# Experimental Study of Sedimentation in Pyroclastic Density Currents

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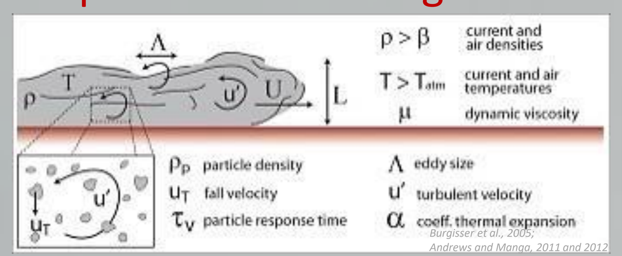
## Motivation

Pyroclastic density currents (PDCs) are composed of pumice and ash at high temperatures (>400°C) that travel at high velocities (>100 km/hr) for large distances (>10 km). These volcanic events are very destructive and therefore are difficult to safely study in nature. Experimental modeling of currents on a laboratory scale is useful to explore parameters that control PDC behavior. Our experiments address the following questions:

- What factors affect how far a pyroclastic density current will travel?
- How are transport processes recorded by deposits?
- How much of the initial current mass fractionates into the coignimbrite plume?


A pyroclastic density current at Mt. Mayon in the Philippines.

## Experimental Scaling




Our experiments are dynamically similar to dilute natural PDCs.

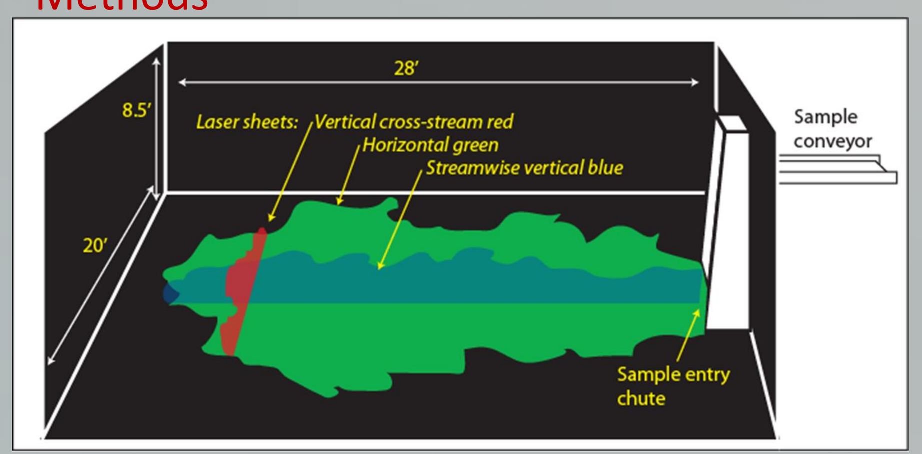
| | Fr | Re | Ri | $Ri_T$ | $S_T$ | $\Sigma_T$ |
|---|---|---|---|---|---|---|
| Natural PDCs | 1 | $10^6$ - $10^9$ | 0.1-10 | <1 | $10^{-6}$ - 10 | $10^{-3}$ - $10^5$ |
| Laboratory Experiments | 1 | $6.0x10^3$ | 0.1-10 | 0-3 | $10^{-4}$ | <1 |

Clarke and Voight, 2000
Burgisser et al., 2005

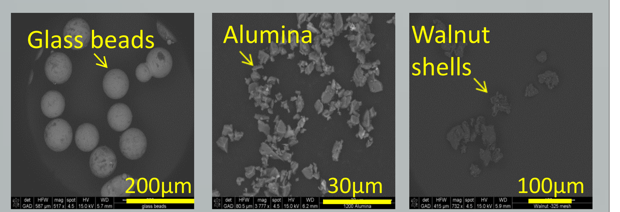
Re- inertial to viscous forces
Fr- inertial to gravitational forces
Ri- stratification

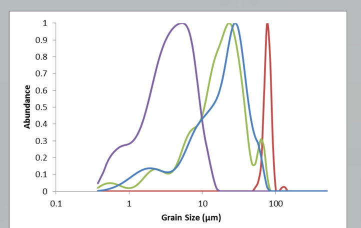
$Ri_T$ -buoyant to forced convection
$S_T$ -particle-to-eddy coupling
$\Sigma_T$ -gravitational to turbulent forces

