RADIOMETRIC DATING, AS A RELIABLE CLOCK OF THE GEOLOGY

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RELATIVE AGE OF THE GEOLOGICAL EVENTS
PRINCIPLES OF K-Ar DATING

$^{40}\text{K} \xrightarrow{\text{electron capture}} ^{40}\text{Ar}$  \hspace{1cm} $T_{1/2} = 1.25 \times 10^9 \text{ year}$

$^{40}\text{Ar}_{\text{rad}} = ^{40}\text{Ar} - 295.5 \times ^{36}\text{Ar}$

$t = \frac{1}{\lambda} \ln \left[ 1 + \frac{\lambda}{\lambda_c} \frac{\text{Ar}_{\text{rad}}^{40}}{\text{K}^{40}} \right]$
1. The rock/mineral was a closed system for K and Ar since the time of formation.

2. At the time of formation the $^{40}\text{Ar}/^{36}\text{Ar}$ ratio was atmospheric.

3. The rock became a closed system in a short time.
EXPERIMENTAL METHODS

- K determination: flame photometry with lithium internal standard
- Ar determination: conventional K/Ar dating
  - High frequency induction heating
  - Isotope dilution method with $^{38}\text{Ar}$ spike
  - Mass spectrometry used in static mode
- Analytical error are given $\pm 1\sigma$ (68% confidence level)
- Age calculation: decay constants given by Steiger and Jäger (1977)
Mágneses tér

Szelep (zárva)

Ionforrás

Szelep

NEG szív.

Faraday kalitka (vagy sokszorozó)

Ultravákuum
Under certain conditions the age equation may give the time of a significant geologic event

1. At one time the Ar content of the rock was fully removed
2. Since then the rock was closed for Ar and K

How can we know, if these conditions were fulfilled or not?

There is no guarantee.

More minerals must be dated and agreement of their ages has be considered.

Reasons of disagreement of geological and K/Ar ages.
Any potassium-bearing mineral is potentially suitable for K-Ar age determination. However, because of their ability to retain radiogenic argon quantitatively, certain minerals have proven superior to others. Below is partial list of those minerals of widest applicability.

**Minerals**

**Micas:**
- Muscovite
- Biotite
- Phlogopite
- Lepidolite
- Sericite
- Illite
- Glauconite

**Amphiboles:**
- Hornblende

**Feldspars:**
- Sanidaine
- Adularia
- Plagioclase

**Feldspathoids:**
- Leucite
- Nepheline

**Sulfates**
- Alunite
- Jarosite

**Whole rocks:**
- Basalt/andesite
- Glassy or fine grained volcanics
- Slates
- Phyllites
- Fine-grained schists
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<th>Volcanic</th>
<th>Hypabyssal and plutonic</th>
<th>Metamorphic</th>
<th>Sedimentar</th>
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<td><strong>Evaporites</strong></td>
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*a* Expanded from Dalrymple and Lanphere (1969)

*b* Wide application

c Useful for provenance studies

d Not generally useful for $^{40}$Ar/$^{39}$Ar dating

e Useful in some circumstances
I. Magmatic rocks

Volcanites. Lava rocks, dykes can be used as whole rocks. Pyroclastics can be dated using their minerals, or their once molten components (bombs, blocks). Since cooling is fast, K/Ar age gives the time of volcanic activity.

Plutonic rocks. Due to perthization, use of feldspars is not suggested. Amphiboles, micas are suitable. The K/Ar age gives the time of cooling down.

II. Metamorphic rocks

Under metamorphic conditions most minerals lose their Ar content: K/Ar age gives the time of cooling down, i.e. it postdates metamorphism.

By dating minerals of different closure temperatures, the rate of cooling down (and the rate of uplift) can be calculated.
III. (Ore)-mineralization processes
The newly formed minerals can be dated directly, if they contained K (e.g. alunite, apophyllite, cryptomelane, illite).
K/Ar age of altered minerals of the host rock may give the time of the process.
Minerals formed on the contact can be dated.

