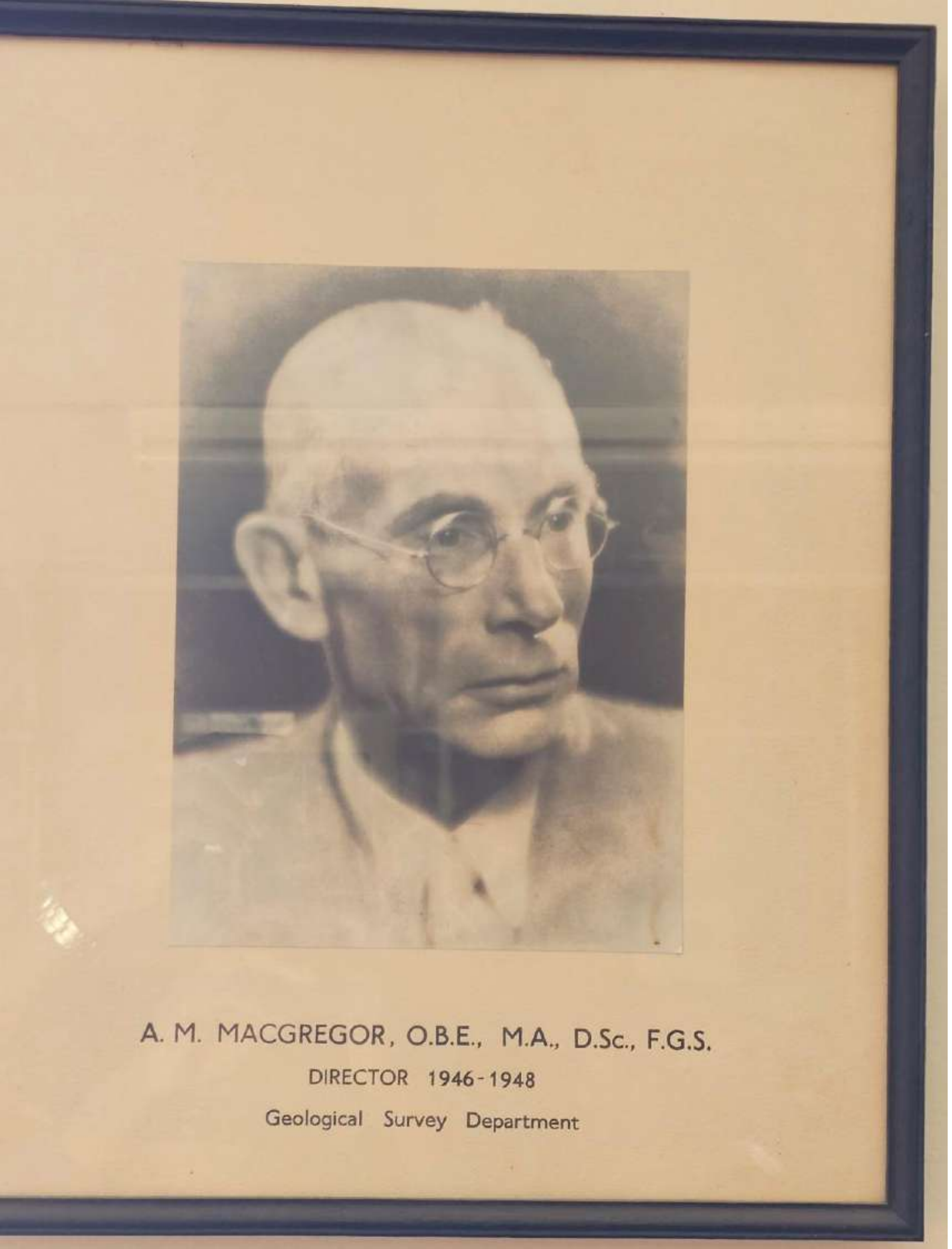


Macgregor Memorial Lecture Zircon and Detrital Zircon Geochronology: a handle in Plate reconstructions, geological evolution of mobile belts and assessment of mineral deposit fertility

Benjamin Mapani

Namibia University of Science and Technology

Faculty of Engineering and the Built Environment

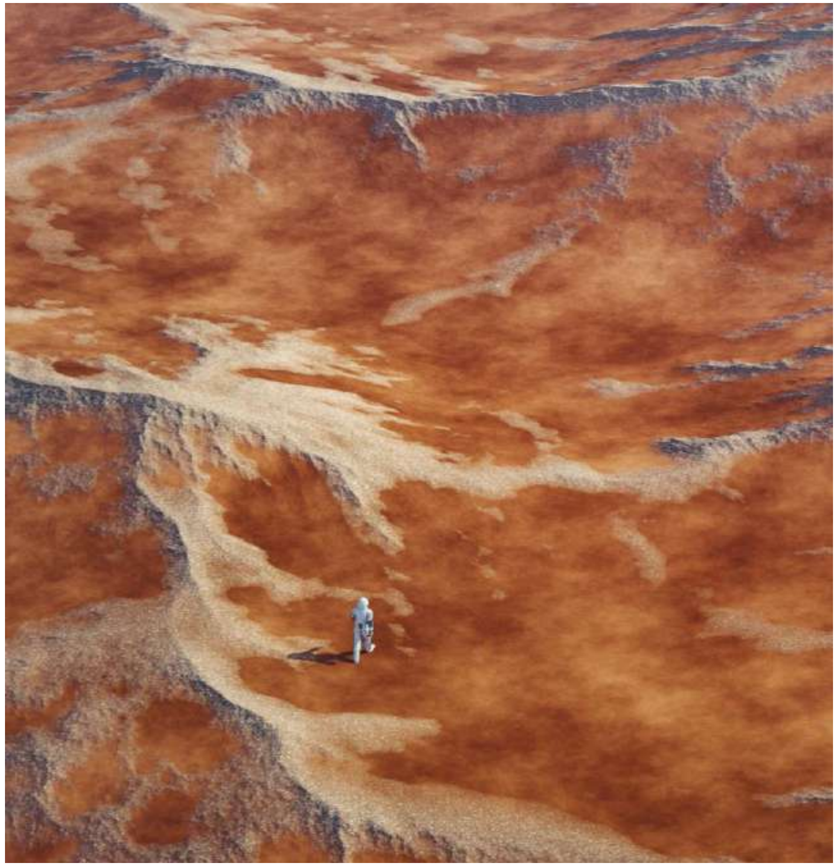
Windhoek

Who was Alexander Miers Macgregor?

- His achievements are too numerous to list here!
- Born in London on 28th July 1888 and died in Bulawayo on 20th October 1961.
- Went to school at West Minister School and Cambridge University, where he obtained a Masters in Geology.
- His first appointment was a geologist at the Bulawayo Museum in 1912.
- In 1916 he served in the First World War until 1918 where he obtained a rank of Lieutenant.
- He left the Museum in 1916 and Joined Geological Survey in Harare (Salisbury).

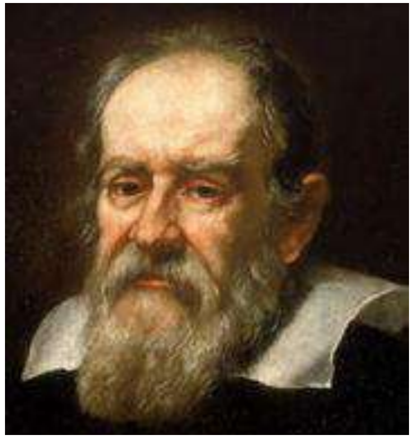
A snapshot of His achievements

- He worked on fossils, hard rock geology and exploration geology with Anglo American Corporation.
- From 1946 to 1948 Dr. Macgregor was director of the Geological Survey.
- Upon retirement he served as a Geologist on the staff of Messrs Keir and Cawder in 1950, and with William Baird and Co. during 1951.
- In 1954 he was engaged by the Anglo American Corporation to start their Geological office in Salisbury (Harare), a post which he retained until 1956.

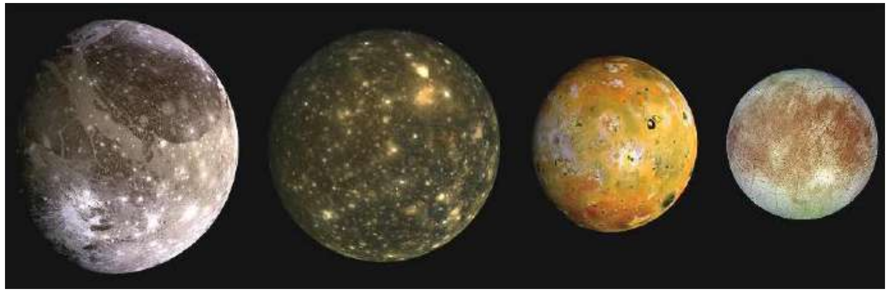


Awards and Scientific Membership

- Draper Memorial Medal 1947- Presented by the Geological Society of South Africa.
- Doctor of Science - Awarded by Natal University College 1947 on a thesis consisting of his numerous published works on Zimbabwean Geology (Southern Rhodesian Geology).
- Dr MacGregor was a member of the following societies: Geological Society of London; The South African Association for the Advancement of Science; Mineralogical Society of London; Rhodesian Scientific Association and Geological Society of South Africa.
- He was President of the South African Association for the Advancement of Science Section B. 1950; South African Geological Society 1950 and Rhodesian Scientific Association, 1946-47.



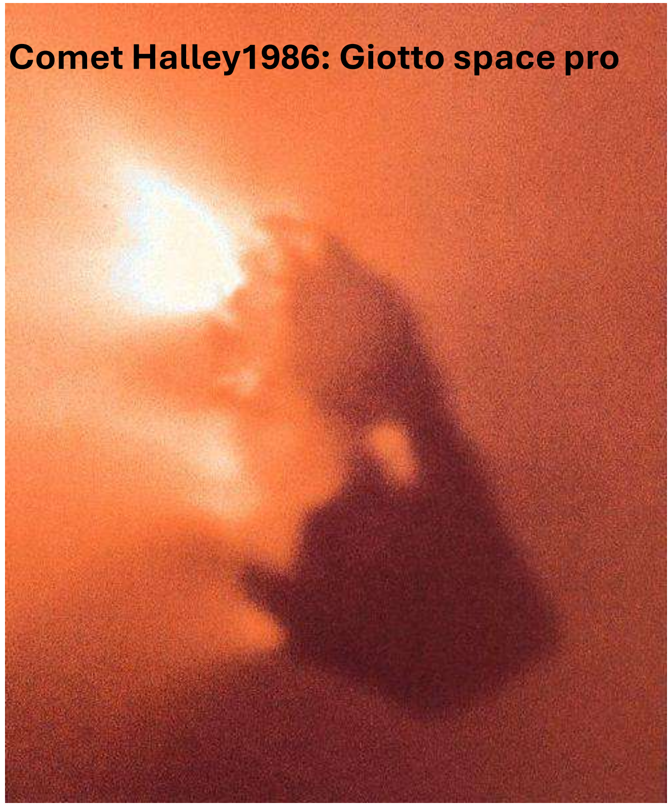
http://de.wikipedia.org/wiki/Galileo_Galilei



➢*Like the Telescope in 1608 – Telescopes changed the way we see starry objects….*
Galileo Galilei (1564-1642) investigated the Moon and concluded "that this body was Earth-like". He was the first to describe craters on the Moon, and he noted the Galilean Moons and he made Jupiter and his Moons a model for the heliocentric system. In "Dialogo" he compared the Ptolemean and Copernican world views and added several barbs against the Pope. Lifelong house-arrest and prohibition of further publications followed.

➢*Zircon changed Geology tremendously….and enhanced its understanding*

http://www.scienca.de/wiki/Galileo_Galilei

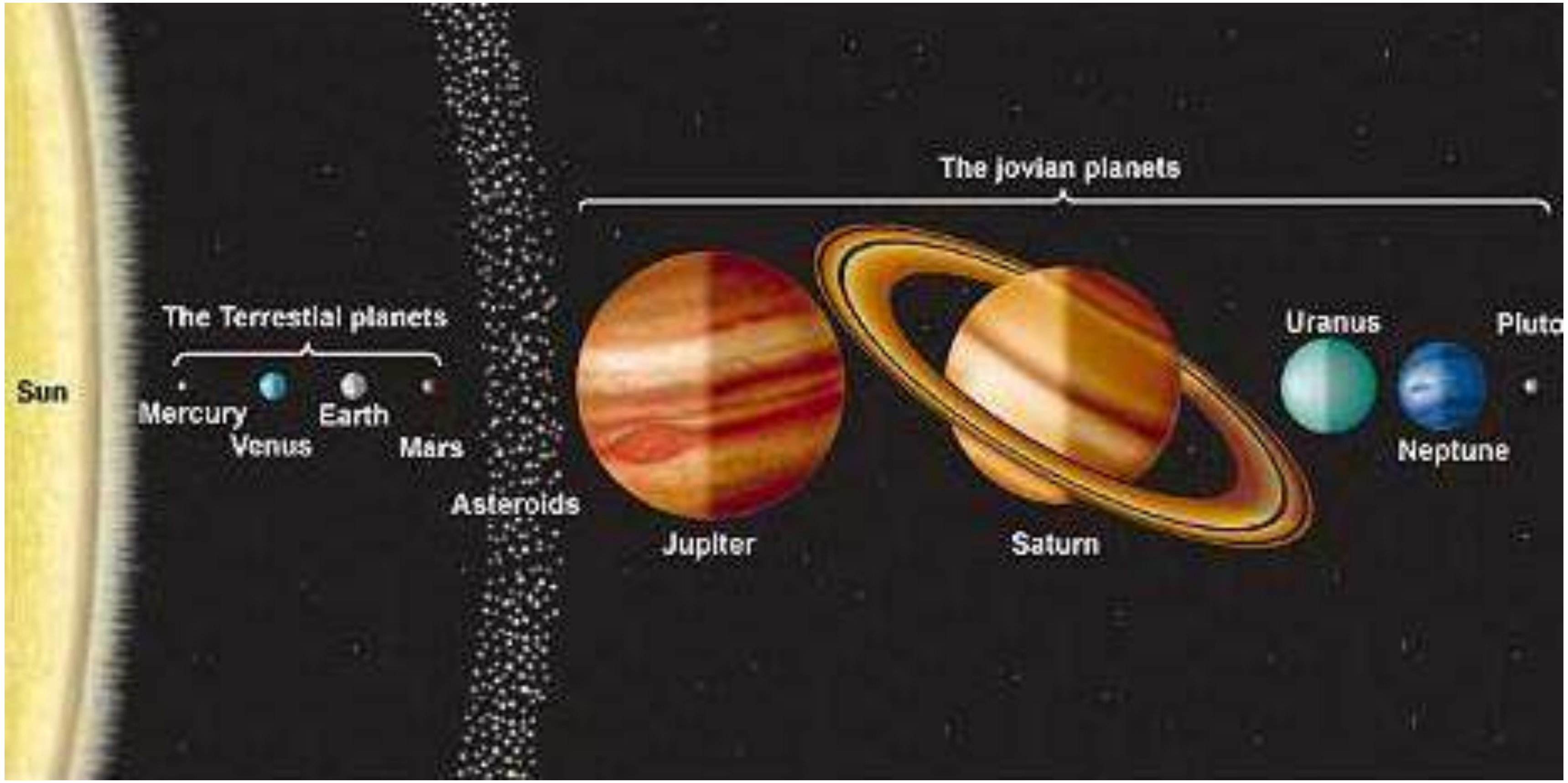


16th century, from: D. Steel, Target Earth

The second half of the 17th century must be credited to Johannes Kepler, Isaac Newton (1643-1727) and Edward Halley (1656-1742).
Kepler: elliptical orbits, celestial mechanics
Newton: laws of gravitation, refinement of orbital determination, calculation of planet masses.
Halley discovered 24 comets / calculated orbits.

The structure of the planetary system was finally understood, some 2000 years after Aristotle.

The Solar System structure was understood after about 200 years after Galileo who invented the Telescope



Geological Theories: Cataclysm Theory / Catastrophism

1. ***A Biblical flood shaped the surface of the Earth***
2. ***Fear of comets triggered the Cataclysm Theory (1750)***

Comte de Buffon, 1745: The planets were formed from a mass ejected from the Sun hit by a vast comet.
Comte de Cuvier (1769-1832) is credited with the thought that the Great Flood was only the last of a series of catastrophes on Earth – as evidenced in the geology and fossil wealth around Paris. He determined six mass extinctions, each followed by new proliferation of life.

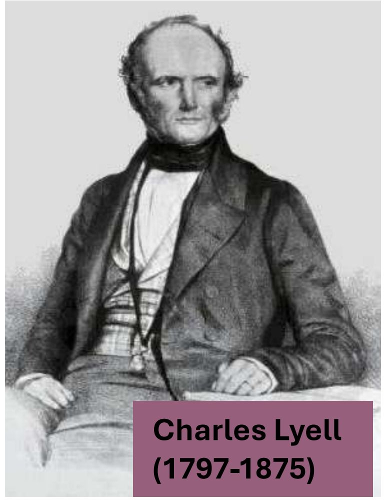
from: D. Steel, Target Earth

Georges Cuvier

http://de.wikipedia.org/wiki/Lord_Byron

Uniformitarianism and Actualism
(Modern Geology)

James Hutton
(1726-1797)



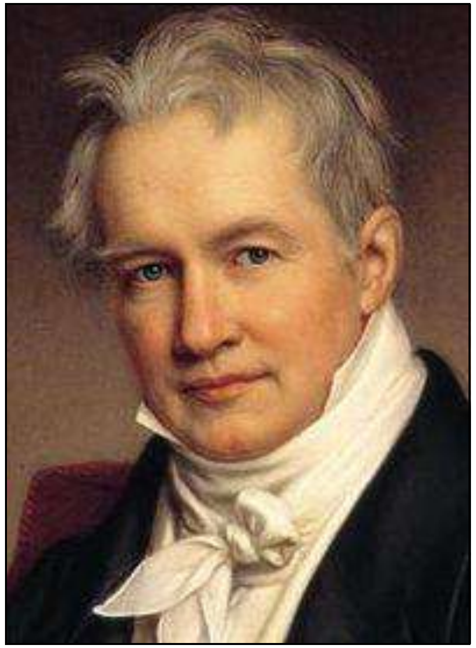
In Britain, the uniformitarianist school was developed: Charles Lyell and his Principles of Geology in 1830
They did not require catastrophes to develop geology or life - but time!
James Hutton and von Hoff added the actualist principle! They and Lyell showed that it would take eons to develop the geology they saw on the British Isles and elsewhere.

The Present is the Key to the Past!

Dynamic Earth - Continental Drift

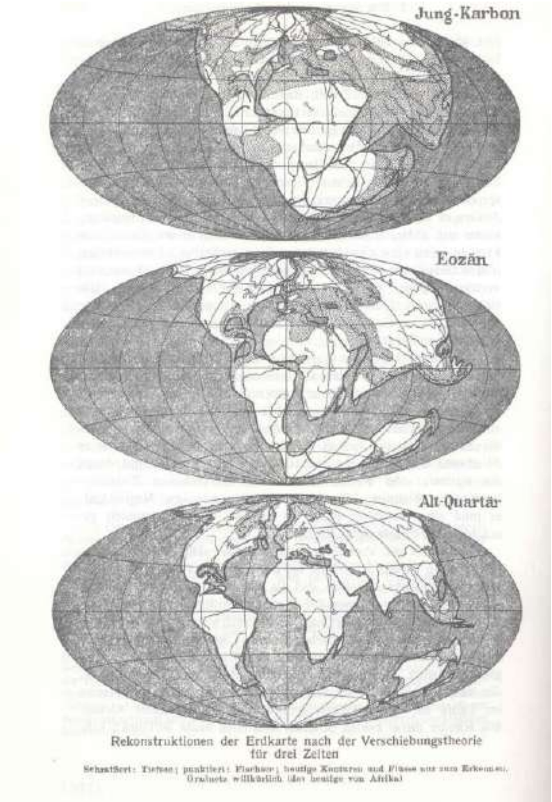
Already individuals like Francis Bacon (1561-1626), Abraham Ortelius (in 1596), the Comte de Buffon (18th century), and Alexander von Humboldt (1796-1859) had ideas about continents breaking apart.

http://de.wikipedia.org/wiki/Sir_Francis_Bacon

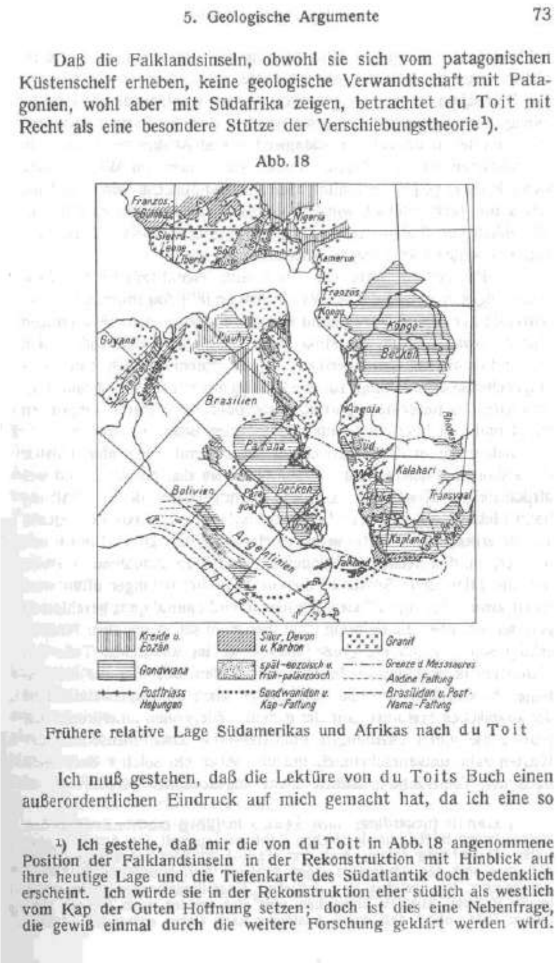


http://de.wikipedia.org/wiki/Alexander_von_Humboldt

Only around 1910 did Alfred L. Wegener (and F.B. Taylor) espouse the theory of Continental Drift, whereby continents come together and drift apart.



Problem: "Continents dont just plough through the ocean floor!"



Daß die Falklandsinseln, obwohl sie sich vom patagonischen Küstenschelf erheben, keine geologische Verwandtschaft mit Patagonien, wohl aber mit Südafrika zeigen, betrachtet du Toit mit Recht als eine besondere Stütze der Verschiebungstheorie[1]).

Abb. 18

Frühere relative Lage Südamerikas und Afrikas nach du Toit

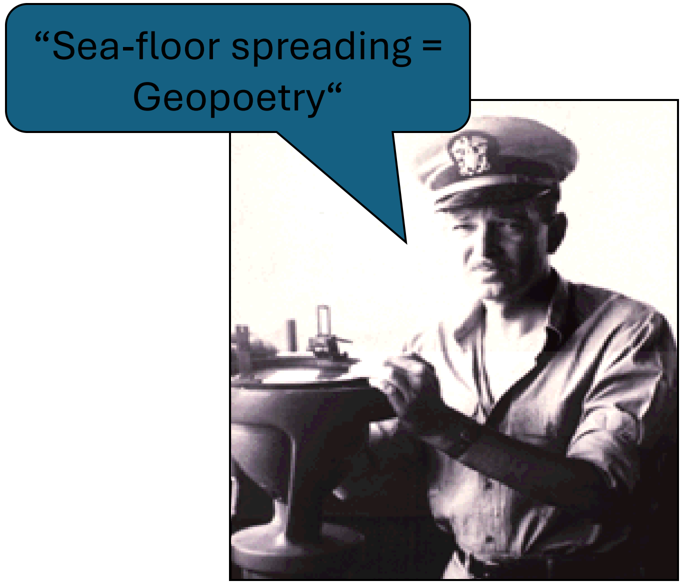
Ich muß gestehen, daß die Lektüre von du Toits Buch einen außerordentlichen Eindruck auf mich gemacht hat, da ich eine so

[1]) Ich gestehe, daß mir die von du Toit in Abb. 18 angenommene Position der Falklandsinseln in der Rekonstruktion mit Hinblick auf ihre heutige Lage und die Tiefenkarte des Südatlantik doch bedenklich erscheint. Ich würde sie in der Rekonstruktion eher südlich als westlich vom Kap der Guten Hoffnung setzen; doch ist dies eine Nebenfrage, die gewiß einmal durch die weitere Forschung geklärt werden wird.

In South Africa, Alex L. Du Toit was a principal follower and exponent of the new Continental Drift theory. Despite much ridicule!

from: Alfred Wegener, Die Entstehung der Kontinente und Ozeane, 4th edition, 1929, p.73

http://geology.asu.edu/resources/museum/dietz.htm



http://pubs.usgs.gov/gip/dynamic/HHH.html

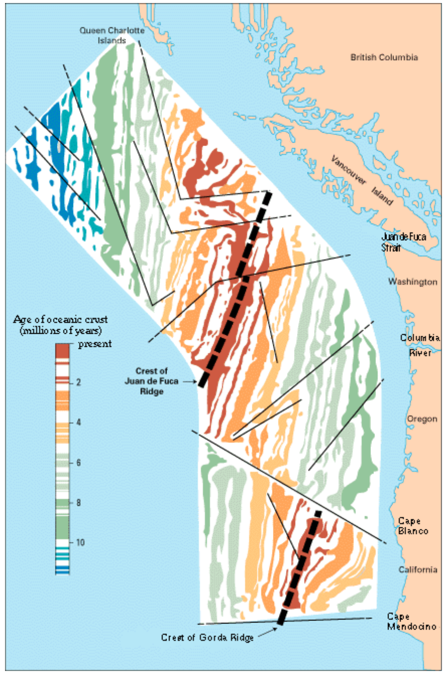
1940s: First voices conc. Impact (Daly, Baldwin, Dietz) and possible link with mass extinction

1960s: Magnetics and Geochronology

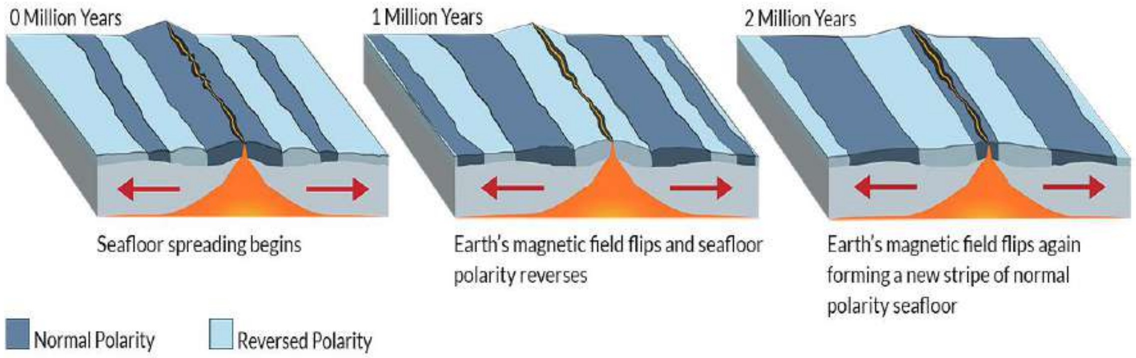
Sea-floor spreading

Not until geophysics and geochronology had developed the tools for understanding of the Earth's dynamic interior in the 1960s could the revolutionary Plate Tectonic Theory, based on the concepts of continental drift and heat convection, be developed.

