



# The formation of the trinitites through their silicon and oxygen isotopic compositions

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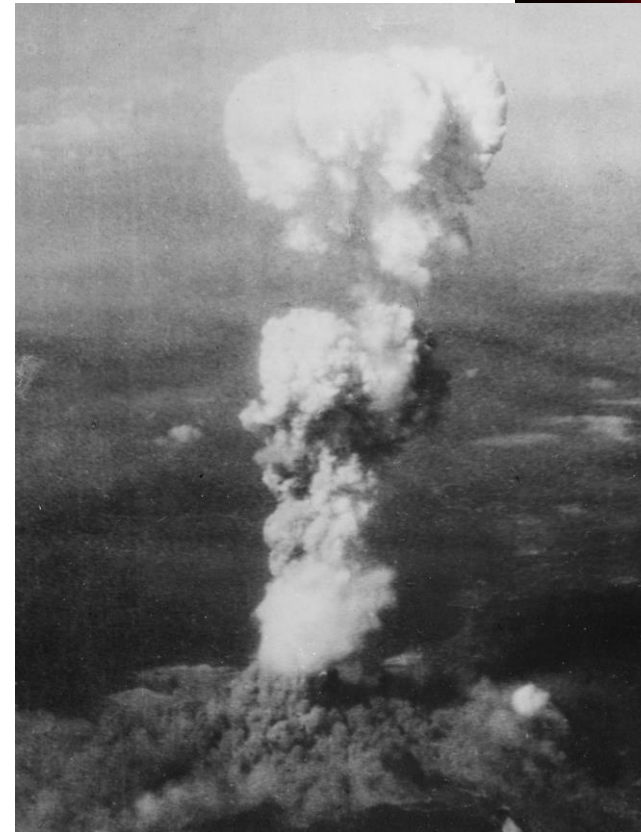
# Introduction

- The first objects of the solar system are condensates
- Nuclear explosion = environment where condensation can happen
- The Hiroshima glasses:
  - Condensates
  - Presents similarities with the first solar system solid

Can other nuclear fallouts be condensates?  
Could these other nuclear fallouts be used as analogs to the first solar system object?



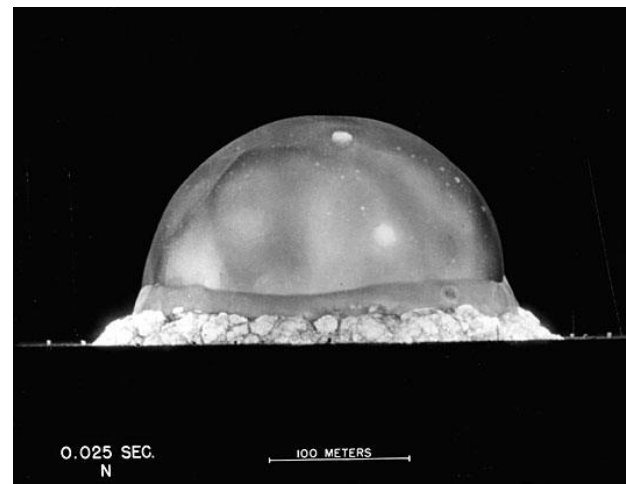
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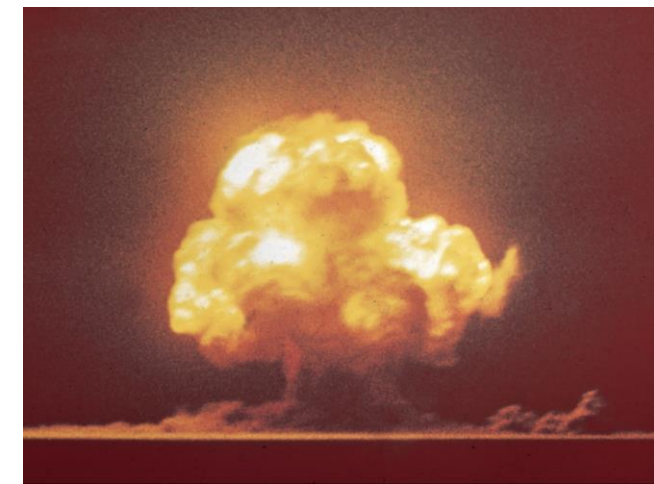
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# The trinity explosion

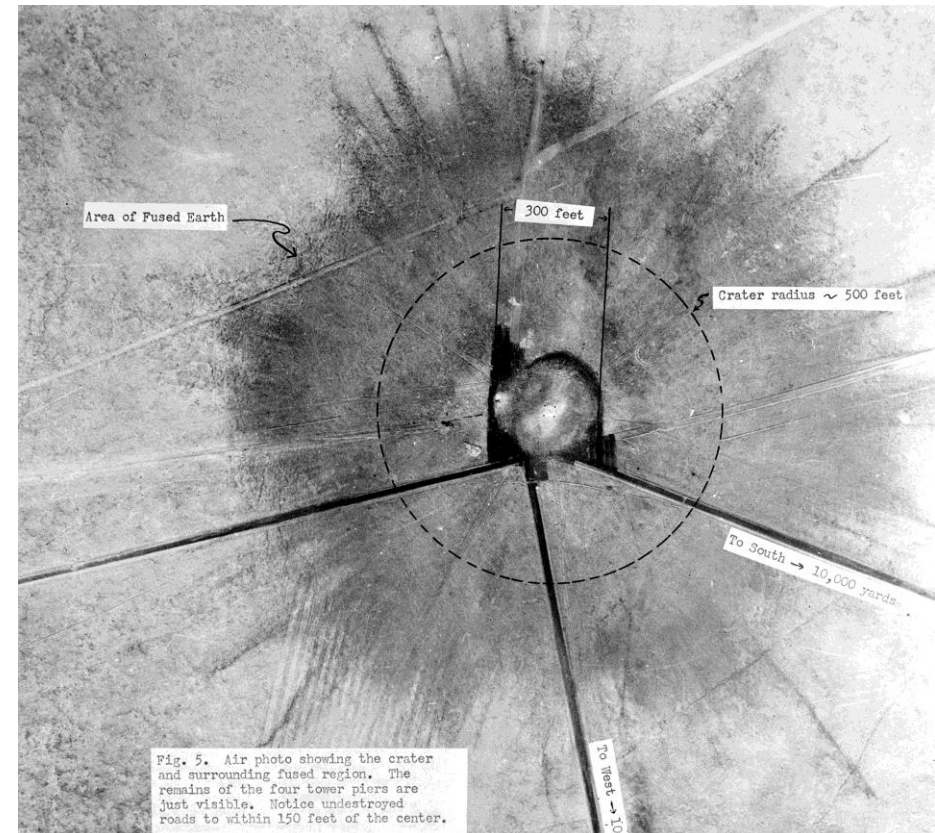
- On the July 16<sup>th</sup>, 1945
- In the White Sand Proving ground, New Mexico, USA
- The 1<sup>st</sup> nuclear test in history
- 21 kilotons of TNT
- The explosion produced:
  - A crater (300 m of radius, 2.5 m of depth)
  - A by-product



