RADIOMETRIC DATING, AS A RELIABLE CLOCK OF THE GEOLOGY

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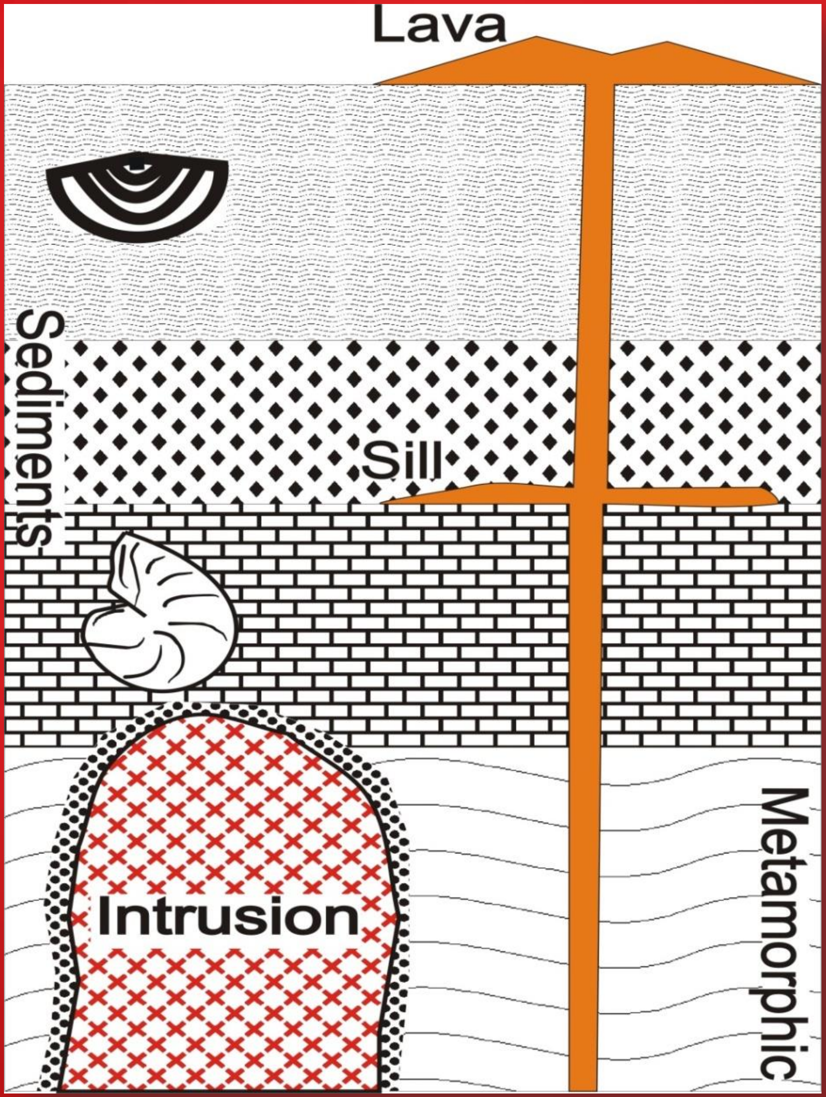
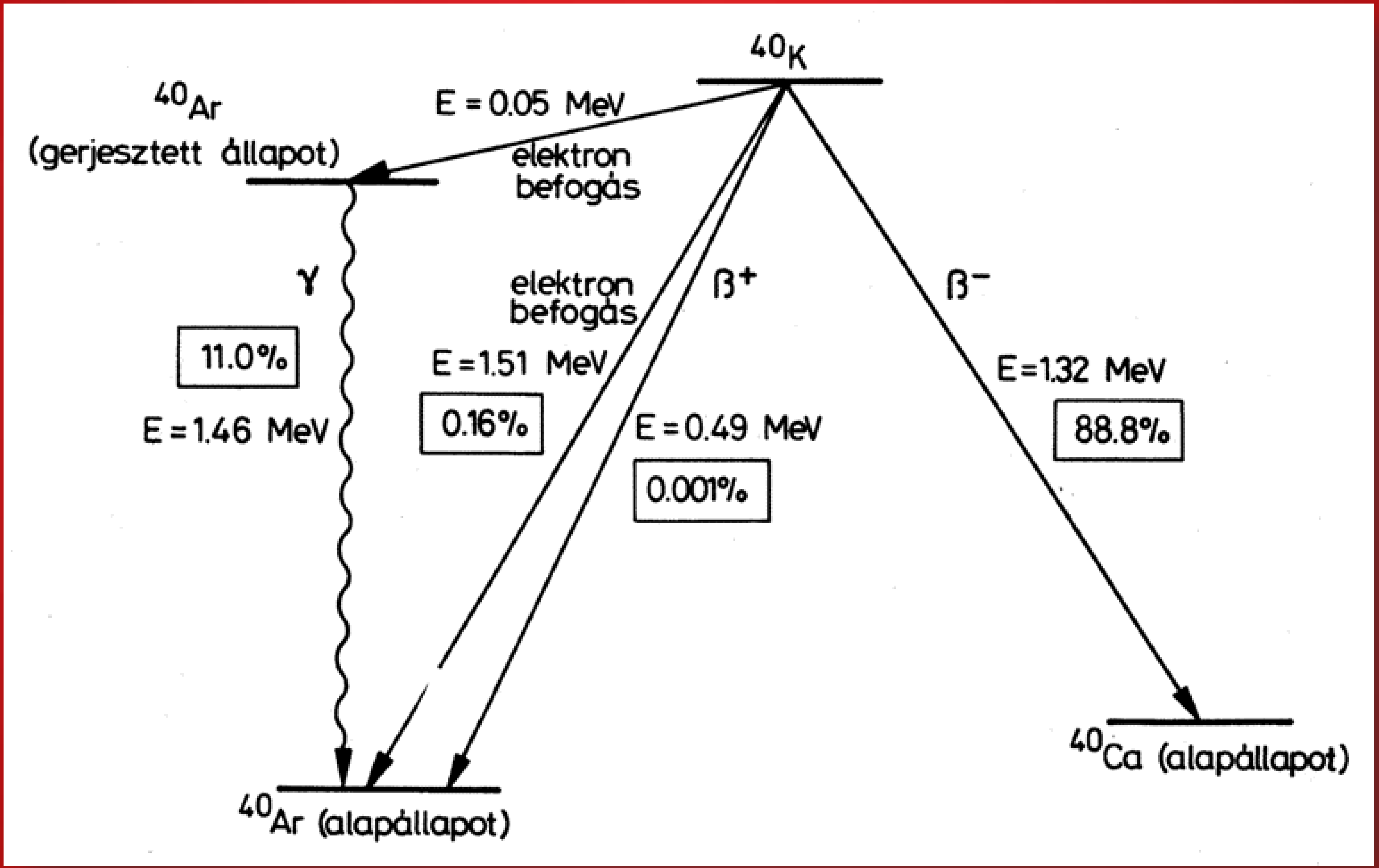
- INTERPRETATION OF RESULTS: GEOLOGICAL- AND ANALYTICAL ERRORS

