment with a larger bubble.
- Overall, bubbles travelled upward because they are less dense than the surrounding oil. The experiments further exhibit that the larger bubble traveled up faster than the smaller one. This was due to a larger buoyancy force in the case of the larger bubble size.



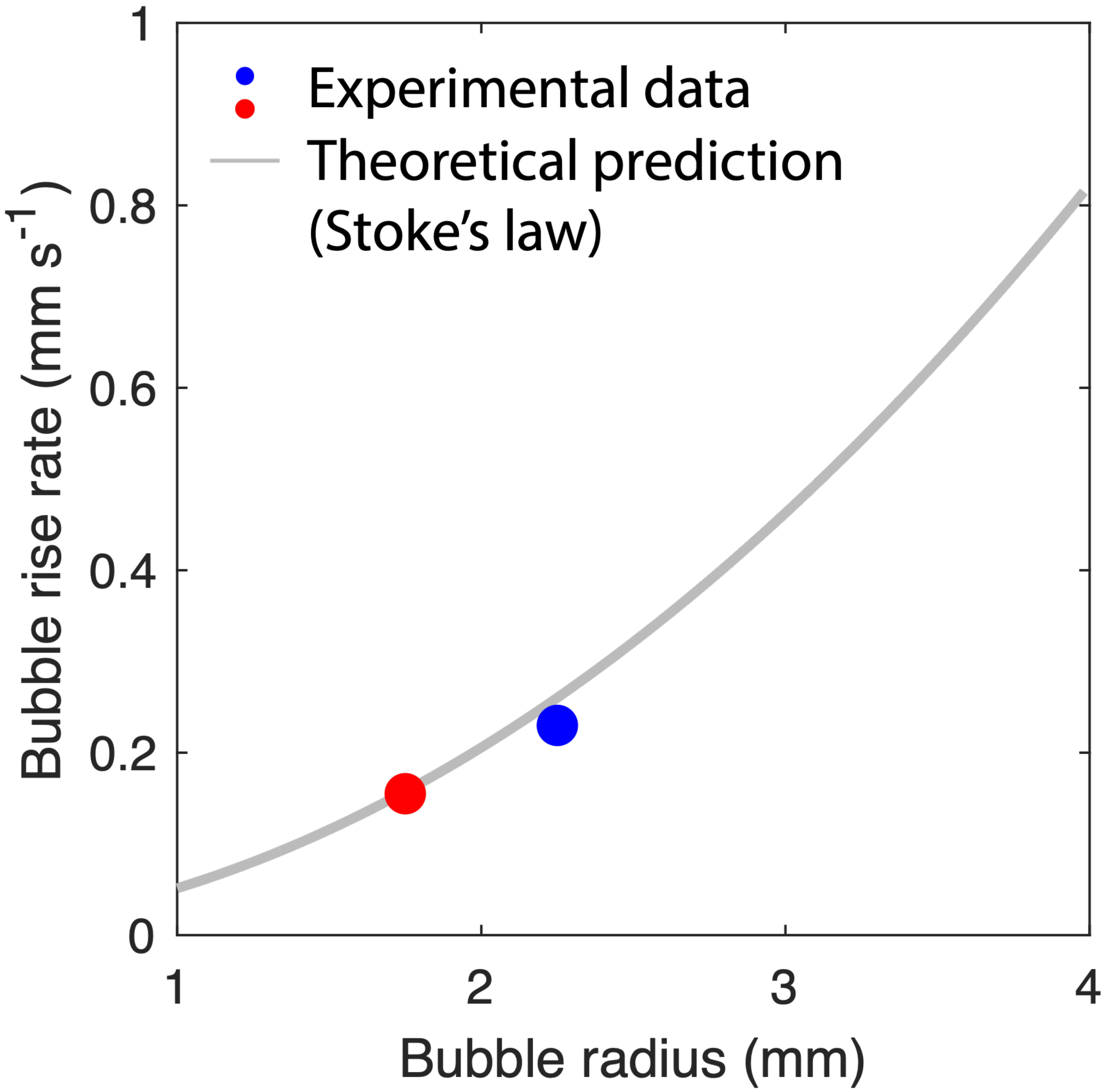
- Bubble Size : 3.5 mm
- 129 seconds to travel 20 mm
- Experimental velocity: 0.15503876 mm/s



- Bubble Size : 4.5 mm
- 87 seconds to travel 20 mm
- Experimental Velocity : 0.22988506 mm/s

