Sustainable Sand Management Control and Solutions - Balancing Performance, Costs, and Environment

20–21 AUGUST 2024 | KUALA LUMPUR, MALAYSIA

Analytical Approaches to the Determination of Retained Permeability and Produced Solids for Sand Screen Retention Tests

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Motivation

The body of knowledge around sand management is very much experiential

Very little actual physics – *this is not surprising. Most fluid mechanics is like this…. because the physics is very hard!*

But some of the physics is amenable to analysis…

What is the filter cake?

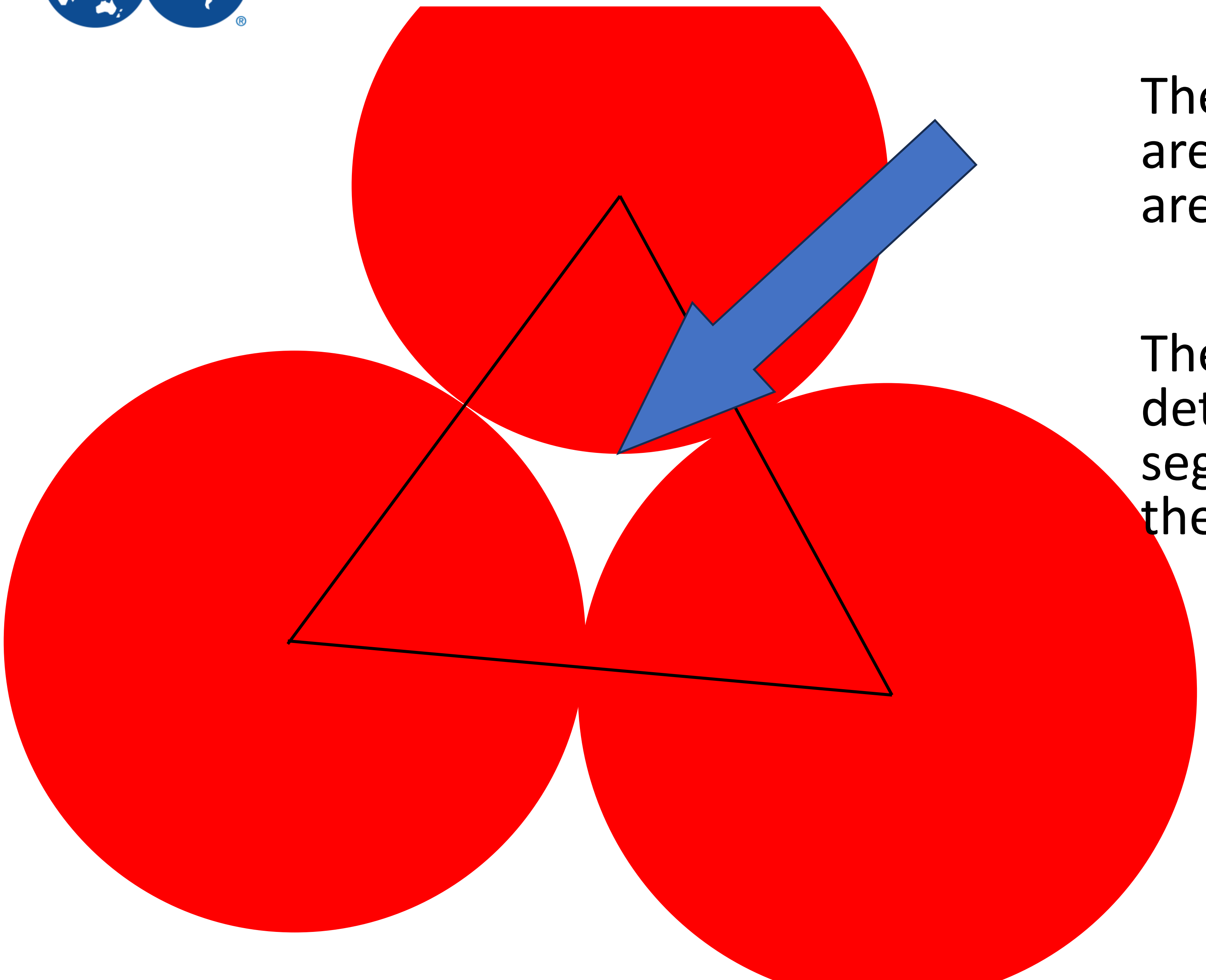
Build-up of grains of outside of the screen

Filter cake has pore spaces and connections so fluid can still pass

But grains are still arriving….

