
K-Ar metoda datiranja

K-Ar datiranje

Najranija istraživanja vezana uz datiranje paleomagnetizma i magnetskog reverzibiliteta u bazaltima srednjo-oceanskih grebena.

Kalij

- **I. grupa alkalnih elemenata (Li, Na, K, Rb, Cs)**
- **jedan od osam najrasprostranjenijih elemenata na Zemlji.**

Datiranje: od 2 do 4500 milijuna godina

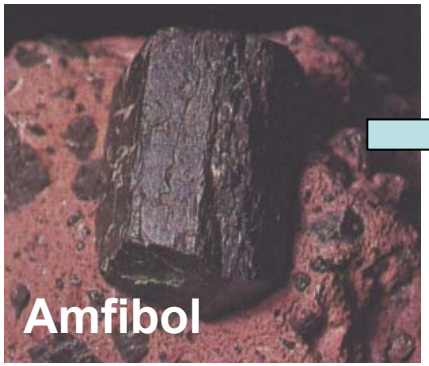
Minerali pogodni za K-Ar datiranje: Amfibol, biotit, flogopit i dr.

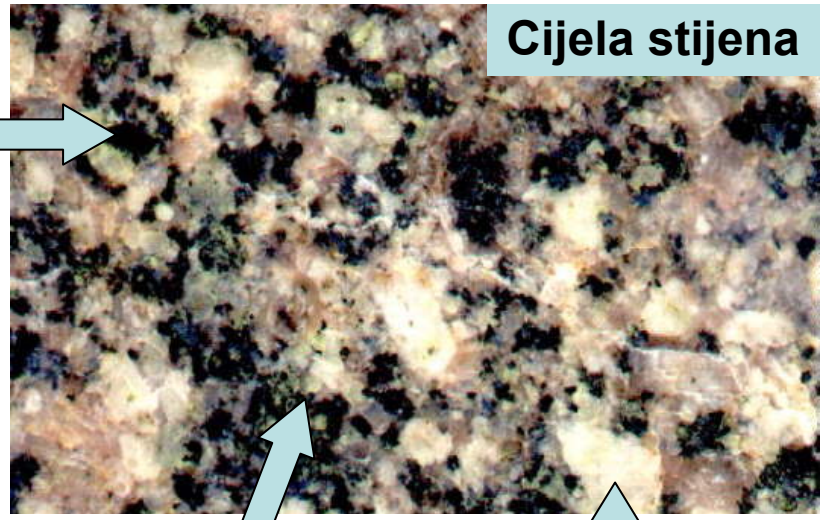

Hornblenda


Biotit


Flogopit

K-Ar datiranje





Biotit

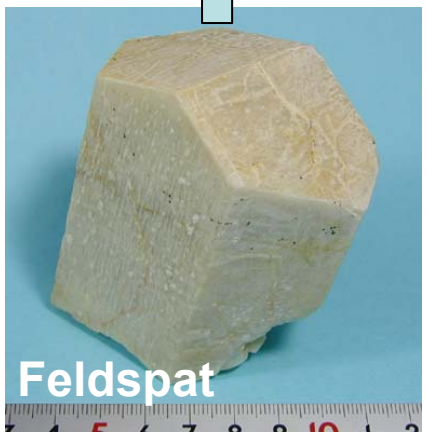


Table 9.2 **Common Rock-forming Minerals Suitable for Dating by the K-Ar Method**

	ROCK TYPE			
	VOLCANIC	PLUTONIC	METAMORPHIC	SEDIMENTARY
Feldspars				
Sanidine	⊗			
Anorthoclase	⊗			
Plagioclase	⊗			
Felsdpathoids				
Leucite	×			
Nepheline	×	×		
Mica				
Biotite	⊗	⊗	⊗	
Phlogopite			⊗	
Muscovite		⊗	⊗	
Lepidolite		×		
Glauconite				×
Amphibole				
Hornblende	⊗	⊗	⊗	
Pyroxene	×	×		
Whole rock	⊗		×	

From Potassium-Argon Dating: Principles, Techniques and Applications by G. Brent Dalrymple and Marvin A. Lanphere. W. H. Freeman and Company. Copyright © 1969.

Key: ⊗ = often useful; × = sometimes useful.

Principi metode K-Ar datiranja

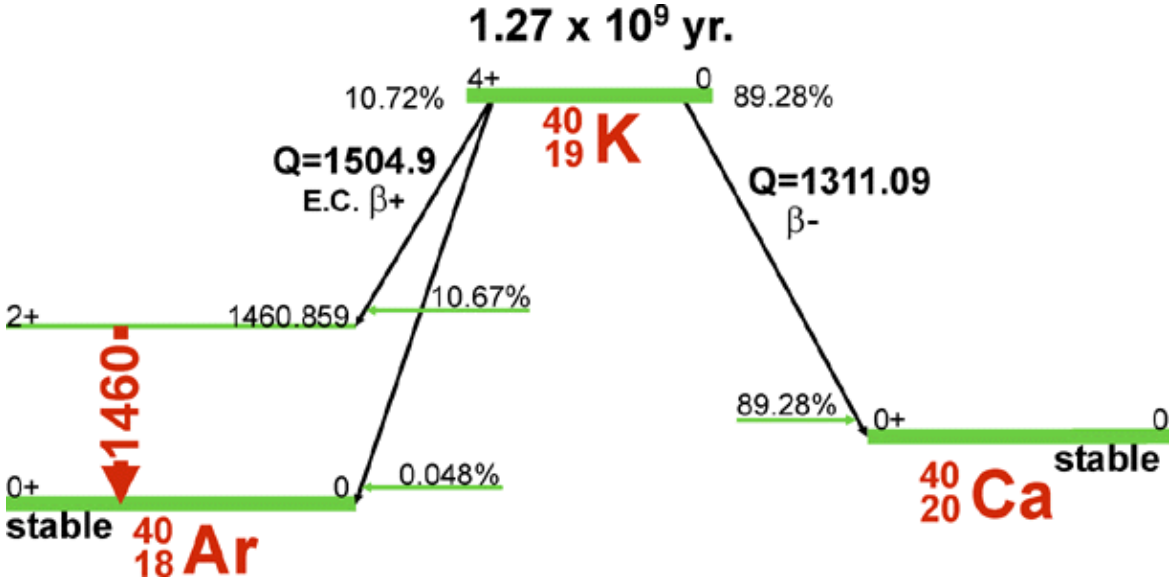


Table 9.1 **Isotopic Abundances of the Naturally Occurring Isotopes of Potassium, Argon, and Calcium**

ISOTOPE	ABUNDANCE, %
Potassium	
^{39}K	93.08
^{40}K	0.0119
^{41}K	6.91
Argon (atmospheric)	
^{36}Ar	0.337
^{38}Ar	0.063
^{40}Ar	99.60
Calcium	
^{40}Ca	96.94
^{42}Ca	0.65
^{43}Ca	0.14
^{44}Ca	2.08
^{46}Ca	0.003
^{48}Ca	0.19

The isotopic abundances of potassium and argon are from Nier (1950) and those of calcium from Holden and Walker (1972).

$$^{40}Ar^{*} + {}^{40}Ca^{*} = {}^{40}K(e^{\lambda t} - 1)$$

$$\lambda = \lambda_e + \lambda_\beta$$

λ= sveukupna konst. raspada ($5.305 \times 10^{-10} y^{-1}$)

λ_e=elektronsko kaptiranje ($0.585 \times 10^{-10}\ y^{-1}$)

λ_β=beta-raspad ($4.72 \times 10^{-10} y^{-1}$)

Principi metode K-Ar datiranja

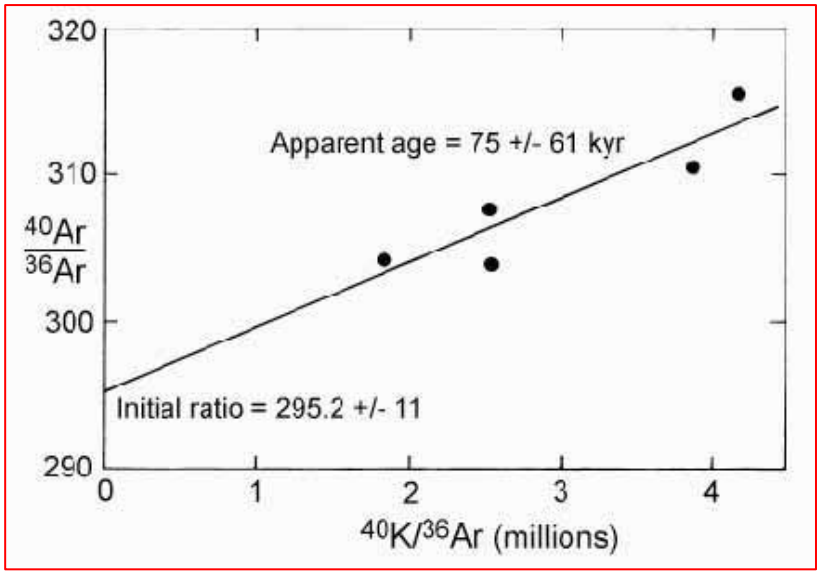
$T_{1/2}$= 1.31 x 10^9 god

$^{40}Ar^* = \lambda_e / \lambda \; ^{40}K(e^{\lambda t}-1)$

Ukupni broj atoma argona

$^{40}Ar = {}^{40}Ar_{poč} + 40Ar^*$

$$\frac{^{40}Ar}{^{36}Ar} = \left(\frac{^{40}Ar}{^{36}Ar}\right)_i + \left[\left(\frac{\lambda_e}{\lambda_t}\right)\frac{^{40}K}{^{36}Ar}(e^{\lambda t}-1)\right]$$



Excess argon («usvojeni argon»)

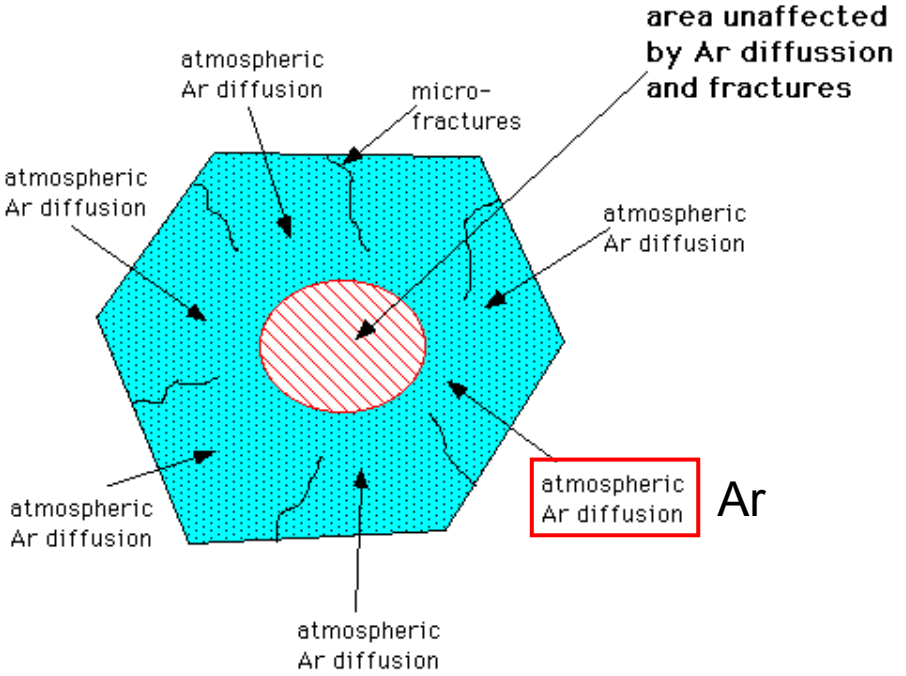
Argon može biti usvojeni u t = 0, ili u neko drugo vrijeme.

$$t = 1/\lambda \;\; \ln [Ar^*/^{40}K \; (\lambda/\lambda_e) + 1]$$

Vrijednost za **t** je ispravna ako:

- Ako se $^{40}Ar^*$ ne gubi iz minerala ili ne dodaje mineralu iz vana (kristalna rešetka mora biti zatvorena za $^{40}Ar^*$)
- $^{40}Ar^*$ se mora korigirati za ^{40} Ar atmosferski dodatak pridodan tijekom analitičkog rada

Analitika



Taljenje uzorka u molibdenskoj epruveti, ekstrakcija plinova CO_2 , N_2 , O_2 , itd.

