EST. 2022

ORE GRADE PETROLOGY

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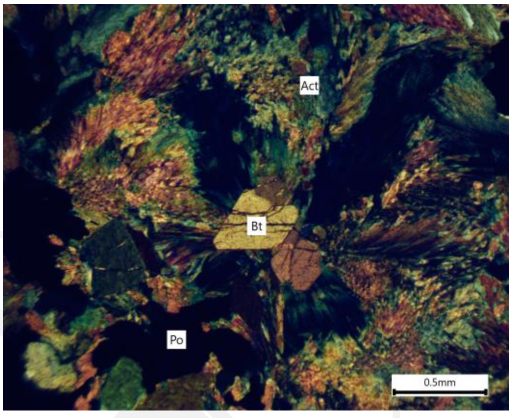
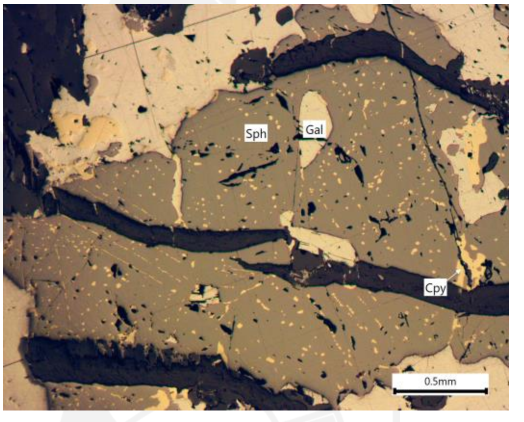
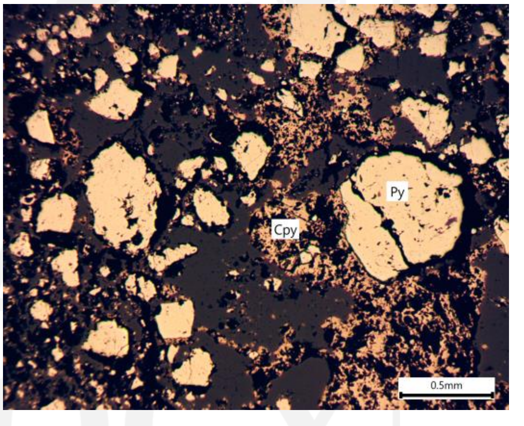
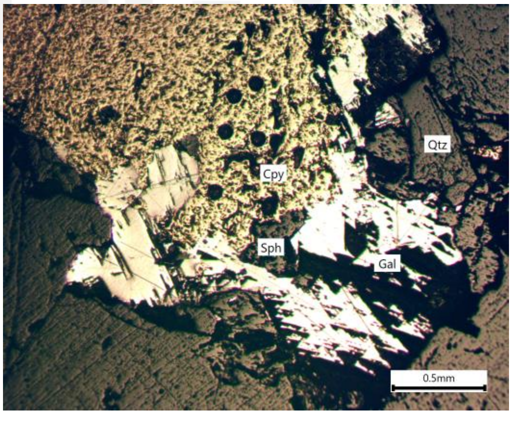
Guide to Ore Deposit Geochronology

2023 Geochronology Guide









U-Pb Geochronology

U-Pb Geochronology refers to using the uranium decay scheme to calculate the age of the mineral in question. Over time, ^{238}U decays to ^{206}Pb, ^{235}U decays to ^{207}Pb and ^{232}Th decays to ^{208}Pb. By measuring these isotopes, we can calculate the age of the mineral. The precision achievable by U-Pb dating via LA-ICP-MS is often ~1% of the calculated age. Please note the availability of each method varies between laboratories.

Minerals that can be dated via U-Pb geochronology include:

- Zircon
- Titanite
- Xenotime
- Monazite
- Apatite
- Hematite*
- Garnet (Andradite)
- Baddeleyite
- Calcite
- Rutile
- Cassiterite*
- Uraninite*
- Allanite
- Epidote*

**These options are considered niche and as a result very few laboratories have the capability of performing the methods.*

Special Considerations:

Apatite has a low closure temperature of (~350°C), which means that fine-grained apatite (>100 µm) produce geological ages that have been reset by a subsequent thermal event.

