



16<sup>th</sup> Annual Symposium of the JAEA's Activities

未来へげんき  
To the Future / JAEA

# Geochronological Studies of Rock Samples by a Local Analysis Technique

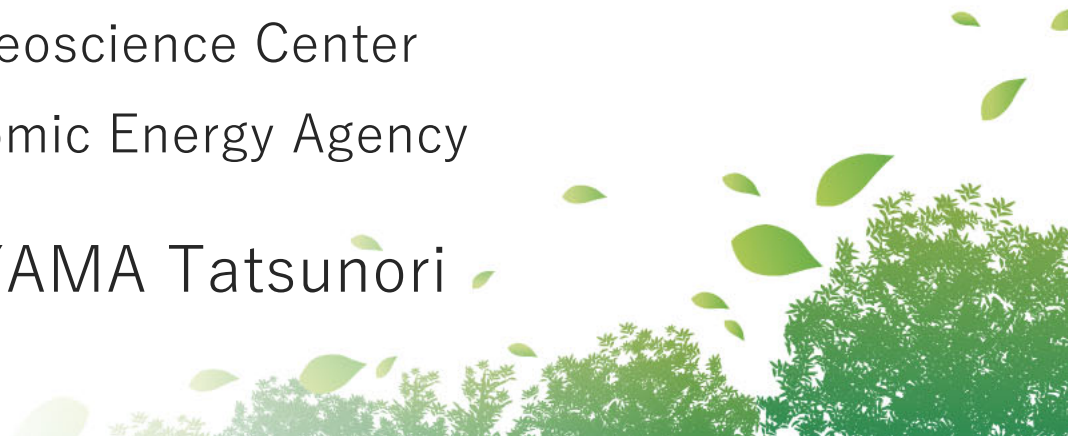
November 18<sup>th</sup> 2021

Geochronology Research Group, Geoscientific Research Department

Tono Geoscience Center

Japan Atomic Energy Agency

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# Geosphere Stability for Long-term Isolation of Radioactive Waste

## Geological Disposal

High-level radioactive waste (HLW) remains radioactive for very long time periods; therefore, it is necessary to isolate the HLW from the human environment.

### Legal process for selection of the repository site

Literature survey

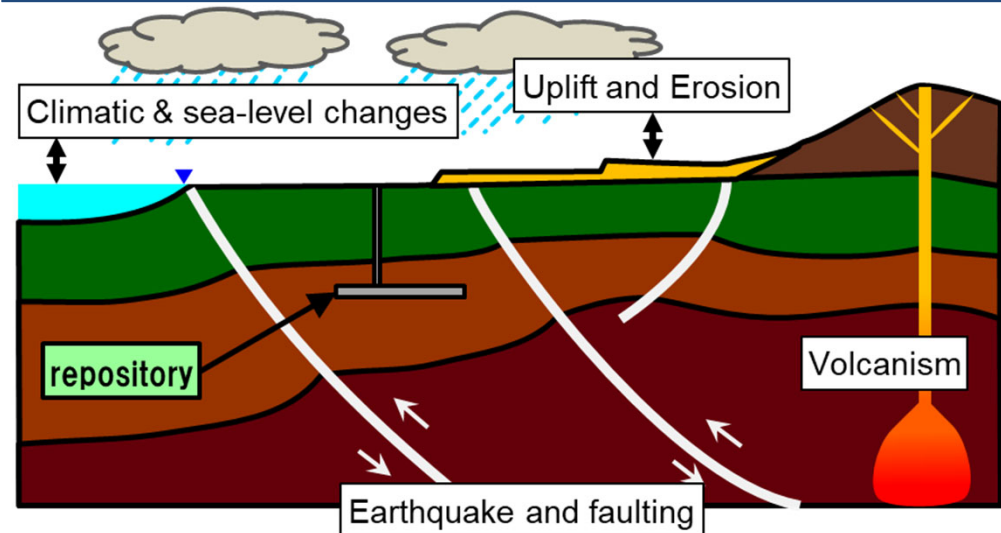
Preliminary investigation

Detailed investigation

Facility construction

⋮

### Potential events affecting geosphere stability



## Objective of study on long-term geosphere stability

To provide scientific information concerning the long-term geosphere stability required for purposes such as site disposal designs, safety assessments, and site selection.

