Modul: Sedimente und Stratigraphie II

Vorlesung: Einführung in die Stratigraphie

*Thema heute: Radiometrische Datierung*

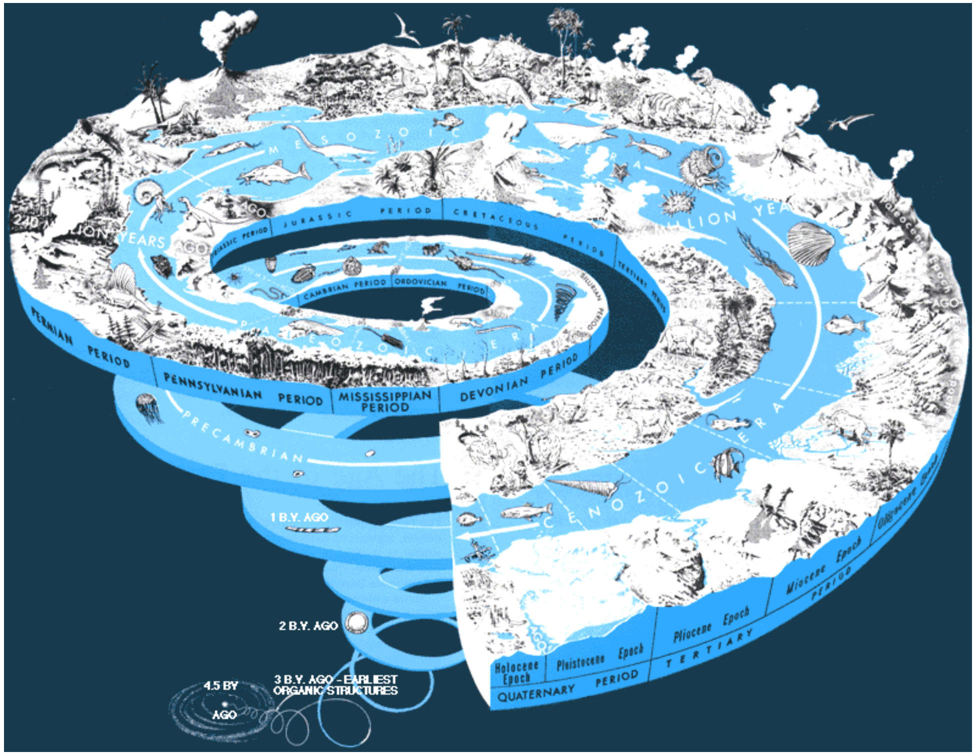
# Stratigraphie + Datierung =

# Chronostratigraphie

# How do we know the age of the Earth?

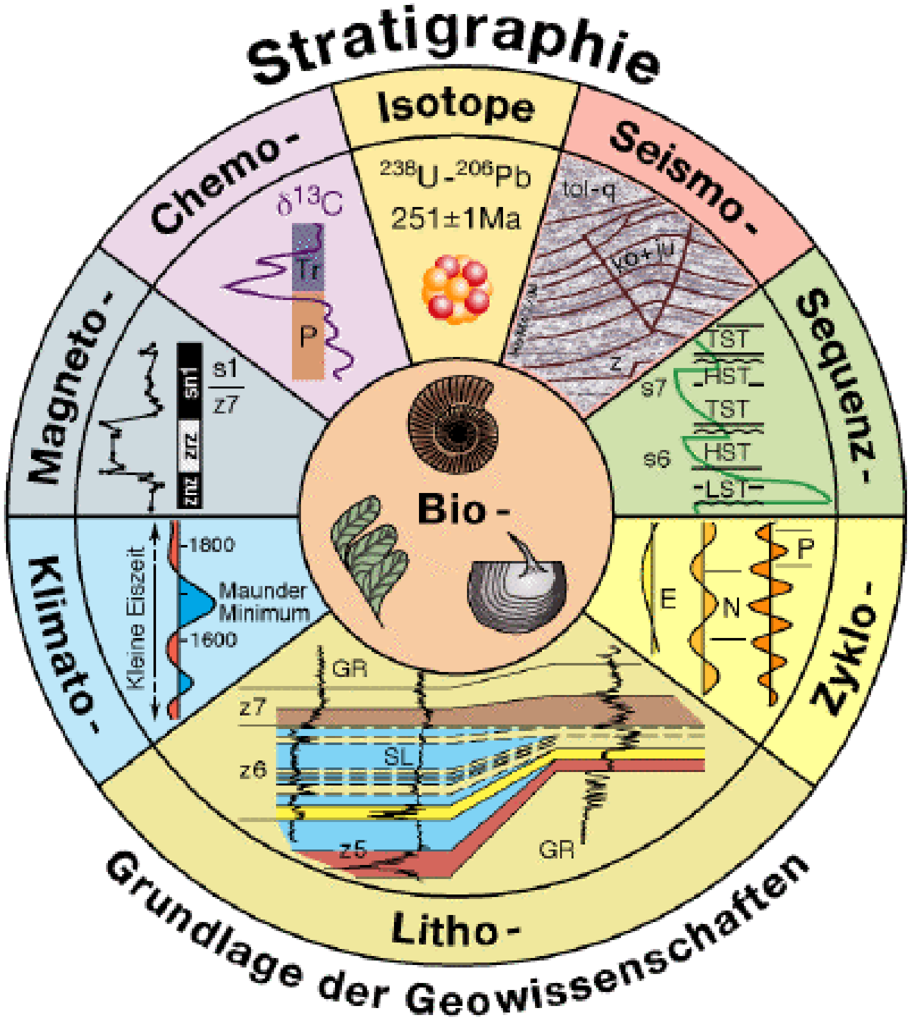
Radiometric dating

A time machine to the past




Arthur Holmes 1913:
*The age of the Earth*

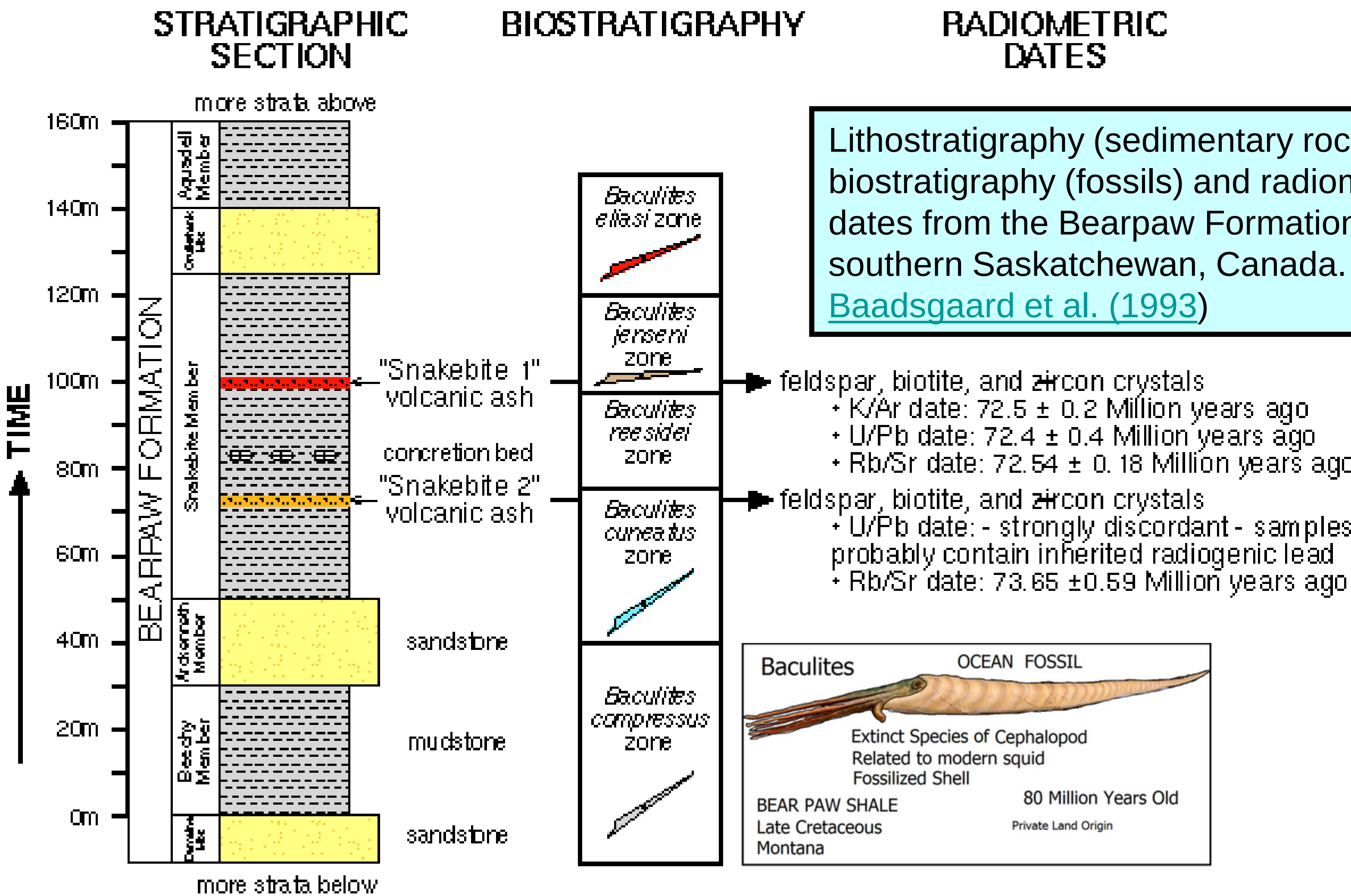
# Stratigraphie und Datierung (Chronostratigraphie)



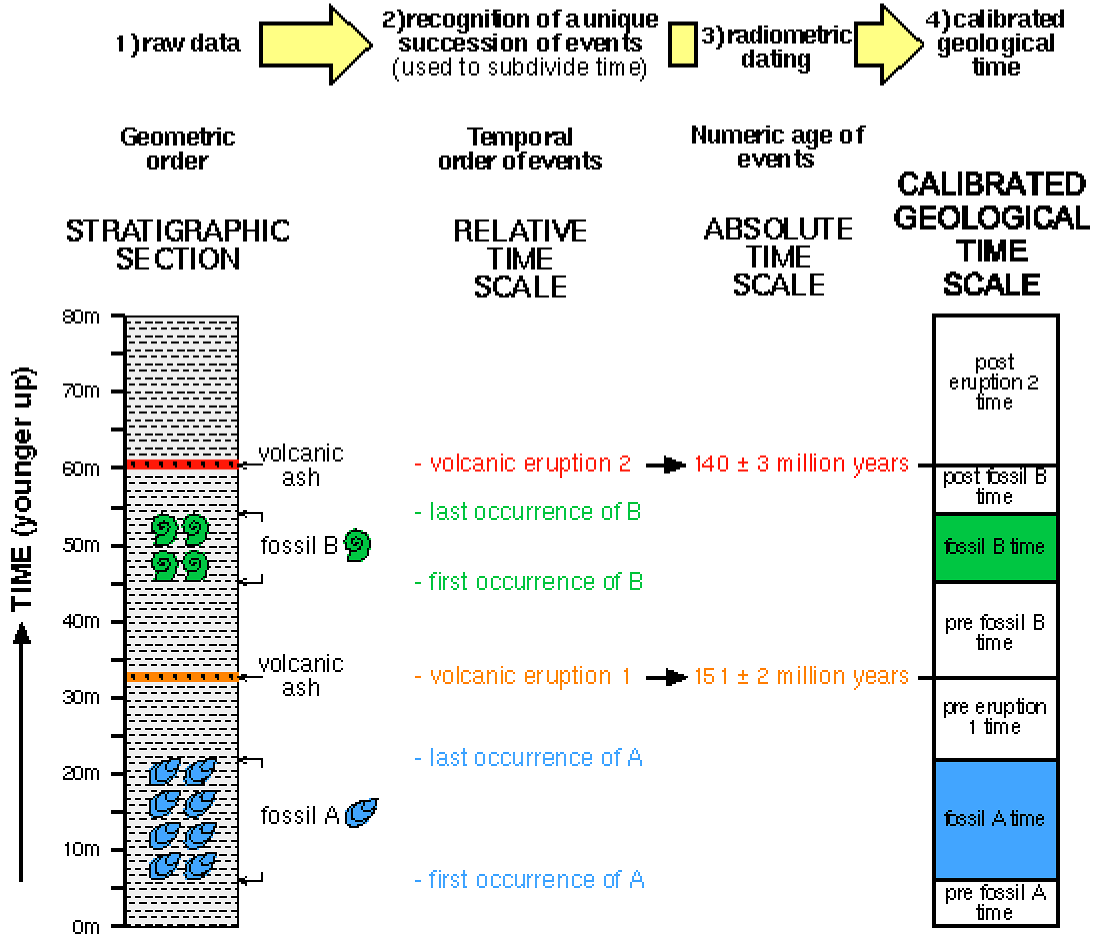
Jutulhogget, Antarctica (photo H. Frimmel)