Will they get stuck or will they wriggle through?

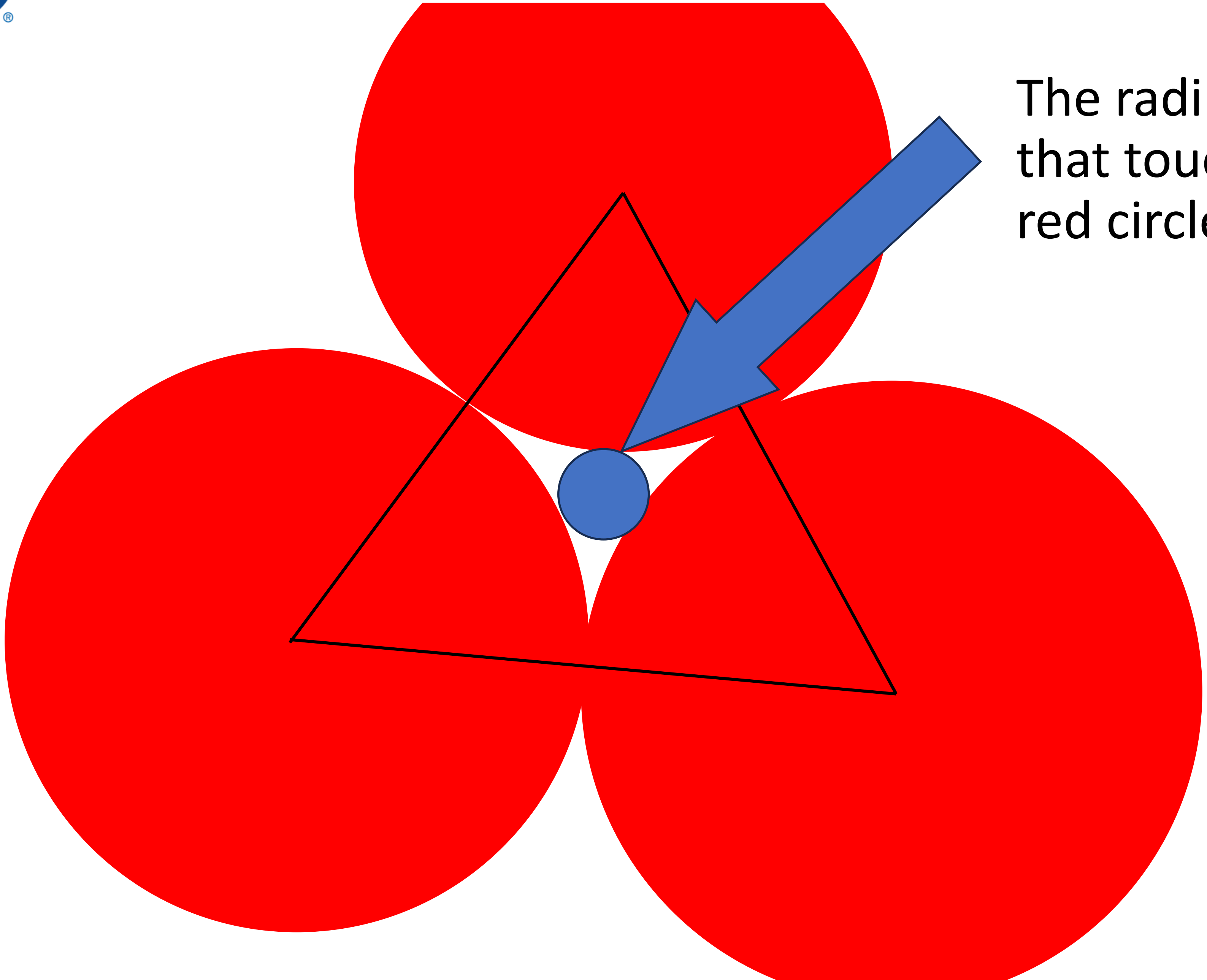
The Hydraulic Radius



The radius of a circle whose area is the same as this white area.

