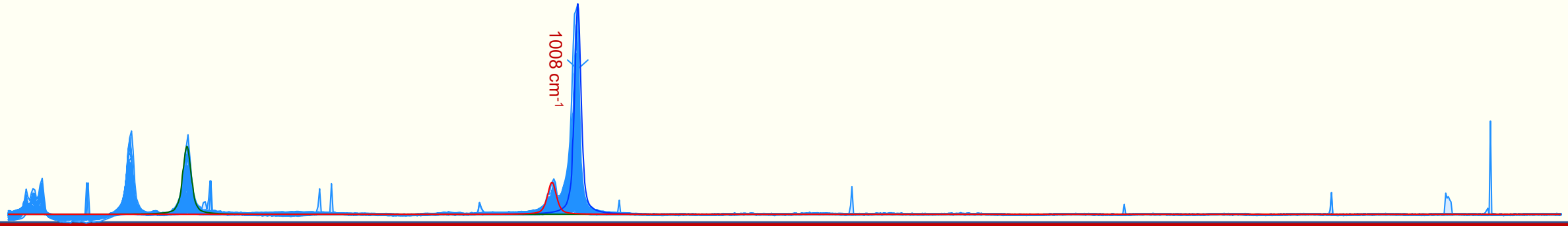
This work was supported by NSF-EAR Award 1848013

Annealing zircon with zoned radiation damage distribution and implications for (U-Th)/He thermochronology



Olivia Thurston, Willy Guenthner, John I Garver

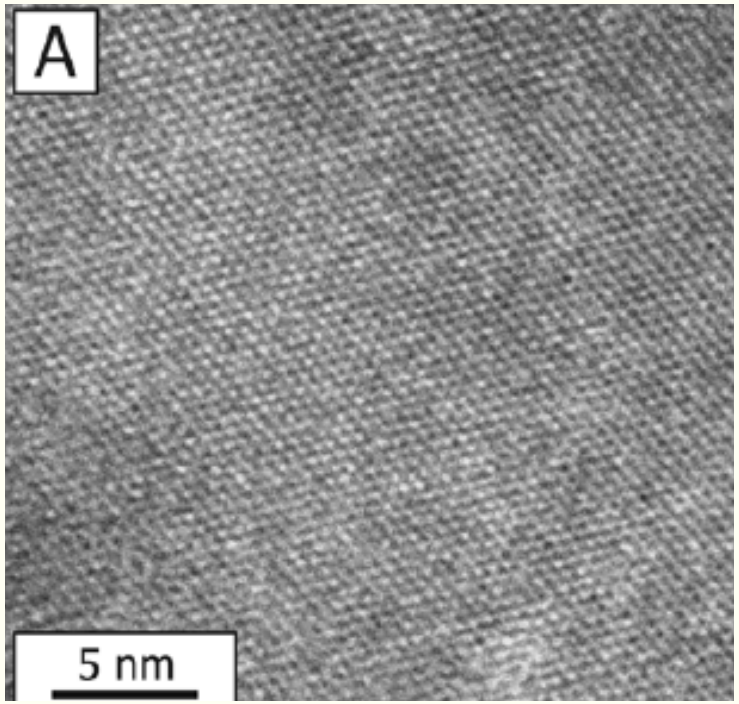
Thermo 2020

Overview

- Background and Motivation
- Methods
- Results
- Implications
- Summary

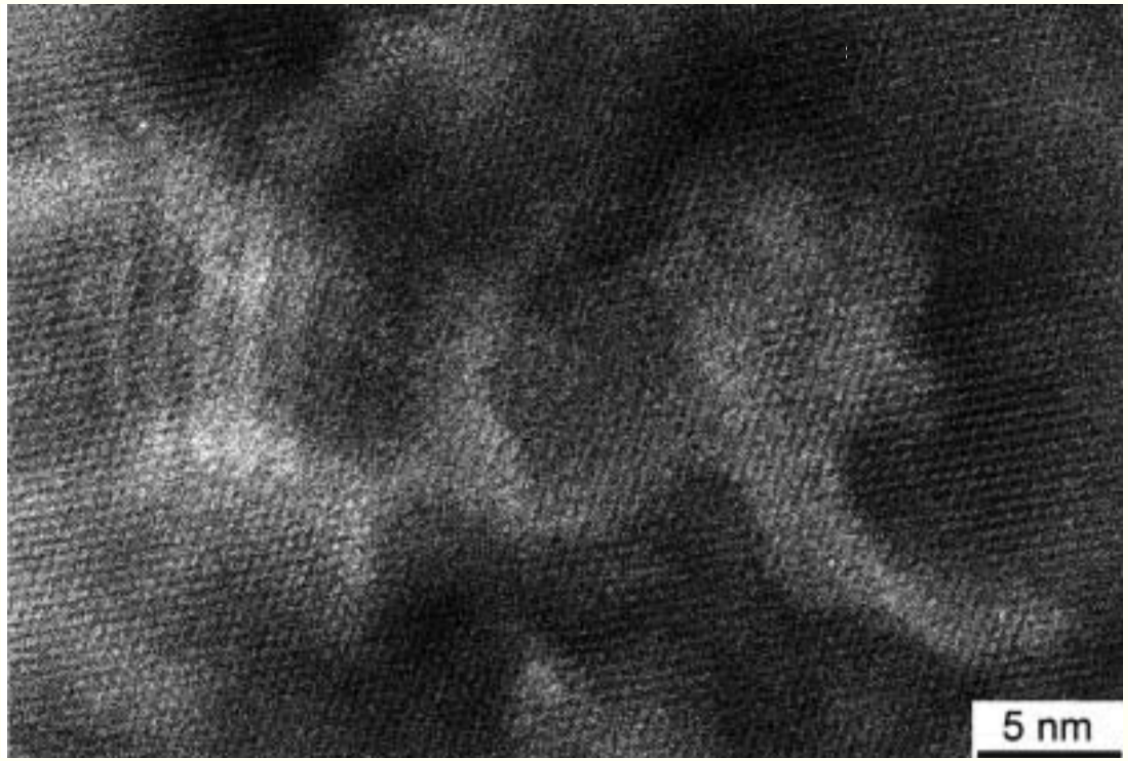
Alpha-Decay Radiation Damage Annealing

Crystalline



Annealed

Annealing t-T: 1 hr, 1125 °C
Initial Damage: 7x10^-18 α-event/gram



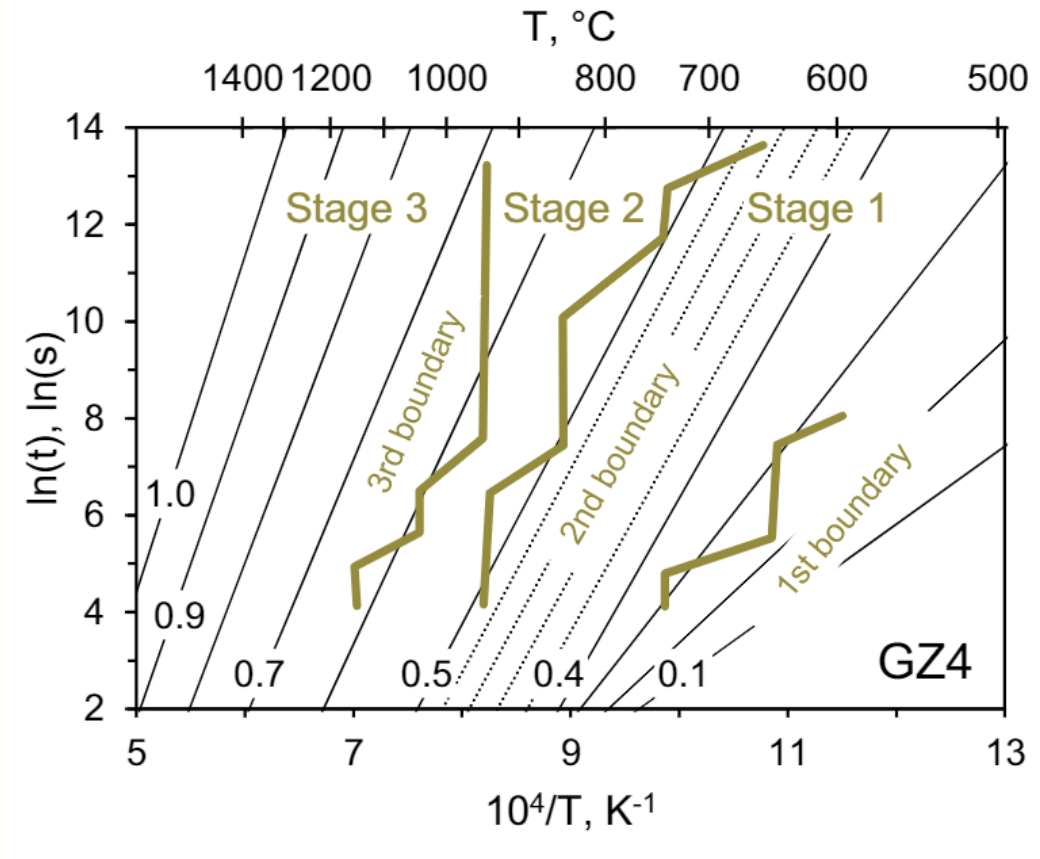
Capitani et al., 2000.

