



***Arabian Shield Geology  
course (GEO 386)***

***Supercontinents Evolution & Arabian-  
Nubian Shield (ANS) Evolution  
North East African Orogen(EAO))  
Divergent/Convergent and Deformation Via***

***Course Director***

***Dr. Bassam A. A. Abuamarah Al Mohannah***

# Objectives of this Lecture

We will present and discuss of major the Arabian-Nubian Shield development and Evolution, via establishing:

1. To show some essential Terms utilized in all Lectures,
2. To show Precambrian Geologic Time Record,
3. The breakup and overhaul of supercontinents;
4. The development of Neoproterozoic supra-subduction, juvenile volcanic-arcs, and plutonic environments;
5. The convergence and amalgamation of Neoproterozoic magmatic arcs ;
6. The initiation of younger Neoproterozoic volcanic and sedimentary basins.

## Cont'd: Objectives

5. Aiming on Arabian-Nubian Shield's Plate Tectonic activities, structure, glancing on its numerous Precambrian evolution and their rocks distribution, that are formed and exposed in the Arabian-Nubian Shield
6. To put emphasis on its geologic features and worldwide geological setting of Neoproterozoic shield.

# Key Words

- *Shield:*
  - ✓ is generally a large area of exposed in a Precambrian crystalline igneous, and a high-grade metamorphic rocks that form tectonically in a stable areas, age of these rocks is greater than 570 million years and sometimes dates back 2 to 3.5 billion years.
- *Orogen:*
  - ✓ is an event leads to both structural deformation and compositional differentiation of the Earth's lithosphere (crust + uppermost mantle) at convergent plate margins.

# Key Words

- Orogenic Belt :
  - ✓ It is belt of rocks and mountain Ranges formed and accomplished by tectonic processes , when a continental plate crumples and pushed upwards above the descending oceanic plate involves a series of geological processes collectively.
    - Orogenies processes can take tens of millions of years to build mountains ranges from plains or from the seabed.
- Craton:
  - ✓ Is a stable part of the earth's crust that has been little deformed for a great period of time. it includes shield areas and adjacent basement beneath young rocks.

# Key Words

- *Neoproterozoic:*

*The period of geologic time between 1000 and 542 million years ago; a time span that encompasses most of the history of the Arabian Shield.*

- *East African Orogen (EAO):*

*a belt of rocks assembled and deformed during the Neoproterozoic, extending from the Arabian-Nubian Shield and Madagascar.*

- *Gondwana Land:*

*is a supercontinent that aged by 530 Ma was assembled out of the rifted Fragments of Rodinia and other continental blocks* and incorporated the Arabian-Nubian Shield.

## Key Words

- *Plate tectonics:*

*The movements of plates on The Earth's surface and the geologic effects of such movement.*

*Plates are large, rigid slabs of rocks into which the Earth's surface is divided.*

*Tectonics comes from the Greek word “to build.”*

- *Juvenile:*

*volcanic and plutonic rocks that were erupted or intruded soon after the separation of their source materials from the mantle.*

- *Supercontinent:*

*It is an unusually an assemblage of pre-existing continental block or cratons formed by the convergence of plate tectonic activities to form a single large landmass.*



# Key Words

- *Rodinia*

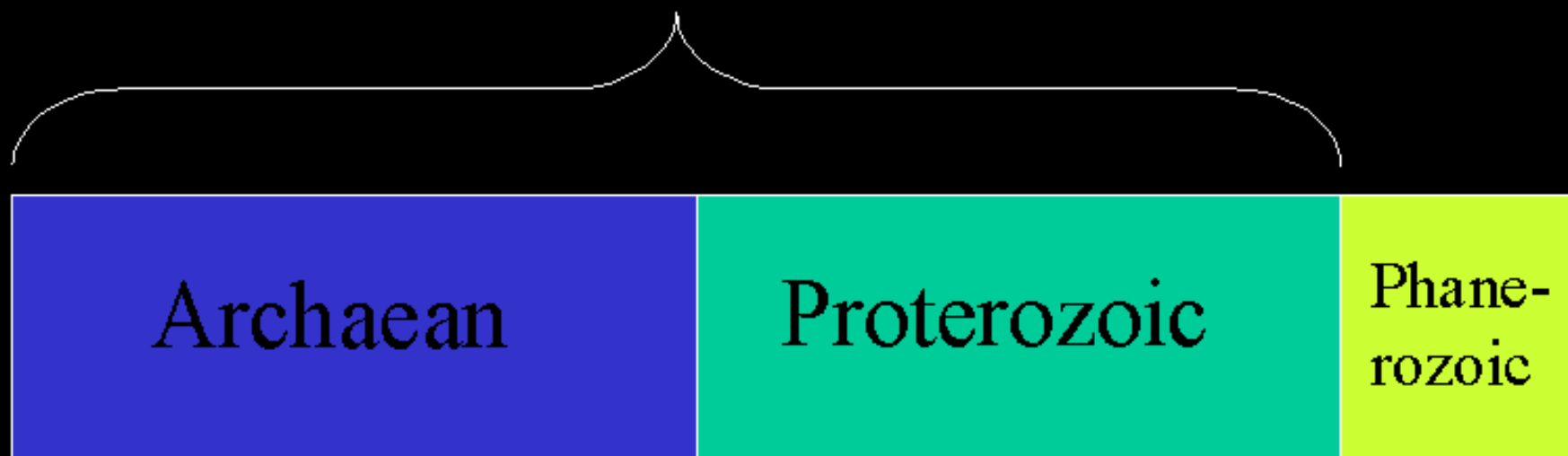
it is a Neoproterozoic Supercontinent that was assembled 1.3–0.9 billion years ago and broke up 750–633 million years ago.

- *Pangaea*

A “supercontinent” on the Earth. It is detached in the past as a large landmass, included all the present continents, which broke up and drifted apart.