## Methods

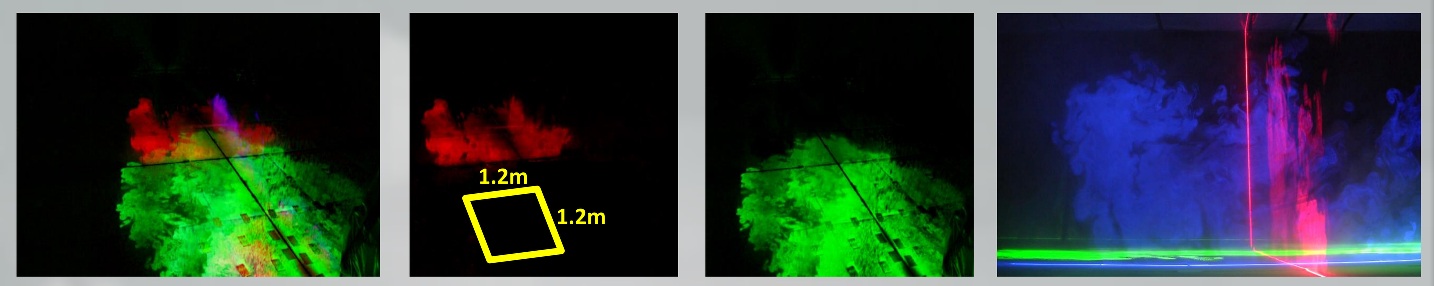



- 28x20x8.5 ft. tank for unconfined currents
- A conveyor belt feeds powder down a chute to generate currents
- Experimental parameters can be varied (temperature, duration, eruption rate, particle distribution)
- Orthogonal laser sheets to illuminate dilute currents
- 3000 fps camera to study particle-particle interaction
- Seven 30 fps cameras sensitive to red, green, and blue



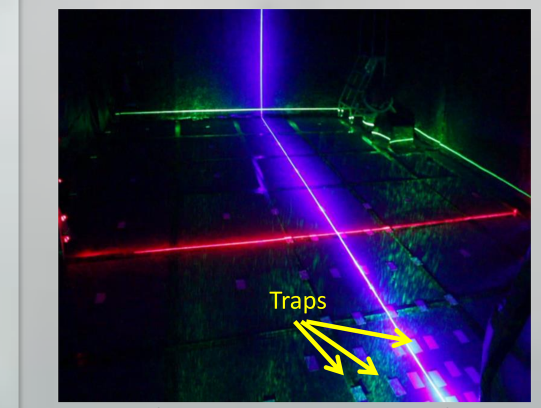



Different particles are used to simulate volcanic currents with broad size and density distributions.

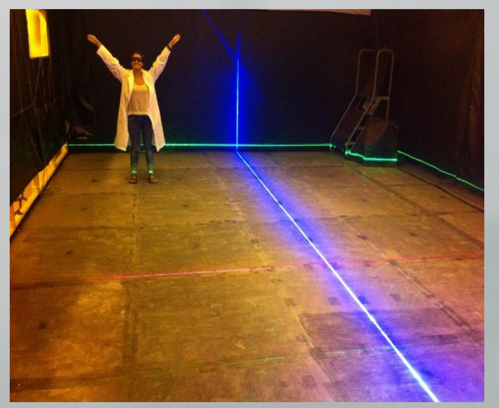



(Above images, from left to right)
Red, green, and blue channels together, just red, just green, and cross-sectional view.

## Sedimentation




64 sediment traps arrayed on the floor.



Traps have been collected and remnants of the deposit can be seen.

Sediment traps are placed at known locations to measure deposition throughout the tank during each experiment.