Annealing Mechanisms (Geisler et al., 2002)

1. Anisotropic Defect Annealing (T: <725°C)

2. Epitaxial Regrowth of Crystalline Remnants (T: >725°C)

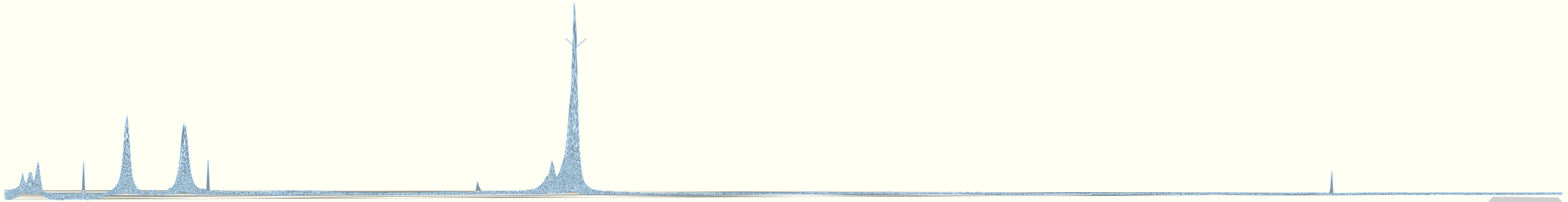
3. Recrystallization of residual amorphous domains (T: <1025°C)



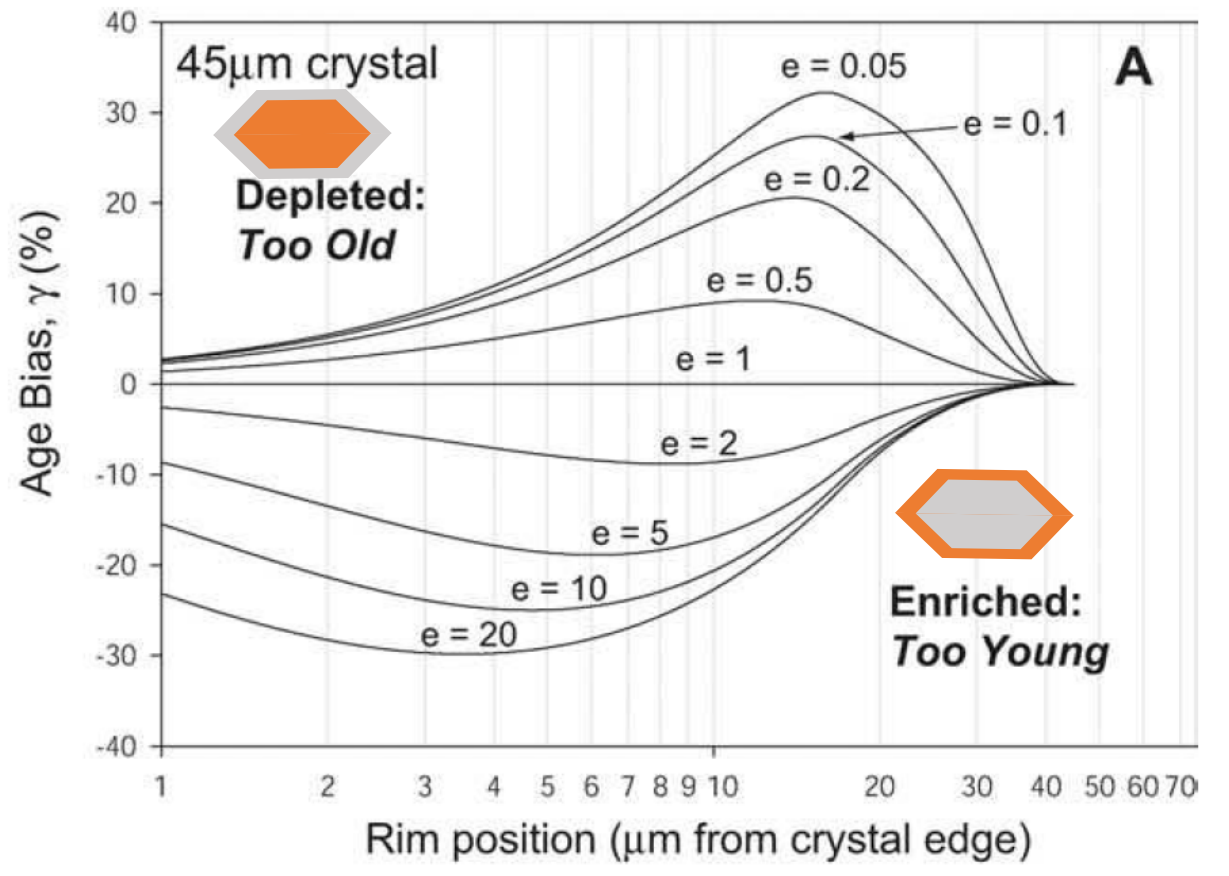
Ginster et al., 2019

MOTIVATION:

Do we understand the kinetics of annealing for different levels of radiation damage in *zoned* zircon crystals?



Errors Associated With Zonation



Current Models:

- ΔHe concentration
- ΔAlpha-ejection distances

Remaining Errors:

- **ΔKinetics across zones**

Hourigan et al., 2005.

Experiment Design

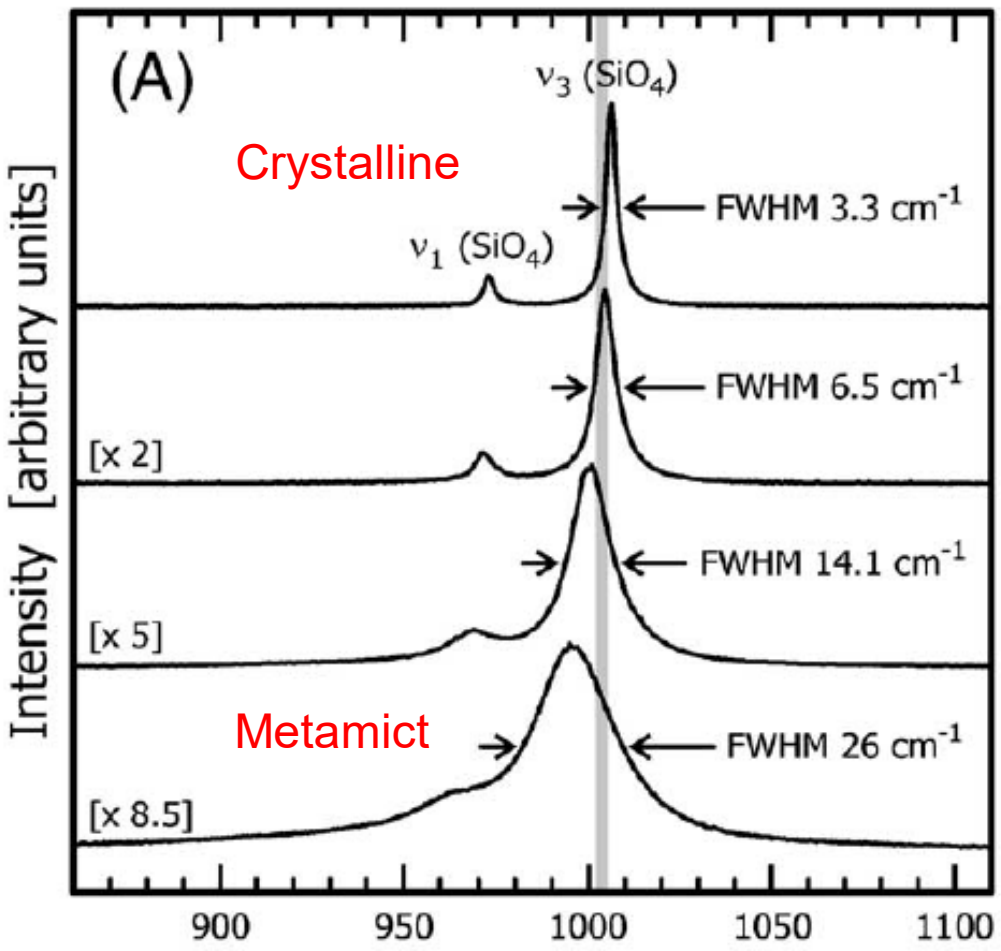
Current Annealing Kinetics (Ginster et al., 2019):