↓

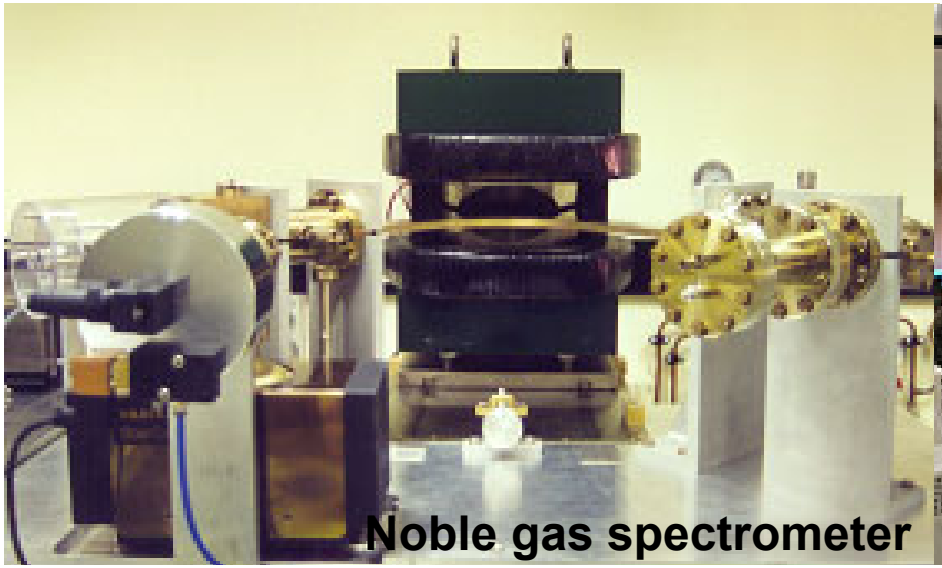
Maseni spektrometar, mjere se omjeri $^{40}Ar/^{38}Ar$, $^{38}Ar/^{36}Ar$

^{40}Ar - izotopno razređenje (isotope dilution)

^{38}Ar – spike (ubačeni standard u poznatoj količini)

K se mjeri plamenom fotometrijom (AAS, NAA)

Plamena fotometrija (AAS, NAA)


Noble gas spectrometer

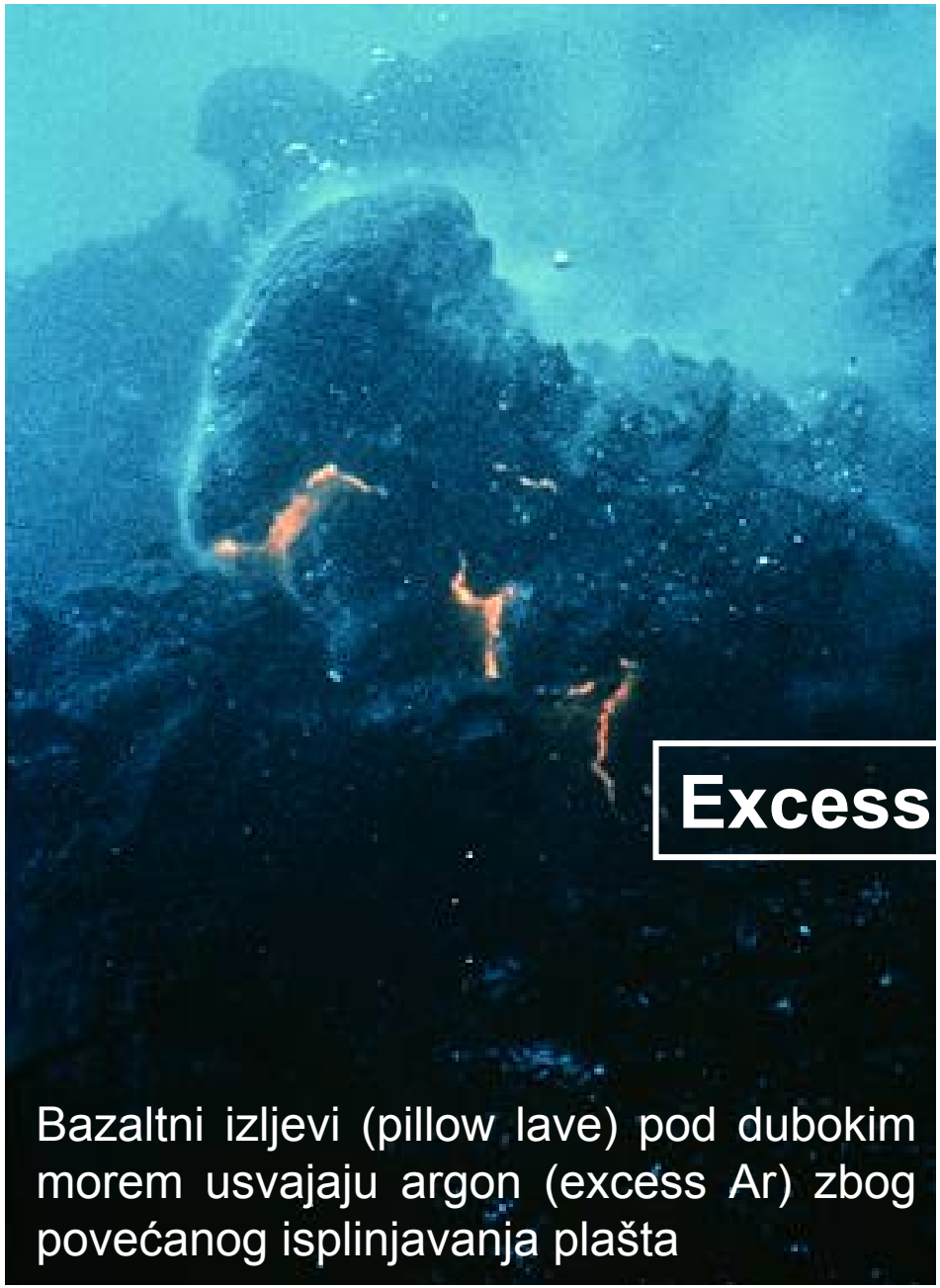

Atomski apsorber

Gubitak ili dobitak Ar iz minerala

POGREŠKE U ODREĐIVANJU STAROSTI MINERALA ILI STIJENA

- Geometrija kristalne rešetke nepogodna za čuvanje Ar
- Metamorfizam istjeruje Ar
- Kemijsko trošenje ili hidrotermalne alteracije (naročito utječu na K)
- Mehaničko razaranje minerala, radioaktivno razaranje (fisioni tragovi)
- Udarni valovi, loša priprema uzorka (pretjerano drobljenje)
- Devitrifikacija stakla
- Neki minerali preferiraju «usvojeni» argon (excess), beril, kordijerit, turmalin
- «Usvojenje» je često tijekom regionalnog metamorfizma, stvaranja pegmatita, kimberlita, kod bazaltnih izljeva pod dubokim morem
- (općenito uz visoke pritiske i prisutnost volatila)
- bogatsvo fluidnih inkluzija

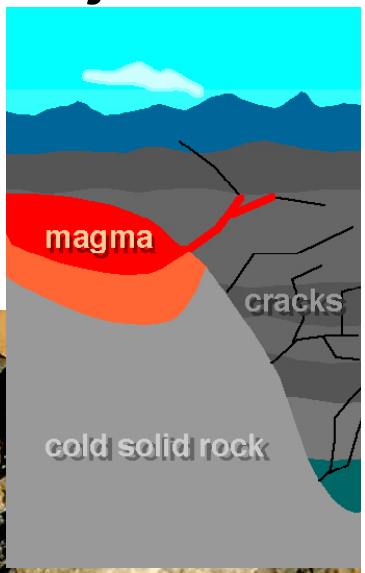
Pogreške u određivanju starosti minerala ili stijena