The white area can be determined by subtracting the segments of the circles from the area of the triangle

Maximum Size of Particle that will PASS



The radius of a circle that touches the three red circles

Descartes’ Theorem

Descartes' theorem states that for every four kissing, or mutually tangent, circles, the radii of the circles satisfy a certain quadratic equation. By solving this equation, one can construct a fourth circle tangent to three given, mutually tangent circles

The trick is to define curvature, k, as the reciprocal of radius. Then the curvature of the fourth circle is;

$$k_4 = k_1 + k_2 + k_3 \pm 2\sqrt{k_1 k_2 + k_2 k_3 + k_3 k_1}.$$

Recap

We can compute the hydraulic radius

We can compute the maximum size of particle that will pass

We know the size distribution of the grains – because we use that to select the screen

So we can work out the probability of a particle getting trapped

…. AND we can work out the reduction in permeability from the change in the area of the pore throat;

New Pore Throat Area = Original Area – Area of Trapped Particle

What a minute – you did all that in 2D and the filter cake is 3D!

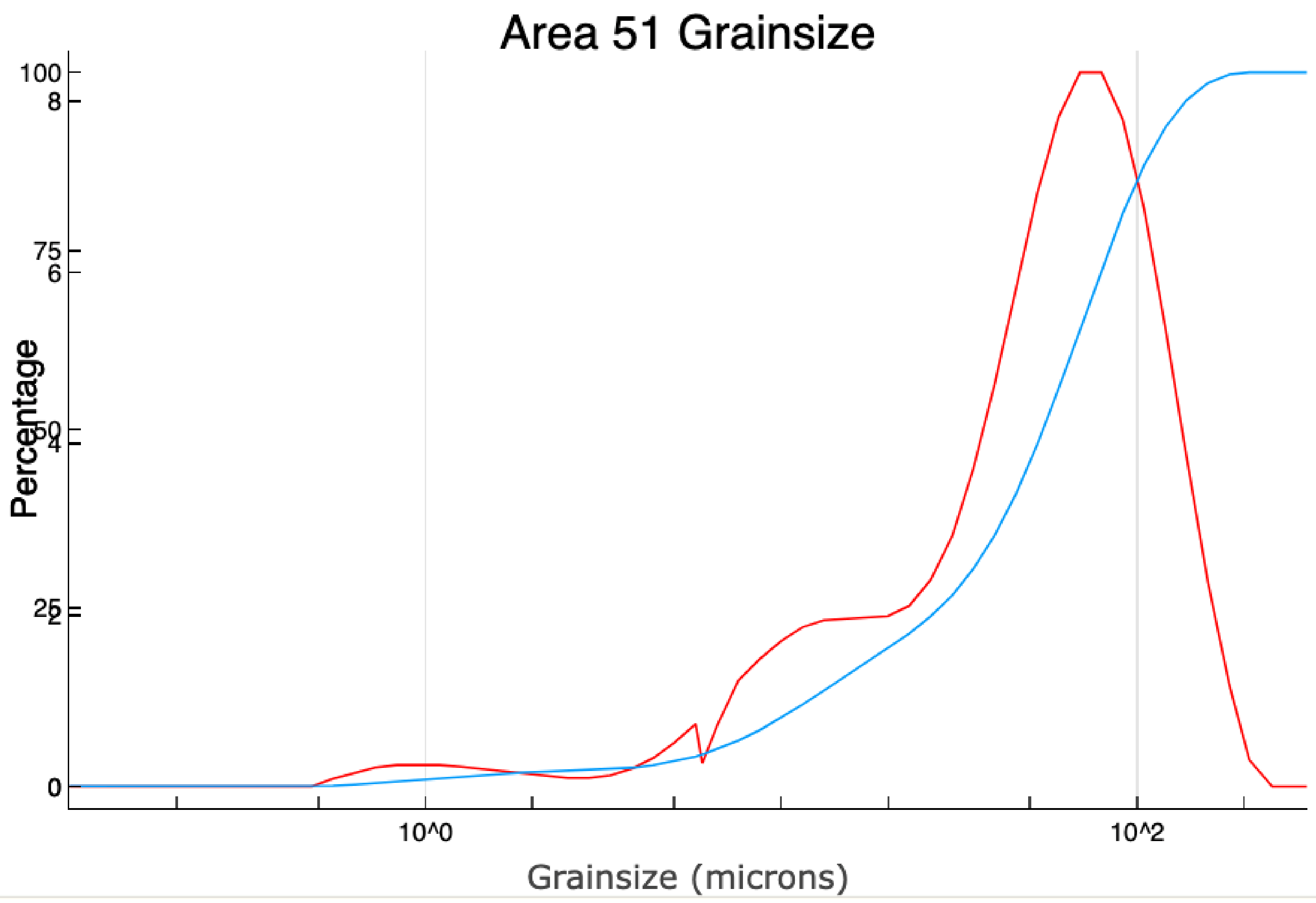
I know….