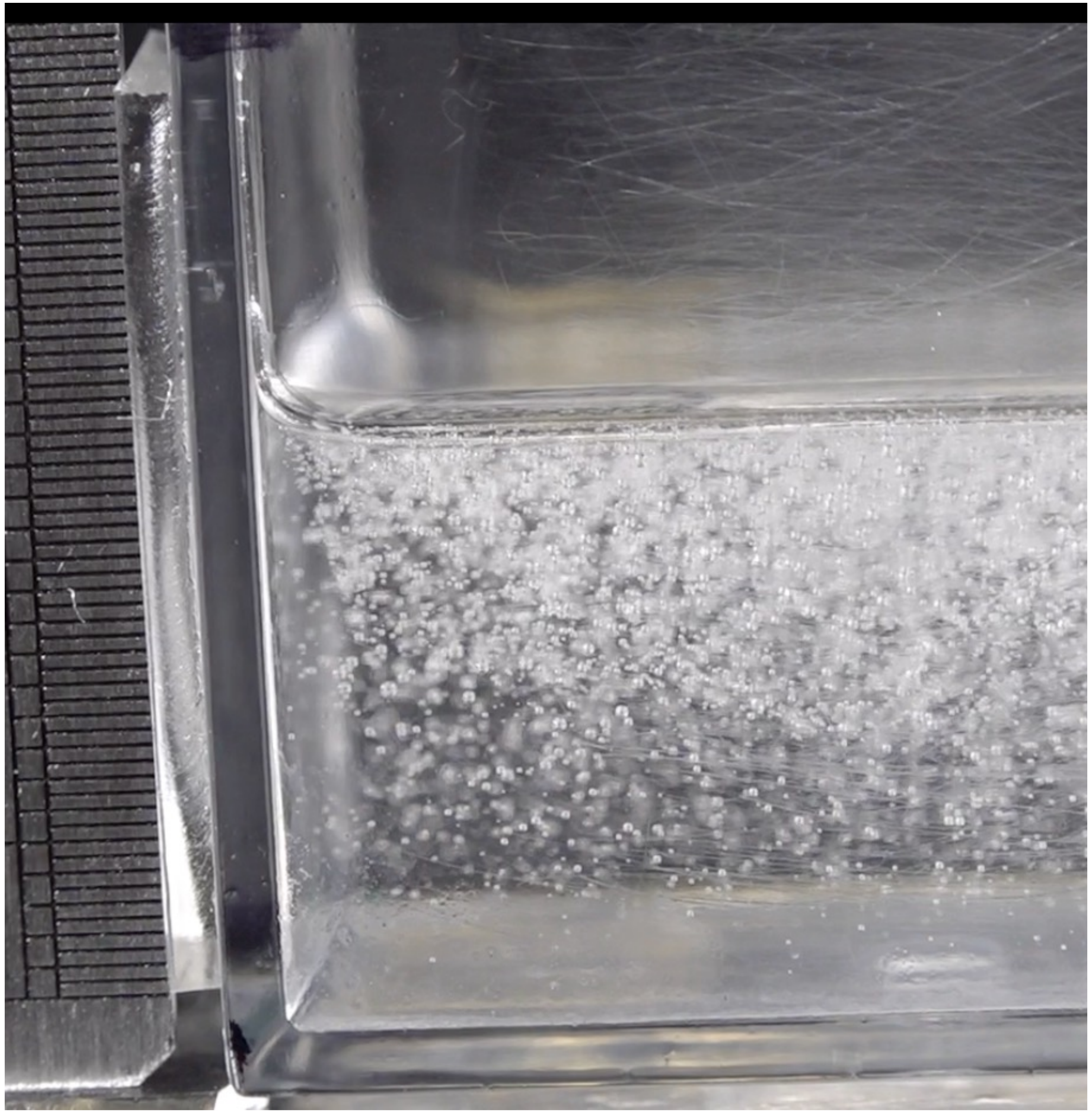
Stokes Law

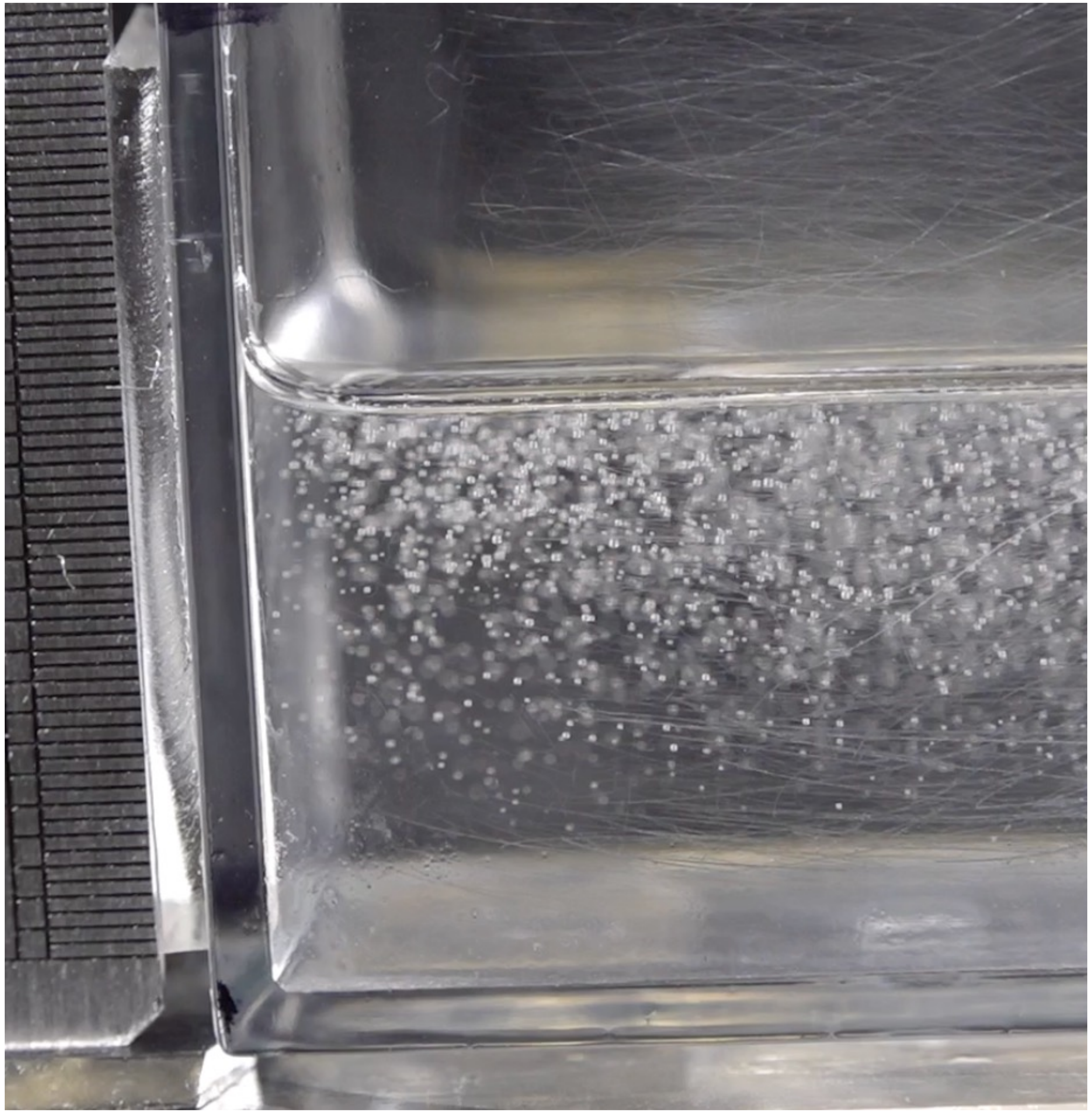
u = (rhol-rhoa)*g*R^2 /(3*eta)



Multiple Bubble Rise Rate

- The single bubble was able to travel at a constant speed because there was nothing in its path to cause hindrance or blockage.
- In this next case, multiple bubbles are creating a hindrance within one another as they are all trying to float up to the surface at the same time.
- In this next experiment, I took a mixer and created multiple bubbles within the oil. This time I used a lower viscosity oil (10 Pa s) to speed up experimental time and recorded them traveling upwards and escaping at the surface from two different angles.
- These bubbles, of all different sizes ranging from .5 mm to 2 mm traveled at different speeds. At this low volume fraction (~1-2 %), the larger bubbles left the oil first, leaving all the smaller ones behind. The smaller bubbles then took longer to travel up to the surface due to the lack of buoyancy.

