

# Direct pyrrhotite testing and map cracking risk assessment using magnetic susceptibility loss and total sulfur method

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# Collaboration of many

- Trinity college undergraduates
- Connecticut State Geologist Margaret Thomas, Meagan Seremet
- Massachusetts State Geologist, Steve Maybe
- Tim Heim (CCACB), Michelle Loglisci (MRACC)
- Dave Sherwood (Sherwood Inspections)
- Gary Presa (Core Solutions)
- Laval University (Quebec)
- Sedex Labs (Quebec)
- UCONN
- Virginia Tech (Alex Brand)
- NSSGA (Hadi Rashidi)

And many more in government, community and industry



What is the minimum concentration of pyrrhotite (Po) in concrete that causes map cracking?



[http://origin.misc.pagesuite.com/fc148219-0226-4627-b023-f64f5efd2a1a/images/IMG\\_HC-HC\\_CrumblingFound\\_2\\_1\\_581VL5UC.jpg](http://origin.misc.pagesuite.com/fc148219-0226-4627-b023-f64f5efd2a1a/images/IMG_HC-HC_CrumblingFound_2_1_581VL5UC.jpg)

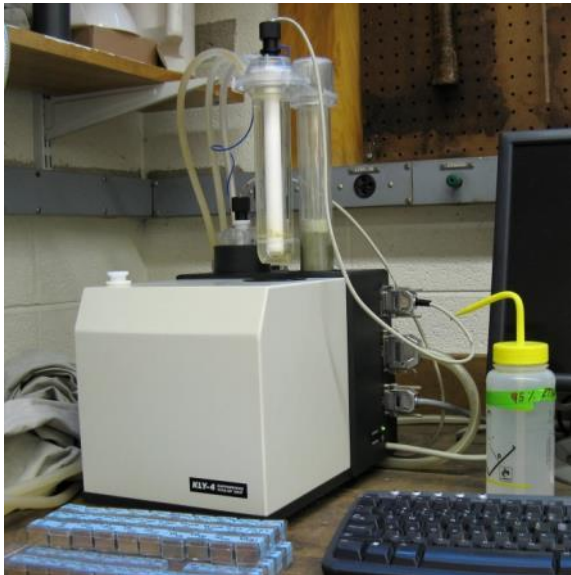


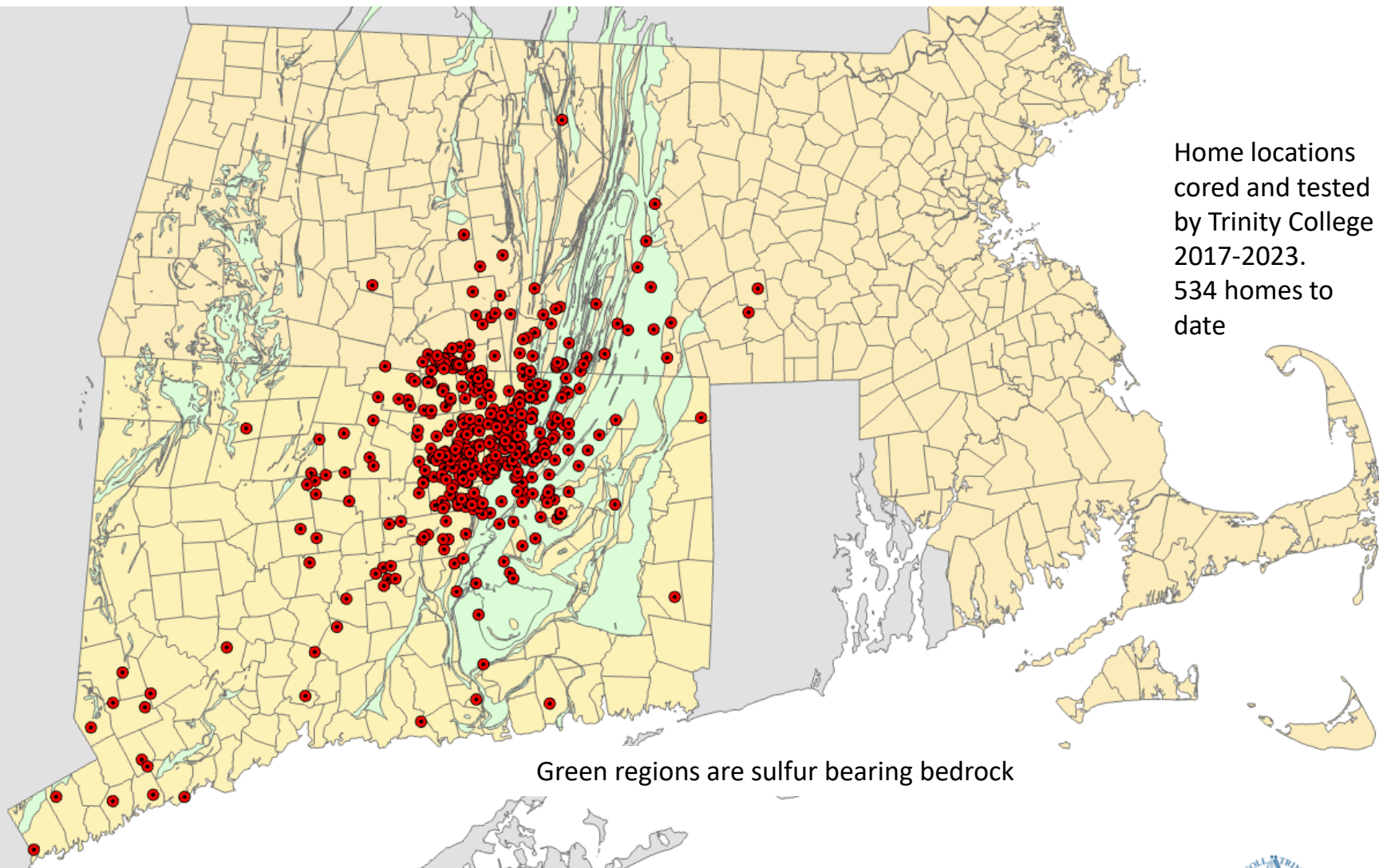
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## 2 independent measurements:

- Thermomagnetic analyses -  $\chi(T)$  to detect the presence of pyrrhotite
- Total Sulphur content (% wt)





Home locations  
cored and tested  
by Trinity College  
2017-2023.  
534 homes to  
date

Green regions are sulfur bearing bedrock



# pyrrhotite solid solution $\text{Fe}_{(1-x)}\text{S}$

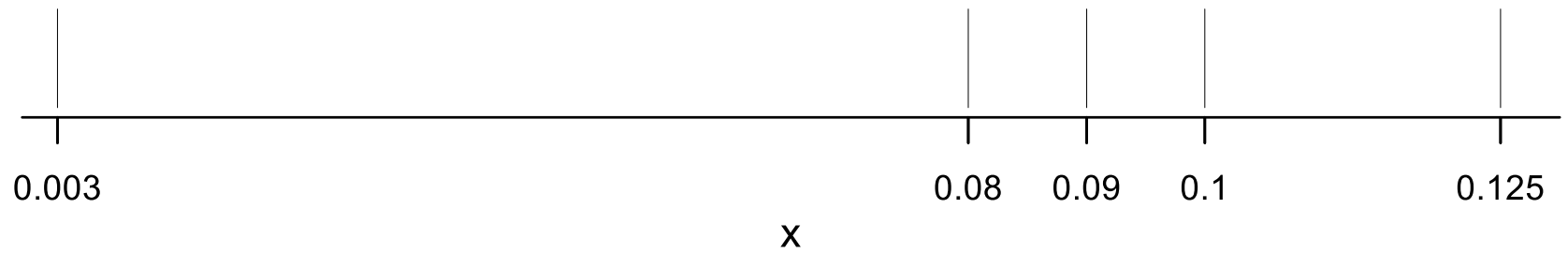
FeS  
(troilite)