Age (dating) of magnetic stripes and changes in polarity



Tectonic Plates-evidence from magnetic stripes on the ocean floor



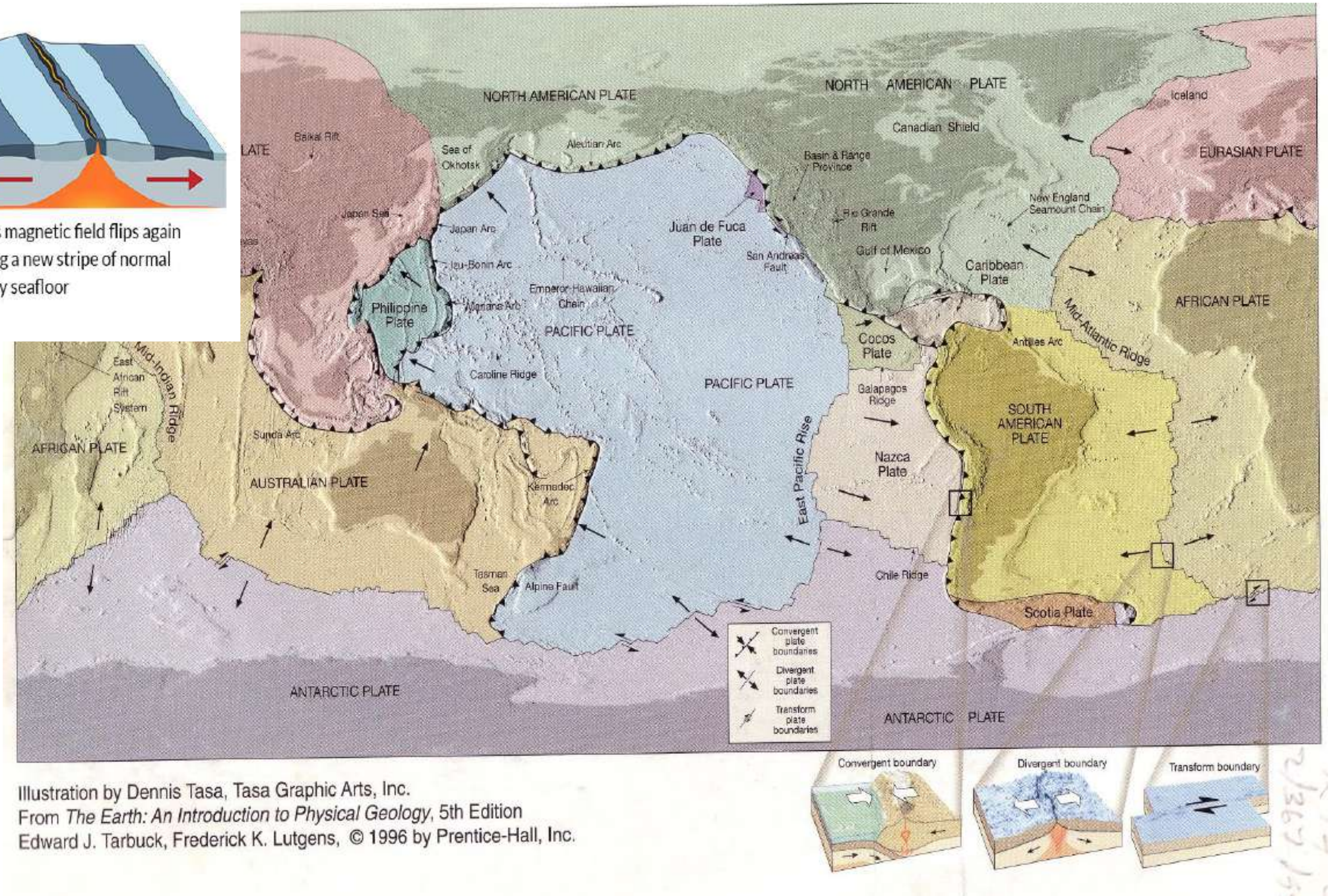
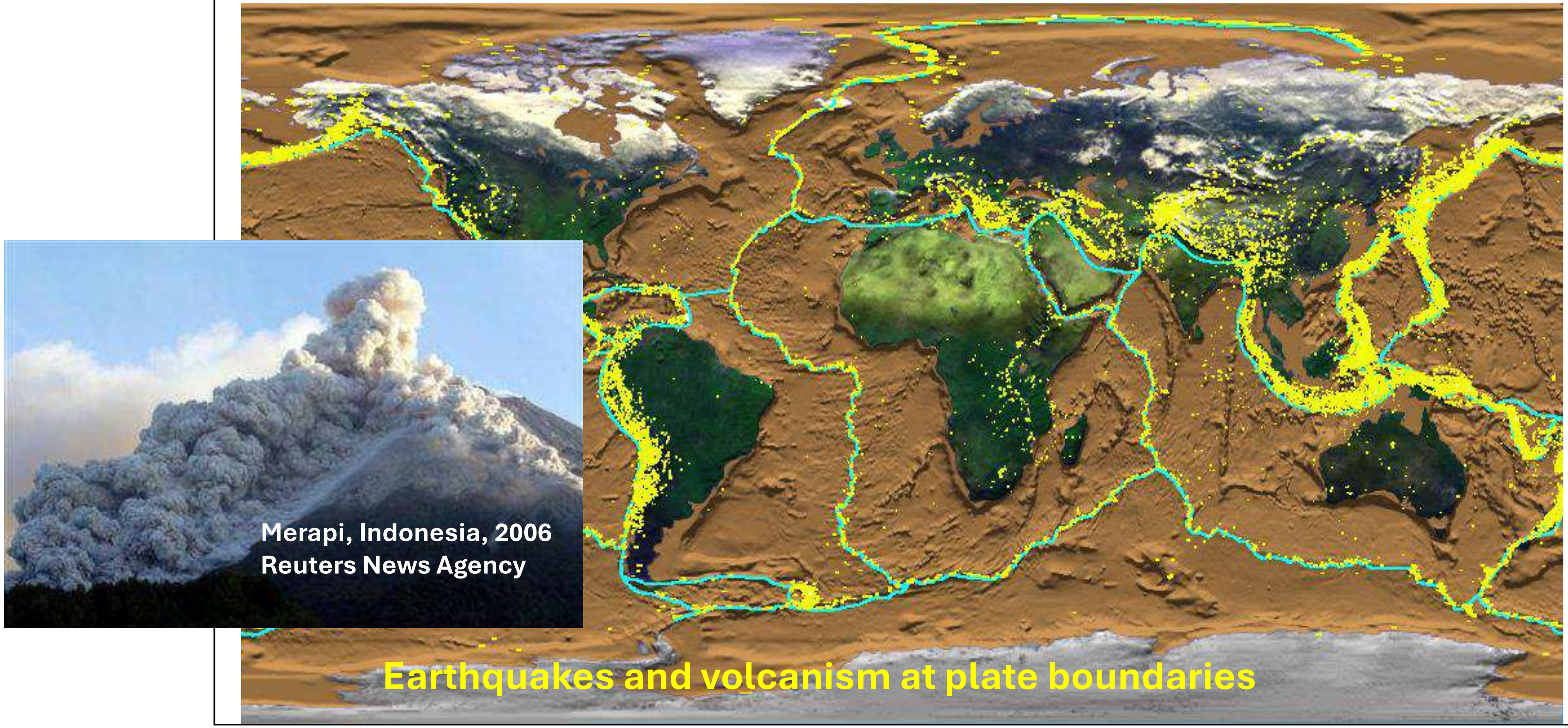


Illustration by Dennis Tasa, Tasa Graphic Arts, Inc.
From *The Earth: An Introduction to Physical Geology*, 5th Edition
Edward J. Tarbuck, Frederick K. Lutgens, © 1996 by Prentice-Hall, Inc.

Table of Contents

- Introduction
- Plate Tectonics and usefulness of Zircon
- Brief History of Zircon Geochronology
- Radioactivity and age dating
- Applications of the Mineral Zircon in different spheres of life (Mineral deposits, Water contamination studies, Naturally occurring radiometric forensics)
- Zircon in plate reconstructions- example of the Damara, Gariep and Kaoko Belts of Namibia.
- Conclusions

The understanding of mountain building, crust subduction, earthquake and volcanism in relation to plate interaction opened up an entirely new perspective on geoscience. This 1960s plate tectonics revolution must be considered as fundamental as the change from cataclysmic to gradualistic/actualistic theory of the early 19th century.
Tuzo Wilson was the greatest advocate of Plate Tectonics via systematic geophysical study of the ocean floor, earthquakes and volcanism (1963)



History of Age Dating with Zircon

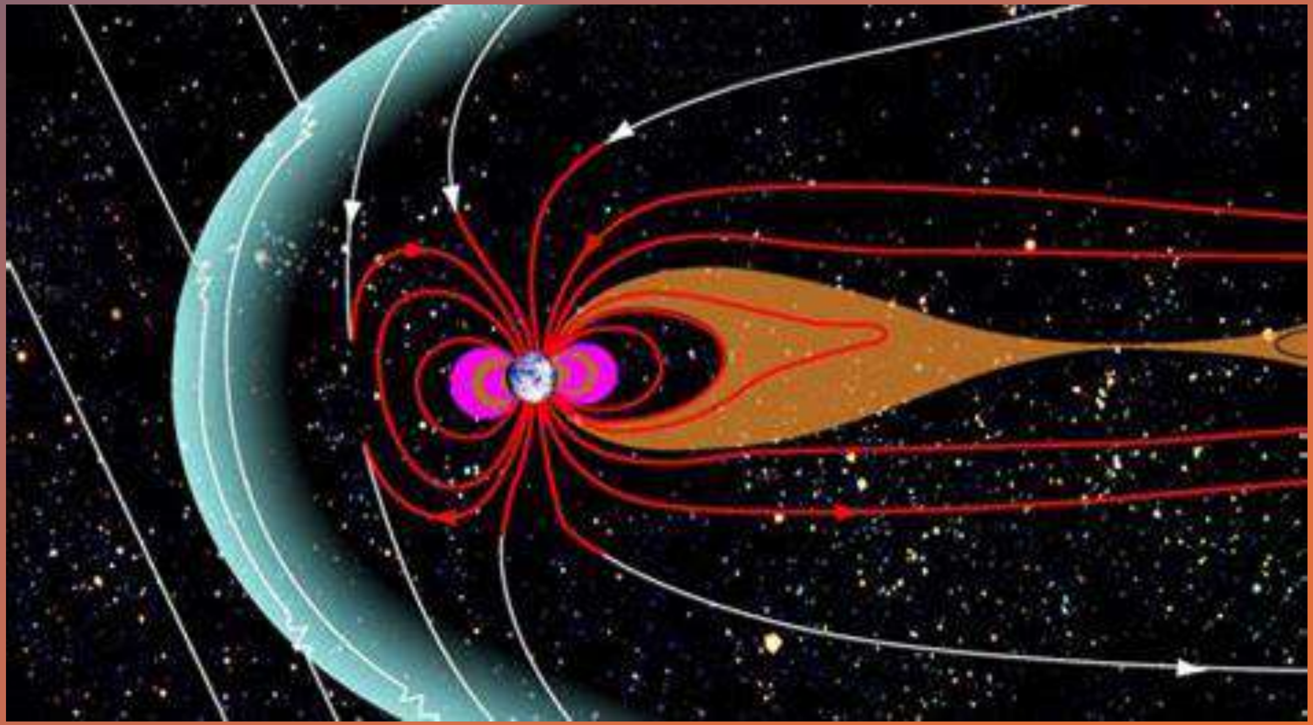
- In 1907, Boltwood was the first person to come up with an estimate of the U-Pb decay constant of 10-10/yr which compares well with our current figure of 1.5×10-10/year
- Thus he measured samples that were 422 my and 2200 my.
- Innovation = Insight (light bulb moment) + Societal Value
- (e.g., Dunlop, Faraday, Pasteur, Flemming e.t.c.)
- After this discovery, geologists realized the value of Zircon in geological processes-that it could unlock long lived events.

Why Zircon Geochronology?

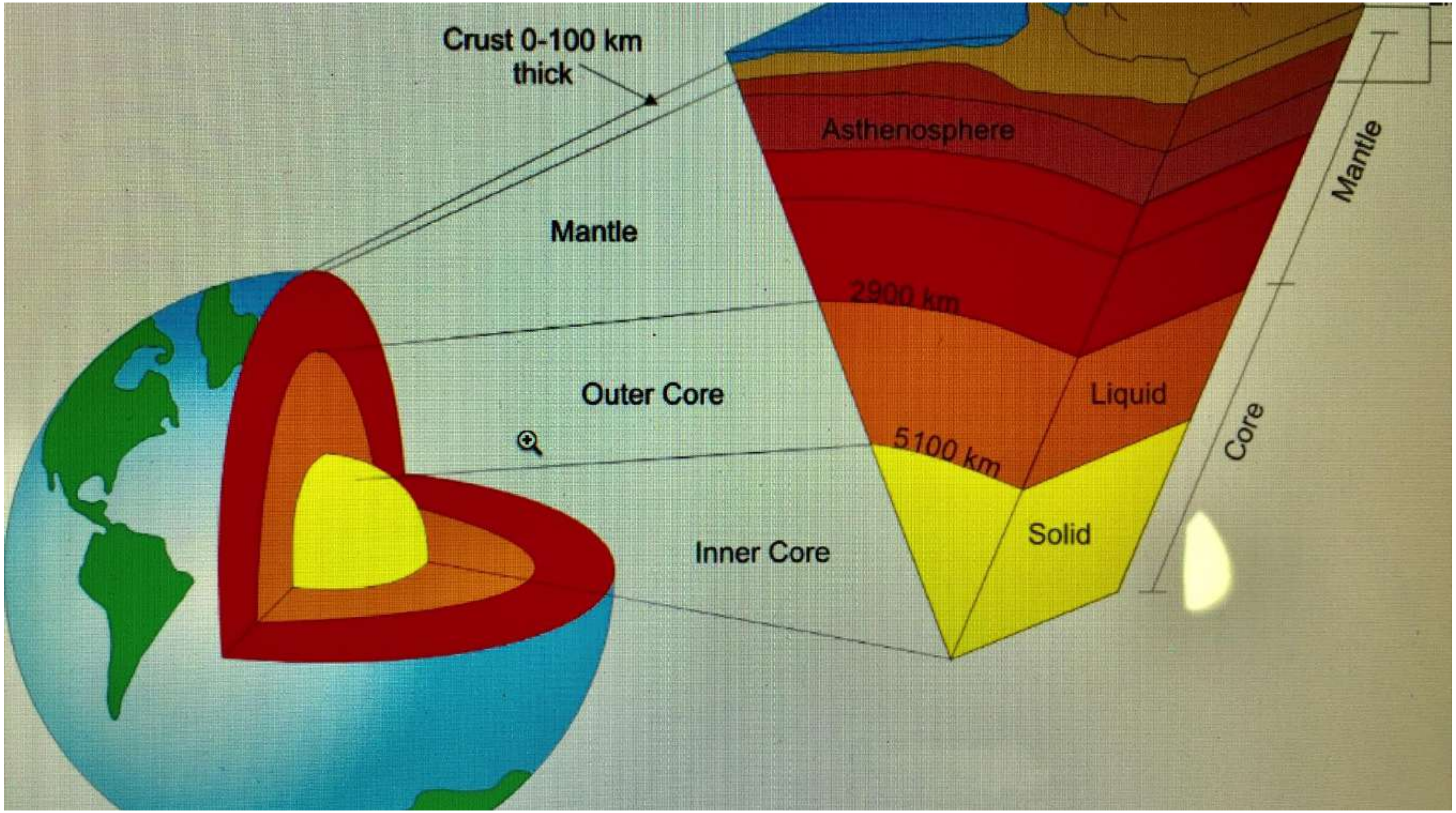
- 1. Its a handle in Plate reconstructions, geological evolution of mobile belts and allows us to select areas suitable for exploration of various mineral deposits- each with its specific setting
- 2. A tool to date granites/gabbros and volcanic rocks to understand intra-plate magmatism.
- 3. A tool to unravel what happens in subduction processes, volcanic and continental arcs
- 4. A tool to be used in the detailed assessment of mineral deposit fertility: an example from the Damara, Gariep and Kaoko belts
- 5. Used to date the age of the Solar System and comets

The Earth has a magnetic field that is produced by the liquid outer core that helps create convection currents to drive Plate tectonics- Plate Tectonics drives life on the planet and reworking of plates-

Thus magnetism is directly related to Plate Tectonics and viability f life on earth



Internal structure of the Earth-the liquid core produces Earths’ magnetic field.



Late Cambrian-Mid Silurian-comparisons-using species to unravel continental collisions and dispersals

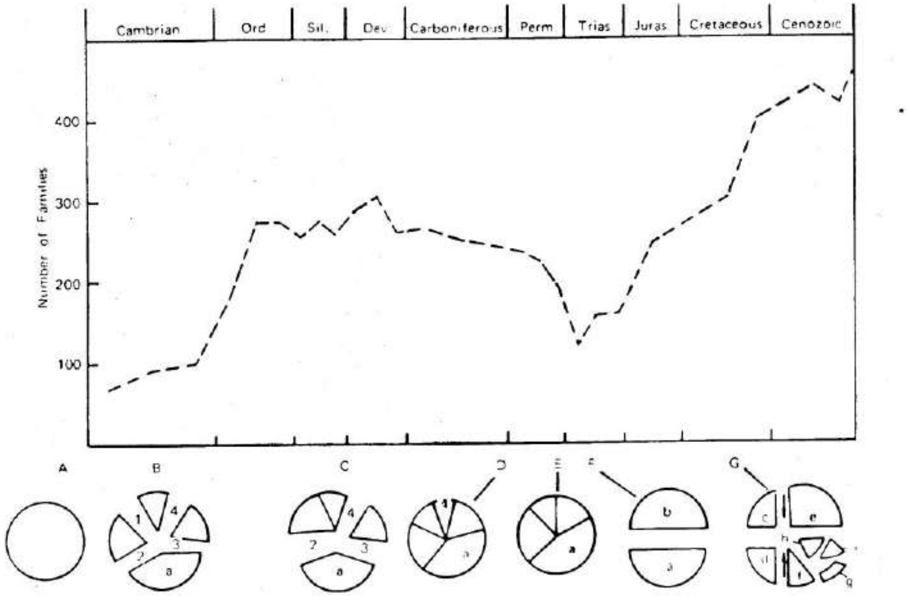
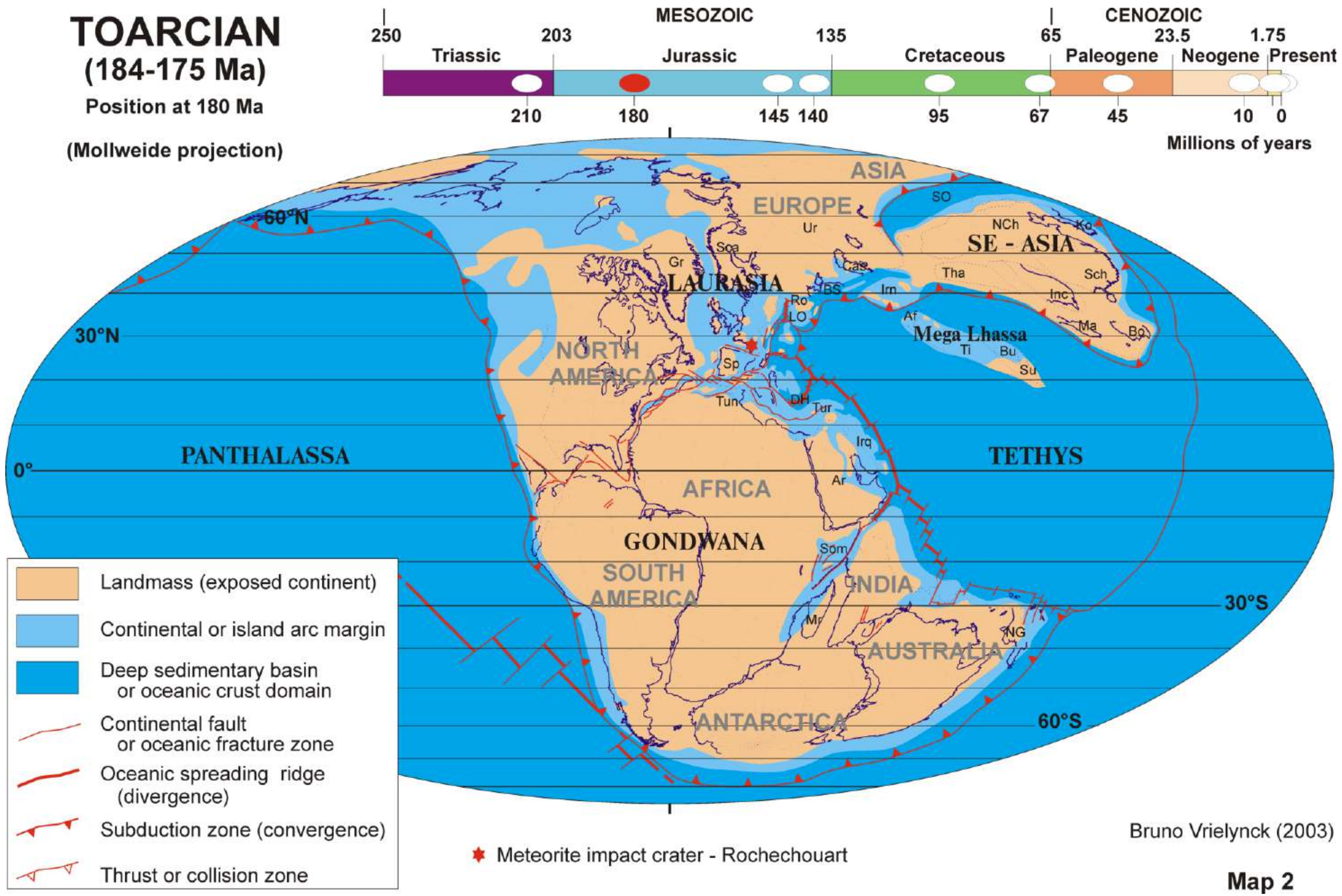
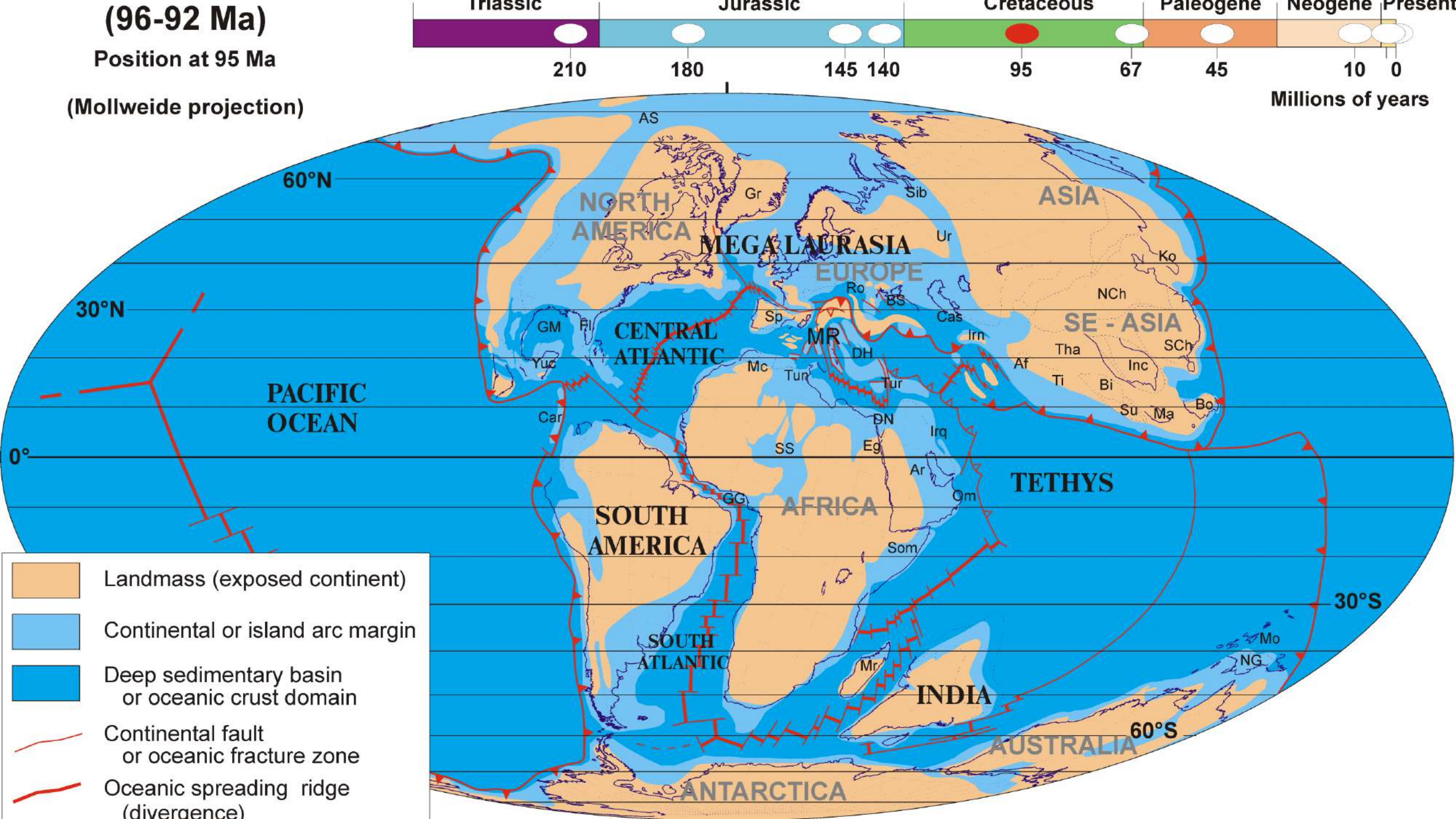
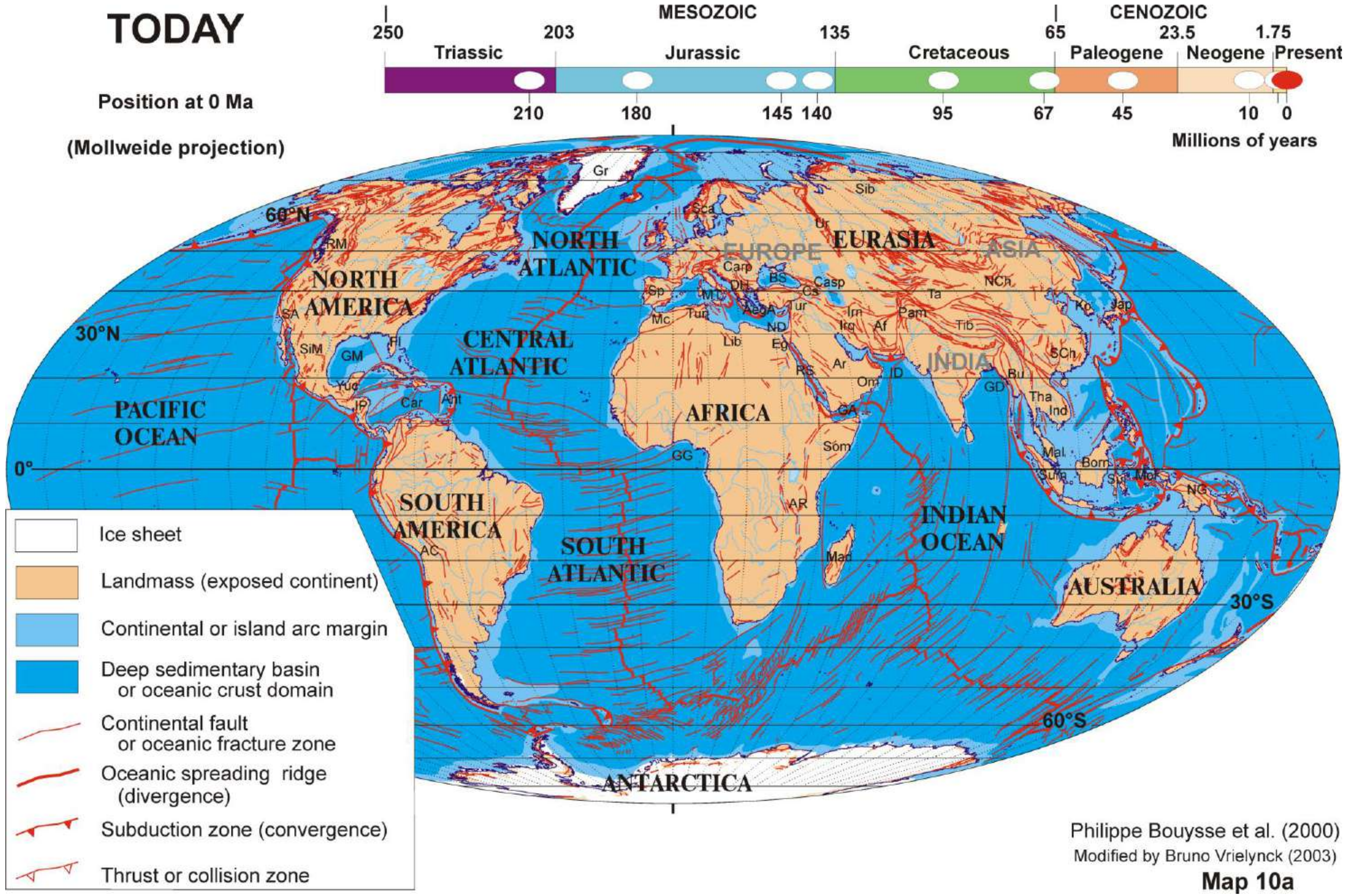


Figure 3 - Correlation between number of invertebrate families and time and with continental fragmentation and assembly: numbers increase at fragmentation and decrease with assembly. The continents are schematically depicted as segments of a circle: (a)=Gondwanaland; (b)=Laurasia; (c)=North America; (d)=South America; (e)=Eurasia; (f)=Africa; (g)=Antarctica; (h)=India; (i)=Australia. (A) represents Pangaea; (E) Reassembly of Pangaea; (F) Opening of Tethys Sea; (G) Closing of Tethys Sea, opening of Atlantic, breaking up of Gondwanaland (Condie, 1982)

- Late Cambrian- gradual increase in species (we had a supercontinent)
- Mid Silurian-Devonian-maximum number of species-fragmentation
- Triassic- drop in species-assembly.


