

# Relative NaCl-enrichment in re-equilibrated synthetic H<sub>2</sub>O-NaCl fluid inclusions in quartz

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and  
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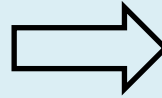
Der Wissenschaftsfonds.

*This study is financially supported by the Austrian Research Fund (FWF): P 22446-N21*

# Previous experiments

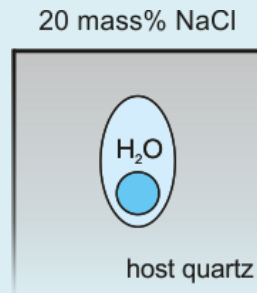
published re-equilibration experiments in the  $\text{H}_2\text{O}$ -NaCl system

- $\Delta P$
- $\Delta f$
- $\beta$ -quartz stability field
- short experimentation time

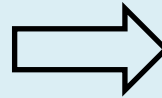


- changes in  $T_h$
- textural changes
- no salinity change

*Sterner & Bodnar (1989)*

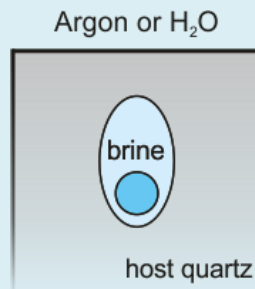


- $\Delta f$
- $\alpha + \beta$ -quartz stability field
- short experimentation time



- preferential  $\text{H}_2\text{O}$  loss/gain only in  $\beta$ -quartz
- insufficient experimental data
- inconsistent  $T_h - T_m$  pairs

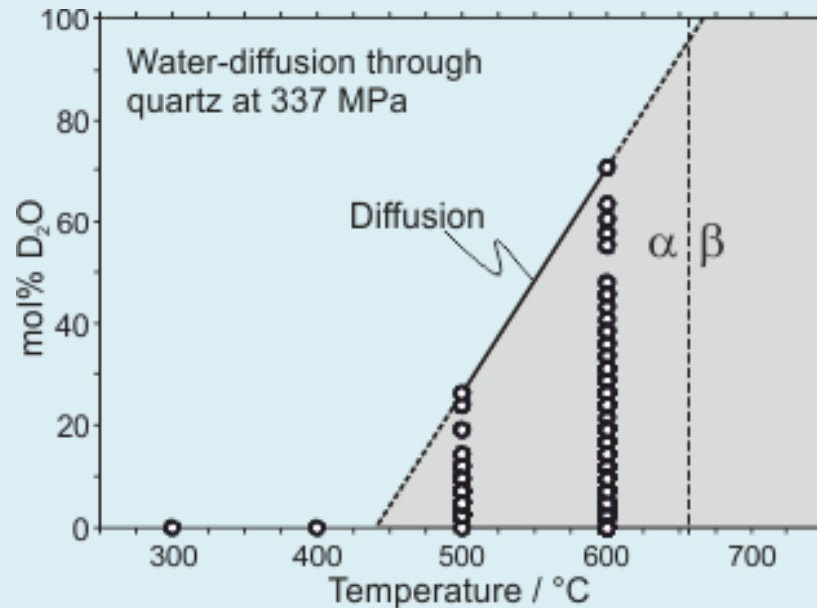
*Sterner et al. (1995)*



# Research Topic

- Can H<sub>2</sub>O-NaCl rich fluid inclusions change their properties in varying geological environments?
- Which processes are responsible for post entrapment alteration?
- How efficient are these processes at a variety of *T-P* conditions?

For example: Diffusion



Doppler et al. (2013) *Contrib Mineral Petrol*, vol. 165

# Experimental procedure

## Synthesis

Experimental  $P$ - $T$

➤ 337 MPa

➤ 600 °C

➤ 19 days

### I) H<sub>2</sub>O-NaCl *fi's*

GMR005 → 20 mass% NaCl

GMR014 → 16.4 mass% NaCl

GMR011 → 10 mass%

### II) pure H<sub>2</sub>O fluid inclusions

GMR004

GMR003

## Analysis

numbers: ~100 *fi's* per experiment

inclusion depth, size and shape

microthermometry ( $T_h$  and  $T_m$ )

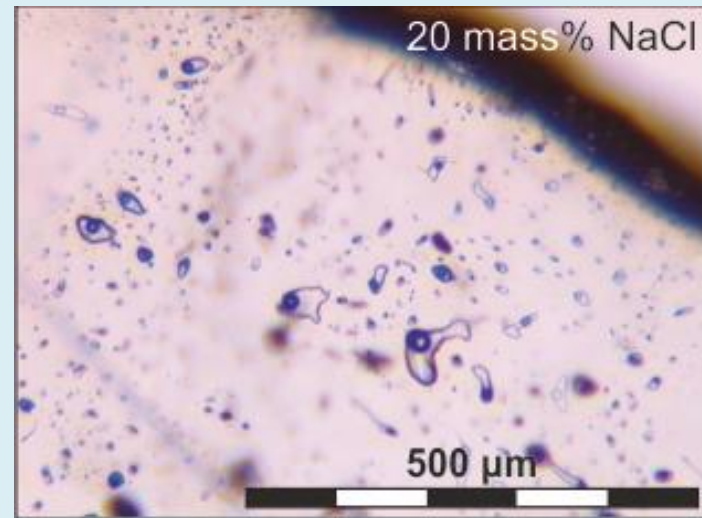
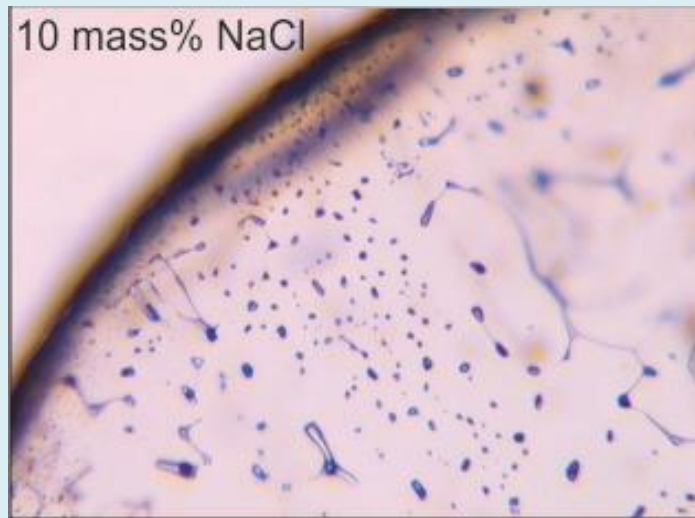
# Experimental procedure

## Re-equilibration

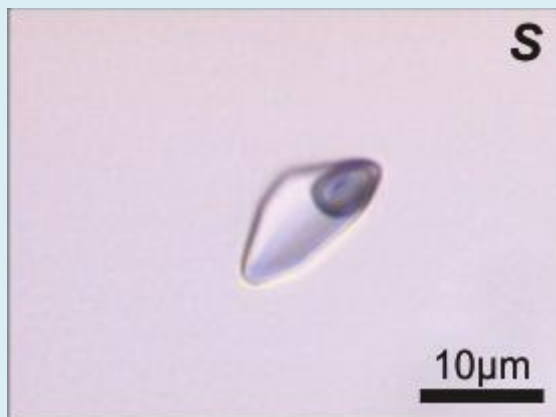
equal  $T$  and  $P$

		Original synthesis			
		20 mass%	16.4 mass%	10 mass%	pure H <sub>2</sub> O
Re-equilibration	pure H <sub>2</sub> O	<i>R005c (5d)</i> <i>R005a (19d)</i> <i>R005b (40d)</i>	<i>R014a (40d)</i>	<i>R011a (19d)</i>	Doppler et al. 2013 (with D <sub>2</sub> O)
	16.4 mass%		<i>R014b (17d)</i> <b>BLANC</b>		
	20 mass%				<i>R003c (40d)</i> <i>R004d (19d)</i>