## Tasks in the long-term future prediction

- Development of dating methods for evaluation of recent activity of faults
- Reduction of uncertainties in understanding of geological events



# Tono Geoscience Center



## Tono Geoscience Center Toki Geochronology Research Laboratory

### R&D activities

1. Development and systematization of investigation techniques for natural phenomena
2. Development of prediction models for evaluating the long-term changes of geological environment
3. Development of dating techniques





# Chemical Analysis of Geological Samples

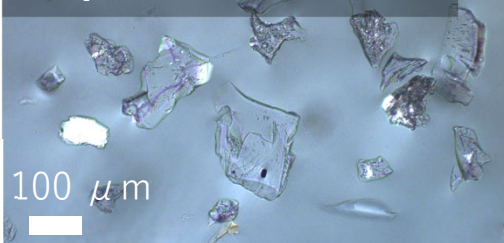
## Natural phenomena

- ◆ Volcanism
- ◆ Uplift and Erosion
- ◆ Earthquake and Faulting
- ◆ Changes in groundwater flow

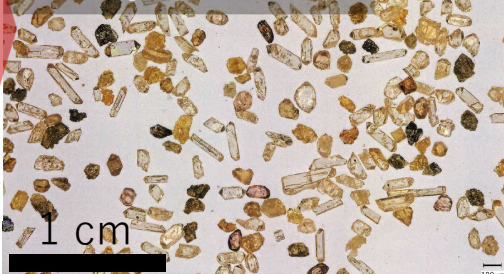
Understanding the past geological events

## Geological samples

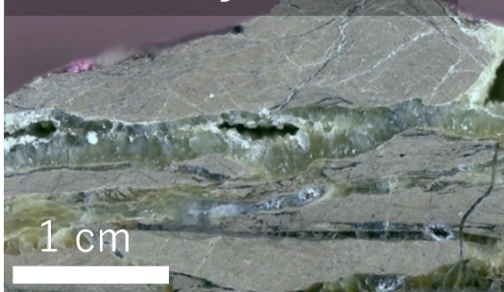
Pyroclastic material (tephra)



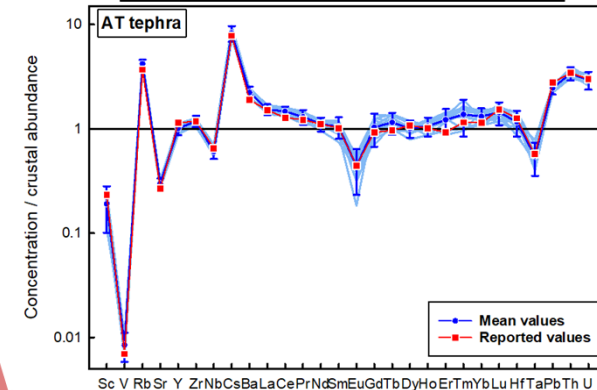
Heavy minerals



Secondary minerals

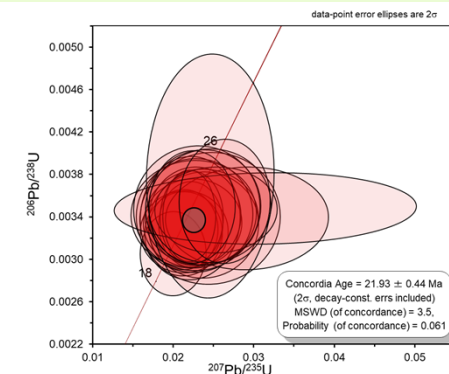


## Chemical Analysis



### Quantitative analysis

Estimate the formation processes (temperature and chemical reaction)