Monazite, titanite, uraninite and ***apatite*** are highly susceptible to resetting via dissolution and reprecipitation in the presence of fluids.

Titanite has a closure temperature of ~550°C, which means that in some cases, it is susceptible to resetting as a result of high temperature metamorphism.

Zircon is a resilient mineral which means that the ages provided by this mineral may be an inherited age representative of a previous geological event. Zircon geochronology should be accompanied with cathodoluminescence (CL) imaging.

Calcite often contains significant common-Pb and low concentrations of U. As a result, calcite U-Pb geochronology is often not suitable for samples older than 500 Ma. It is suggested that LA-ICP-MS maps are carried out prior to and U-Pb geochronology.

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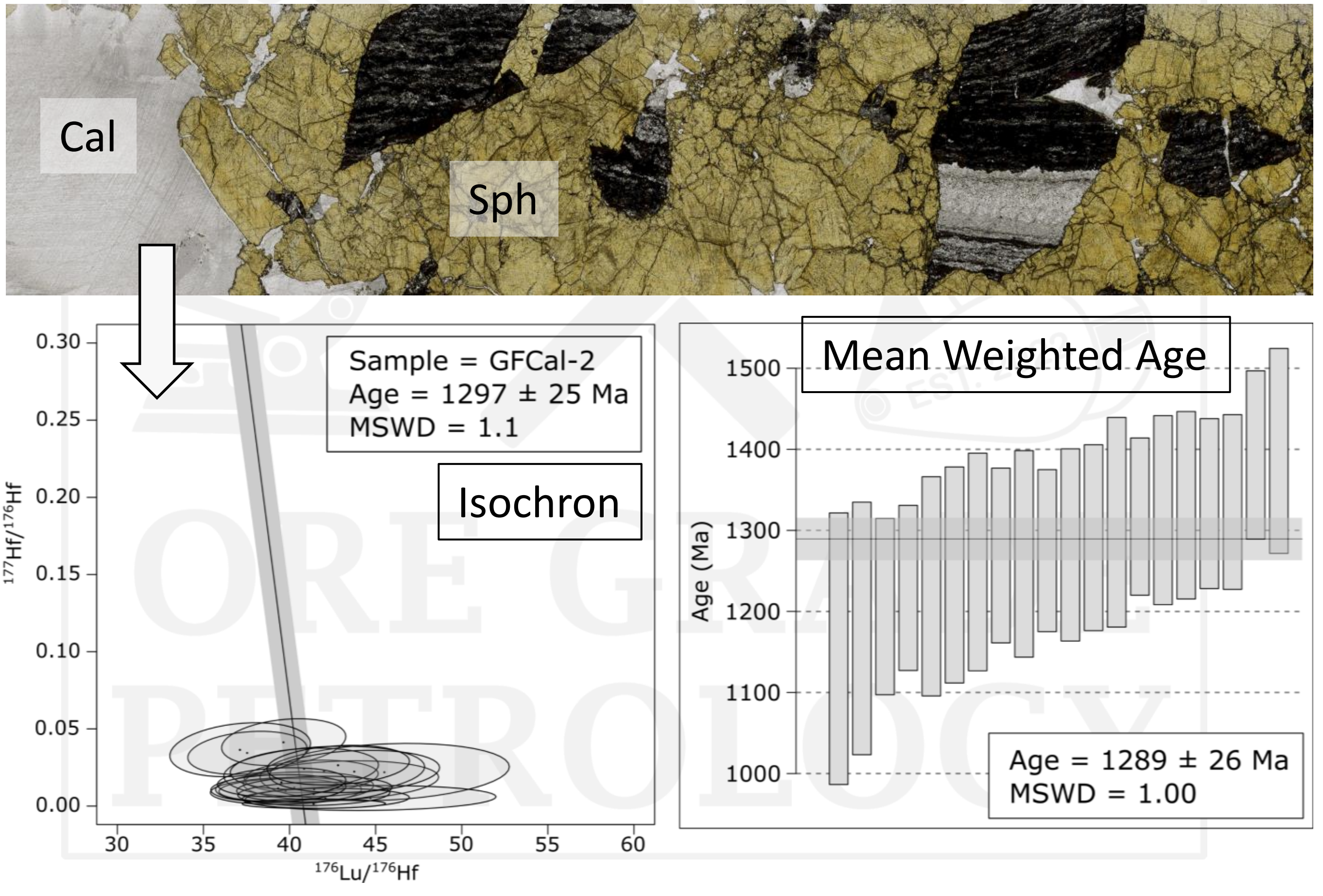
Lu-Hf Geochronology