# Fluid inclusion examples



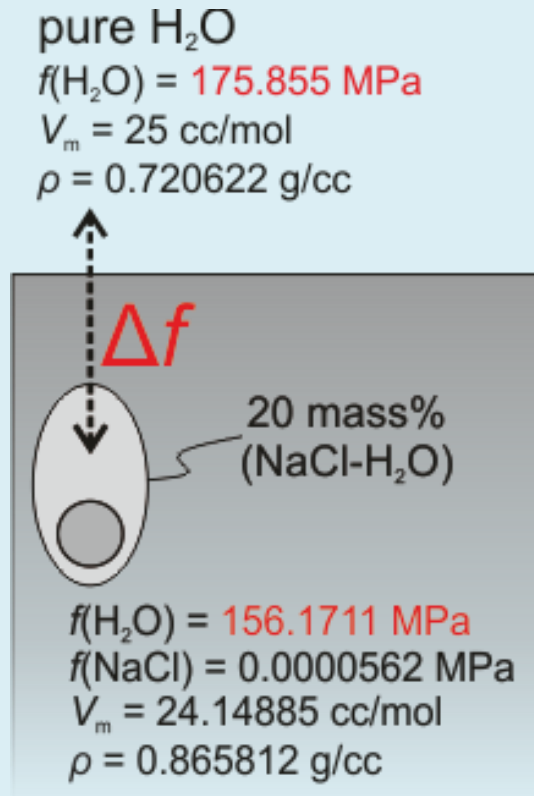
Relatively high solubility of host quartz



after 40 days  
→  
no morphological  
changes!



# Diffusion



calculated with software package „FLUIDS“  
 program Loner AP (Bakker, 2003)

## Fugacity gradients H<sub>2</sub>O

R005a,b,c  $\Delta f(\text{H}_2\text{O}) = 11\% \triangleq 20 \text{ MPa}$

R014a  $\Delta f(\text{H}_2\text{O}) = 13\% \triangleq 21 \text{ MPa}$

R014b  $\Delta f(\text{H}_2\text{O}) = 0\% \triangleq 0 \text{ MPa}$

R011a  $\Delta f(\text{H}_2\text{O}) = 4\% \triangleq 7 \text{ MPa}$

R003c  $\Delta f(\text{H}_2\text{O}) = -12\% \triangleq -19 \text{ MPa}$

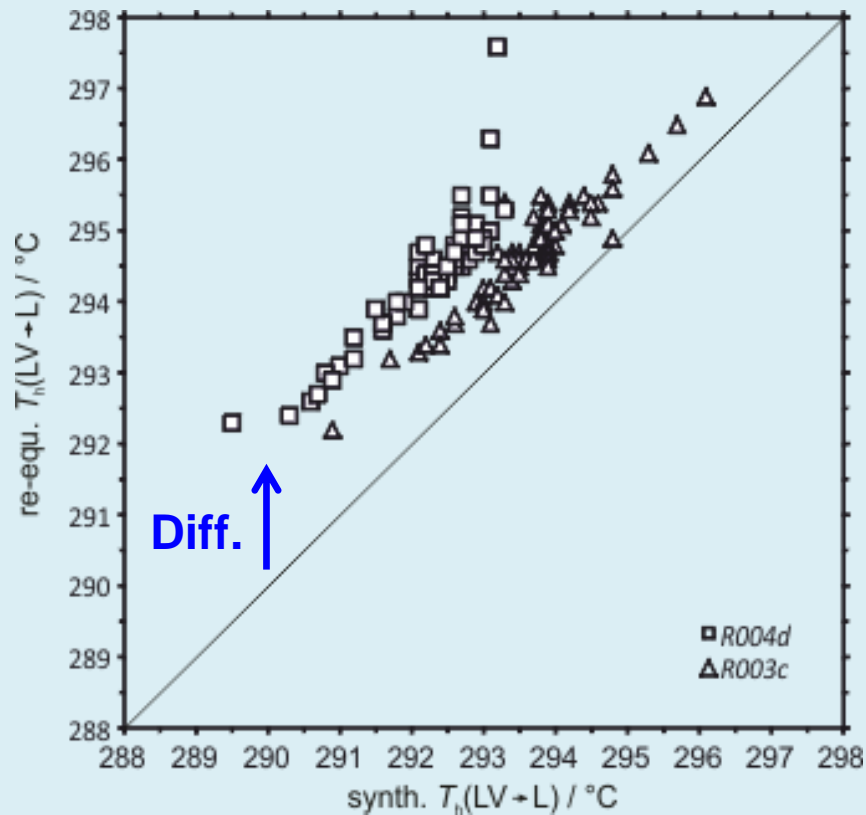
R004d  $\Delta f(\text{H}_2\text{O}) = -12\% \triangleq -19 \text{ MPa}$

out  
↓  
in

out  
↑  
in

## Exp. *R003c* & *R004d*

Synth.: pure  $\text{H}_2\text{O}$   
Re-equ.: 20 mass% NaCl



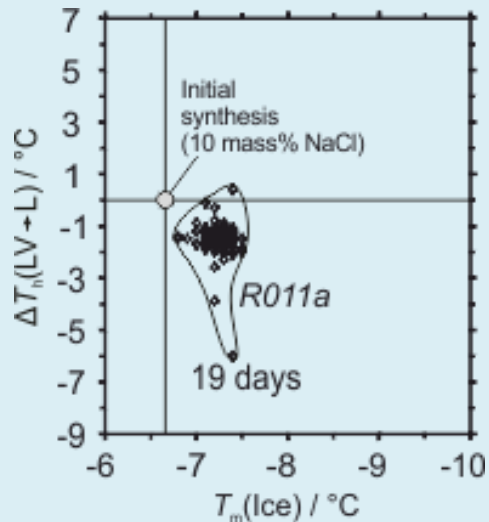
### Results:

- water diffusion according to fugacity gradients
- no NaCl diffusion!

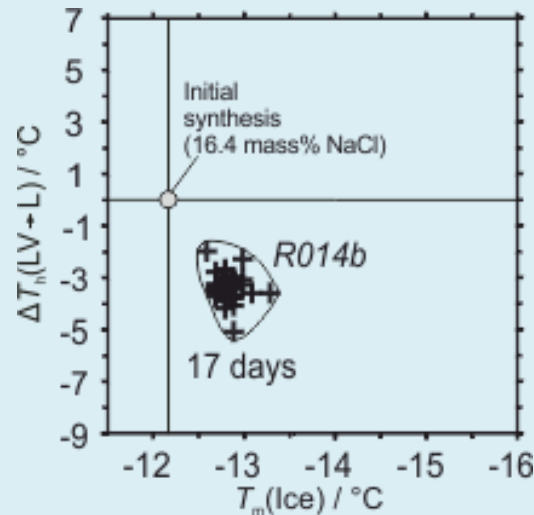


# Microthermometry

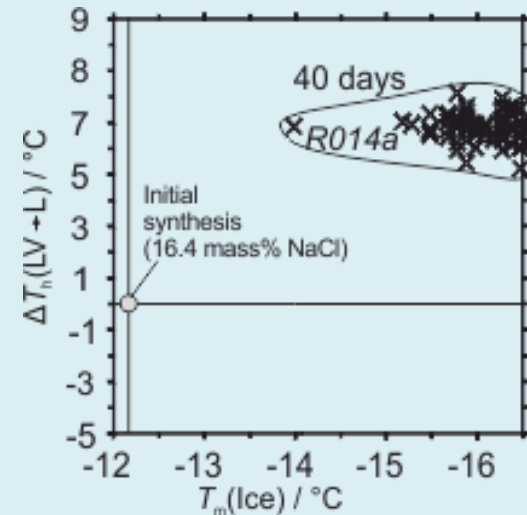
- NaCl concentration by variable melting temperatures
- fluid density by variable homogenization temperatures