## Data

**Sedimentation maps show the amount of sediment deposited by each current.**

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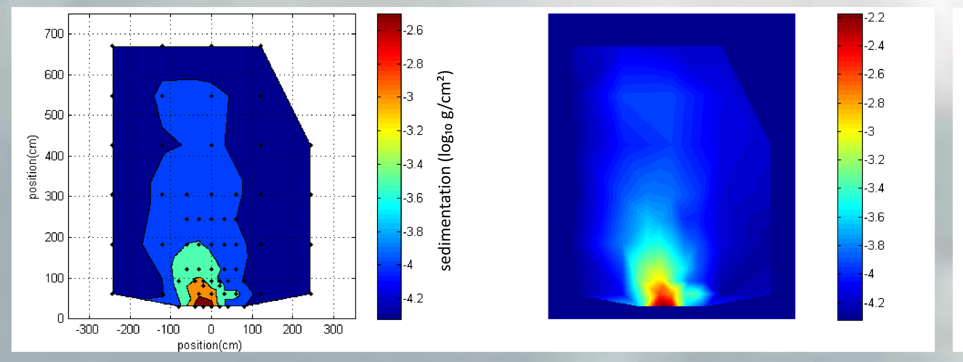


- Current mass: 58.1 g
- Eruption rate: 1.87 g/s
- Initial powder temperature: ΔT = 17.3°C

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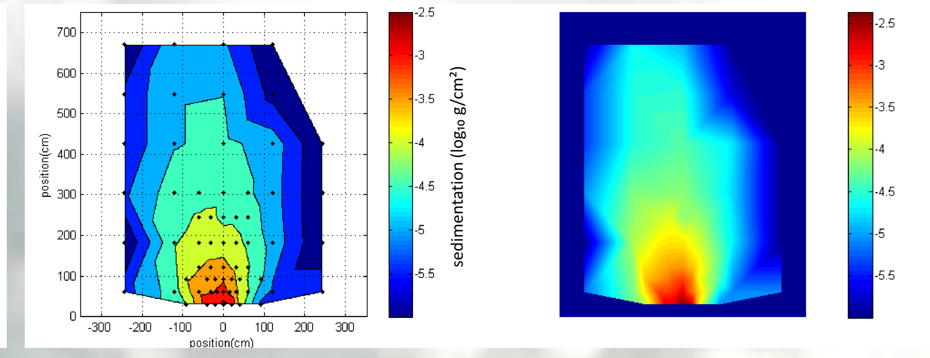


- Current mass: 43.8 g
- Eruption rate: .44 g/s
- Initial powder temperature: Ambient

Hot currents produce noticeably narrower deposits and have shorter run-out distances.

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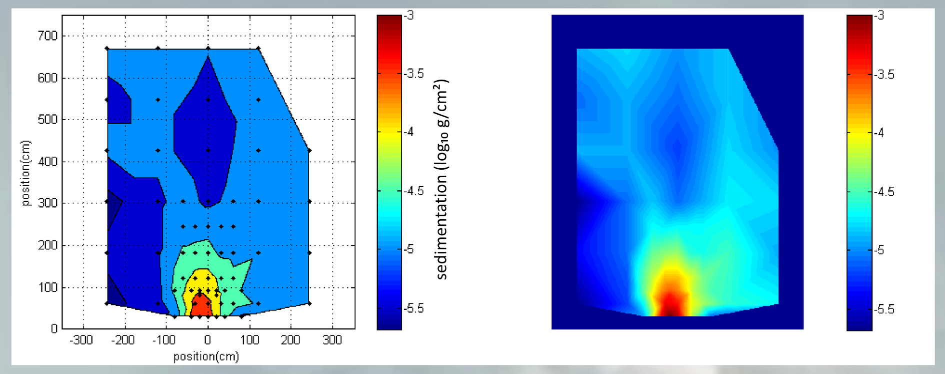


- Current mass: 72.1 g
- Eruption rate: .12 g/s
- Initial powder temperature: Ambient

Long duration currents show oscillating patterns of transport and deposition.