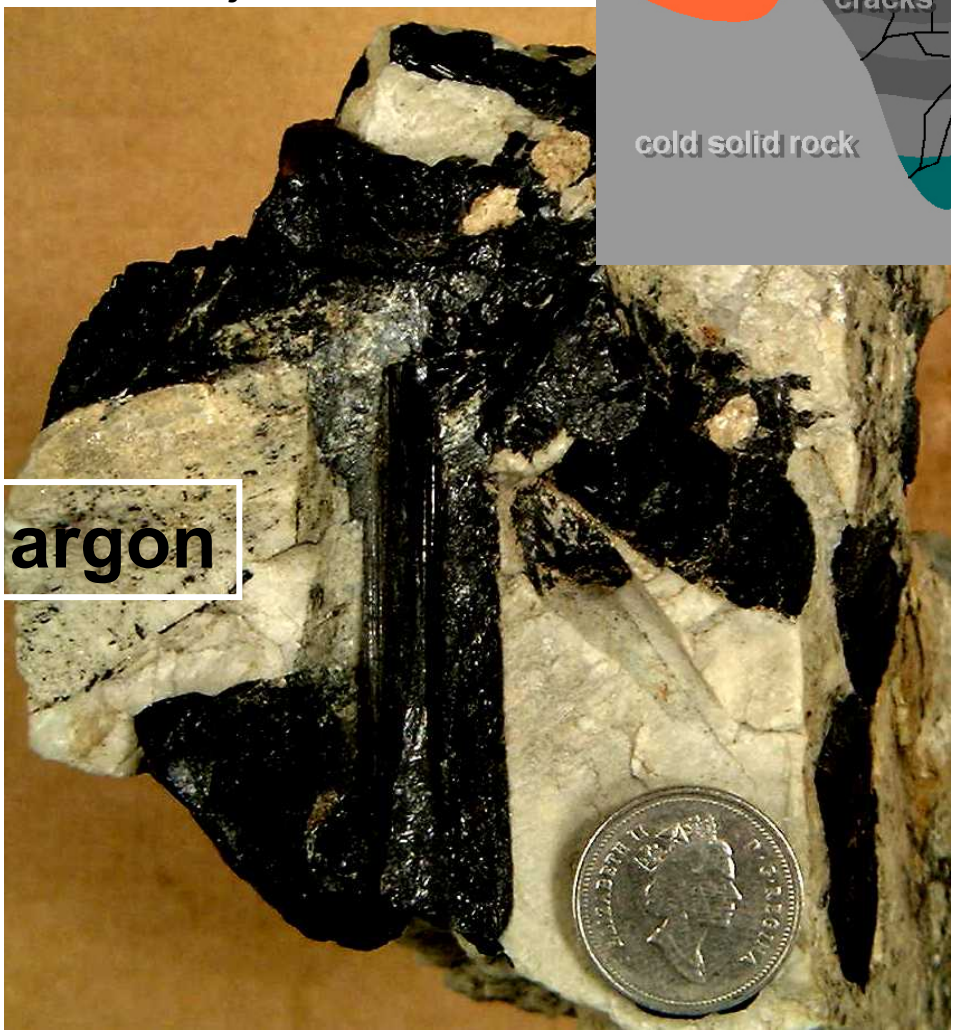


Excess argon

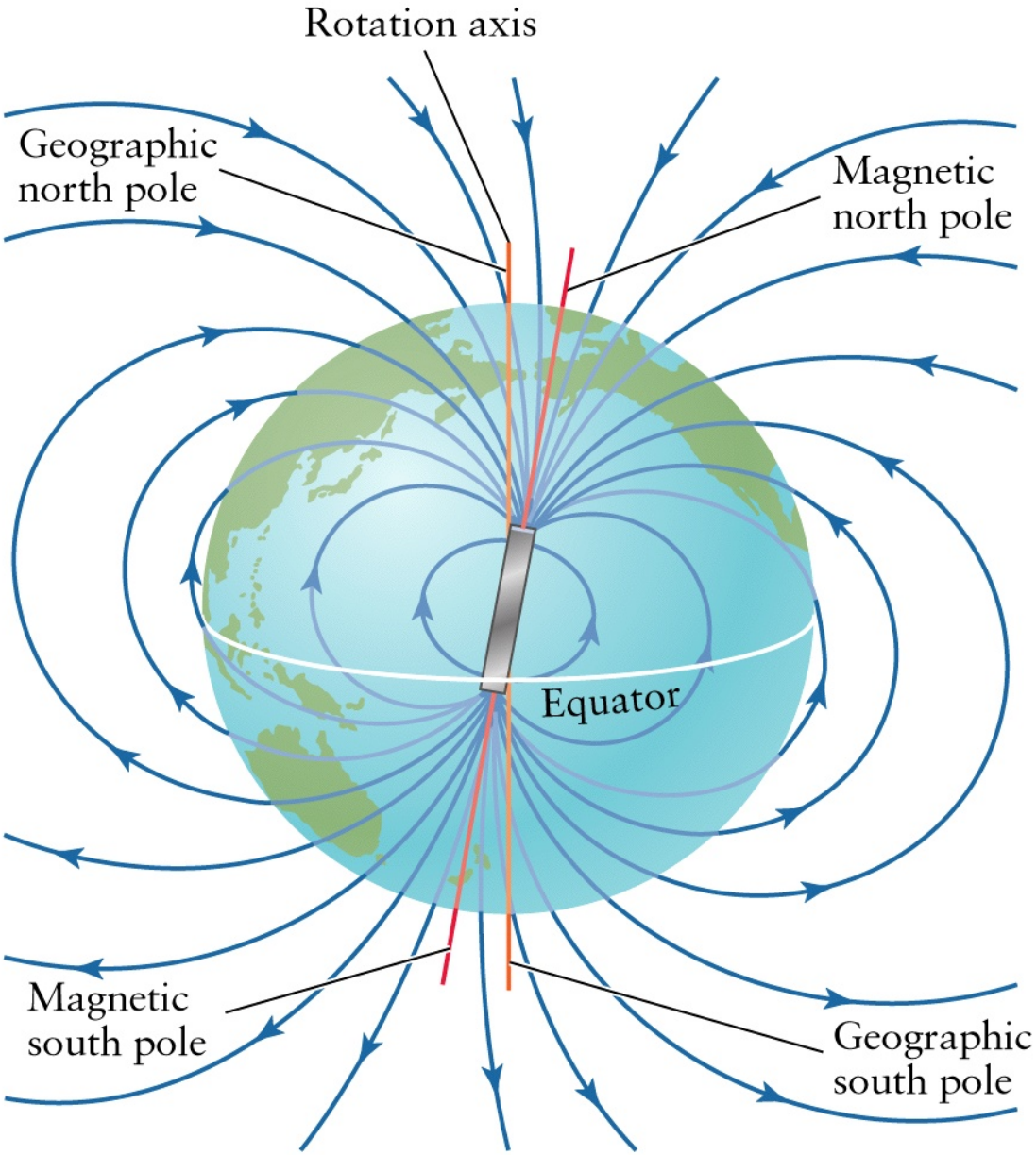
Bazaltni izljevi (pillow lave) pod dubokim morem usvajaju argon (excess Ar) zbog povećanog isplinjavanja plašta

Neki minerali u pegmatitima preferiraju «usvojeni» argon zbog visokog pritiska volatila: beril, kordijerit, turmalin

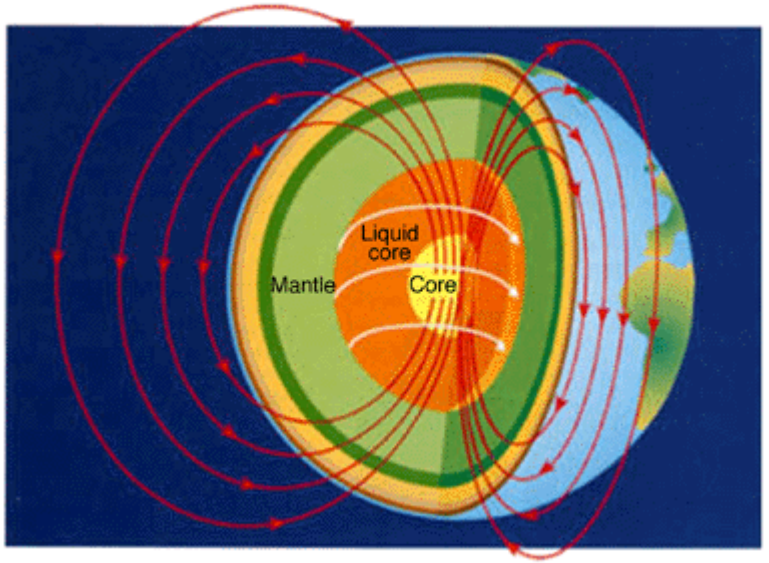




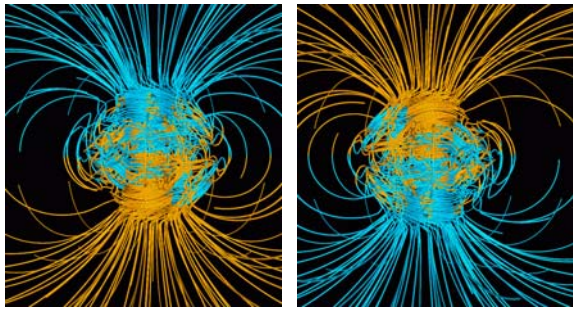
Magneto-stratigrafija



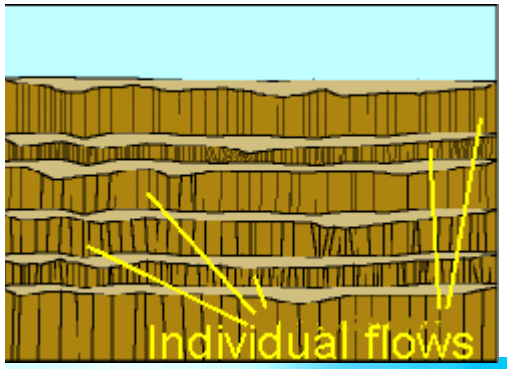
Zemljino magnetsko polje nastaje kretanjem rastaljenog vanjskog dijela jezgre.

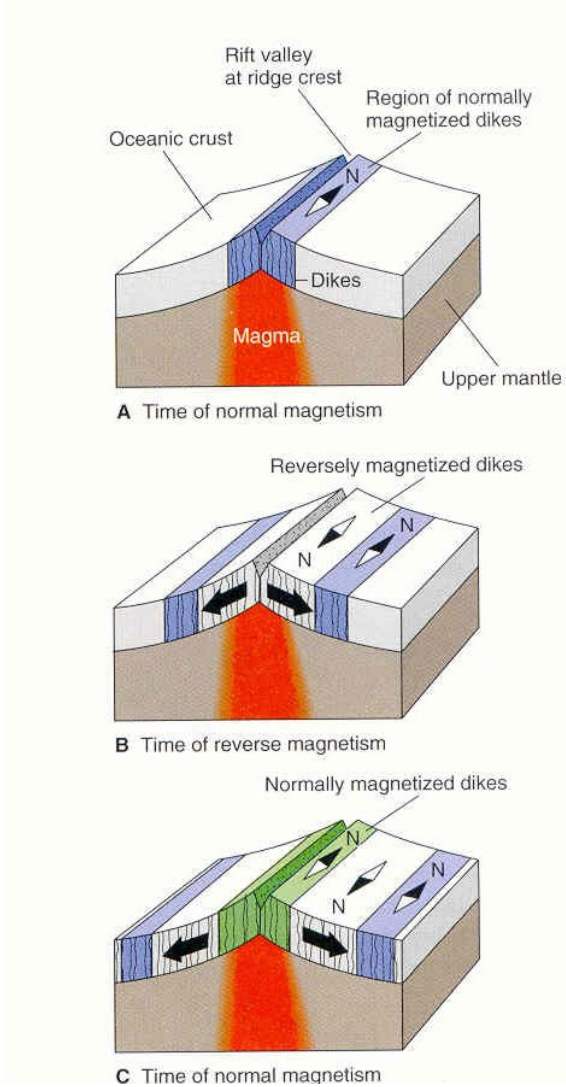


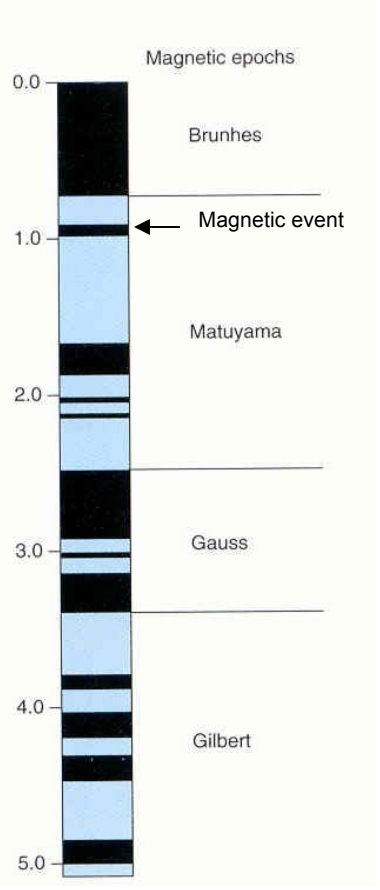
Magneto-stratigrafija



Reverzibilnost polariteta zemljinog magnetskog polja je vremenski nepredvidiva pojava.
Razlikuju se «Epohe» i «Događaji»