RELATIVE AGE OF THE GEOLOGICAL EVENTS

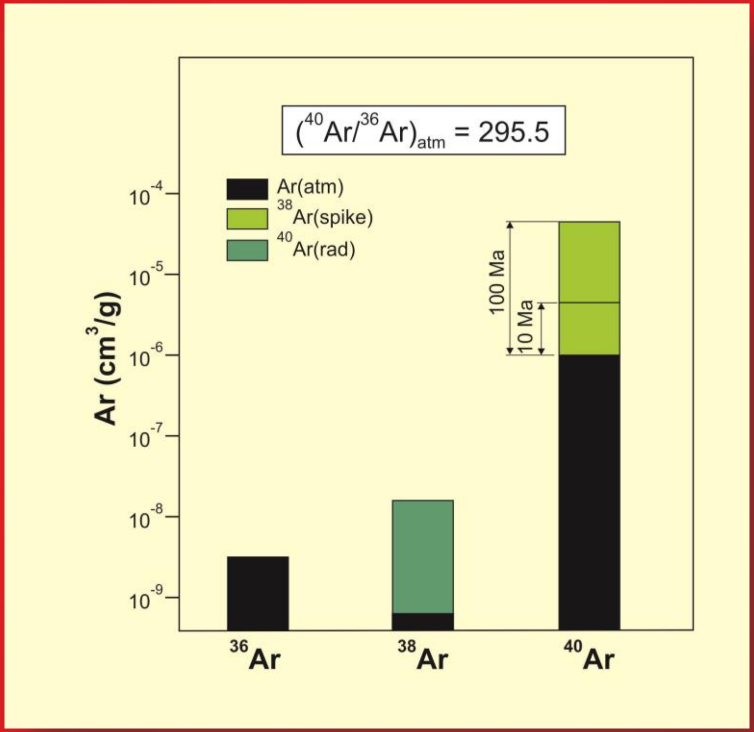




40K
40Ar
(gerjesztett állapot)
E = 0.05 MeV
elektron
befogás
γ
11.0%
E = 1.46 MeV
elektron
befogás
E = 1.51 MeV
0.16%
β+
E = 0.49 MeV
0.001%
β−
E = 1.32 MeV
88.8%
40Ar (alapállapot)
40Ca (alapállapot)

PRINCIPLES OF K-Ar DATING

$$^{40}K \xrightarrow{\textit{electron capture}} {}^{40}Ar \qquad T_{1/2} = 1.25\times10^{9}\ \text{year}$$



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

$$t = \frac{1}{\lambda}\ln\left[1+\frac{\lambda}{\lambda_e}\frac{^{40}Ar_{rad}}{^{40}K}\right]$$

FUNDAMENTAL ASSUMPTIONS

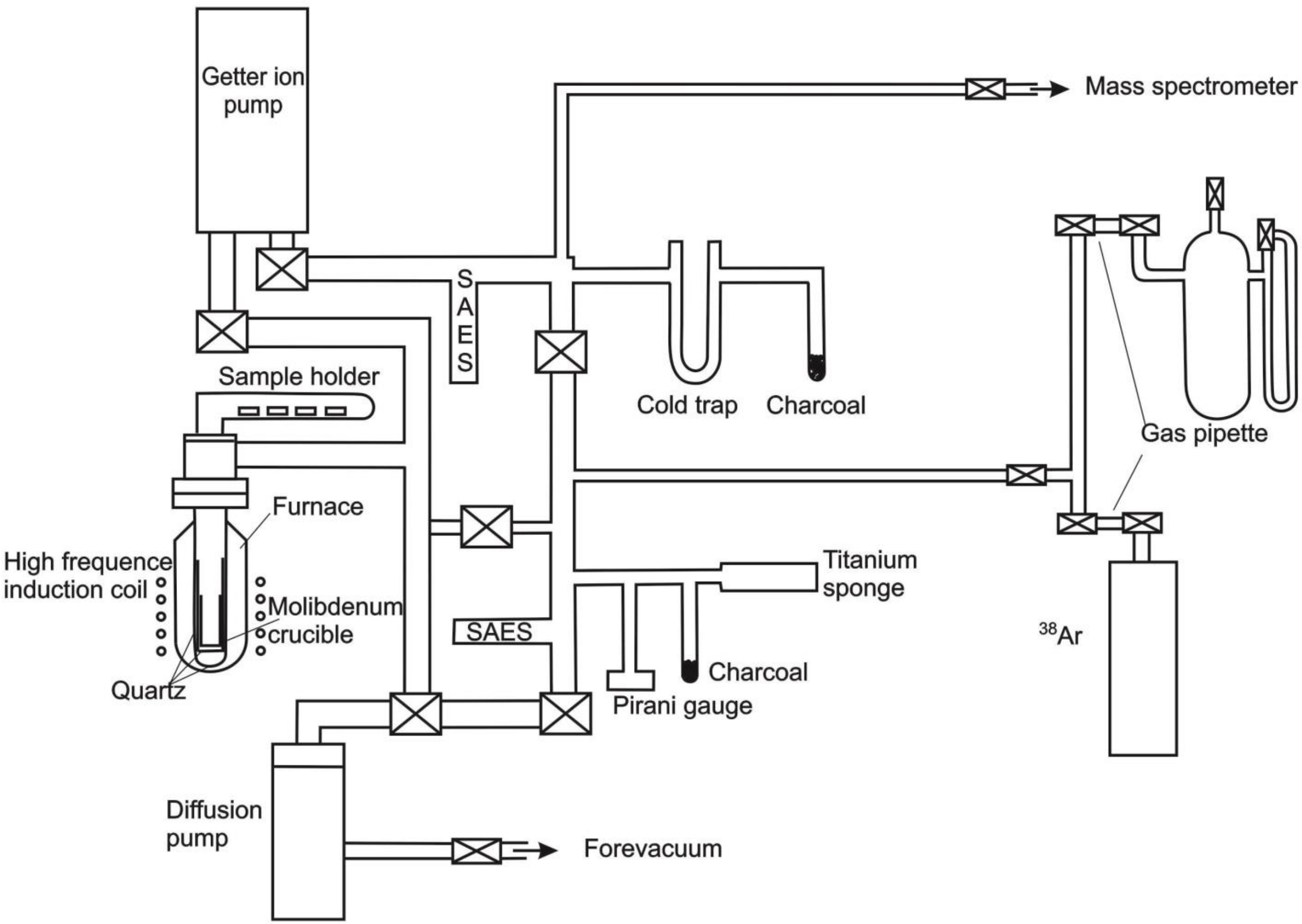
1. THE ROCK/MINERAL WAS A CLOSED SYSTEM FOR K AND Ar SINCE THE TIME OF FORMATION