$\text{Fe}_{11}\text{S}_{12}$

$\text{Fe}_{10}\text{S}_{11}$

$\text{Fe}_9\text{S}_{10}$

$\text{Fe}_7\text{S}_8$



hexagonal  
antiferromagnetic

monoclinic  
ferrimagnetic





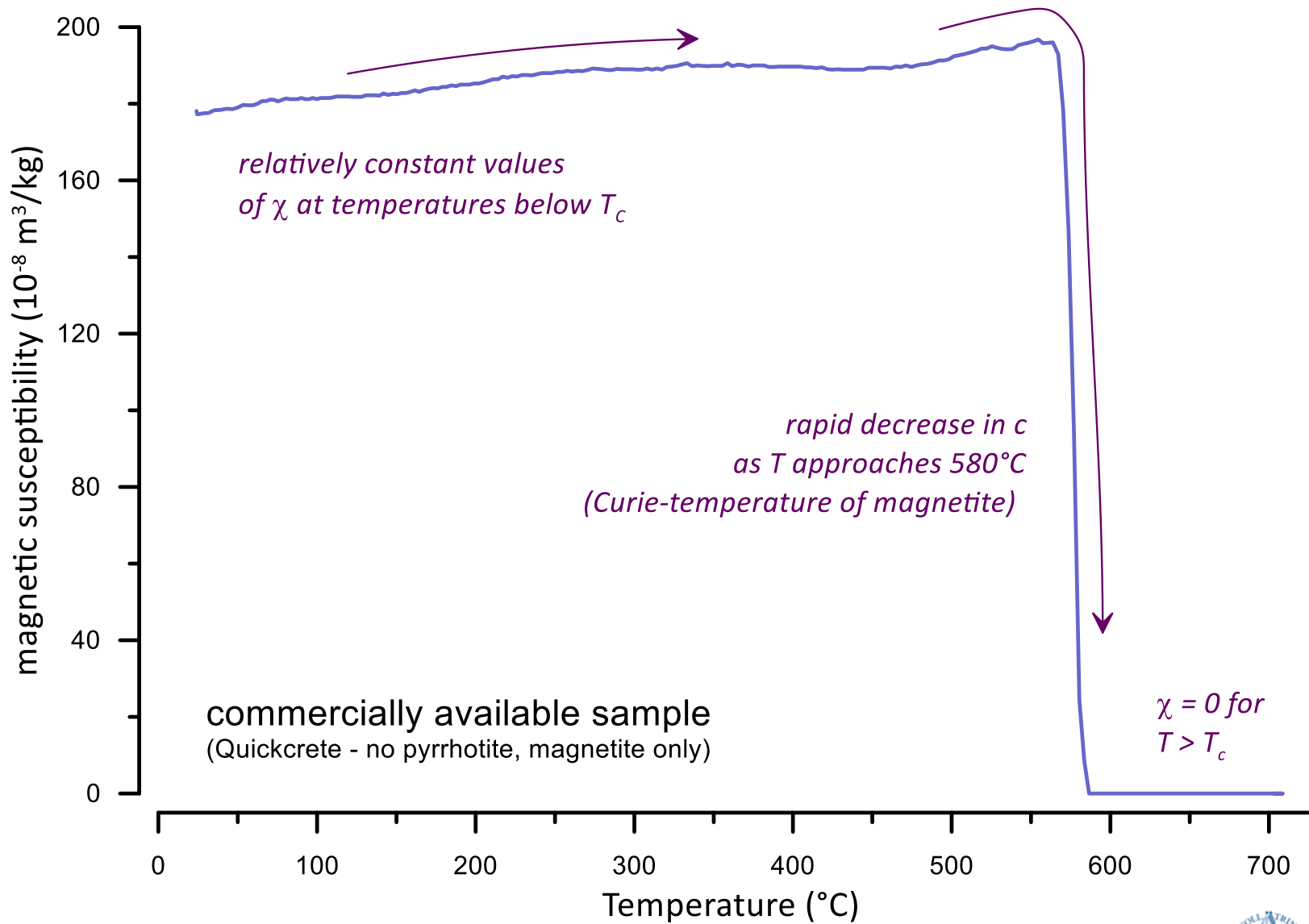
# magnetic susceptibility ( $\chi$ )

$$\chi = \frac{\text{sample magnetization}}{\text{applied magnetic field}}$$

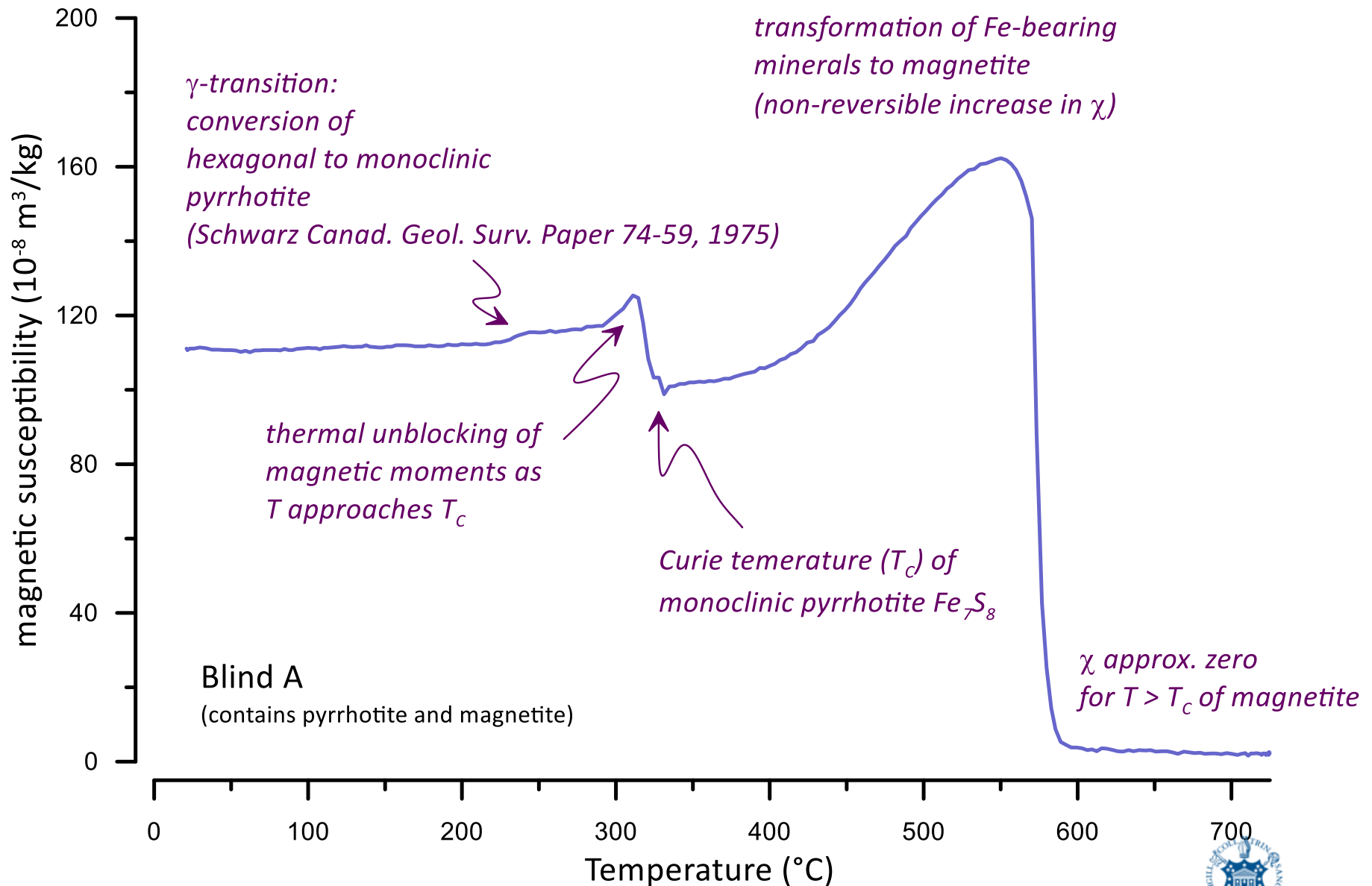
Depends on:

- Mineralogy
- Abundance of magnetic minerals
- Magnetic grain size / shape
- Sample temperature ( $\chi = 0$  at  $T > T_c$ )

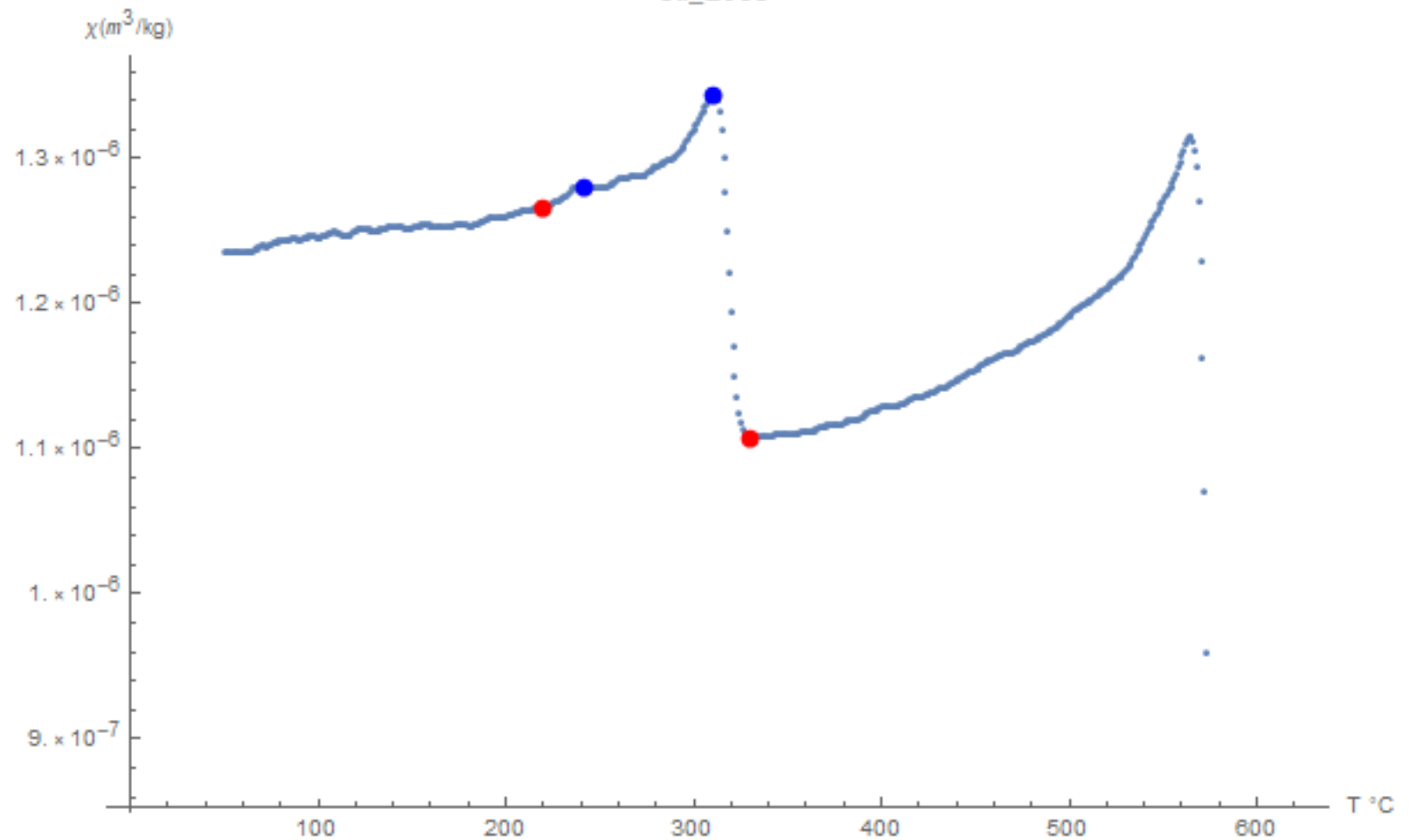








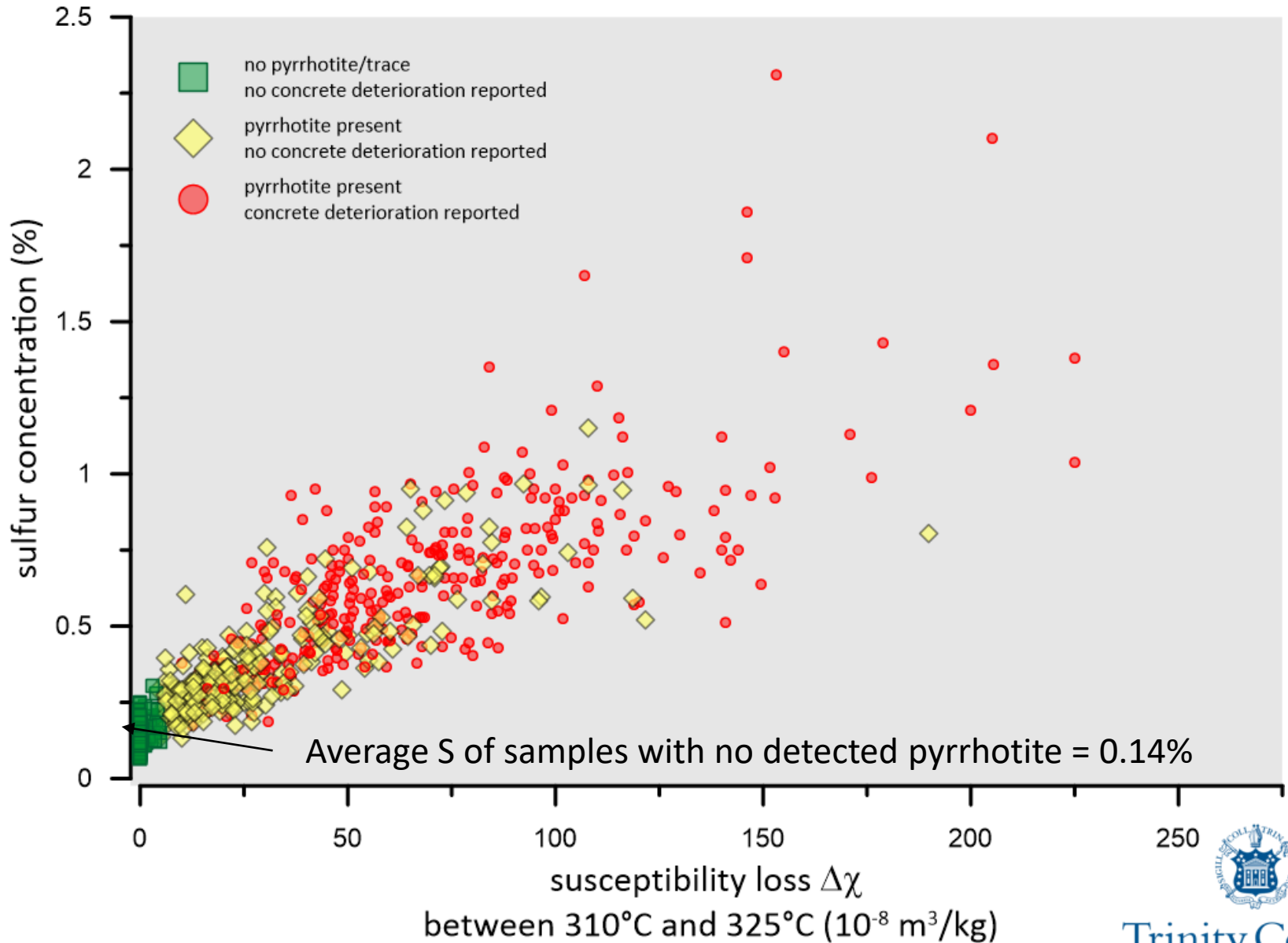
stf\_20e5