TOARCIAN
(184-175 Ma)
Position at 180 Ma
(Mollweide projection)
MESOZOIC
CENOZOIC
250
203
135
65
23.5
1.75
Triassic
Jurassic
Cretaceous
Paleogene
Neogene
Present
210
180
145
140
95
67
45
10
0
Millions of years
ASIA
EUROPE
SE - ASIA
LAURASIA
NORTH AMERICA
Mega Lhassa
PANTHALASSA
TETHYS
AFRICA
GONDWANA
SOUTH AMERICA
INDIA
AUSTRALIA
ANTARCTICA
60°N
30°N
0°
30°S
60°S
Landmass (exposed continent)
Continental or island arc margin
Deep sedimentary basin or oceanic crust domain
Continental fault or oceanic fracture zone
Oceanic spreading ridge (divergence)
Subduction zone (convergence)
Thrust or collision zone
Meteorite impact crater - Rochechouart
Bruno Vrielynck (2003)
Map 2


(96-92 Ma)
Position at 95 Ma
(Mollweide projection)
Triassic
Jurassic
Cretaceous
Paleogene
Neogene
Present
210
180
145
140
95
67
45
10
0
Millions of years
60°N
30°N
0°
30°S
60°S
NORTH AMERICA
MEGA LAURASIA
EUROPE
ASIA
SE - ASIA
CENTRAL ATLANTIC
PACIFIC OCEAN
SOUTH AMERICA
AFRICA
TETHYS
SOUTH ATLANTIC
INDIA
AUSTRALIA
ANTARCTICA
AS
Gr
Sib
Ur
Ko
NCh
Ro
BS
Cas
Irn
Sp
MR
GM
Fl
Yuc
Mc
Tun
DH
Tur
Af
Tha
Ti
Inc
Bi
SCh
Su
Ma
Bo
Car
DN
Irq
SS
Eg
Ar
Om
GG
Som
Mr
Mo
NG
Landmass (exposed continent)
Continental or island arc margin
Deep sedimentary basin or oceanic crust domain
Continental fault or oceanic fracture zone
Oceanic spreading ridge (divergence)



TODAY
Position at 0 Ma
(Mollweide projection)
MESOZOIC
CENOZOIC
250
203
135
65
23.5
1.75
Triassic
Jurassic
Cretaceous
Paleogene
Neogene
Present
210
180
145
140
95
67
45
10
0
Millions of years
Gr
Sib
Sca
Ur
60°N
RM
NORTH ATLANTIC
EUROPE
EURASIA
ASIA
NORTH AMERICA
Carp
BS
Casp
Sp
DH
Ca
NCh
Ta
Kr
Jap
SA
Mc
Tun
AegA
Tur
Irn
Pam
Irq
Af
Tib
30°N
SiM
GM
Fl
CENTRAL ATLANTIC
Lib
ND
Eg
SCh
INDIA
Ar
ID
RS
Bu
Yuc
Om
GD
Tha
PACIFIC OCEAN
IP
Car
Ant
AFRICA
Ind
GA
Som
Mal
0°
GG
Bom
Sum
NG
SOUTH AMERICA
AR
INDIAN OCEAN
AC
SOUTH ATLANTIC
Mad
AUSTRALIA
30°S
60°S
ANTARCTICA
Ice sheet
Landmass (exposed continent)
Continental or island arc margin
Deep sedimentary basin or oceanic crust domain
Continental fault or oceanic fracture zone
Oceanic spreading ridge (divergence)
Subduction zone (convergence)
Thrust or collision zone
Philippe Bouysse et al. (2000)
Modified by Bruno Vrielynck (2003)
Map 10a

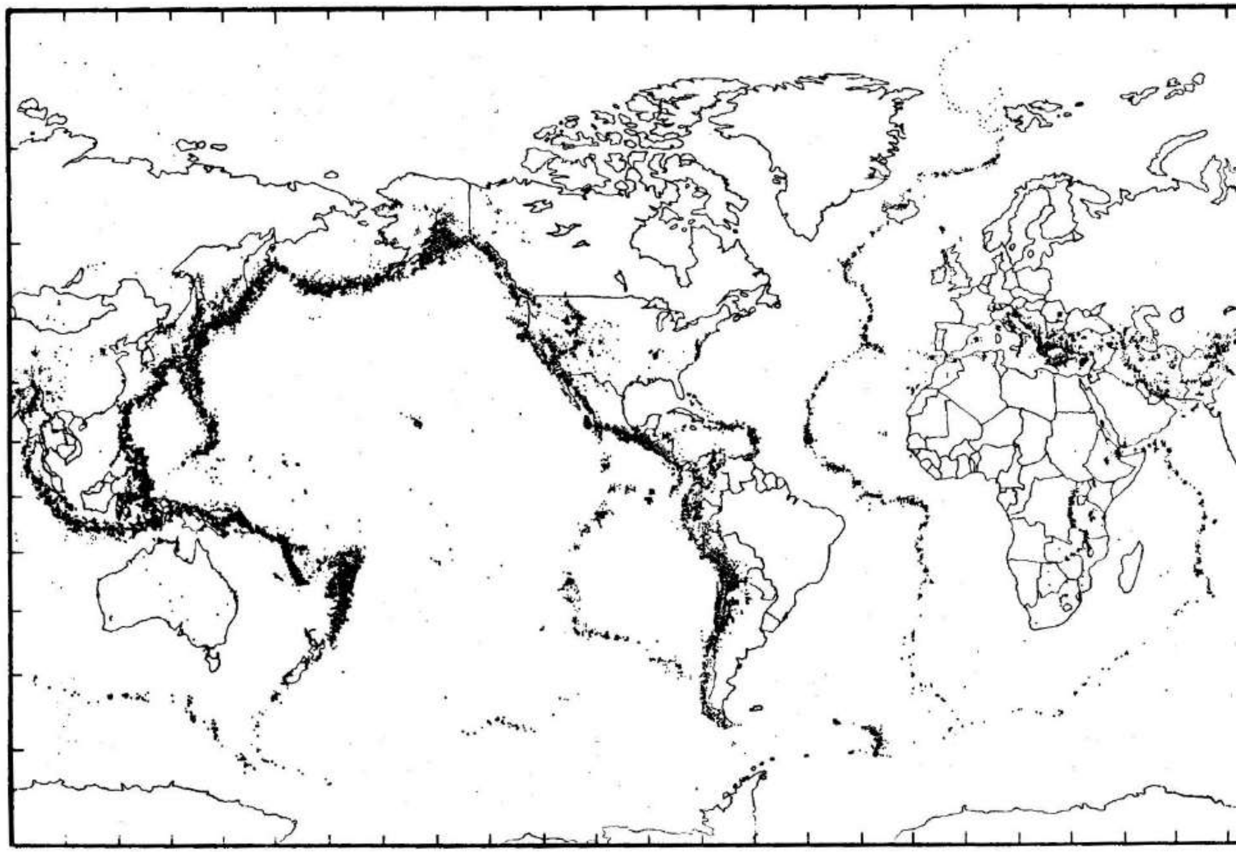


Figure 1.4 Distribution of world earthquakes 1961–1969. From National Earthquake Information Center Map NEIC-3005.

Earthquake distribution is not chaotic-showing that plates actually do move

Dominant processes though Earth's development –how can we unravel them?

- Early Earth - chemical and density differentiation
- Bombardment and Moon collision/extraction (Hadean)
- Plume and/or subduction dominated processes (Paleo/Mesoarchean)
- Plate tectonics (dominated in Paleoproterozoic, possibly Neoarchean)

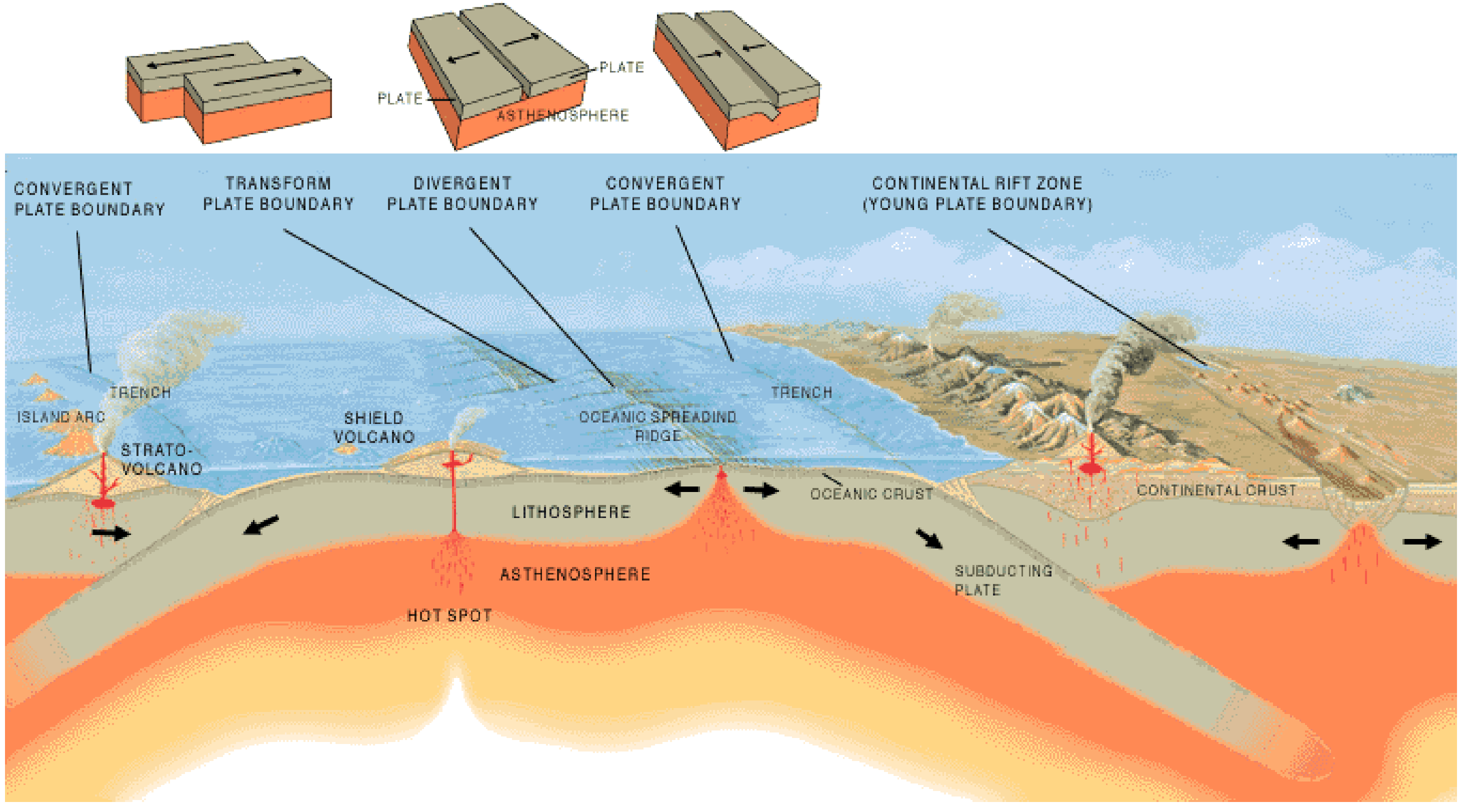
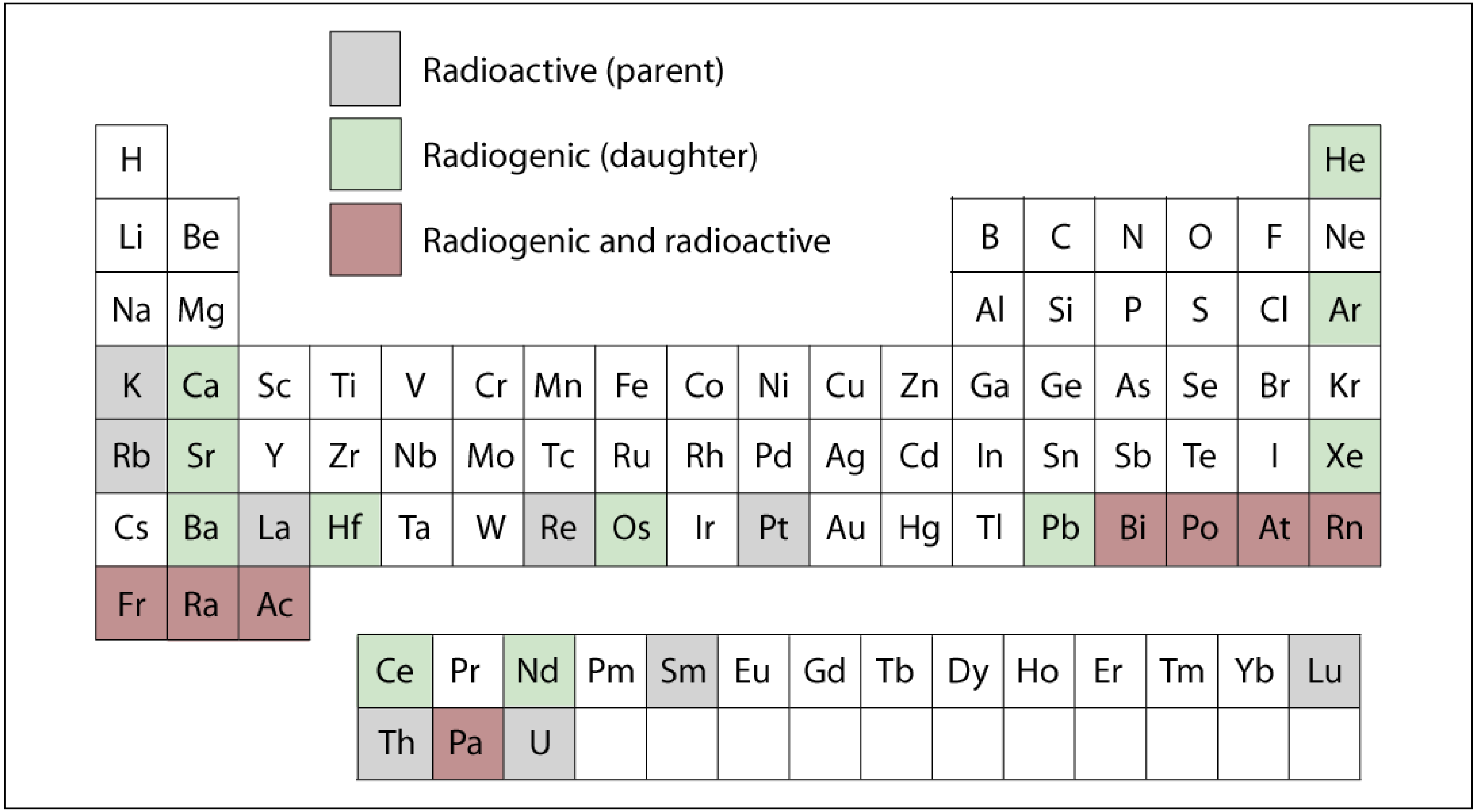


Table of the naturally occurring elements.

A radiogenic nuclide is a nuclide that is produced by a process of radioactive decay. It may itself be radioactive (a radionuclide) or stable (a stable nuclide). Radiogenic nuclides (more commonly referred to as radiogenic isotopes) form some of the most important tools in geology



U is the largest Naturally occurring

Element

It is radioactive

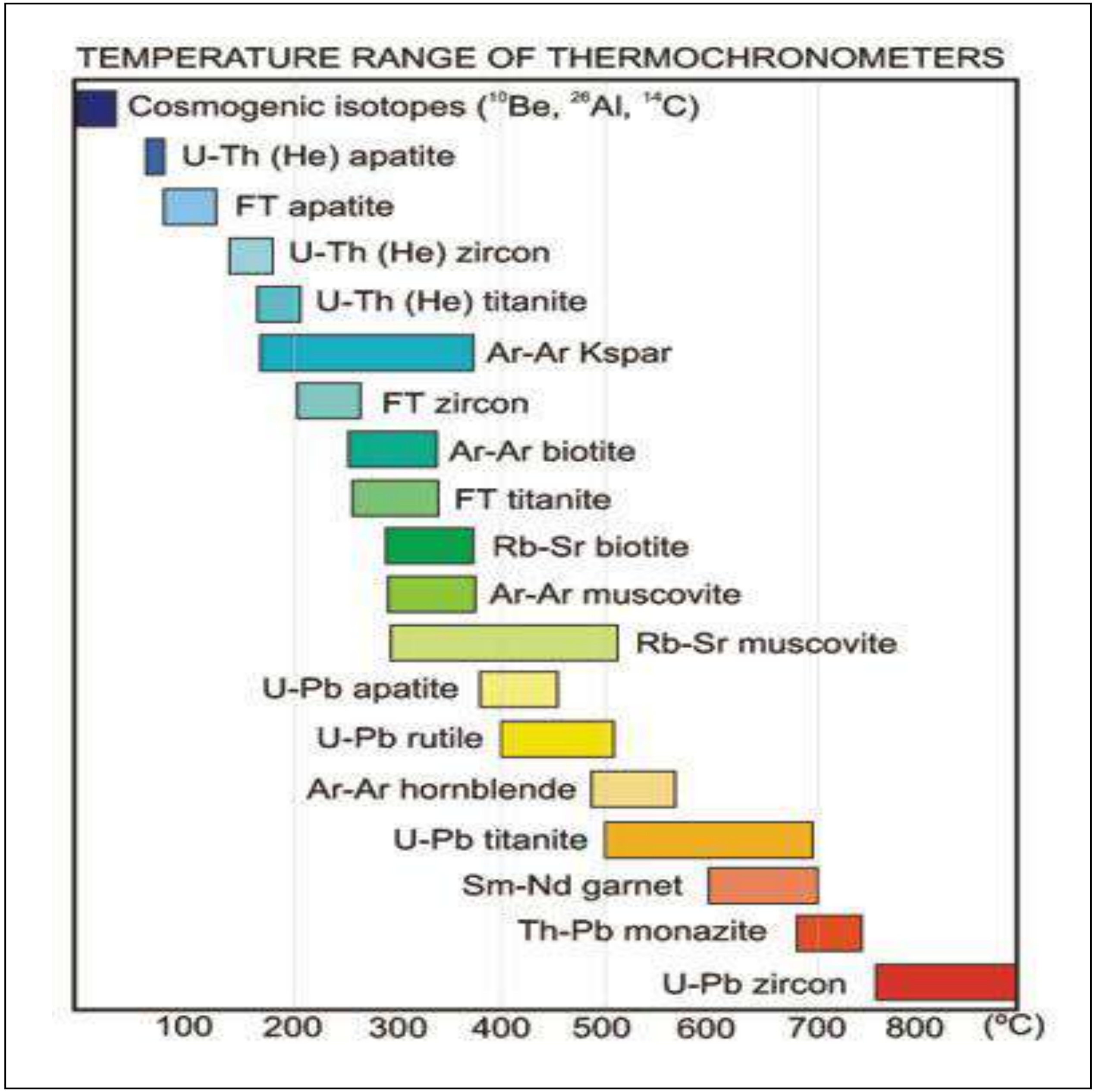
Used for energy purposes

One of the few geologic clocks we use

Is always present in the Mineral ZIRCON and Baddeleyite

THREE COMMONLY OCCURRING RADIOACTIVE ELEMENTS IN ROCKS AND SOILS

- ***Uranium (U_3O_8) – has a decay series***
  - *98.27% occurs as ^{238}U*
  - *0.72% occurs as ^{235}U (used in reactors)*
  - *0.0057% occurs as ^{234}U*
- ***Thorium (ThO_2) – has a decay series***
- ***Potassium (K_2O) – no decay series, single isotope***

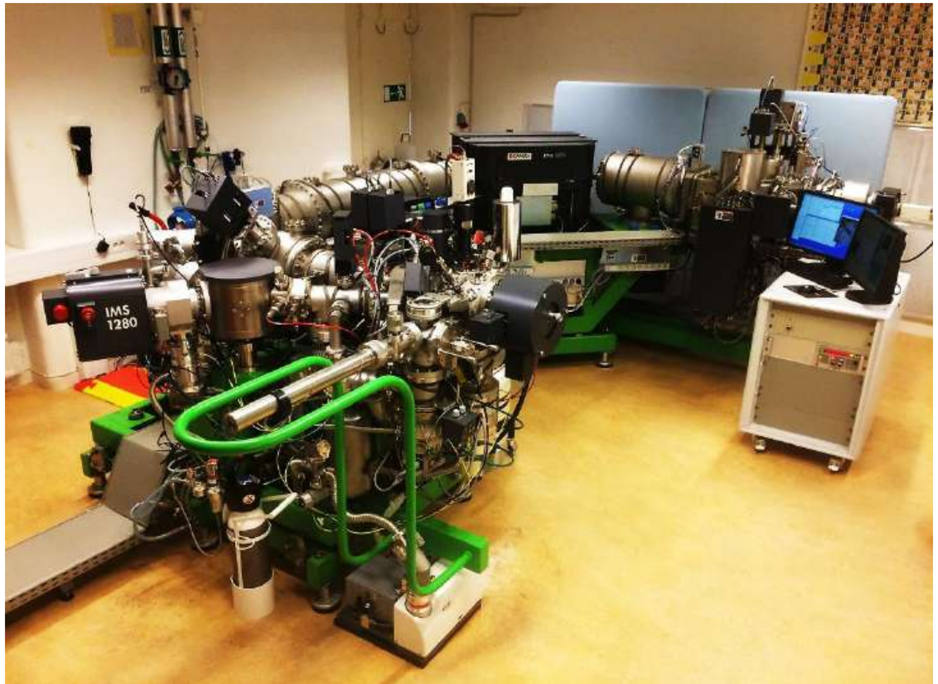

TEMPERATURE RANGE OF THERMOCHRONOMETERS
Cosmogenic isotopes (10Be, 26Al, 14C)
U-Th (He) apatite
FT apatite
U-Th (He) zircon
U-Th (He) titanite
Ar-Ar Kspar
FT zircon
Ar-Ar biotite
FT titanite
Rb-Sr biotite
Ar-Ar muscovite
Rb-Sr muscovite
U-Pb apatite
U-Pb rutile
Ar-Ar hornblende
U-Pb titanite
Sm-Nd garnet
Th-Pb monazite
U-Pb zircon
100
200
300
400
500
600
700
800
(°C)

METHODOLOGY- Pick rocks that contain zircon grains-felsic, in mafic we can use baddeleyite