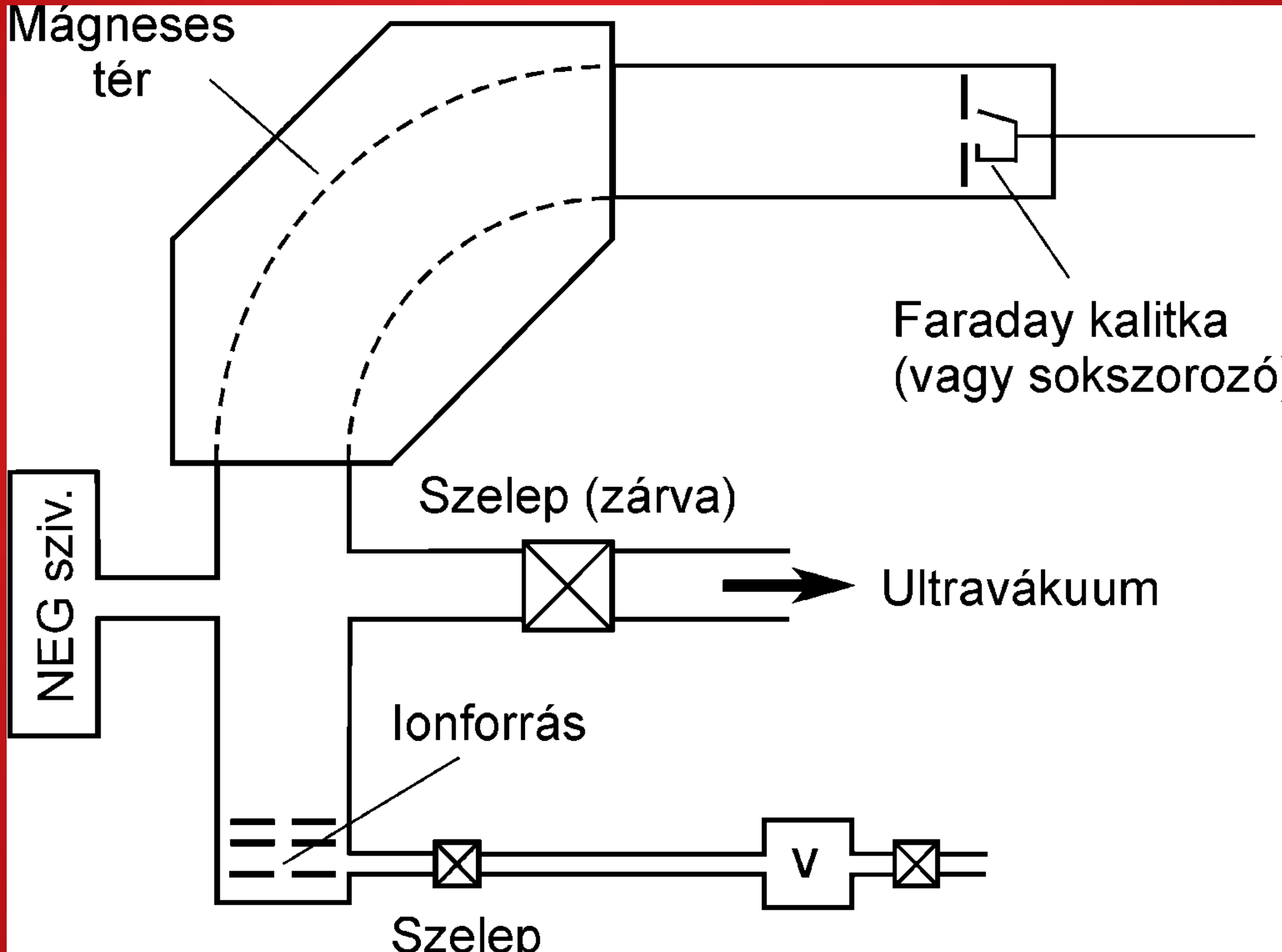
2. AT THE TIME OF FORMATION THE $^{40}Ar/^{36}Ar$ RATIO WAS ATMOSPHERIC

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}Ar spike
  - Mass spectrometry used in static mode
- Analytical error are given ±1σ (68% confidence level)
- Age calculation: decay constants given by Steiger and Jäger (1977)


Getter ion pump
Mass spectrometer
SAES
Sample holder
Cold trap
Charcoal
Gas pipette
Furnace
High frequence induction coil
Molibdenum crucible
Quartz
SAES
Titanium sponge
Charcoal
Pirani gauge
^{38}Ar
Diffusion pump
Forevacuum


Mágneses
tér
Faraday kalitka
(vagy sokszorozó)
NEG sziv.
Szelep (zárva)
Ultravákuum
Ionforrás
V
Szelep

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.

MATERIALS SUITABLE FOR ANALYSIS

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:
- **Sanidine**
- **Adularia**
- **Plagioclase**

Feldspathoids:
- **Leucite**
- **Nepheline**

Sulfates
- **Alunite**
- **Jarosite**

Whole rocks:
- **Basalt/andesite**
- **Glassy or fine grainded volcanics**
- **Slates**
- **Phyllites**
- **Fine-grained schists**

COMMONLY UTILIZED MATERIALS FOR K-Ar AND $^{40}Ar/^{39}Ar$ DATING AND ROCK TYPES IN WHICH THEY occur[a]

	Rock type			
	Volcanic	Hypabyssal and plutonic	Metamorphic	Sedimentar
Feldspars				
High-temperature				
Alkali feldspar	b			
Low-temperature				
Alkali feldspar		b	b	c
Plagioclase	b	b	b	
Feldspathoids				
Leucite	b	b		
Nepheline	b	b		
Mica				
Biotite	b	b	b	c
Phlogopite			b	
Muscovite		b	b	c
Phengite			b	
Lepidolite		b		
Glauconite				d
Amphibole	b	b	b	
Pyroxene	e	e		
Whole rock	b		e	
Volcanic glass	d			
Clays				c,d
Evaporites				d

[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

DATING OF DIFFERENT ROCK TYPES

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). Sine 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 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 formd 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.