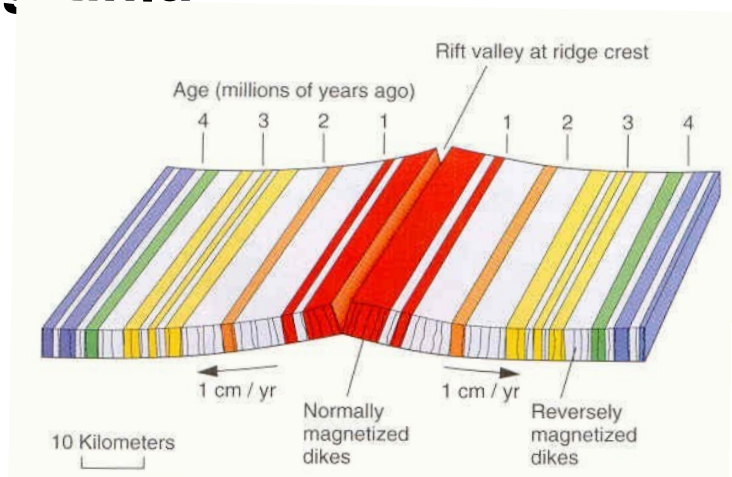




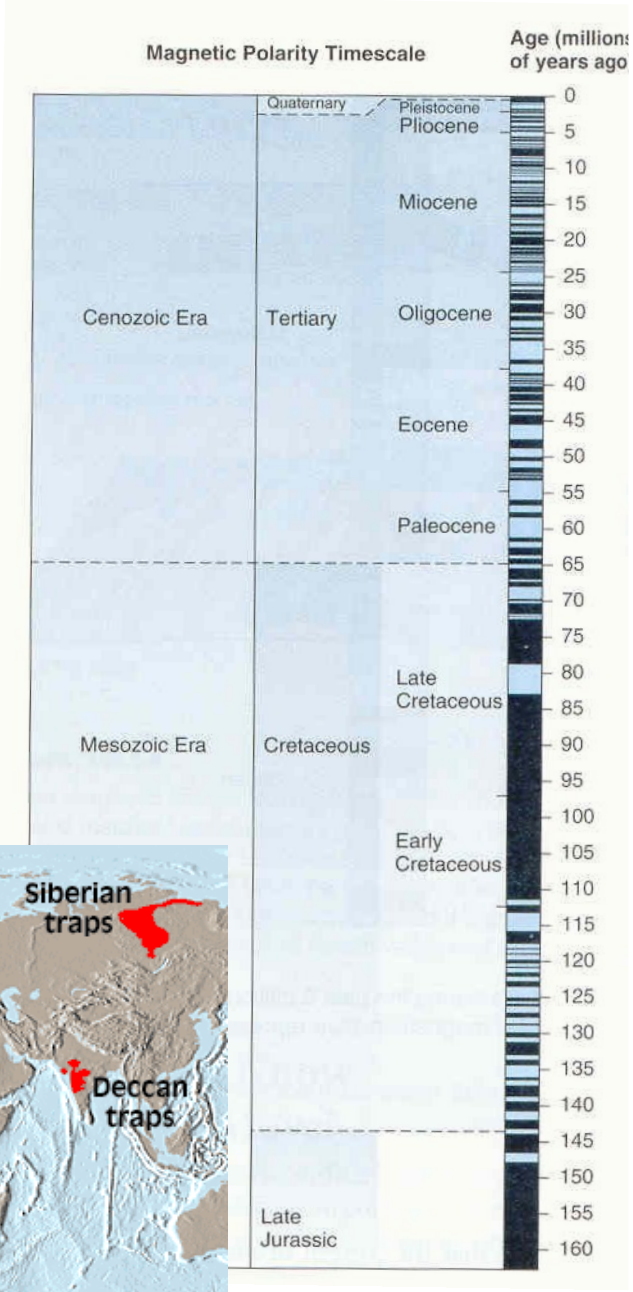
Magneto-stratigrafija

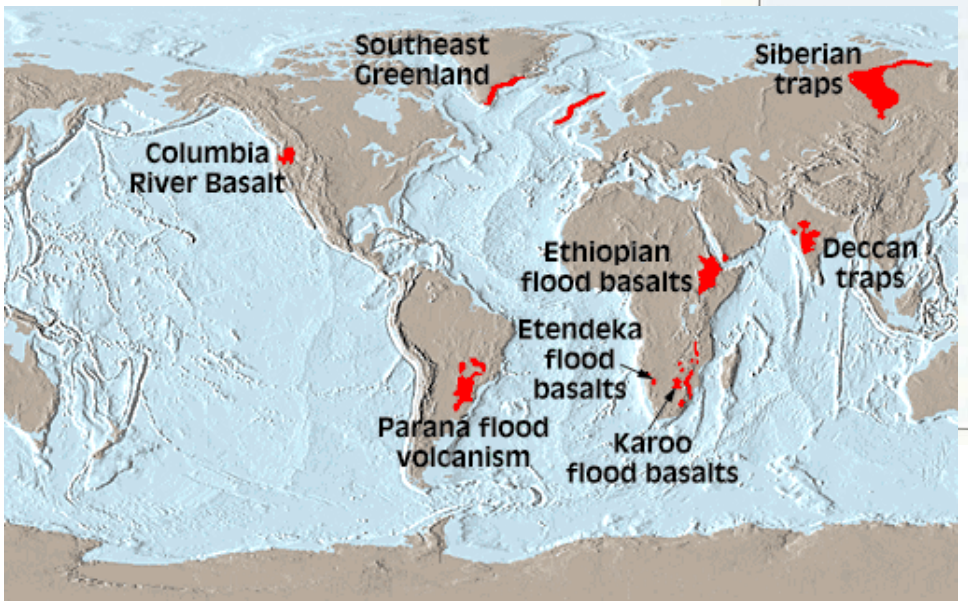
Širom Svijeta nalaze se prostrane vrlo debele akumulacije tokova bazaltnih lava.

Bazaltne provincije su *Siberian Traps* (~248 Ma), *Karoo* (~183 Ma), *Parana* (~132 Ma) i *Deccan* (~66 Ma), s otprilike 2×10^6 km^3 lave. Lava je izlazila iz pukotina u količini od 1-2 km^3 na godinu (50× više nego na Hawaiima). To su najveći vulkanski događaji na Zemlji.



Correlation of magnetic anomalies with magnetic reversals allows anomalies to be dated. Magnetic anomalies can therefore be used to predict the age of the sea floor and to measure the rate of sea-floor spreading (plate motion).

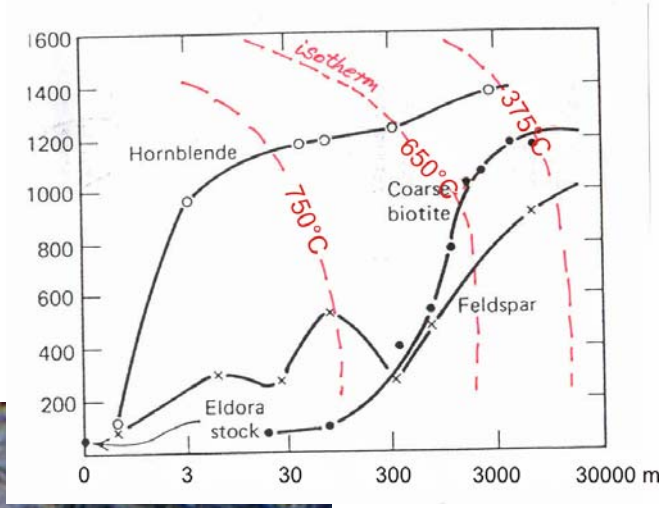


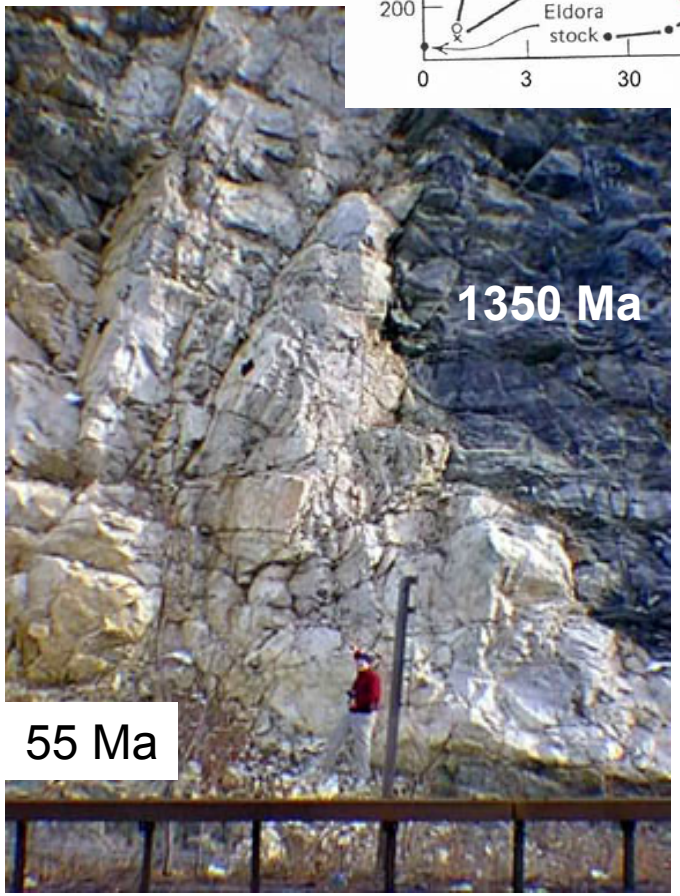


Paleomagnetizam bazaltnih izljeva na kopnu poslužio za konstrukciju magnetostratigrafskih ljestvica.

Temperatura blokiranja

(blocking temperature ili closure temperature)





Temperatura blokiranjaje temperatura ispod koje mineral uspješno čuva Ar što u njemu nastaje radioaktivnim raspadom ^{40}K.

Difuzija Ar iz minerala postaje zanemarivo mala.

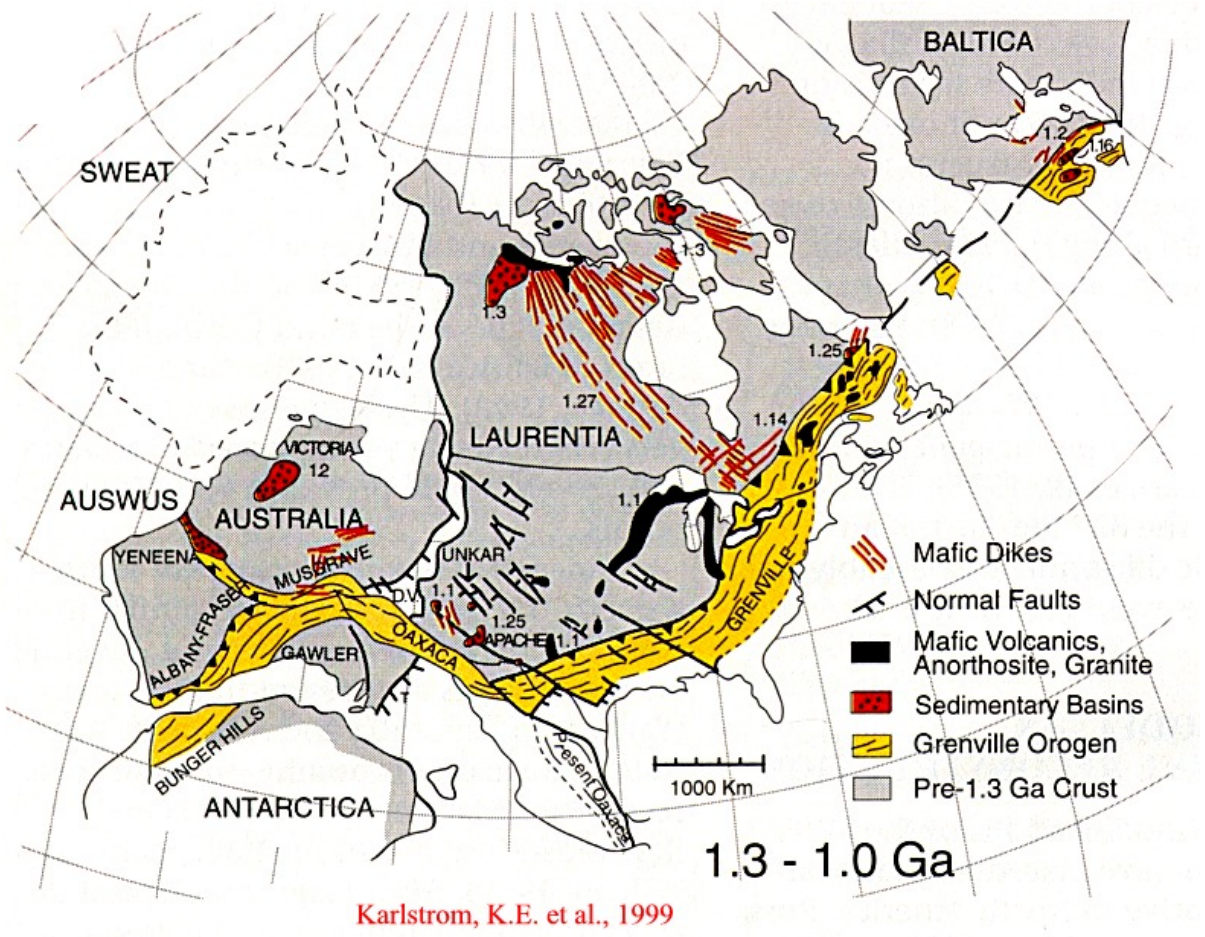
Neke temperature blokiranja:

Hornblenda	**650 °C**
Biotit	**375 °C**
K-feldspat	**230 °C**
Plagioklas	**175 °C**

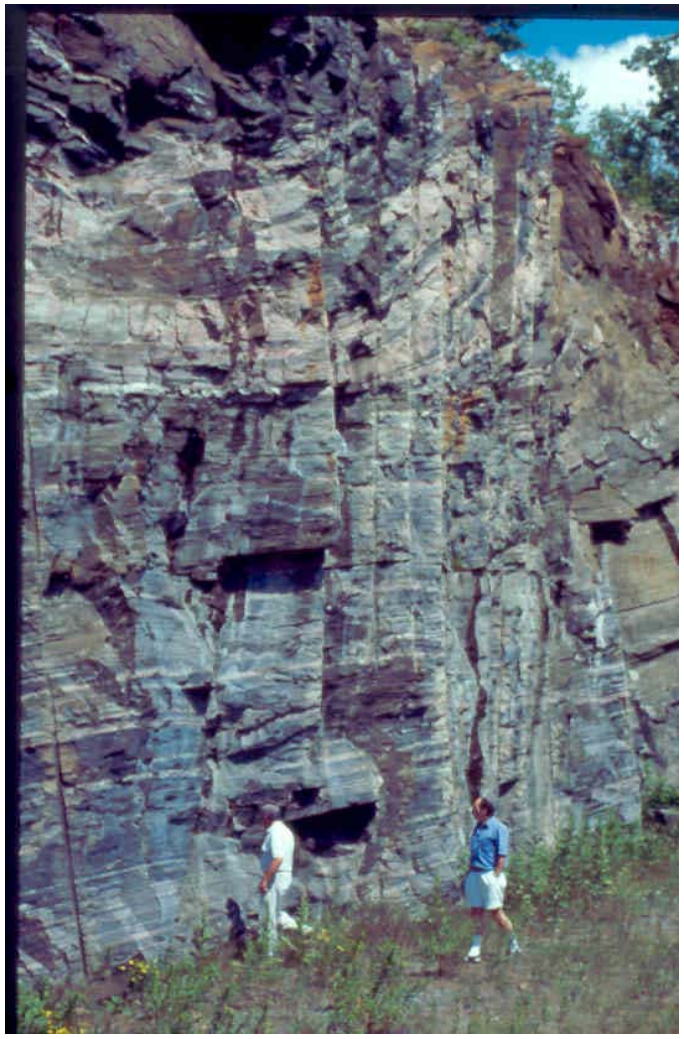
Primjer 1:

K-Ar vrijednost «prividne» (appearent) starosti minerala hornblende, biotita i feldspata u gnajsevima Idaho Spring formacije u Front Rangeu u Coloradu (starost 1350 do 1400 mil.god., regionalni metamorfizam). Eldora intruzivna, granitska doma je stara 55 mil.god.

Temperatura blokiranja
Metamorfni veo

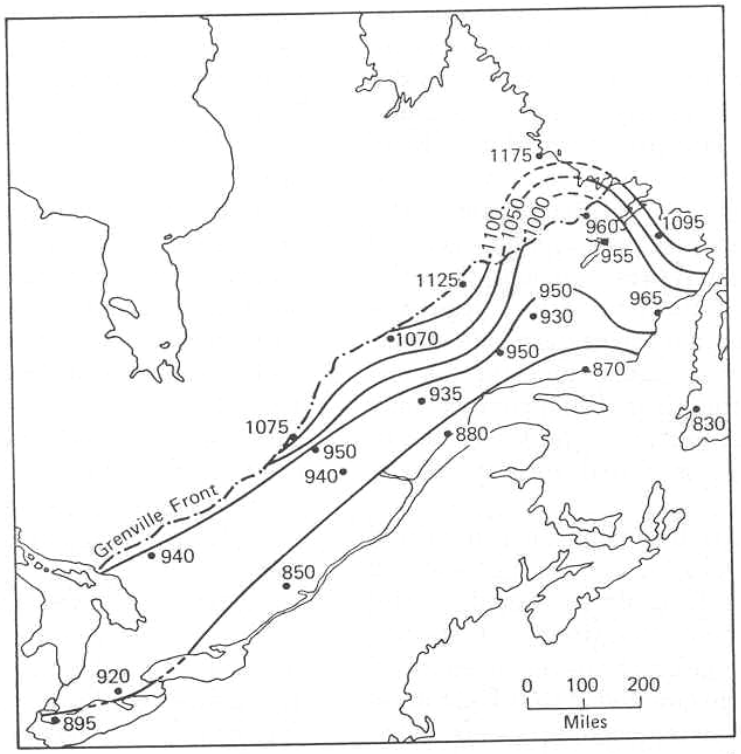


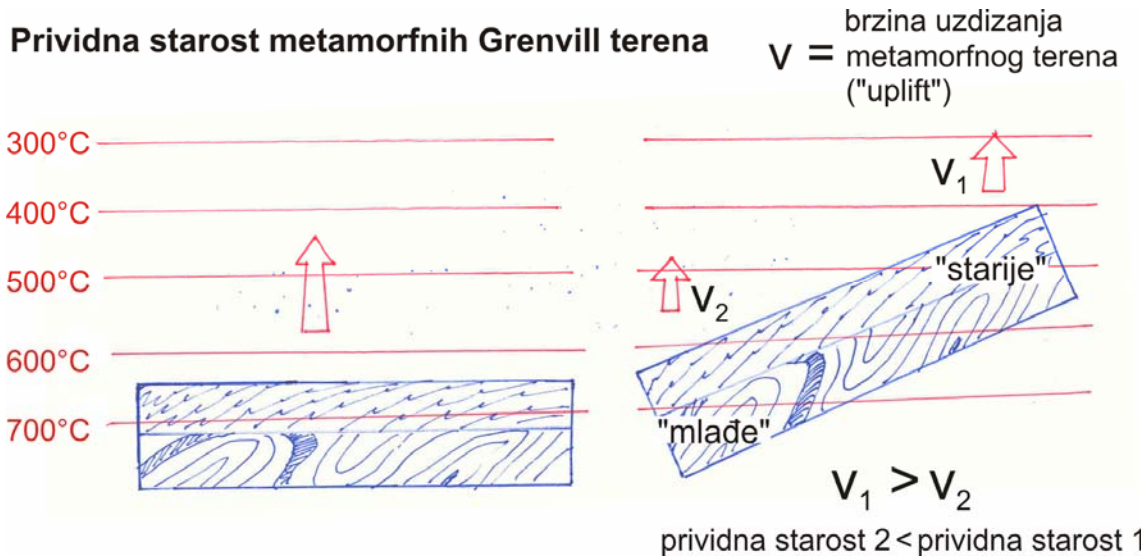
Grenvillski orogen, Kanada



Grenville migmatiti

Temperatura blokiranja
Metamorfni veo





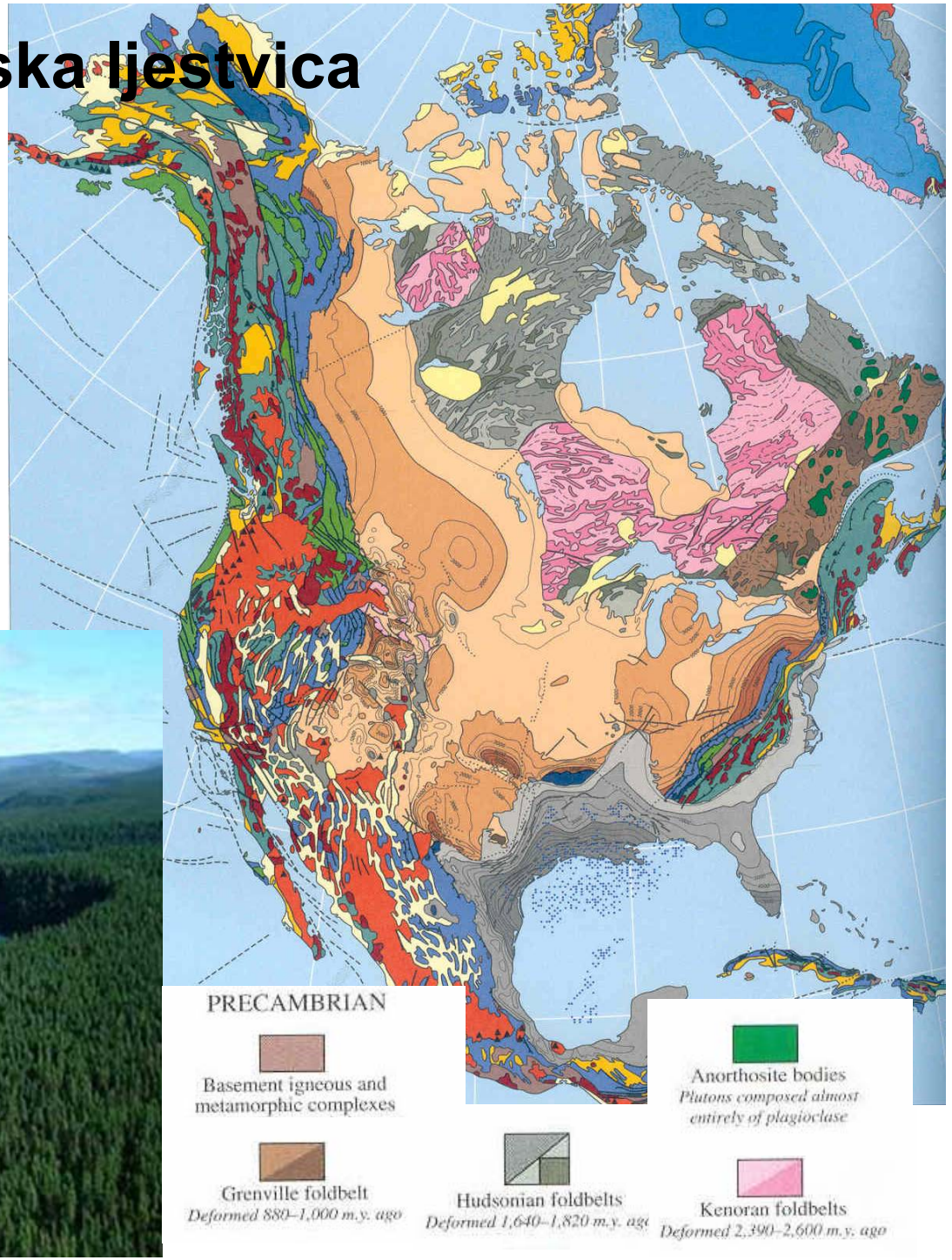
Primjer 2:
Datiranje gnajseva u Grenvilleskoj provinciji u Kanadi (Grenvillski orogen 950 mil.god.) pokazuje porast «prividne» starosti od istoka prema zapadu (izolinije starosti).