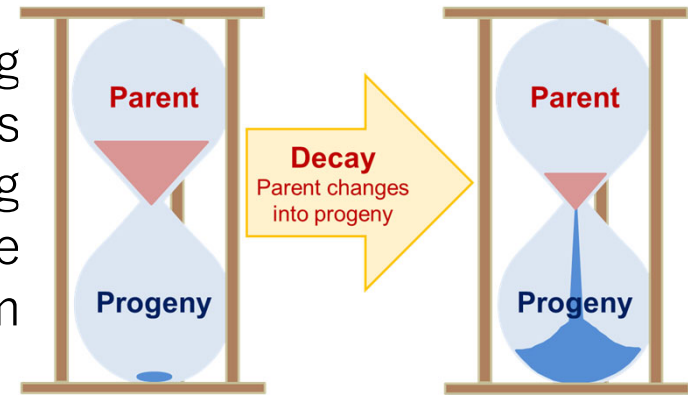
### Isotopic analysis

Determine the formation, thermal metamorphism, and aqueous alteration age

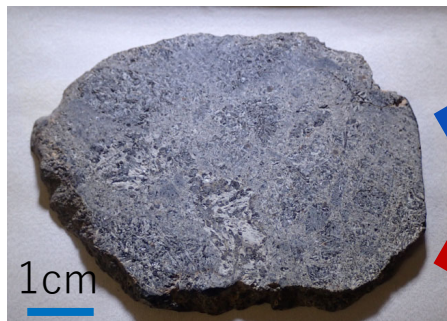
# Radiometric Dating of Rock Samples

## Radiometric dating

A method of dating rocks and minerals using radioactive isotopes. The method compares the abundance of a naturally occurring radioactive isotope within the material to the abundance of its decay products, which form at a known constant rate of decay.

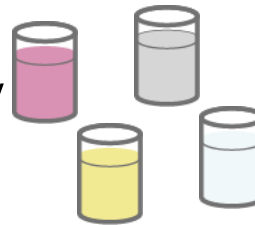


## Procedure of isotopic analysis



Sample

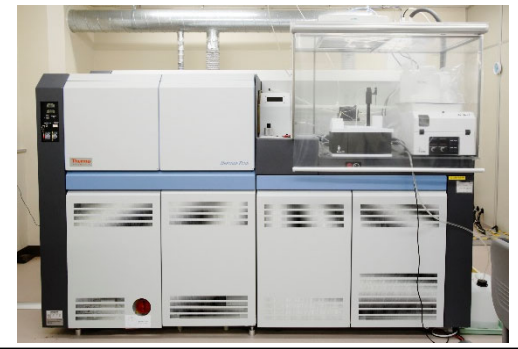
Wet  
chemistry



Local  
analysis



Mass spectrometry



# An Analytical Method by Using Laser System

LA-ICP-MS: Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry

A laser beam focused on the sample surface to generate fine particles – a process known as Laser Ablation. The ablated particles are transported to the excitation source of the ICP-MS instrument. The excited ions in the plasma torch are introduced to a mass spectrometer detector for both elemental and isotopic analysis.

Sample introduction (LA)

Transport tubing with carrier gas

ICP ion source/Mass spectrometer (ICP-MS)

**Advantages**

- Observable direct analysis
- Simple preparation
- Large quantity and multi-point measurements

**Disadvantages**

- Insufficient comprehension of phenomena at LA and ICP-MS site
- Difficulty in analytical correction