# THE EONS

Precambrian



4.6 Billion

2.5 Billion

543 Million

0

Years Ago

# ANS Geologic Time: Proterozoic Eon:

- The Proterozoic is the younger divisions of Precambrian Eon than Archaean Eon.
- The Proterozoic Eon extended from 2.5 billion to 541 million years ago.
- Proterozoic rocks have been identified on all the continents,
- They often constitute important sources of metallic ores, notably of iron, gold, copper, uranium, and nickel.
- During the Proterozoic, the atmosphere and oceans changed significantly

Proterozoic Eon

	Eonothem/ Eon	Erathem/ Era	System/ Period	millions of years ago
Precambrian ↓	Proterozoic	Neoproterozoic	Ediacaran	~541
			Cryogenian	~635
			Tonian	850
		Mesoproterozoic	Stenian	1,000
			Ectasian	1,200
			Calymmian	1,400
		Paleoproterozoic		1,600
			Statherian	1,800
			Orosirian	2,050
			Rhyacian	2,300
			Siderian	2,500

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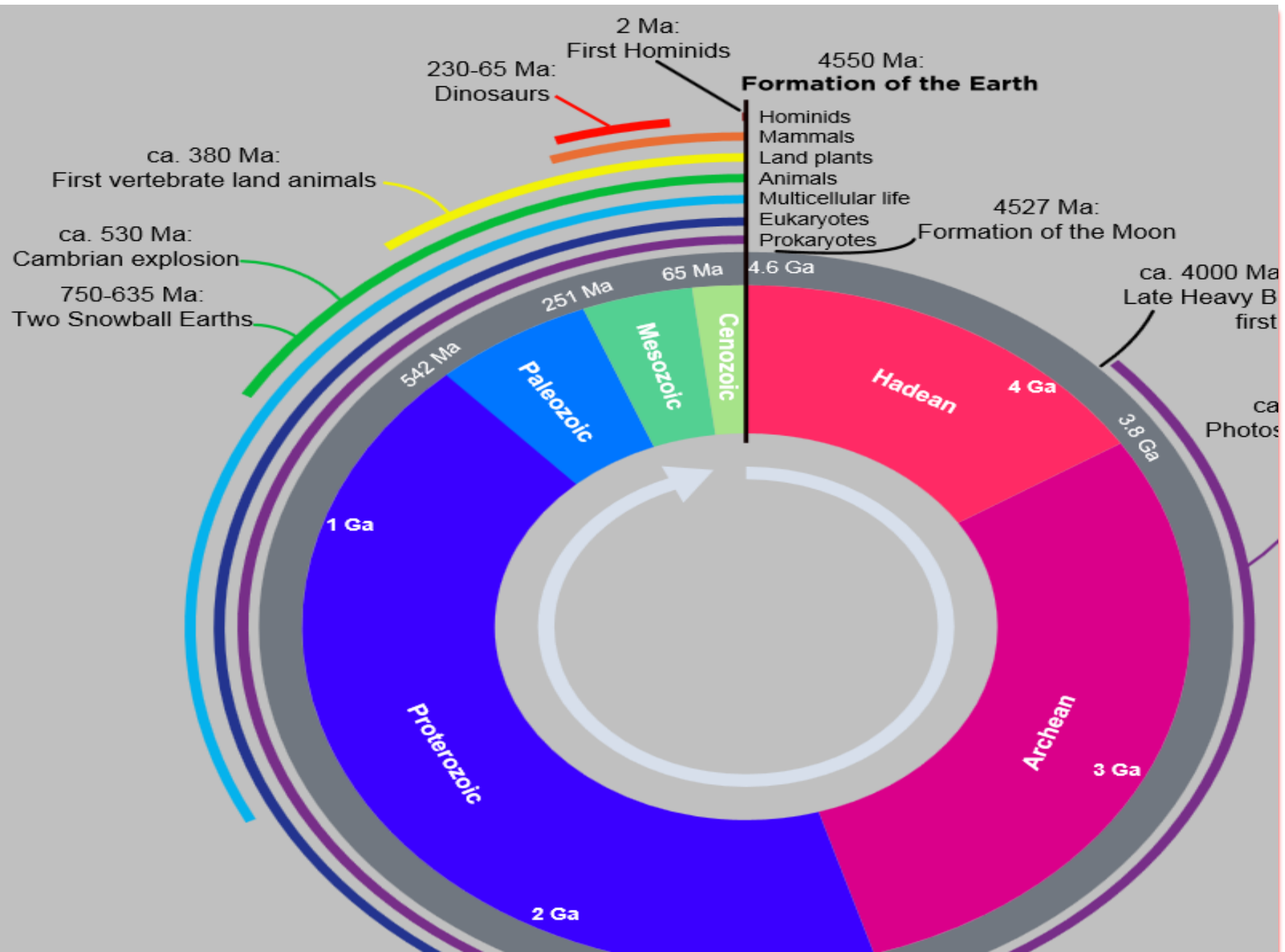
Source: 2012 International Stratigraphic Chart produced by the ICS.

# PROTEROZOIC

Neoproterozoic

Mesoproterozoic

Paleoproterozoic



# Cont'd: ANS Geologic Time: Proterozoic Eon:

Proterozoic is often divided into:

1. **Paleoproterozoic Era** aged from 2.5 billion to 1.6 billion years ago.
2. **Mesoproterozoic Era** aged from 1.6 billion to 1 billion years ago, and,
3. **Neoproterozoic Era** aged from 1 billion to 541 million years .

Proterozoic Eon

	Eonothem/ Eon	Erathem/ Era عصر	System/ Period فترة	millions of years ago
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Source: 2012 International Stratigraphic Chart produced by the ICS.

# Development of Supercontinent

- They predicted, five Supercontinents that are nowly recognized as corresponding to the *amalgamation* of Pannotia , Gondwana, Rodinia, Columbia (or Nuna)m and Kenorland
- *Explained, evidents and cleared up by the studies of:*
  - ✓ Paleo-magnetic, isotopic data, and geologic data are only definite enough to establish their reconstructions and the breakup.

They are

Firstly done by [Worsley et al. \(1985\)](#); [Nance et al., \(1986\)](#) whom they Proposed :

1. Supercontinents Assembly and break up , and
  2. Their occurring mode episodically throughout geologic time , with consequences to the Earth history ,
- These five supercontinents (Kenorland, Columbia, Rodinia, Pannotia, and Pangea) formed before pre-Pangea Supercontinents at about 2,6, 1.6 . 1.1Ga, 0.6, 5.5 Ma years.