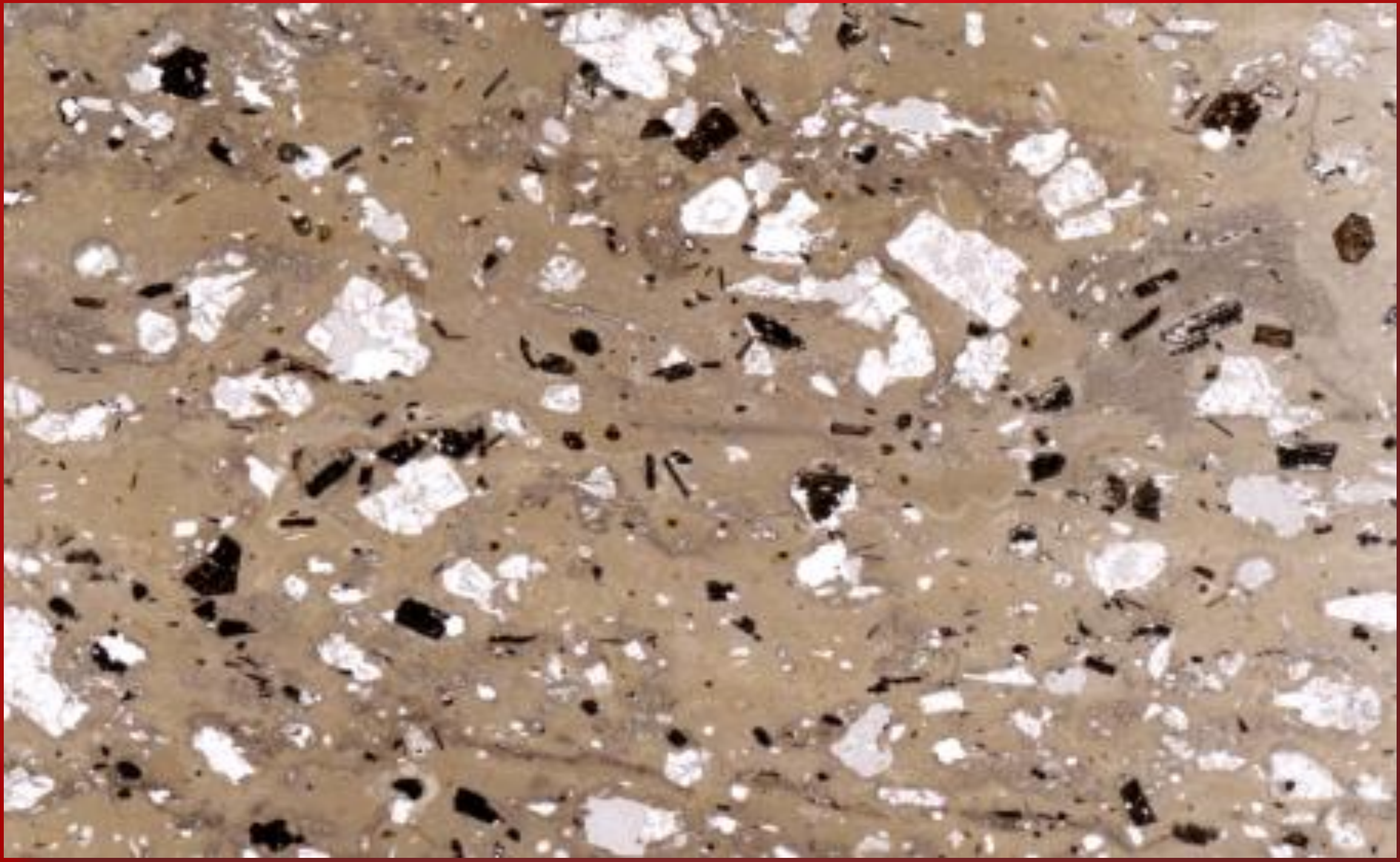
Minerals formed on the contact can be dated.

IV.Sedimentary rocks

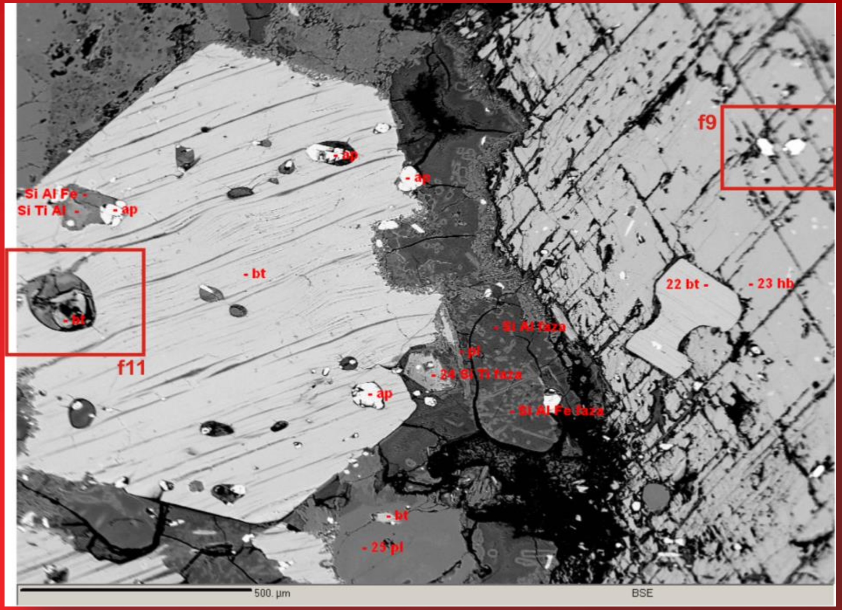
Usually these can not be dated, it can be tried with glauconite.

Dating of illite is very useful. It can be formed below its closure temperature. In this case we obrain 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