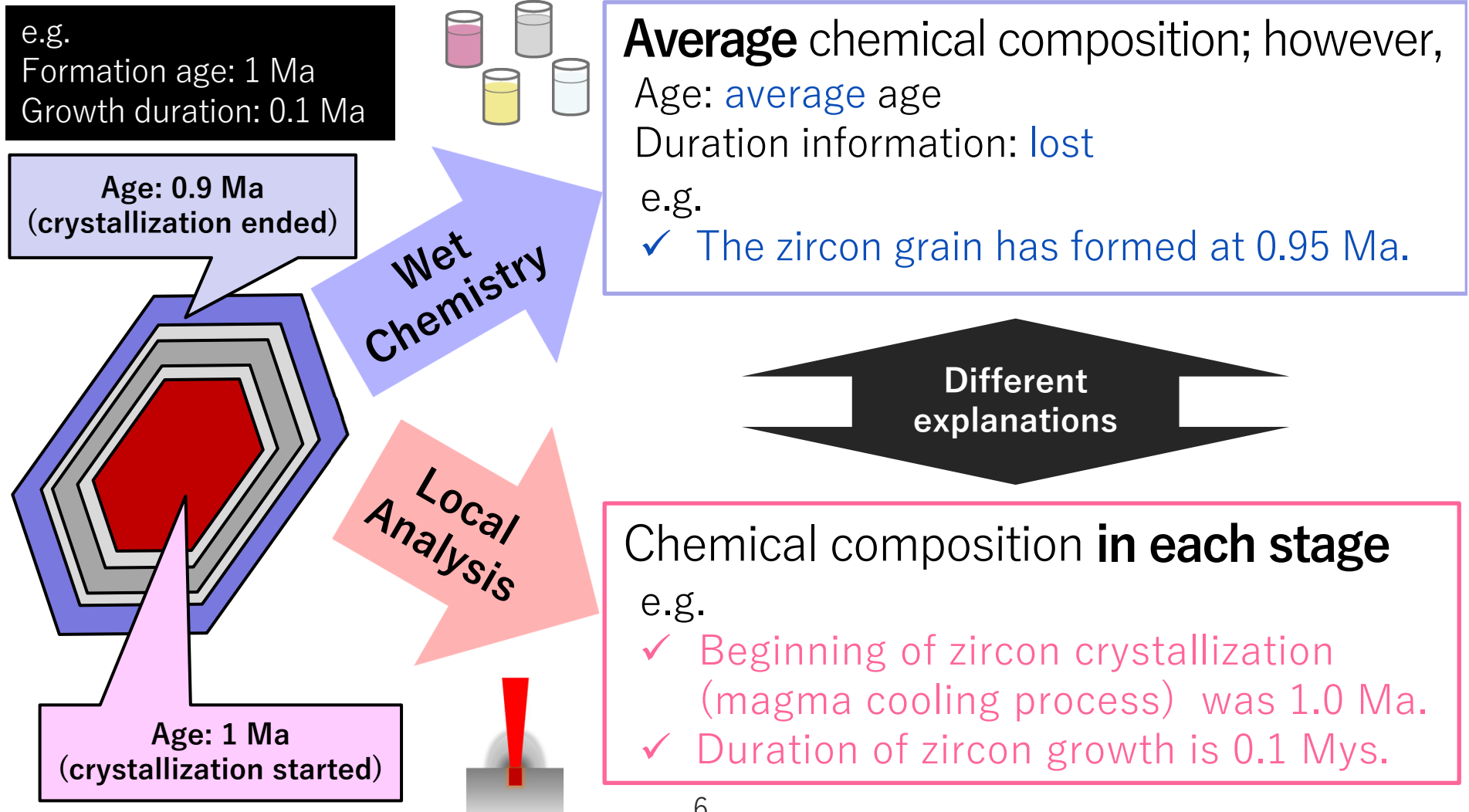
Craters formed by laser ablation  
dia.:  $30\ \mu\text{m}$   
depth:  $40\ \mu\text{m}$

5



# The Greatest Advantage of Local Analysis Methods

The local analysis method makes it possible to understand a past geological events in each stages.