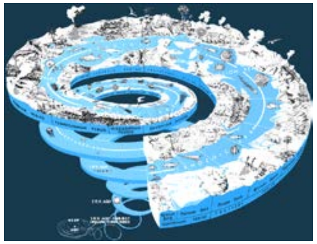
# Towards a calibrated geological time scale

Lithostratigraphy (sedimentary rocks), biostratigraphy (fossils) and radiometric dates from the Bearpaw Formation, southern Saskatchewan, Canada. Baadsgaard et al. (1993)

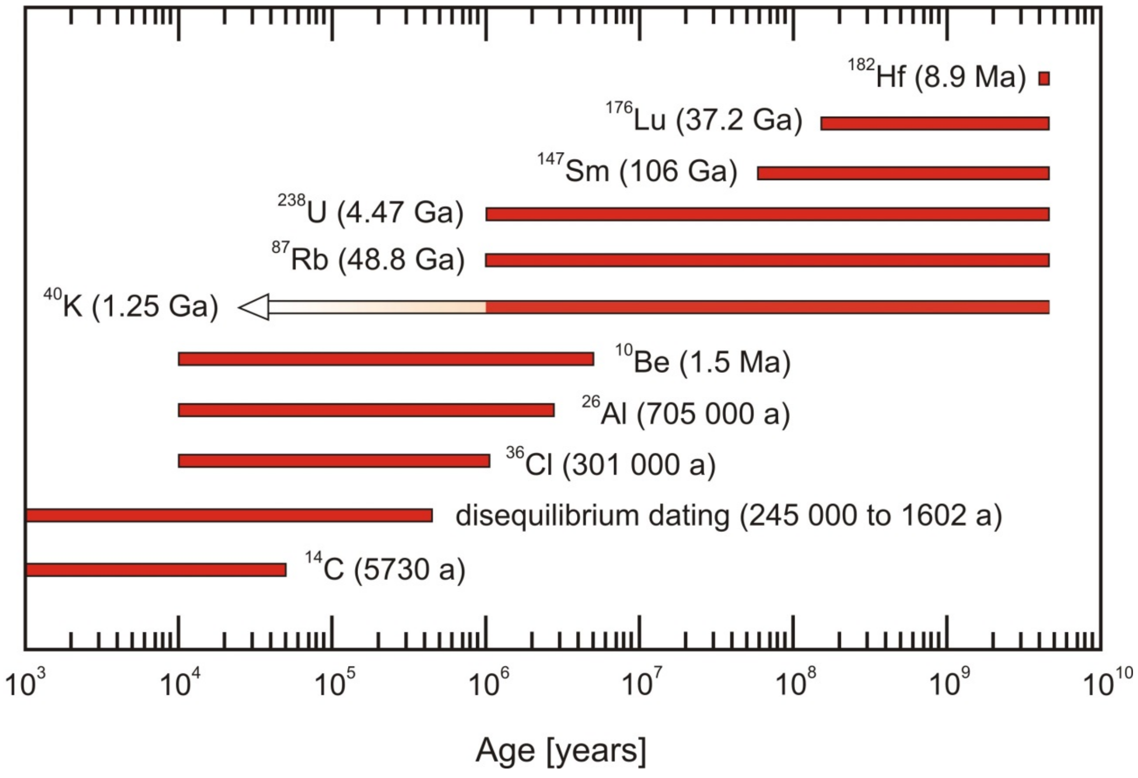


# Towards a calibrated geological time scale

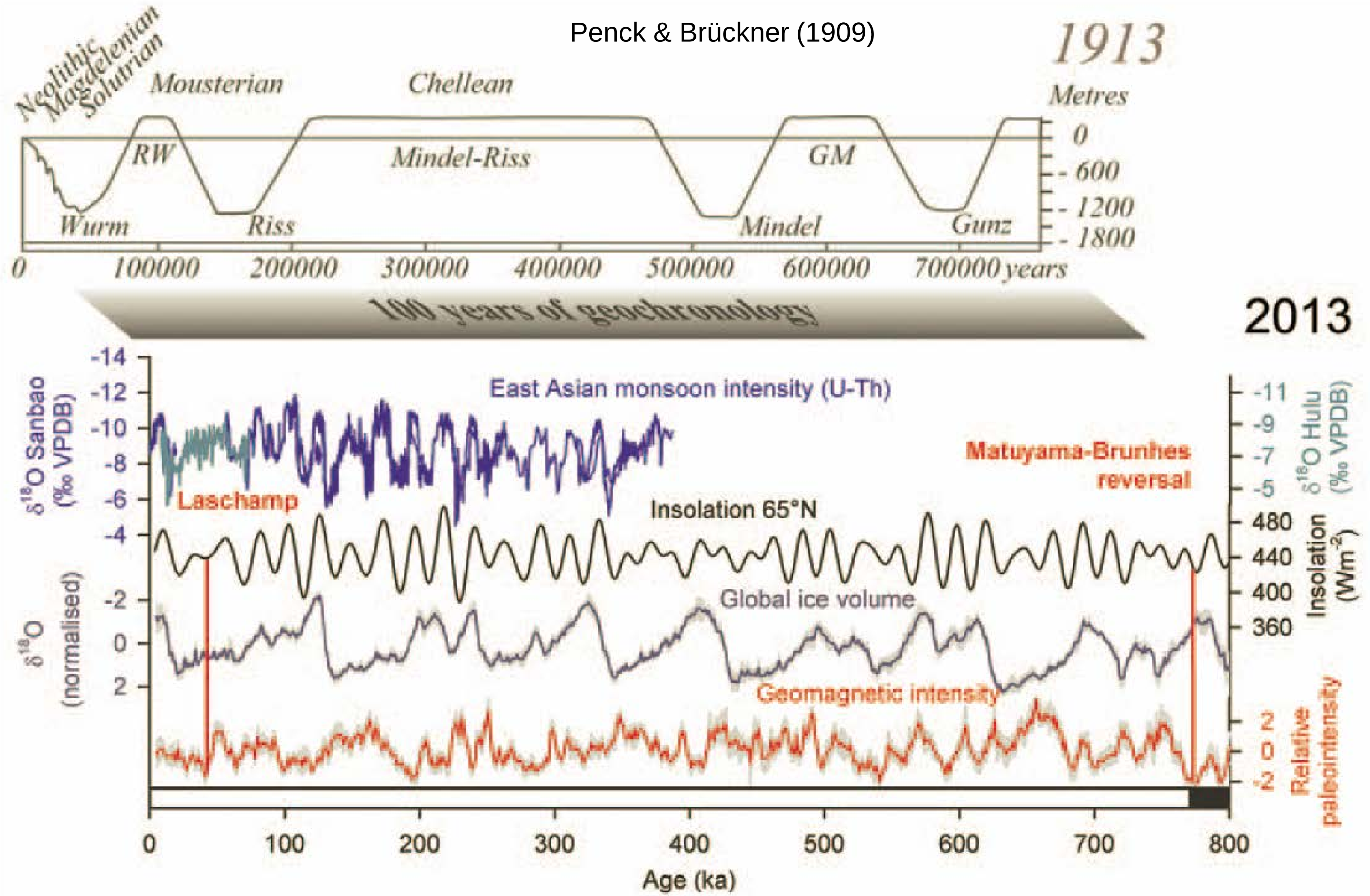


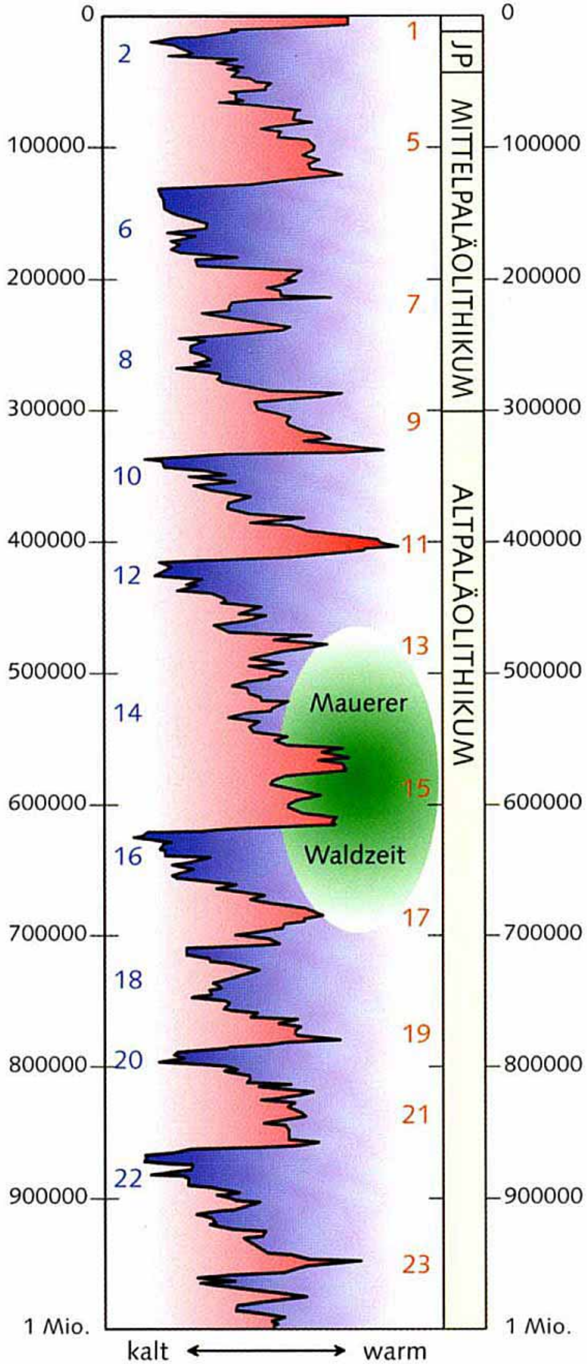



# Tools and methods



Penck & Brückner (1909)