lower base :	$1.2658 \times 10^{-6}$	lower peak :	$1.27944 \times 10^{-6}$
upper base :	$1.10735 \times 10^{-6}$	upper peak :	$1.34243 \times 10^{-6}$

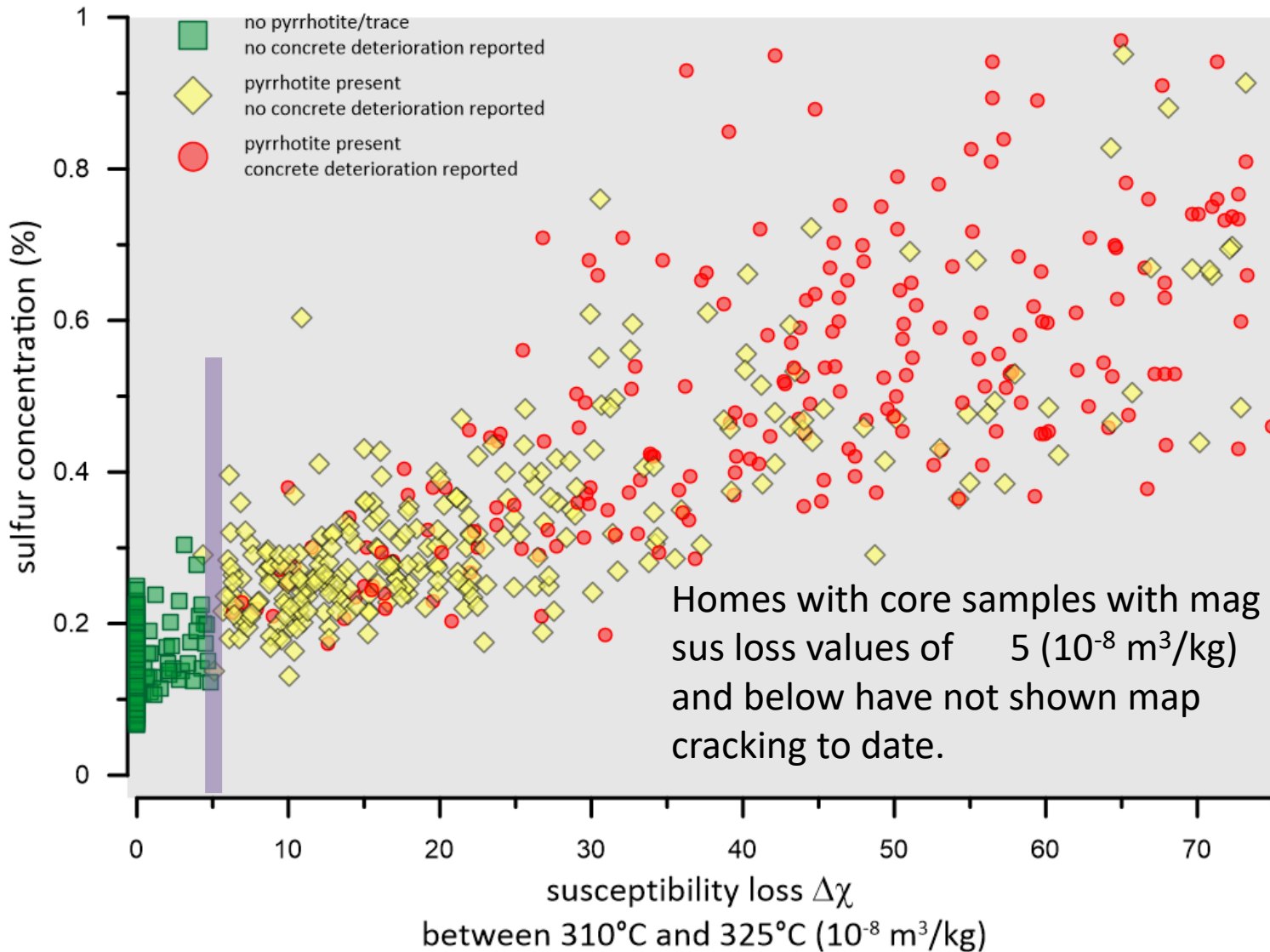
po 1 =	$1.36 \times 10^{-8}$
po 2 =	$1.72 \times 10^{-7}$
po 3 =	$2.35 \times 10^{-7}$