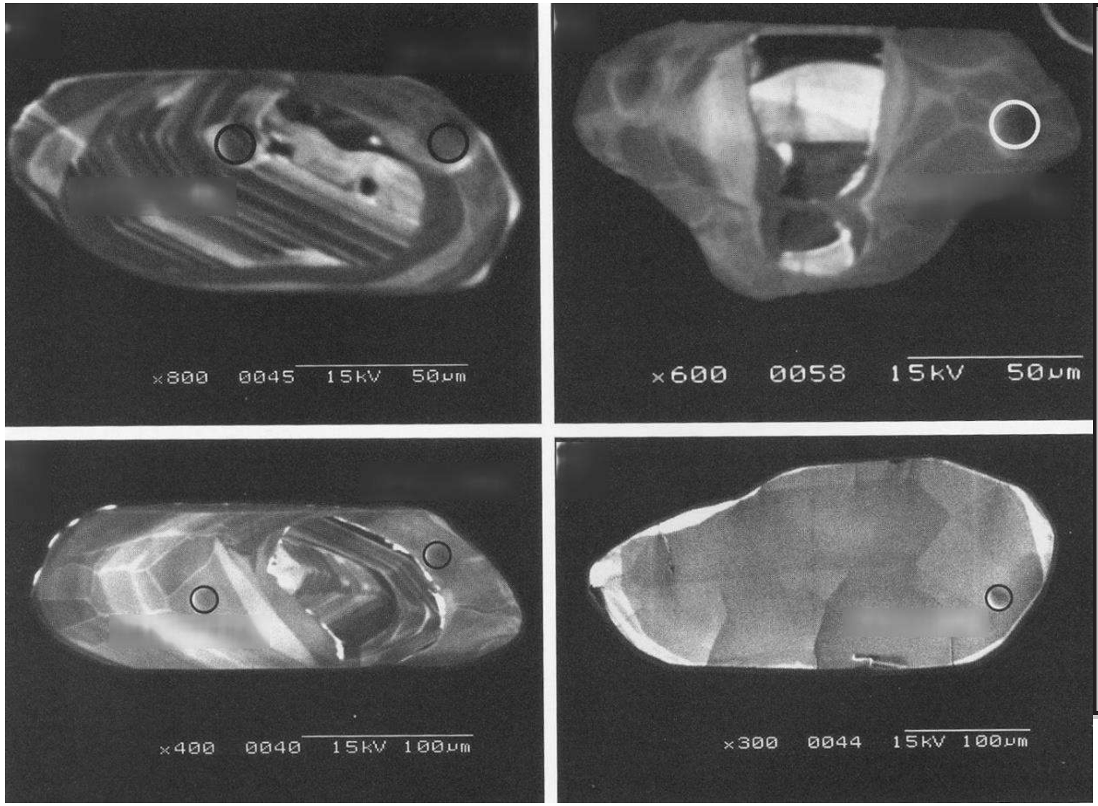

Crush the rocks in a swing mill and extract zircons (time of milling is important)

METHODOLOGY-pick the zircons and analyse



What is Zircon (Zr, U, REE)2SiO4 and Baddeleyite [Zr(U, Th)O2]

Once formed it is resistant to heat; erosion and metamorphic processes



$^{238}U \longrightarrow {}^{206}Pb \qquad \lambda\, ^{238}U = \lambda_1 = 1.55125 \times 10^{-10}$

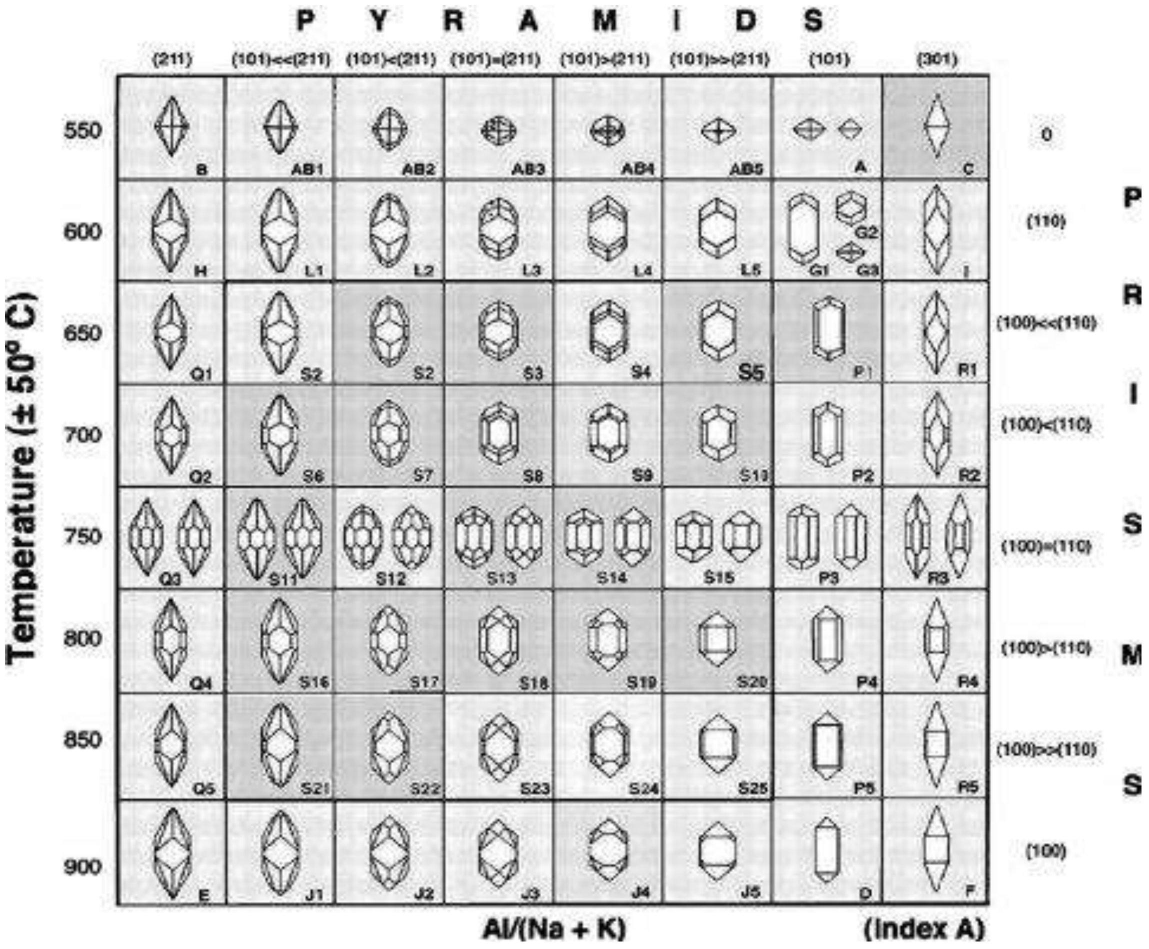
$^{235}U \longrightarrow {}^{207}Pb \qquad \lambda\, ^{235}U = \lambda_2 = 9.8485 \times 10^{-10}$

$^{232}Th \longrightarrow {}^{208}Pb \qquad \lambda\, ^{232}Th = \lambda_3 = 4.9475 \times 10^{-11}$

$^{238}U / {}^{235}U = 137.88$

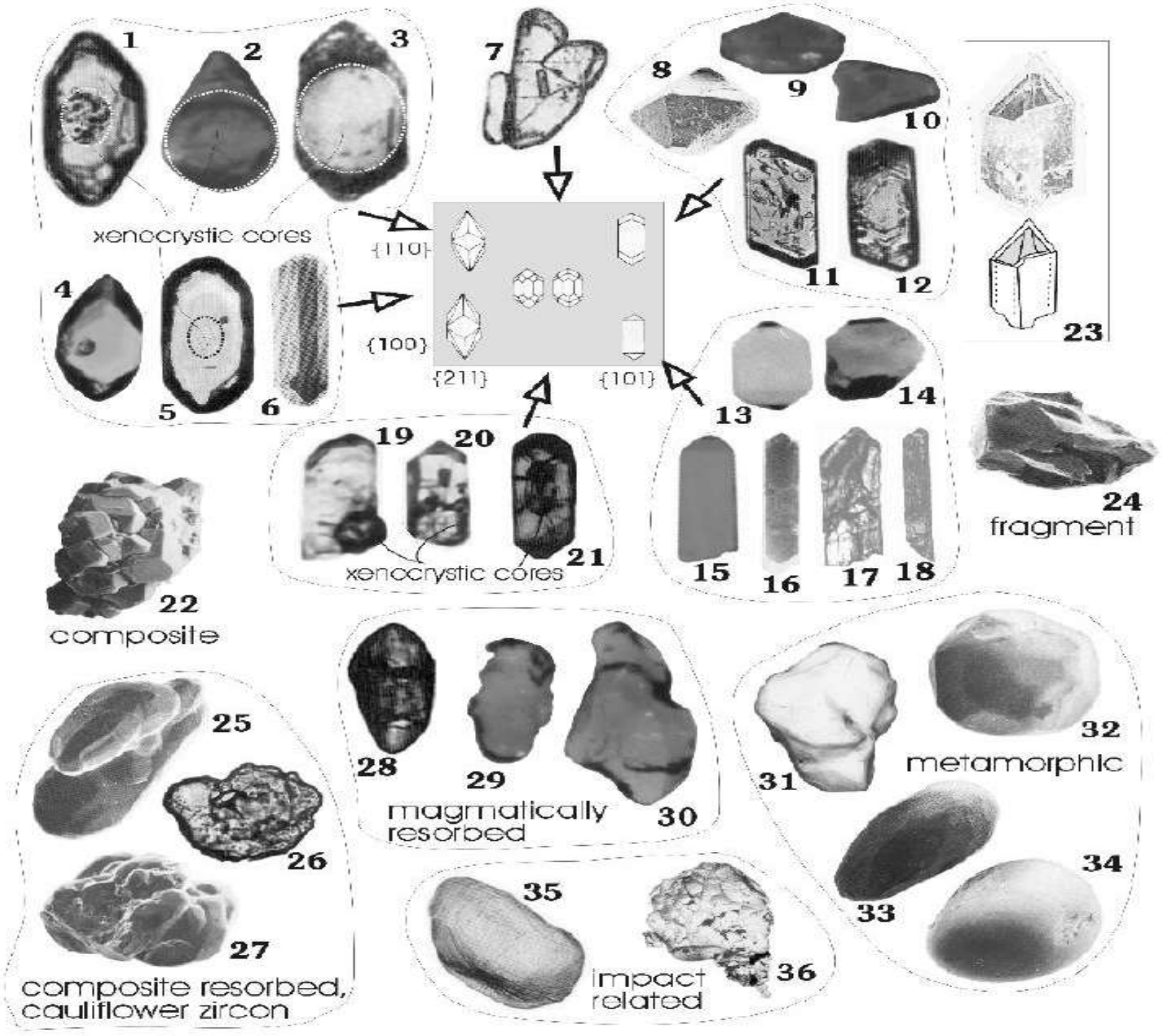
The power of the zircon crystal-thermometry (after Puppin, 1980)-nature's gift to man

At this time we used to dissolve the whole zircon grain for dating

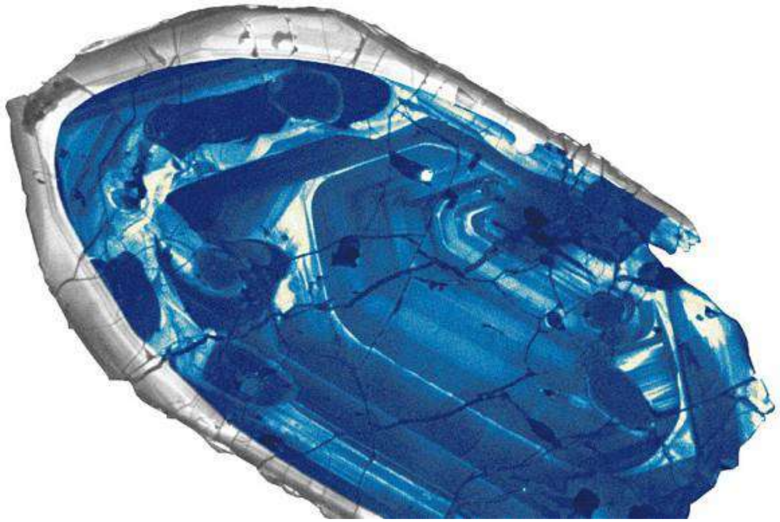


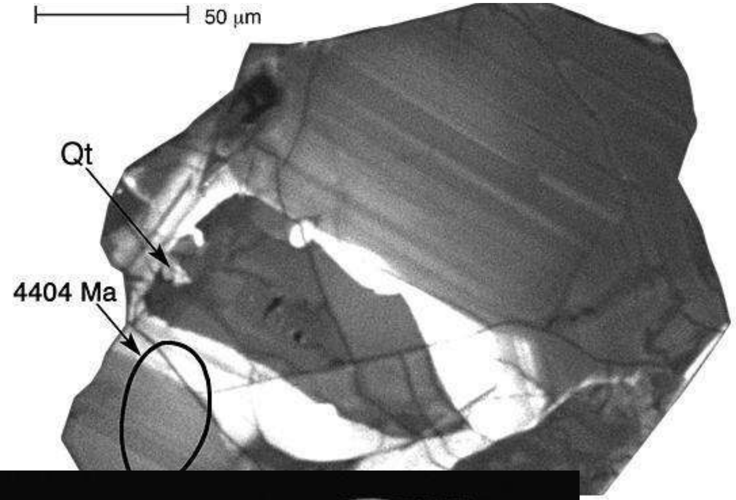
- The shape of the zircon is also an indication of the temperature at which it formed and composition- *important in mineral deposits studies*
- Better pyramids indicate higher Al/(K+Na) ratio- *Tectonic setting indicators*
- Better prisms indicate higher temperatures of formation
- Index A reflects the ratio controlling the development of zircon pyramids, whereas temperature affects the development of zircon prisms.

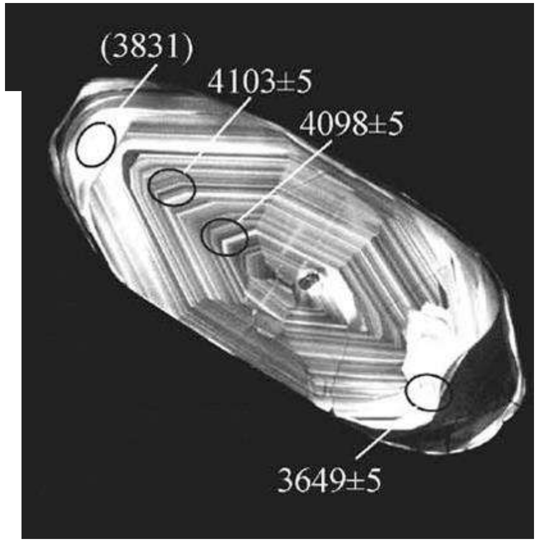
After Corfu et al., 2002-Atlas of Zircon Texture

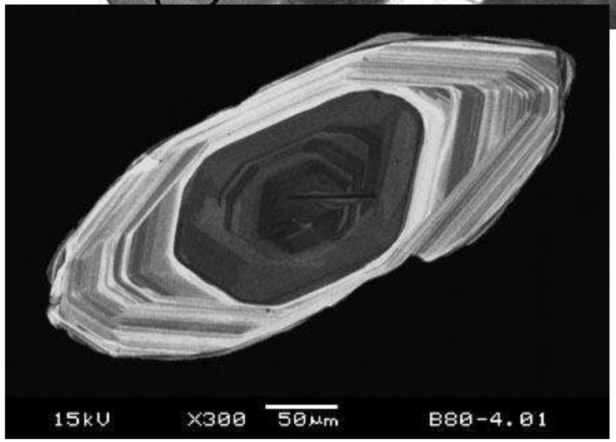


Jack hills zircons(Froude et al, 1983-Nature vol 304, 616-618) some of the oldest rocks on Earth. The story of Zircon is the story of life on Earth



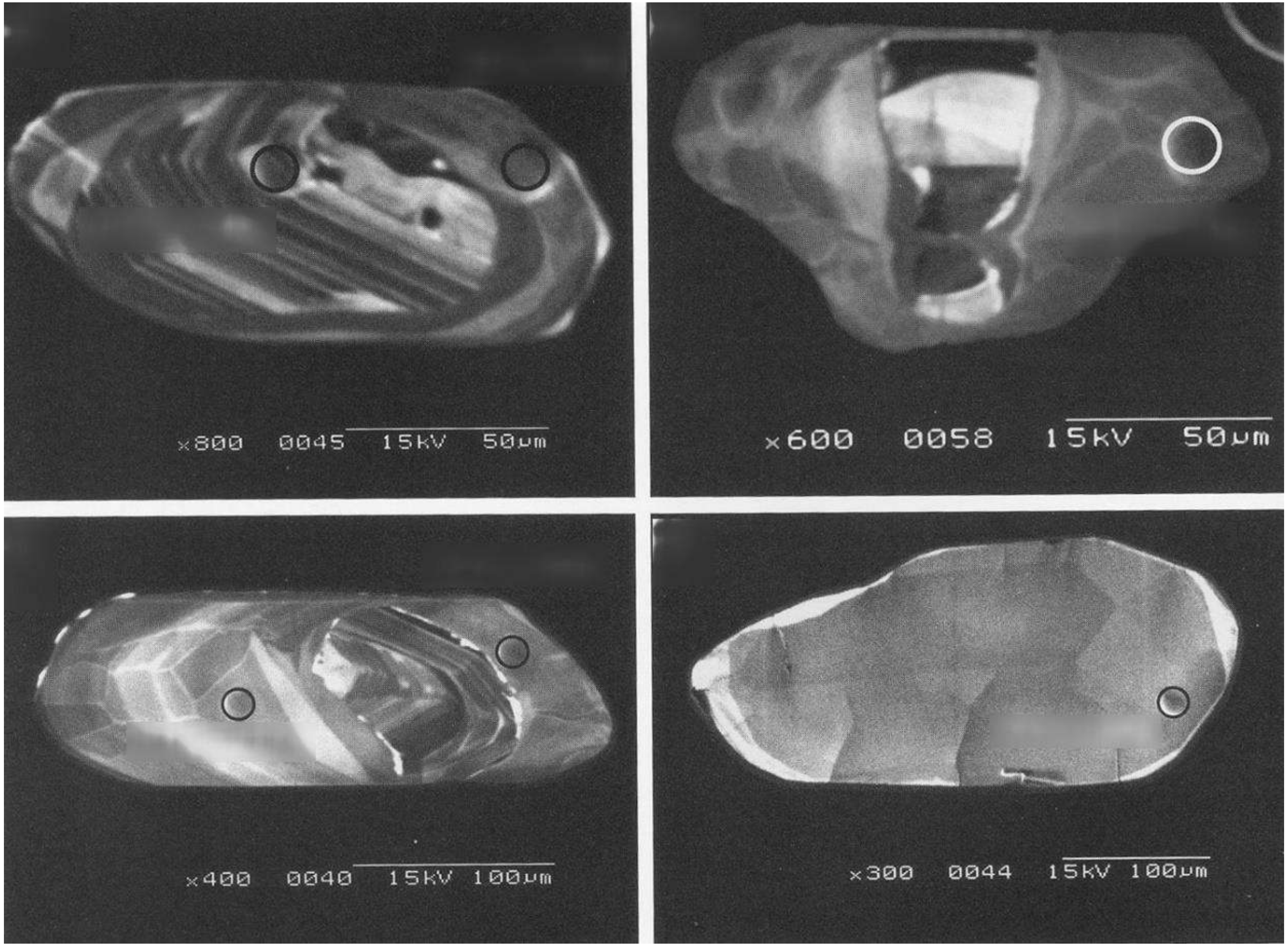




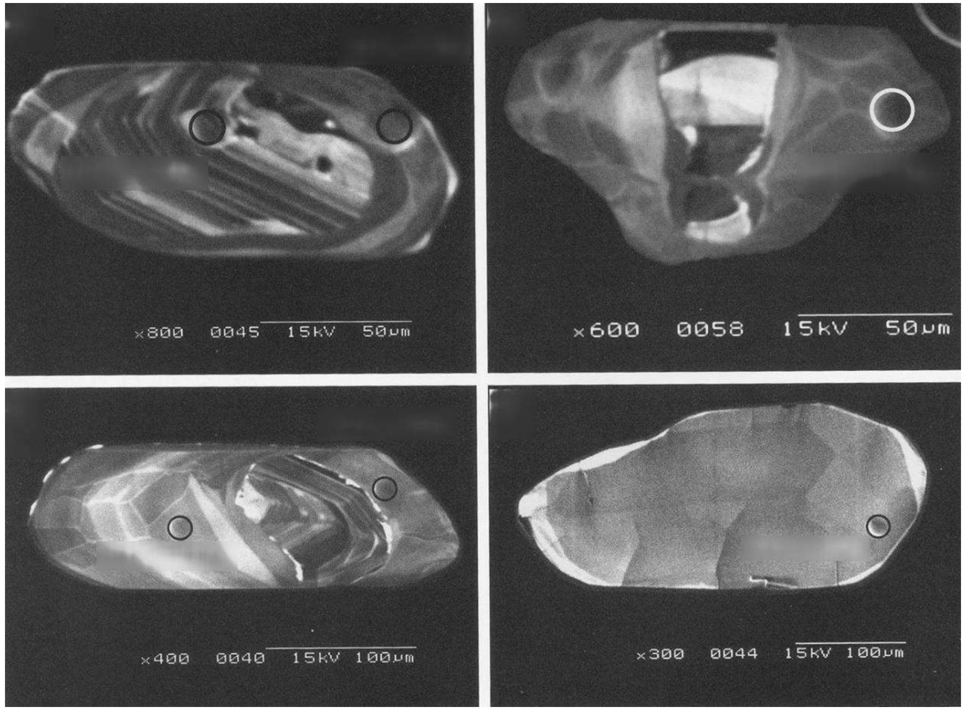


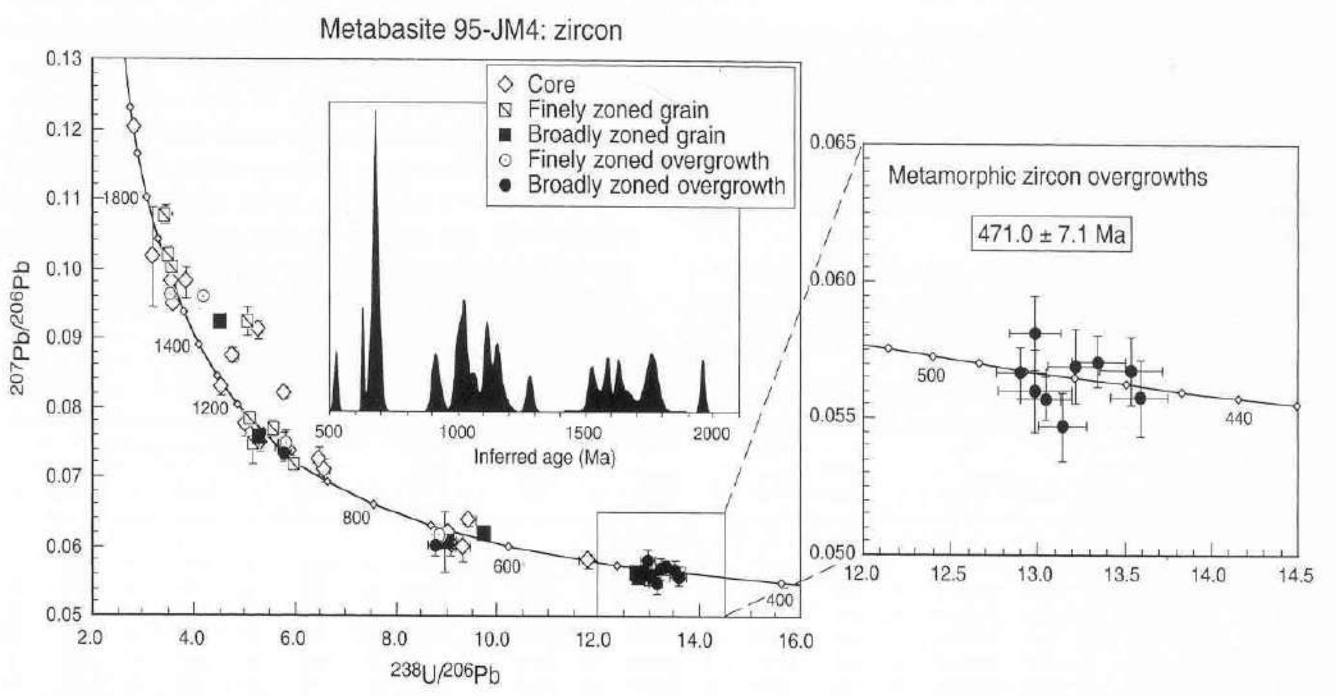
Texture and evolution of zircon grains

Recycling and cratonization- zircons can be recycled several times, overgrown in different geologic environments- interpretation

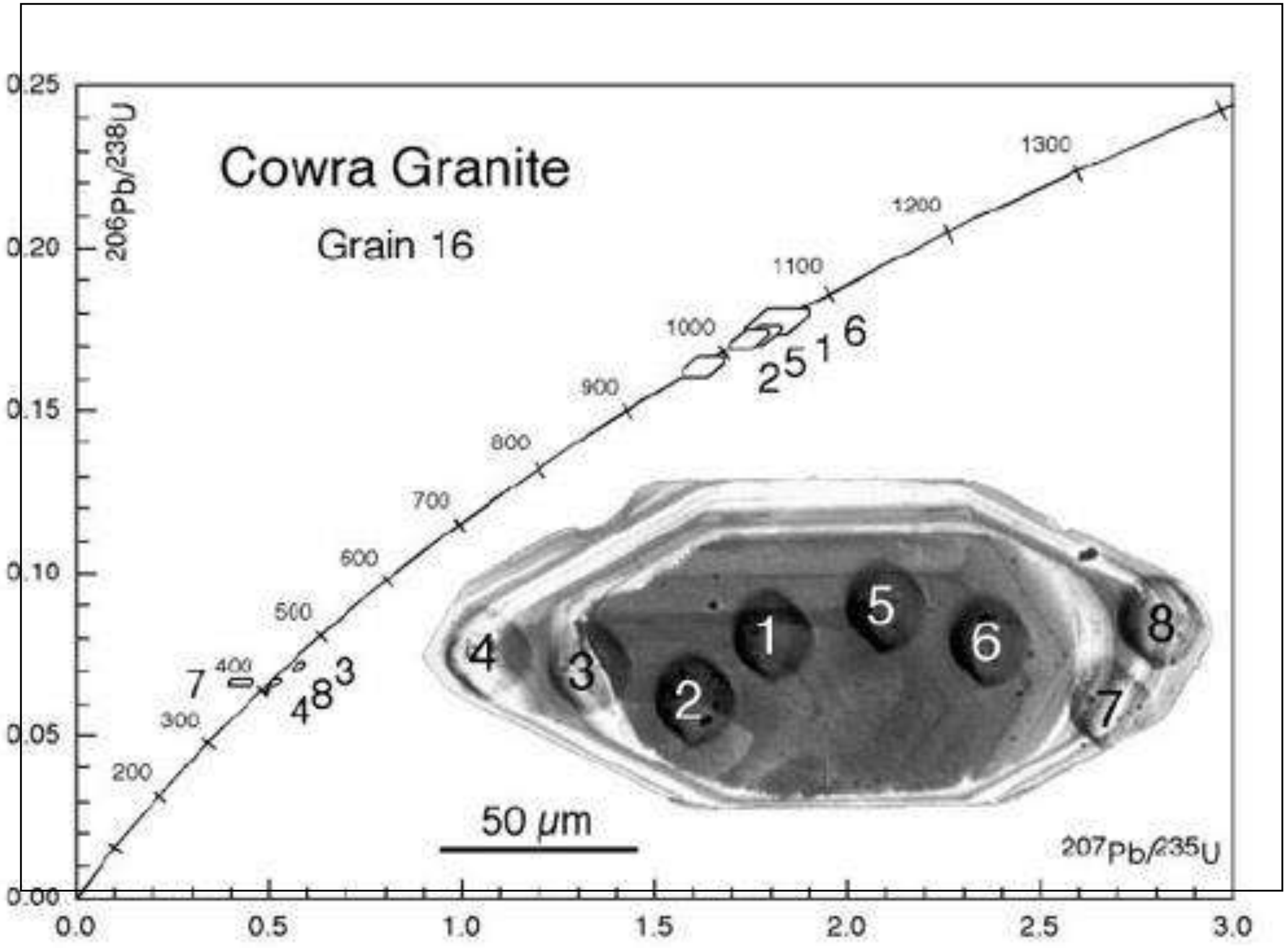


Combined Zircon interpretation of Grain morphology and age in geological evolution