- Homogenous zircon crystals
- Restricted range of initial radiation damage (FWHM: 4.9-17.9 cm^{-1})

This Study:

- Zircon with *heterogenous* U and Th distribution
- Wide range of initial radiation damage (FWHM: 2-56 cm^{-1})

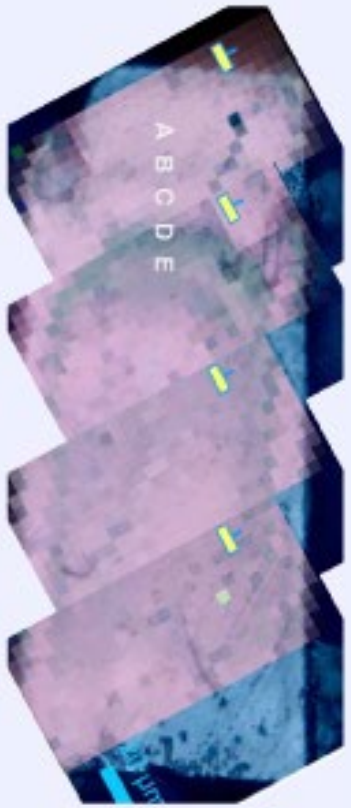
Raman Spectroscopy



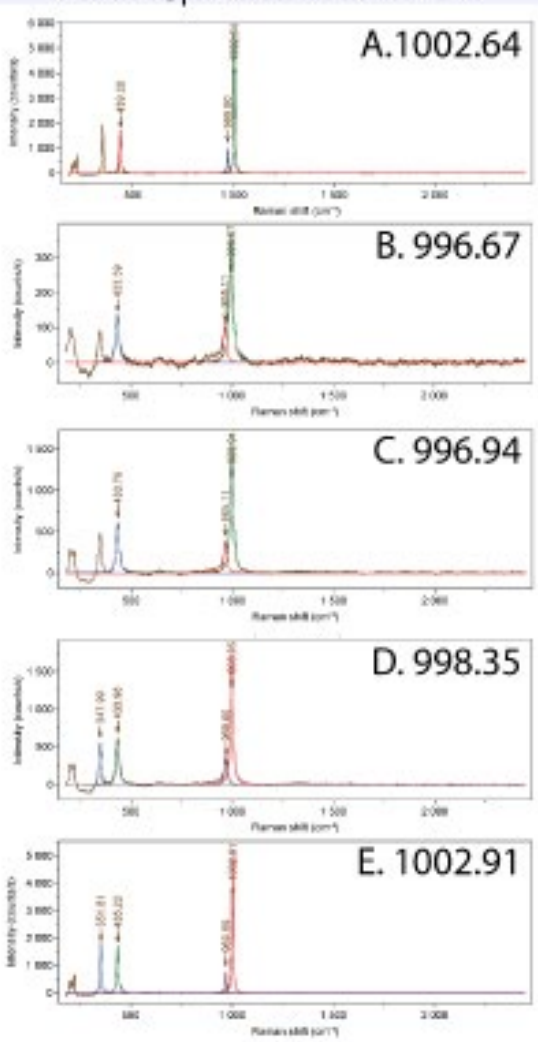
Nasdala et al., 2005.

- Zircon has a specific Raman spectra
- Main peak is at 1008 cm^{-1}
- As bonds are broken by alpha decay the signature peaks degrade:
  - → decrease in height
  - → widen
  - → shift to lower frequencies
- FWHM tracks changes in long range order of crystallinity
- Intensity tracks changes in short range order of crystallinity