0
100000
200000
300000
400000
500000
600000
700000
800000
900000
1 Mio.
1
2
5
6
7
8
9
10
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13
14
15
16
17
18
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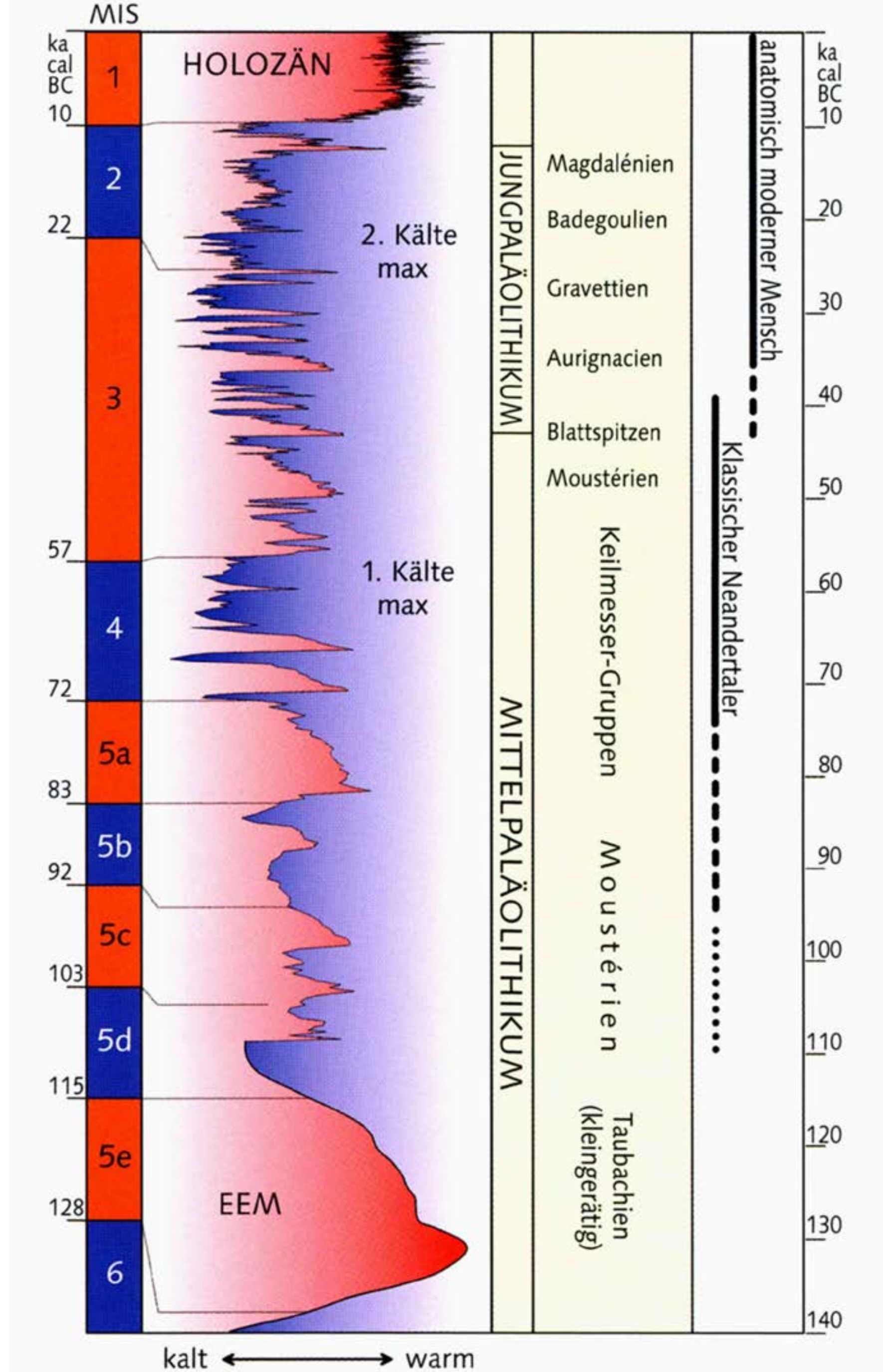
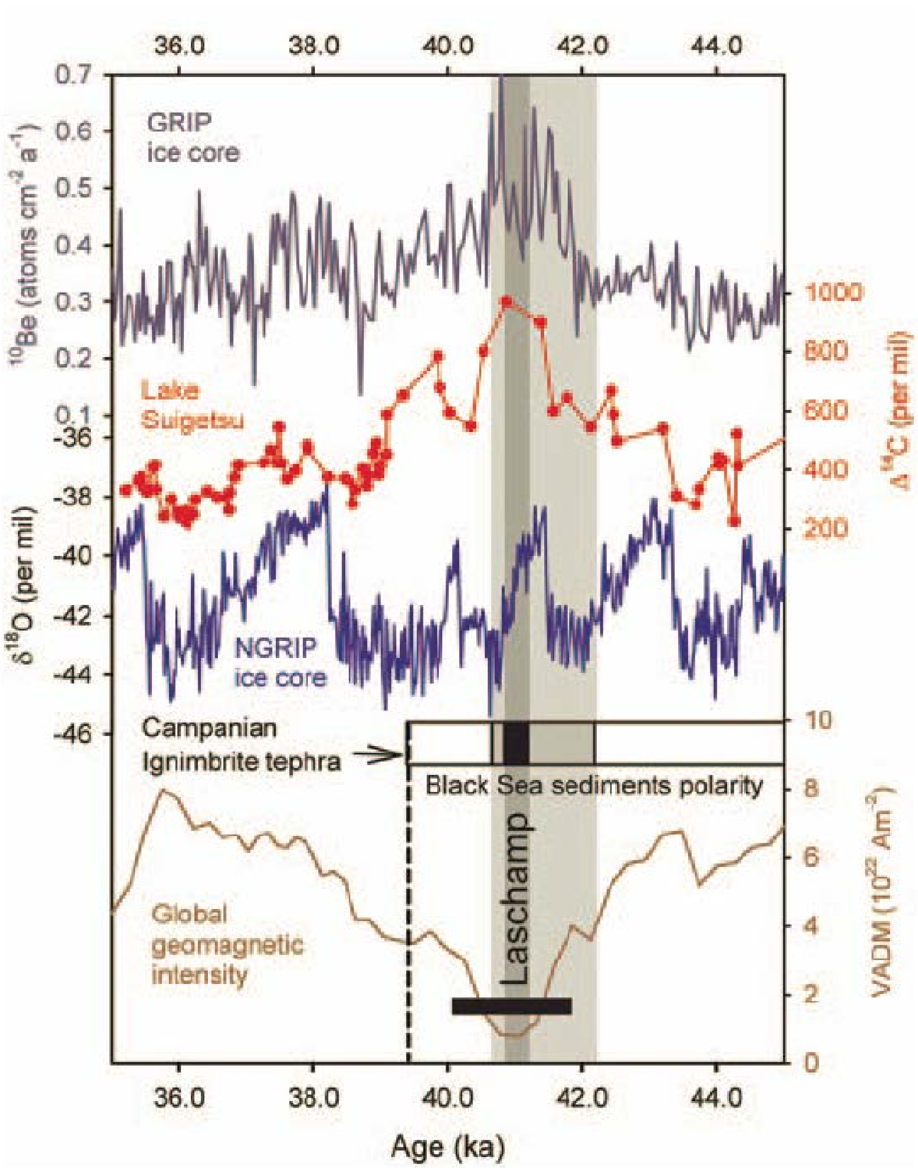
23
JP
MITTELPALÄOLITHIKUM
ALTPALÄOLITHIKUM
Mauerer
Waldzeit
kalt
warm

MIS
ka cal BC
1
2
3
4
5a
5b
5c
5d
5e
6
10
22
57
72
83
92
103
115
128
HOLOZÄN
2. Kälte max
1. Kälte max
EEM
JUNGPALÄOLITHIKUM
MITTELPALÄOLITHIKUM
Magdalénien
Badegoulien
Gravettien
Aurignacien
Blattspitzen
Moustérien
Keilmesser-Gruppen
Moustérien
Taubachien (kleingerätig)
anatomisch moderner Mensch
Klassischer Neandertaler
ka cal BC
10
20
30
40
50
60
70
80
90
100
110
120
130
140
kalt
warm