SHRIMP Resolution (after Jodie Miller, 2008)-
Recycling via magmatism, sedimentation, magmatism and metamorphism

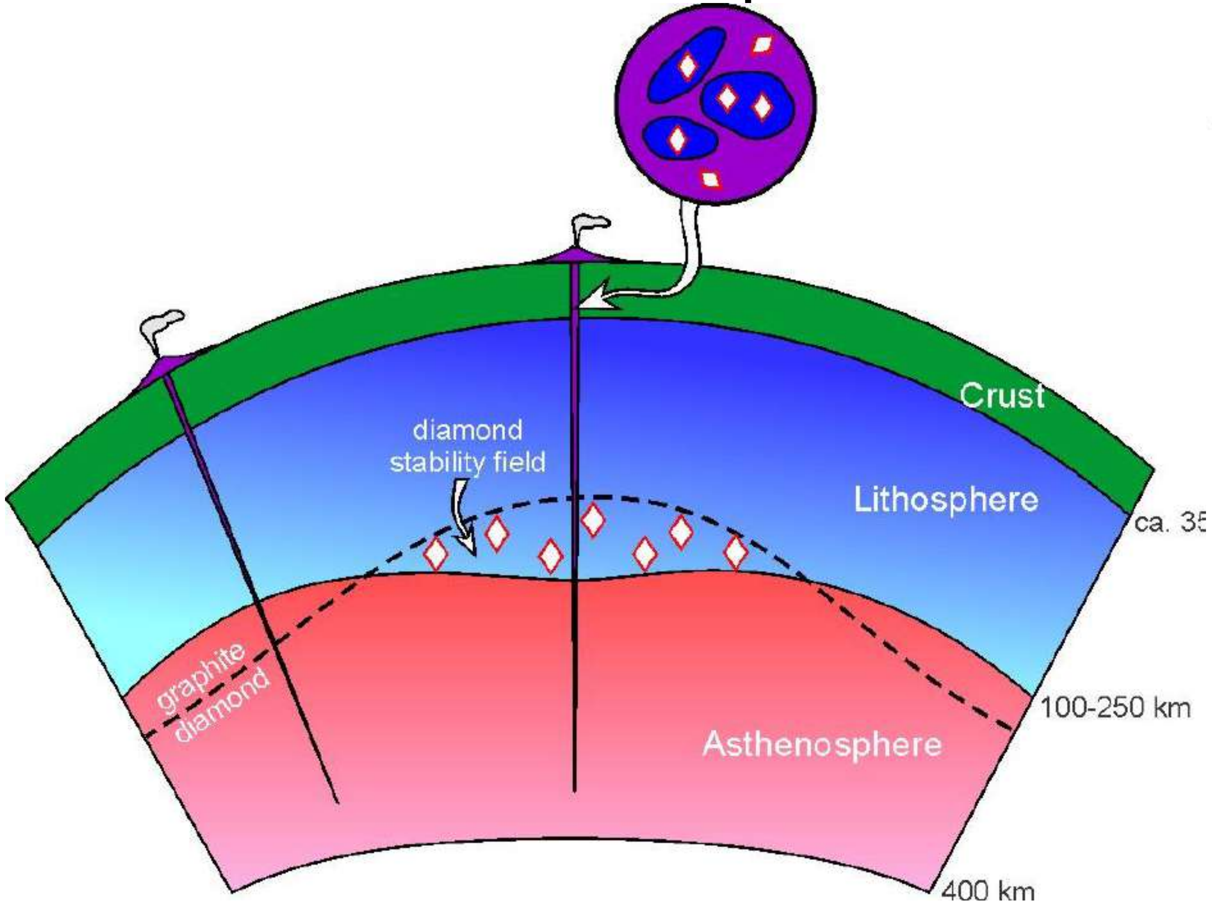


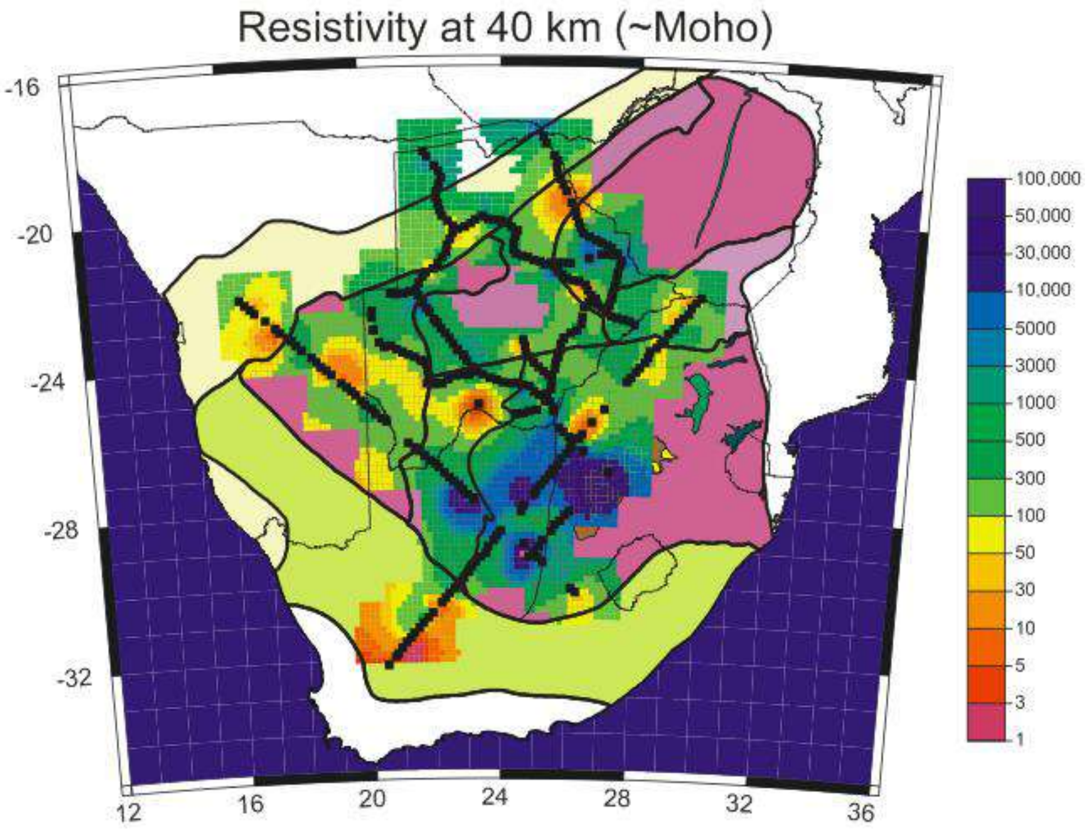
Formation of Oceanic & Continental Crust

	Oceanic Crust	Continental Crust
First Appearance	4.6 billion years ago	4.4 billion years ago
Where Formed	Ocean ridges	Subduction zones
Composition	Komatiite & basalt	Tonalite-Granodiorite
Lateral Extent	Widespread	Locally developed
Mechanism of formation	**Partial melting of ultramafic rocks in the upper mantle**	**Partial melting of wet mafic rocks in descending slabs**

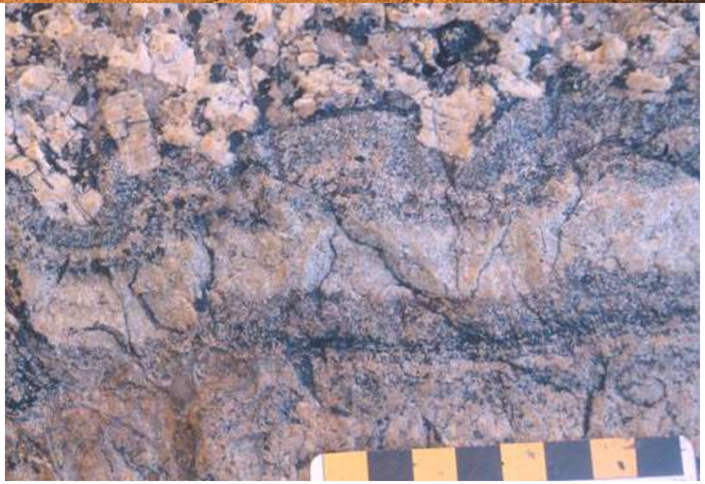
Applications: How we use Zircons in Mineral Exploration

Diamonds do not form in Mobile belts (too warm and not dense enough)- zircon in cratons- we prefer low to med temp for diamond fertility





Spitzkoppe Granite (A-type) came up as the Atlantic Ocean was opening
(dated at 132 Ma)



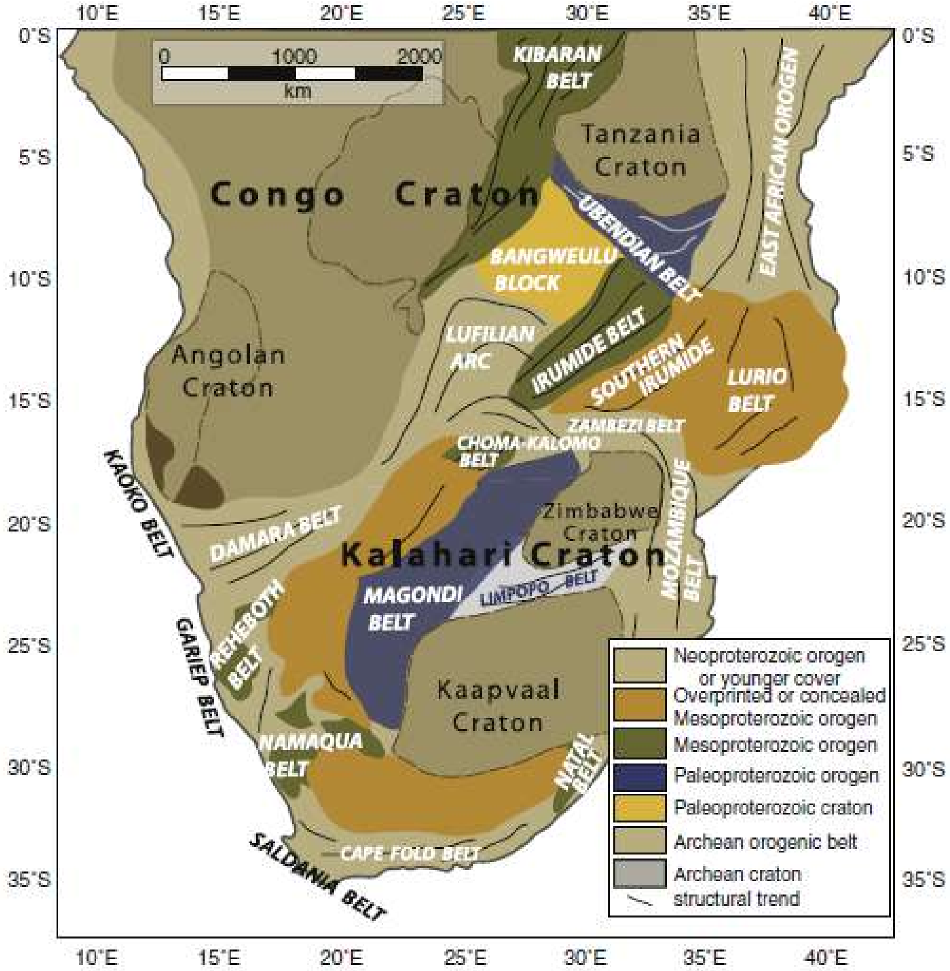


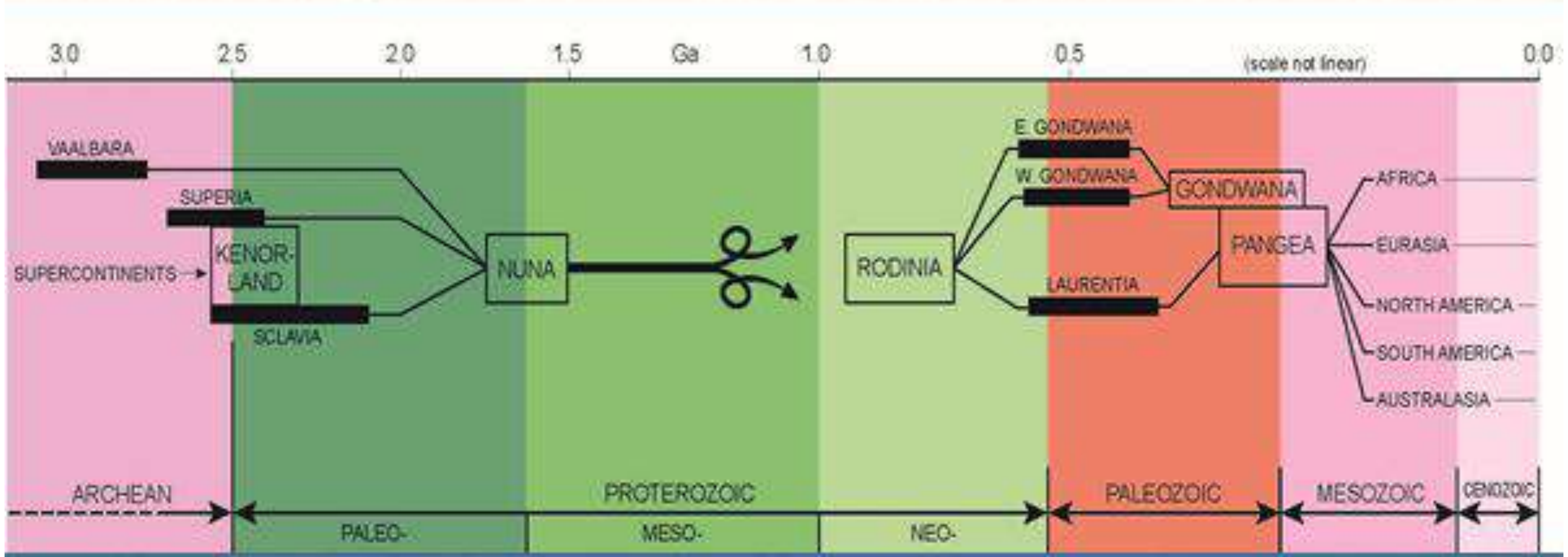
Fig. 2 Map of major geologic provinces and Precambrian orogenic belts in southern Africa. Compiled after Goscombe et al. (2000) and Hanson (2003).

Crustal differentiation, melt generation and melt migration-lessons from zircons

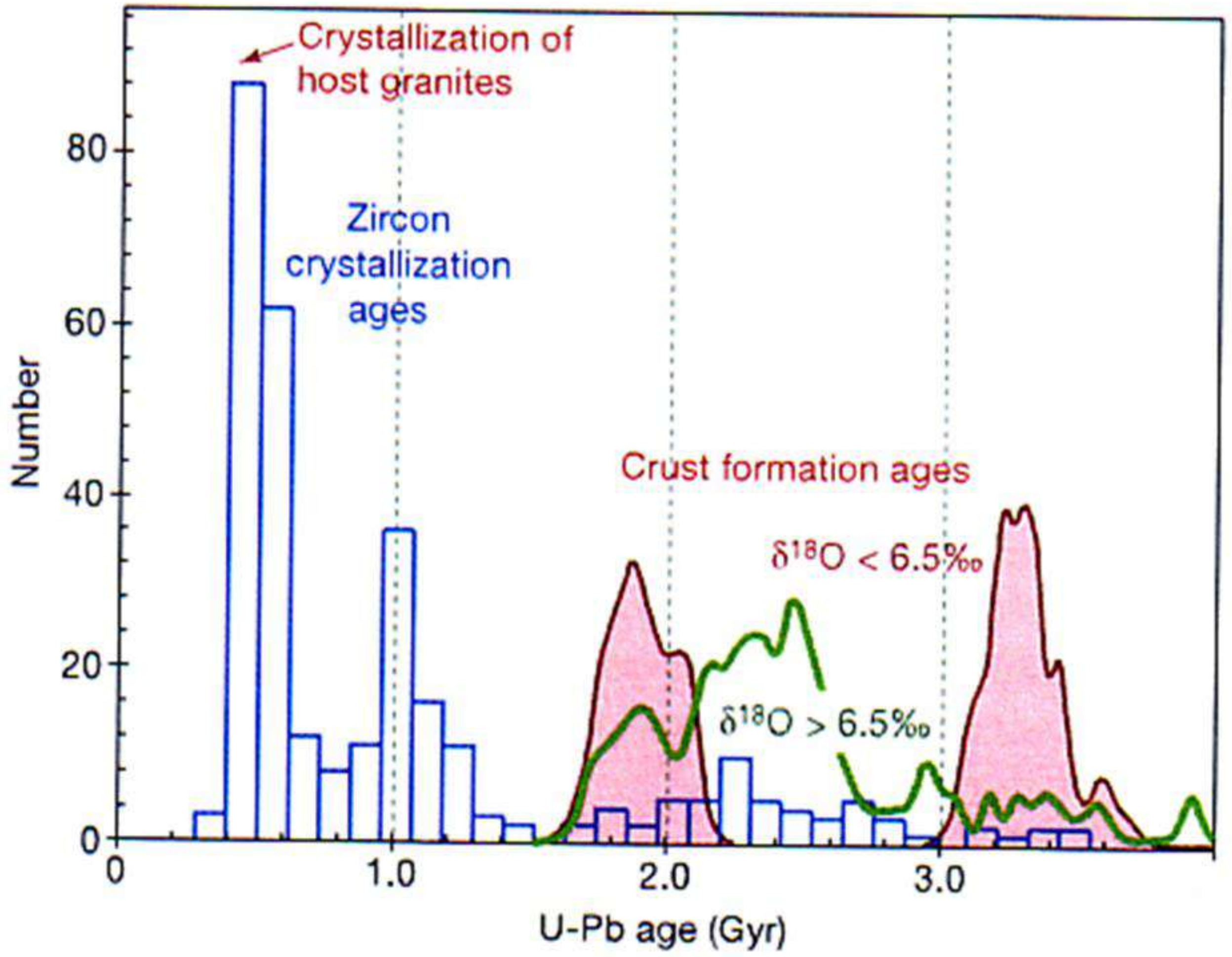
- Continents represent the cycles of repeated differentiation- *inherited zircons in granites*.
- Mineral Deposits signatures occur in these igneous and metamorphic processes
- Dense oceanic crust gets recycled in the Upper Mantle, while less dense felsic crust is upwardly stratified by a combinations of geological and tectonic processes- *we see resorbed magmatic zircons*.
- Anything more felsic than basalt will accrete uniquely in magmatic arcs above subduction zones
- However, true felsic crust of granite composition, requires repeated and multiple differentiation events to reach the average composition of continents- *complex zircons that have undergone several metamorphic and granite episodes are common*

Crustal Evolution: the tectonic framework for ore deposits

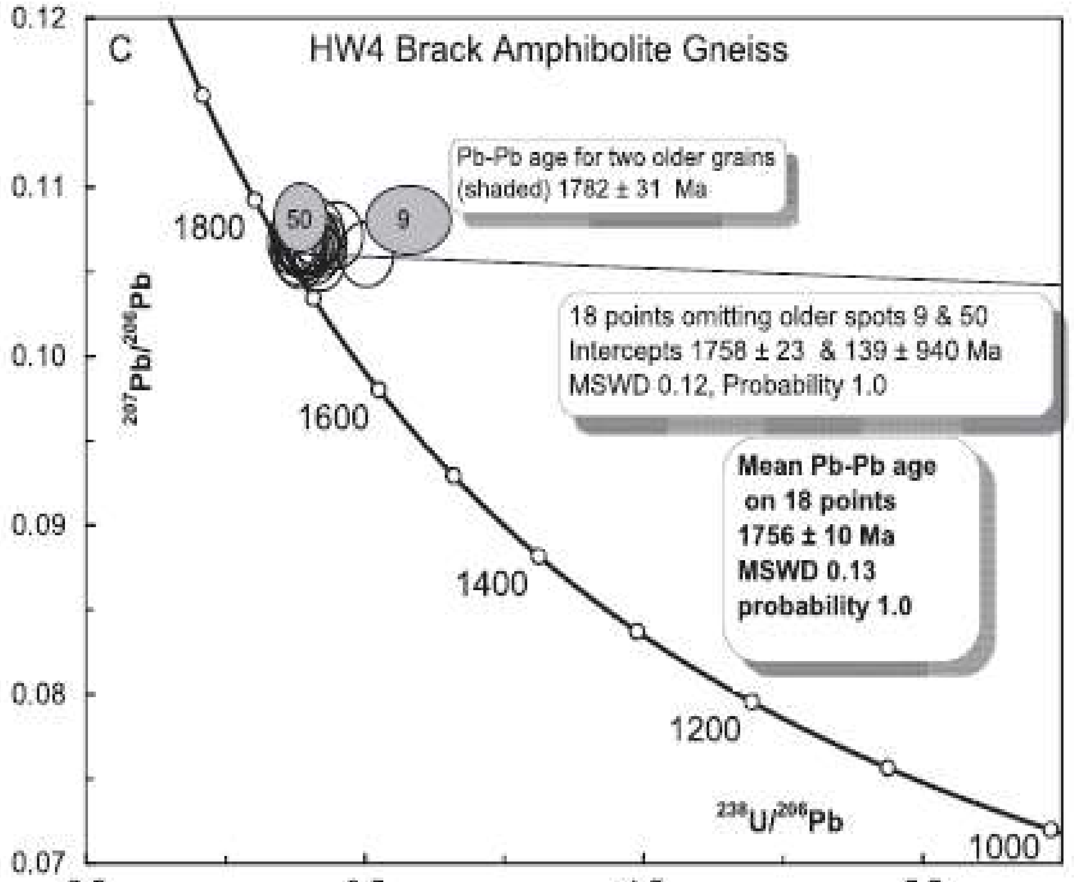
THE SUPERCONTINENT CYCLE....................

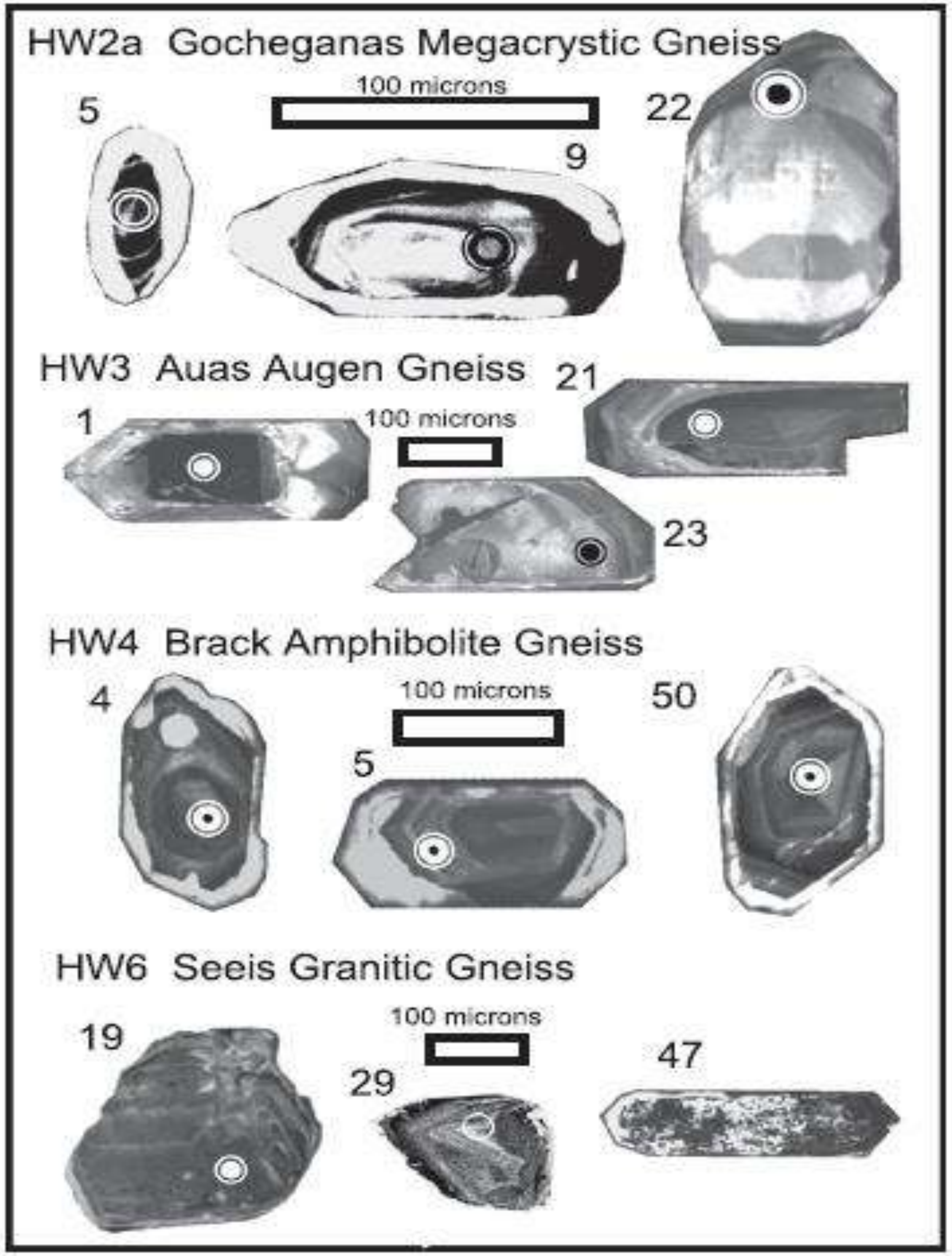


Formation of continental crust and its evolution over the geologic history (after Hawkesworth, 1987)



Mapani et al., 2014
You can add value on your interpretation by looking at zircon grains





One zircon under different observation environments. RF gives us the surface and a thin upper layer morphology of zircon; CL allows us to go into the inside of the zircon, BSE gives us a good understanding of the U/Pb ratios of different zones

Can we guess how the zircon grains will look in these 5 rocks.