# A geochronological case study by LA-ICP-MS



## Simultaneous determination of zircon U-Pb age and titanium concentration using LA-ICP-MS for crystallization age and temperature

Yuguchi et al., 2020

### Overview

Understanding cooling processes of magma, such as the time-temperature ( $t$ - $T$ ) path of plutonic rock, allows us to reveal the exhumation history of the plutonic rock body. This study contributes to **evaluating the regional uplift and erosion history of the plutonic rock body.**

### 【Zircon】

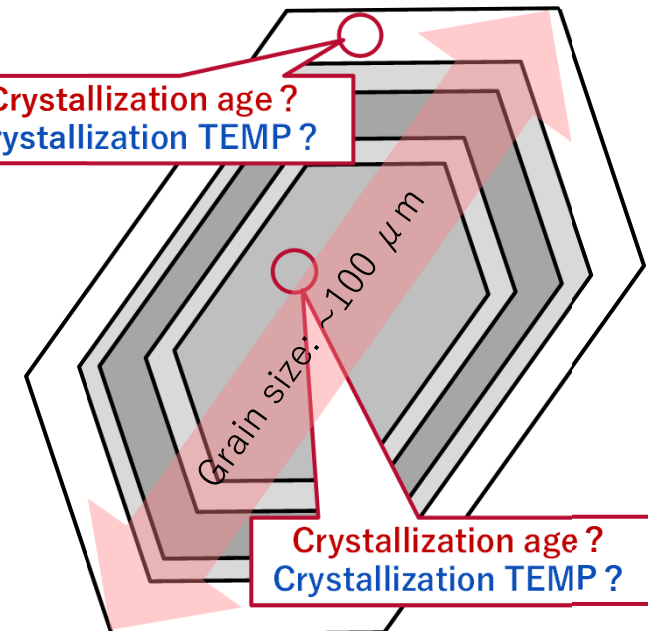
- ◆ Fairly hard and chemically stable
- ◆ Highly resistant to weathering
- ◆ Showing zonation

The crystallization age and TEMP pairs collected from individual zone of zircon enable us to characterize the cooling paths of rock bodies.

This study was carried out under a contract with the Ministry of Economy, Trade and Industry (METI), Japan, as part of its R&D supporting program titled 'Establishment of Advanced Technology for Evaluating the Long-term Geosphere Stability (FY2019)'

### Zircon crystal

Crystallization age?  
Crystallization TEMP?





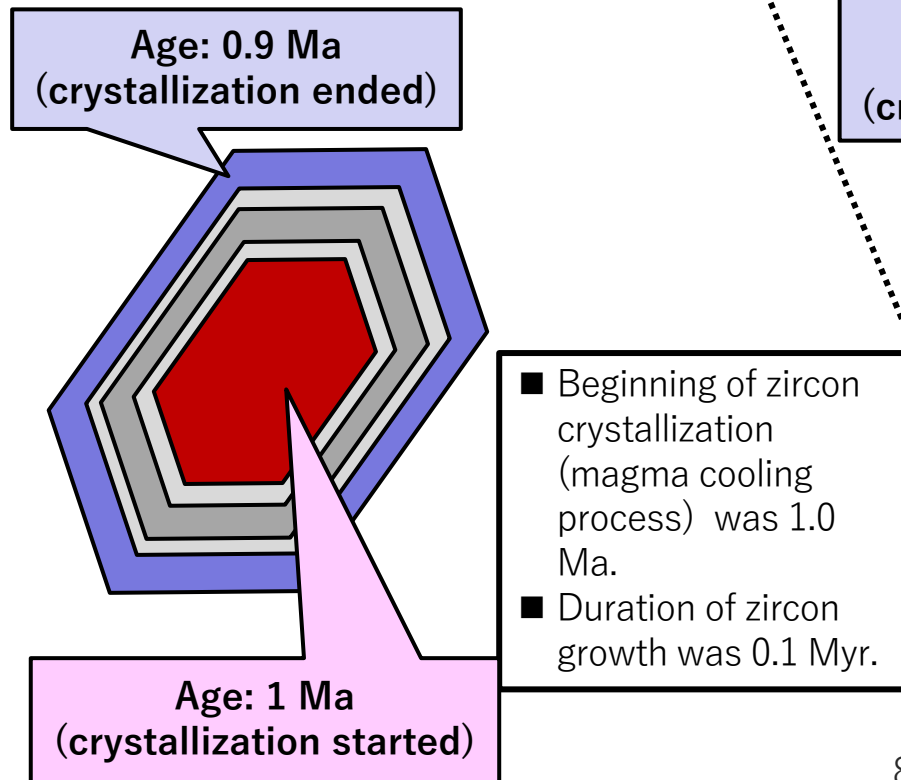
# A geochronological case study by LA-ICP-MS