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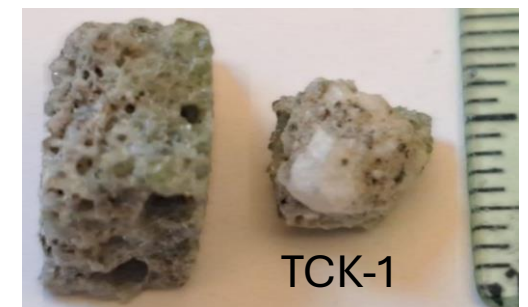
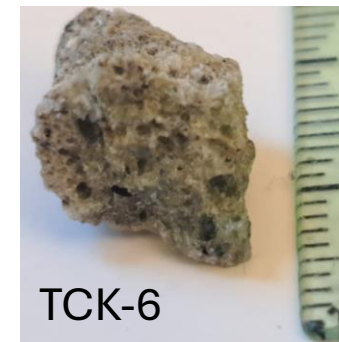
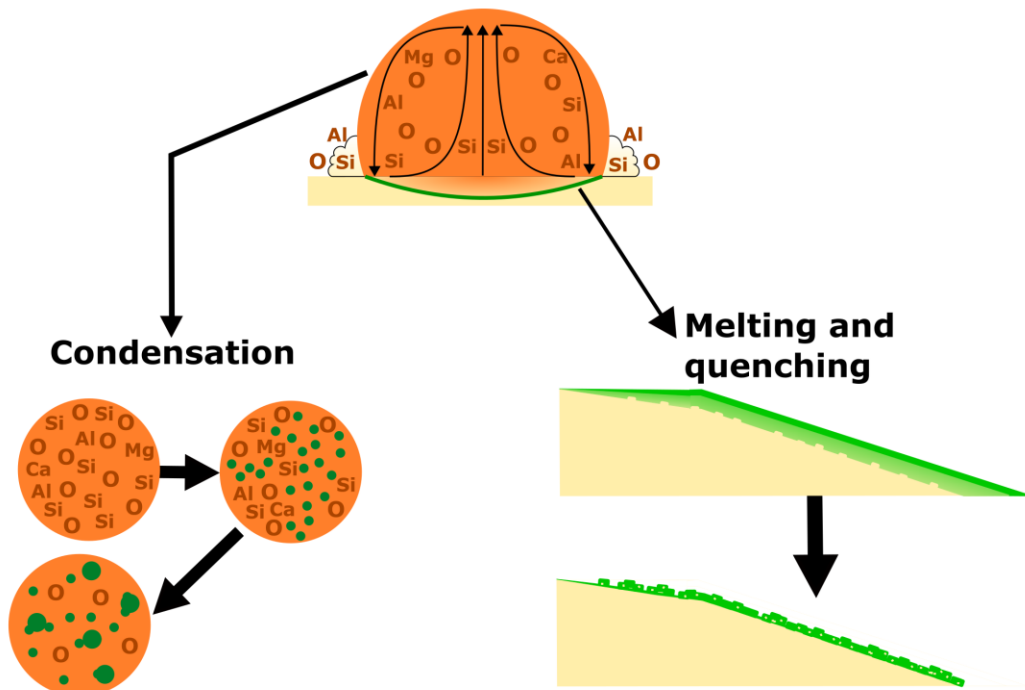
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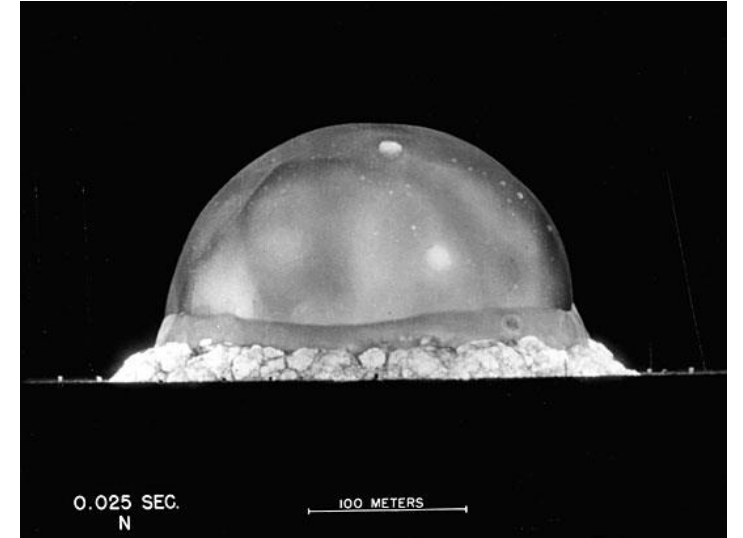
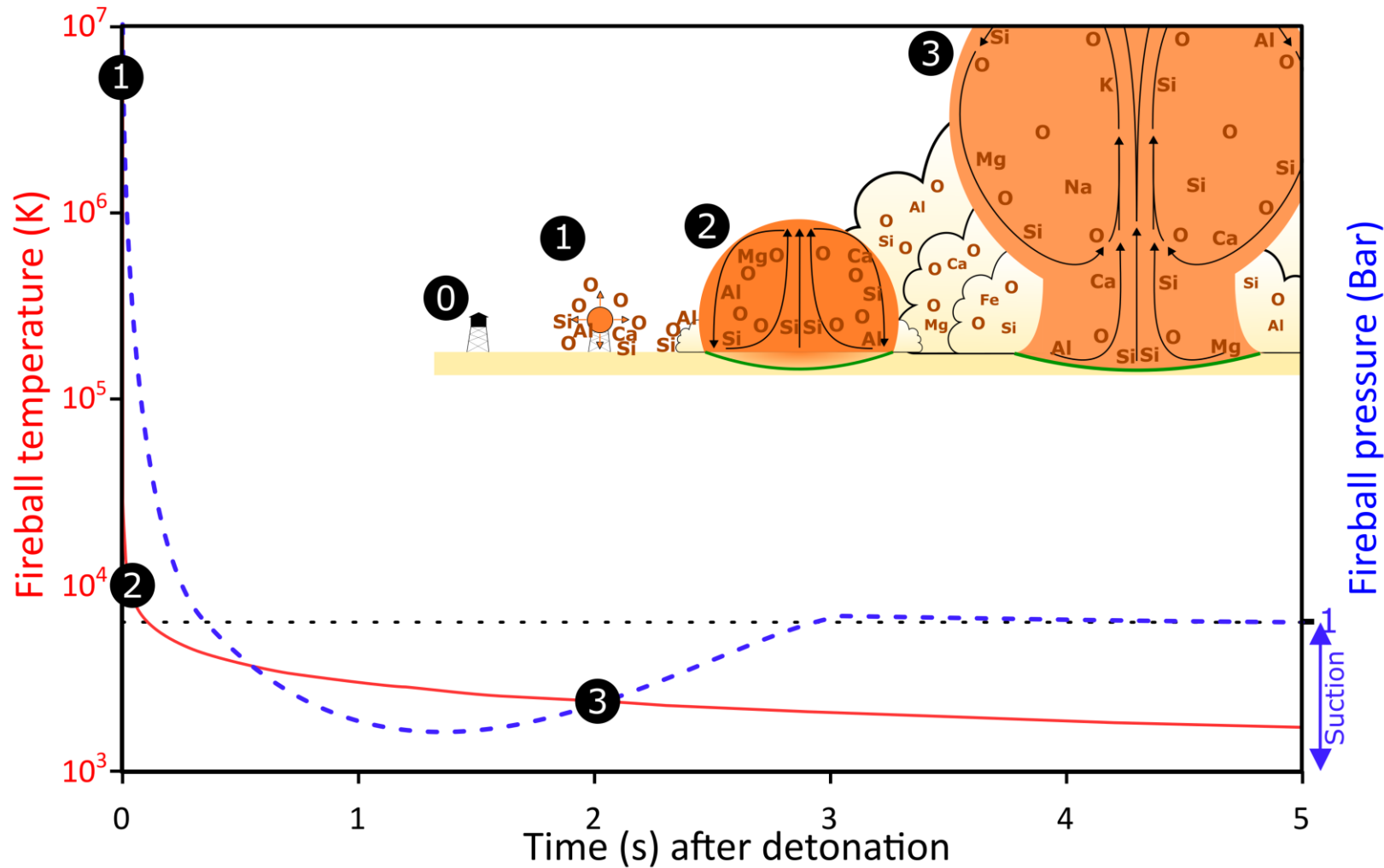
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# The trinitites