Plane light photo and v3SiO4 Peak Intensity

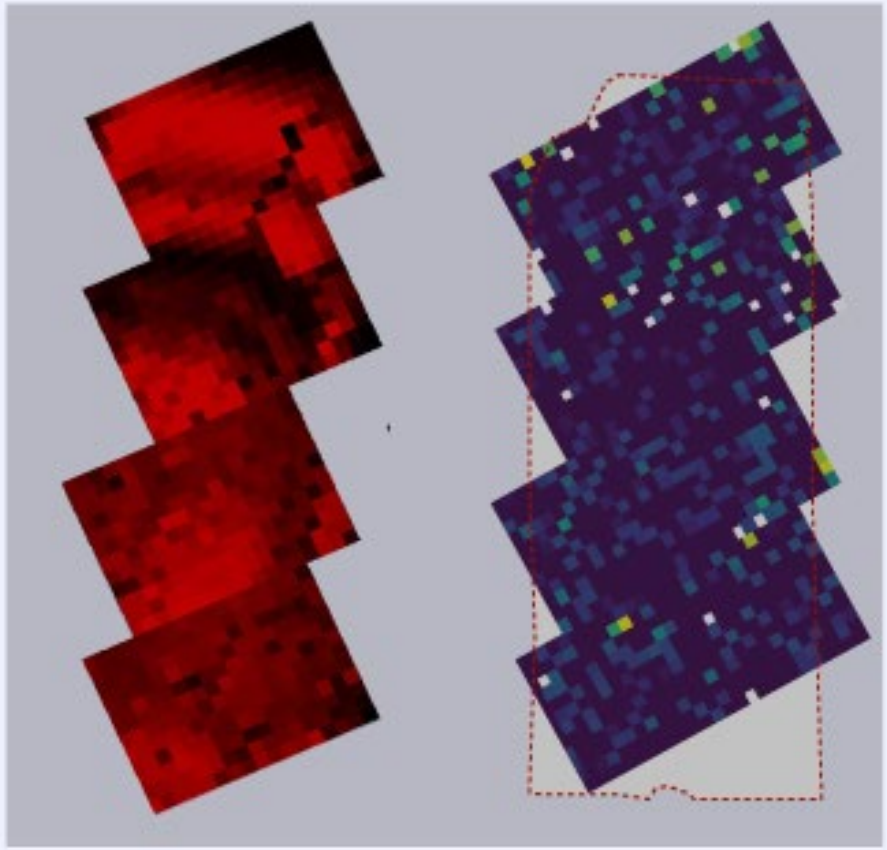


Raman Spectra across zones



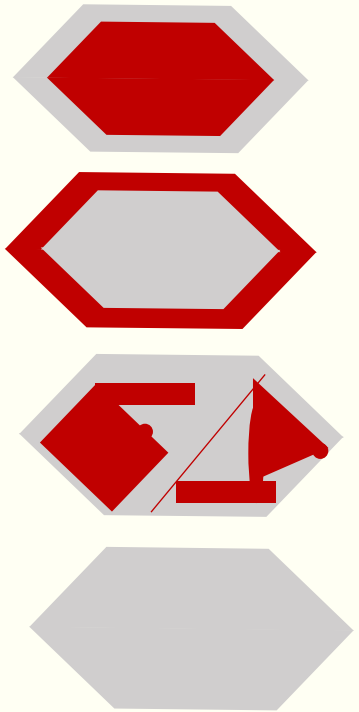
v3SiO4 Peak Intensity

v3SiO4 FWHM



Zonation Types

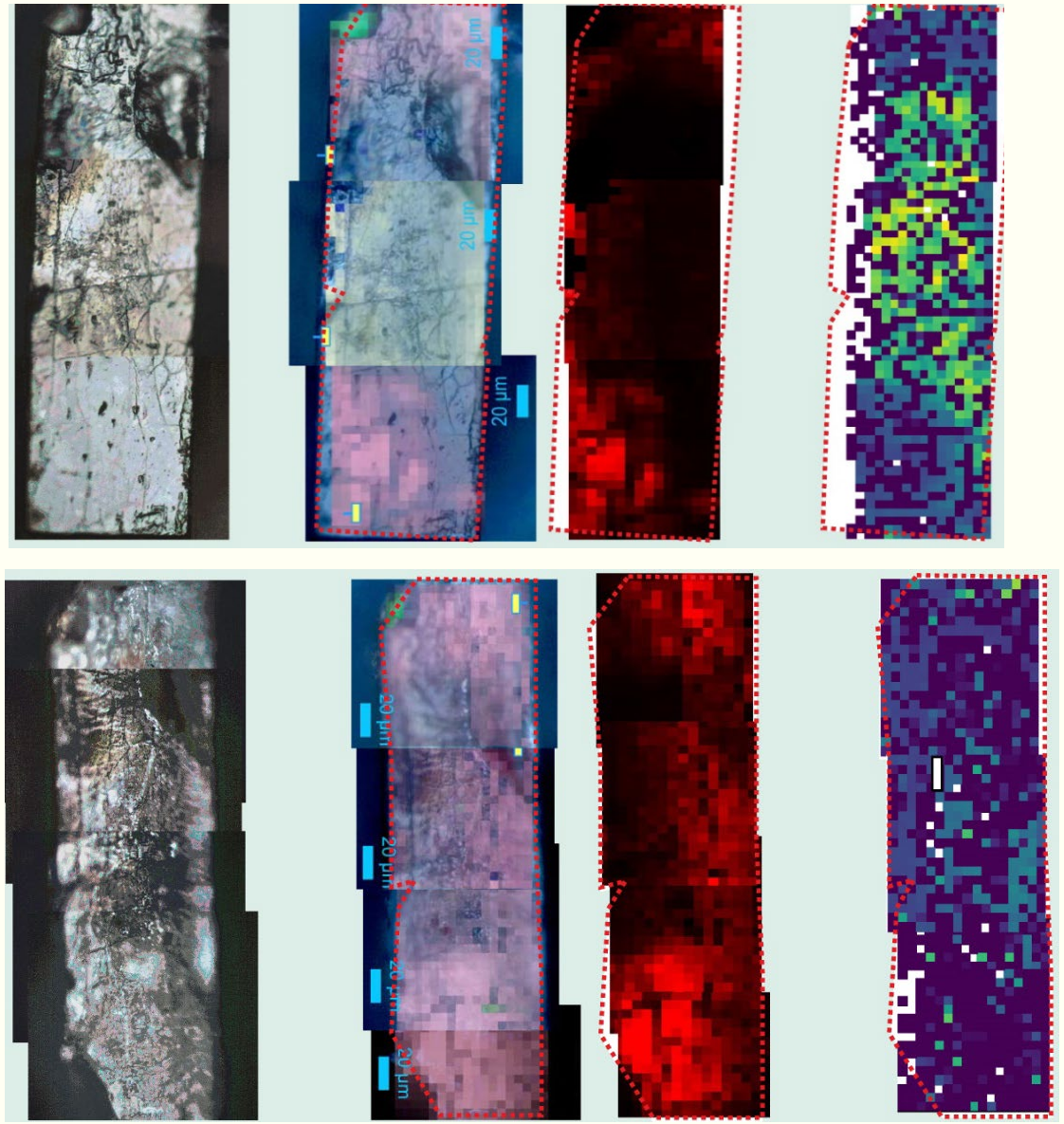
- High-Damage Core
- High-Damage Rim
- Heterogenous Damage
- Low-Damage