IV. Sedimentary rocks
Usually these can not be dated, it can be tried with glauconite.
Dating of illite is very useful. It can be formed below its closure temperature. In this case we obtain a mixture of detrital illite and newly formed illite ages. Temperature of illite formation very from ~60 to 400 °C, pending on the concentration of fluids. Illite ages can be related to the time of fluid migration.
EXAMPLES OF DATED MINERAL FRACTIONS FROM A RECENT WORK ON RHYOLITES
Sanidine – magmatic phase

Subsolidus K-feldspar in groundmass

Biotite and amphibole phenocrysts

Spherulitic groundmass
Felsitic groundmass

Adularia replacing plagioclase

Rhyolitic glass

Adularia and sericite in groundmass

Dating hydrothermal process
TECHNICAL ASPECTS

- Sampling on the field: rocks without weathering and alteration
- Crushing, sieving and drying
- Defining the proper grain size of the sample
- Mineral separation based on the petrographic and minerologic information
- Checking the purity of the mineral fraction and improvement by hand-picking
Milling, sieving to grain-size fractions
Fractions: 0.6-0.4, 0.4-0.25 and 0.25-0.125 mm

Electromagnetic separation
Nonmagnetic, weakly / strongly paramagnetic fractions

Heavy liquid
Biotite, amphibole > 2.82 g.cm⁻¹
Plagioclase, quartz > 2.6 g.cm⁻¹
K-feldspar, glass < 2.6 g.cm⁻¹

Final improvement of purity
Shaking (biotite/amphibole+pyroxene)
Handpicking (purification under binocular microscope)
<table>
<thead>
<tr>
<th>Adularia concentrate</th>
<th>Spherulitic groundmass</th>
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<tr>
<td>Adularized groundmass</td>
<td>Biotite</td>
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<tr>
<td>Rhyoilitic glass</td>
<td>Amphibole</td>
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</table>
APPLICATIONS AND CASE HISTORIES

- Regional and Tectonic Studies
- Stratigraphy (Time Scale of Central Paratethys) and Diagenesis
- Economic Geology
- Reconstruction of the evolution of volcanic activity on different volcanic fields
- Geochronological study of different metamorphic events
CASE HISTORIES

- Geochronology of Neogene-Quaternary magmatism in the Carpathian arc and Intra-Carpathian area
- Relationships of calc-alkaline magmatism and epithermal systems in the Western Carpathians: K/Ar dating of volcanic and hydrothermal processes
- Timing of intrusive magmatism in the Carpathian Pannonian Area
- Space and time distribution of alkaline basaltic volcanism in the CPR
GEOLOGICAL AND ANALYTICAL ERRORS: INTERPRETATION OF THE RADIOMETRIC AGES

An hourglass illustrates an ideal closed system

$$N_0 = N + D$$
$$N = (N + D)e^{-\lambda t}$$
$$t = \frac{1}{\lambda} \times \ln(1 + D/N)$$
Analytical error is given at 68% confidence level (1σ). We use equation of Cox and Dalrymple (1967)

\[
\sigma = \left[ (\sigma_k)^2 + (\sigma_x)^2 + (\sigma_{38}^{40})^2 \left( \frac{1}{r} \right)^2 + (\sigma_{36}^{38})^2 \left( \frac{1-r}{r} \right)^2 \right]^\frac{1}{2}
\]

- \( \sigma_k \) – relative error of K-concentration = 2%
- \( \sigma_x \) – relative error of \(^{38}\text{Ar}\) spike = 2%
- relative error of isotope ratio = 1%
- relative error of isotope ratio = 1%
- \( r \) – percentage of \(^{40}\text{Ar}_{\text{rad}}\) in \(^{40}\text{Ar}_{\text{total}}\) in rock.
Plot showing how the error in the measurement of radiogenic argon increases exponentially as its proportion relative to the total argon decreases toward zero. Based upon formula derived by Baksi et al. (1967). In the calculations the curves. Errors are standard deviations expressed as a percentage. These curves relate to argon measurement by isotope dilution, but very similar relations hold for the $^{40}\text{Ar}/^{39}\text{Ar}$ dating technique.
The amount of $^{36}\text{Ar}$ is supposed to be consistent, so we may multiply I. e. 1 with it:

$$\left( e^{2\lambda t} - 1 \right) \frac{\lambda_e}{\lambda} 40\text{K} + 40\text{Ar}_0 = 40\text{Ar}_p$$

(I. e. 2.)

That is samples, for which the original excess $^{40}\text{Ar}$-$^{40}\text{K}$ coordinate system. The fitted straight lines are called „isochrons”. The slope of the isochrones is proportional with the age, their intercept with the y axis gives the original $^{40}\text{Ar}/^{36}\text{Ar}$ ratio or the $^{40}\text{Ar}$ content. Isocron methods are most important when dating young basalts.
How to obtain samples with highly differing Potassium concentrations from a rock body?

The method suggested by Fitch et al. (1976) has been used:

Rock fractions have been prepared from a single piece of rock by magnetic and heavy liquid separation.

The fractions are not monomineralic, but differ in their mineral composition.
THANK YOU FOR YOUR ATTENTION!