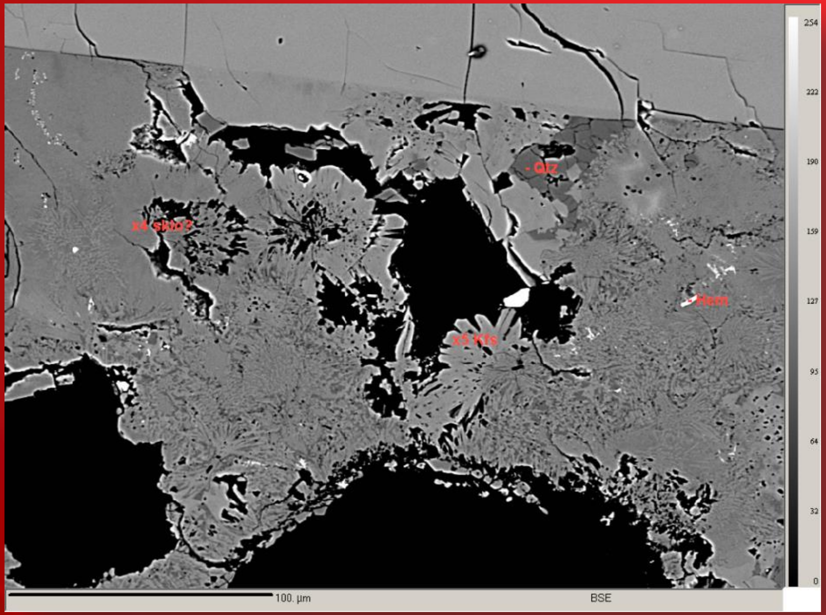


Sanidine – magmatic phase

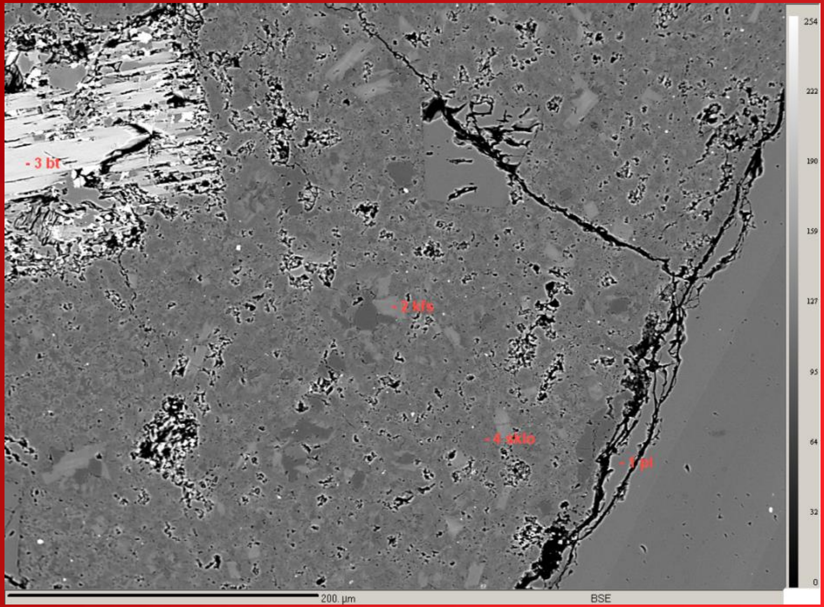


Biotite and amphibole phenocrysts

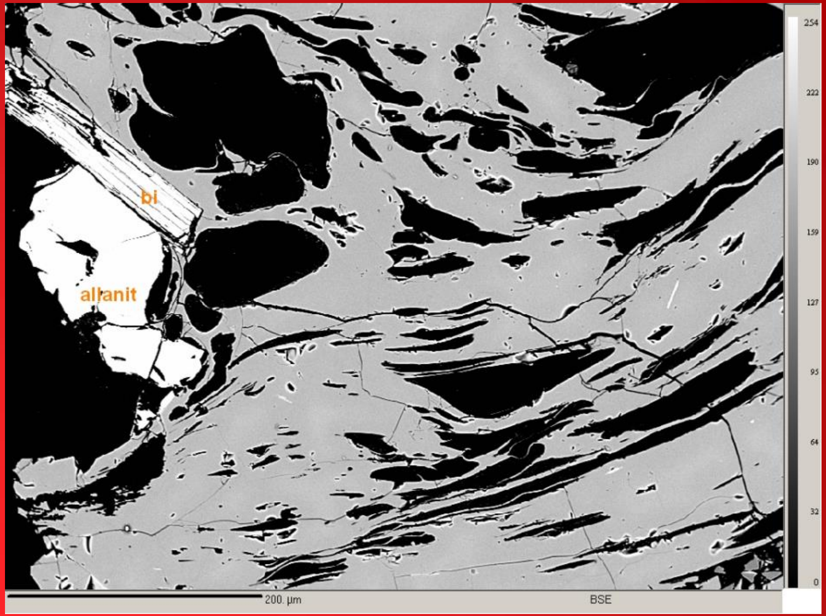
Subsolidus K-feldspar in groundmass



Spherulitic groundmass

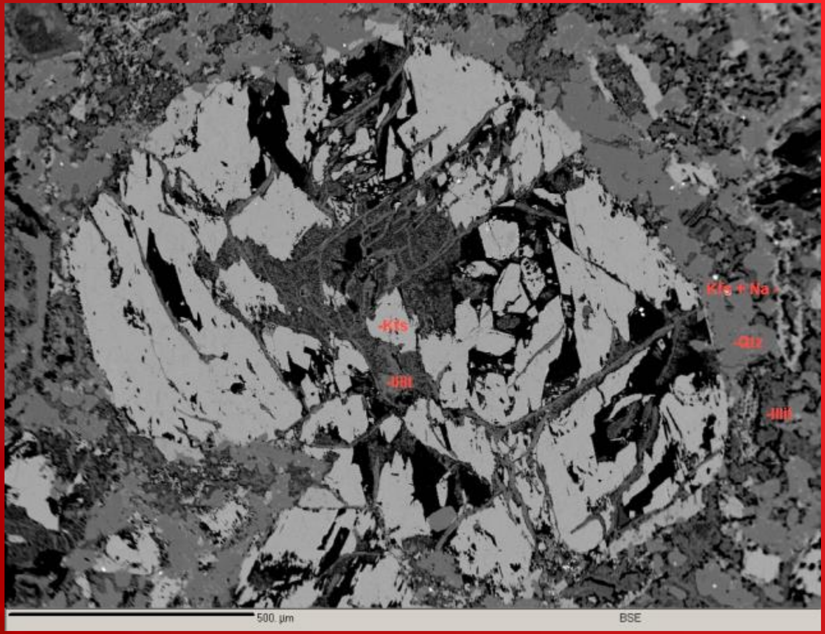


Felsitic groundmass

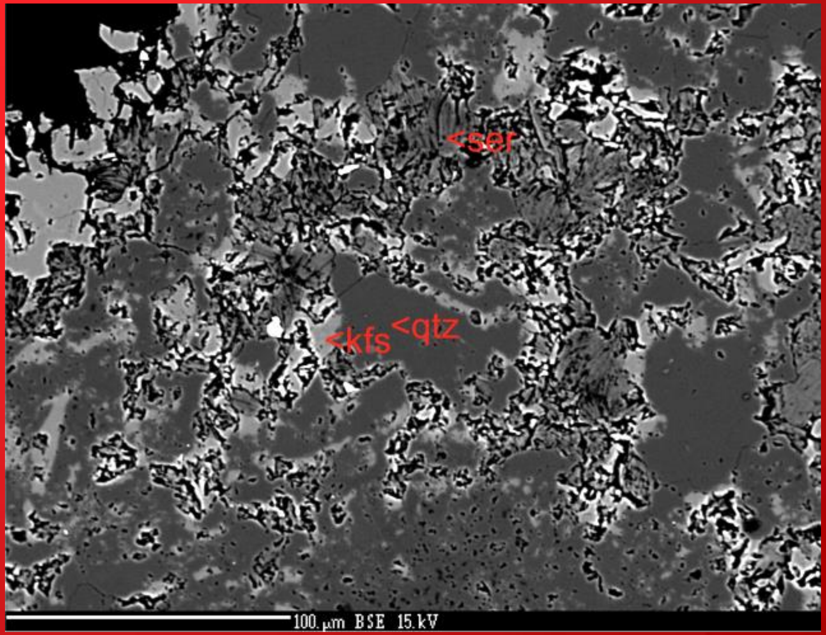


Rhyolitic glass

Adularia replacing plagioclase



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**

MINERAL SEPARATION

Milling, sieving to grain-size fractions

Fractions: 0,6-0,4, 0,4-0,25 and 0,25-0,125 mm

Electromagnetic separation

Nonmagnatic, 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}

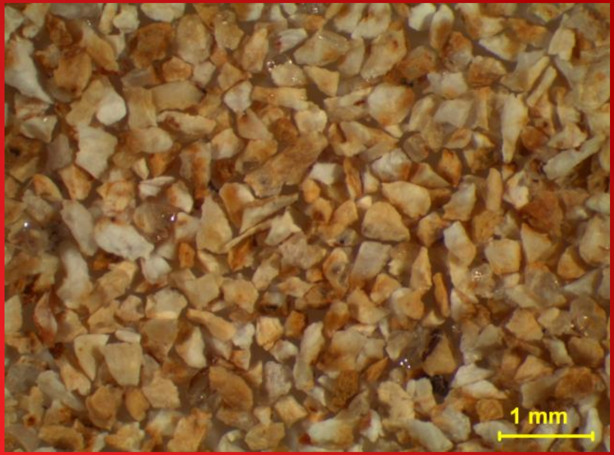
Final improvement of purity

Shaking (biotite/amphibole+pyroxene)

Handpicking (purification under binocular microscope)