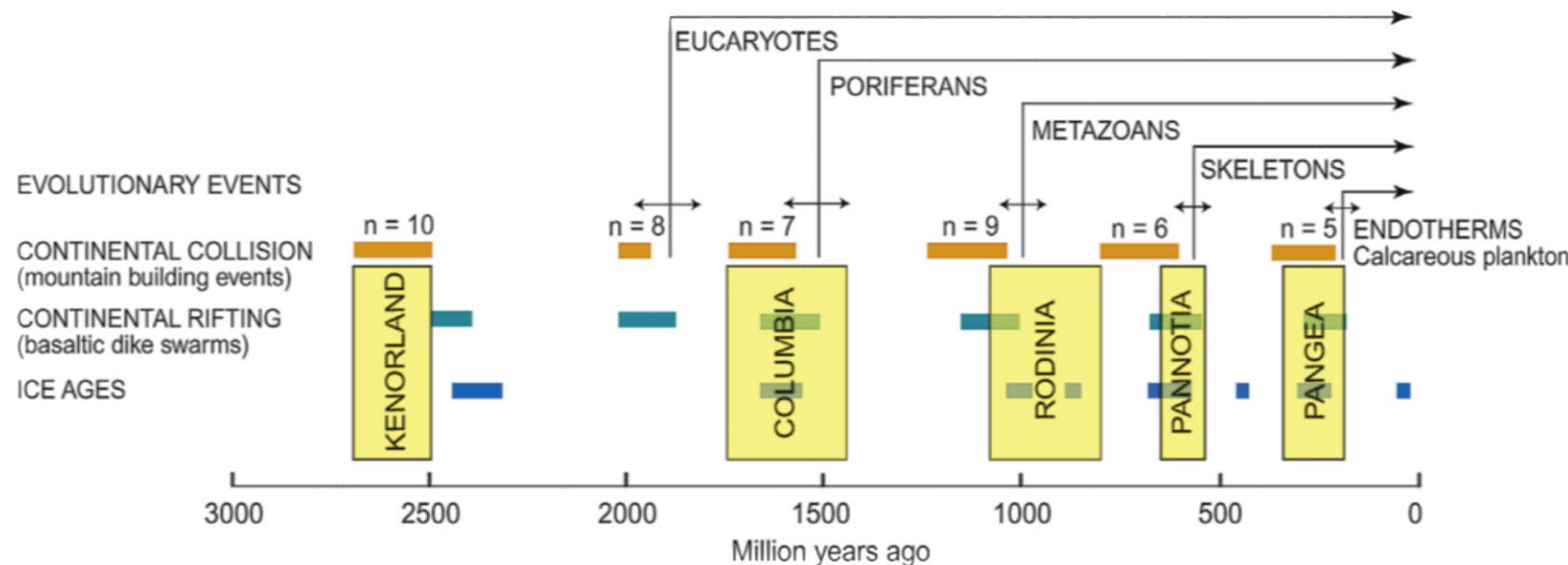
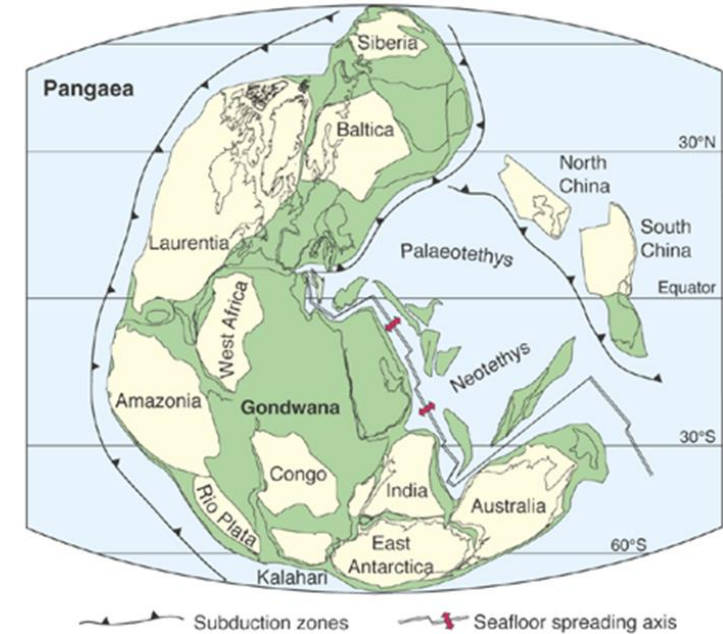
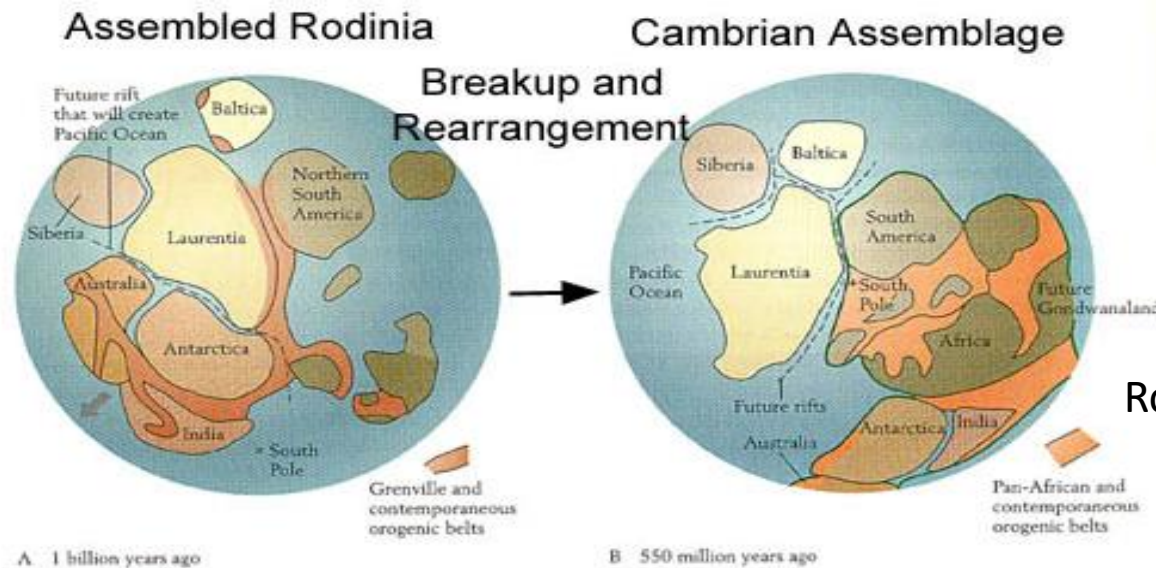
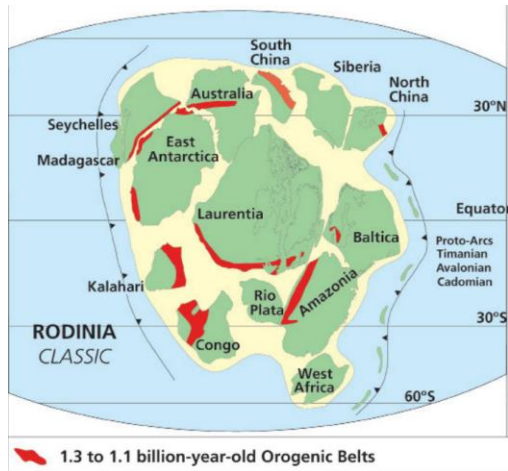