Note patterns of an increase in HREEs (HW2a) and reduction in LREEs and a suture sample with almost a constant REEs pattern

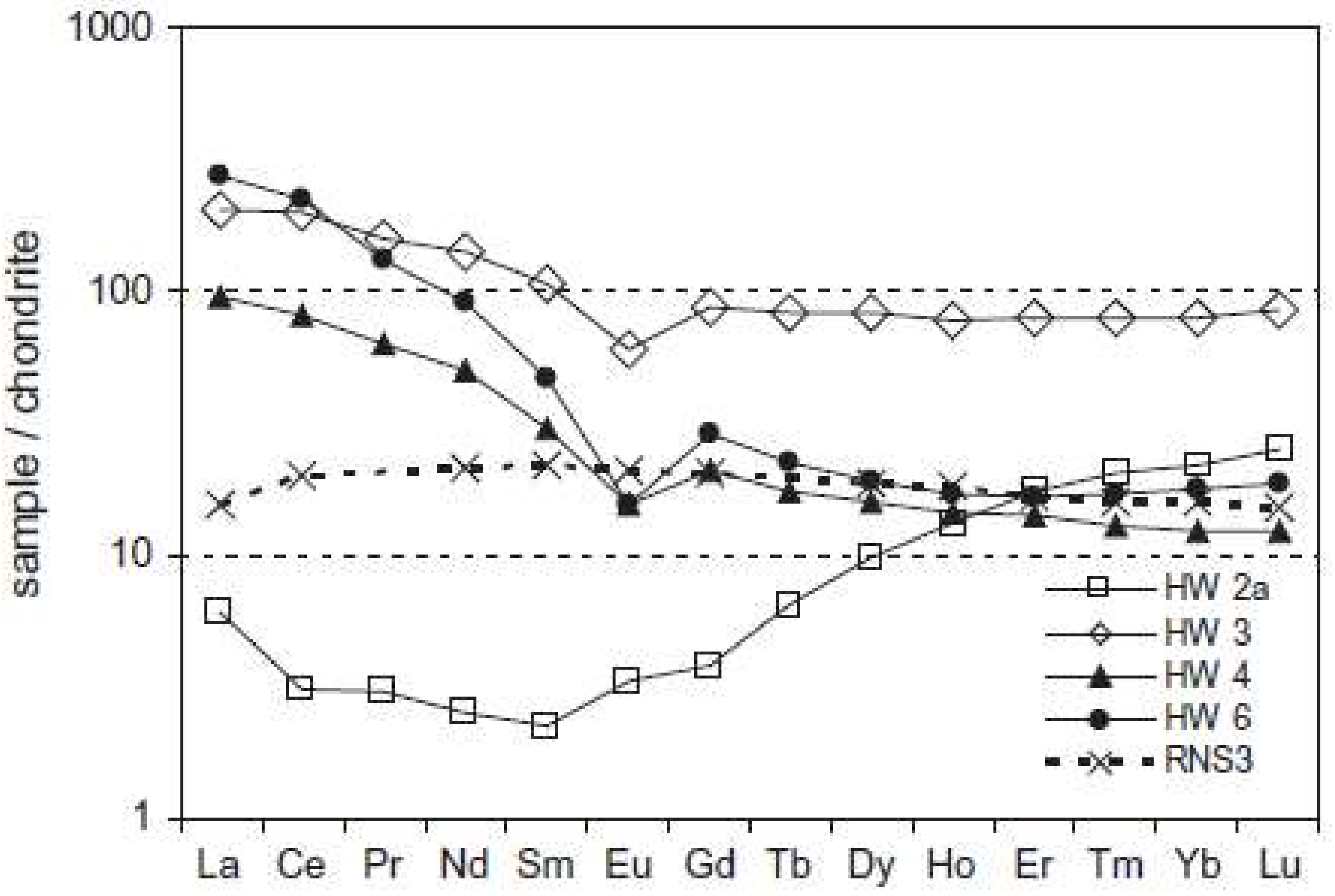


Fig. 6. Rare Earth Element profiles for Hohewarte Complex samples, showing the unusual profile for Gocheganas Megacrystic gneiss sample HW2a, probably related to metasomatic alteration. Sample RNS3 is a Hindus Suture Zone plagiogranite of Rao et al. (2004), shown for comparison with sample HW4 which has a similar normative composition.

Beauty of Zircon- you can obtain Hf-Lu ratios

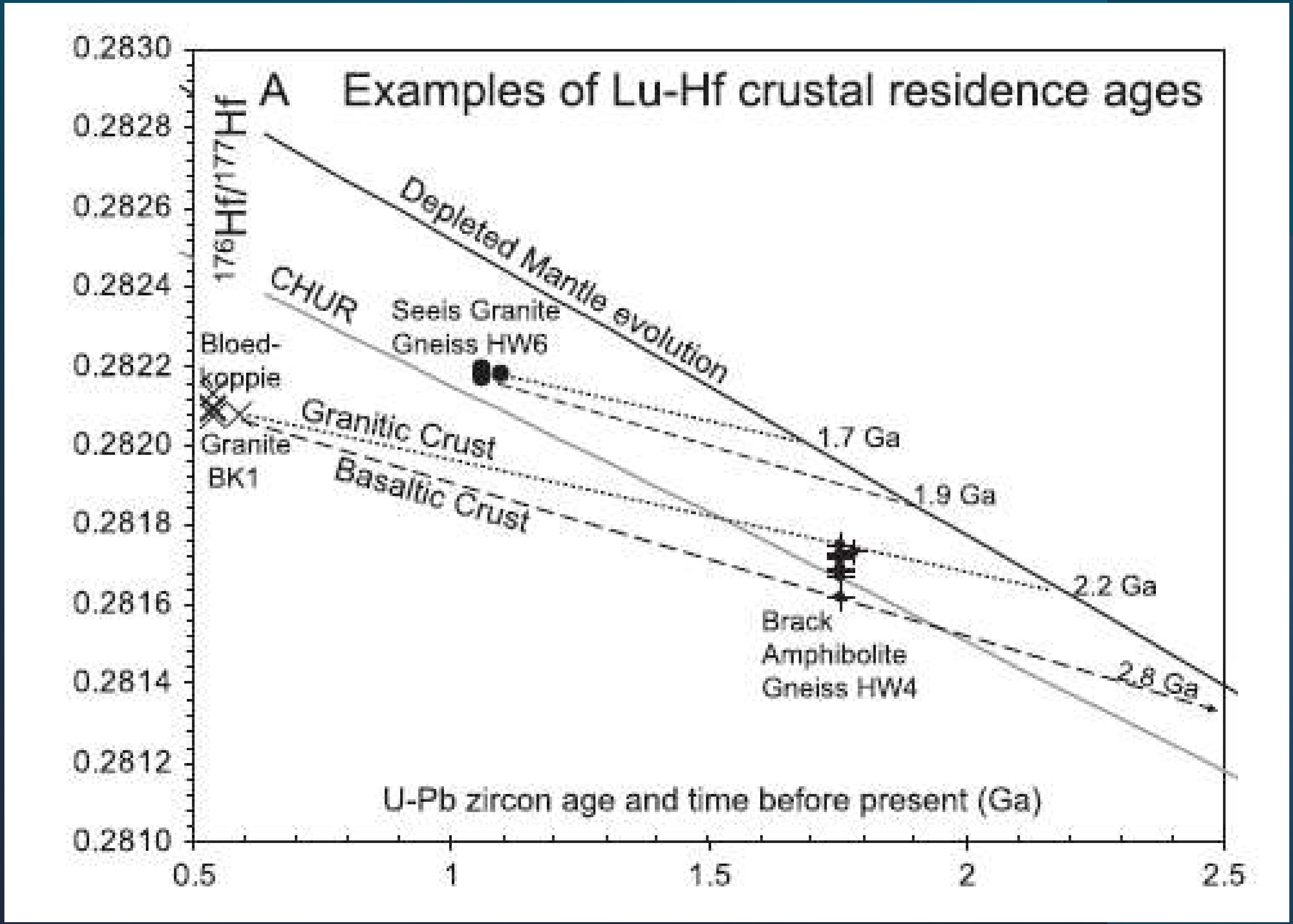
On the same grain where you obtain the U-Pb ratios, you can quantitatively obtain the the Hf-Lu ratios as well.

Hf and Lu give us another dimension in unravelling continental crust evolution.

We use the Hf/Lu ratios from zircons to fully understand the evolution of the rock-Lu is preferred in the Mantle and Hf fractionates more in crustal rocks.

Therefore, with episolon Hf, we assess the time when a rock from the mantle was brought into the crust.

That age tells us the geological event I that occurred rise to the fractionating of Hf.



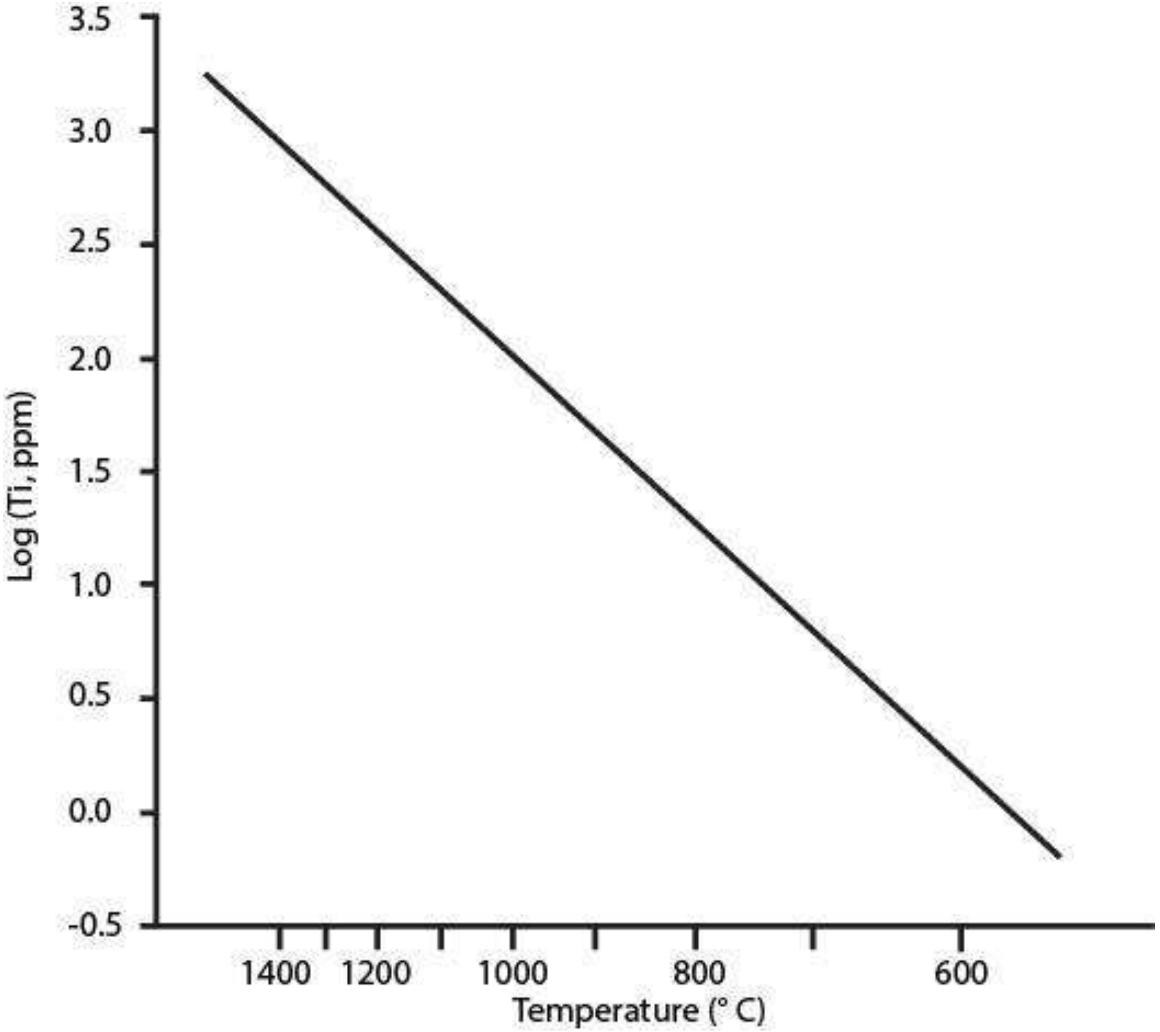
A Examples of Lu-Hf crustal residence ages
$^{176}Hf/^{177}Hf$
Depleted Mantle evolution
CHUR
Seeis Granite
Gneiss HW6
Bloed-
koppie
Granite
BK1
Granitic Crust
Basaltic Crust
1.7 Ga
1.9 Ga
2.2 Ga
2.8 Ga
Brack
Amphibolite
Gneiss HW4
U-Pb zircon age and time before present (Ga)
0.2830
0.2828
0.2826
0.2824
0.2822
0.2820
0.2818
0.2816
0.2814
0.2812
0.2810
0.5
1
1.5
2
2.5

Isotopes and their use in continental crust formation

- Firstly, zircons form in magmatic rocks of felsic in composition (granites, rhyolites, rhyodacites, tonalites, granodiorites)-rare zircons occur in basic rocks (mostly baddeleyite)
- Zircons are resistant to weathering and can be recycled in sedimentary rocks over many cycles.
- By doing Zircon petrography, we can assess or tell its story
- Therefore, when we date them(U-Pb), we find the age of crystallisation of granite or felsic rock or metamorphic ages as rims on previously existing zircons
- Altered zircons reveal LREE abundance especially in long residence crystals

Zircon Thermometry (after Watson et al., 2006; Contr. Min. Pet., 151; 413-433)

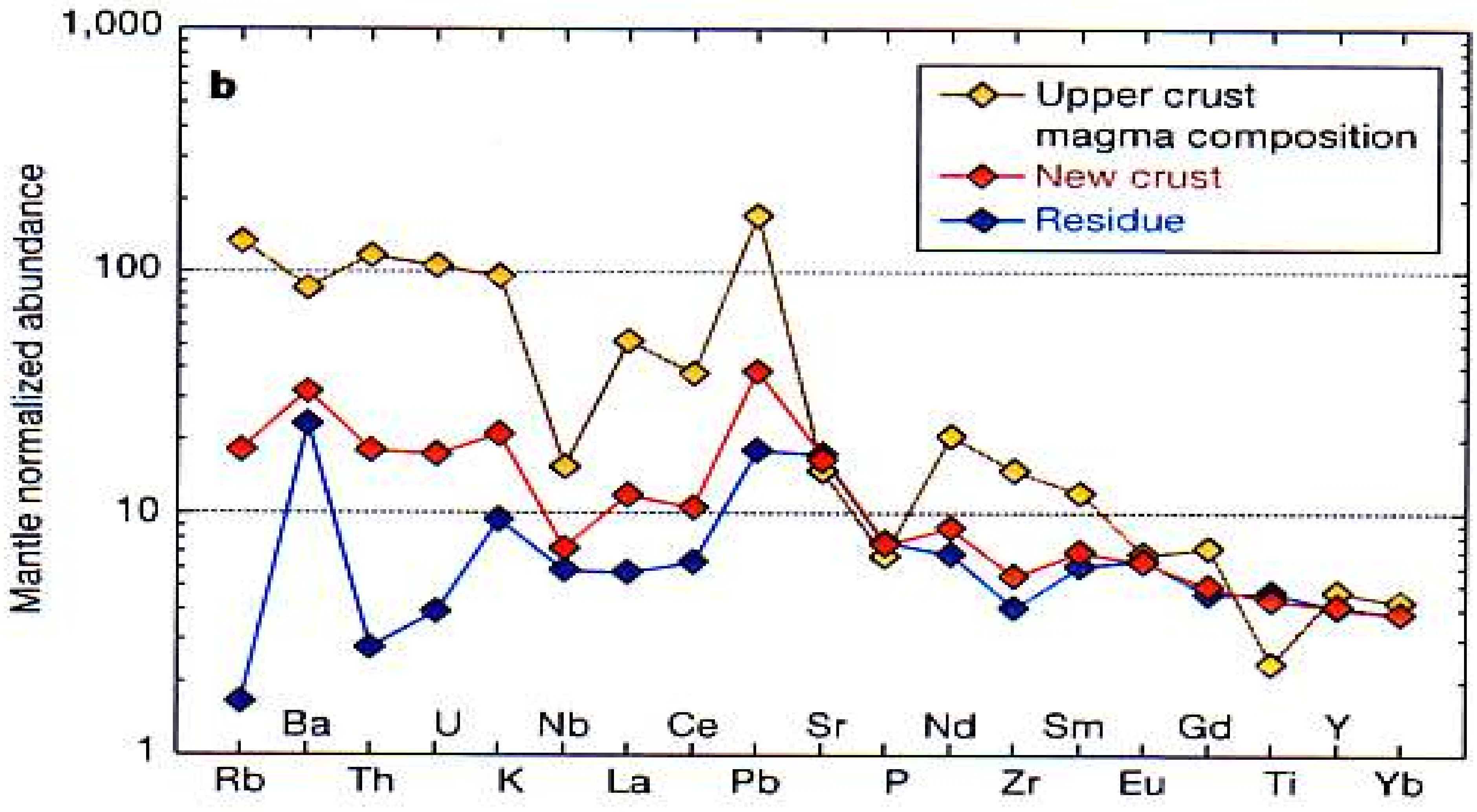
- Titanium in zircon geothermometry is a technique used to estimate the crystallization temperature of zircon crystals.
- We measure the amount of titanium in the zircon lattice.
- Titanium replaces zirconium and silicon atoms in the crystal structure, and its incorporation is largely influenced by temperature—significantly increasing with higher temperatures—while being mostly unaffected by pressure.



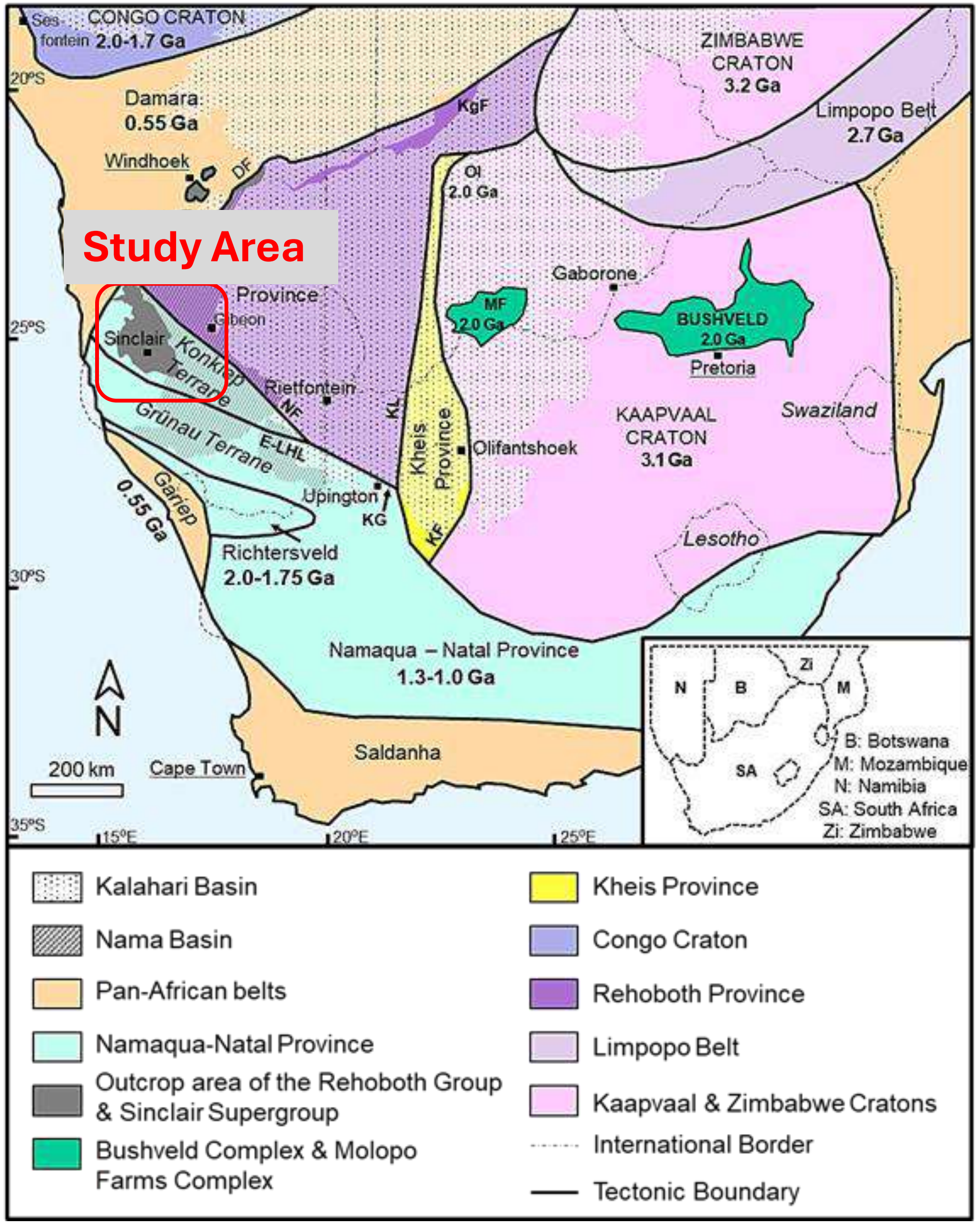
How do we know that the continental crust is juvenile or is not mixed with sedimentary material?

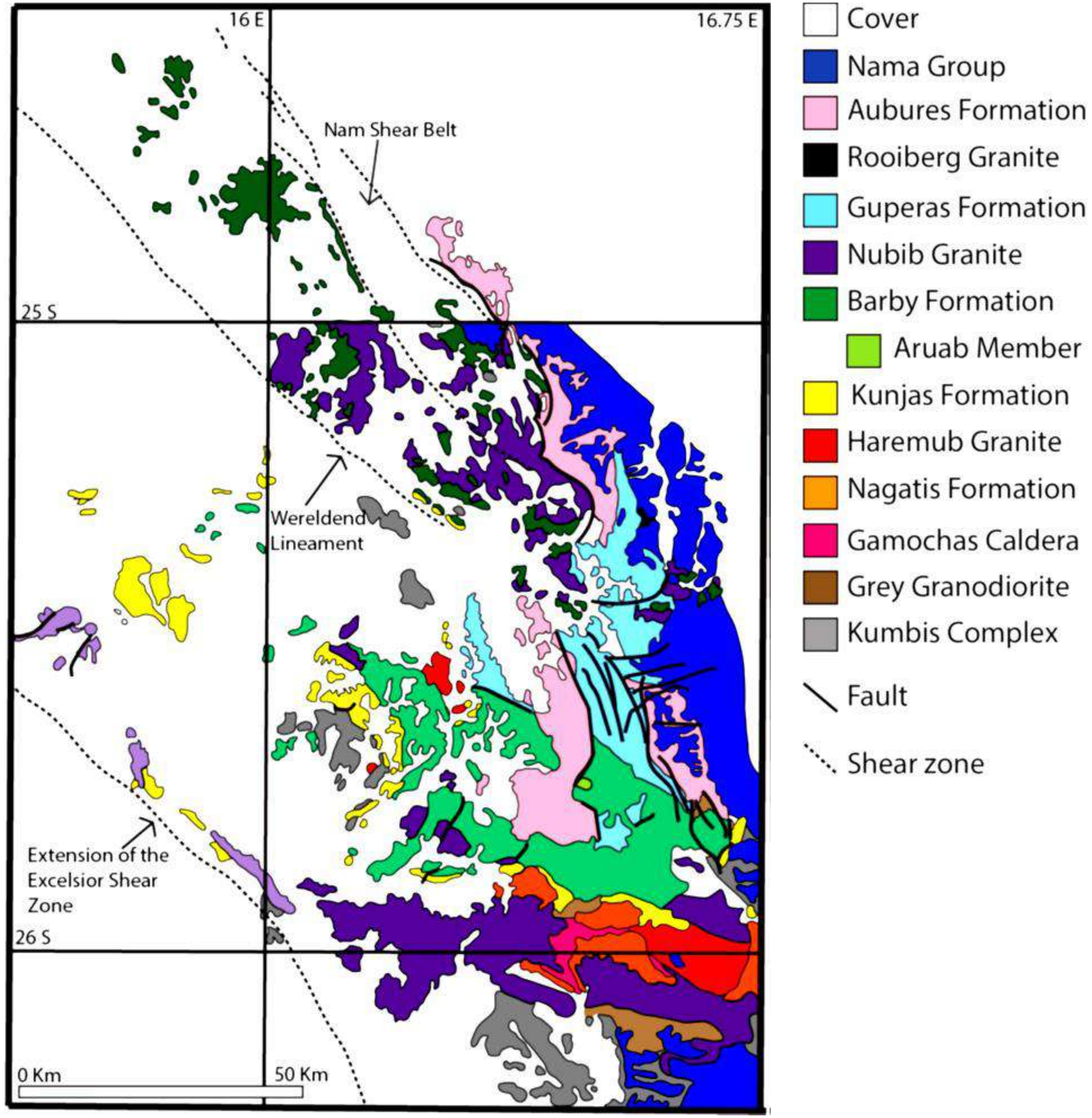
- For this we use a combination of isotopes.
- 1. Sm/Nd isotopes: Nd indicates whether the rock was derived from the crust or mantle.
- Rocks with high Nd values are from the mantle
- La and Rb are high in crustal rocks and therefore Rb/Sr and Nb/La ratios can tell us about the origin.
- High Sr87/Sr86 is common to crustal rocks (above 0.6900).
- We use the Hf/Lu ratios from zircons to fully understand the evolution of the rock-Lu is preferred in the Mantle and Hf fractionates more in crustal rocks.