Let's triangulate the particles in 3D – we get a set of tetrahedra

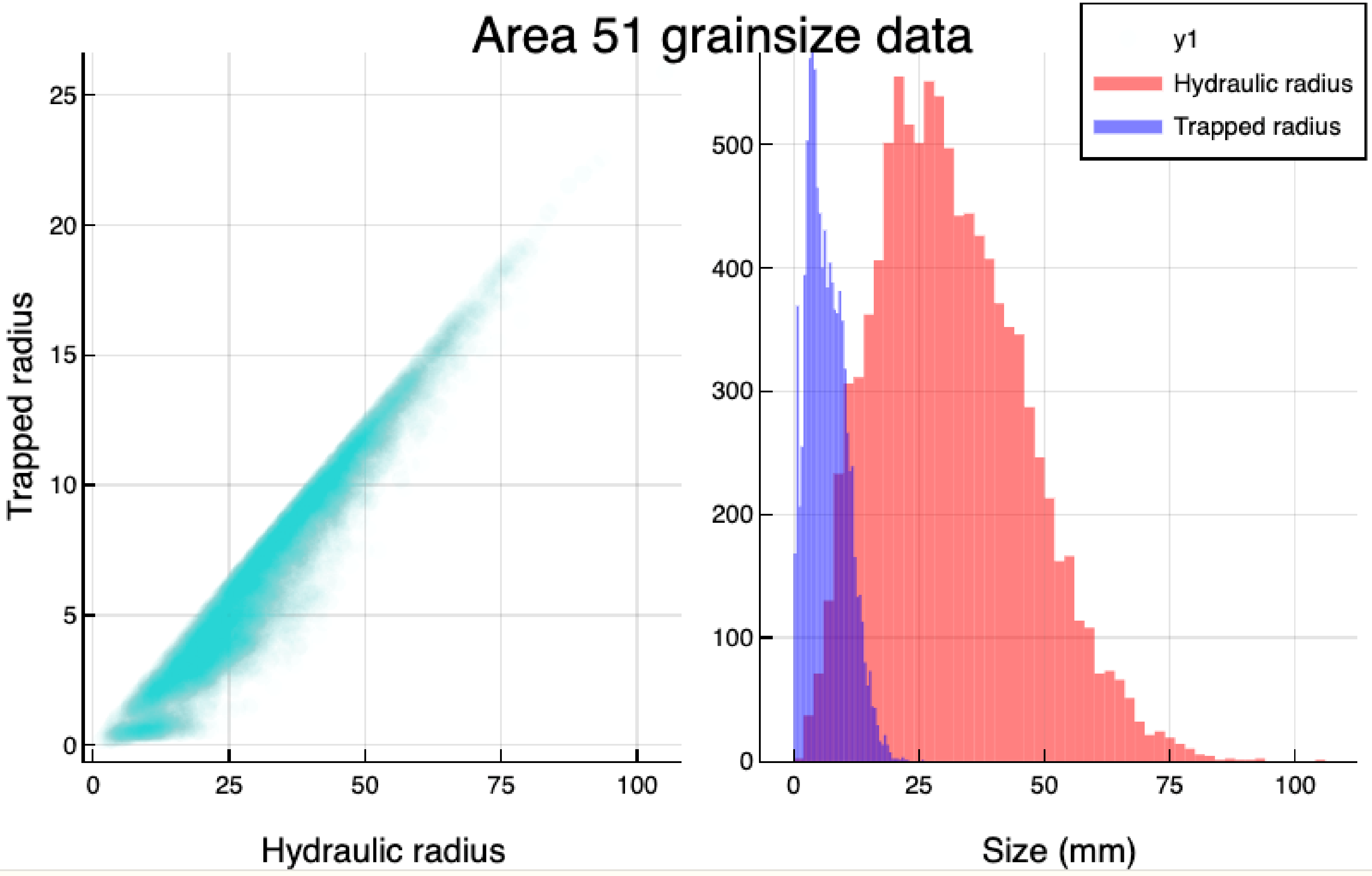
Each tetrahedra has four faces

Each face is a 2D triangle. Happy?