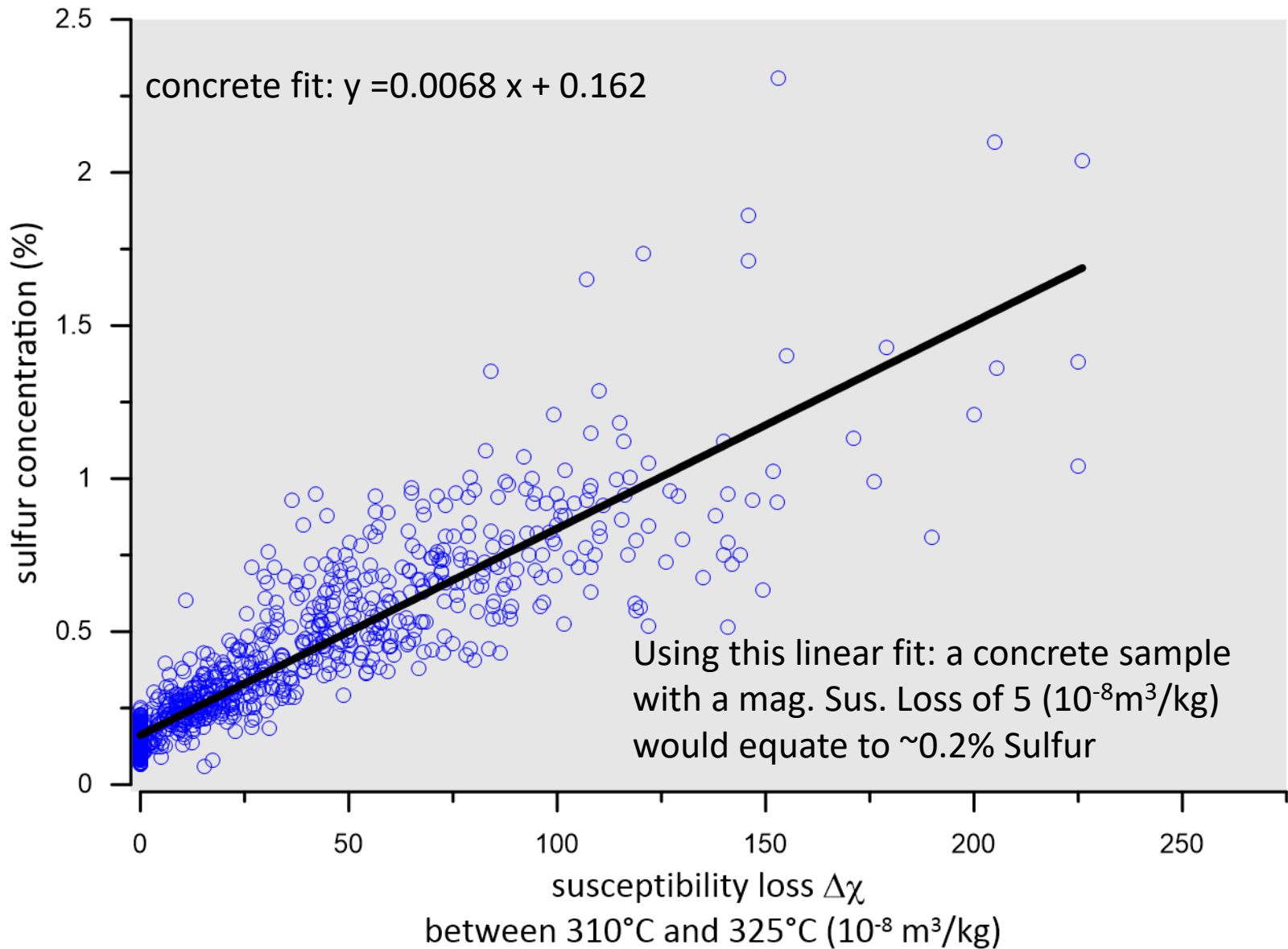
# Concrete foundations tested by Trinity (534 homes) in Connecticut and Massachusetts – as of October 2023