Fig.: shows a Comparison of episodic events in Earth history linked to the supercontinent cycle with the duration of supercontinents as they are presently known by [Worsley et al. \(1984, 1985\)](#)



# I . Rodinia Supercontinent Evolution

- *It is a Neoproterozoic Supercontinent,*
- *Assembled between 1.3 to 0.9 billion years ago ,and broke up at about 750–633 million years ago.*

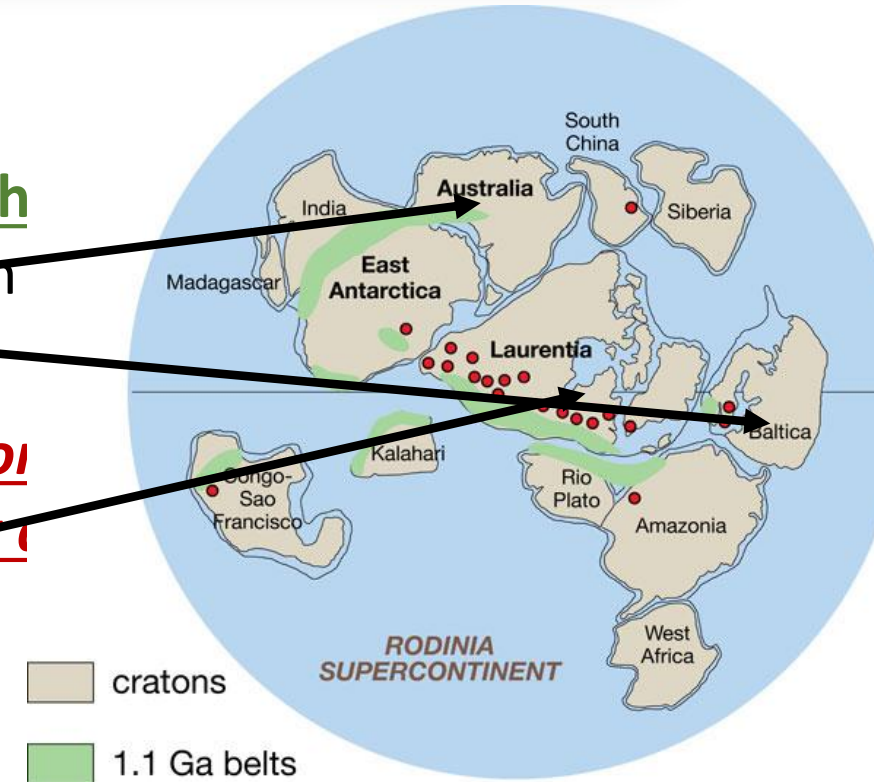


Rodinia Jigsaw shape

Rodinia Jigsaw Puzzle

## Rodinia Reform (include five ))

- *Its amalgamation began just after 1100 Ma, with:*
- Collision of Baltica (north-east Europe) and Amazonia (north east South America) along the east coast of Laurentia (North America),
- Australia-Antarctica, the Kalahari (South Africa), and the Congo (Central Africa) cratons colliding along the west, south-west and south margins respectively,
- and Siberia colliding with the northern margin.
- The Laurentia is considered the heart of Rodinia (Supercontinents) central position, and its breakup i.e. rifting off to continents, occurring around 750 Ma, resulted all reforming cratons into Gondwana (from 650-520 Ma),



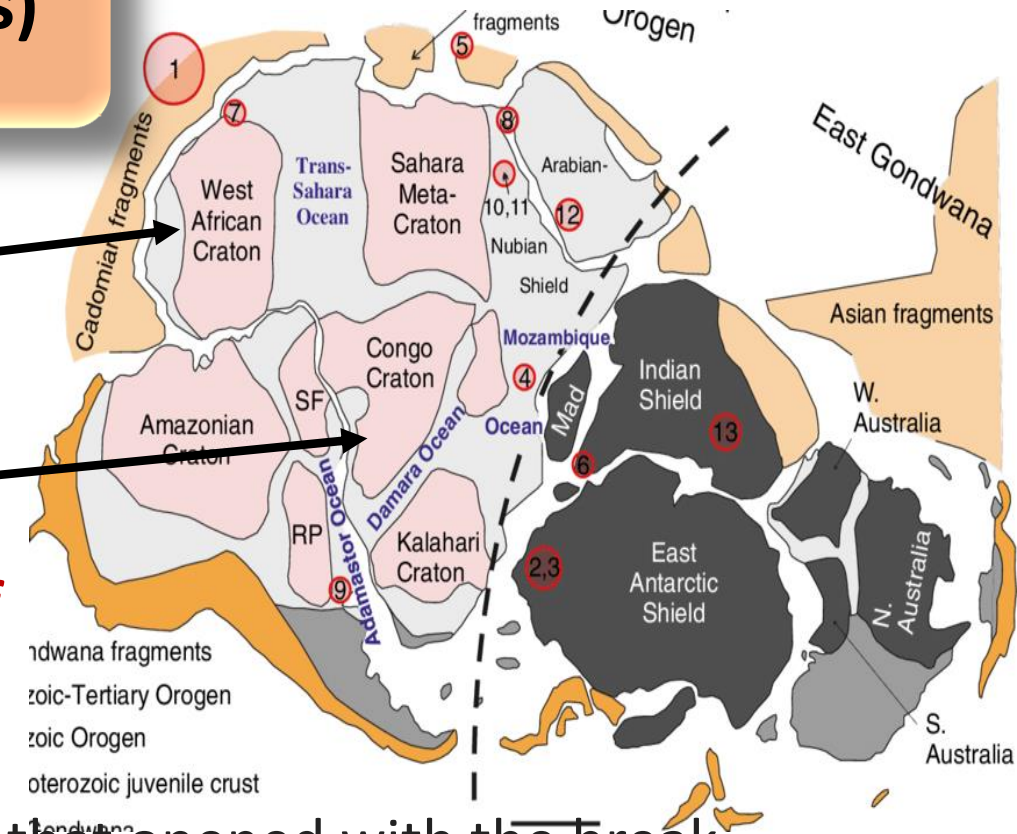
# Rodinia Reconstructions (include five elements)