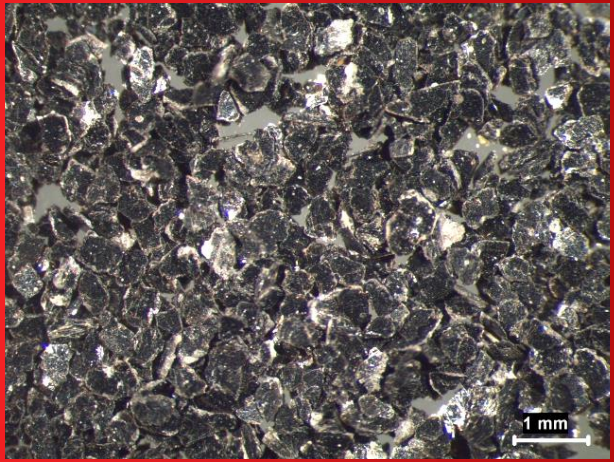
Adularia concentrate

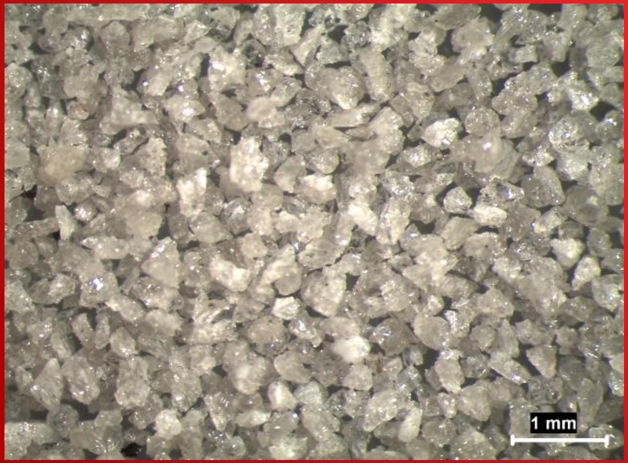
Spherulitic groundmass



Adularized groundmass

Biotite





Rhyoilitic glass

Amphibole

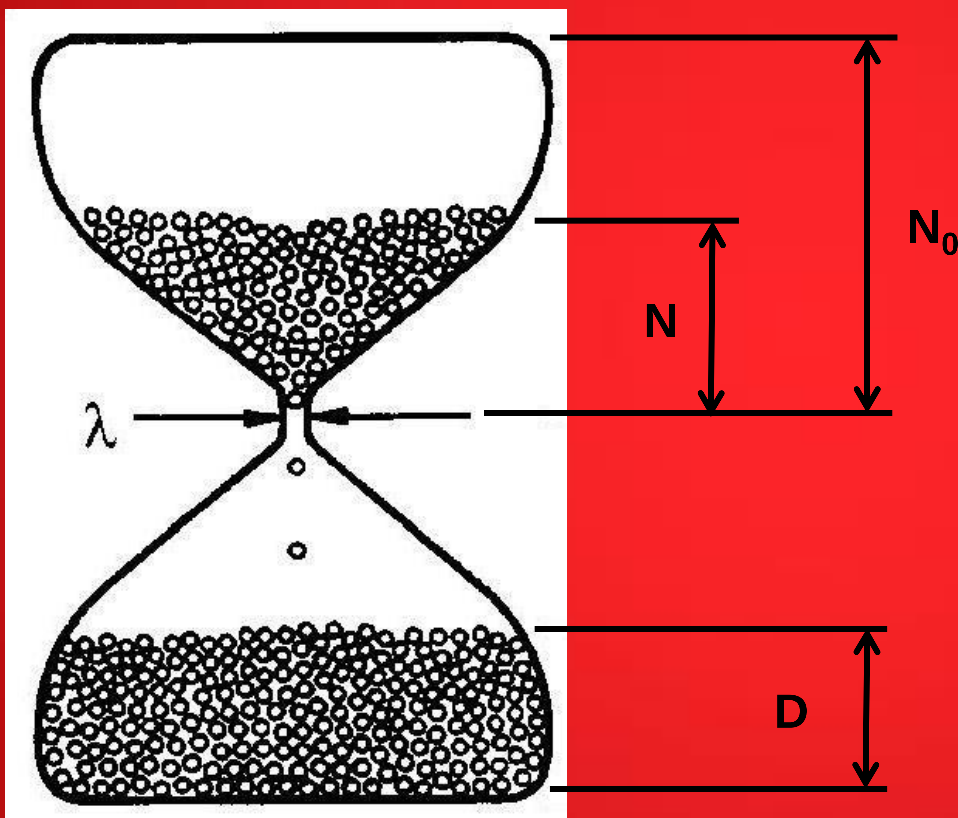
APPLICATIONS AND CASE HISTORIES

- 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



$N_0 = N + D$

$N = (N + D)e^{-\lambda t}$

$t = 1/\lambda \times \ln(1 + D/N)$

An hourglass illustrates an ideal closed system

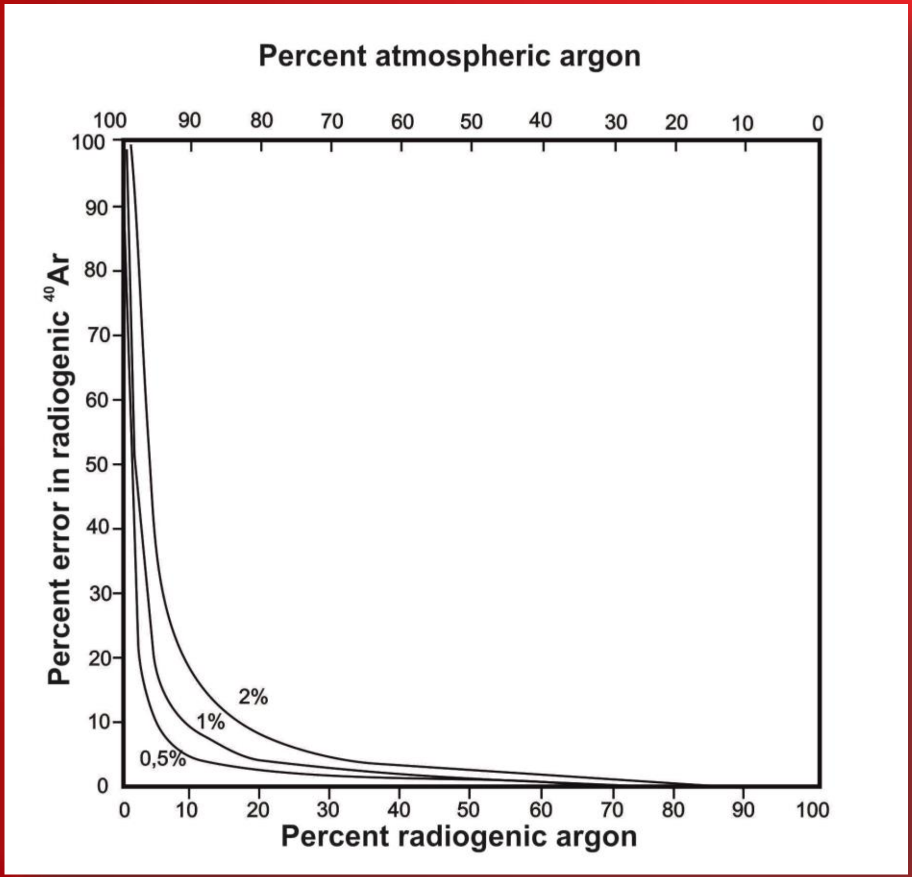
ANALYTICAL ERROR CALCULATION AND MEANING OF THE GEOLOGICAL ERROR

Analytical error is given at 68% confidence level (1σ). We use equation of Cox and Dalrymple (1967)

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