Real Data from a secret location

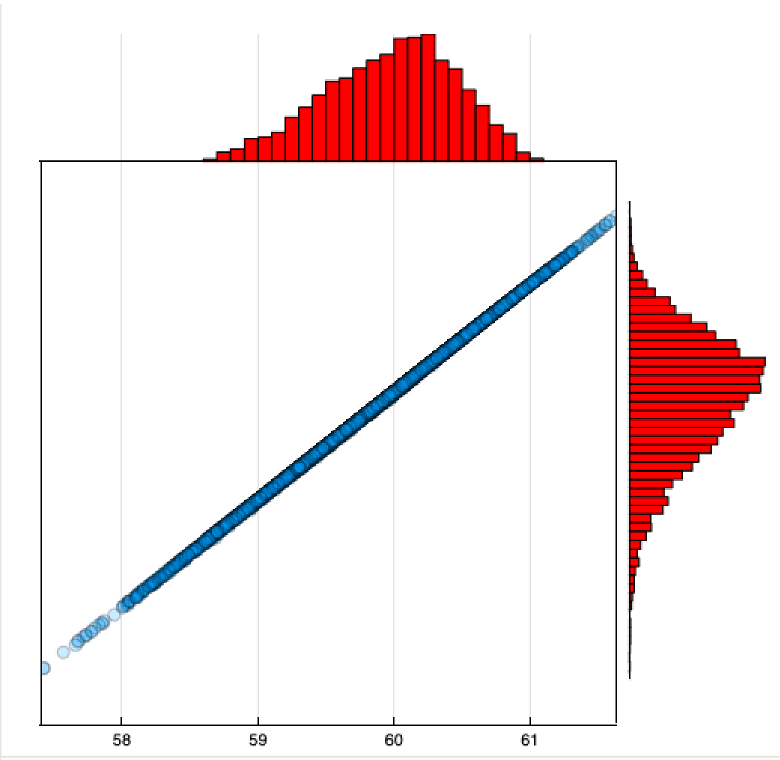


Relationship between the hydraulic radius and trapped radius

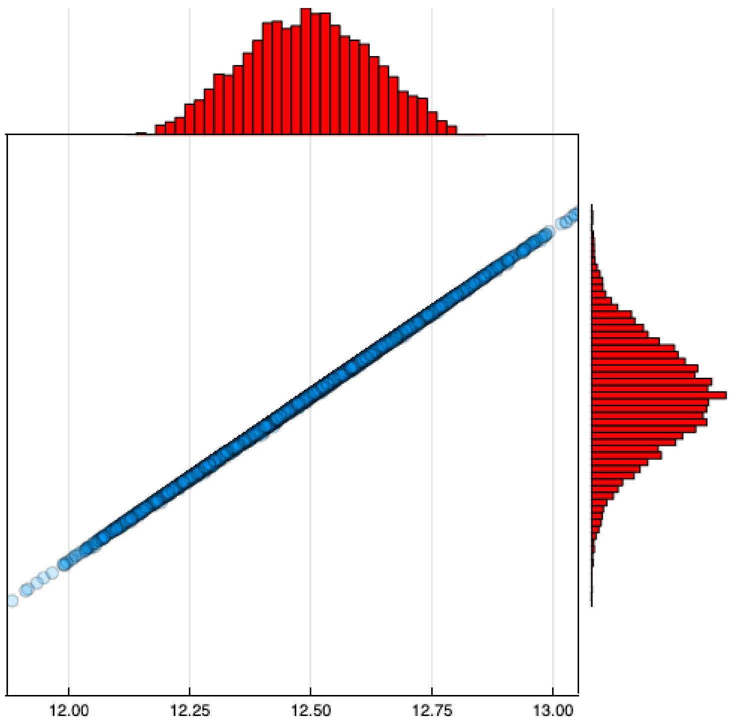


Sensitivity to skewness and kurtosis

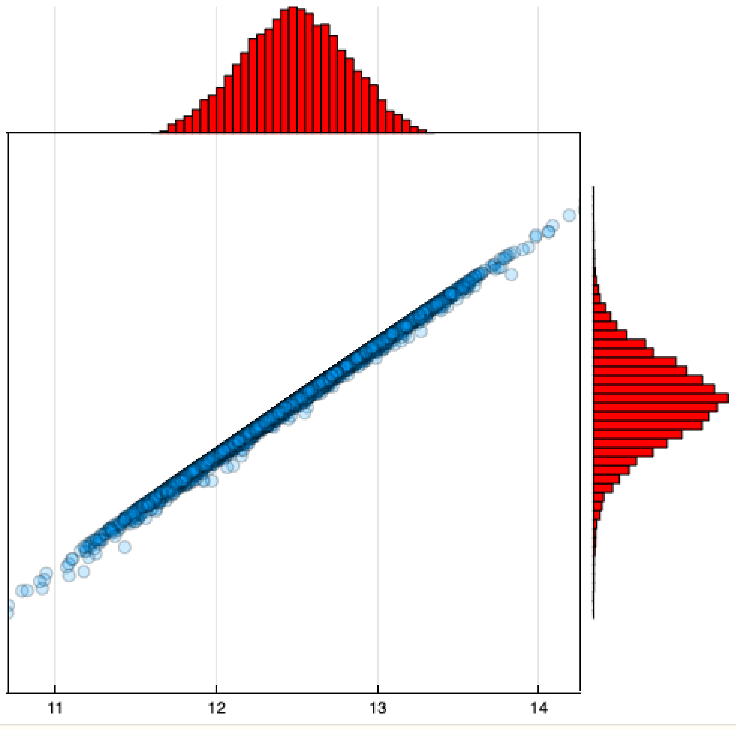
Skewness = -5.0



Kurtosis = 0.2



Kurtosis = 2.0



Insensitive to skewness