# Laschamp

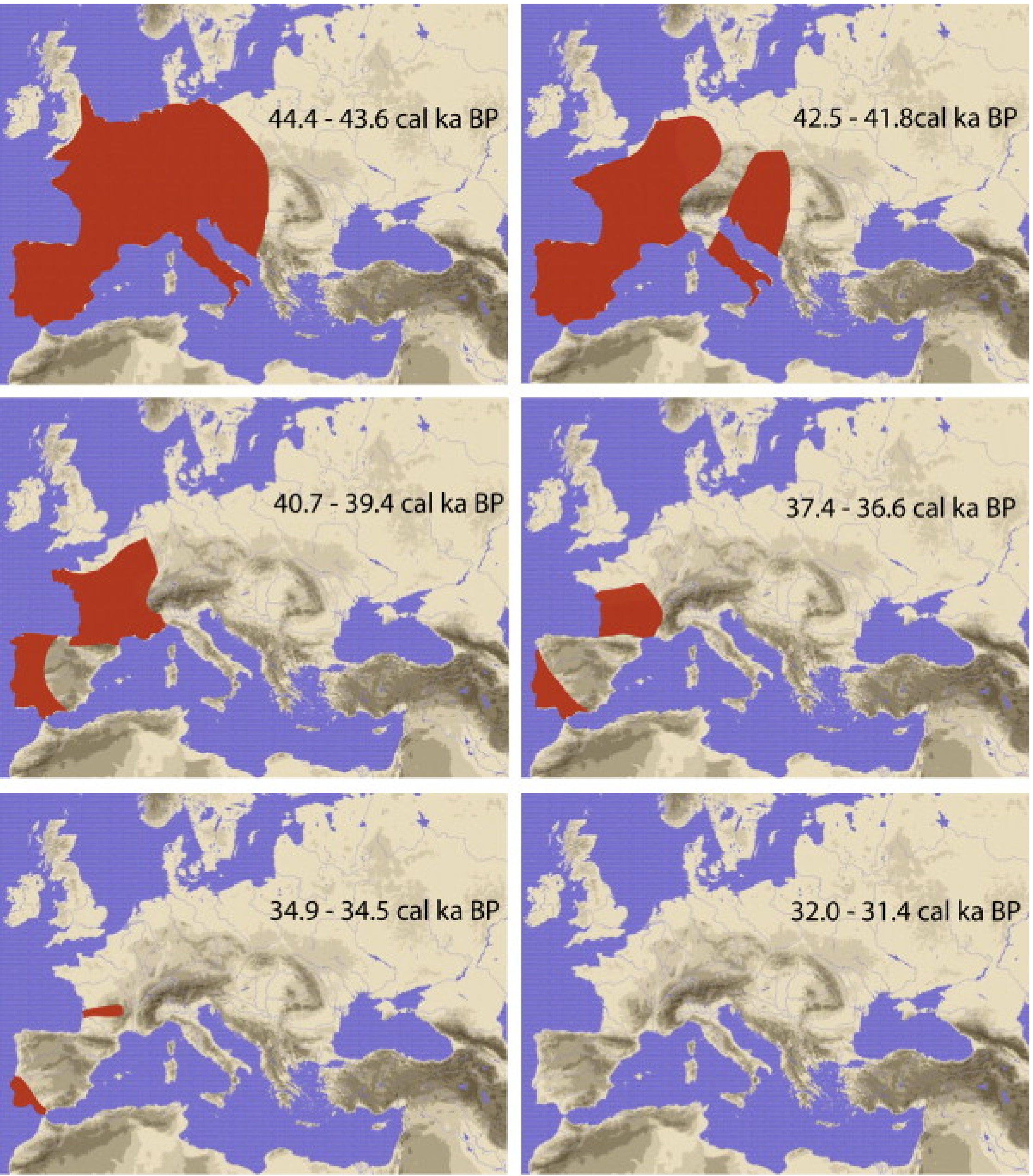
# the Earth at 40 ka

short and fast reversal of the Earth's magnetic field

short-term climate variability of the last ice age

and volcanic eruption in Italy

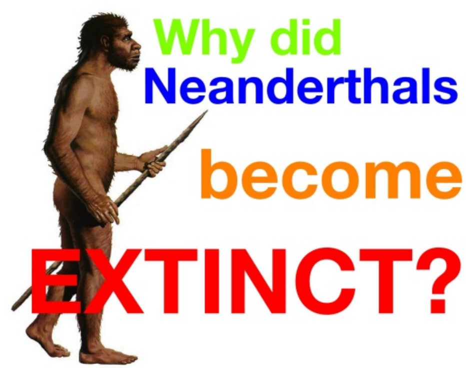
# Das Laschamp Ereignis



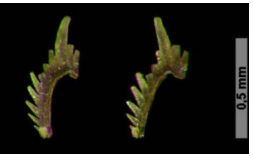

short and fast reversal of the Earth's magnetic field

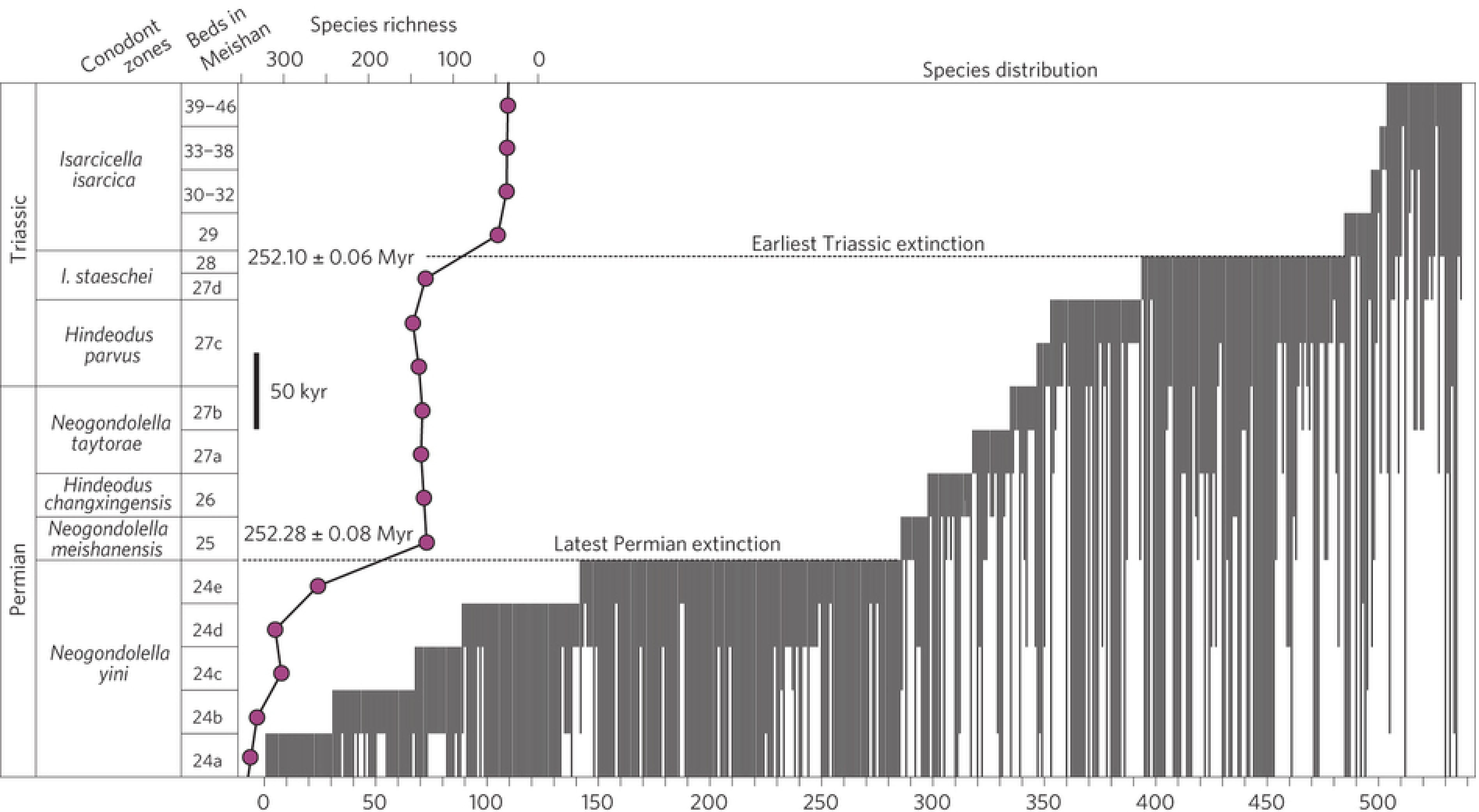
short-term climate variability of the last ice age