Objašnjenje: «Starije» stijene su ranije prošle kroz «temperaturu blokiranja» pa su nakupile više argona i računski postigle veću «prividnu» starost.

$$(t = 1/\lambda \ln [^{40}Ar^*/^{40}K (\lambda/\lambda_e) + 1])$$

Prekambrijska vremenska ljestvica

Geological Survey of Canada u ranim 70-tim prošlog stoljeća inicirao datiranje biotita i muskovita u magmatskim i metamorfnim stijenama, na kanadskom štitu, da se ustanove glavni orogenetski događaji.



Datiranje orogeneze

Jungfrau, Švicarska (4000 m)

Orogeneza u nekom terenu (Stockwell, 1972), je glavno boranje praćeno regionalnim metamorfizmom i intruzijom granita. Prema TuzoWilsonu (1960s) to je faza kolizije.

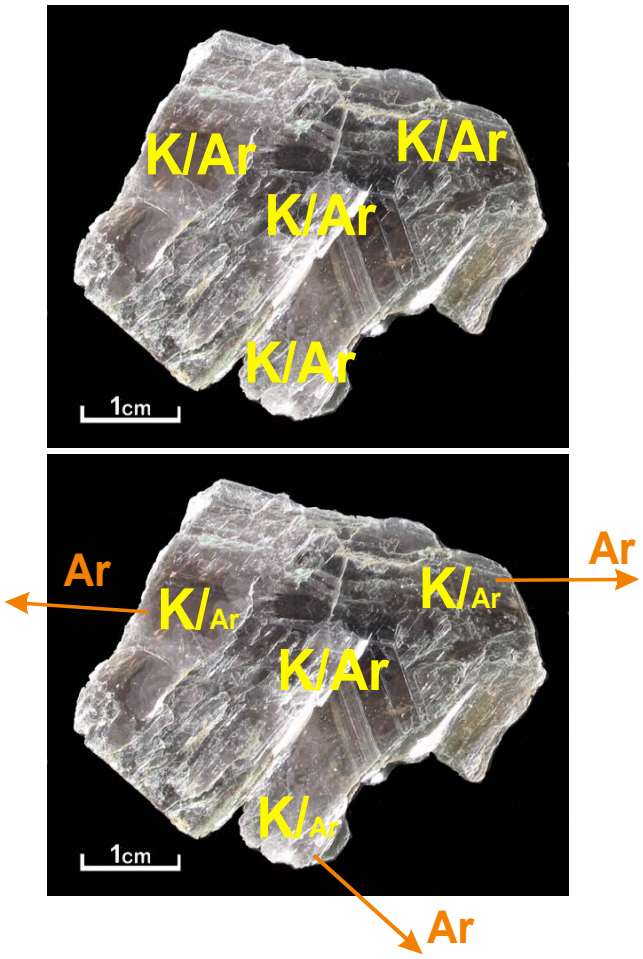
Prividne K-Ar starosti u orogenetskim terenima najčešće bilježe značajne metamorfne ili strukturne zapise, ali u fazi uzdizanja (**temperatura hlađenja**) a to je obično iza glavne faze orogeneze (u Dinaridima to je alpski gornjo-kredni metamorfizam).

$^{40}Ar/^{39}Ar$ metoda datiranja

$^{40}Ar/^{39}Ar$ metoda datiranja

K-Ar metoda je bazirana na pretpostavci da je radiogeni $^{40}Ar^*$ sačuvan u rešetci minerala, tj. da je po cijelom volumenu kristala odnos K/Ar stalan.

Muskovit, $KAl_2(Si_3Al)O_{10}(OH)_2$



$$t_1 = 1/\lambda \ln [^{40}Ar^*/^{40}K (\lambda/\lambda_e) + 1]$$

$\mathbf{t_1}$ predstavlju pravu starost termalnog događaja ili starost minerala

Gubitkom $^{40}Ar^*$ na rubovima kristala snižava se količina $^{40}Ar^*$ u cijelom mineralu.

$$t_2 = 1/\lambda \ln [^{40}Ar^*/^{40}K (\lambda/\lambda_e) + 1]$$

$\mathbf{t_2}$ = netočno vrijeme !!!

$$\mathbf{t_2 < t_1}$$

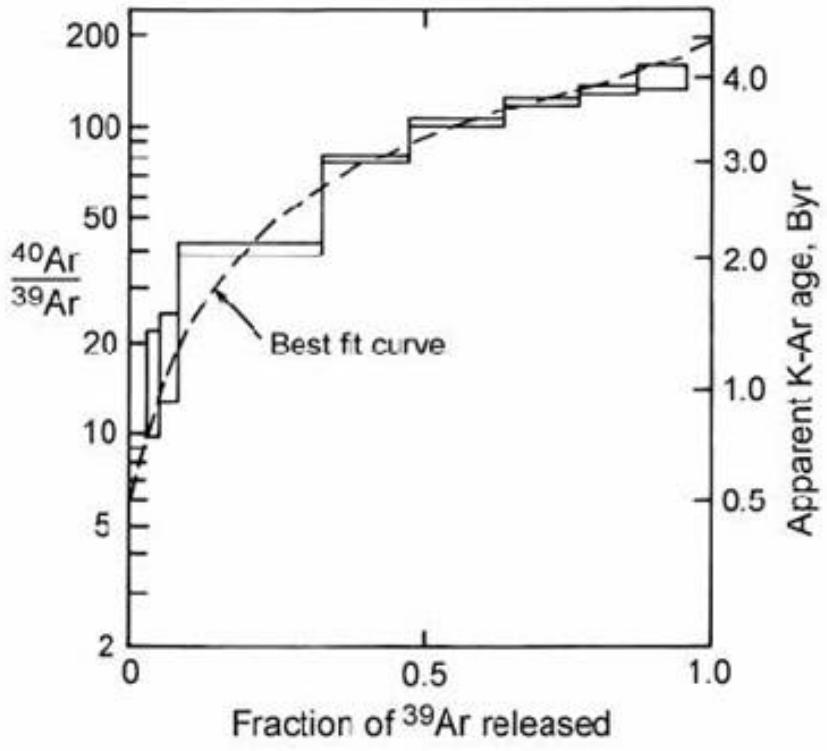
$^{40}Ar/^{39}Ar$ metoda datiranja

Pitanje:

Kako riješiti problem kontrole konstantnosti K/Ar po cijelom uzorku ?

Odgovor:

Osigurati konstantno praćenje odnosa K/Ar tijekom procesa mjerenja.



Pitanje:

Na koji način???

Odgovor:

Pretvoriti ^{39}K u ^{39}Ar i zatim pratiti kontinurano odnos $^{40}Ar/^{39}Ar$ tijekom zagrijavanja uzorka.

Pitanje:

Kako to postići???

Postupak pretvaranja ^{39}K u ^{39}Ar

Zračenje uzorka brzim i termalnin neutronima u nuklearnom reaktoru.

$^{39}K \rightarrow {}^{39}Ar$.....β-raspad....$\rightarrow {}^{39}K$ ($T_{1/2}$ = 269 god.) (to možemo zanemariti!!)

(Prirodni odnos K-izotopa: ^{39}K 93.1%, ^{40}K 0.01%, ^{41}K 6.91%)

Komentar: Poznati ^{39}Ar znači poznati ^{39}K odnosno ^{40}K!

Jednadžba

$$^{40}Ar/^{36}Ar = (^{40}Ar/^{36}Ar)_{poč} + [(\lambda_e/\lambda_t)\ ^{40}K/^{36}Ar(e^{\lambda t}-1)]$$

se pretvara u:

$$^{40}Ar/^{36}Ar = (^{40}Ar/^{36}Ar)_{poč} + {}^{39}Ar/^{36}Ar\ J^{-1}\ (e^{\lambda t}-1)$$

J = mjerna konstanta, određena uvjetima u reaktoru pomoću standarda (poznata starost t_m) – monitora toka

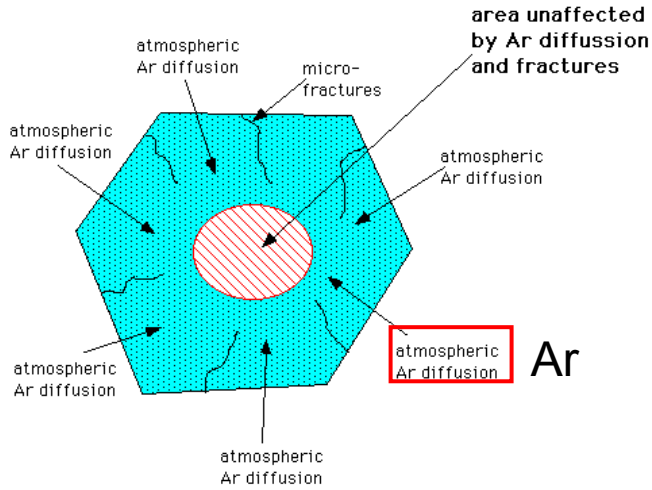
$J = e^{\lambda tm} - 1/(^{40}Ar^*/^{39}Ar)$

$\lambda = 5.305 \times 10^{-10}\ y^{-1}$

Određivanje atmosferskog argona $^{40}Ar_{atmosferski}$

Uvjeti da mjerenje uspije su da je:

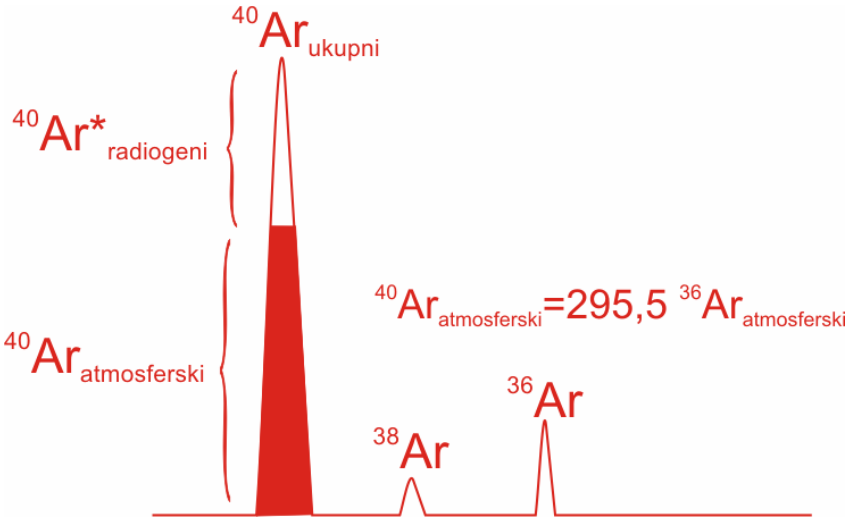
- sav ^{40}Ar radiogeni i atmosferski
- izračunat utjecaj atmosferskog ^{40}Ar mjerenjem atmosferskog ^{36}Ar
- sav ^{36}Ar atmosferski
- sav ^{39}Ar nastao zračenjem ^{39}K