- Here, we analyzed three different green trinitites:
- There are two main theories:
  - Condensation in the fireball
  - Melting and quenching of the surface



# The explosion

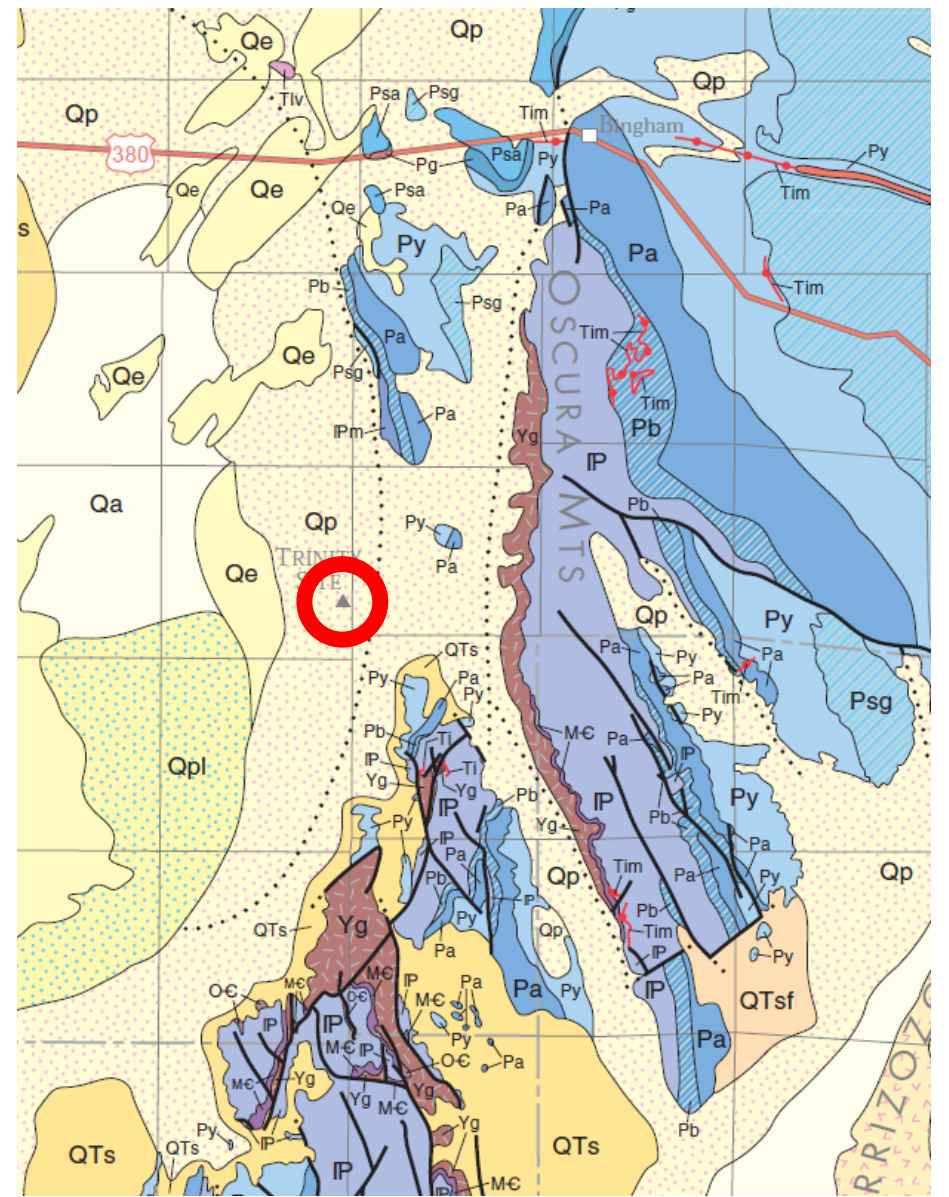


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- The fireball start:
  - $10^7$  K and  $10^6$  bar
- In 0,25s, the pressure reaches 1 bar
- In 0,03s, the fireball reaches  $10^4$ K
- And reaches 2000 K in 10s

# The geology of the site

- The trinity site:
  - Is an alluvial basin
  - Has for main source the Oscura mountain
- The main components of the sediment are:
  - Quartz –  $\text{SiO}_2$
  - Feldspar –  $(\text{Ca,Na,K})(\text{Al,Si})_4\text{O}_8$
  - Pyroxene –  $(\text{Ca,Mg,Fe})_2\text{Si}_2\text{O}_6$
  - Calcite –  $(\text{CaCO}_3)$