and volcanic eruption in Italy

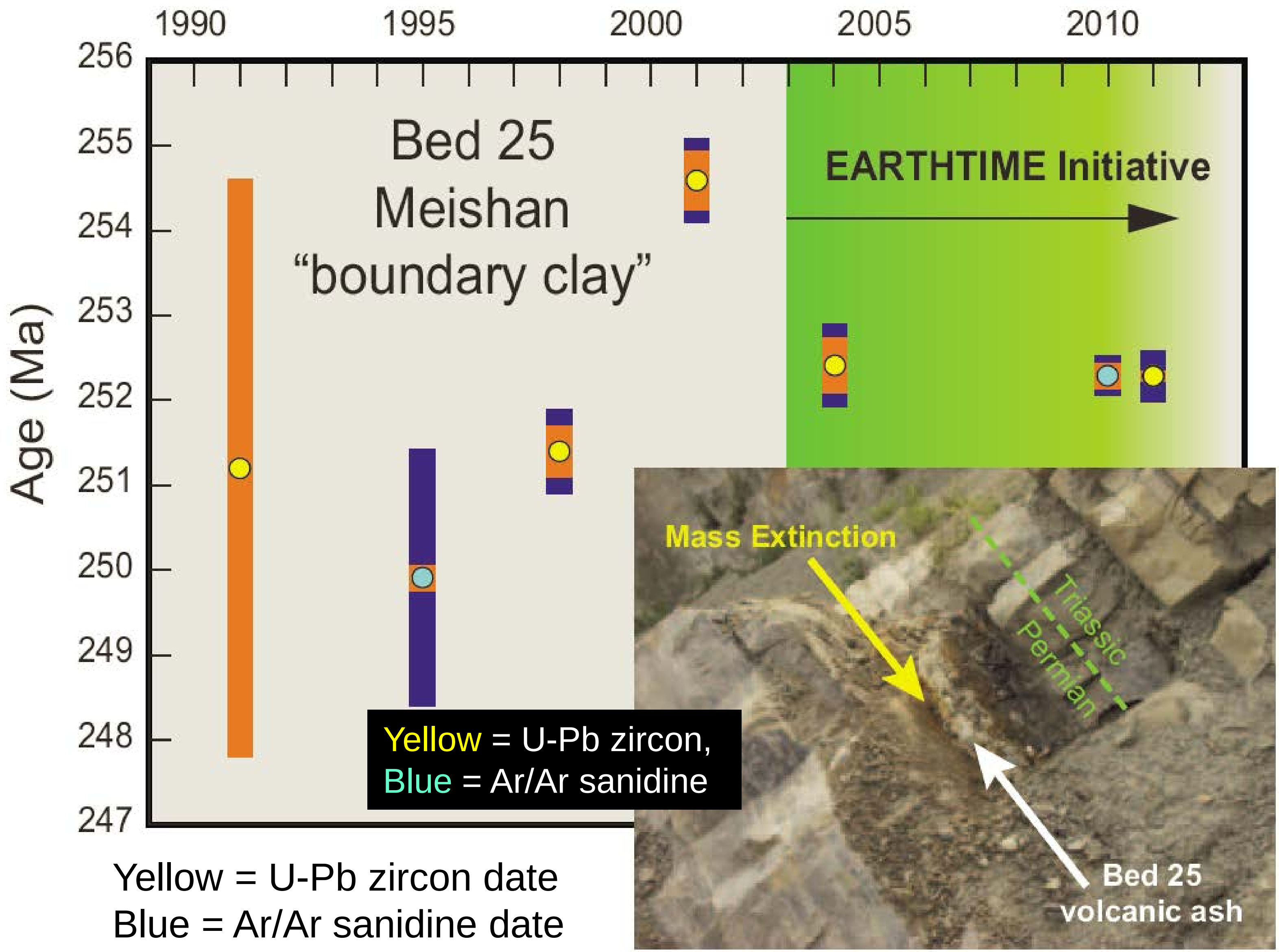


# Permo-Triassic mass extinction



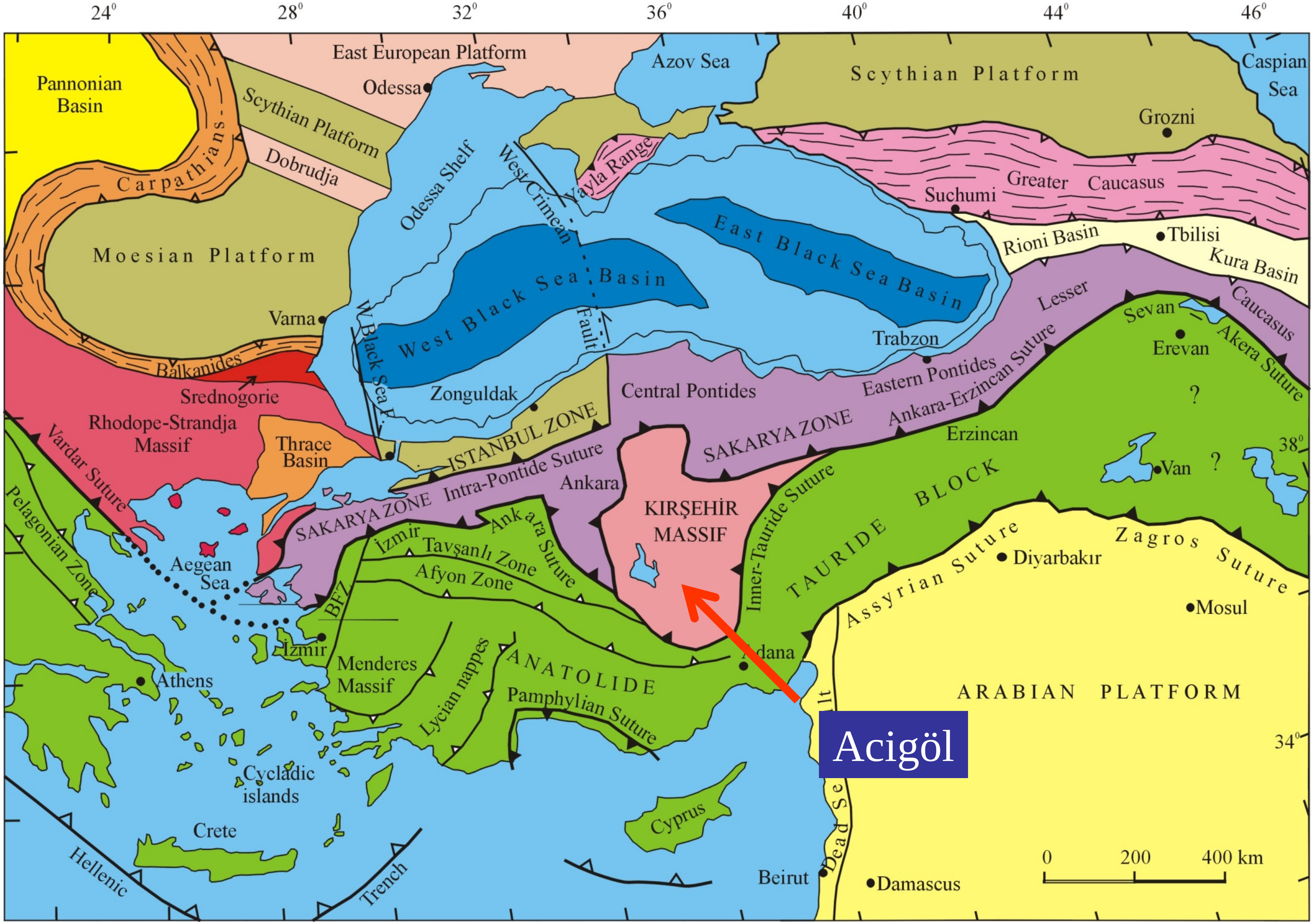



# Permo-Triassic mass extinction

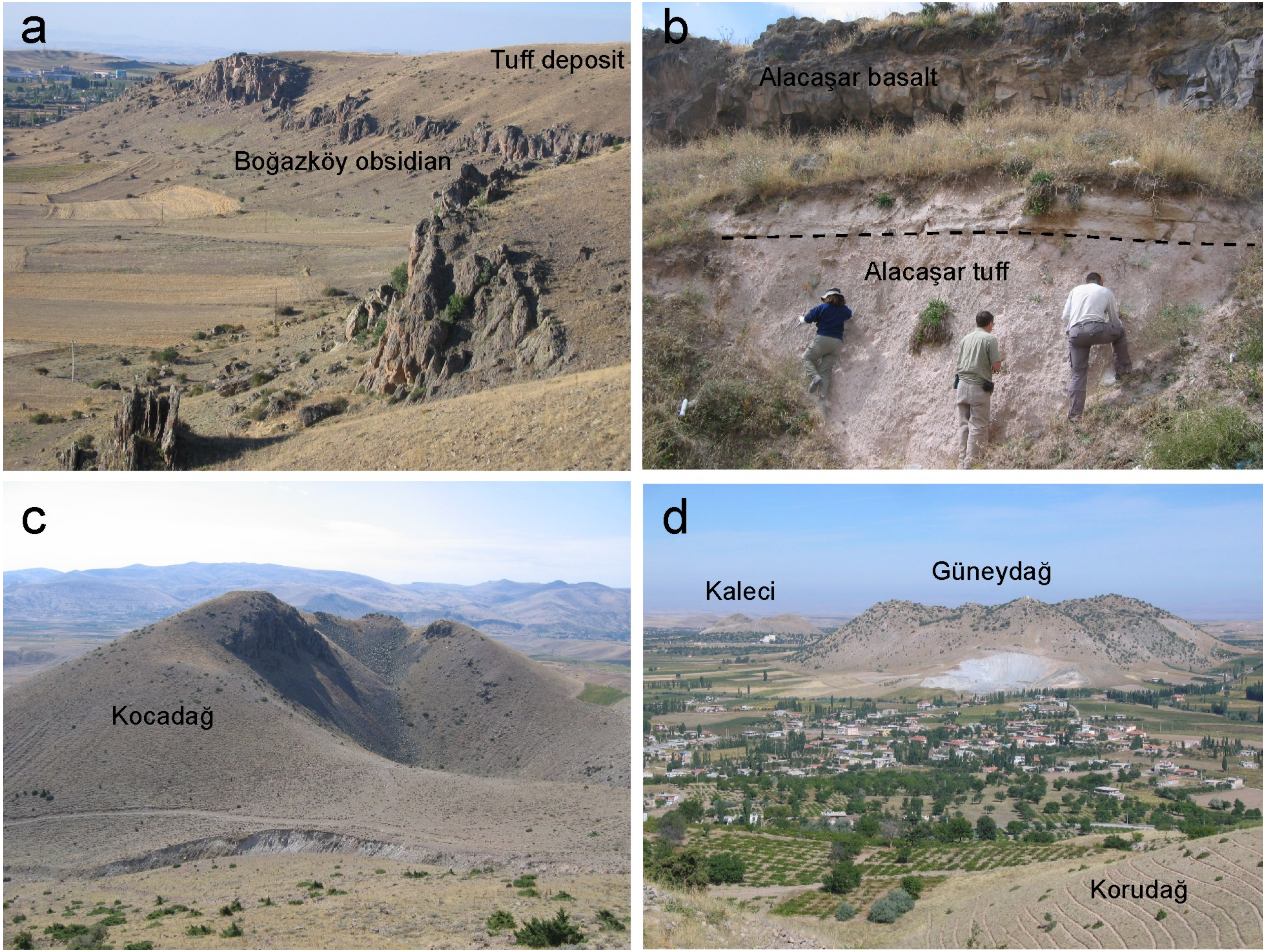



Yellow = U-Pb zircon date
Blue = Ar/Ar sanidine date

Beginning of Siberian Traps volcanism: 250.0 ± 1.6 Ma (Renne et al. 1995)



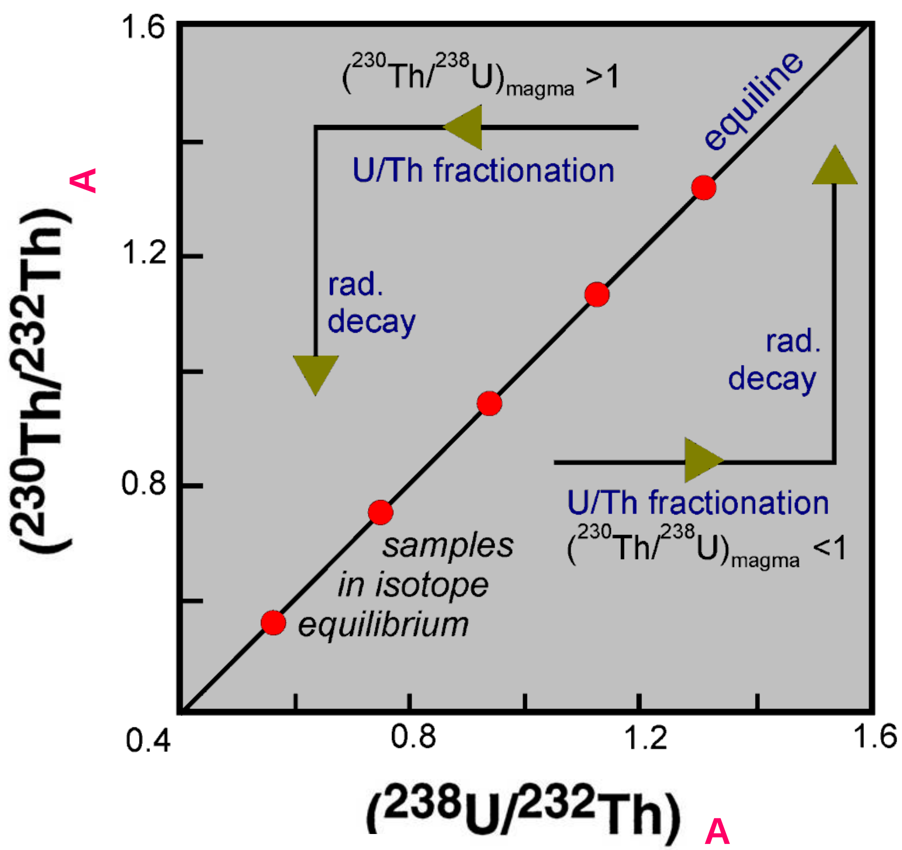
24°
28°
32°
36°
40°
44°
46°
46°
42°
38°
38°
34°
Pannonian Basin
East European Platform
Odessa
Azov Sea
Scythian Platform
Caspian Sea
Scythian Platform
Dobrudja
Carpathians
Grozni
Odessa Shelf
West Crimean Fault
Yayla Range
Greater Caucasus
Suchumi
Moesian Platform
East Black Sea Basin
Rioni Basin
Tbilisi
Kura Basin
West Black Sea Basin
Varna
W. Black Sea F.
Lesser Caucasus
Sevan
Trabzon
Erevan
Akera Suture
Balkanides
Srednogorie
Zonguldak
Central Pontides
Eastern Pontides
Ankara-Erzincan Suture
Rhodope-Strandja Massif
Thrace Basin
ISTANBUL ZONE
SAKARYA ZONE
Erzincan
Vardar Suture
Intra-Pontide Suture
Ankara
Van
Pelagonian Zone
SAKARYA ZONE
KIRŞEHİR MASSIF
Inner-Tauride Suture
TAURIDE BLOCK
Aegean Sea
İzmir
Tavşanlı Zone
Ankara Suture
Zagros Suture
Diyarbakır
BFZ
Afyon Zone
Assyrian Suture
Mosul
İzmir
Menderes Massif
Lycian nappes
ANATOLIDE
Adana
Athens
Pamphylian Suture
ARABIAN PLATFORM
Cycladic islands
Crete
Cyprus
Dead Sea Fault
Hellenic Trench
Beirut
Damascus
0
200
400 km
Acigöl


a
Tuff deposit
Boğazköy obsidian
b
Alacaşar basalt
Alacaşar tuff
c
Kocadağ
d
Kaleci
Güneydağ
Korudağ

# U-series disequilibrium in young volcanic rocks

$^{238}U \rightarrow {}^{234}U \rightarrow {}^{230}Th \rightarrow {}^{206}Pb$ (excluding some "shorties")

**$T_{1/2}$ = 75 ka**




Equilibrium:
$\lambda_1 N_1 = \lambda_2 N_2$
$A_1 = A_2$
$(^{230}Th/^{238}U) = 1$

**Allègre & Condomines (1976) EPSL 28, (1982) Nature 299**

$$\frac{A(^{230}Th)}{A(^{232}Th)} = \left[\frac{A(^{230}Th)}{A(^{232}Th)}\right]_{excess} \cdot (e^{\lambda 230 t}) + \frac{A(^{238}U)}{A(^{232}Th)} \cdot (1 - e^{\lambda 230 t})$$