In-situ Lu-Hf geochronology is a relatively new analytical technique that utilizes the decay scheme of ^{176}Lu to ^{176}Hf. Detailed information regarding this method is found in in Simpson et al (2021) and Simpson et al (2022). By measuring the appropriate isotopes, we can constrain the age of the mineral phase by using a multi-point isochron or mean weighted age (if there is only a small amount of common Hf).

Minerals that can be dated via Lu-Hf geochronology include:

- Xenotime
- Apatite
- Garnet
- Calcite



Special Considerations:
For the minerals to be datable by this method, they must contain adequate Lu (typically >2 ppm) concentrations. Furthermore, a spread in the Lu-Hf ratio is required to produce a reliable geochronological age for apatite, garnet and xenotime. The precision of this technique will vary depending on the age of the sample, the number of successful analyses, and the spread in Lu-Hf data. This method is most suitable for older samples (>0.5 Ga).

Re-Os Geochronology

In-situ Re-Os geochronology utilizes the decay scheme of ^{187}Re to ^{187}Os. Re-Os geochronology can be performed using the conventional ID-TIMS method or the recently developed LA-ICP-MS/MS method. Conventional Re-Os geochronology requires extensive preparation and analyses using this method typically takes 6-12 months. In-situ LA-ICP-MS/MS is currently under development at various laboratories and allows data to be obtained within hours (Hogmalm et al, 2019). The Re-Os age is constrained using an isochron or mean weighted age (molybdenite).

Minerals that can be dated via U-Pb geochronology include:

- Pyrite
- Molybdenite
- Sphalerite
- Chalcopyrite
- Galena
- Arsenopyrite

Special Considerations:

- *Molybdenite is the only mineral suitable for in-situ Re-Os geochronology.*
- *The Re-Os system is prone to resetting via fluid-aided alteration and therefore the minerals pyrite, sphalerite, chalcopyrite, galena and arsenopyrite are not suitable for constraining the age of metamorphosed ore deposits or deposits that have experienced post-mineralisation fluid flow.*

Molybdenite

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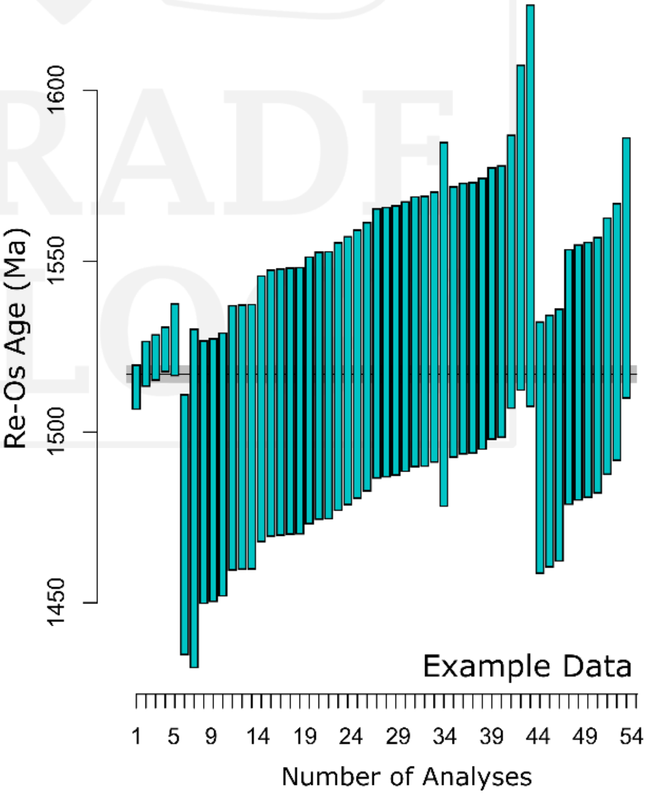