Annealing: 6 hours, 800 °C

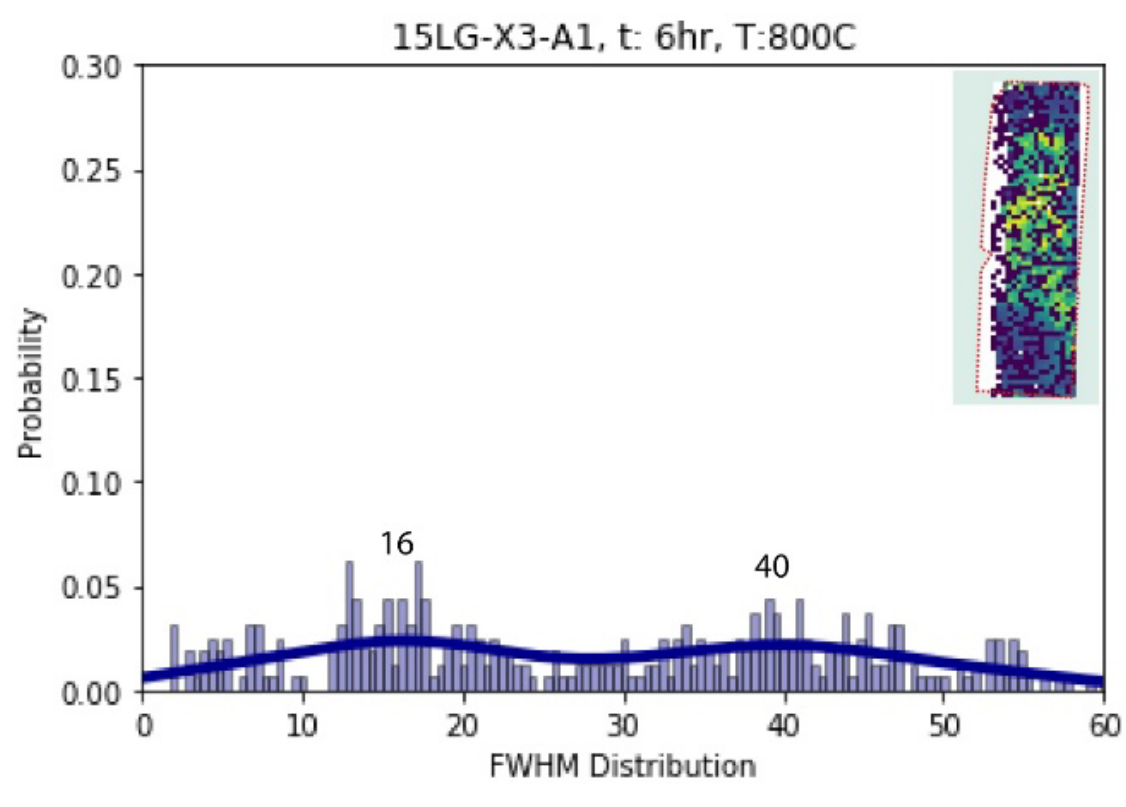
PRE-ANNEALING

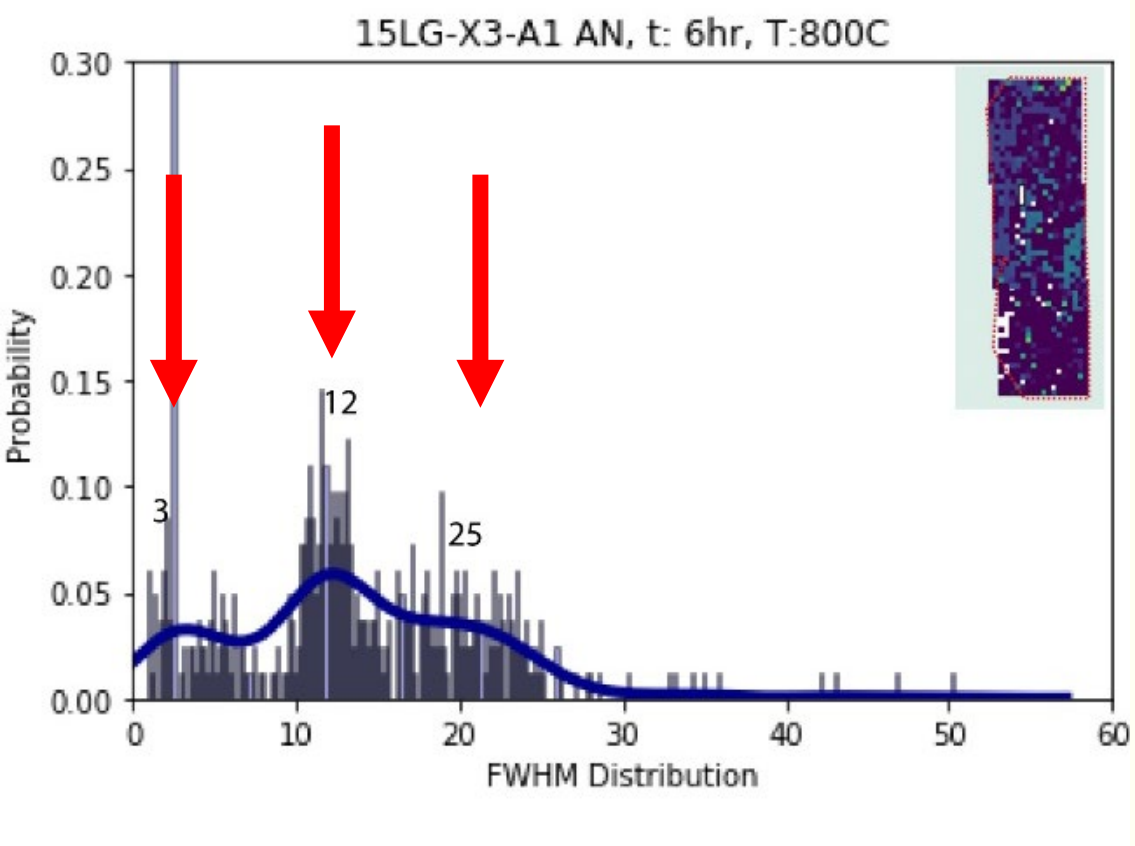
POST-ANNEALING



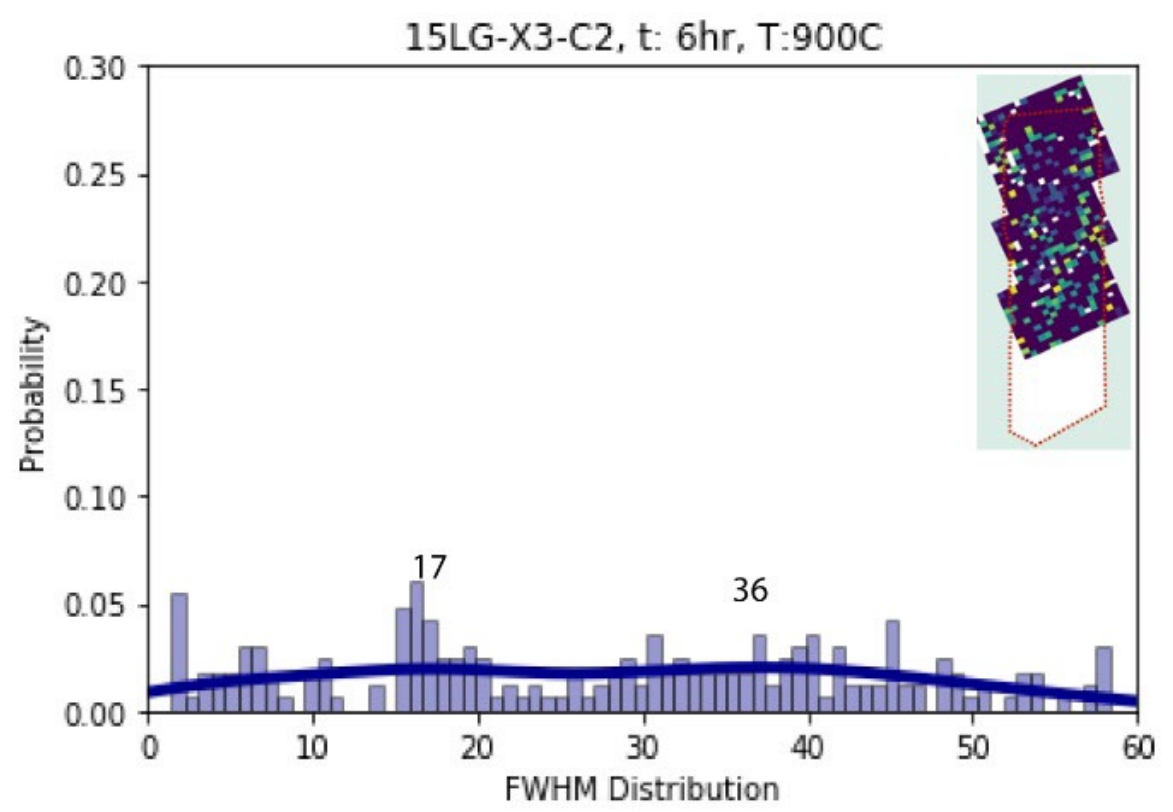
Thurston, Thermo 2020

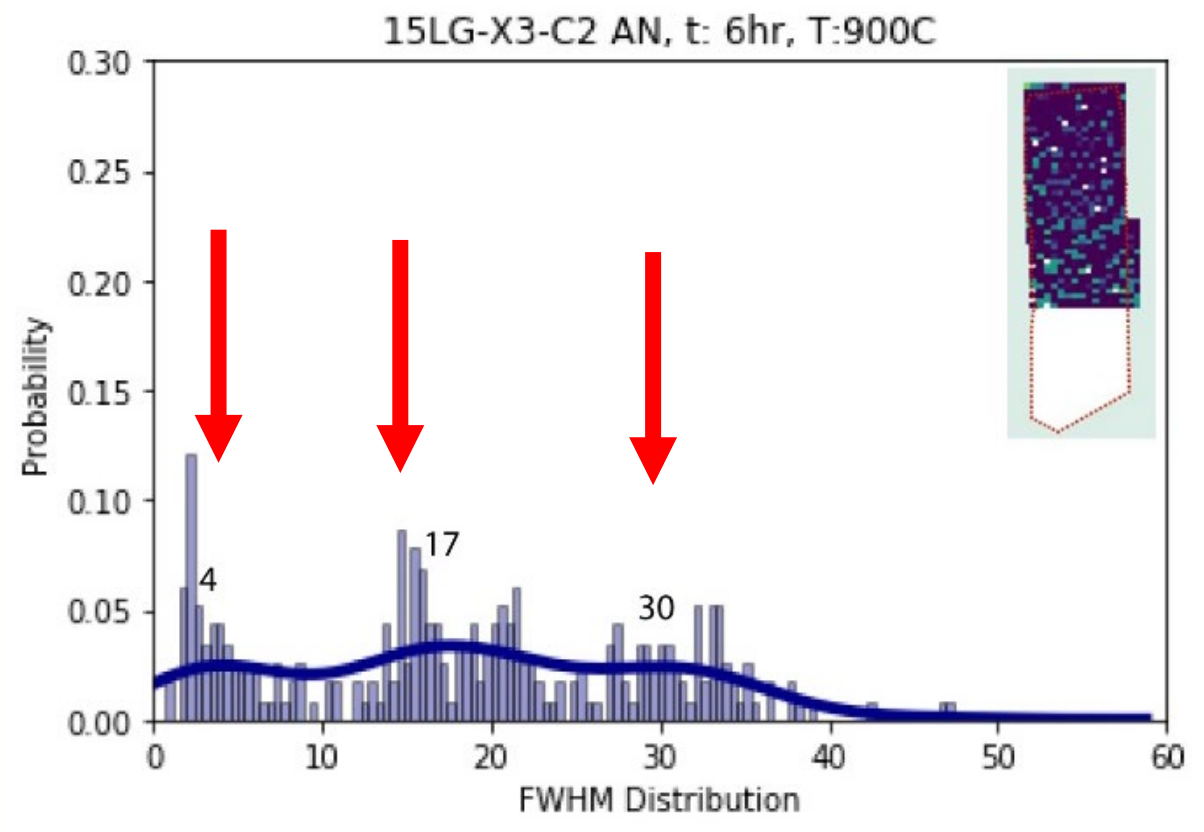
High-Damage Core



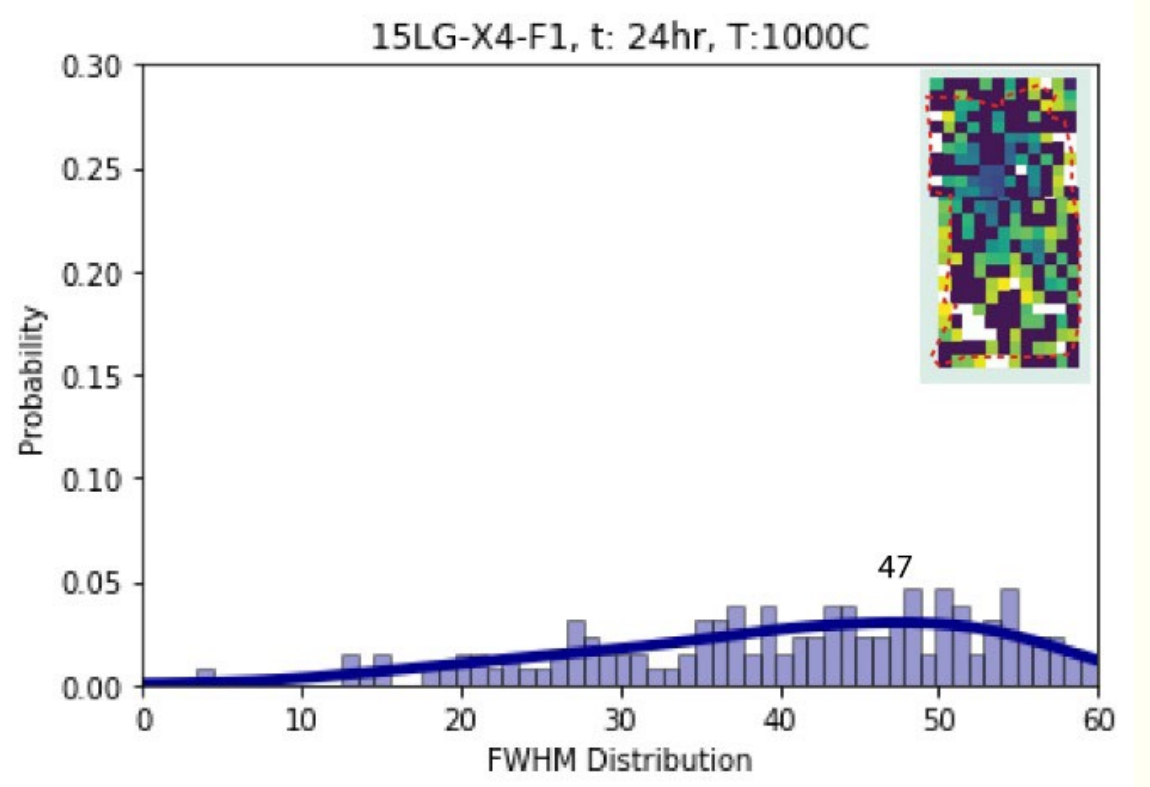


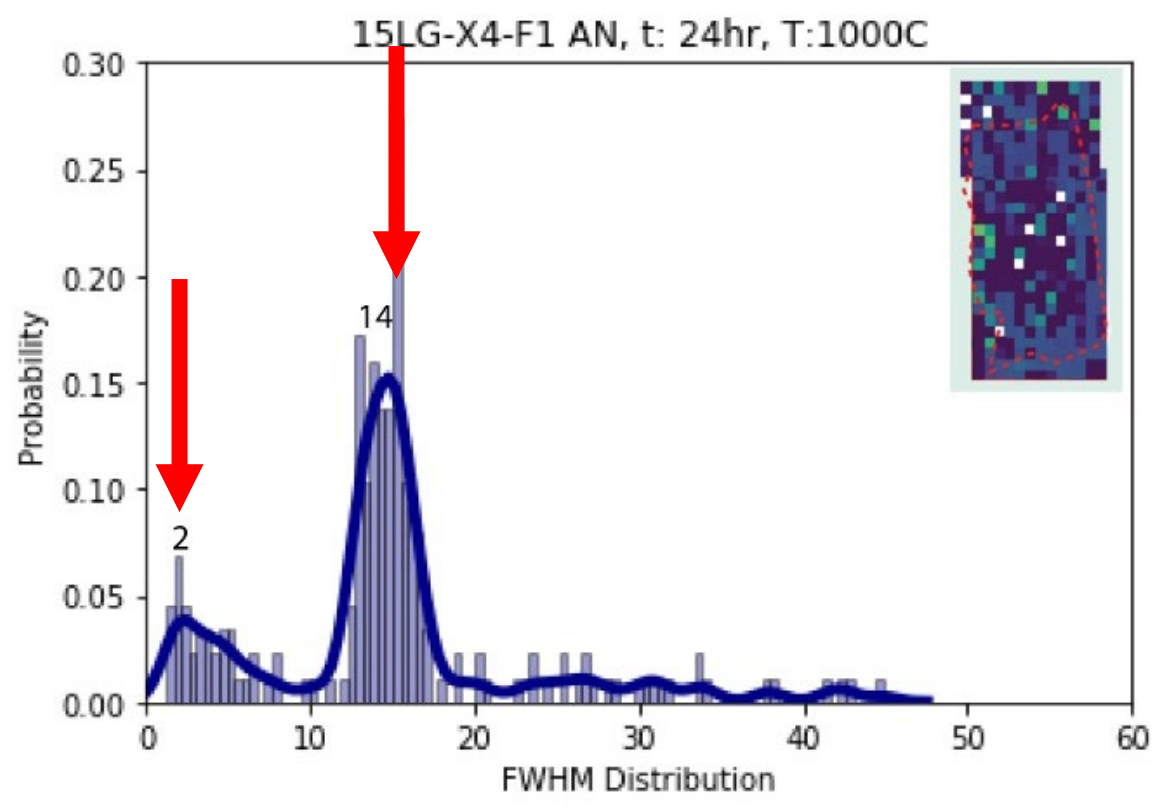