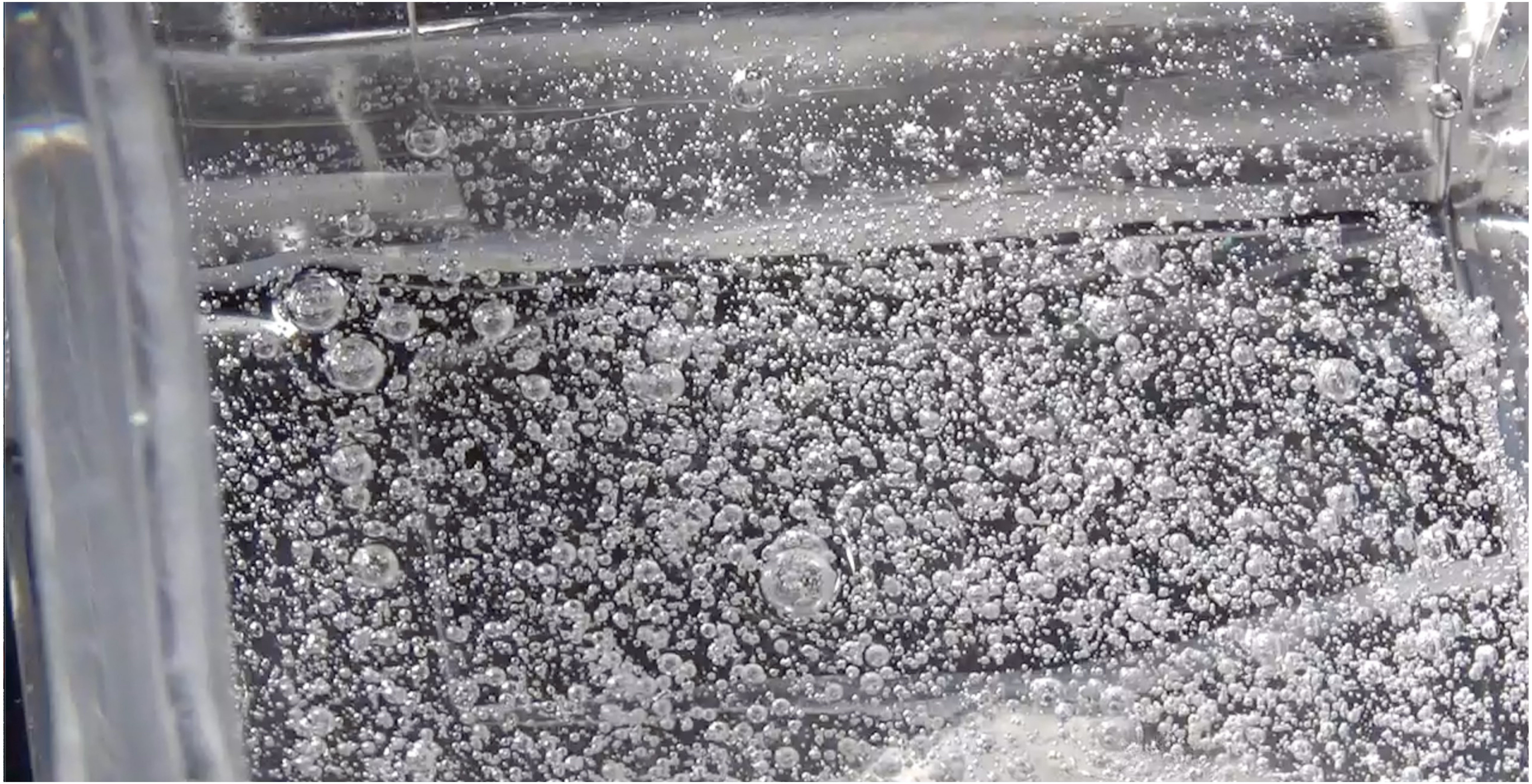




After 5 minutes

After 30 minutes

Second Angle (Aerial)



Next Steps

- Future research will determine the hindering effects on the rise rate of bubbles in dense suspensions (a high volume fraction of gas/bubbles suspended in oil).
- Mix oil and see if I could get the volume fraction of the bubbles to increase by at least 30%. This was attempted once using 60 pa s and 10 pa s oils but didn't work out due to the possibility of the mixer not being strong enough.

Key Outcome

- Here I performed analog laboratory experiments to determine the rise rate of bubbles of different sizes within magma.
- I find that larger bubbles rise relatively faster than the smaller bubbles due to a larger buoyancy.
- For low volume fraction bubbly suspension (multiple bubbles+liquid), I find that the larger bubbles tend to rise to the surface earlier than the smaller ones.
- The experiments show that adding bubbles cause an increase in the oil volume, suggesting that the presence of bubbles in magma would also increase its volume affecting its buoyancy and ascent rate.
- It further indicates that larger bubbles may leave magma faster causing a release of the pressurized gas, whereas the smaller bubbles might stay coupled with the magma aiding to the explosivity of a volcanic eruption.