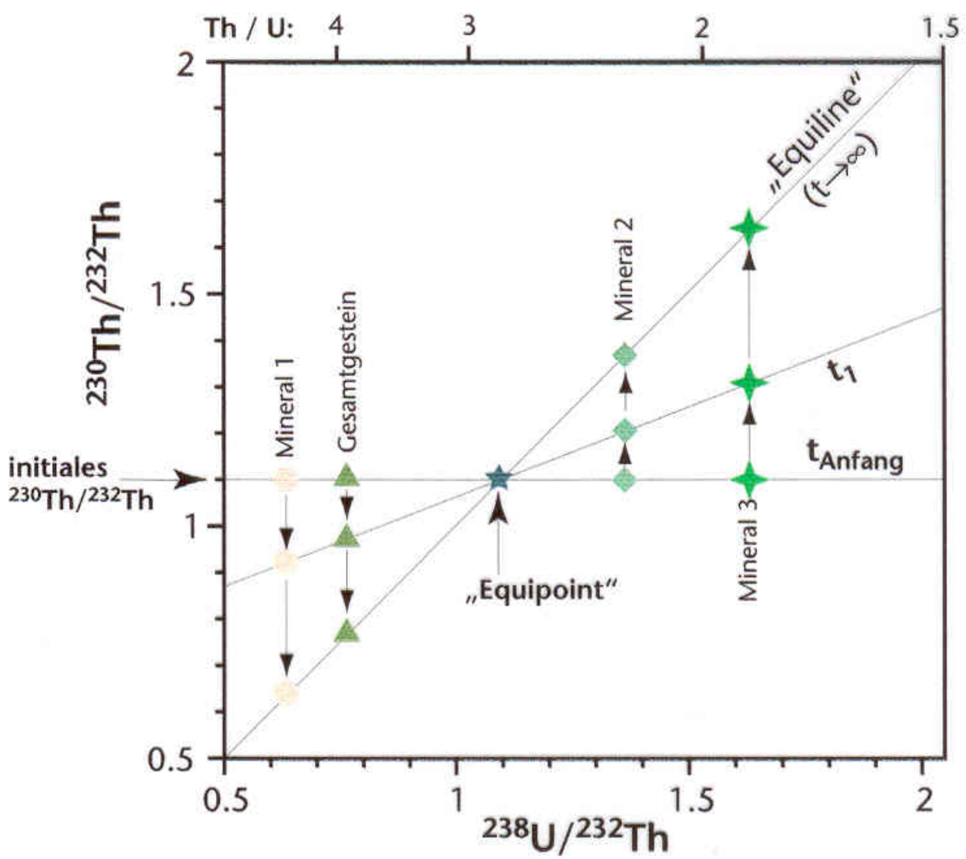
$^{230}$Th aus excess Th

$^{230}$Th aus $^{238}$U-Zerfall

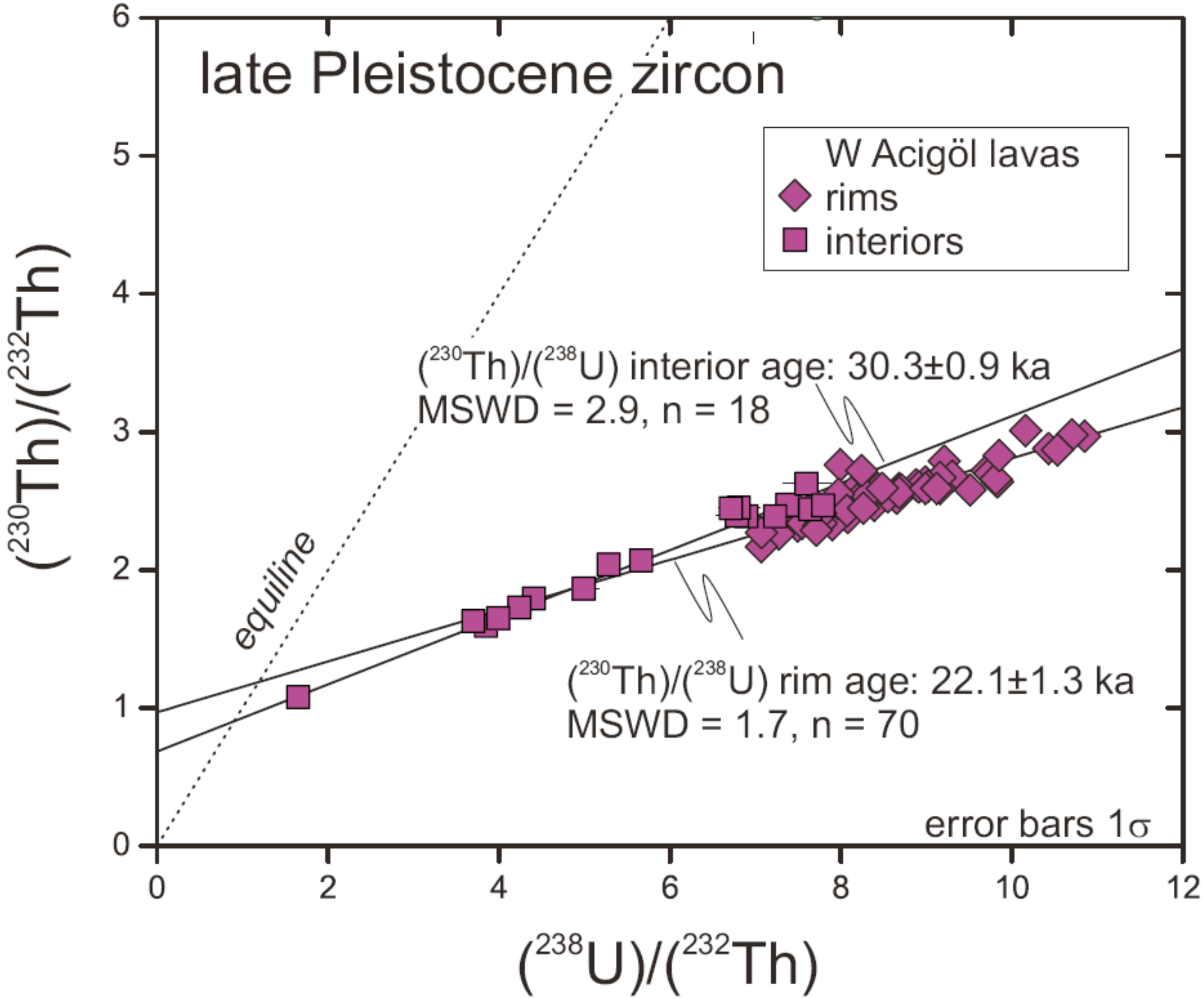
# U-series disequilibrium in young volcanic rocks

$^{238}U \rightarrow {}^{234}U \rightarrow {}^{230}Th \rightarrow {}^{206}Pb$ (excluding some "shorties")

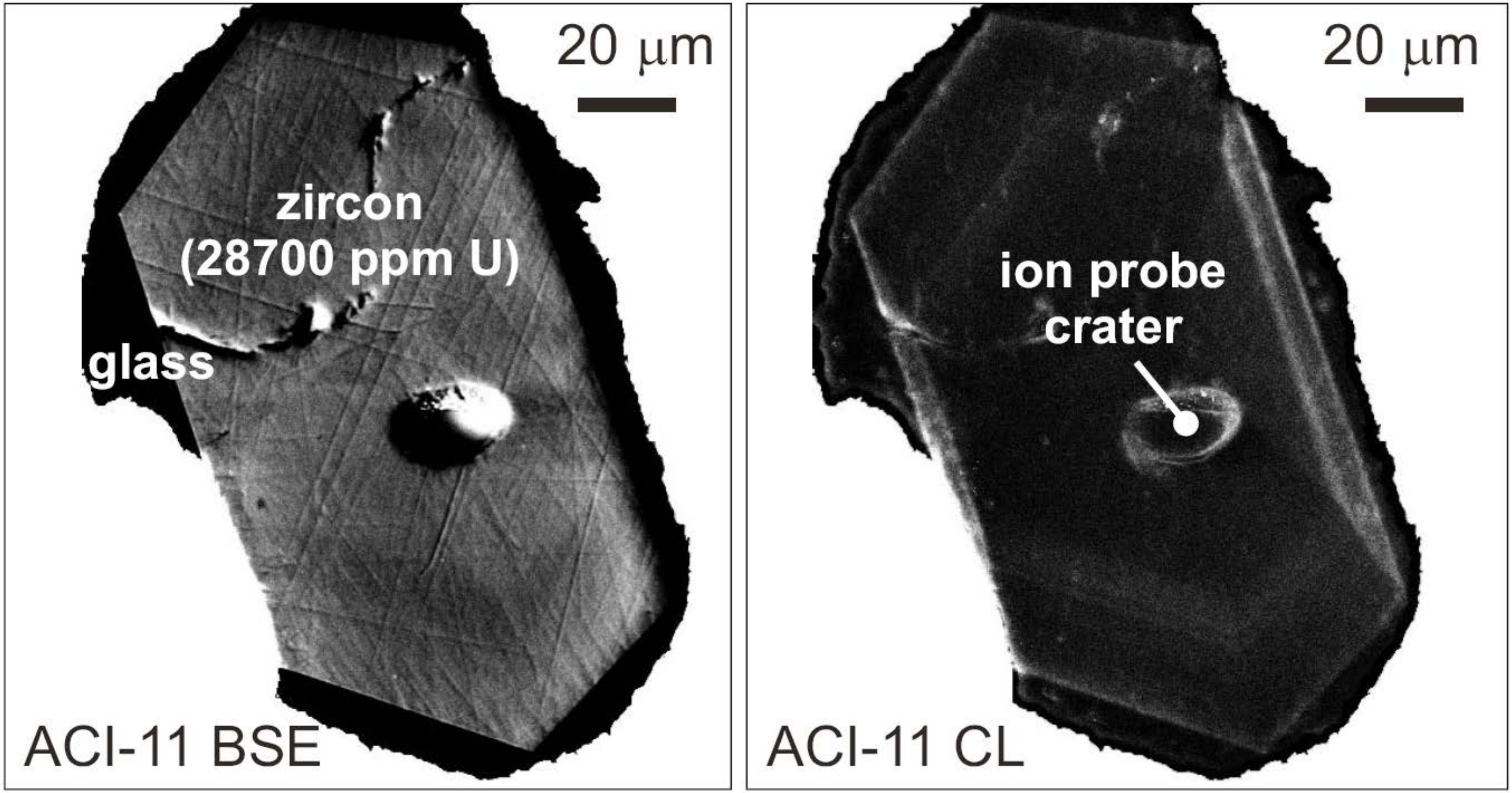
**$T_{1/2}$ = 75 ka**




For equilibrium:
$\lambda_1 N_1 = \lambda_2 N_2$
$A_1 = A_2$
$({}^{230}Th/{}^{238}U) = 1$



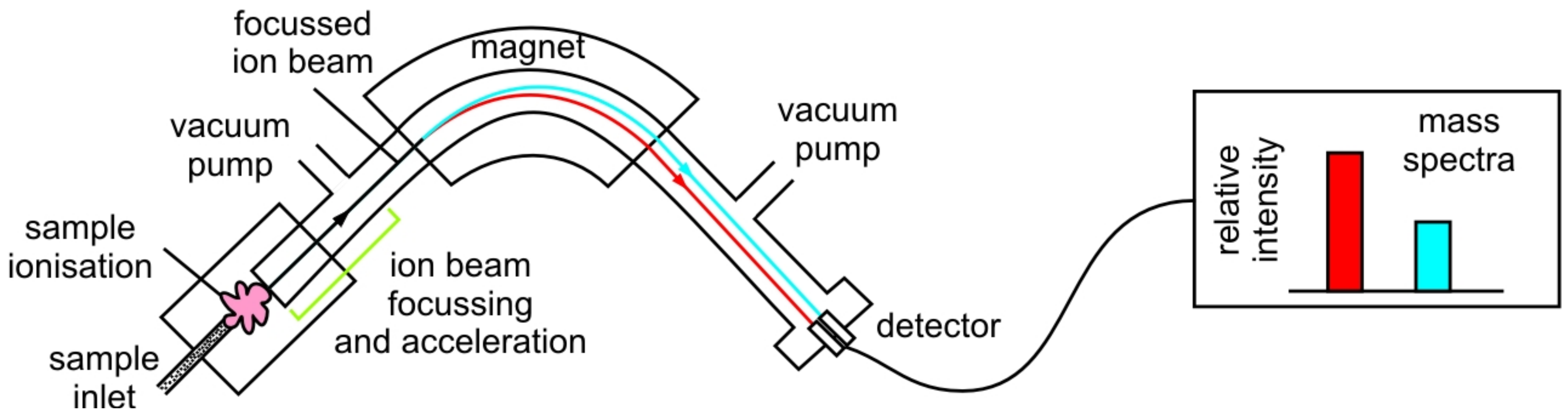
late Pleistocene zircon
W Acigöl lavas
rims
interiors
(230Th)/(238U) interior age: 30.3±0.9 ka
MSWD = 2.9, n = 18
(230Th)/(238U) rim age: 22.1±1.3 ka
MSWD = 1.7, n = 70
equiline
error bars 1σ
(230Th)/(232Th)
(238U)/(232Th)
0
1
2
3
4
5
6
0
2
4
6
8
10
12