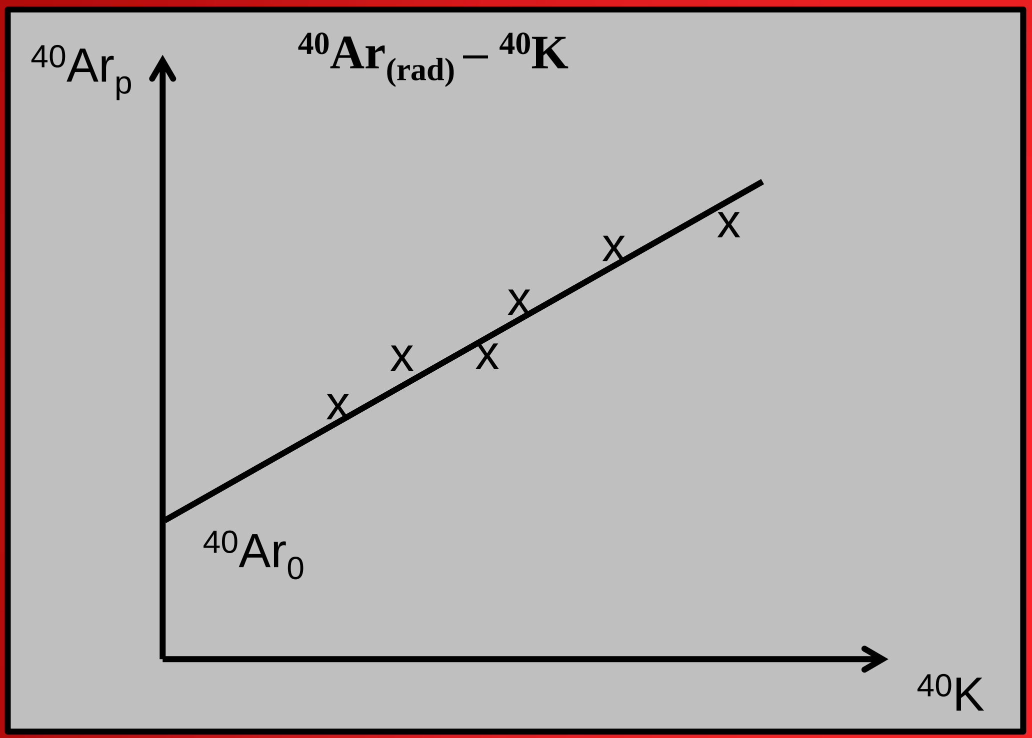
σ_k – relative error of K-concentration = 2%
σ_x – relative error of ^{38}Ar spike = 2%
– relative error of isotope ratio = 1%
– relative error of isotope ratio = 1%
***r* – percentage of $^{40}Ar_{rad}$ in $^{40}Ar_{total}$ in rock.**

GEOCHRONOLOGY AND THERMOCHRONOLOGY BY THE $^{40}Ar/^{39}Ar$ METHOD



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 $^{40}Ar/^{39}Ar$ dating technique.

The amount of ^{36}Ar is supposed to be consistent, so we may multiply I. e. 1 with it:



$$\underbrace{\left(e^{\lambda t}-1\right)\frac{\lambda_e}{\lambda}}_{m}\underset{x}{{}^{40}K} + \underset{b}{{}^{40}Ar_0} = \underset{y}{{}^{40}Ar_p}$$

(I. e. 2.)