synth. 10 mass% NaCl  
re-eq. pure  $\text{H}_2\text{O}$



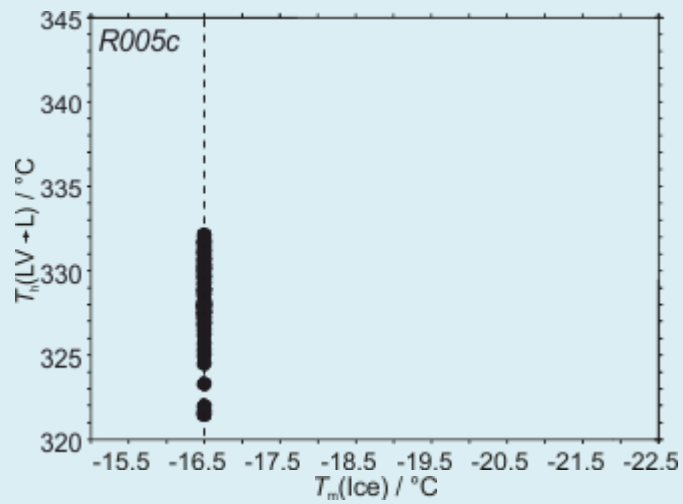
synth. 16.4 mass% NaCl  
re-eq. pure  $\text{H}_2\text{O}$