Korekcija radiogenog $^{40}Ar^*_{radiogeni}$ za vrijednost atmosferskog $^{40}Ar_{atmosferski}$

$$^{40}Ar^*_{radiogeni} = {}^{40}Ar_{mjereni} - {}^{40}Ar_{atmosferski} = {}^{40}Ar_{mjereni} - 295.5\ {}^{36}Ar_{atmosferski}$$

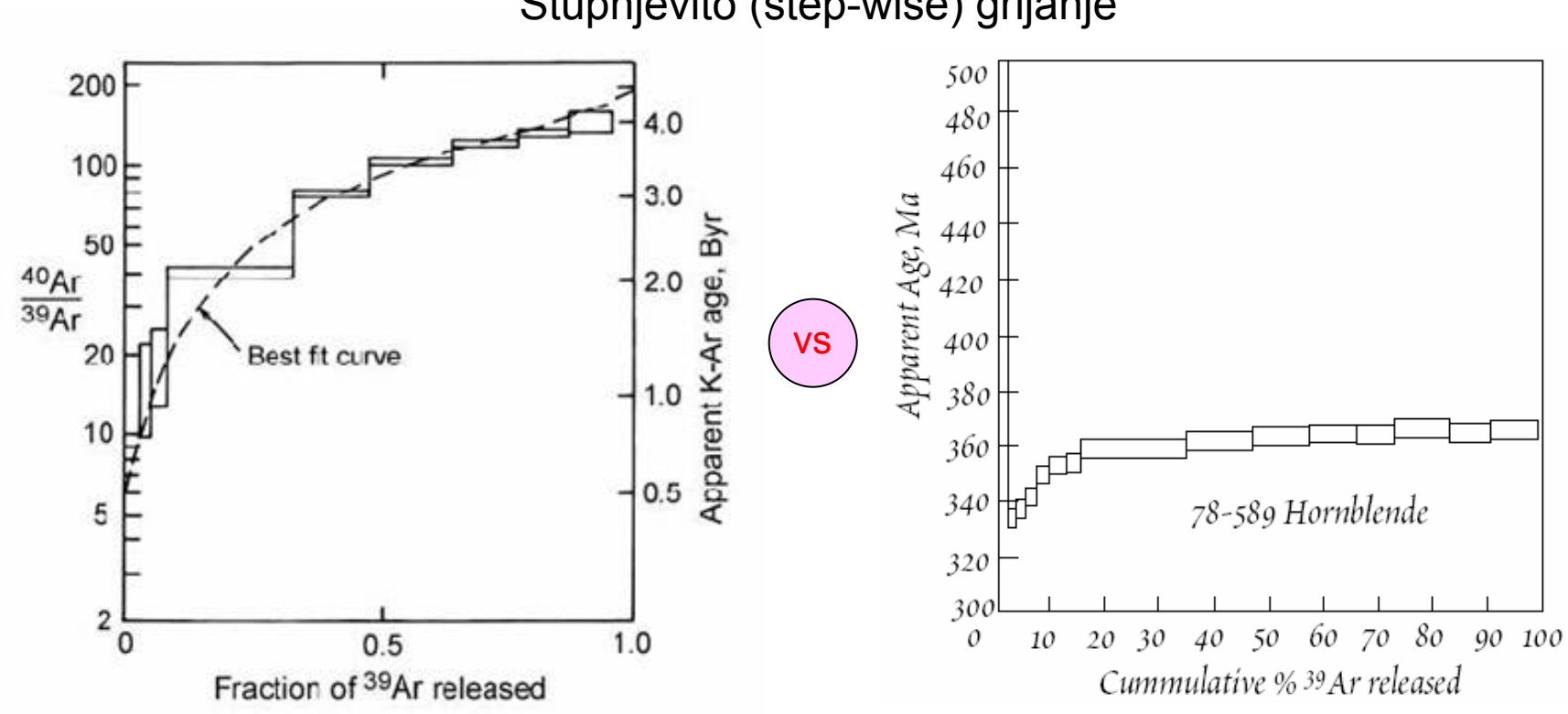
Opaska:
prirodni odnos Ar-izotopa u atmosferi;
^{36}Ar 0.34%, ^{38}Ar 0.06%, ^{40}Ar 99.6%
$^{40}Ar/^{36}Ar = 295.5$



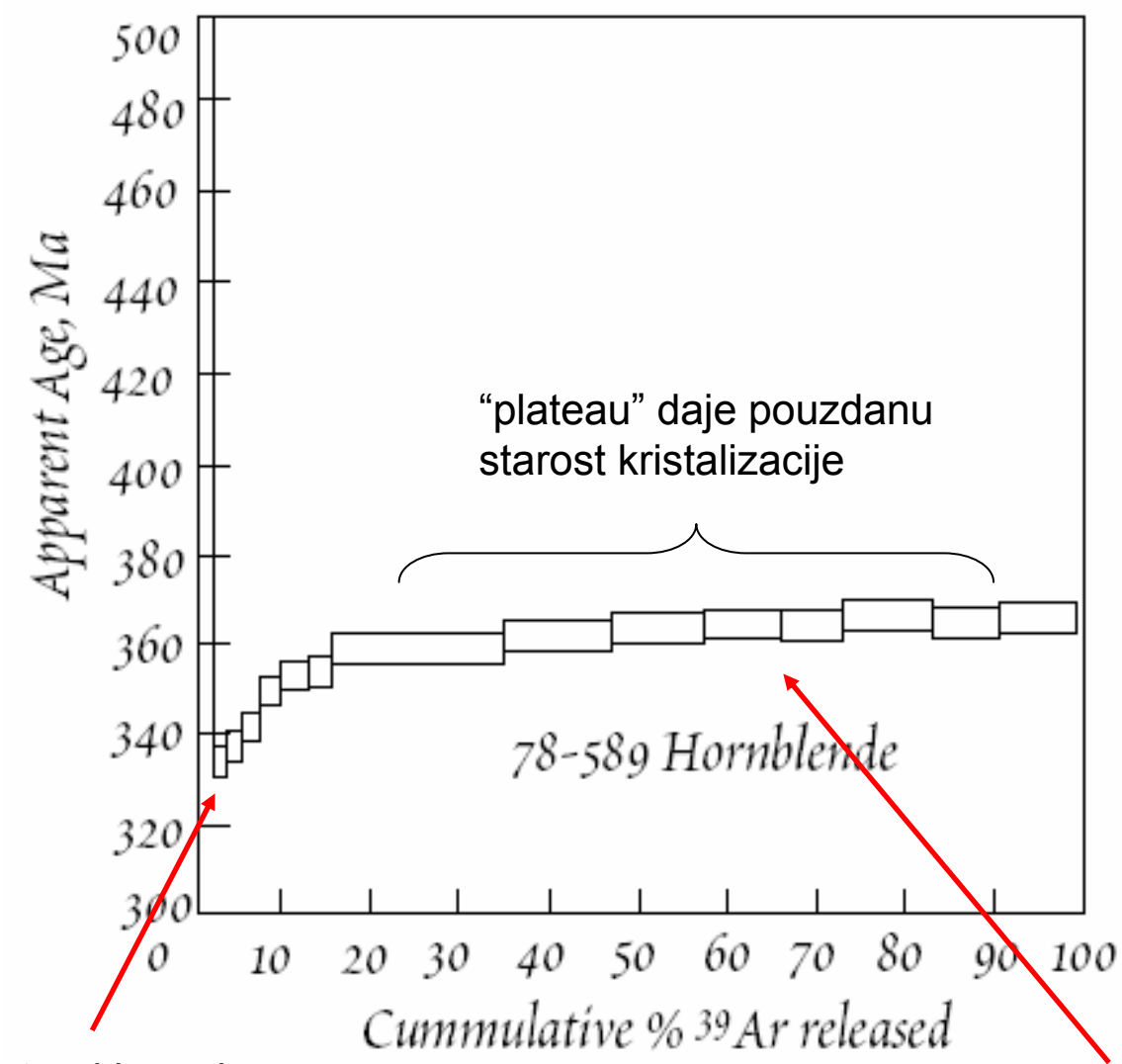
Vremenska jednadžba

$$t = 1/\lambda \ln[(^{40}Ar^*/^{39}Ar)\ J + 1]$$

Stupnjevito (step-wise) grijanje



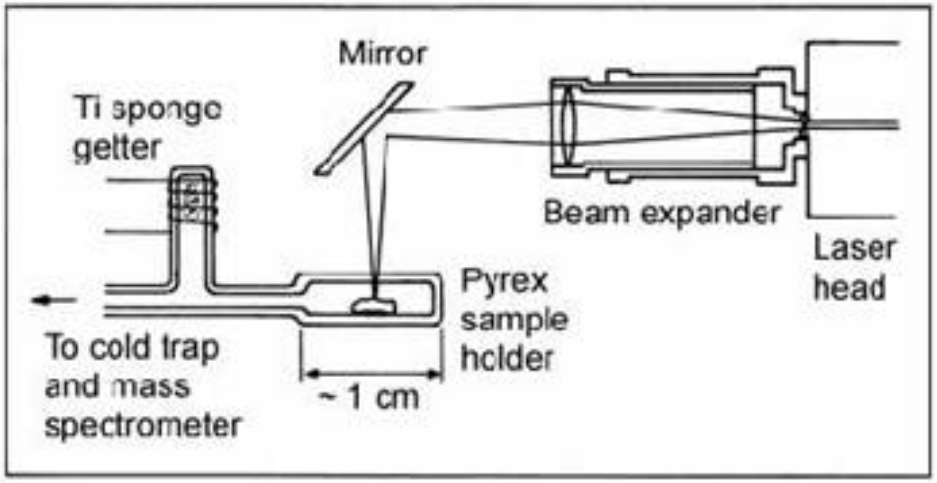
Vremenska jednadžba

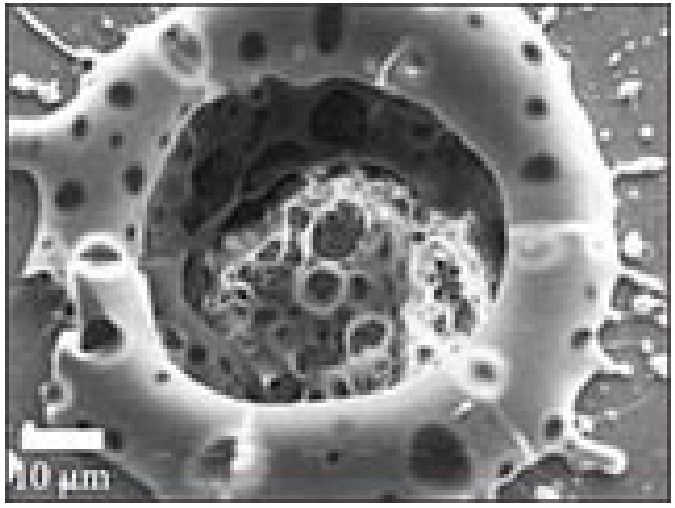


nisko-temperaturni koraci
ukazuju na gubitak $^{40}Ar^*$

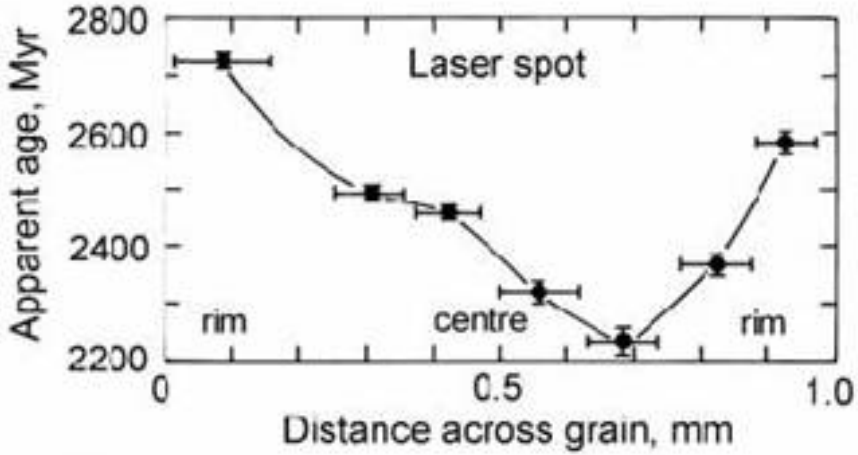
više-temperaturni koraci
daju pouzdani odnos $^{40}Ar^*/^{39}Ar$