- Less certain position of continental blocks includes:

✓ the West African Craton was simply appears as an extension of the Amazonian Craton;

✓ The Congo Craton was located on the south coast of Laurentia (Amazon Craton), probably separated from Rodinia by the Mozambique and Adamastor oceans.

- ❖ The **Adamastor Ocean** was a "proto-Atlantic" ocean that opened with the break-up of the Rodinia supercontinent 780-750 Ma.
- ❖ It separated the Rio Plate Craton from the Congo Craton.
- ❖ The reversal of the Adamastor Ocean began 640 Ma with the development of a large back-arc along the western margin of the Kalahari Craton, and the ocean closed when Río Plata collided with Kalahari at about 545 Ma.
- ❖ The Congo-São Francisco plate and the Río Plata plate amalgamated 630–620 Ma, closing the Adamastor Ocean on the South American side and forming around 600 Ma



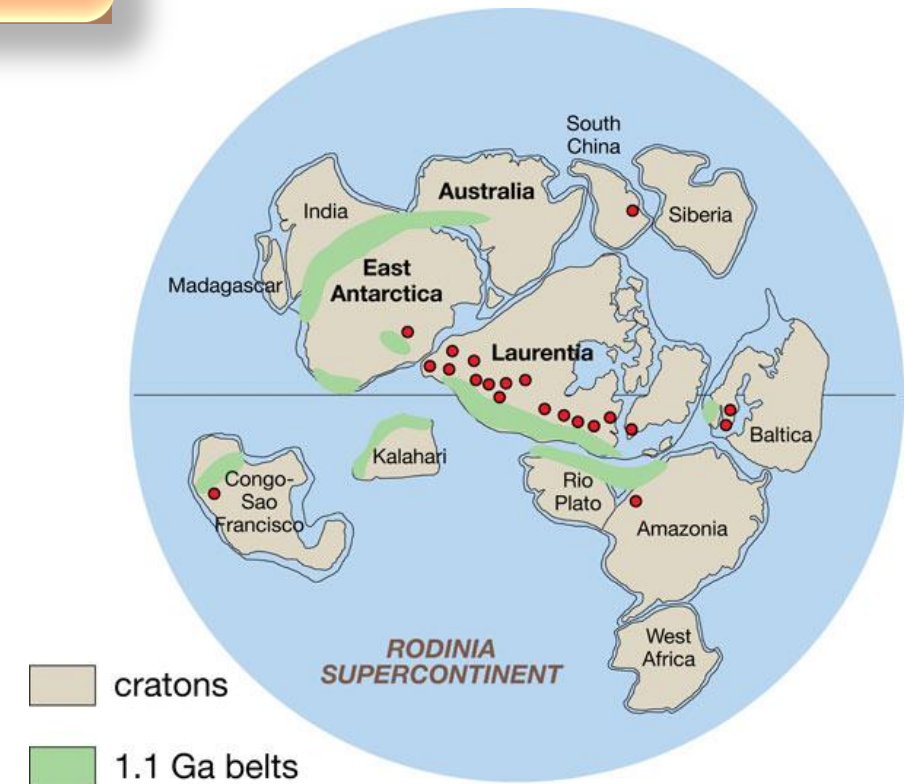


# I-I Rodinia Break Up

- UNESCO's IGCP project 440 (In 2009 ) concluded that:
  - ✓ Rodinia Supercontinent Assembly formed during the Precambrian time in/at about one billion years and

Then

It broke into five stages between 825–550 Ma.



## Stage I:

The break up was initiated by a Super Plumes at about 825–800 Ma whose influence by crustal arching, penetrating bimodal magmatism, and

# Rodinia Break Up

## Stage 2 :

Accumulated in a thick rift-type sedimentary successions recorded in South of Australia, South China, Tarim, Kalahari, India, and the Arabian-Nubian Craton.

## Stage 3 :

Rifting progressed in the same cratons 800–750 Ma and spread into Laurentia and perhaps Siberia.

✓ India (including Madagascar) and the Congo- São Francisco Craton were either :

- 1) Detached from Rodinia during this period, or
- 2) Simply, they never were part of the supercontinent