## Analytical technique

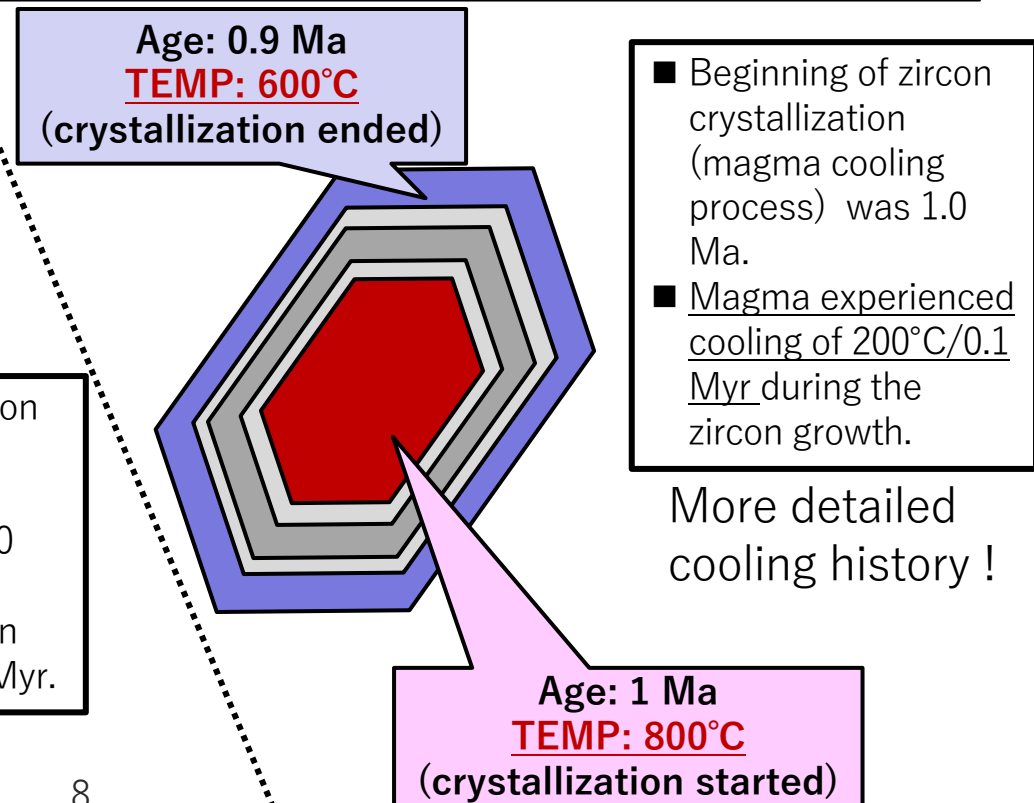
Simultaneous determination of U-Pb age and titanium concentration of zircon for a single spot gives

- ✓ U-Pb age : crystallization age
- ✓ Ti concentration: crystallization TEMP estimated by Ti-in-zircon thermometry