synth. 16.4 mass% NaCl  
re-eq. 16.4 mass% NaCl

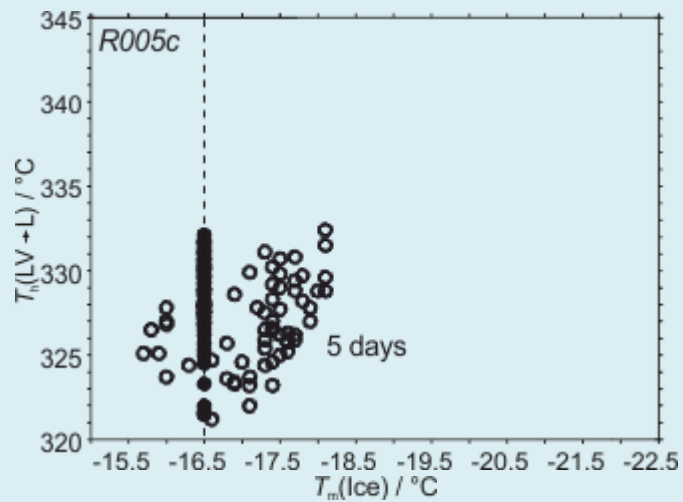
# Microthermometry

synthesized 20 mass% NaCl



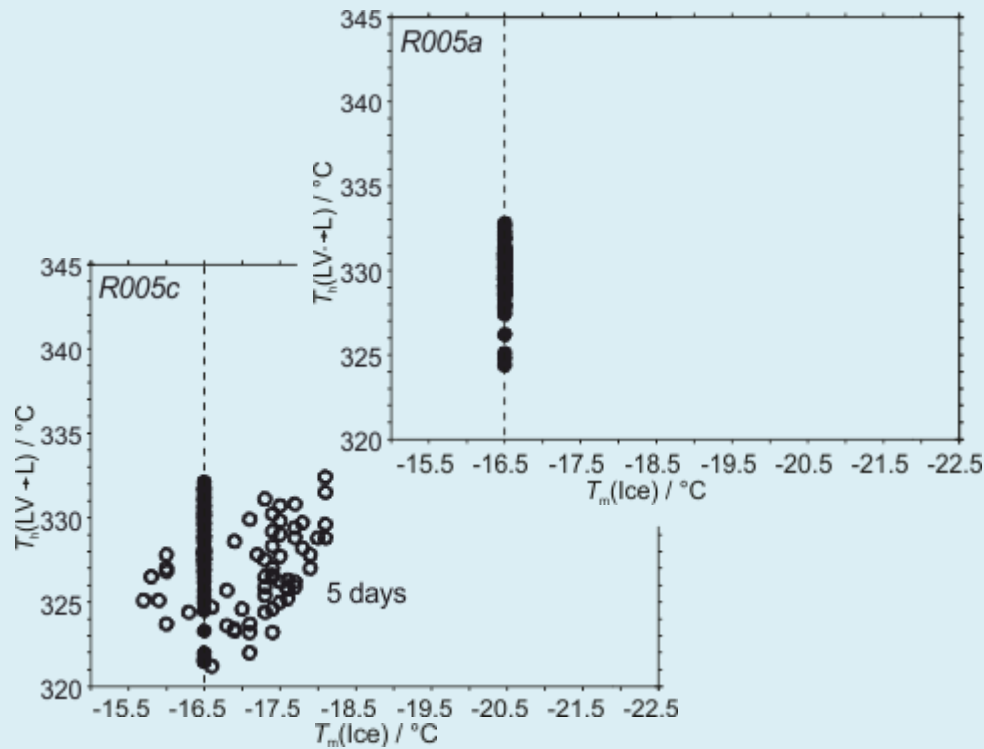
# Microthermometry

synthesized 20 mass% NaCl  
re-equilibrated with pure H<sub>2</sub>O



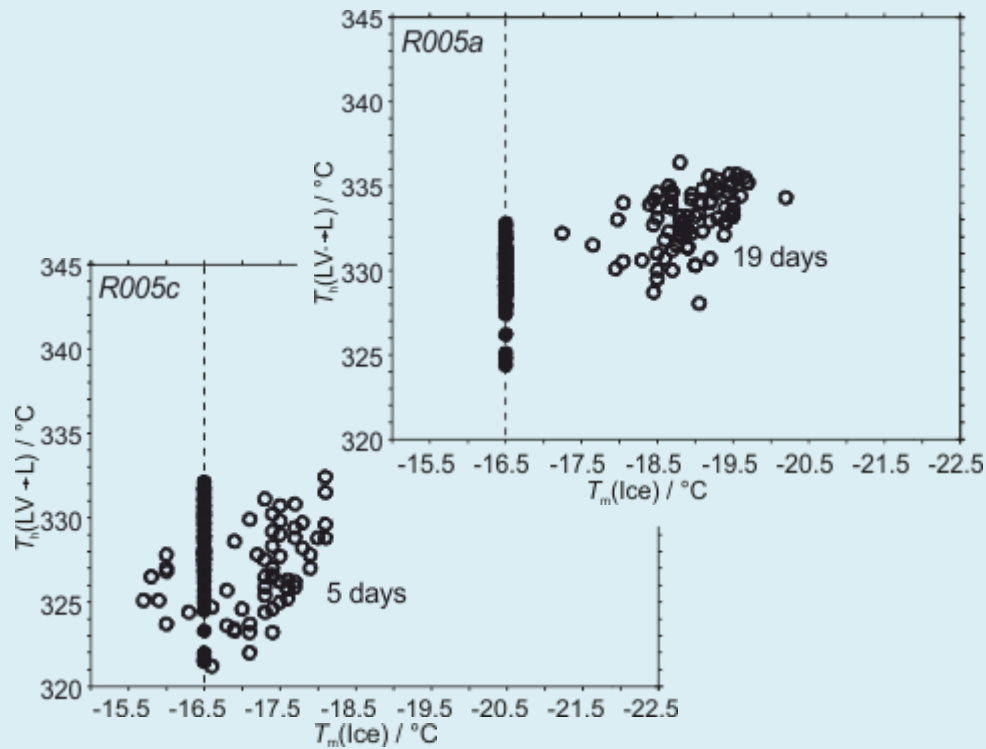
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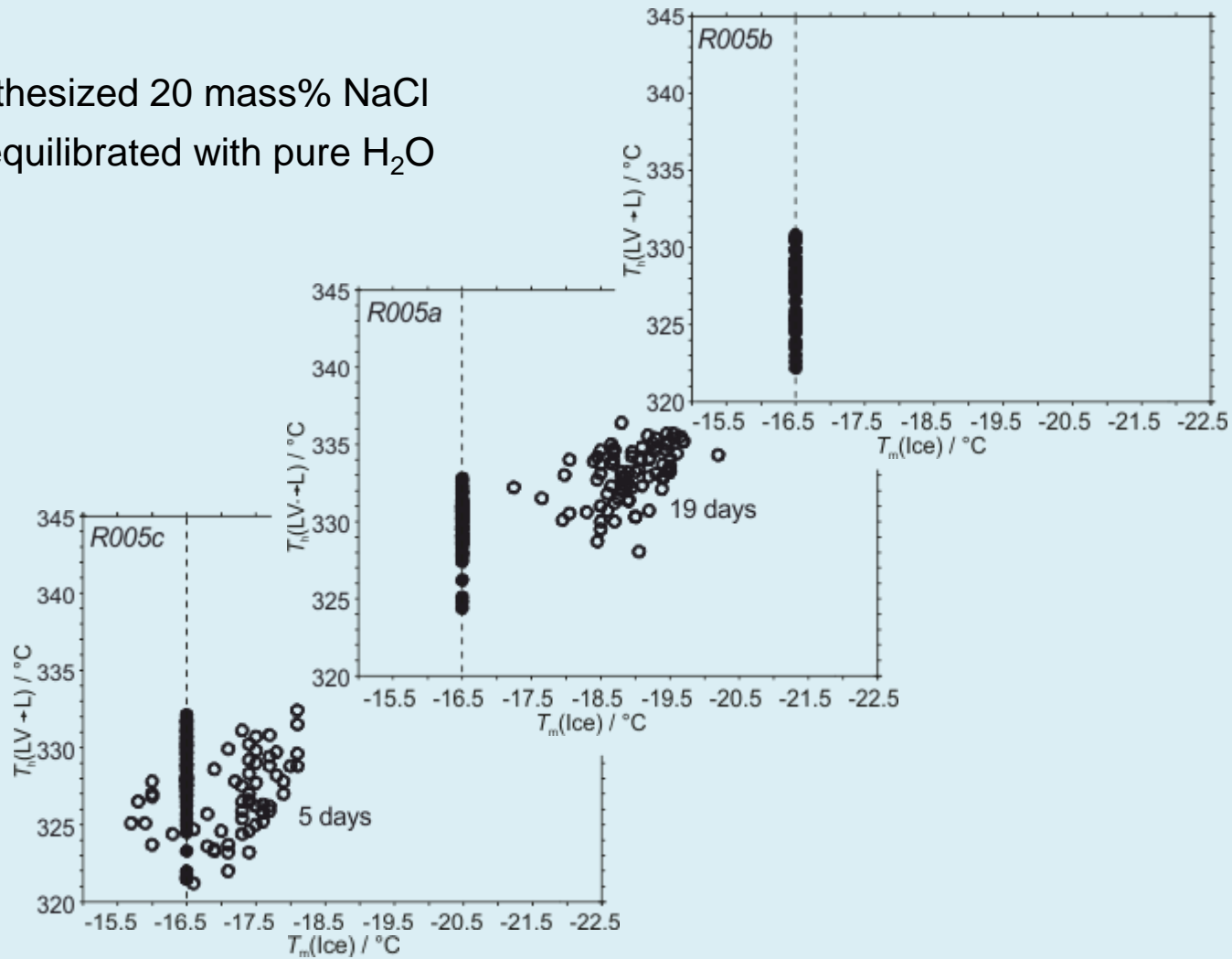
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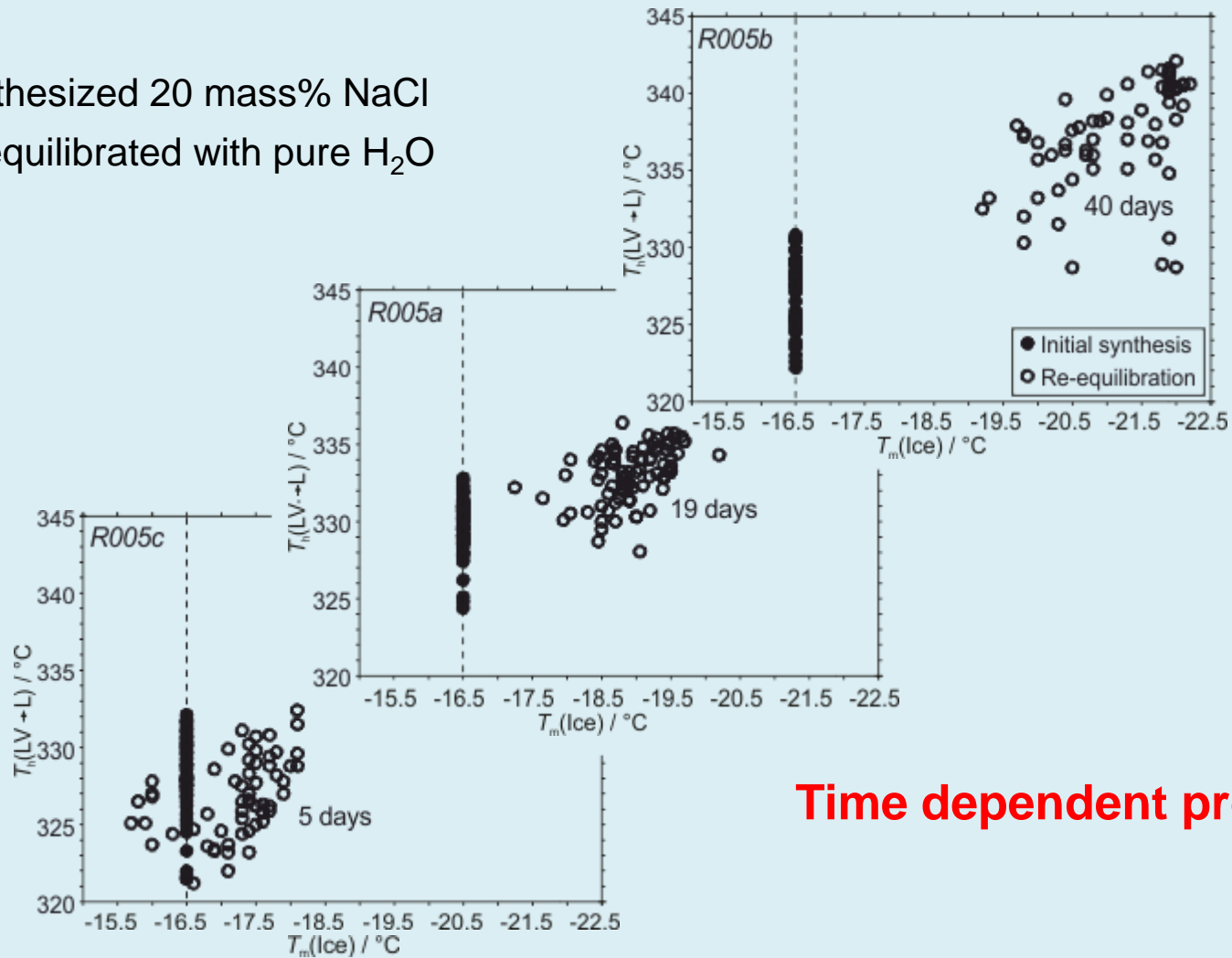
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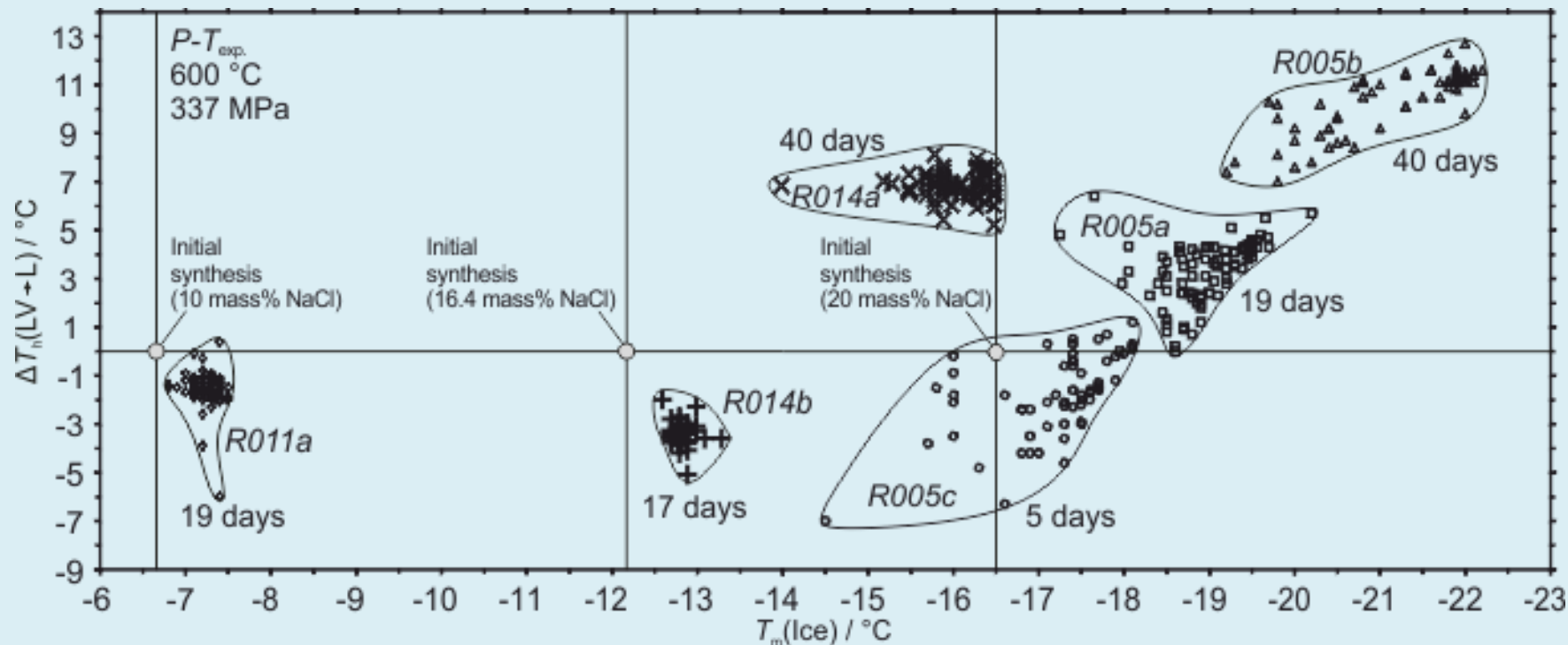
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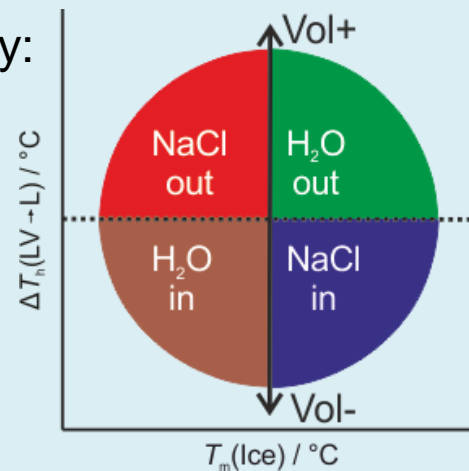