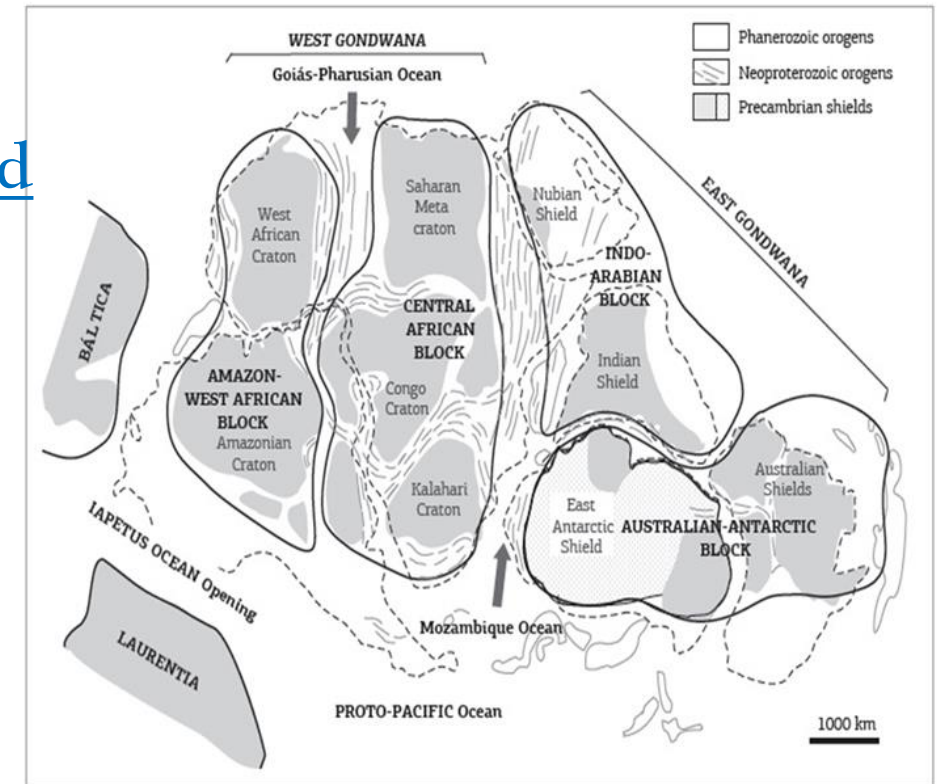
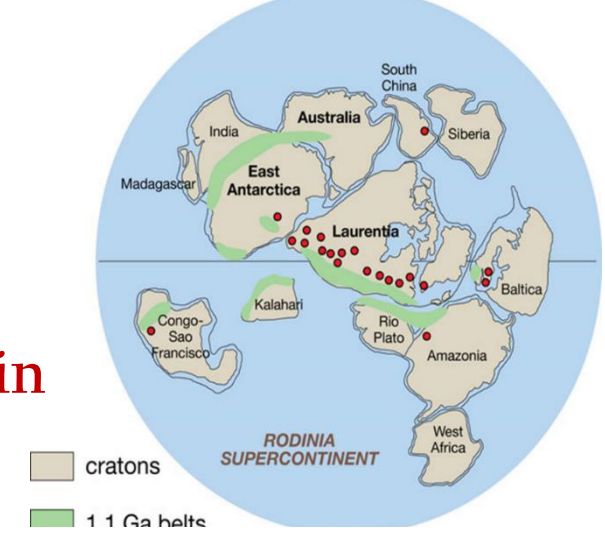


Figure 1. Crustal building blocks for the amalgamation of Gondwana, after the closing of the Goiás-Pharusian and Mozambique oceans. Location of the Iapetus Ocean between SW Gondwana, Laurentia and Baltica, and location of the Proto-Pacific Ocean before the onset of the subduction of the Pacific Plate.

# Rodinia Break Up

## Stage 4 :

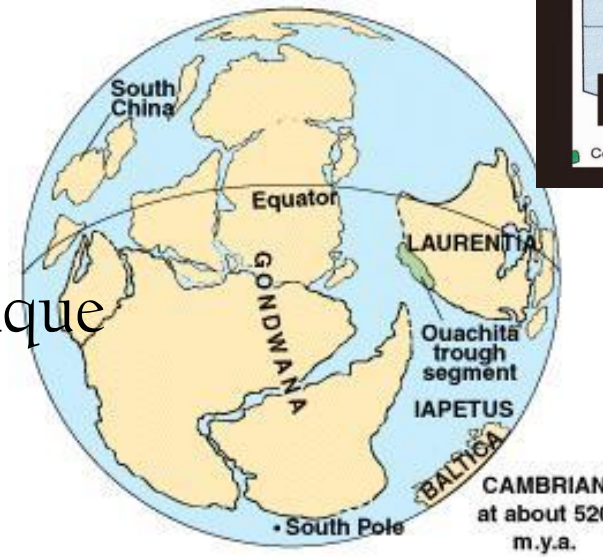
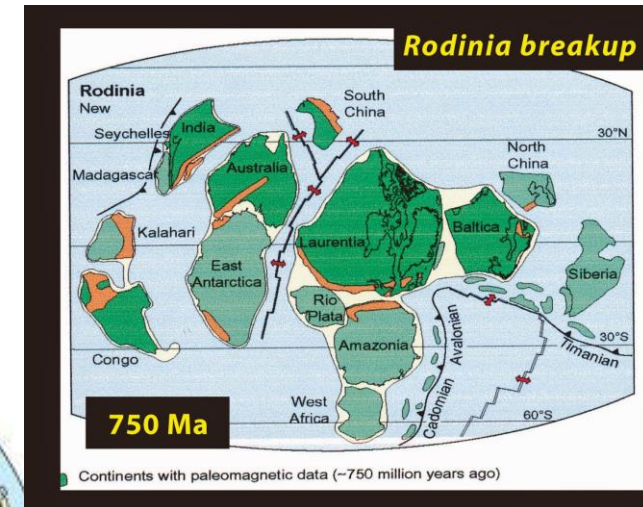
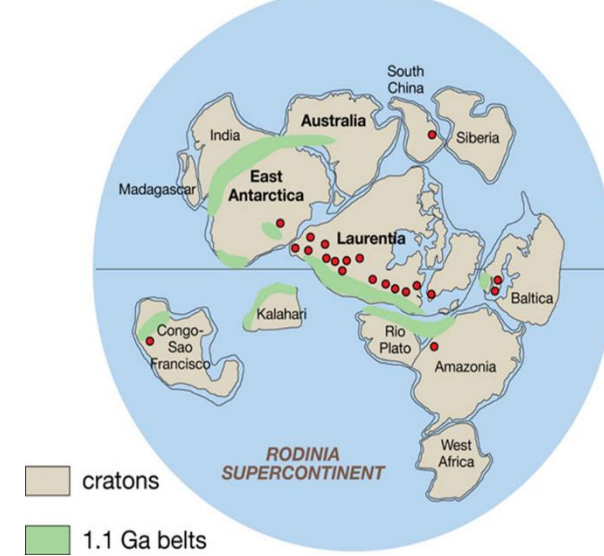
As the central part of Rodinia reached the Equator around 750–700 Ma,

- ✓ a *new generation of magmatism and rifting continued the disassembly in western Kalahari, West Australia, South China, Tarim palea (in Hadramouth)-continents and basin, and most margins of Laurentia.*