**Top view of currents at 50 second intervals.**

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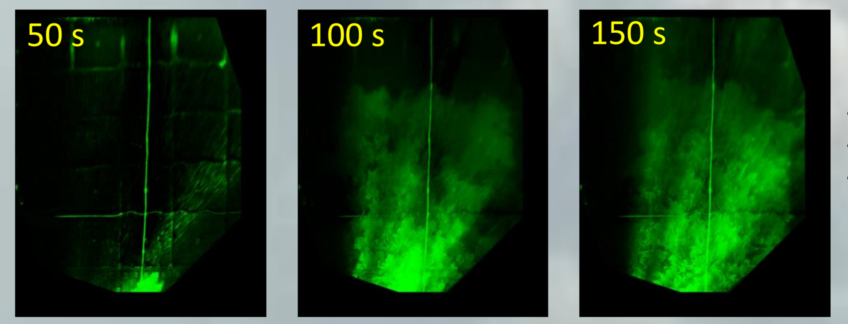


- Current mass: 40.8 g
- Eruption rate: .41 g/s
- Initial powder temperature: Ambient

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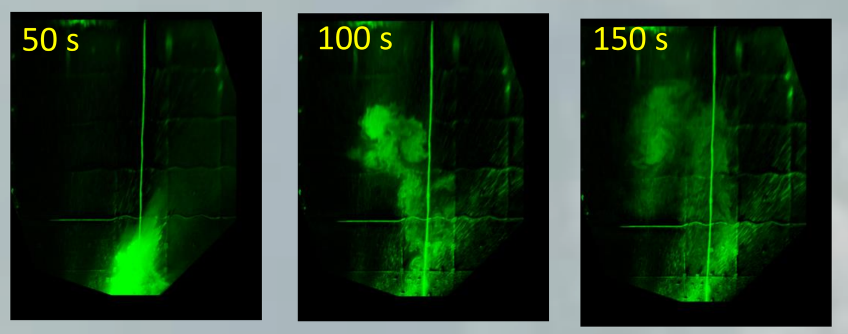


- Current mass: 60.6 g
- Eruption rate: 1.95 g/s
- Initial powder temperature: ΔT = 25.2°C

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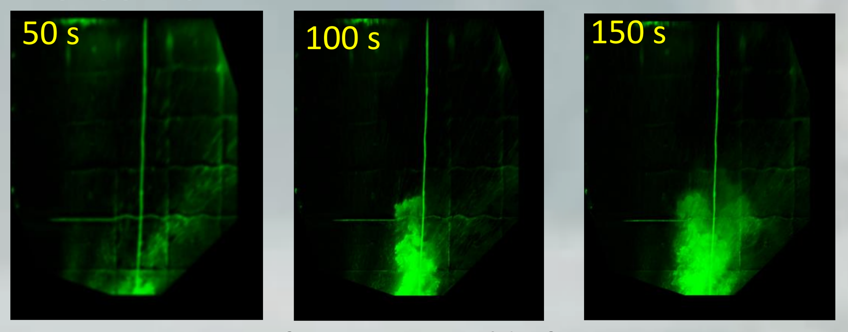



- Current mass: 44.4 g
- Eruption rate: .44 g/s
- Initial powder temperature: ΔT = 23.0°C

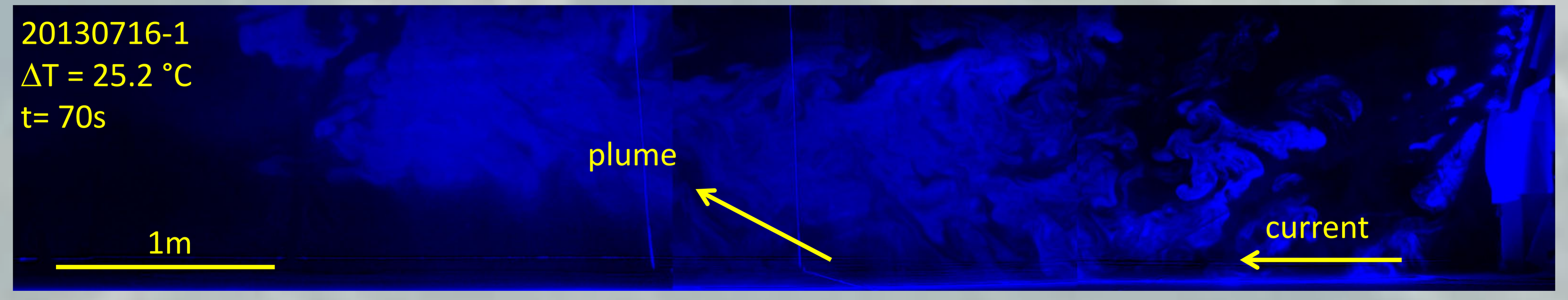
Map projections of currents . Field of view is 7.5x6.1 m.