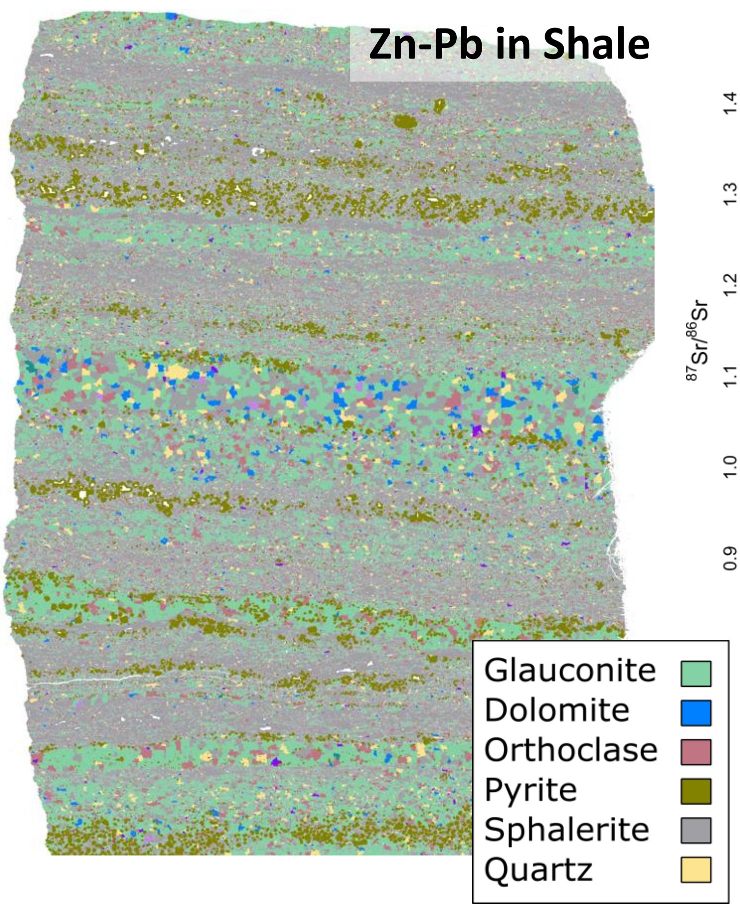
Rb-Sr Geochronology

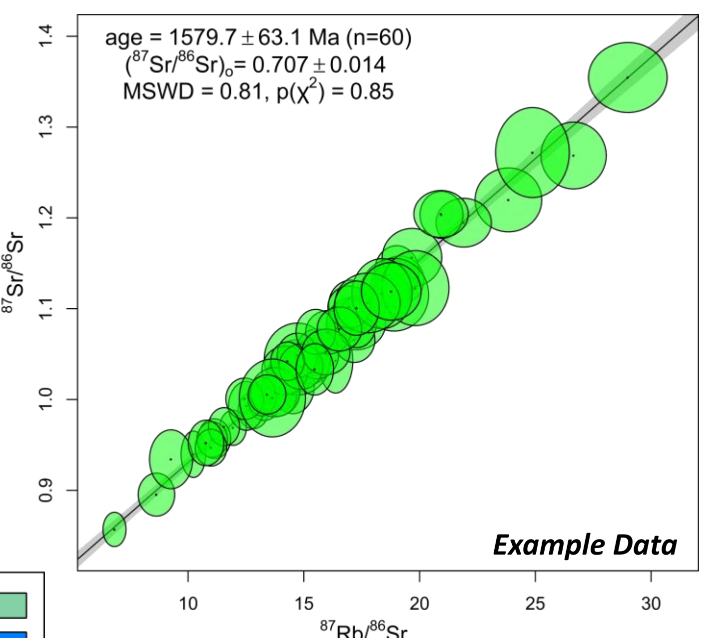
In-situ Rb-Sr geochronology is a relatively new in-situ analytical technique that utilizes the decay scheme of ^{87}Sr to ^{87}Rb. Detailed information regarding this method is published in Reda et al (2021), Subarkah et al (2021) and Wang (2022). By measuring these isotopes, we can constrain the age of the mineral phase using a multi-point isochron. This technique works on a variety of common K-bearing minerals depending on the standards available to each laboratory. A precision of ~5% of the calculated age is generally associated with this method. However, the precision varies with the age of the sample, the amount of Rb and the spread in Lu-Hf ratios.