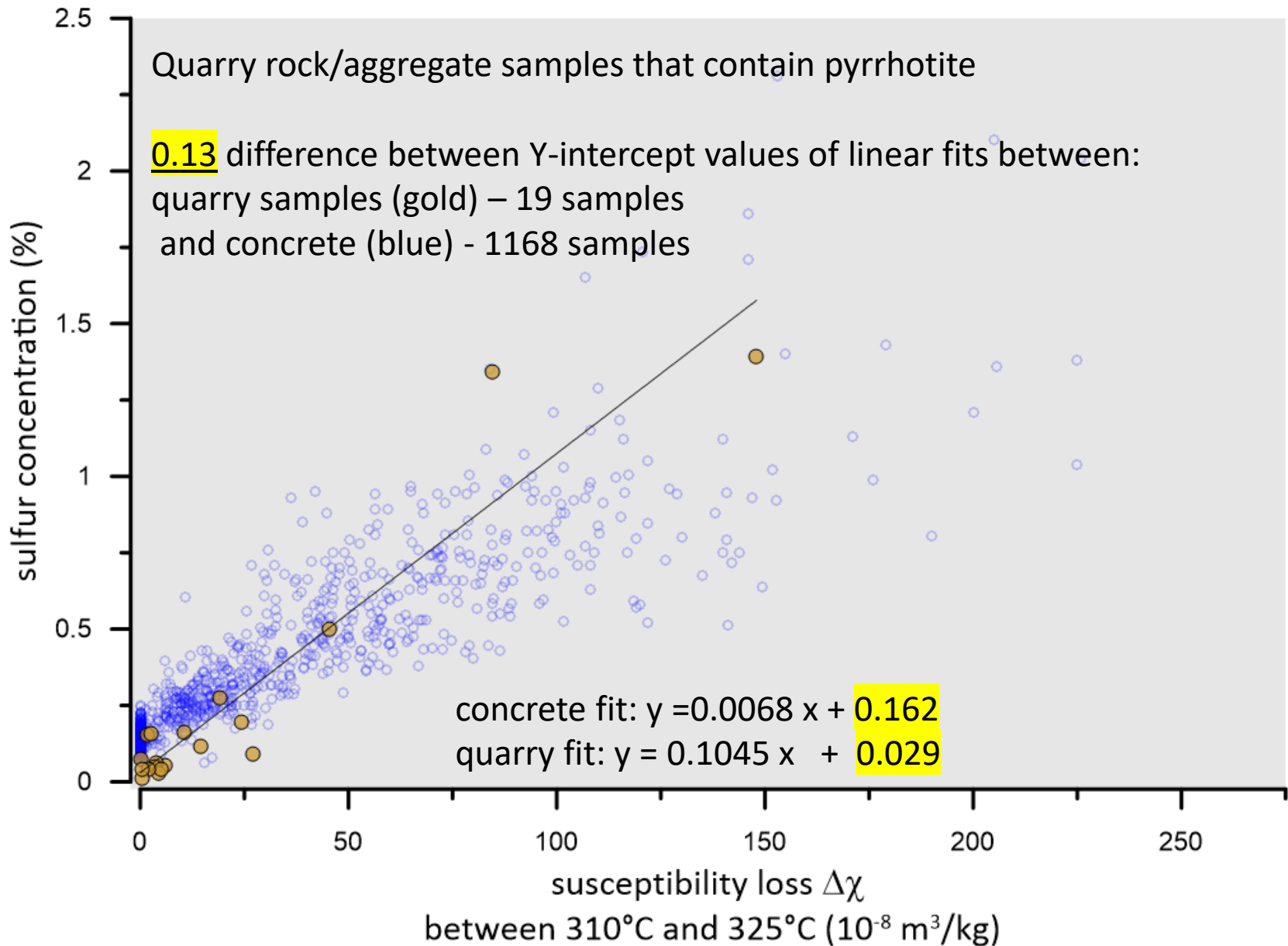




# How does mag. sus. loss translate to % pyrrhotite?









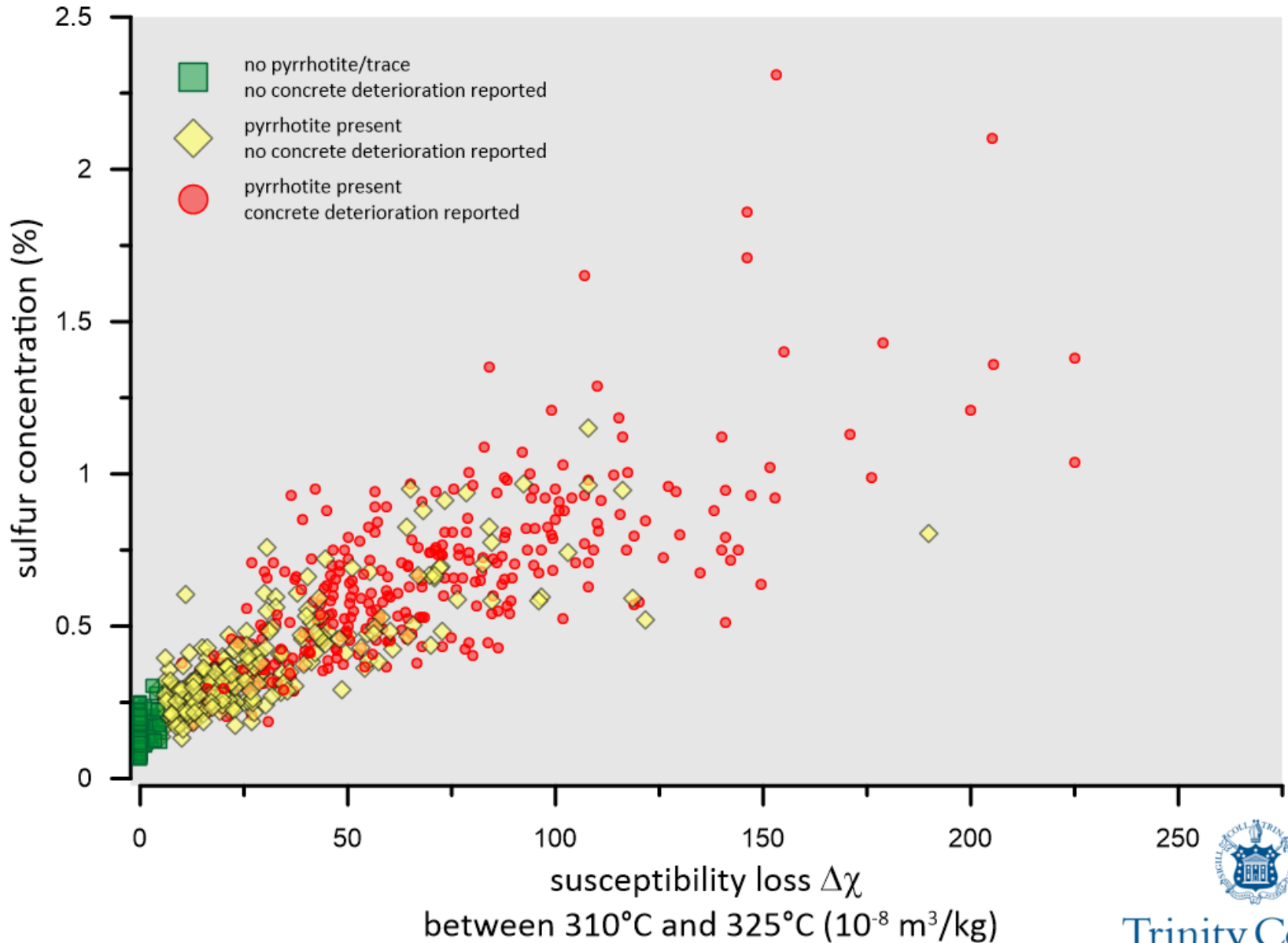
# What is the min concentration of Po?

- $0.20\%S - 0.14\%S \cong 0.06\%$  sulfur bound to Po
- The relationship between S and Po is based on the chemical formula.
- As explained, Po formula is variable but on average, Po% is 2.5 times S% by weight.
- $0.06\% S * 2.5 \cong 0.15\% Po$  by weight. Is equivalent to a mag susceptibility loss of  $5 (10^{-8}m^3/kg)$ .

Our estimate of 0.15% Po is very close to established standards for sulfur/Po and are probably quite reasonable.