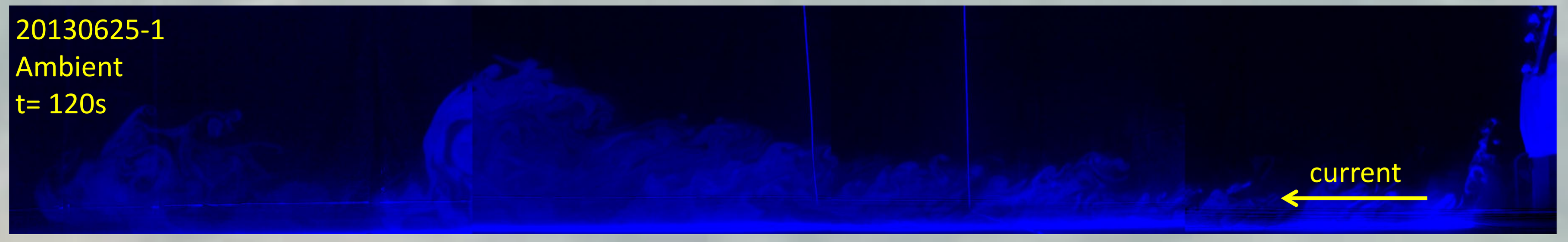
Comparing the ambient temperature to the hotter experiments, the currents spread out like a fan as opposed to staying narrow. Run-out distance is shorter for the hotter experiments.

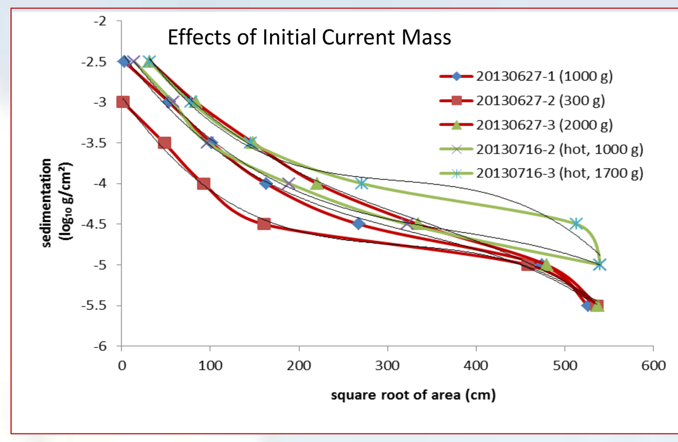
Currents with high eruption rates travel faster and farther than currents with slower rates.

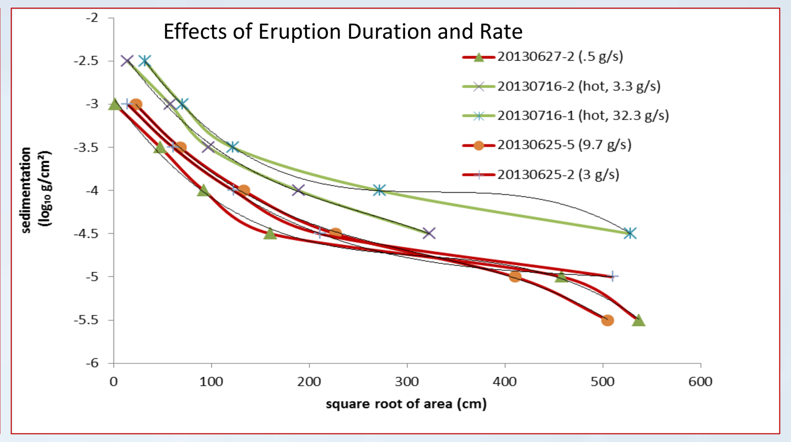
**Cross-sectional view of currents**

(Below) Hot currents are thicker then ambient currents and have shorter run-out distances because they lift off into plumes.