Zircon ages U-Pb; Lu-Hf; Pb-Pb in combination with geochemistry of rocks can allow us to trace the evolution of continental crust



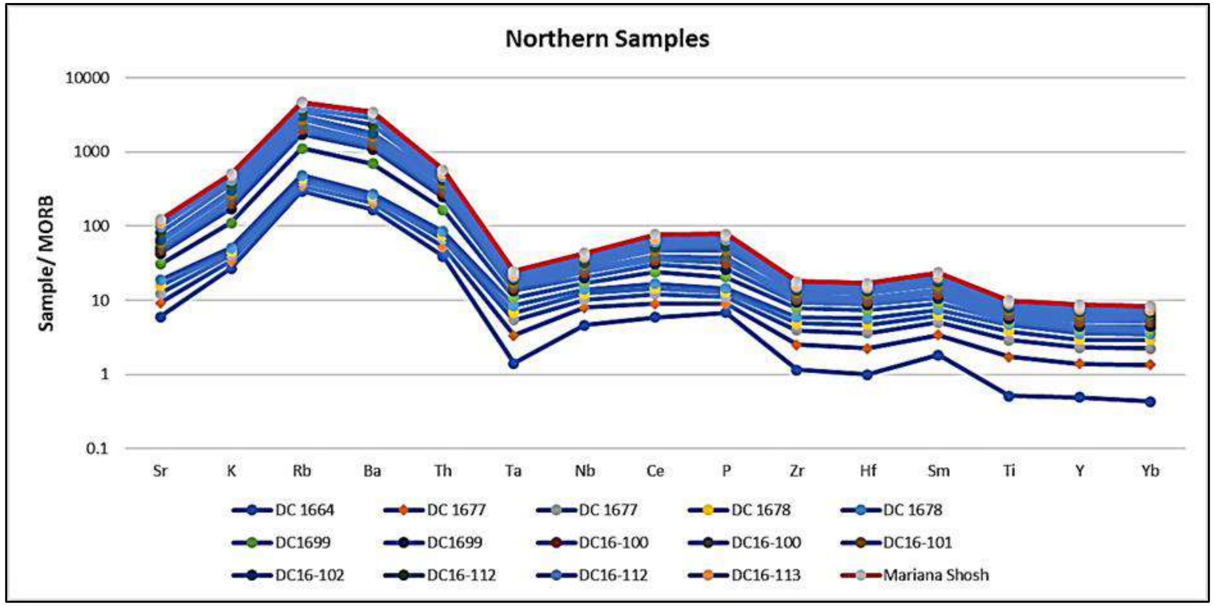
Example 1: Re-organisation of the Stratigraphic Column





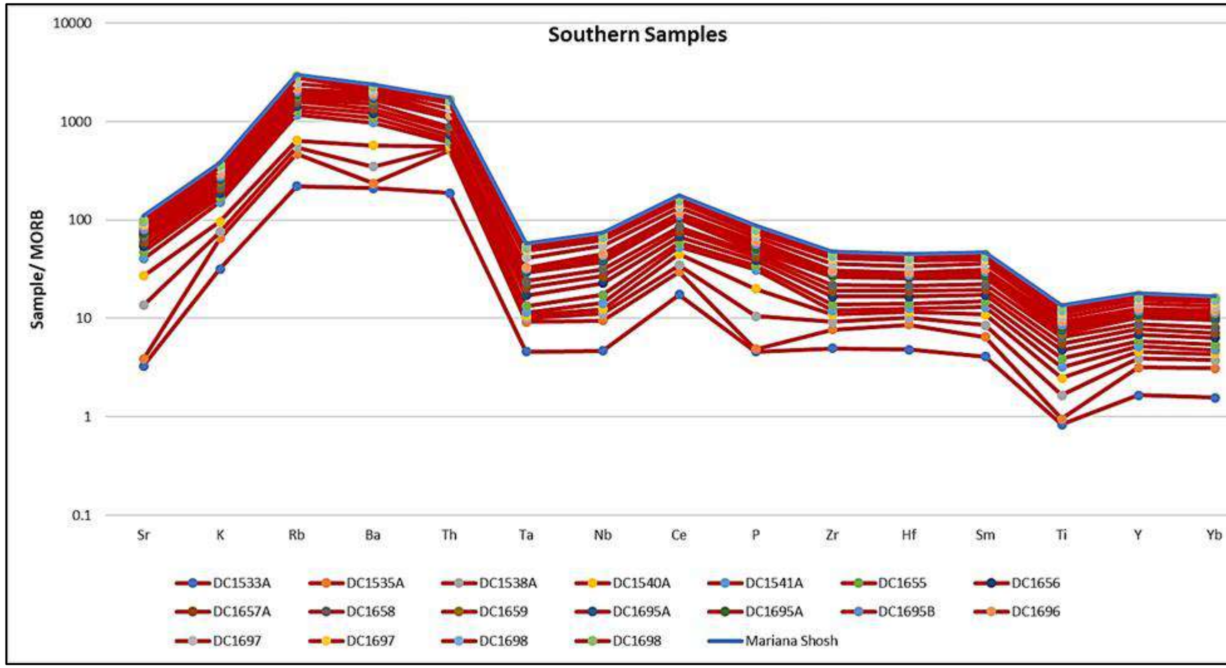
RESULTS

- MORB-normalised spider diagrams

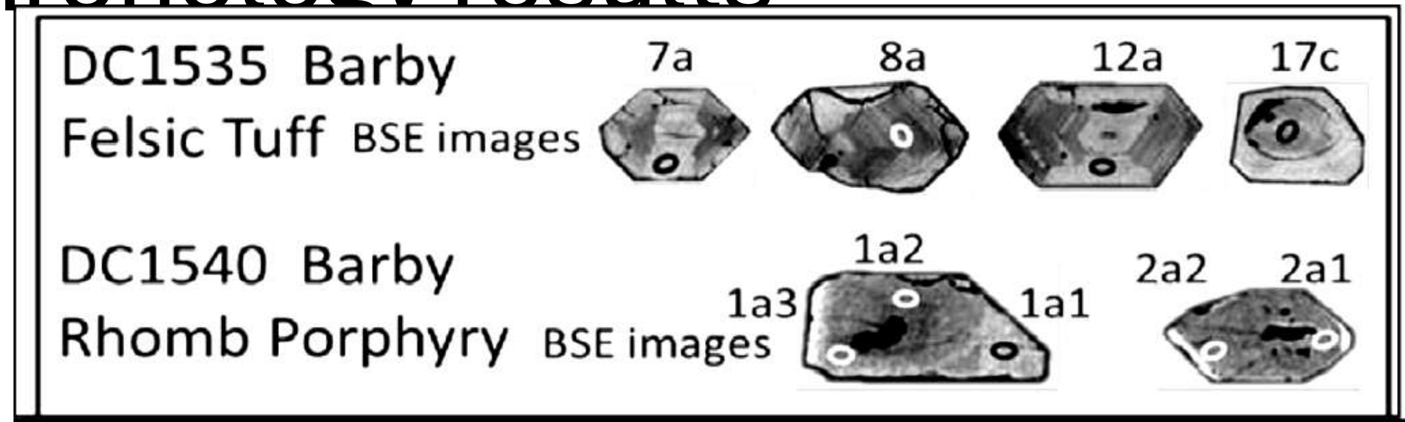


- Enrichment of the mobile elements Sr, K, Rb and Ba
- Decreasing immobile elements Th to Yb
- Negative Nb-Ta, Ti and P anomalies typical of **volcanic arc magmas.**

- Shoshonitic samples having much lower Sr and large negative anomalies for Ba, P and Ti compared with the high-K calc-alkaline samples.



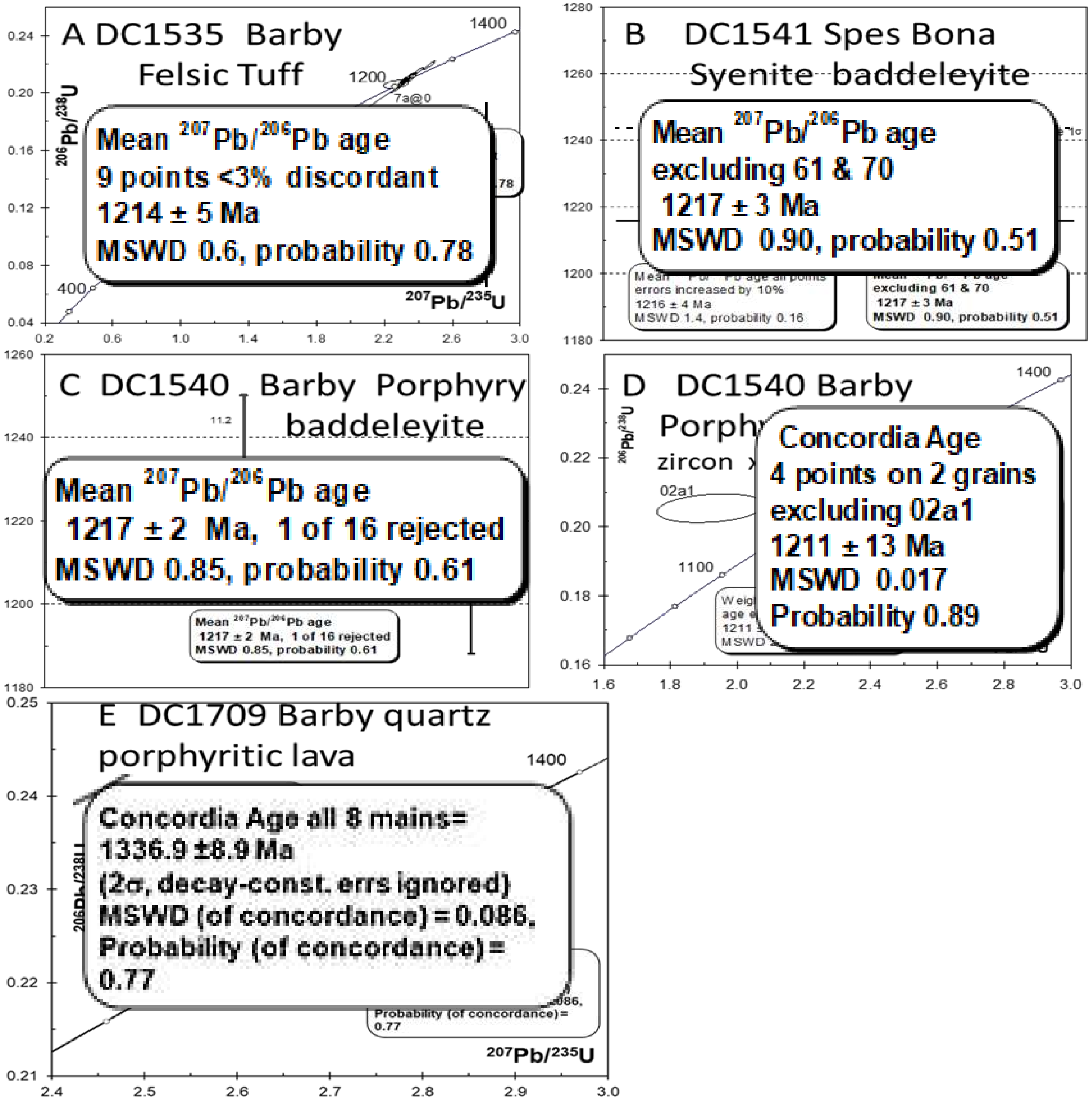
Geochronology results



DC1709 Barby quartz porphyritic lava

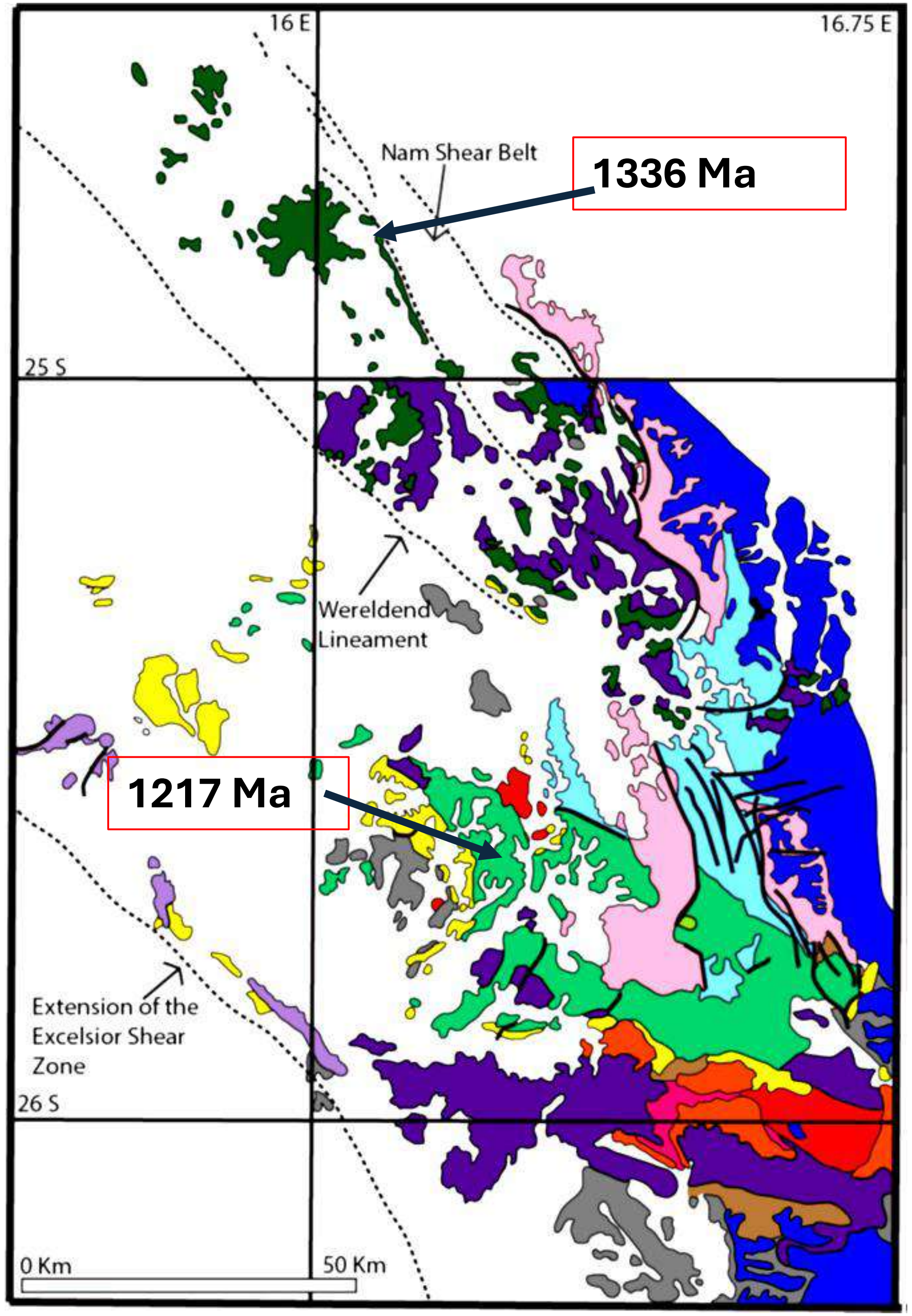
DC1541Spes Bona syenite

- U-Pb data

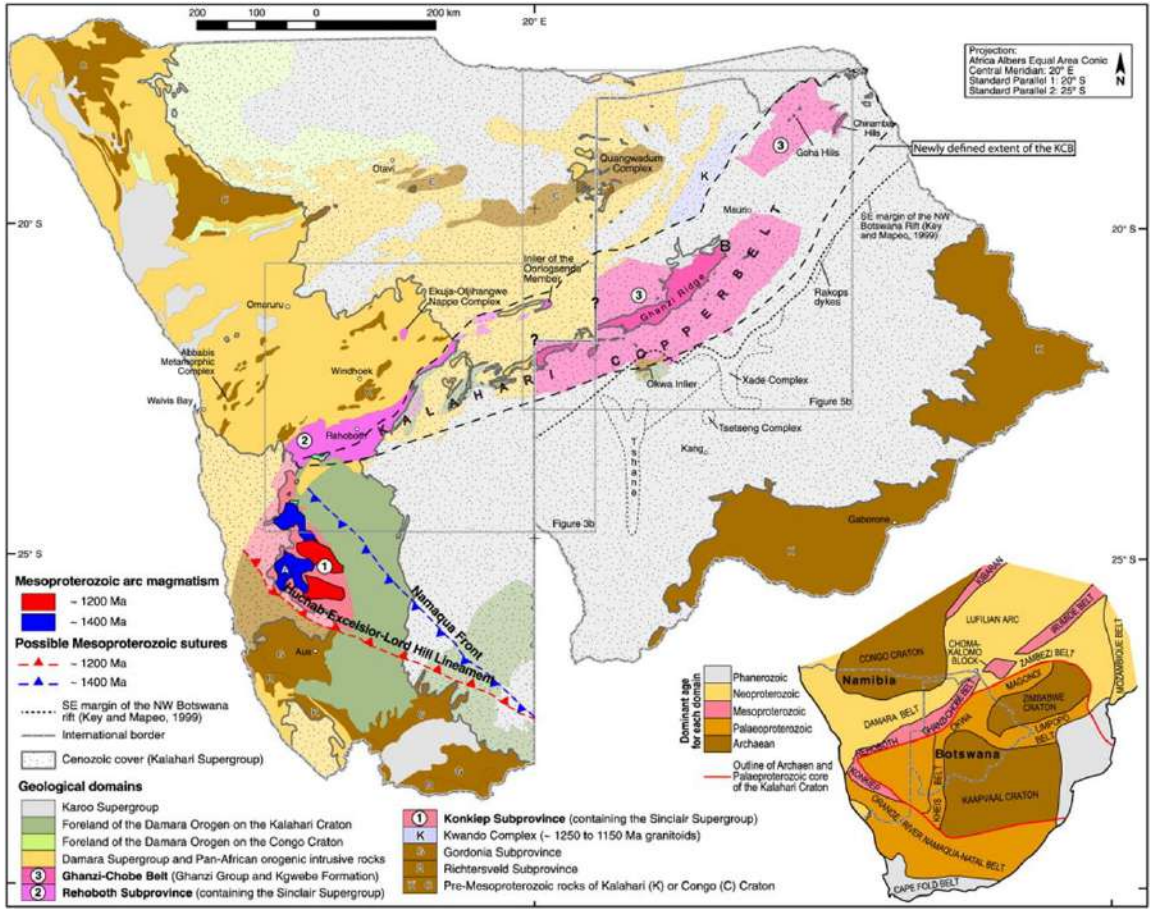

A DC1535 Barby
Felsic Tuff
Mean 207Pb/206Pb age
9 points <3% discordant
1214 ± 5 Ma
MSWD 0.6, probability 0.78
206Pb/238U
207Pb/235U
B DC1541 Spes Bona
Syenite baddeleyite
Mean 207Pb/206Pb age
excluding 61 & 70
1217 ± 3 Ma
MSWD 0.90, probability 0.51
errors increased by 10%
1216 ± 4 Ma
MSWD 1.4, probability 0.16
C DC1540 Barby Porphyry
baddeleyite
Mean 207Pb/206Pb age
1217 ± 2 Ma, 1 of 16 rejected
MSWD 0.85, probability 0.61
D DC1540 Barby
Porphy
zircon
02a1
Concordia Age
4 points on 2 grains
excluding 02a1
1211 ± 13 Ma
MSWD 0.017
Probability 0.89
E DC1709 Barby quartz
porphyritic lava
Concordia Age all 8 mains=
1336.9 ±8.9 Ma
(2σ, decay-const. errs ignored)
MSWD (of concordance) = 0.086,
Probability (of concordance) =
0.77
207Pb/235U

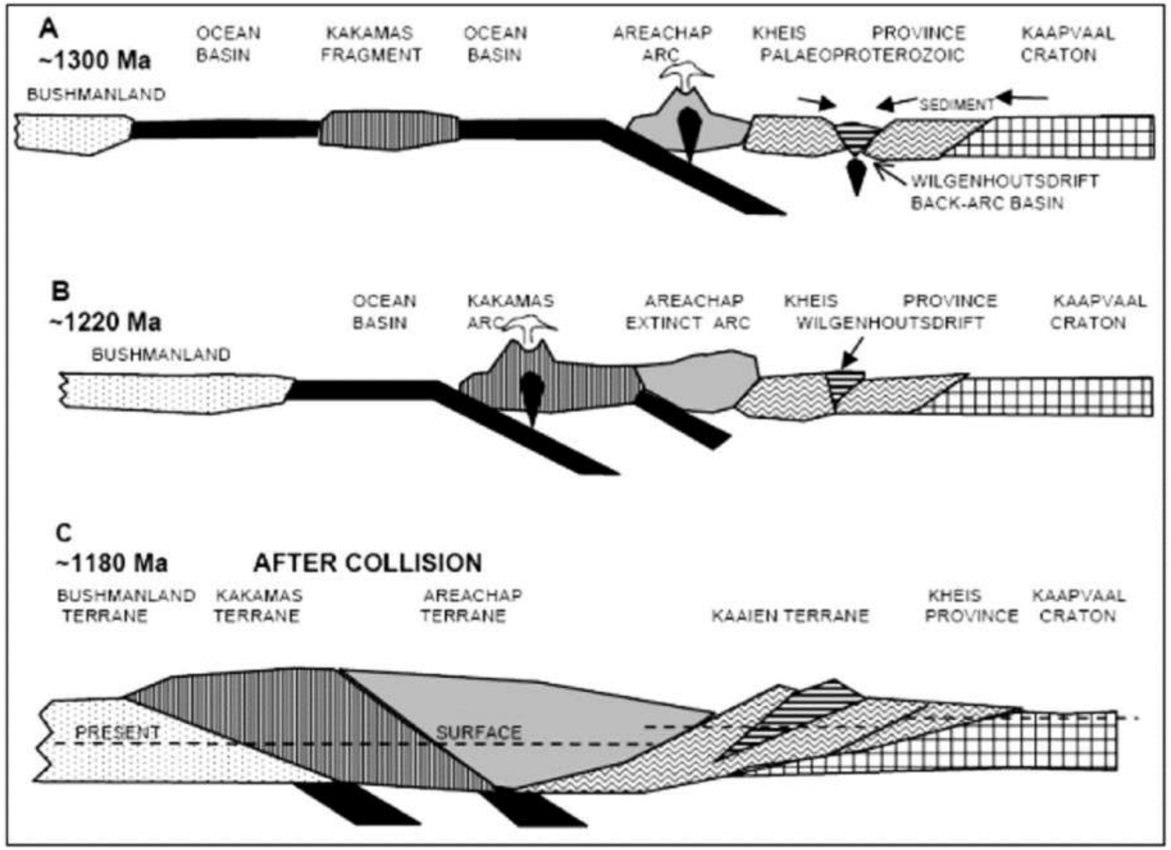
- Dark green is the Barby Formation in the North
- Age: 1336 Ma

- Light green is the Barby Formation in the south
- Age: 1217 Ma

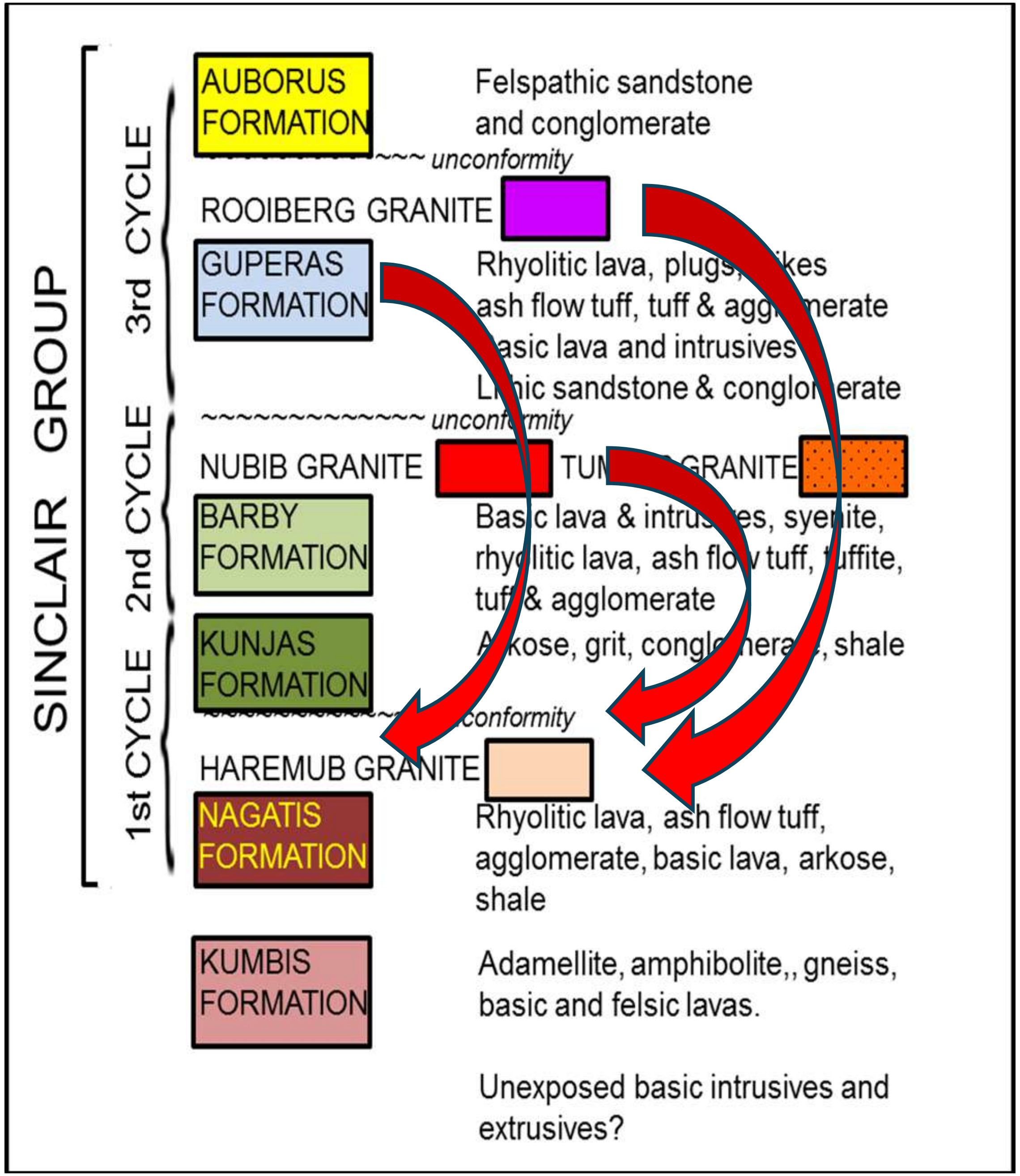


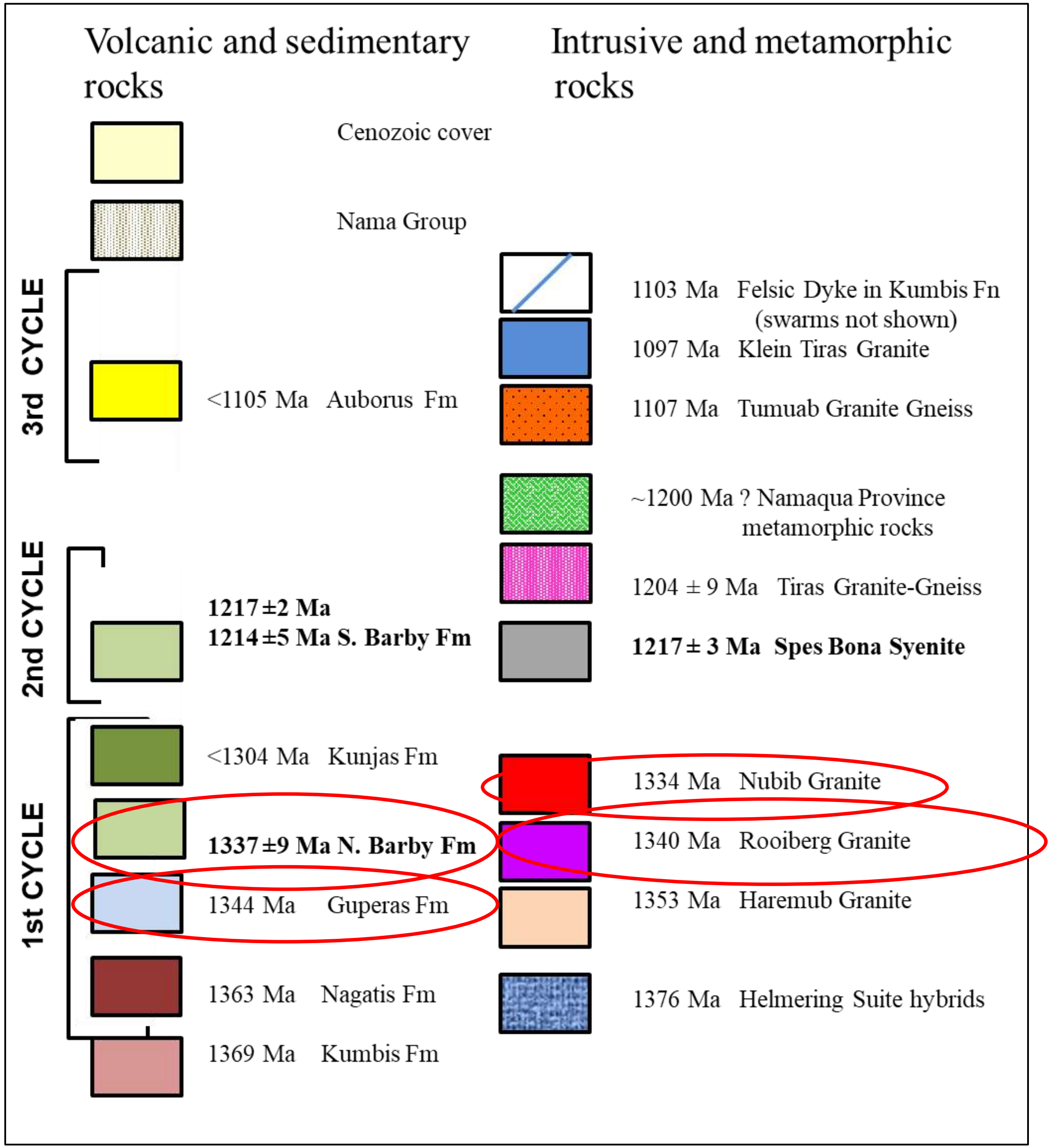
Tectonic Evolution





NEW FINDINGS





The Damara, Gariep and Kaoko Belts – Fertility for metal deposits-The power of Zircon in mineral discovery