20 μm
zircon
(28700 ppm U)
glass
ACI-11 BSE
20 μm
ion probe
crater
ACI-11 CL

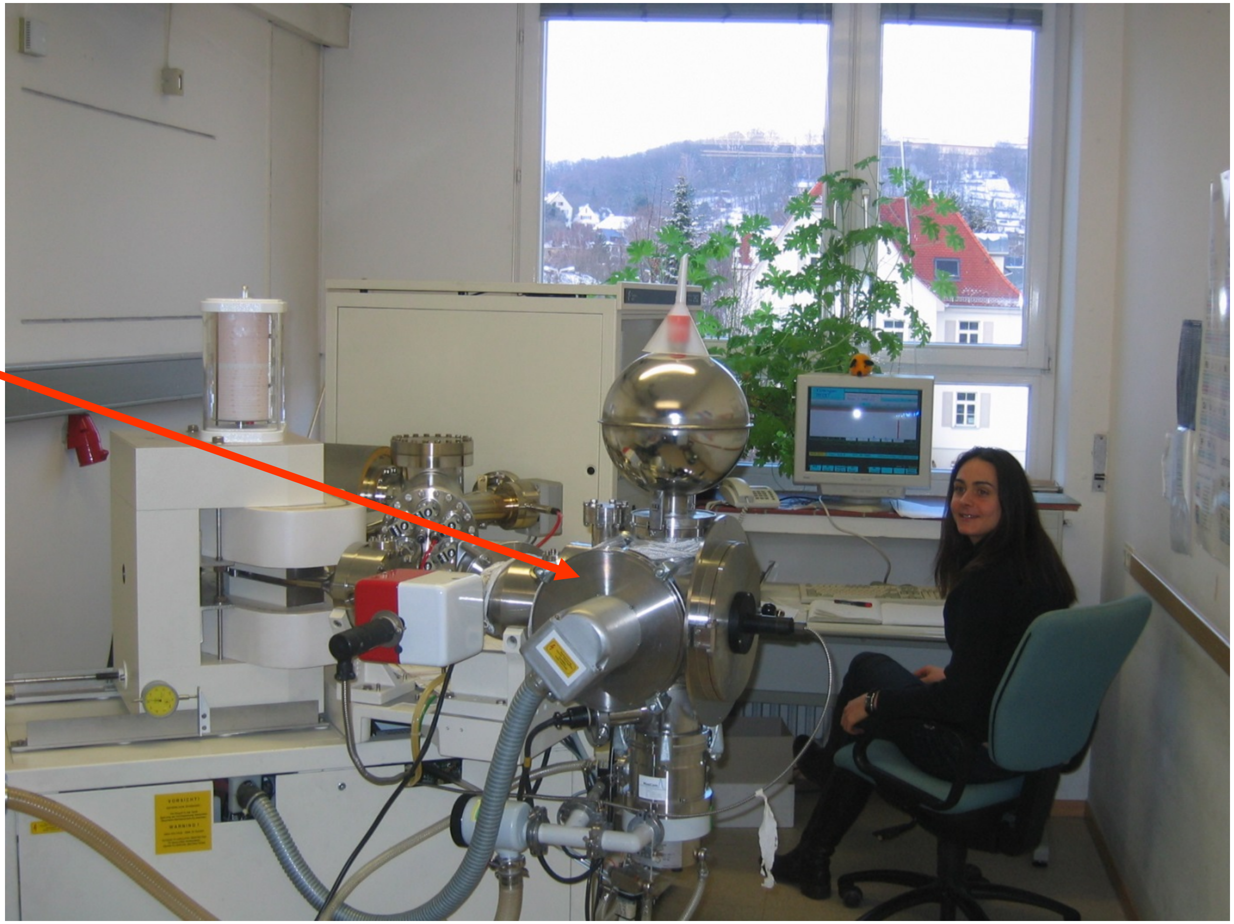
# Massenspektrometrie

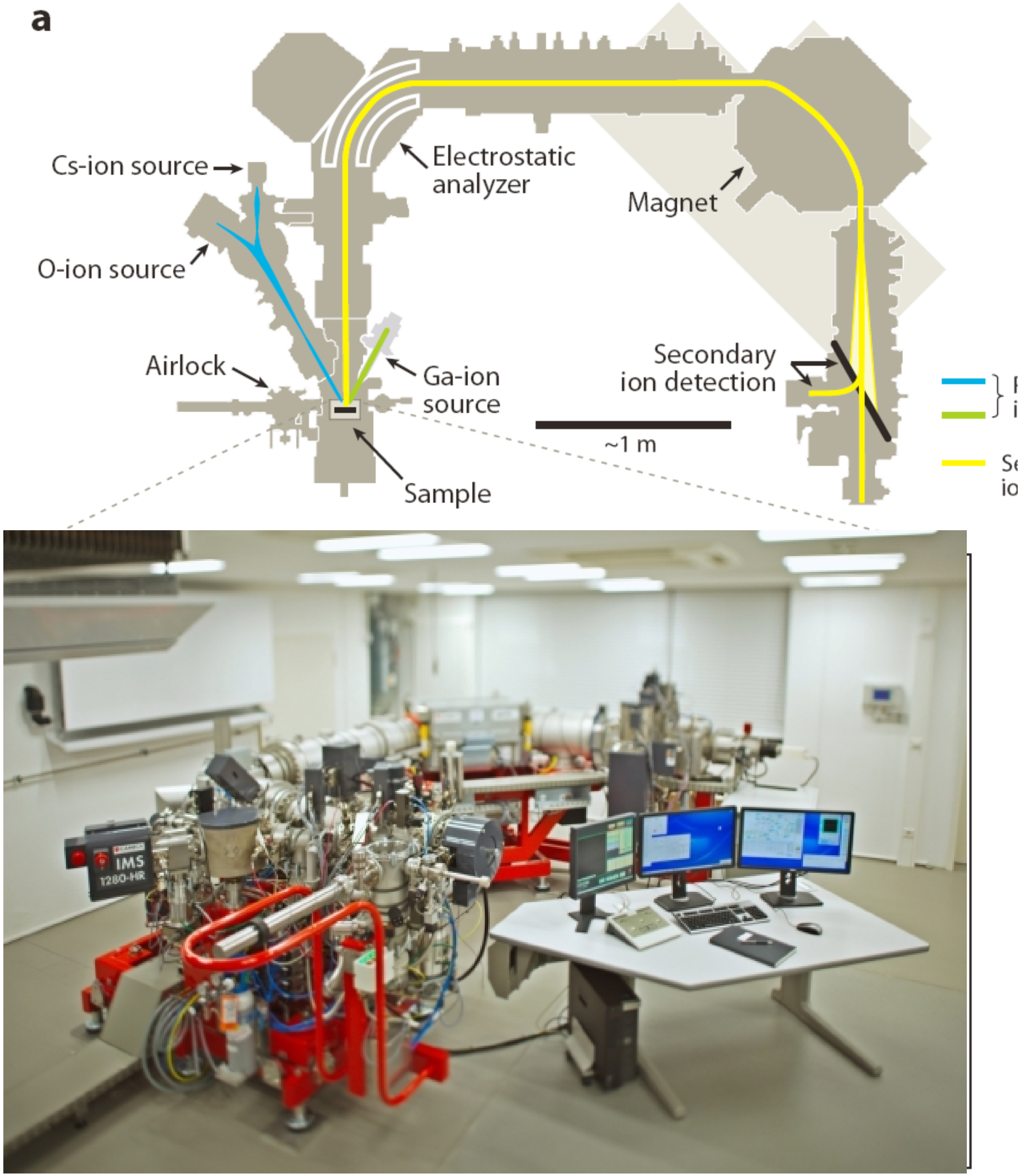
Prinzip der massenspektrometrischen Untersuchung

Reservoir → Ionenquelle → Beschleunigung → Elektrom. Feld → Nachweis



# Das Finnigan MAT 262 Massenspektrometer in der Geochemie






# Measuring Uranium-series nuclides

## Secondary ionization mass spectrometry (SIMS)

## CAMECA ims 1280 hr microprobe at Heidelberg

# Measuring cosmogenic nuclides


Accelerator mass spectrometer

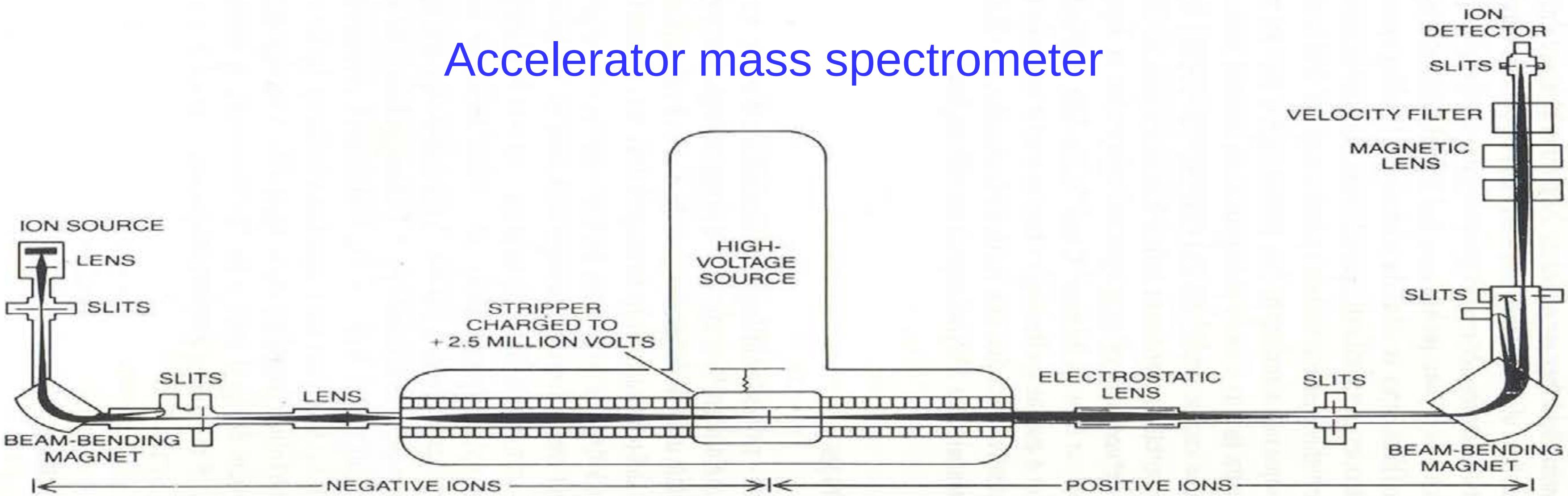
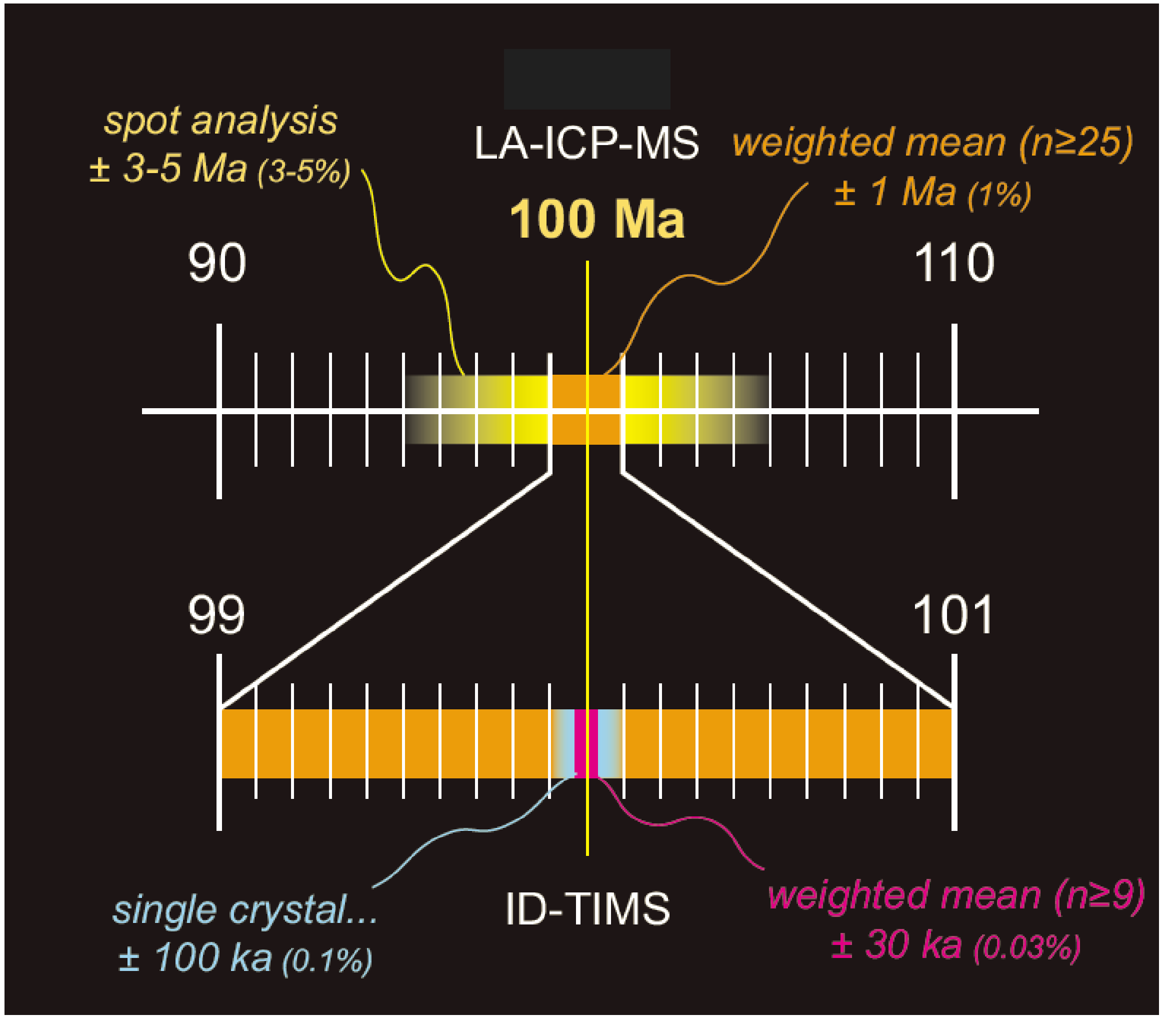