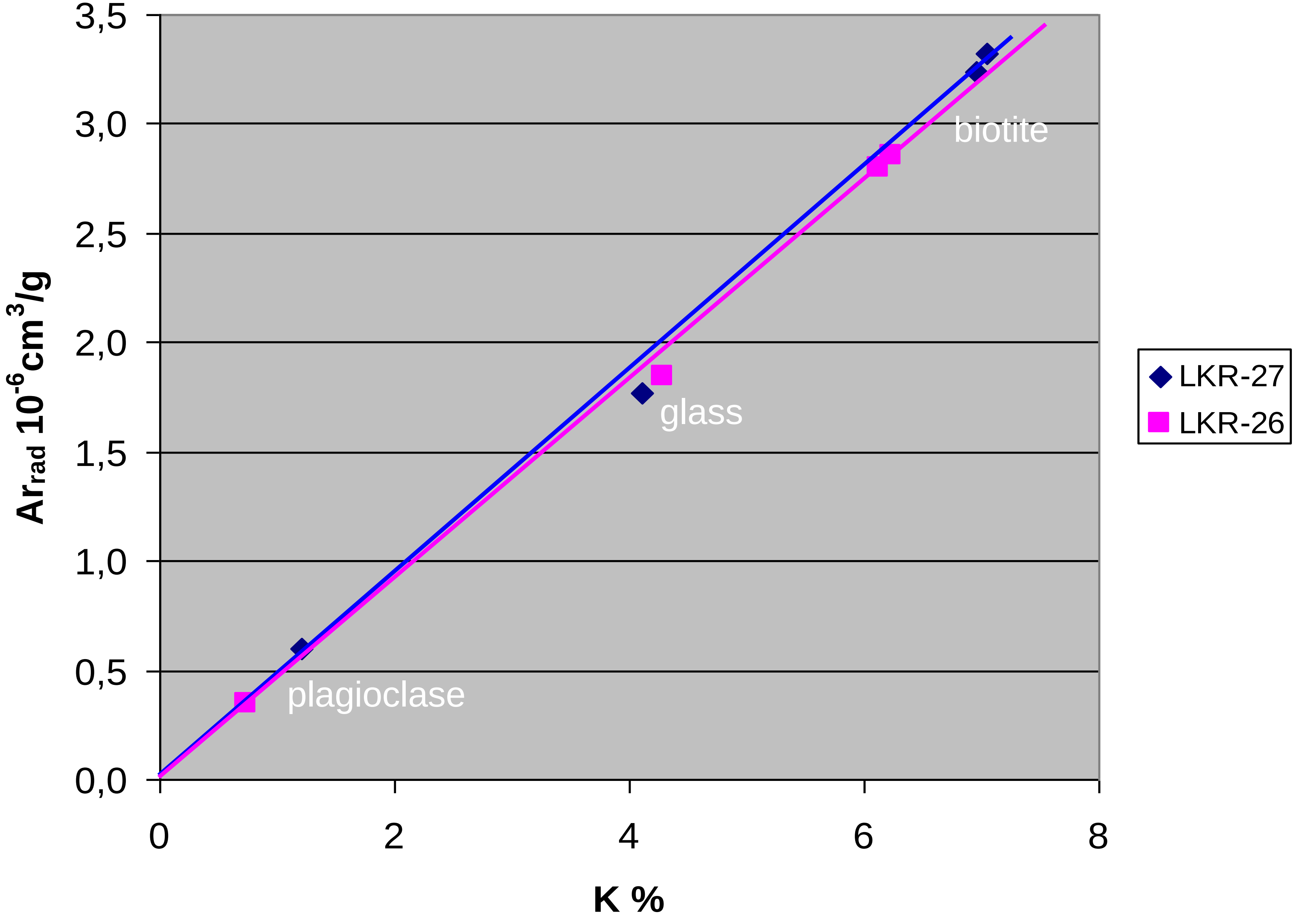
That is samples, for which the original excess ^{40}Ar-^{40}K coordinate system. The fitted straight lines are called „isochrons". The slope of the isochrones is proportional with the age, their intercept with the y axis gives the original $^{40}Ar/^{36}Ar$ ratio or the ^{40}Ar content.
Isocron methods are most important when dating young basalts.

How to obtain samples with highly differing Potassium concentrations from a rock body?

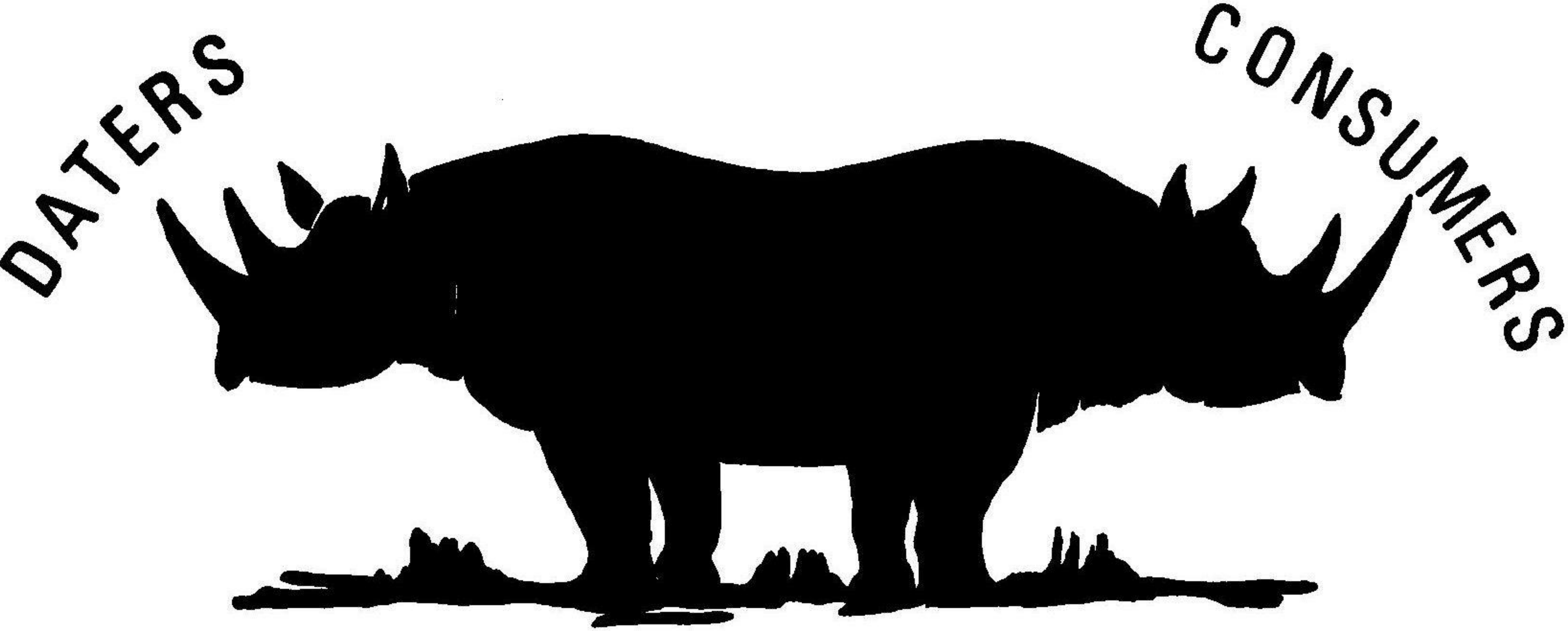
The method suggested by Fitch et al. (1976) has been used:

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.



3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0
2
4
6
8
Ar_{rad} $10^{-6}cm^{3}/g$
K %
biotite
glass
plagioclase
LKR-27
LKR-26


DATERS
CONSUMERS

THANK YOU FOR YOUR ATTENTION!