High-Damage Rim



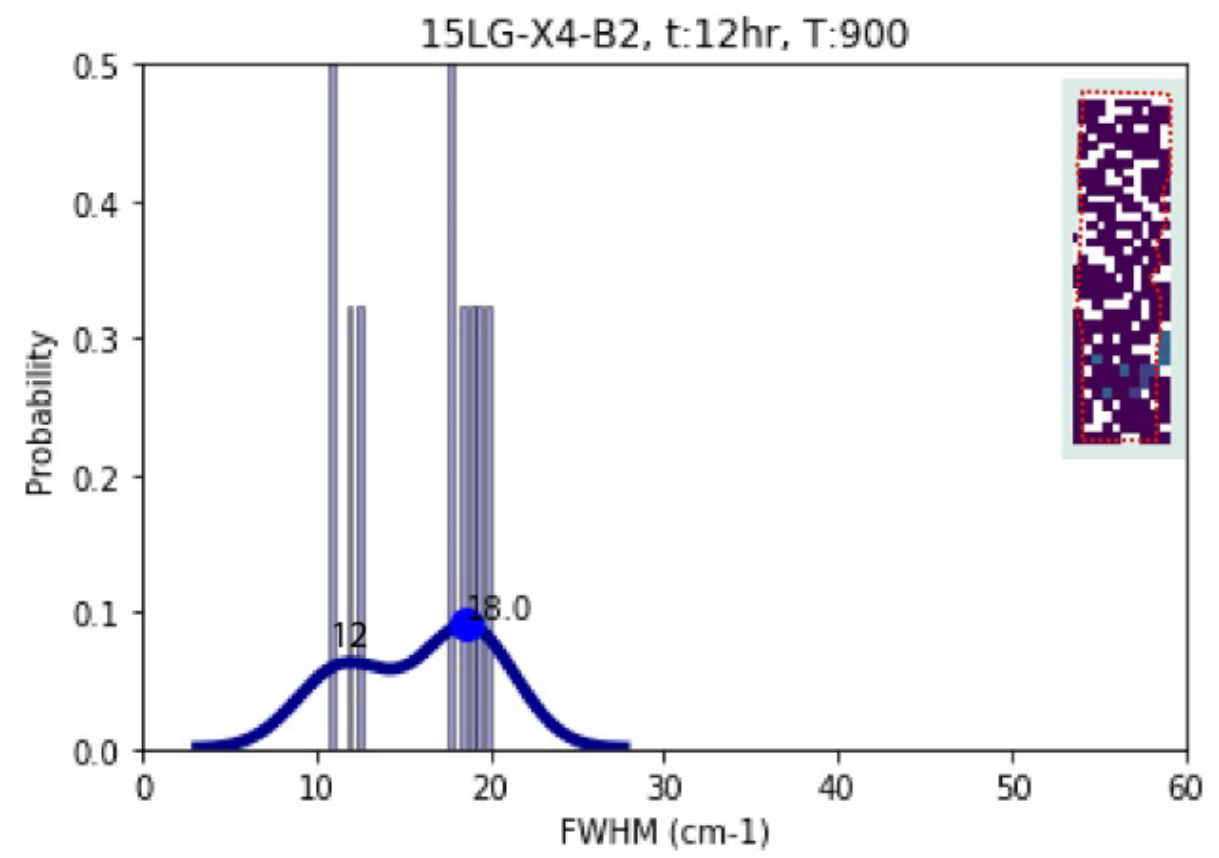


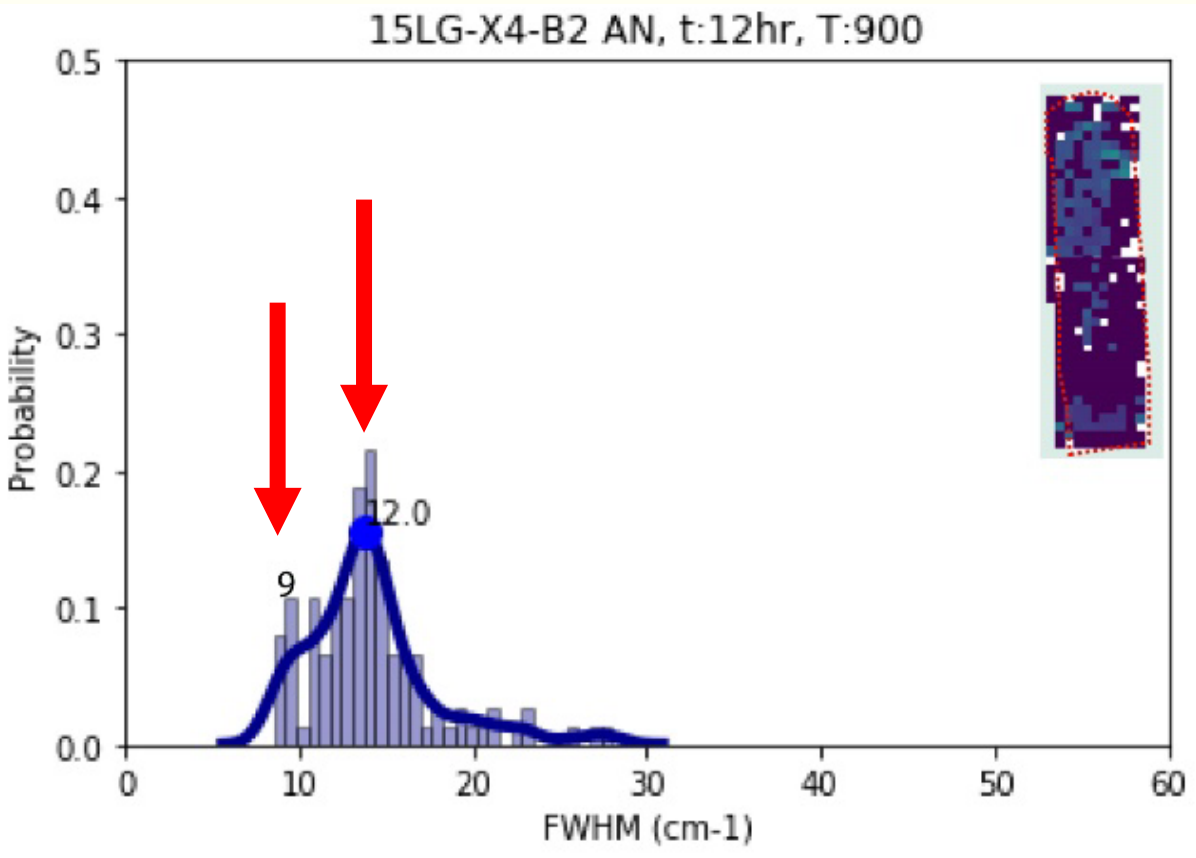
Heterogenous



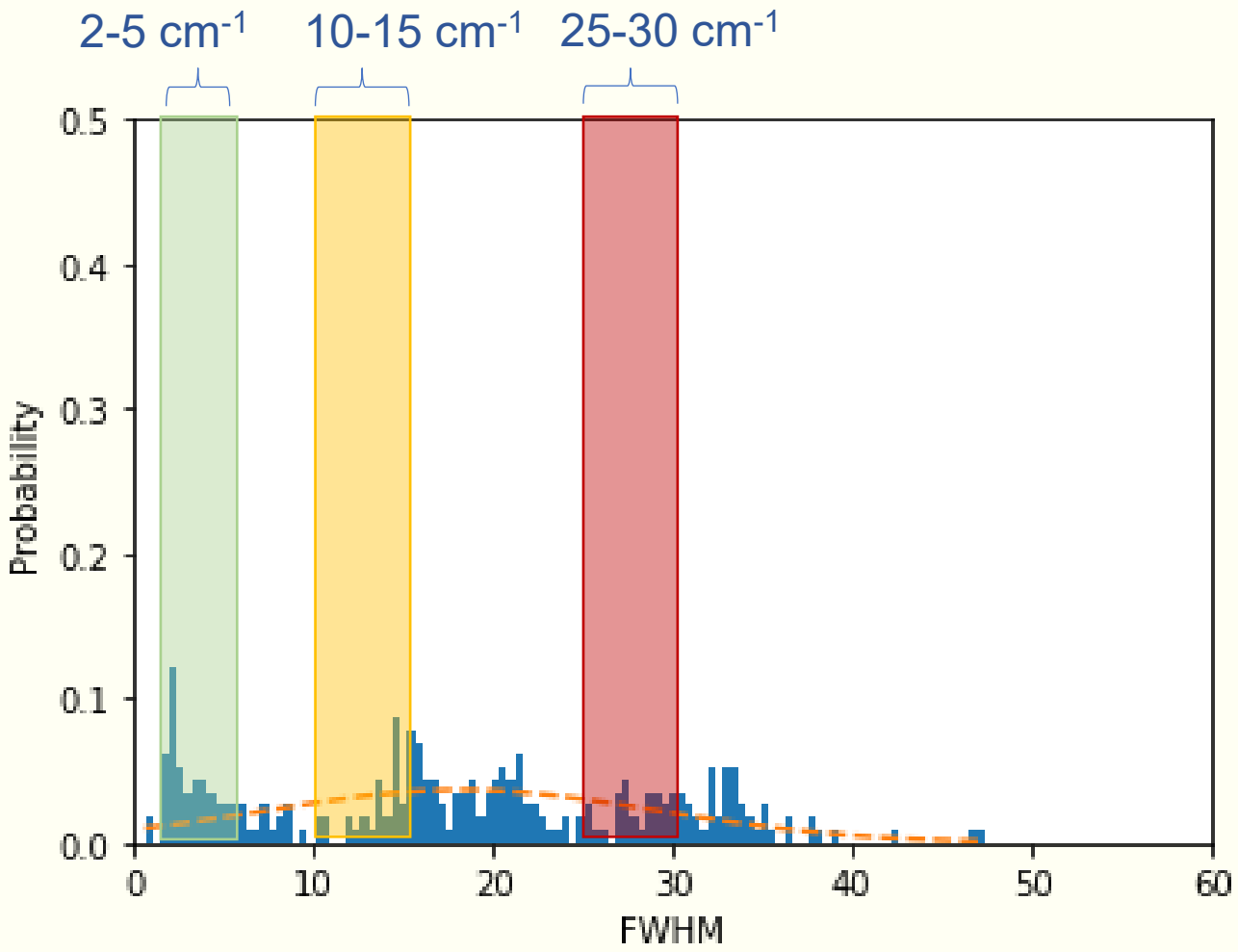


Low-Damage

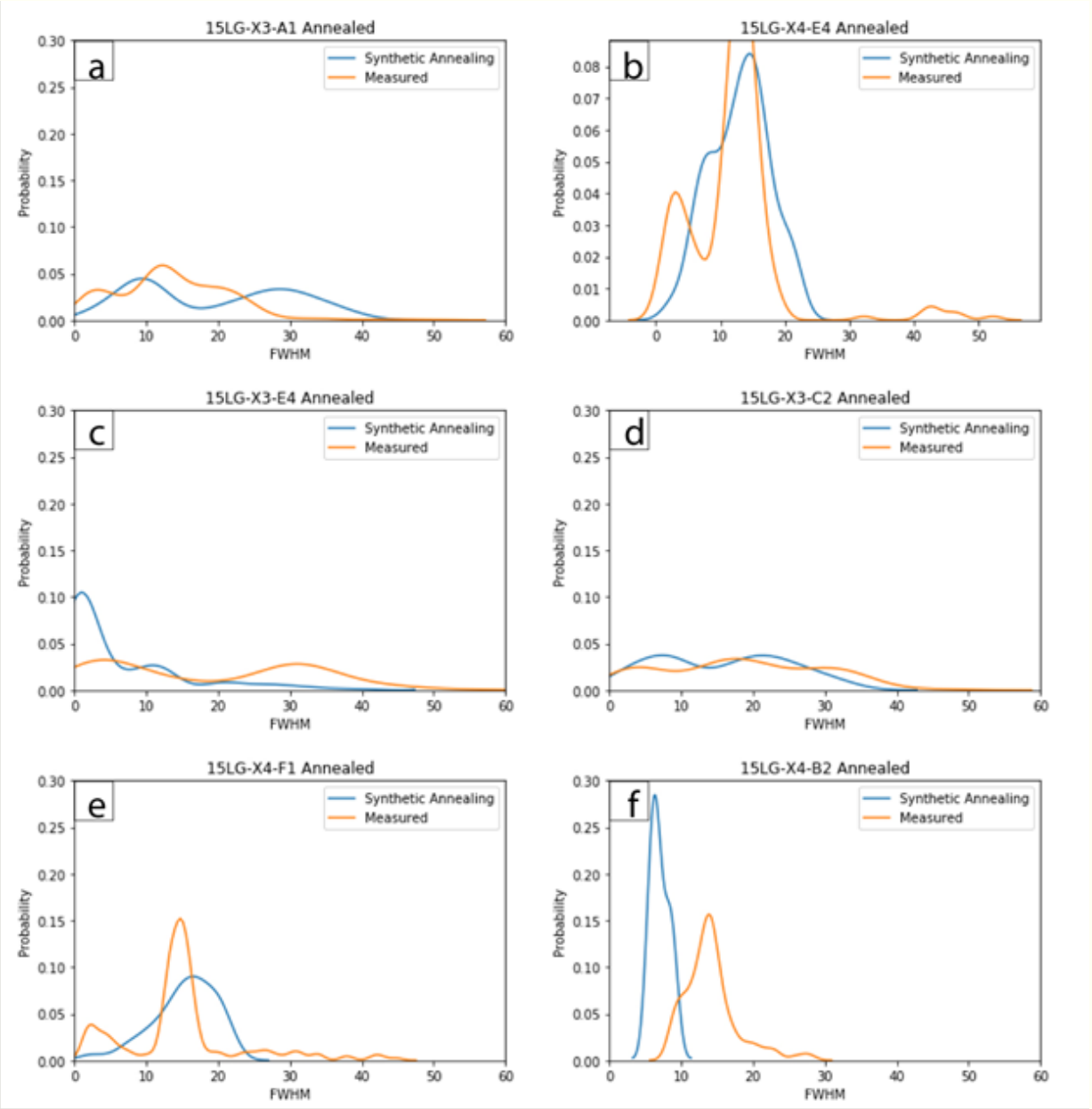

15LG-X4-B2, t:12hr, T:900
Probability
FWHM (cm-1)
12
18.0


15LG-X4-B2 AN, t:12hr, T:900
Probability