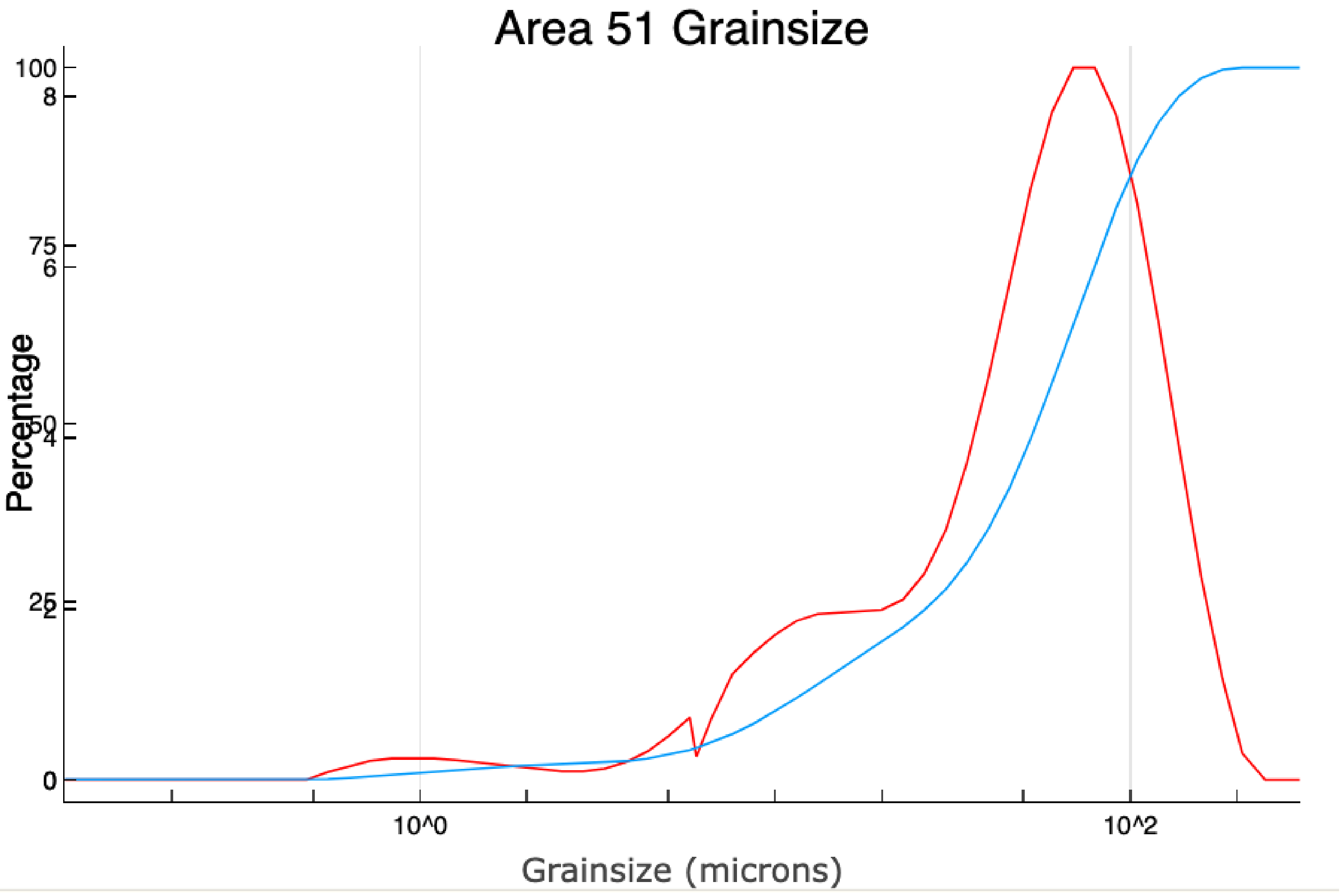
Excess kurtosis weakens the relationship between hydraulic radius and trapping radius

What's the point of all this?

For any grain that has been dislocated from the rock matrix being carried towards the filter cake there are 3 options, depending on its size;

Size	Probability	Effect	Effect on permeability	Quantification
Very small	$P_{pass} = f(\overline{r_t}, \overline{r_g})$	Grain passes through filter cake	No change	$\Delta k = 0$
Small	$P_{stuck} = f(\overline{r_t}, \overline{r_g})$	Grain gets stuck in filter cake	Reduced	$\Delta k \propto \frac{r_h - r_t}{r_h}$
Not small	$P_{add} = f(\overline{r_g})$	Grain is added to the outside of the filter cake	No change	$\Delta k = 0$