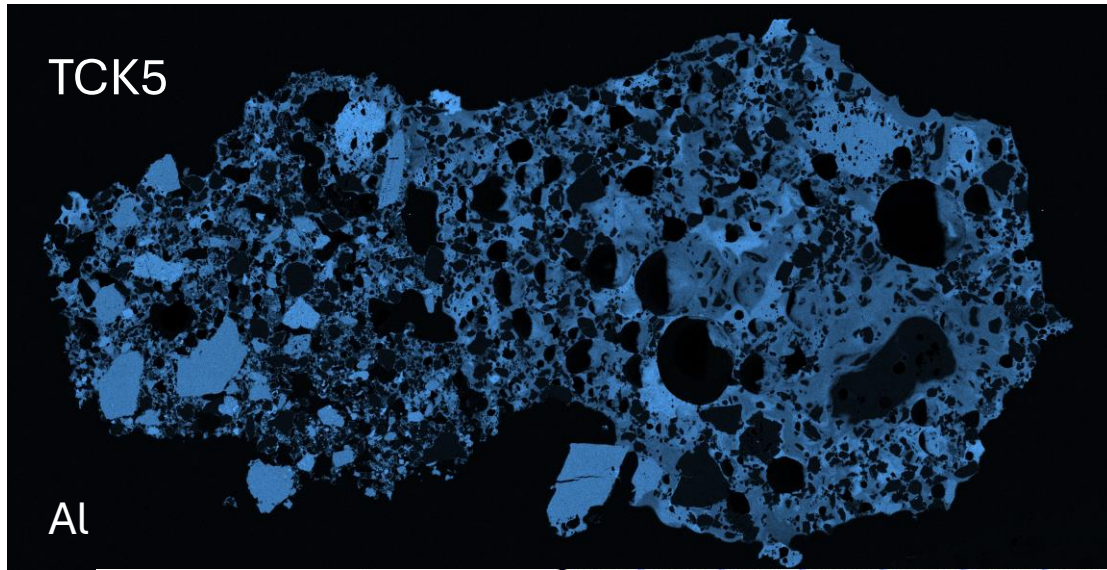


**Yg** Mesoproterozoic granitic plutonic rocks—Mainly 1.45-1.35 Ga megacrystic granites, generally weakly foliated except locally at their margins

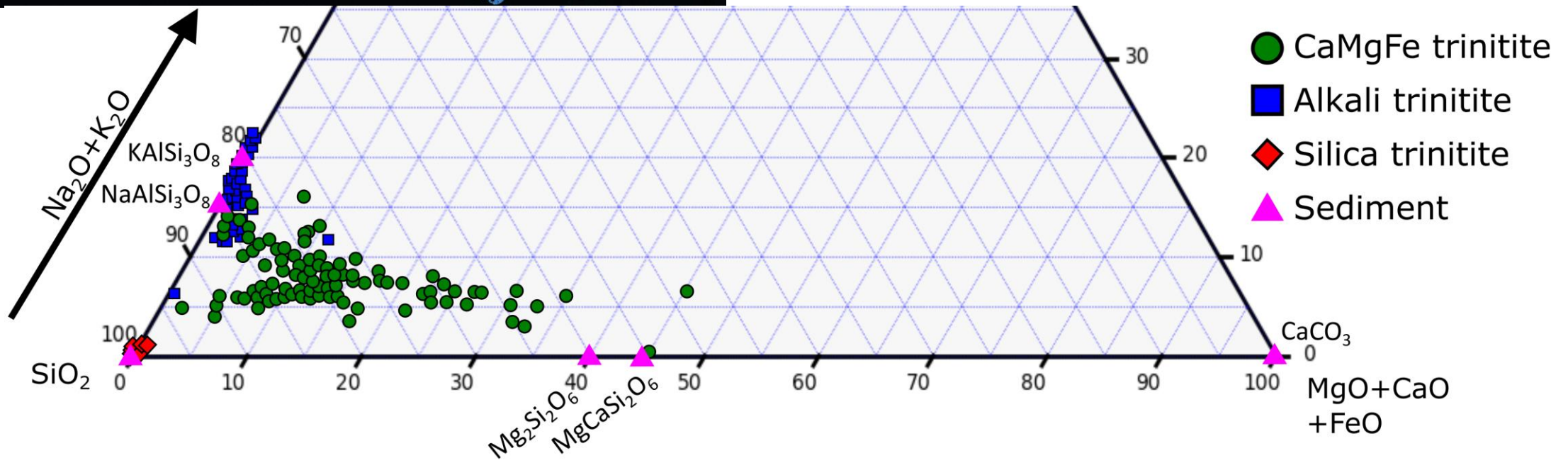
**IP** Pennsylvanian rocks, undivided—In Sangre de Cristo Mountains may include Sandia, Madera, La Pasada, Alamitos, and Flechado Formations; elsewhere may include Bar-B, Nakaye, Red House, Oswaldo, and Syrena Formations

**Qp** Piedmont alluvial deposits (Holocene to lower Pleistocene)—Includes deposits of higher gradient tributaries bordering major stream valleys, alluvial veneers of the piedmont slope, and alluvial fans. May locally include uppermost Pliocene deposits

# The chemical composition



- There are three chemical families:
  - Silica
  - Alkali
  - CaMgFe
- The silica and alkali families could be the result of melting
- The CaMgFe doesn't result from melting



# The isotopic composition

For the sediment of the site:

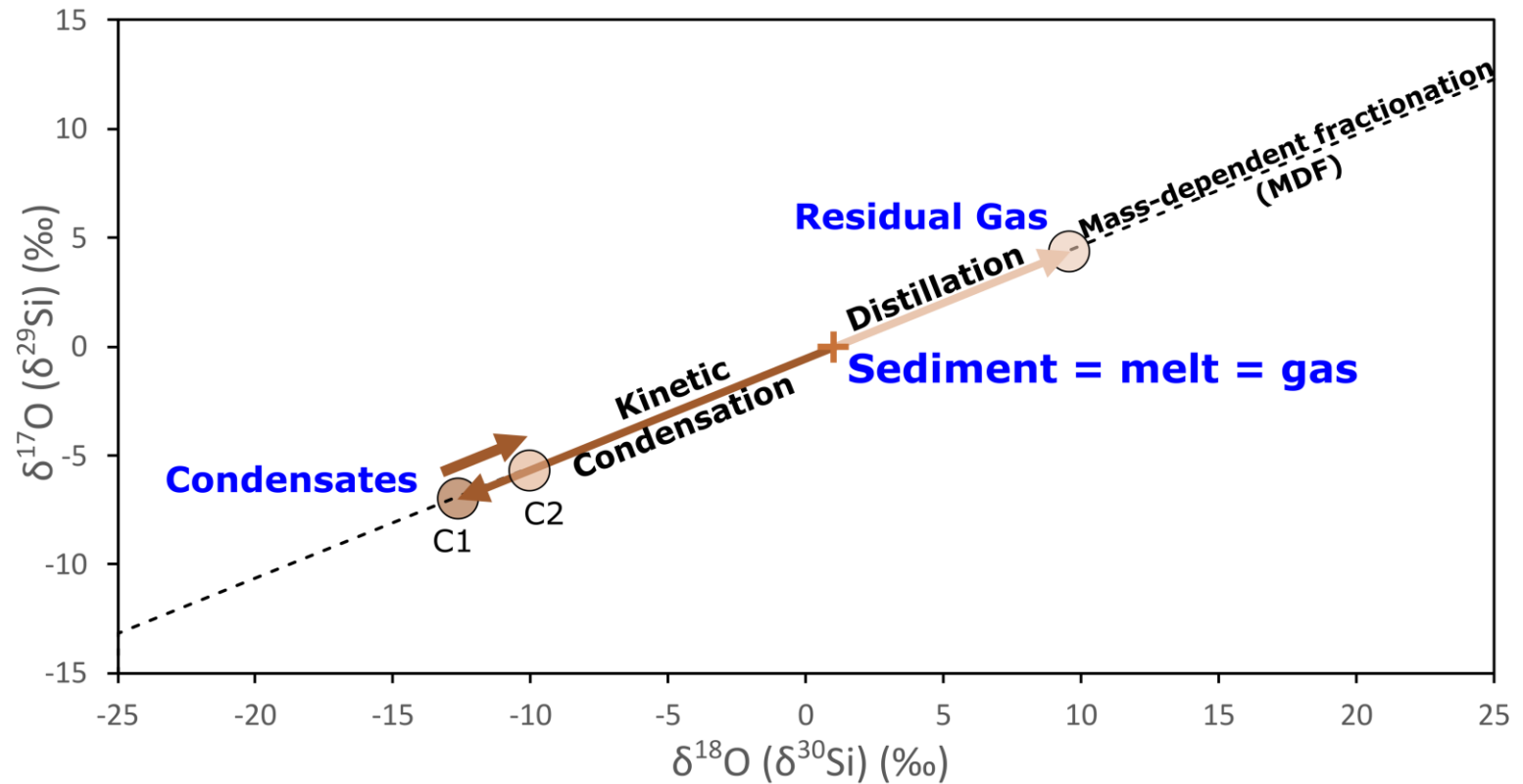
- The quartz:
  - $\delta^{18}\text{O} \approx 7,5\text{‰}$
  - $\delta^{30}\text{Si} = -0,1\text{‰}$
- The feldspar:
  - $\delta^{18}\text{O} = 5 - 12,9 \text{‰}$
  - $\delta^{30}\text{Si} = -0,15\text{‰}$
- The calcite:
  - $\delta^{18}\text{O} \approx 27,4\text{‰}$

3 oxygen isotopes:  $^{16,17,18}\text{O}$   
 3 silicon isotopes:  $^{28,29,30}\text{Si}$

$$\delta^{18/30}\text{X} = \left( \frac{\left( \frac{^{18/30}\text{X}}{^{16/28}\text{X}} \right)_{\text{Sample}}}{\left( \frac{^{18/30}\text{X}}{^{16/28}\text{X}} \right)_{\text{SMOW/NBS-28}}} - 1 \right) \times 10^3$$

If the trinitites are:

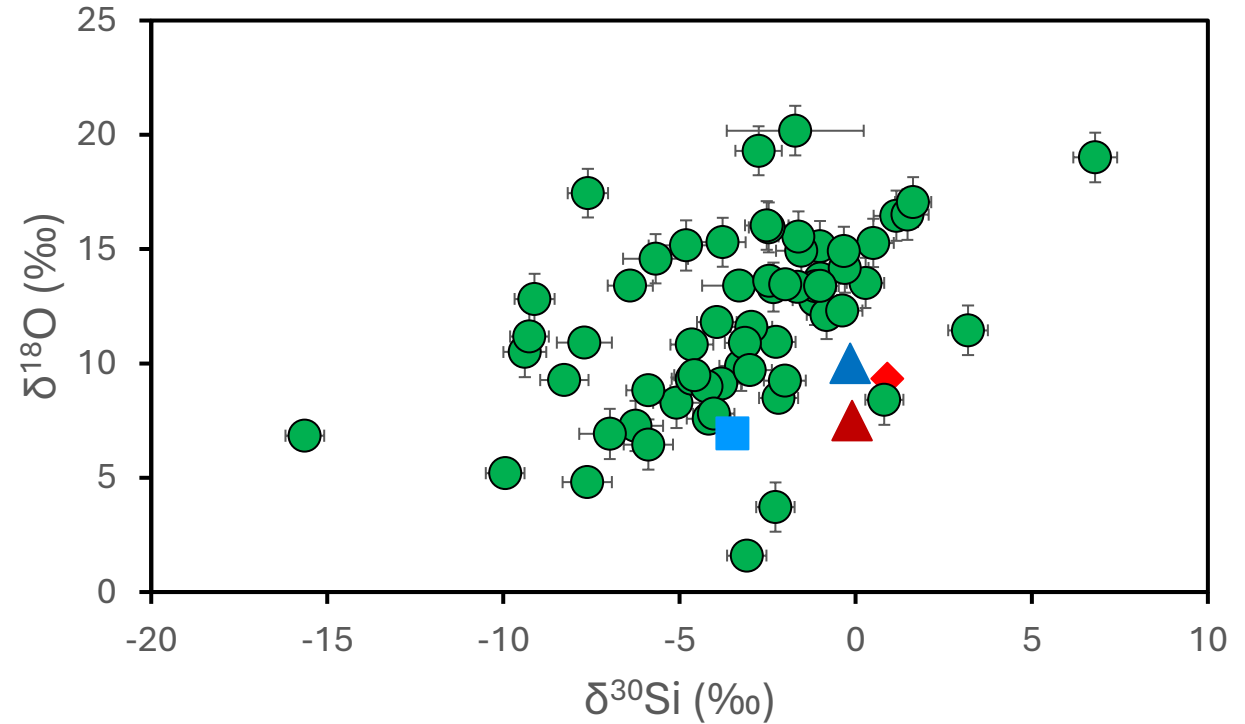
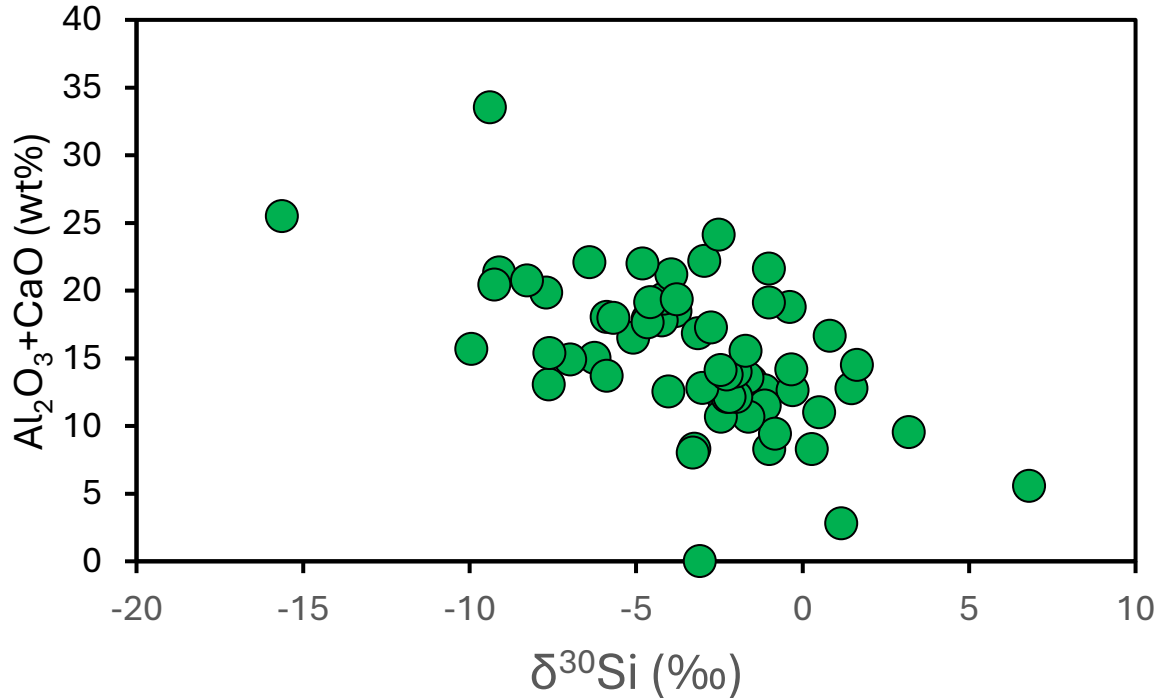
- Melt
  - $\delta^{18/30}\text{X}_{\text{trinitite}} \approx \delta^{18/30}\text{X}_{\text{sediment}}$
- Condensates
  - $\delta^{18/30}\text{X}_{\text{trinitite}} \neq \delta^{18/30}\text{X}_{\text{sediment}}$