### Only crystallization age

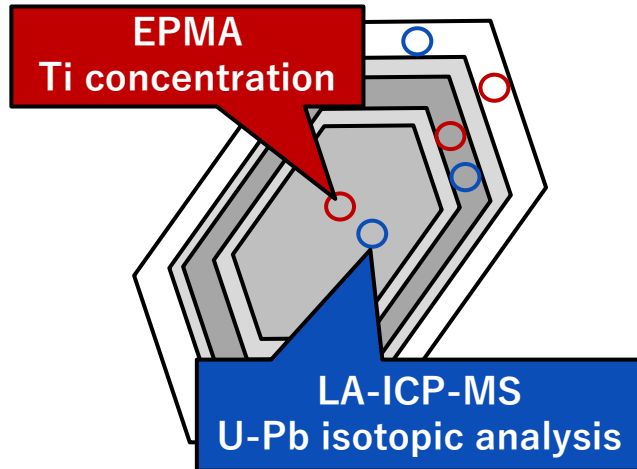


### Data-set of crystallization age and TEMP



# A geochronological case study by LA-ICP-MS

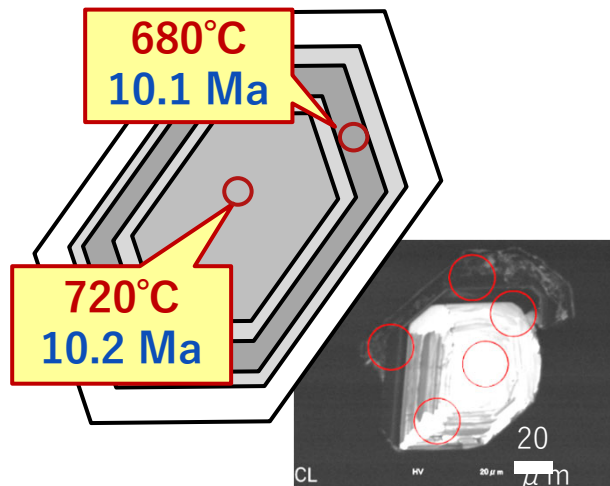
## Conventional technique



## Problems in conventional method

- ◆ The ablation pit for LA-ICP-MS cannot arrange the identical location to the analysis point for EPMA, and thus the U-Pb age (crystallization age) cannot be related directly with the titanium concentration (crystallization temperature).
- ◆ There are technical difficulties to analyse a low level of titanium concentration.

## Our new technique



Cathodoluminescence image of zircon grain

## Our new method

- ◆ This study presented the procedure and result of **simultaneous determination of** zircon U-Pb age and titanium concentration for a single pit on the LA-ICP-MS analysis.

Our new analytical technique contributes to evaluating of  $t$ - $T$  path of magma process.

Yuguchi et al. (2020), Lithos,373-373,105682

# Summary



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- ◆ In Tono Geoscience Center, we perform development of new analytical techniques for dating geological samples to provide scientific information concerning the long-term geosphere stability.
- ◆ The local analysis method such as LA-ICP-MS makes it possible to understand a past geological events in each stages.
- ◆ We developed an analytical technique for simultaneously determining zircon U-Pb age and titanium concentration for a single pit on the LA-ICP-MS analysis.



# Prospect towards the 4<sup>th</sup> Medium-/Long-Term Objectives

- ◆ In the nuclear energy field, the analytical techniques for dating have been developed and demonstrated by JAEA, and it is a fundamental technology for long-term safety assessment of geological disposal and fault investigation of nuclear facilities.
- ◆ We will continue to push forward R&Ds for geochronology with high specialty to lead the world in this field.

## Recent developments of analytical technique by LA-ICP-MS

- **Zircon U-Pb isotopic analysis**
- **Calcite U-Pb isotopic analysis (first trial of Japan, 2018)**
- **Zircon Hf Isotopic analysis**
- **Sr isotopic analysis (under development)**
- **Titanate U-Pb isotopic analysis (under development)**