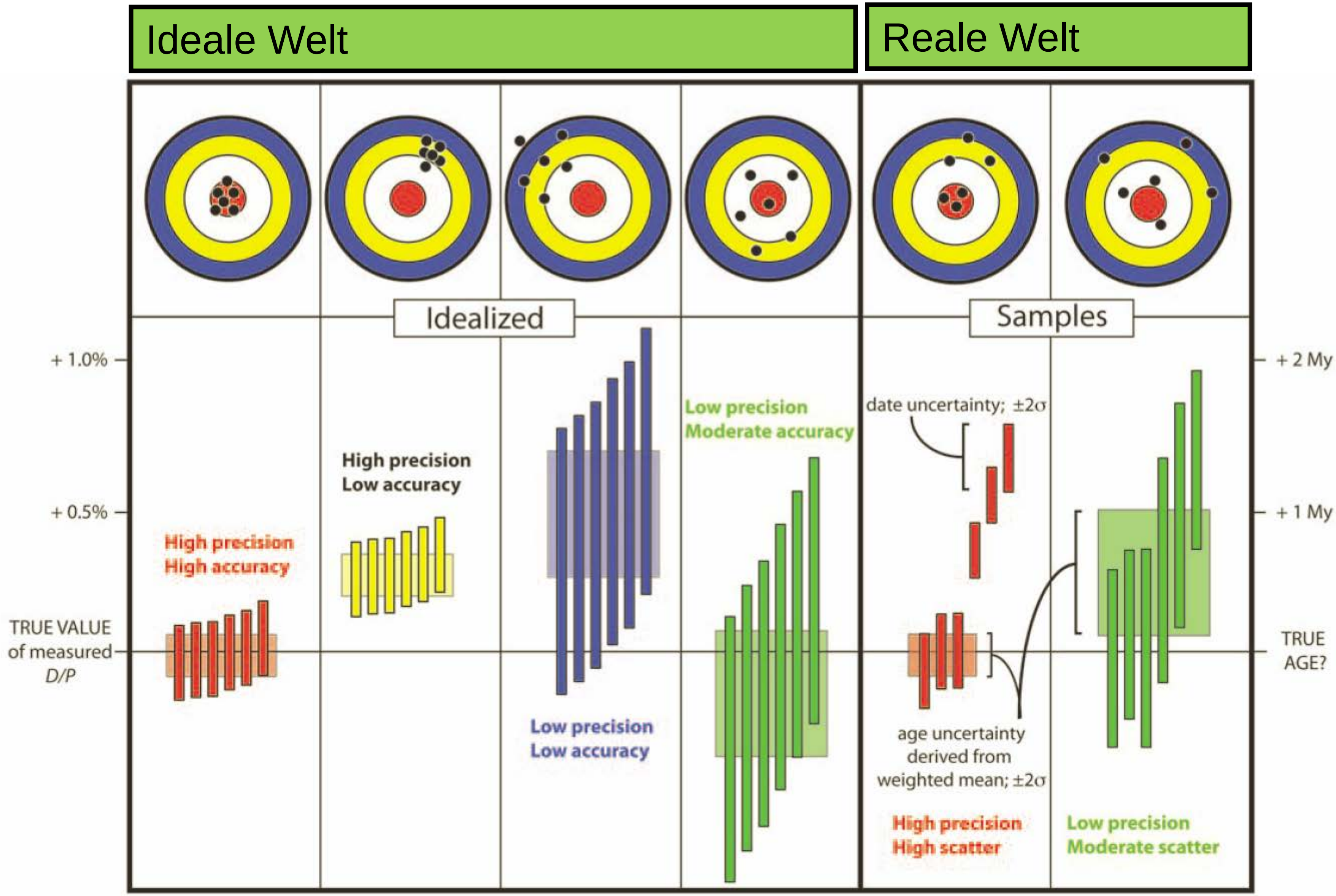

Fig. 37. Principal components of an accelerator mass spectrometer. (After Hedges and Gowlett 1986)

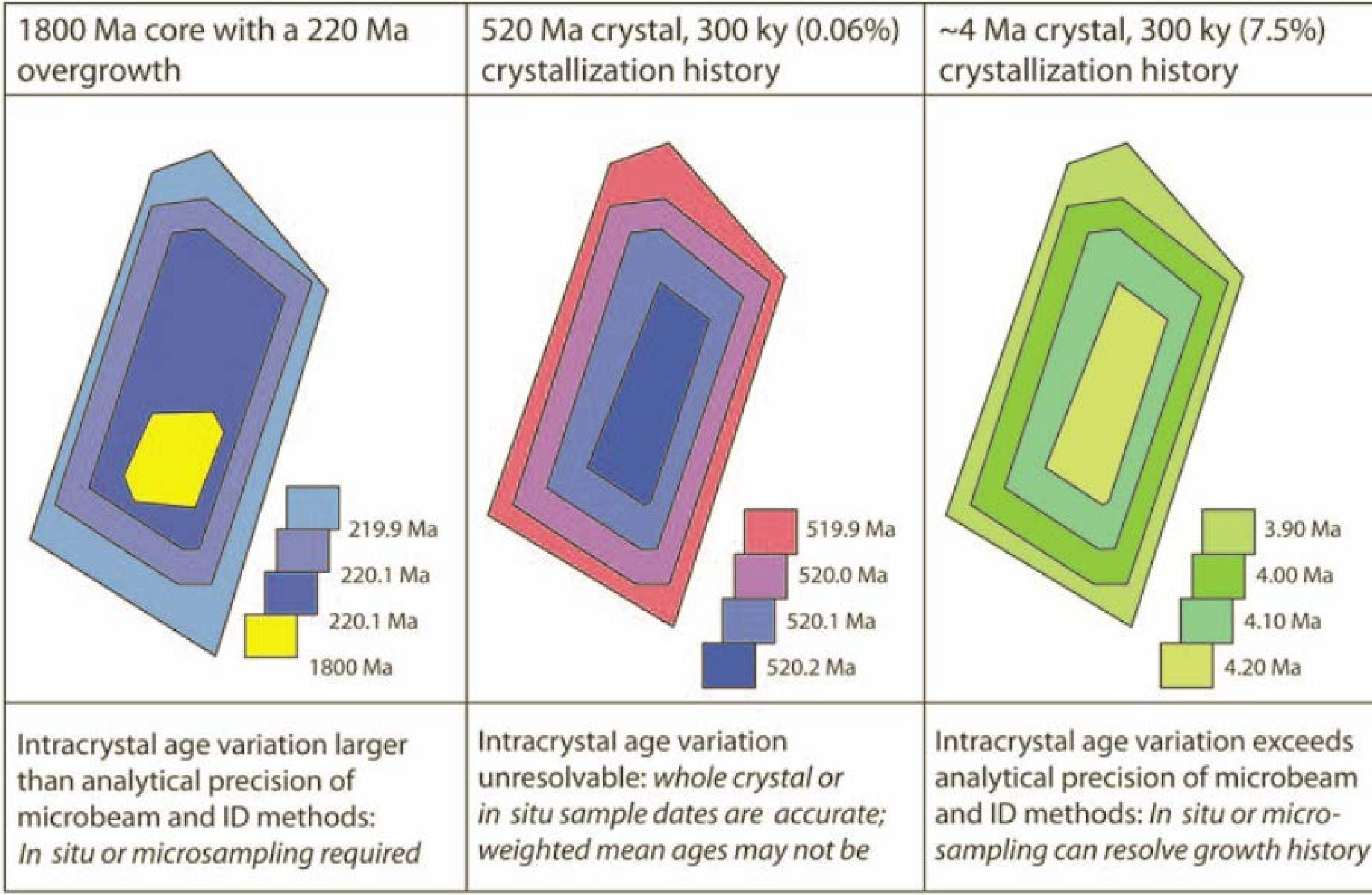
AMS has a factor of a millon lower detection limit for $^{14}C$, $^{36}Cl$, $^{10}Be$, $^{26}Al$ compared to counting methods

*The uncertainty of a data (age) is as important as the data (age) itself*
(Ken Ludwig)



The uncertainty of a date is as important as the date itself (Ken Ludwig 2003)





1800 Ma core with a 220 Ma overgrowth
520 Ma crystal, 300 ky (0.06%) crystallization history
~4 Ma crystal, 300 ky (7.5%) crystallization history
219.9 Ma
220.1 Ma
220.1 Ma
1800 Ma
519.9 Ma
520.0 Ma
520.1 Ma
520.2 Ma
3.90 Ma
4.00 Ma
4.10 Ma
4.20 Ma
Intracrystal age variation larger than analytical precision of microbeam and ID methods: *In situ or microsampling required*
Intracrystal age variation unresolvable: *whole crystal or in situ sample dates are accurate; weighted mean ages may not be*
Intracrystal age variation exceeds analytical precision of microbeam and ID methods: *In situ or micro-sampling can resolve growth history*

# Dating methods and Closure Temperature

Closure Temp: the temperature at which a cooling mineral can no longer exchange isotopes with it's surroundings

| **Mineral** | **Method** | **T (°C)** |
|---|---|---|
| Zircon | U-Pb | >800 |
| Monazite | U-Pb | >800 |
| Titanite (Sphene) | U-Pb | 600 |
| Garnet | Sm-Nd | >550 |
| Hornblende | K-Ar | 500 |
| Muscovite | Rb-Sr | 500 |
| Muscovite | K-Ar | 350 |
| Apatite | U-Pb | 350 |
| Biotite | Rb-Sr | 300 |
| Biotite | K-Ar | 280 |
| K-Feldspar | K-Ar | 200 |
| Apatite | Fission Track | 120 |

Closure temperatures for common minerals for different isotopic systems. Note that closure temperatures for different systems in the same minerals can vary.

# Dating methods and Closure Temperature