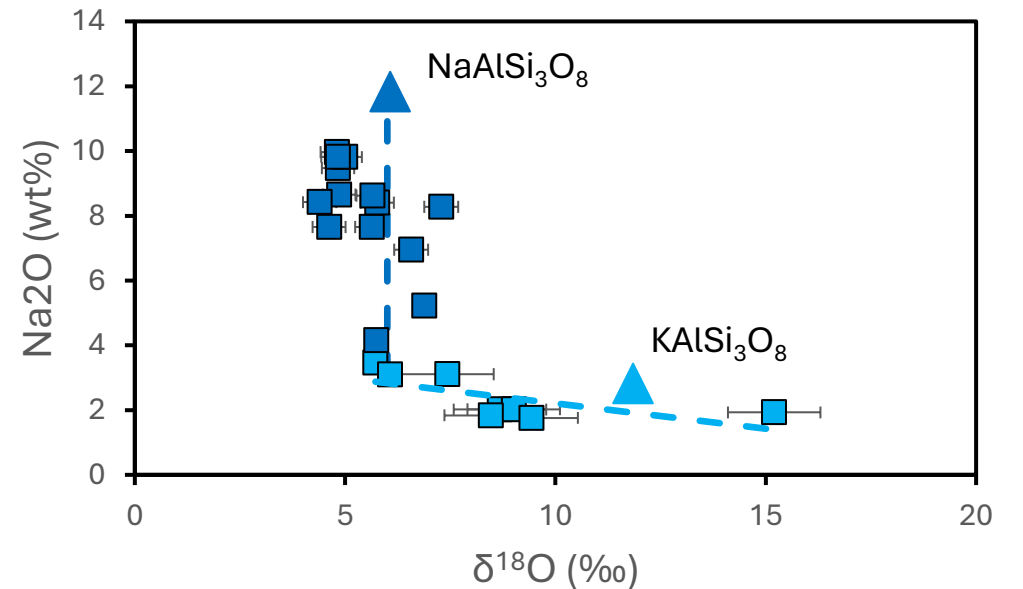
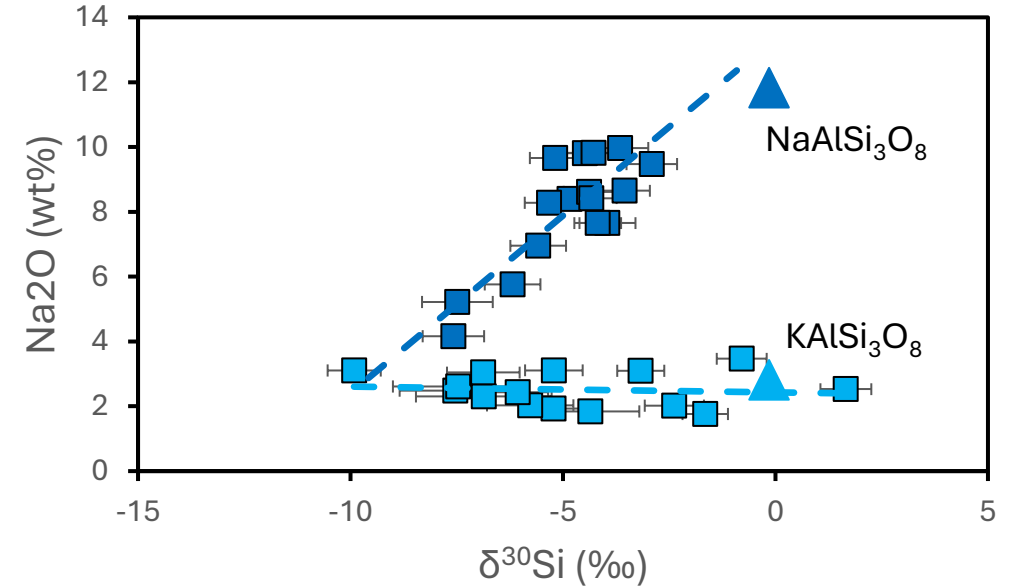
# Formation of CaMgFe trinitite

- The CaMgFe glasses are very heterogeneous
- Their isotopic composition shows condensation
  - $\delta^{30}\text{Si}_{\text{trinitite}} (-3.2\text{‰}) < \delta^{30}\text{Si}_{\text{sediment}} (-0.11\text{‰})$
  - $\delta^{30}\text{Si}_{\text{trinitite}} (11.7\text{‰}) < \delta^{30}\text{Si}_{\text{sediment}} (7.5 - 27\text{‰})$