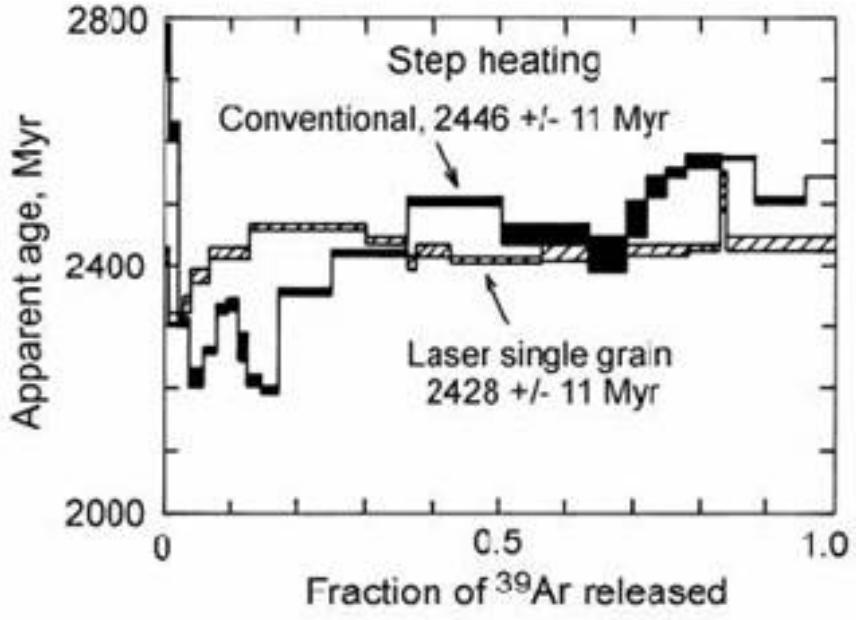
Primjena lasera u Ar-Ar datiranju





laser spot

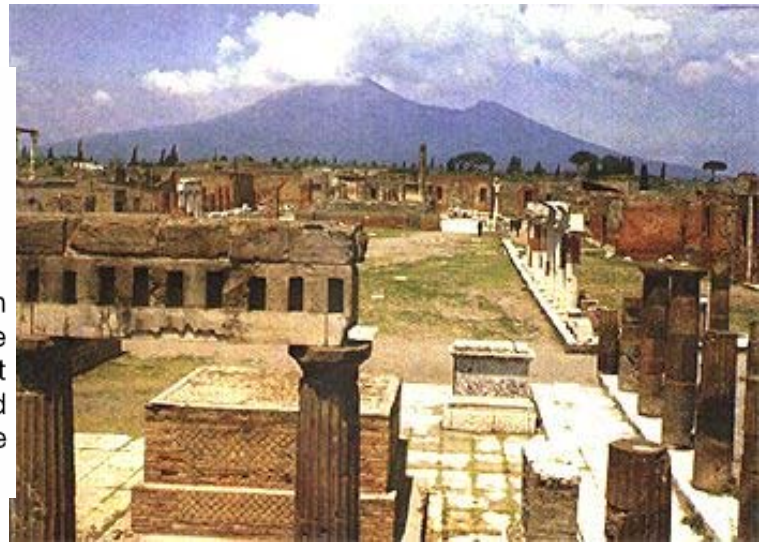




$^{40}Ar/^{39}Ar$ Dating into the Historical Realm: Calibration Against Pliny the Younger

P. R. Renne,* W. D. Sharp, A. L. Deino, G. Orsi, L. Civetta

Laser incremental heating of sanidine from the pumice deposited by the Plinian eruption of Vesuvius in 79 A.D. yielded a $^{40}Ar/^{39}Ar$ isochron age of 1925 ± 94 years ago. Close agreement with the Gregorian calendar–based age of 1918 years ago demonstrates that the $^{40}Ar/^{39}Ar$ method can be reliably extended into the temporal range of recorded history. Excess ^{40}Ar is present in the sanidine in concentrations that would cause significant errors if ignored in dating Holocene samples.



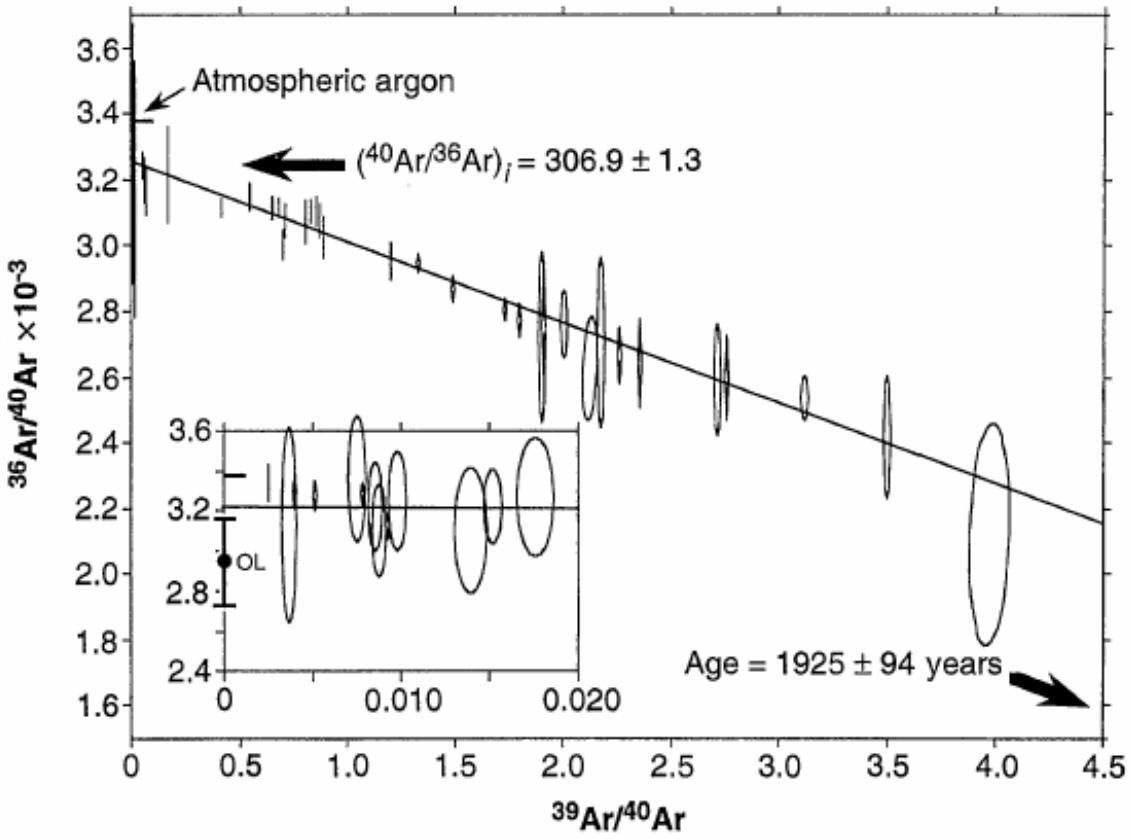
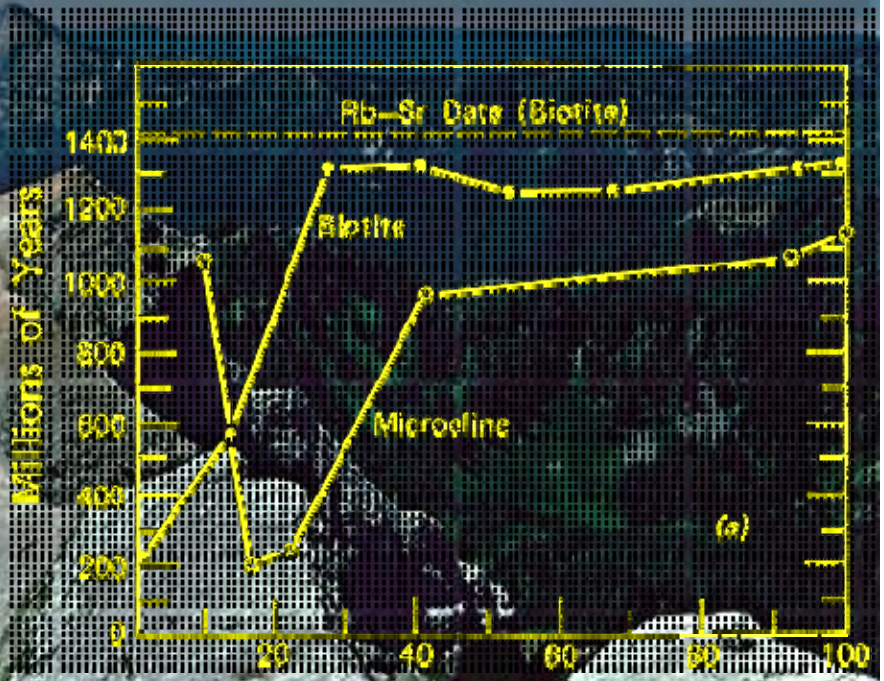


Fig. 1. Isotope correlation diagram showing isochron obtained by regression of 46 analyses. The inset shows detail of 13 analyses with the lowest $^{39}Ar/^{40}Ar$. The mean of five olivine analyses is shown on the $^{36}Ar/^{40}Ar$ axis of the inset with error bars, labeled OL. OL data are not included in the regression. Trapped component $[(^{40}Ar/^{36}Ar)i]$ is shown by bold arrow.

Metamorfiti Marble Mts. Californija

gubitak (difuzija) Ar na rubovima

gnajs, 1450 Ma (Rb/Sr)
biotit, 1350 Ma (Ar/Ar)
1150 Ma (K/Ar)



Spektar starostiizračunat iz odnosa $^{40}Ar^*/^{39}Ar$ uz postupno zagrijavanje neutronski ozračenog biotita i mikroklina iz prekambrijskog temeljnog kompleksa Marble Mts. u JI Kaliforniji.

- Starost kompleksa 1400 do 1450 Ma, određeno Rb/Sr metodom.
- Visoko-temperaturna plinska frakcija (isplinjeno više od 30% argona) daje prihvatljivu «plato vrijednost» od 1300 Ma.
- K/Ar metoda na istom uzorku biotita dala je prenisku vrijednost od 1152 Ma±30 Ma.
- Mikroklin nije izgradio uvjerljivu plato vrijednost.

Dijabaz u granitima Liberije (zapadna Afrika)

Usvajanje Ar (excess Ar) na rubovima minerala

- Dijabaz intrudirao u stari granitski fundament u mezozojsko vrijeme u Liberiji (2700-3400 Ma).
- K/Ar metoda dala neprihvatljivo visoku vrijednost za dijabaz od 853±26 Ma.
- Ar/Ar metoda ukazala na visoku vrijednost usvojenog argona (excess argona) tijekom intruzije.
- Plato vrijednost neprihvatljiva zbog nejasne interpretacije cijele krivulje spektra.