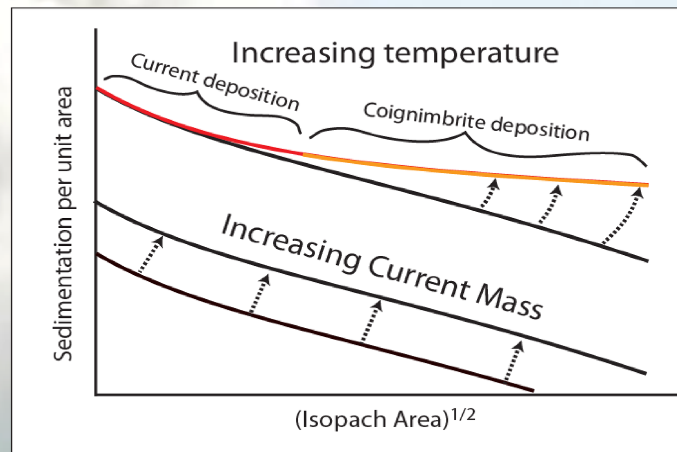



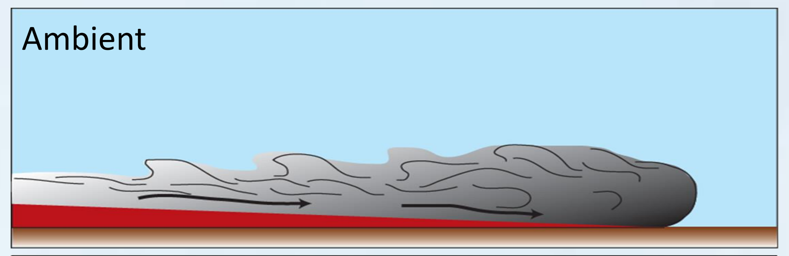

Isopach plots show that proximal deposition is similar between hot and ambient temperature experiments but deviates with increasing distance. The distal slopes differ between ambient temperature and hot current deposits. Third order polynomials fit all curves well ($R^2$>0.9).

Currents with high eruption rates and short durations produce proximally thicker but distally thinner deposits.

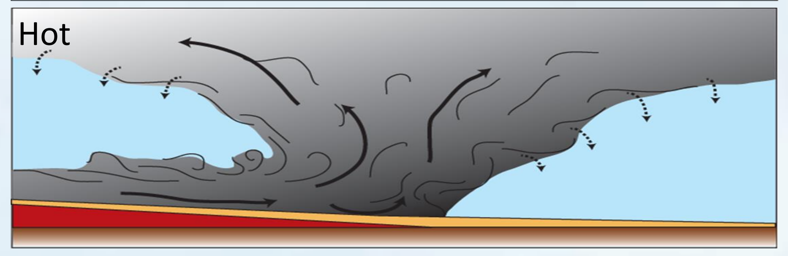



Schematic showing deposition as a function of eruption parameters.

Ambient



Hot



Cartoons illustrating deposition from density current (red) and coignimbrite plume (yellow). Ambient temperature systems only deposit from the current whereas hot systems deposit from both current and plume.

## Discussion

- Hot currents have shorter run-out distances compared to ambient temperature currents, because of buoyancy reversals due to entrainment, heating and expansion of air. Hot currents have narrower deposits because liftoff prevents lateral spreading.
- At fast eruption rates, more energy is put into the system which makes the currents denser and thicker, therefore they travel faster and farther (these are density driven currents).
- Increased duration does not increase run out, but does affect transport processes. For example, long duration currents oscillate laterally.
- Deposits can all be fit with third order polynomials relating mass to isopach area. Depositional curves shift in predictable ways in response to changes in eruption parameters.

## Future Research

- Develop sedimentation model as a function of current parameters.
- Explore effects of particle distribution on current transport and deposition.
- Describe how current "residence time" at one position is reflected by the deposit.
- Quantify coignimbrite fractionation.


## Acknowledgements and References

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(Background image) Newhall