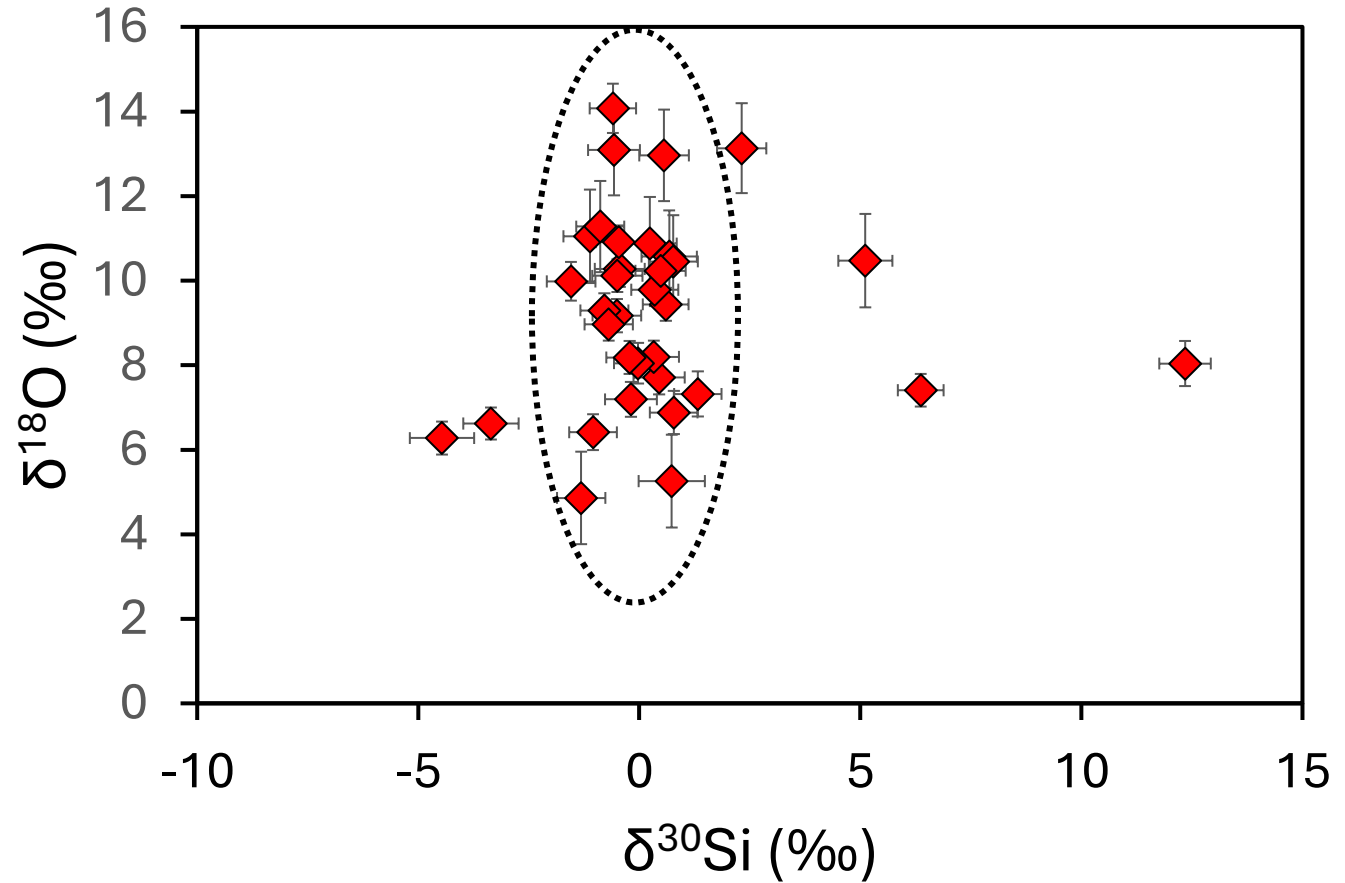
# Formation of Alkali trinitites

- There are two families of Alkali trinitites
  - K-rich family / K to Na family
- They have a similar precursor:
  - $\delta^{30}\text{Si} = -10\text{‰}$ , and a  $\delta^{18}\text{O} \approx 5\text{‰}$
  - The precursor is a condensate
- The Alkali trinitites are the result of mixing between felspathic melt and liquid condensate