## *Stage 5:*

In time from 650 to 550 Ma. several events in::

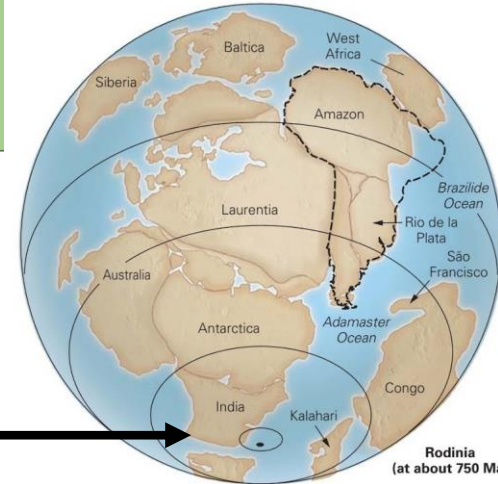
- ✓ The opening of the Iapetus Ocean;
- ✓ The closure of the Braziliano, and Mozambique oceans; and the Pan-African orogeny.





## II. Pannotia Supercontinent Evolution

1. Dalziel 1997, aged **Pannotia Supercontinent** at about 545 Ma, viewed at the centred of the South Pole; rotated 180° relative to the reconstruction of Rodinia.
2. The **Pannotia** commenced and originated during the Pan-African orogeny, when the Congo continent got trapped between the northern and southern halves of the previous Rodinia supercontinent at about 700 to 750 Ma.
3. The peak is characterized by the mountain building event that was around 640–610 Ma, but these continental collisions may have been continued into the Early Cambrian some 530 Ma. (See Fig. above)



(a) Rodinia formed around 1 Ga and lasted until about 700 Ma. North America and Greenland together comprise Laurentia.



(b) According to one model, by 570 Ma Rodinia had broken apart; continents that once lay to the west of Laurentia ended up to the east of Africa. The resulting supercontinent, Pannotia, broke up soon after it formed.



# ***Pannotia Supercontinent Evolution***

4. So, ***Pannotia*** initiation was due to the result of Rodinia turning itself inside out.
5. When ***Pannotia*** formed; Africa was located at its centre bounded by the rest of Gondwana: ***South America (Amazonian Craton), Arabia, Madagascar, India, Antarctica, and Australia.***
6. ***Laurentia, Baltica, and Siberia*** 'escaped' out of ***Rodinia***, kept their relative positions they had in Rodinia



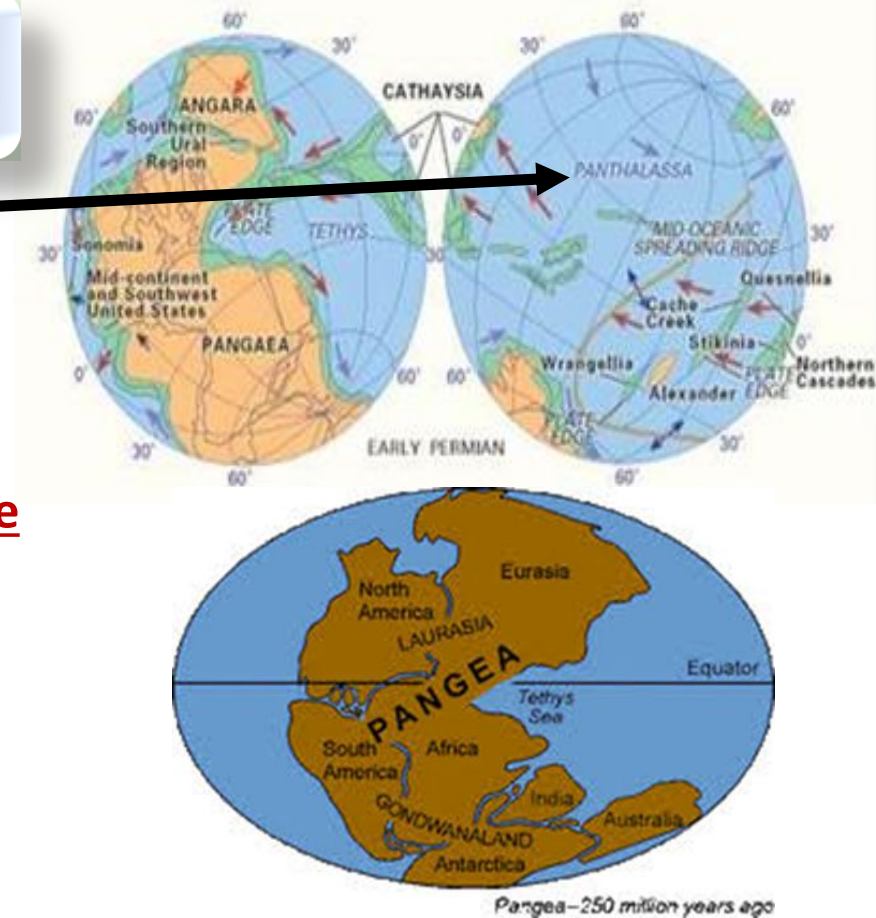


### III. Pangea Supercontinent Evolution

- Pangea globally surrounded by an ocean called Panthalassa,
- Fully assembled by the Early Permian Epoch (some 299 million to 273 million). Then,
- It stated simply that” the Earth’s continents joined together forming the Pangea supercontinent”. lasted for most of geologic time.