Gondwana Research 28 (2015) 179–190

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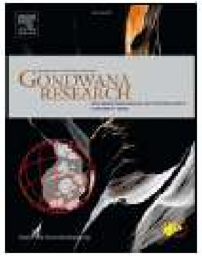


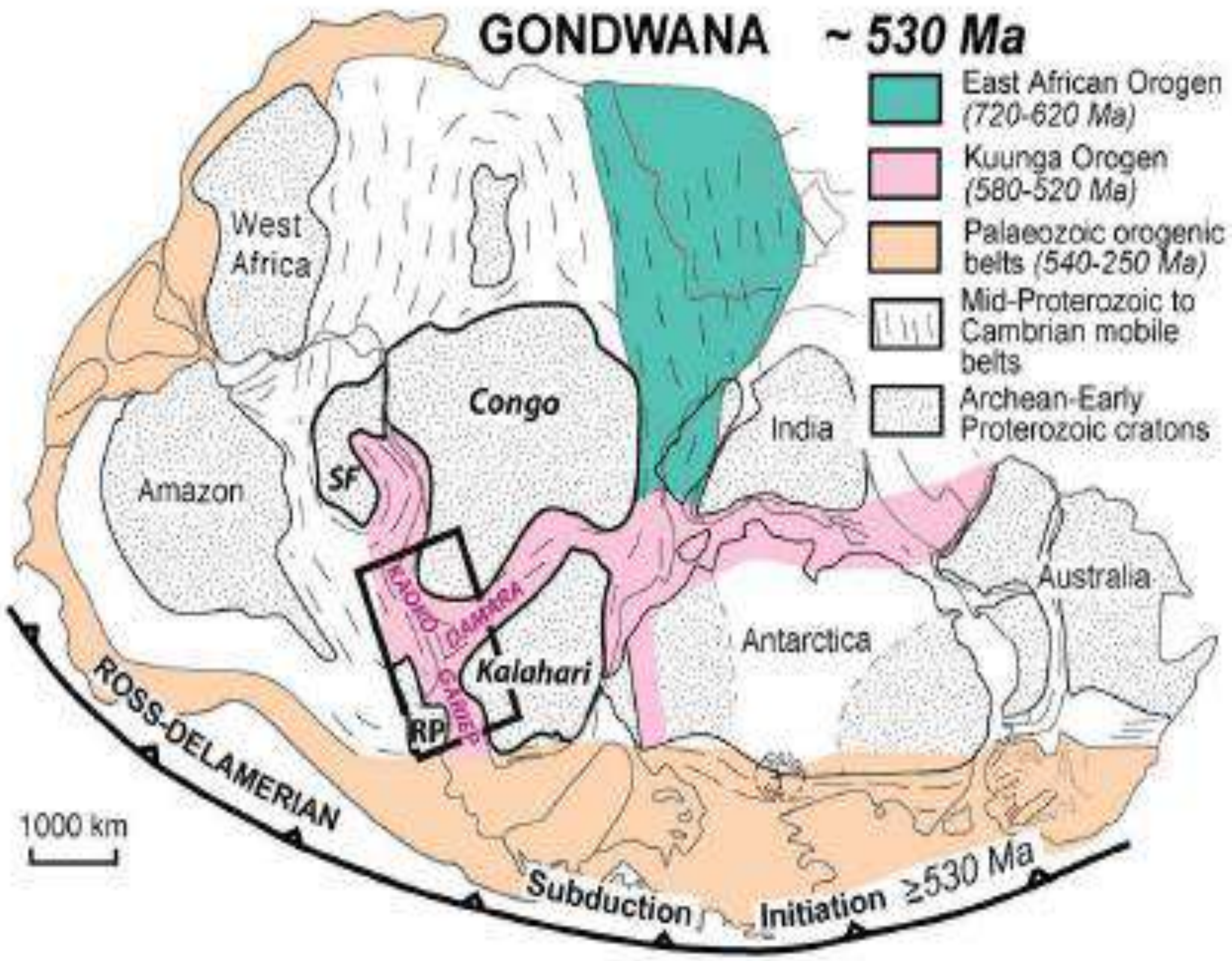
CrossMark

U–Pb age and Lu–Hf isotopic data of detrital zircons from the Neoproterozoic Damara Sequence: Implications for Congo and Kalahari before Gondwana

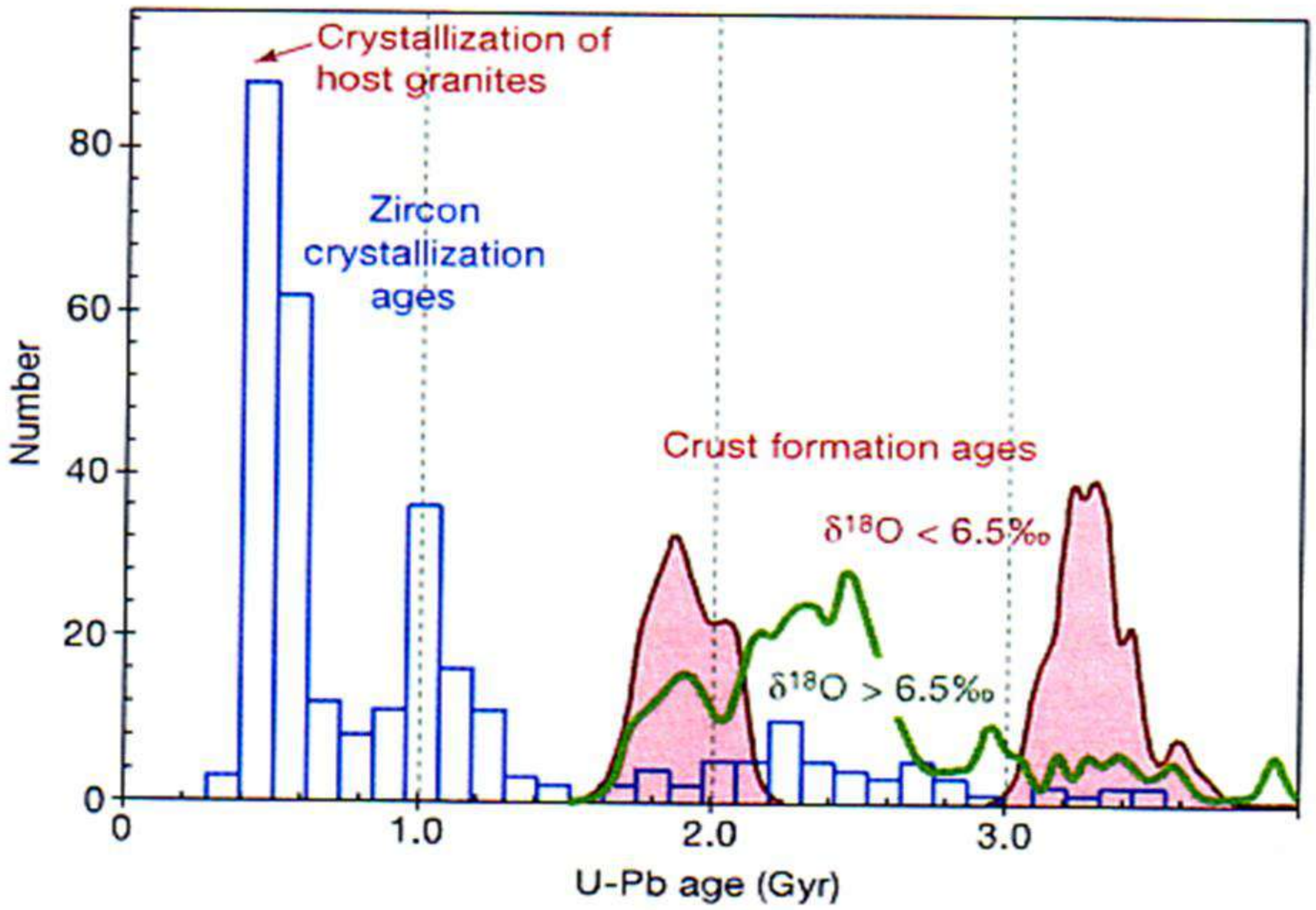
David A. Foster [a,*], Ben D. Goscombe [b], Brittany Newstead [a], Ben Mapani [c], Paul A. Mueller [a], Laura C. Gregory [a,d], Ewereth Muvangua [c,e]

[a] Department of Geological Sciences, 241 Williamson Hall, University of Florida, Gainesville, Florida 32611, United States
[b] Integrated Terrane Analysis Research, 18 Cambridge Road, Aldgate, South Australia 5154, Australia
[c] Department of Geology, University of Namibia, Windhoek, Namibia
[d] School of Earth and Environment, University of Leeds, Leeds LS2 9JT, United Kingdom
[e] Regional Geosciences, Geological Survey of Namibia, Windhoek, Namibia

Gondwana at 530 Ma and distribution of Sediment Hosted type deposits



Formation of continental crust and its evolution over the geologic history (after Hawkesworth, 1987) has followed 250 Ma cycles



Example 1-Damara belt-identification of fertile crust

Gondwana Research 28 (2015) 179–190

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Damara belt units with different types of zircons or no zircon!

Gondwana at 750 Ma and its dispersal and assembly of Pangea

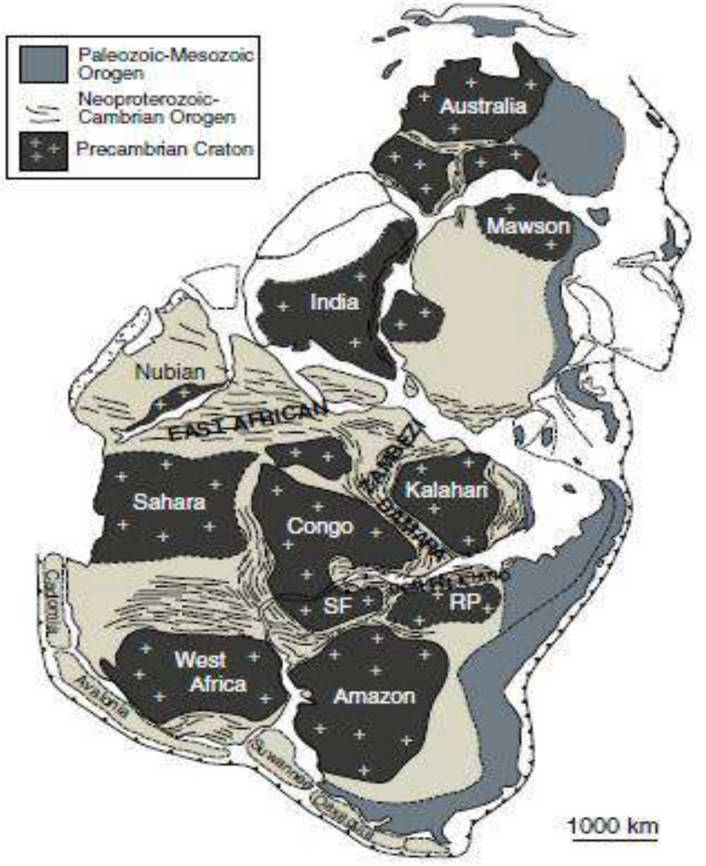


Fig. 1. Map of Gondwana (after Gray et al., 2006) showing the locations of Pan-African orogenic belts in southern Africa. RP, Rio de la Plata craton; SF Sao Franscisco craton.

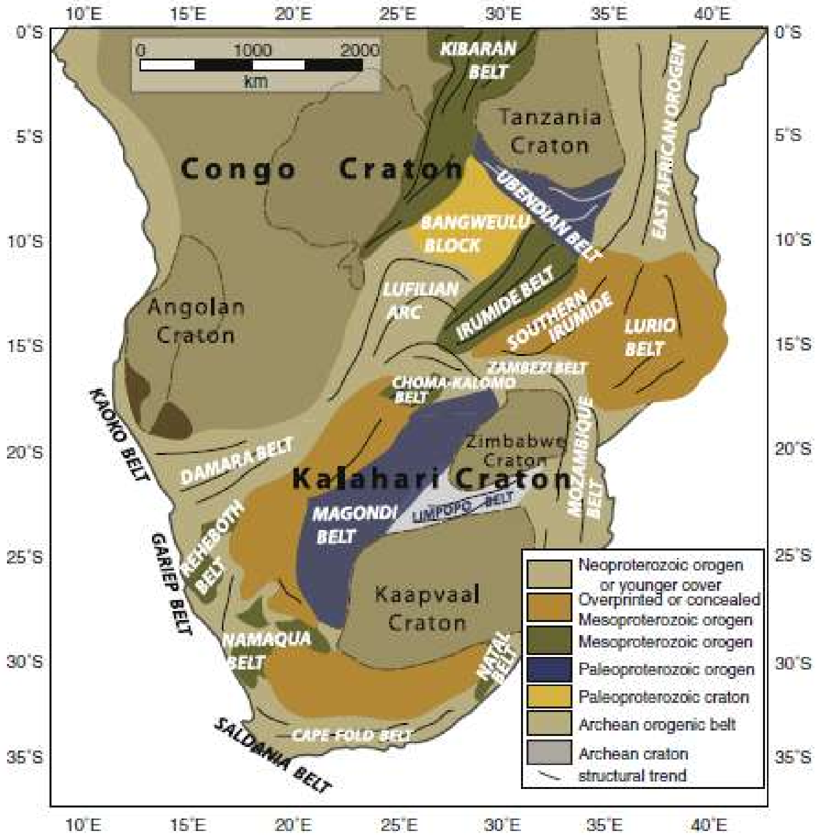


Fig. 2. Map of major geologic provinces and Precambrian orogenic belts in southern Africa. Compiled after Goscombe et al. (2000) and Hanson (2003).

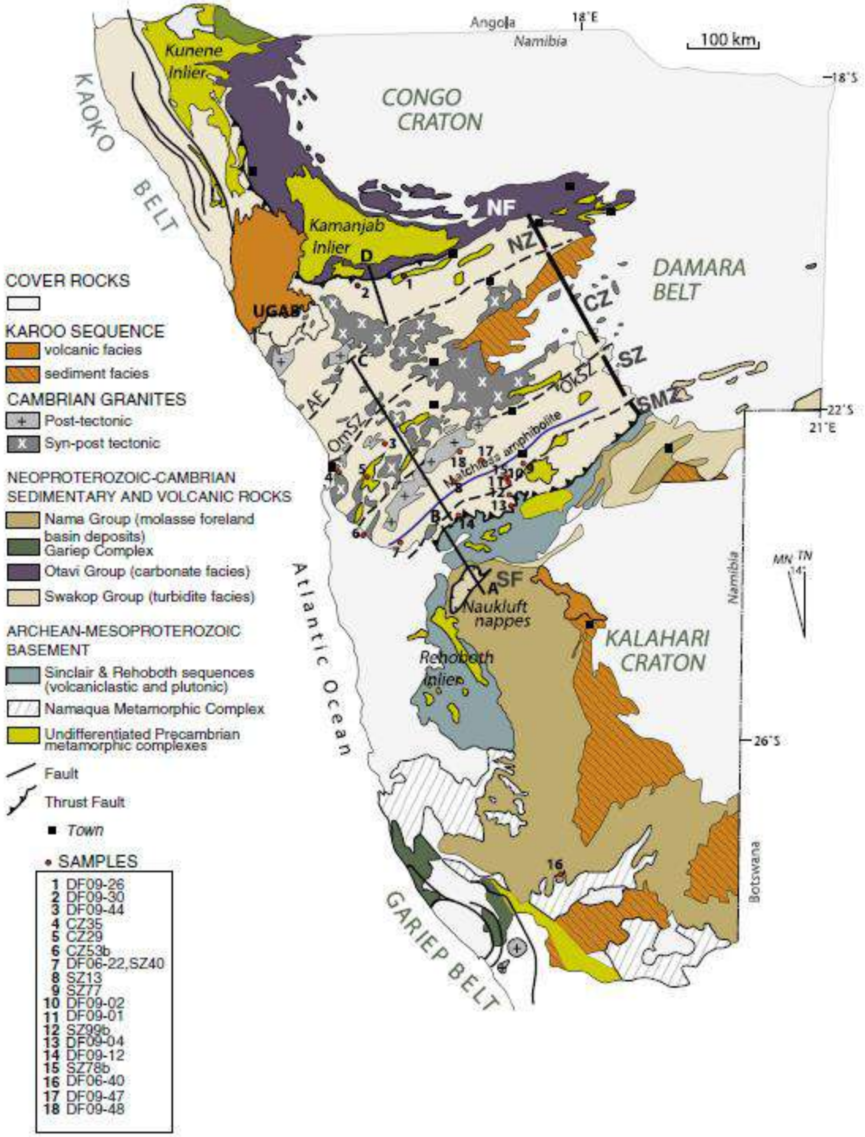
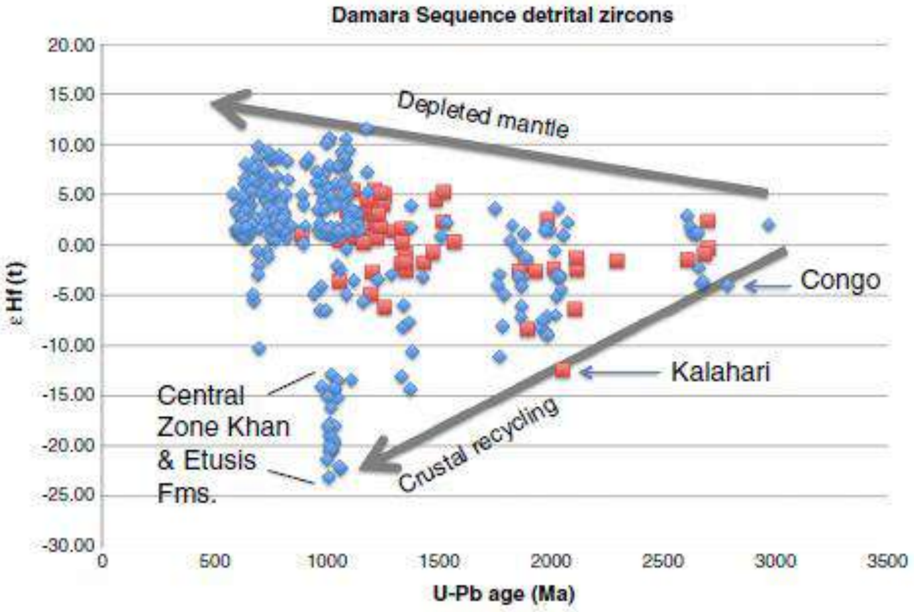


Fig. 3. Simplified geologic map of Namibia and the Damara Orogen (after Gray et al., 2006). Sample locations are indicated by the dots and numbers refer to the sample name. Abbreviations: SF, Southern Foreland; SMZ, Southern Margin Zone; SZ, Southern Zone; CZ, Central Zone; NZ, Northern Zone; NF, Northern Foreland; OkSZ, Okahandja shear zone; OmSZ, Omaruru shear zone; AF, Autseib fault. A–B–C–D denote the endpoints of segments of the cross section in Fig. 5.

SUMMARY FOR CONGO AND KALAHARI CRATONS



- A nearly 1050-1000 Ma detrital zircon population in the Congo strata is absent in the Kalahari craton together with a 900-600 Ma detrital zircon population

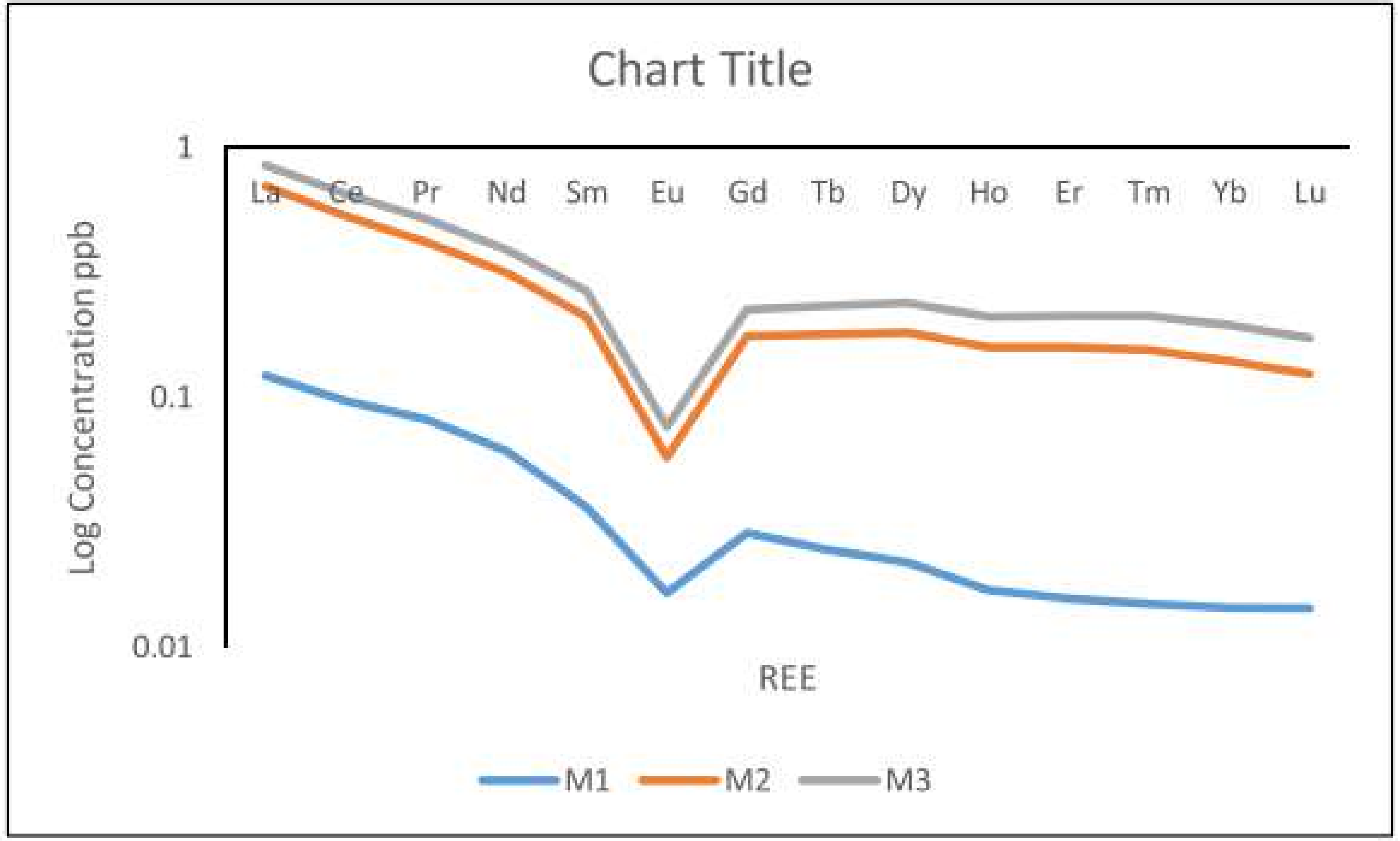
- Most abundant zircon grains from Neoproterozoic strata on the Congo margin give ages of 1150-1000 and 800-600 Ma
- The most abundant grains on the Kalahari craton margins range from 1350-1100 Ma.
- A 1350-1200 detrital zircon population is absent in the Congo strata
- This means that in Rodinia, Congo and Kalahari were not proximal and only came together during the collision that assembled Gondwana

Other Applications of Zircon geochronology, scientific contribution to society

1. Crime control in the trafficking of uranium materials for enrichment (IAEA, Vienna in conjunction with cooperating countries)
2. Identifying sources of uranium in groundwater with a view to remediate and protect communities (e.g., Hamutoko, Mapani and Ellmies, 2010) (Khan and Swakop Rivers, Namibia)
3. You can take stable isotope ratios of zircons- they give you fluid evolution
4. Used in thermometry on the estimation the fertility of continents (First used by Foster, Goscombe, Newstead, Mapani, Weber, Mueller and Muvangua, 2012)- Damara Belt vs Congo and Kalahari Cratons collision

(beneficiaries- discovery of Osino Gold, discovery of Gergarub Deposit, Rosh Pinah)

The power of zircon in forensic science- fingerprinting sources of uranium and lead sources- Namibian uranium mines examples (Madzunya *et al.*, 2021)



Conclusions:
Zircons: the lessons we learn from them

- Collectively in Namibia, the Northern Foreland provenance contrasts with that of correlative units in the Central Zone of the Damara Orogen, where only two detrital zircon age peaks (1030 Ma and 2040 Ma) have been identified (Foster et al., 2015).
- Zircon chemistry also shows that the Congo grains have favourable O18/O16 ratios pointing to fluid activity- therefore fertility for metal deposits is high.
- Field evidence shows that where conditions were moist, deposits emerged, e.g., Rossing, Husab, Langer Heinrich, Navachab, Ondundu, B2Gold (Otjikoto), Tsumeb, Berg Aukas, Kombat, Kuiseb Springs- all on the Congo platform.
- The edge of the Congo has Cu ores such as Omitiomire, Onganga and Mn at Otjosondu.
- The Kalahari Craton only has sedimentary type mineral deposits such as Klein Aub Cu, Dordabis Cu and Ghanzi Cu in Botswana.

Kaoko belt a haven for field geology
Thank you