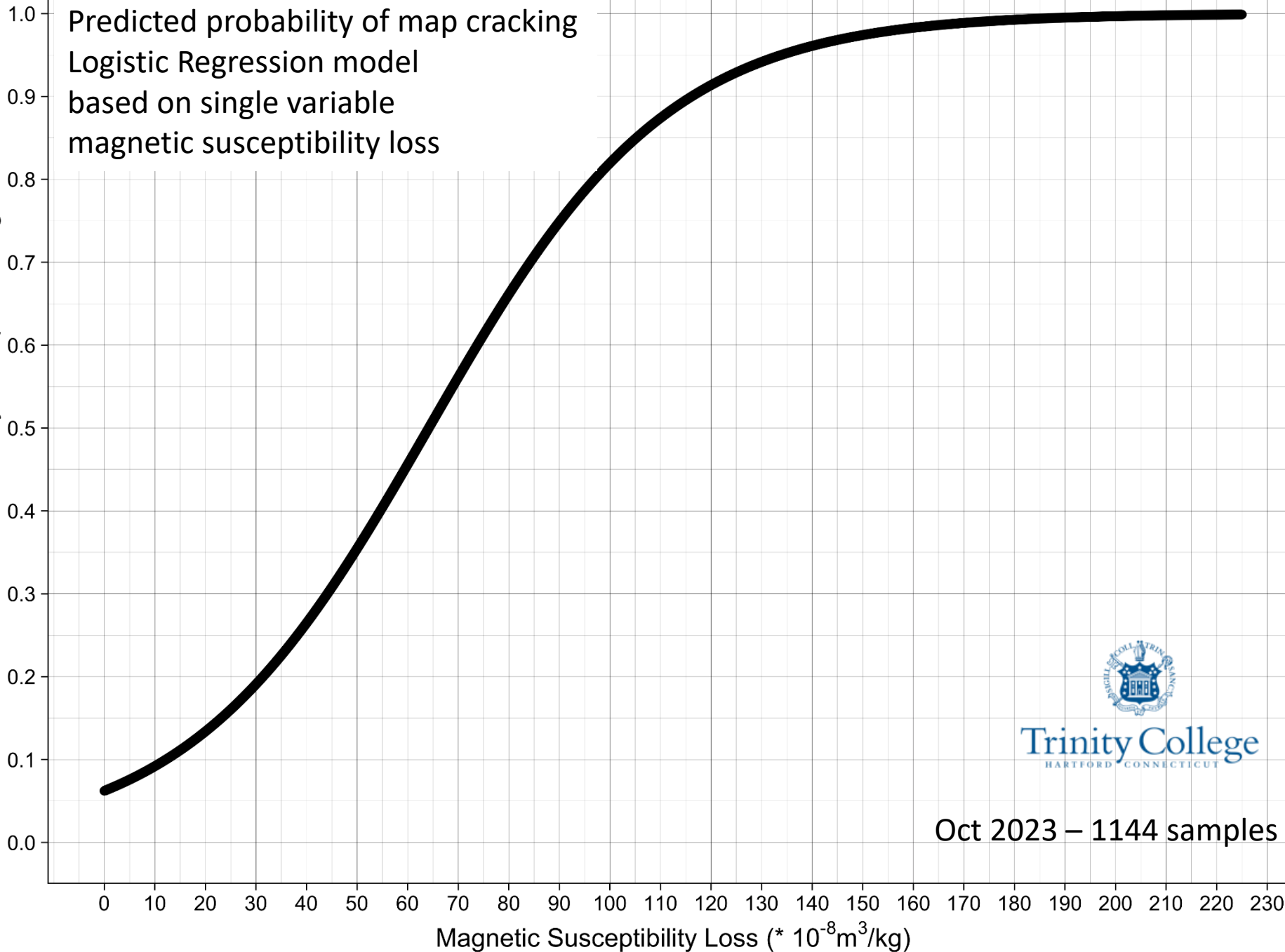


# Concrete foundations tested by Trinity (534 homes) in Connecticut and Massachusetts – as of October 2023



Predicted probability of map cracking  
Logistic Regression model  
based on single variable  
magnetic susceptibility loss

Predicted Probability of Map Cracking



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Oct 2023 – 1144 samples



Example – using risk model

Input: Home concrete results  
mag sus loss of 23 ( $*10^{-8}m^3/kg$ )

These numbers help frame conversations about risk with home owners, realtors, mortgage brokers, lawyers, quarry owners..etc.