**Time dependent process!**

# Microthermometry

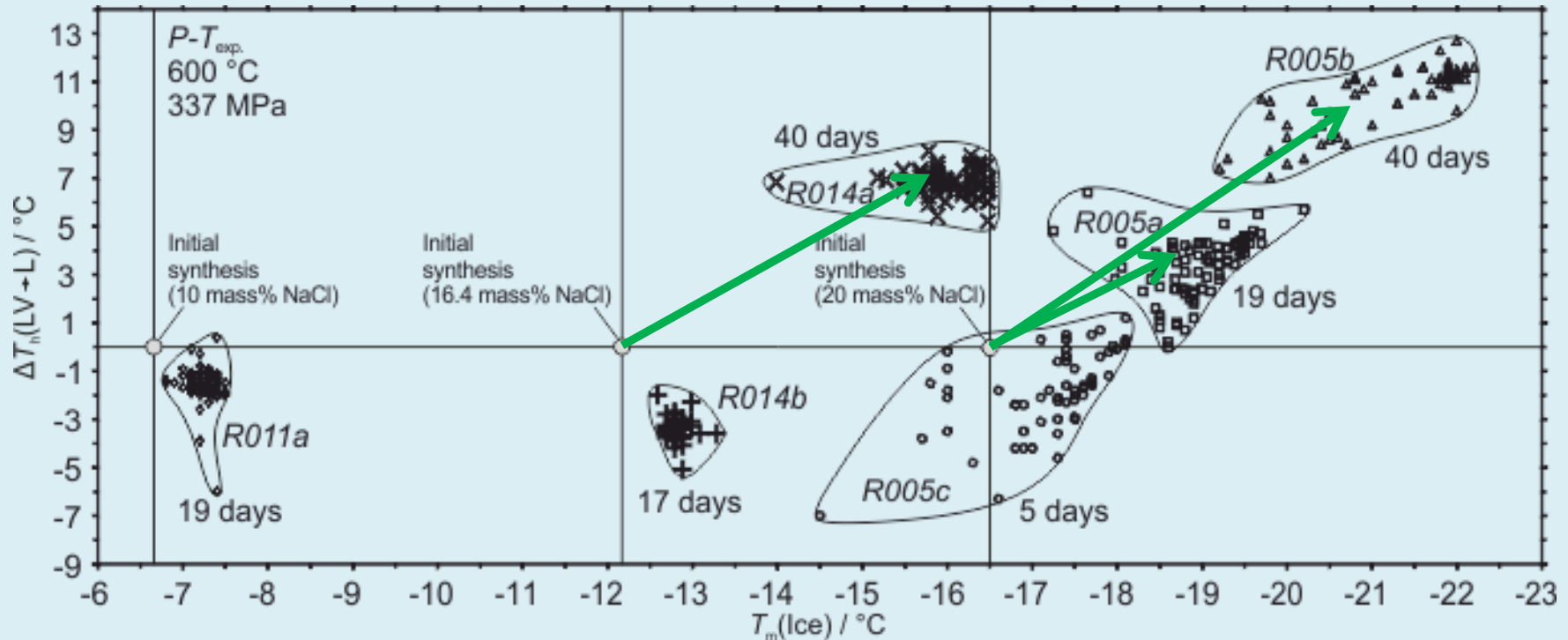


Theory:





# Microthermometry

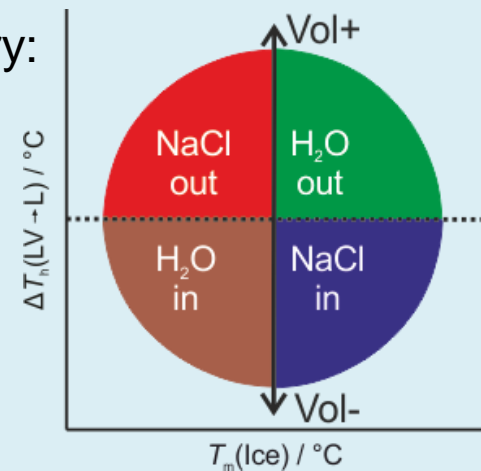


$\text{H}_2\text{O}$  loss  $\rightarrow$  decreasing density & higher salinity

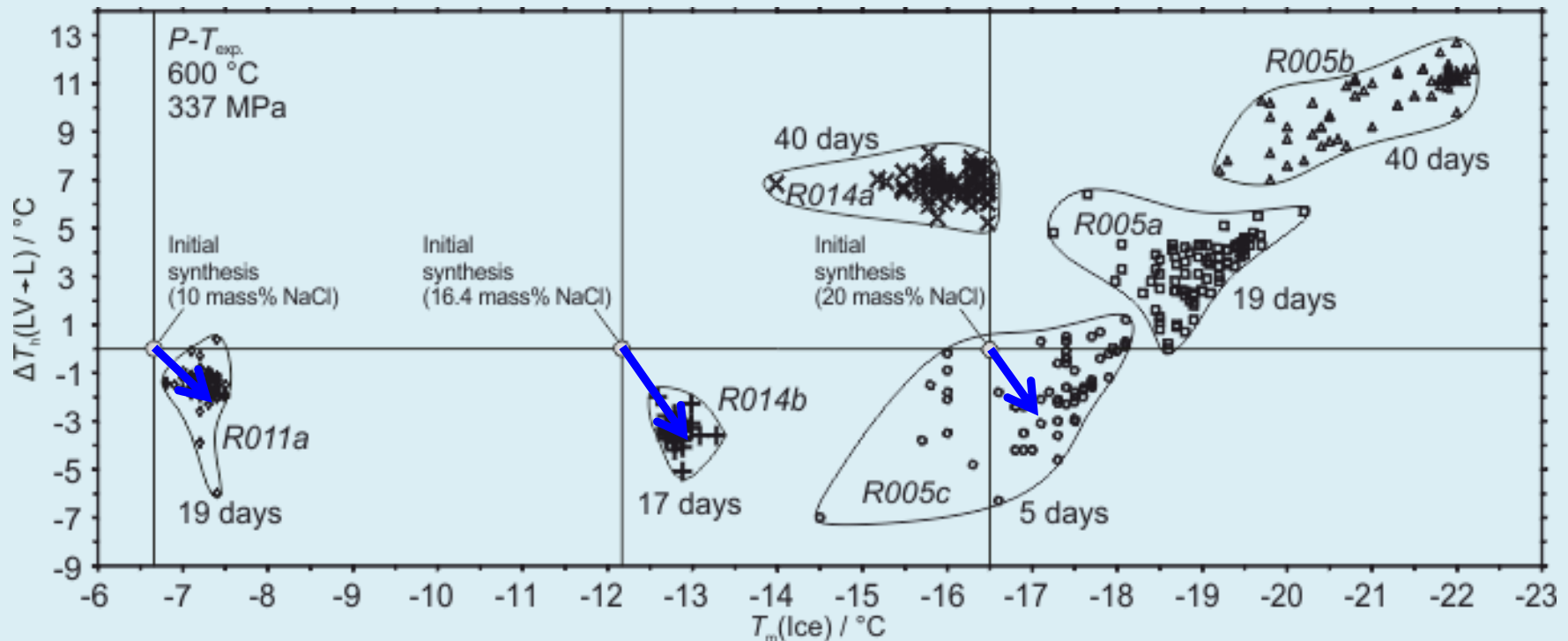
NaCl gain  $\rightarrow$  higher salinity & higher density

$\text{H}_2\text{O}$  gain  $\rightarrow$  increasing density & lower salinity

Theory:



# Microthermometry

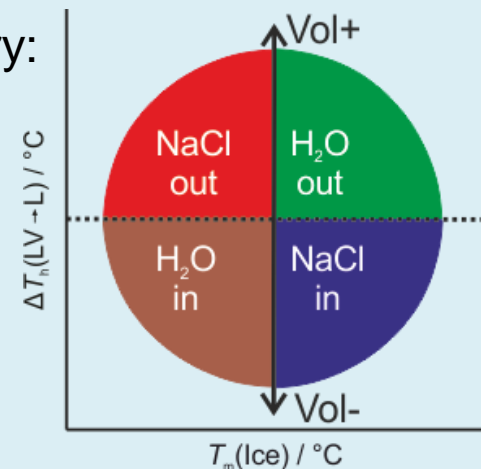


H<sub>2</sub>O loss → decreasing density & higher salinity

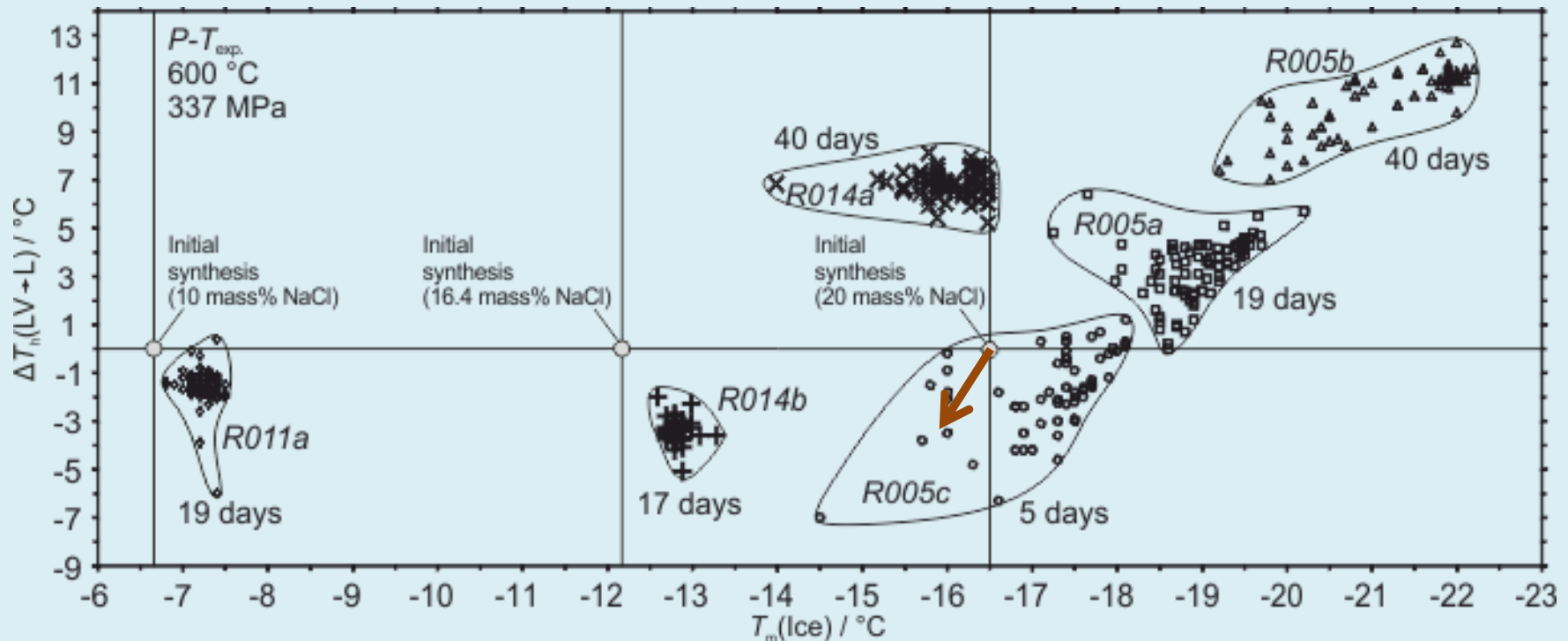
NaCl gain → higher salinity & higher density