FWHM (cm-1)
9
12.0

Persistent Damage Modes



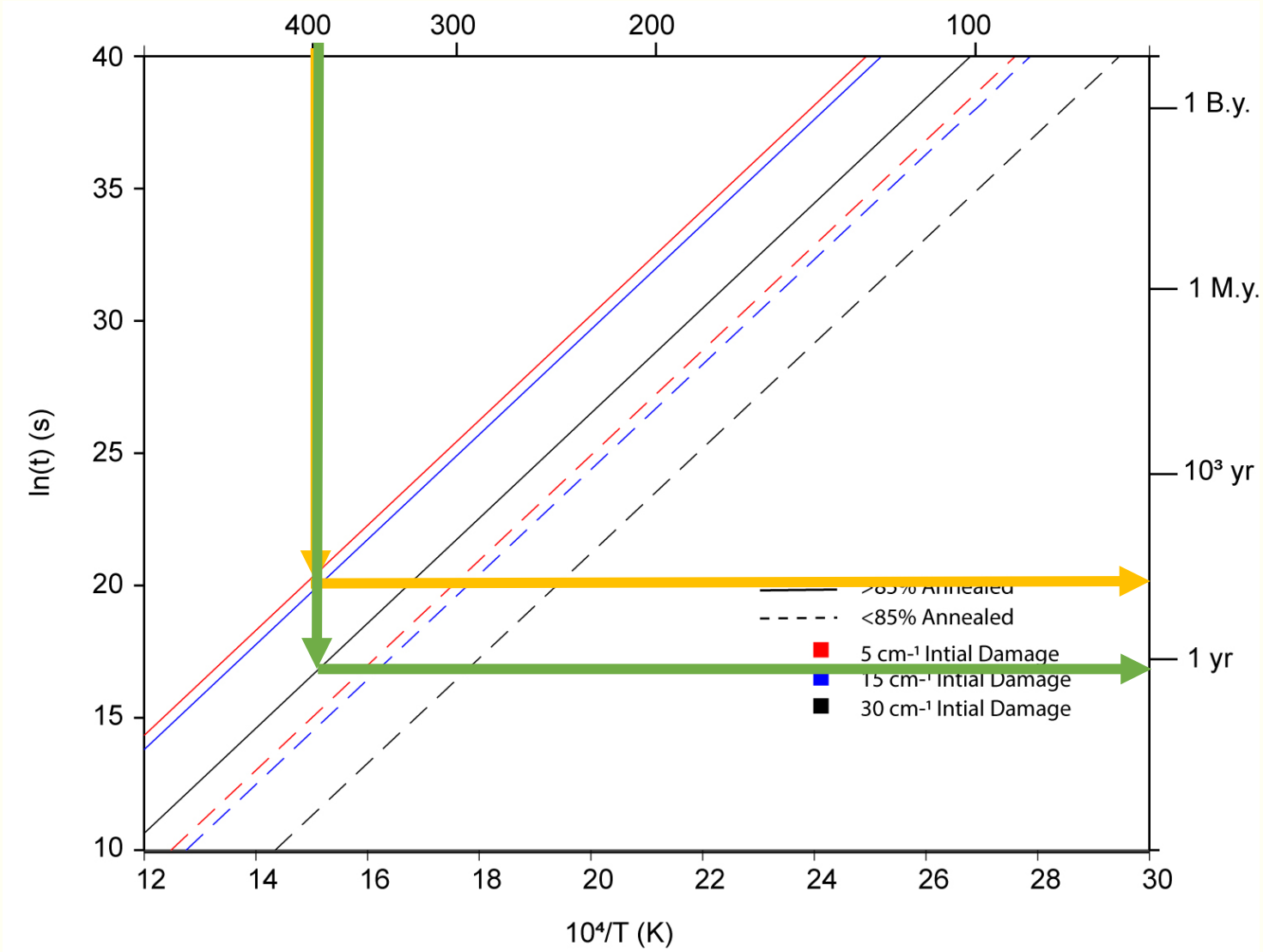
Thurston, Thermo 2020



Homogenous modeled vs. Heterogenous measured:

a. Modeled and measured generally agree

b. Multimodal damage distribution is predicted by Ginster et a., (2019) kinetics


400
300
200
100
40
35
30
25
20
15
10
ln(t) (s)
12
14
16
18
20
22
24
26
28
30
10⁴/T (K)
1 B.y.
1 M.y.
10³ yr
1 yr
<85% Annealed
5 cm⁻¹ Intial Damage
15 cm⁻¹ Intial Damage
30 cm⁻¹ Intial Damage

Summary:

1. Zones anneal independently

2. Persistent damage creates a lag in annealing rate

3. Current annealing kinetics models (Ginster et al., 2019) can be used for individual zones