Let's look at the grain size data again with our new knowledge…

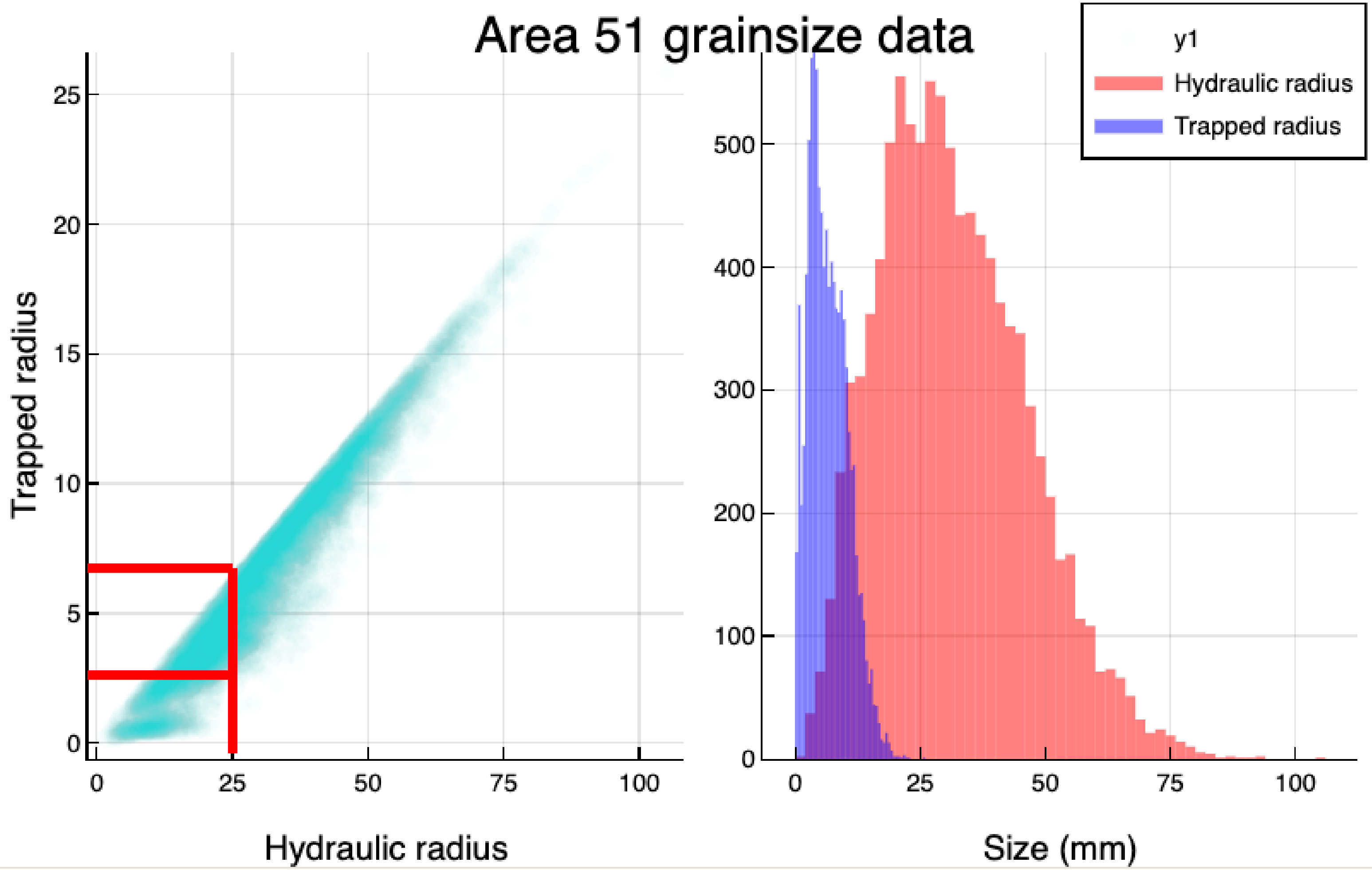


Relationship between the hydraulic radius and trapped radius

In this dataset, for a given hydraulic radius there is a broad range of trapping radii…

This means a greater likelihood of trapping…

… and a greater likelihood of reducing the retained permeability



Future work

Still need to determine the exact form of an analytical solution to the retained permeability as a function of the grain size distribution… but we’re really close

Need to consider the impact of angularity and sphericity on this approach; spheres are easy, ellipsoids are surprisingly tricky

We have some techniques to replace spheres with real granular shapes but are waiting to complete the analysis on spheres before implementing these

Conclusions

An analytical approach to the determination of retained permeability as a function of grainsize distribution is being developed.

Early insights are encouraging and our research suggests than proportions of particles in the tails of the distributions are influential, i.e. the proportion of fines

Narrow ranges of particles are much less susceptible to clogging

Screen aperture is largely irrelevant

But wait… there's a little problemette..

My lab team recently ran a test and noticed that the grainsize curve was the same as a test they ran in February

But the retained permeability was very different

The geologist described one sample as "Shore face" and the other as "Fluvial flood plain"

Same grain size – different depositional setting

So what's different and how can we include this in our analysis

Agglomeration? Electrostatic charges? Somehow the grains are sticking together in one sample

We need to change our math to consider particles that are stuck together…

… or we work out a way to stop them sticking together in the filter cake

Discussion Questions…

I know you're shy so I thought I would help….

1. How accurate is the solution likely to be?
2. How close do you think a solution will be to the retained permeability for real sediments?
3. Why are you ignoring the screen?
4. How does the presence of charged particles (clays) affect this analytical approach?