H<sub>2</sub>O gain → increasing density & lower salinity

Theory:



# Microthermometry

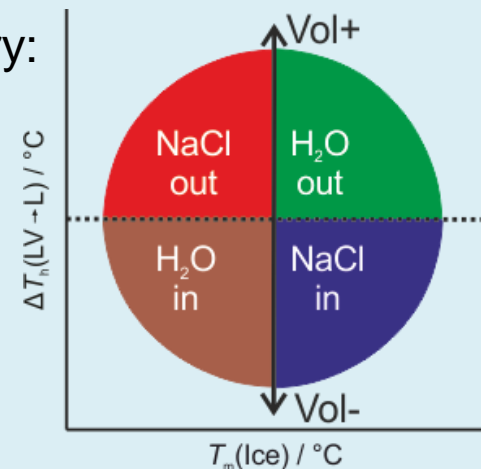


H<sub>2</sub>O loss → decreasing density & higher salinity

NaCl gain → higher salinity & higher density

H<sub>2</sub>O gain → increasing density & lower salinity

Theory:



# Concentration profiles

Experimental conditions

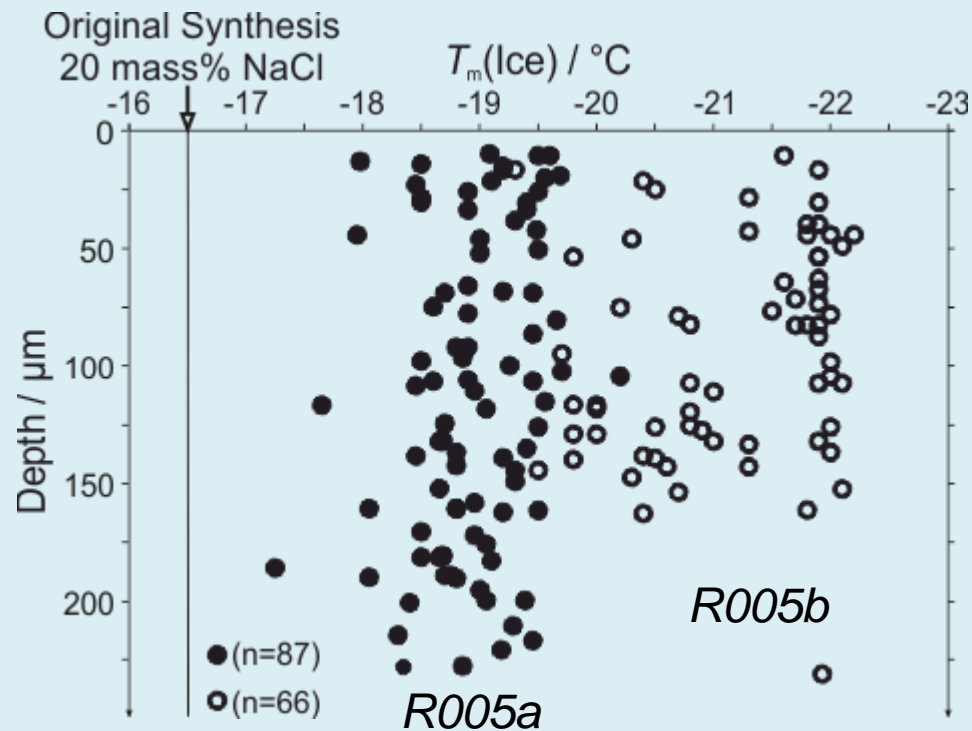
$P = 337 \text{ MPa}$

$T = 600 \text{ }^{\circ}\text{C}$

Fluid system

Synthesis: 20 mass% NaCl

Re-equilibration: pure  $\text{H}_2\text{O}$



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Experimental conditions

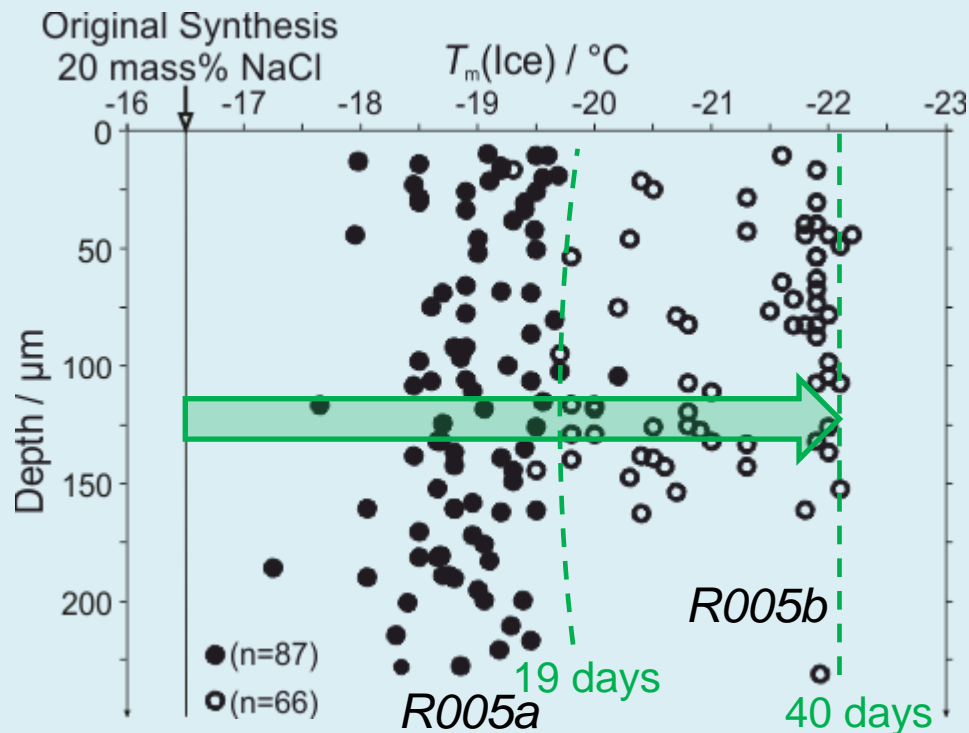
$P = 337 \text{ MPa}$

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**No depth dependency!**

Diffusion independent concentration profile!