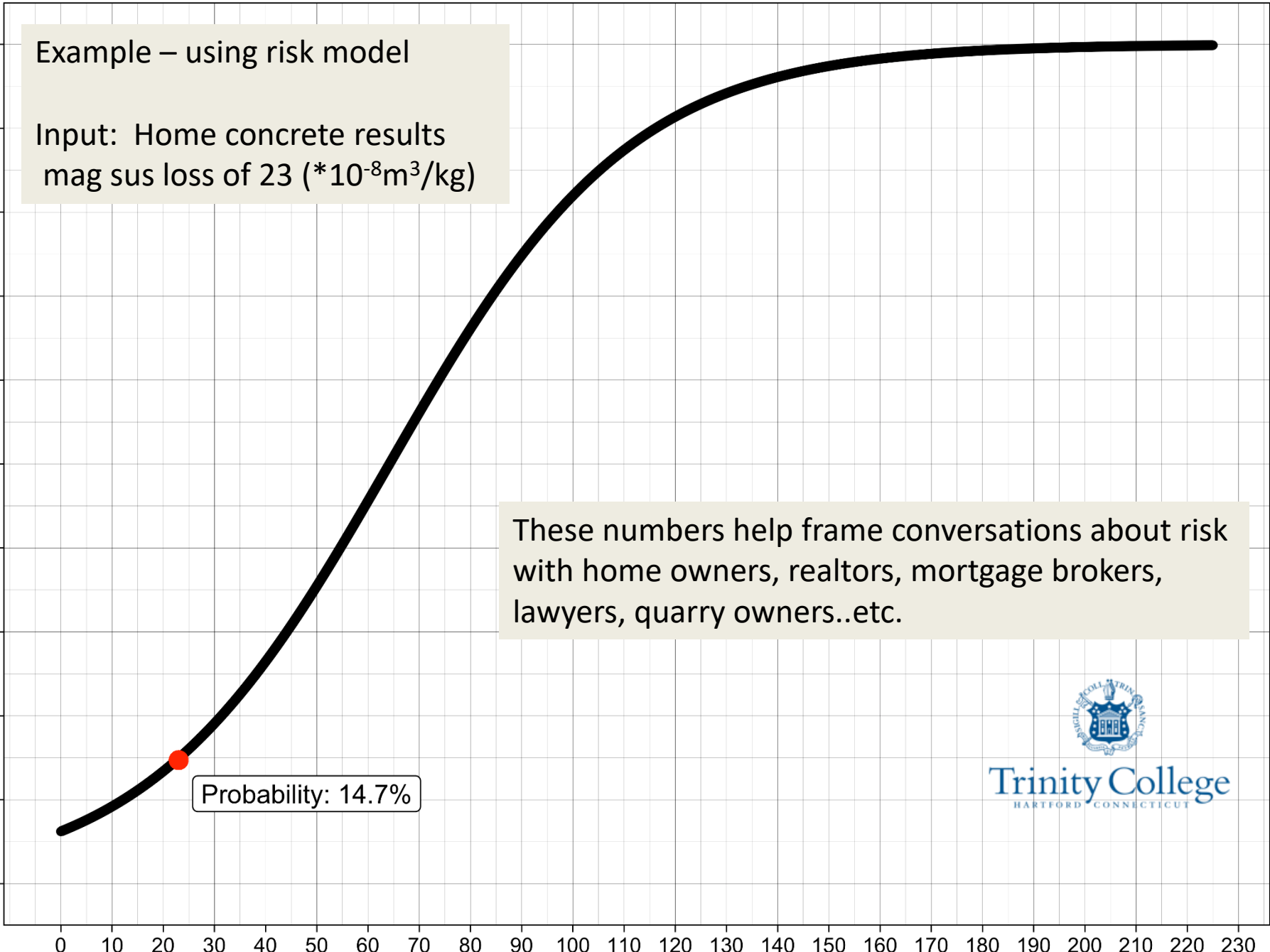
Probability: 14.7%



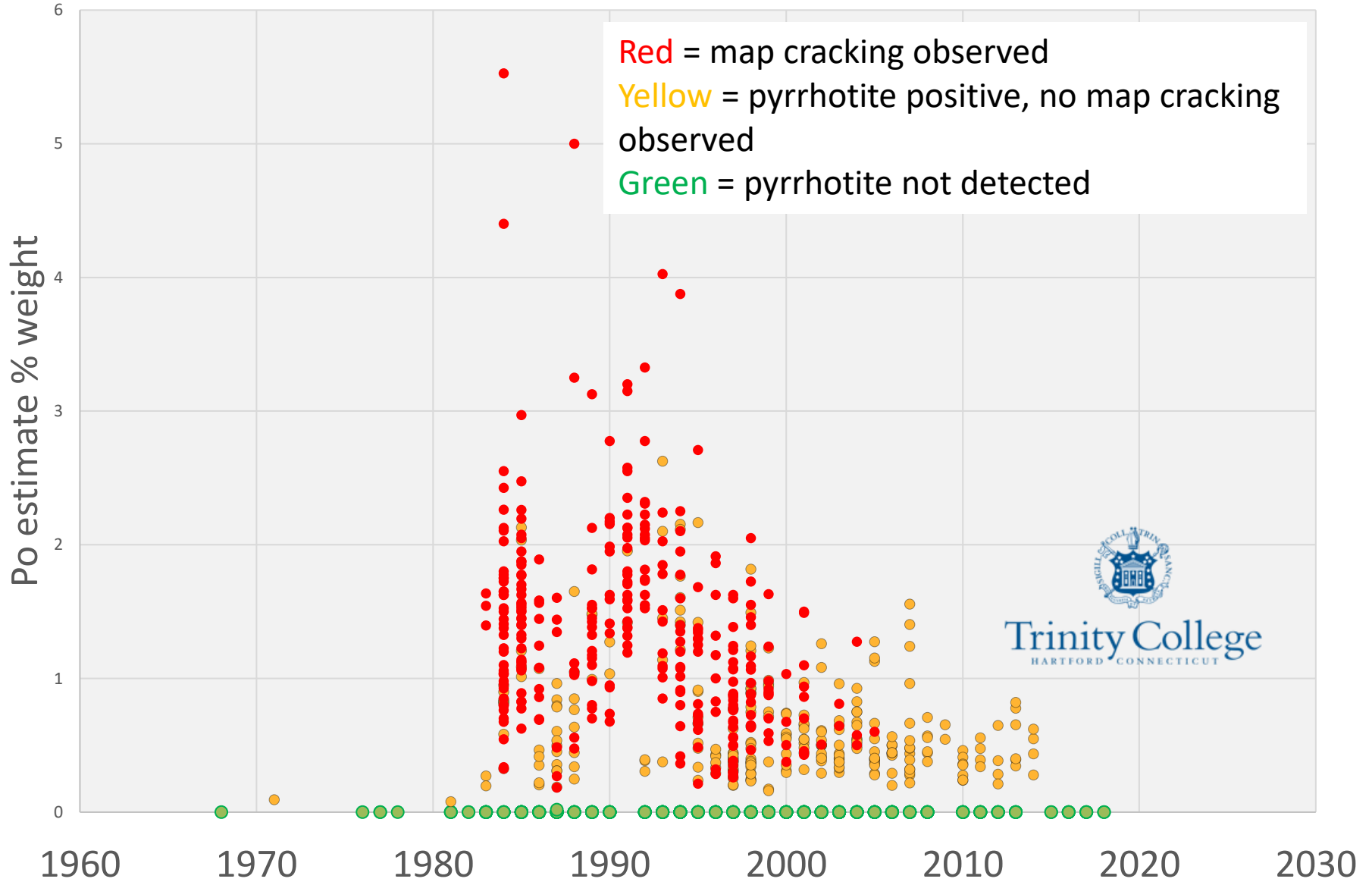
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Predicted Probability of Map Cracking

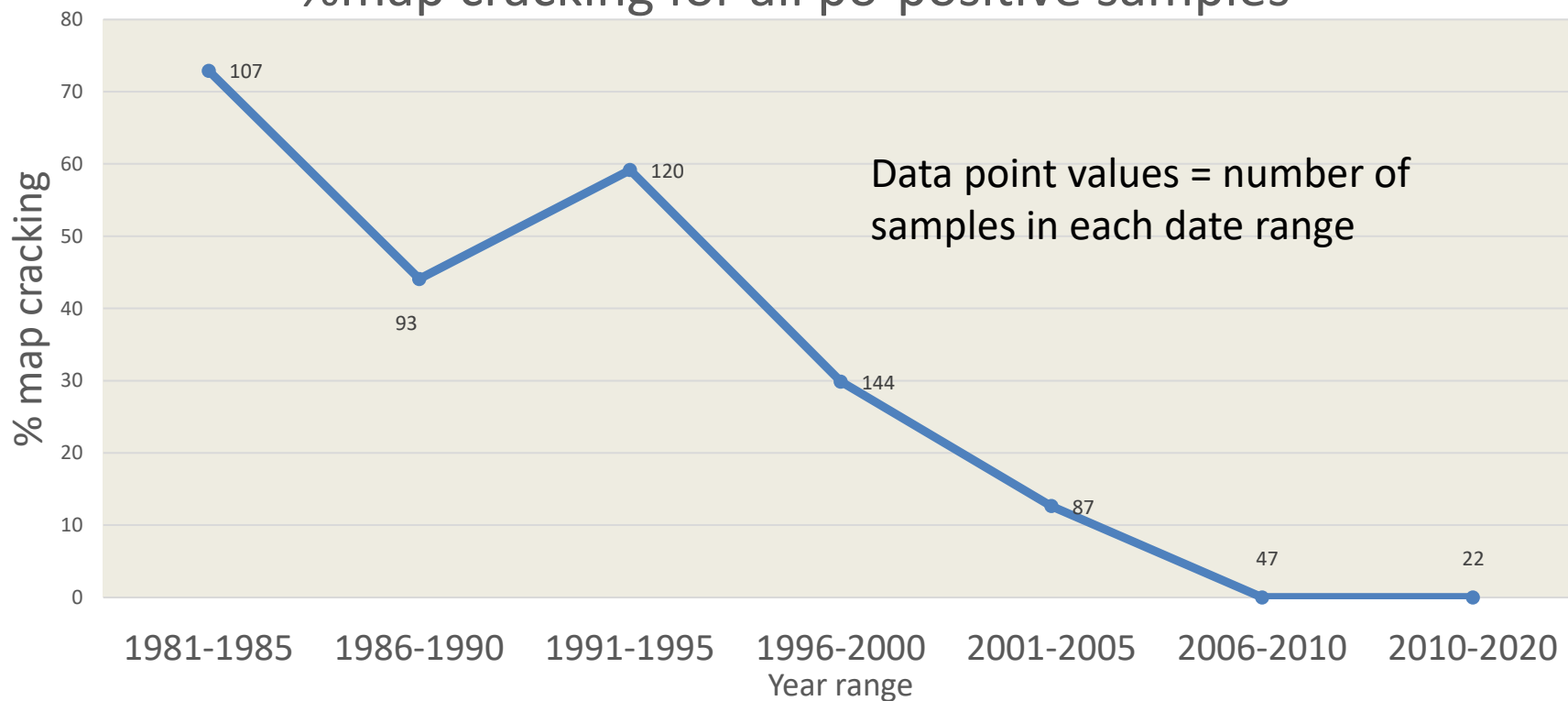
Magnetic Susceptibility Loss ( $* 10^{-8}m^3/kg$ )



# Pyrrhotite % in concrete through time (n = 1068)



## %map cracking for all po-positive samples



# Summary

- Rapid direct test to determine the presence of pyrrhotite in concrete/aggregate samples combining thermomagnetic analysis and total sulfur.
- We predict map cracking can occur in concrete when pyrrhotite > 0.15% wt.
- Risk analysis is possible as map cracking probabilities increase as the concentration of pyrrhotite in concrete increases.
- Time series data suggests both a decrease in pyrrhotite and about a 15yr delay in the onset of map cracking at lower concentrations.



# Thank You!



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