Minerals that can be dated via Rb-Sr geochronology include:

- K-feldspar
- Biotite
- Muscovite
- Sericite
- Chlorite
- Illite
- Phengite
- Glauconite
- Shale (High Re minerals required)

Analyses from a variety of the minerals listed above are typically used to constrain the Rb-Sr isochron. Matrix matched standards are unavailable for many of these minerals.





Rb-Sr geochronology has previously been completed on sphalerite, galena and pyrite. However, Rb-Sr geochronology on these minerals is relatively uncommon.

Ar-Ar & K-Ar Geochronology

The Ar^{40}-Ar^{39} and K^{40}-Ar^{40} geochronology techniques utilize the decay of naturally occurring ^{40}K to ^{40}Ar which has a half life of 1.25 Ga. These techniques typically produce an age in which the sample became closed to the isotopic exchange of ^{40}K and ^{40}Ar loss (closure temperature). The closure temperature is different for each mineral and ranges from approximately 500°C to 300°C. Analyses using this method typically takes between 6-12 months. A precision of ~0.5% of the calculated age is generally associated with this method. For more information on these techniques, see Schaen et al 2020.

Minerals that can be dated via Ar-Ar & K-Ar geochronology include:

- Hornblende
- Biotite
- Muscovite
- Phengite
- Clinopyroxene*
- Orthopyroxene*
- Osumilite*
- K-Feldspar

**Only Ar^{40}-Ar^{39} geochronology has been successfully performed on these minerals.*

Biotite

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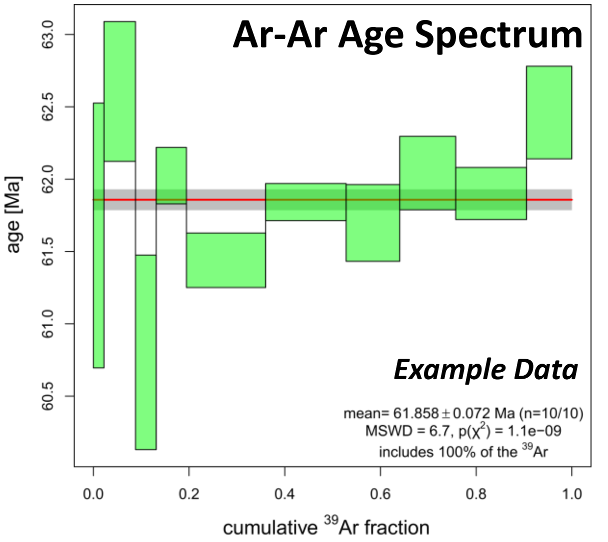

K-feldspar

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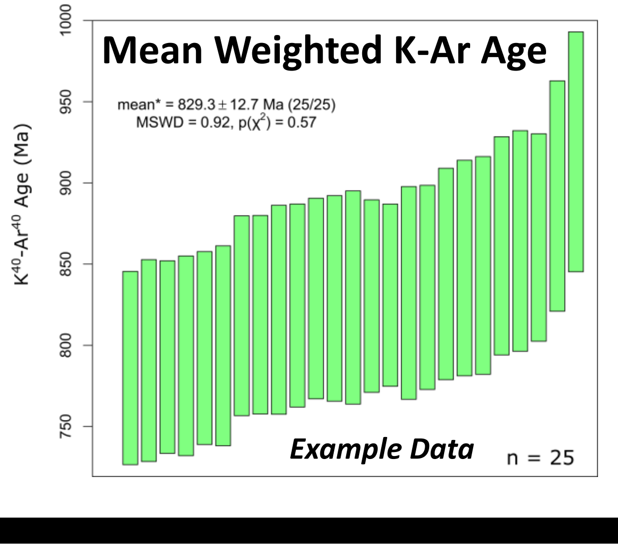

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