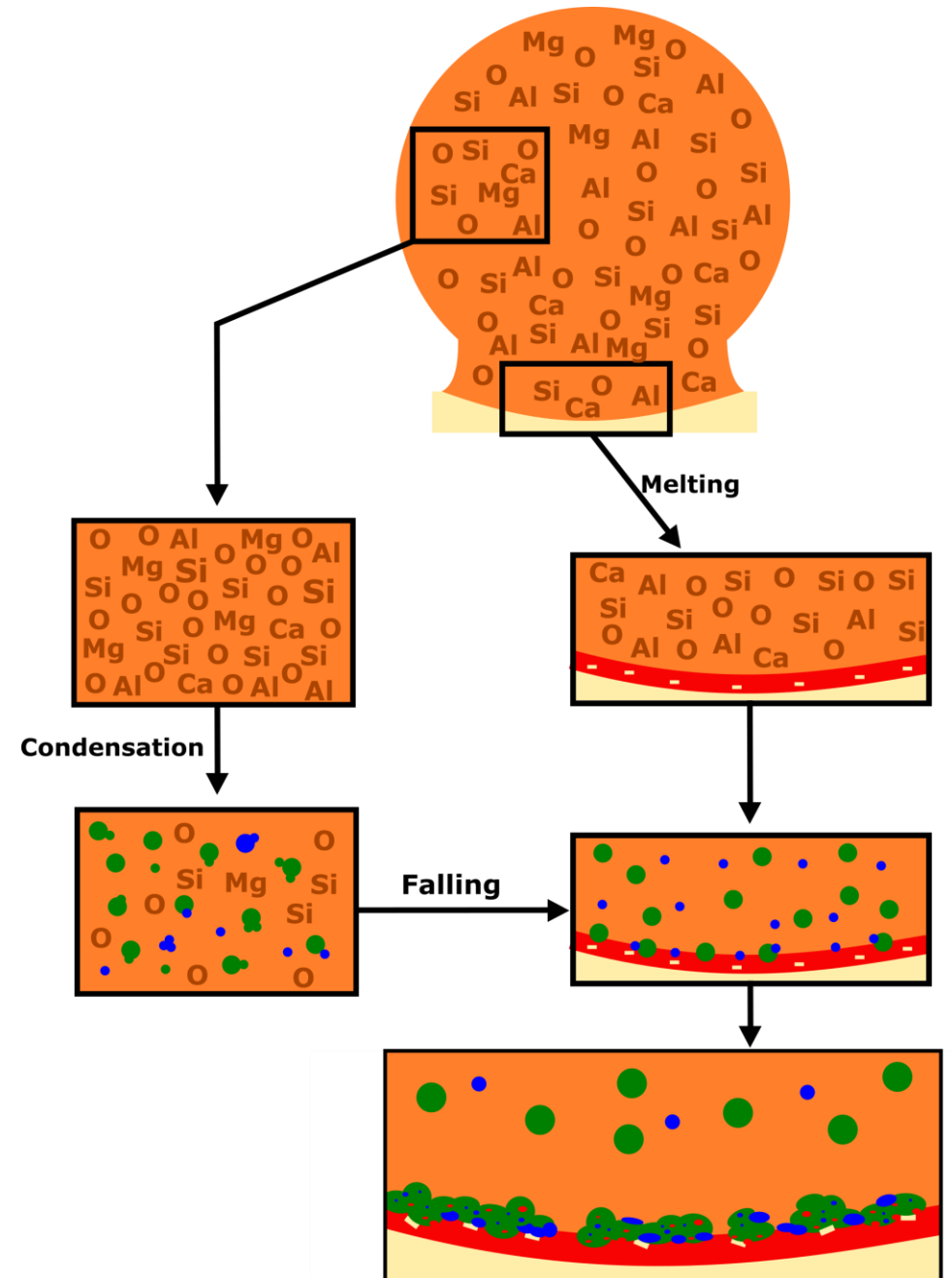
# Formation of the silica trinitites

- The Silica trinitites have most of their values (74%) of  $\delta^{30}\text{Si}$  between -2 and 2‰.
- The silica trinitites are not condensated but are melted sediment



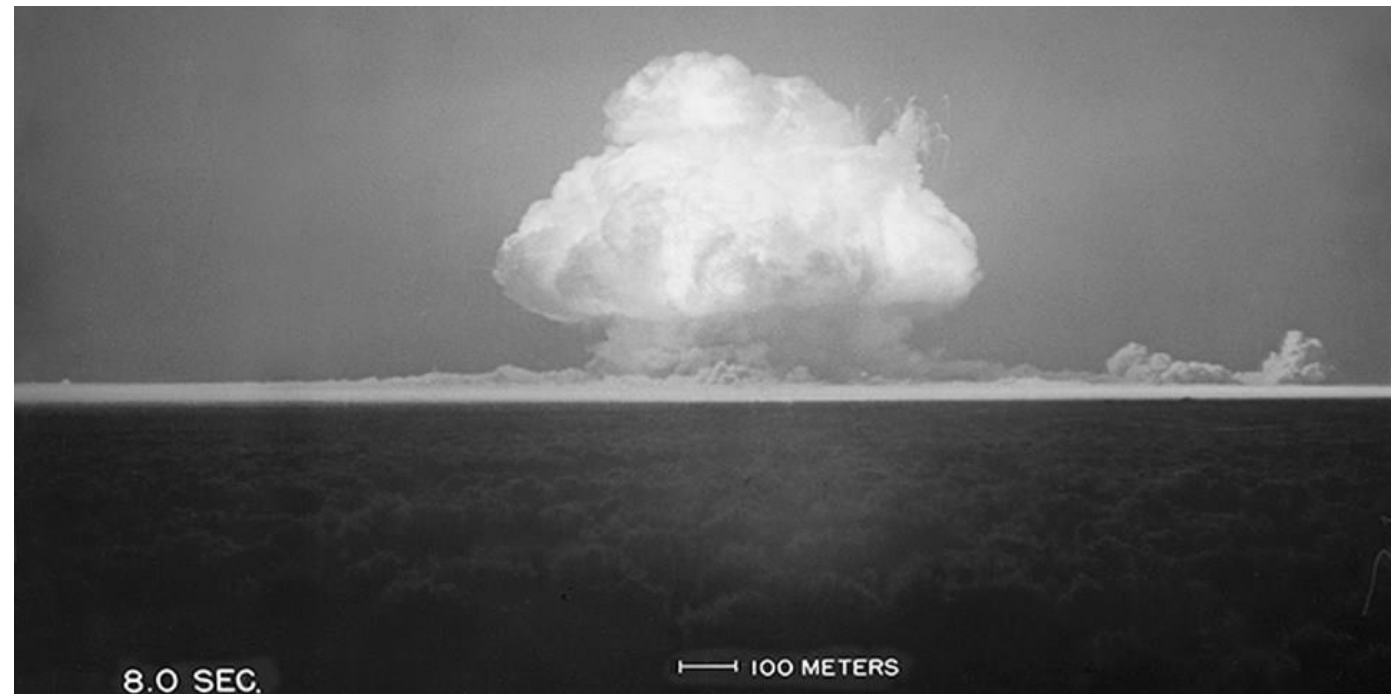
# The scenario

1. Vaporization of the surface
2. Condensation of little liquid droplets of CaMgFe
  - O and Si isotopic fractionation
  - >10 seconds events
3. Agglomeration of droplets
4. Fall of the droplets on the melted crater
5. Mixing between the melts and with the crystal
6. Quenching of the trinitites

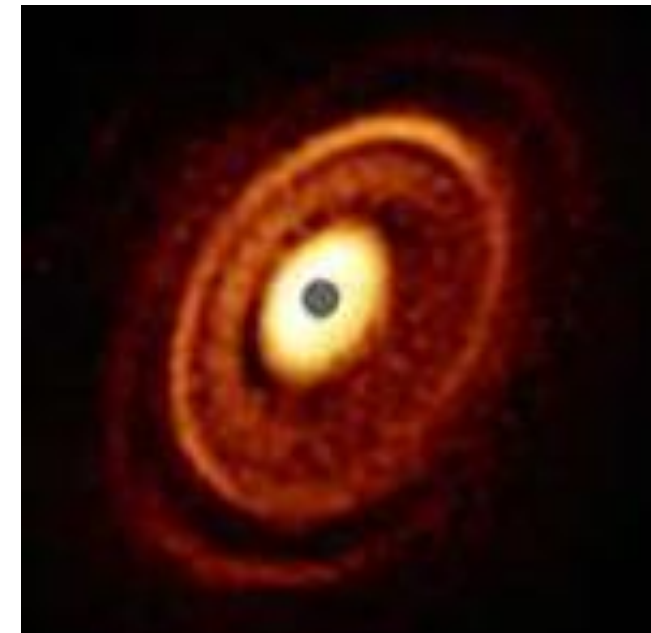


# Conclusion

- Trinitites are composed of condensates
- The interaction between melt and condensate impacts the possibility analogy
- The green trinitites are not analog to the first objects of the solar system



US air force



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