# Concentration profiles

Experimental conditions

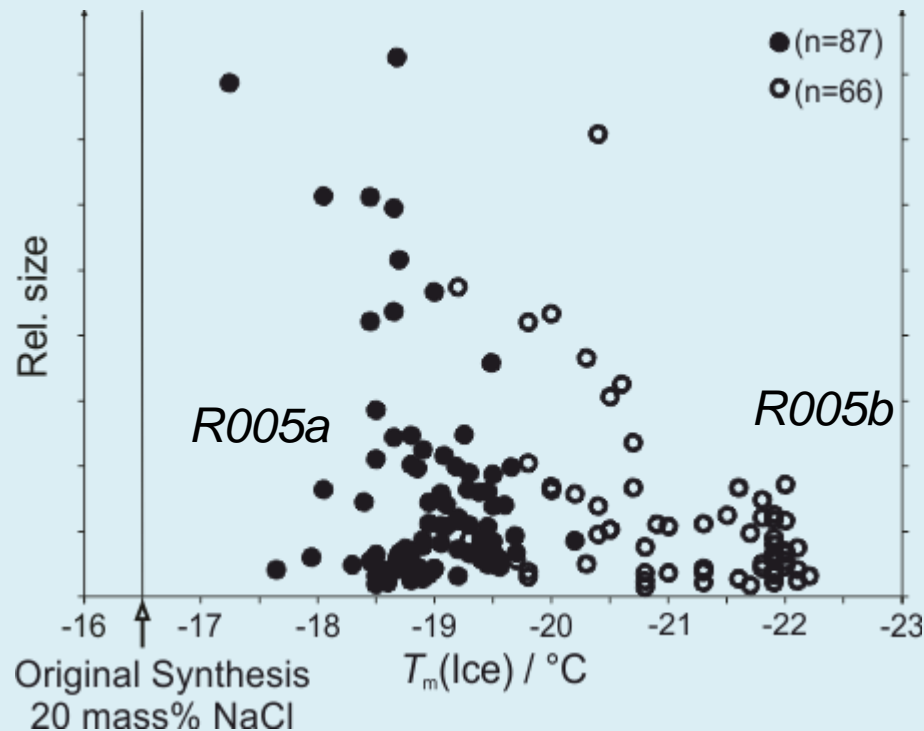
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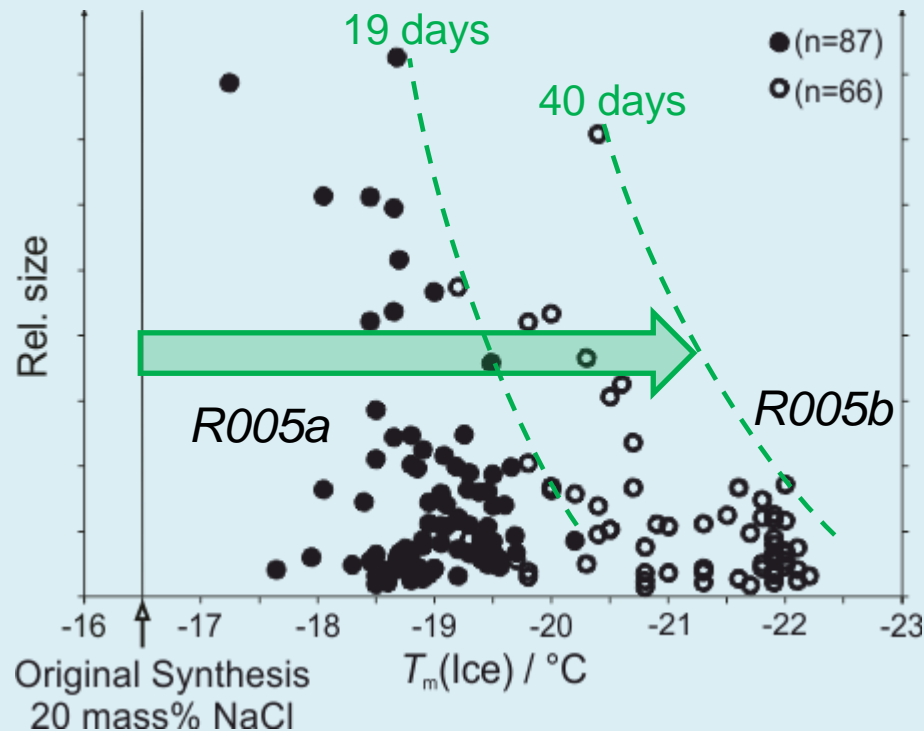
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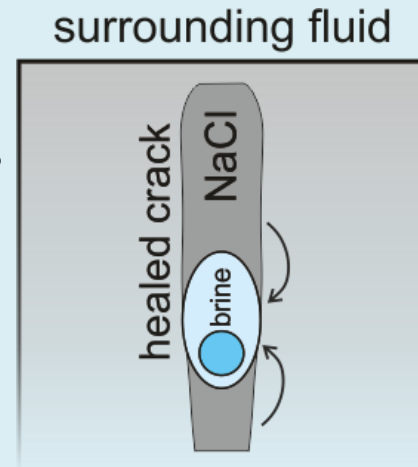
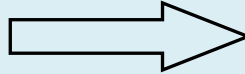
**Size dependency!**

# Conclusion

Where is the NaCl coming from?

crystal defects in synthetic healed cracks

Check with LA-ICP-MS!



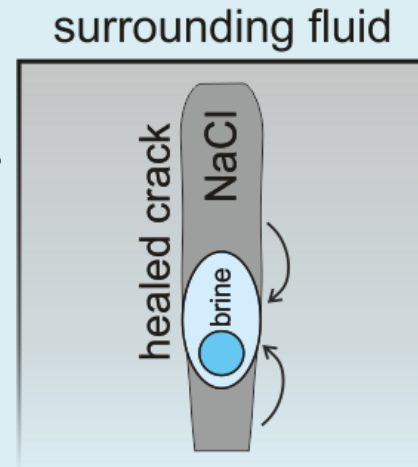
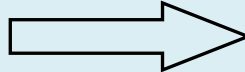


# Conclusion

## Where is the NaCl coming from?

crystal defects in synthetic healed cracks

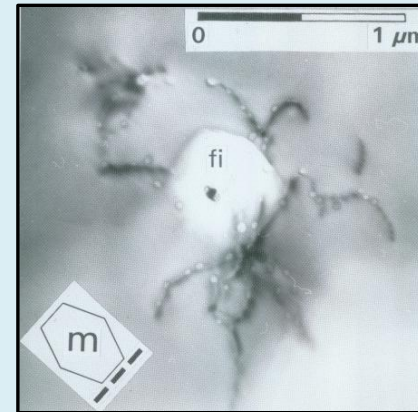
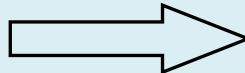
Check with LA-ICP-MS!



## Where is the H<sub>2</sub>O gone?

crystal defects in synthetic healed cracks

Check with TEM!



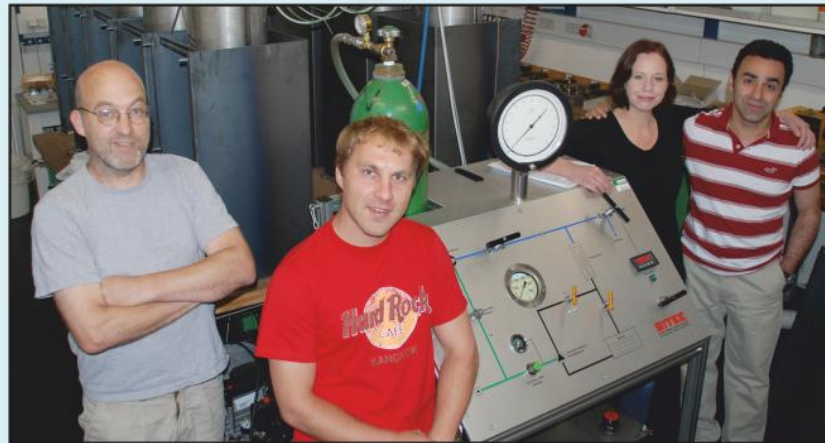
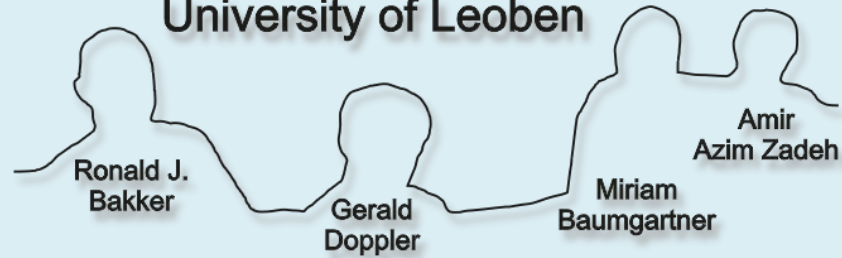
*Bakker & Jansen (1994)*

→ Independent of fugacity gradients!

→ Internal re-distribution of species!

Thank you for your attention!

## Fluid Inclusion Team University of Leoben



**FWF**

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