Finally,

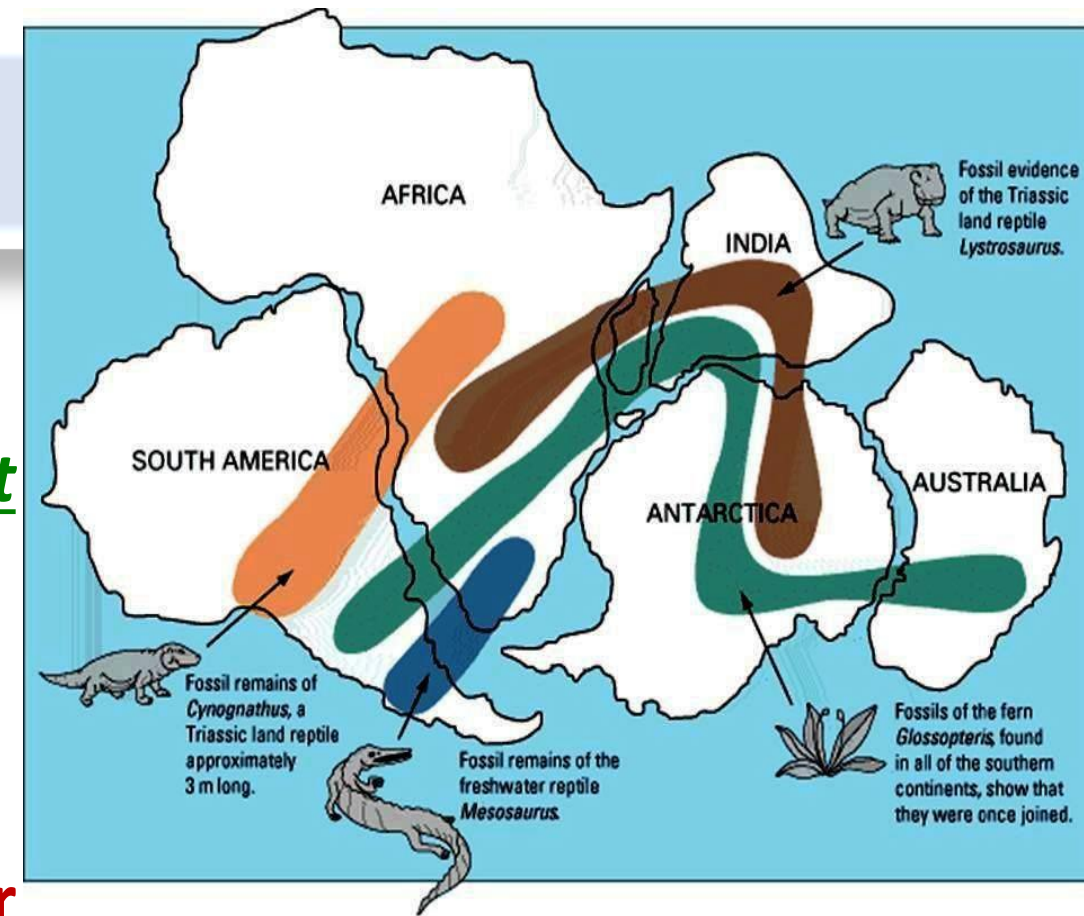
- Pangea started to break apart at about 200 million years, during the Early Jurassic Epoch (201 million to 174 million),
- They were forming the recent continents, in addition the Atlantic and Indian Ocean.
- Pangea breaks up mechanism called PLATE TECTONICS (Wegener’s concept of continental drift),
- Plate tectonics theory states that Earth’s outer shell, or Crust+ Lithosphere, consists of large rigid plates that move apart at Oceanic Ridge, and together at Subduction Zones, or slip past one another along a Fault Lines.



# Pangea Supercontinent (Break Up)

- The pattern shows Seafloor Spreading indicate that Pangea Supercontinent did not break apart all at once, but fragmented in distinct stages.
- Plate tectonics also postulates (assumes) that the continents joined with one another and broke apart several times in Earth's geologic history.

➤ Finally, The result was the formation of Gondwana by merging together.



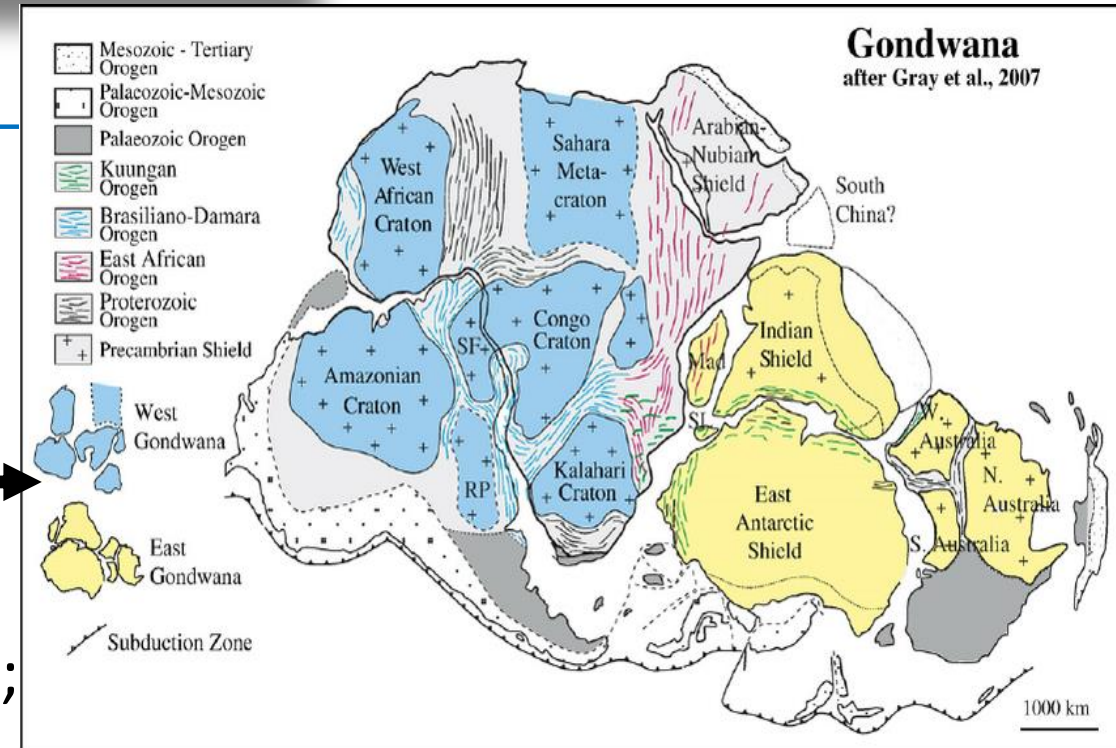
# IV - The Gondwana Supercontinent

➤ The Gondwanas Supercontinent involve of E & Gondwana via plate tectonic activities (divergent) within Mozambique Ocean and then:

- Started as a convergent boundary activities between E & W Gondwana, initiating the Arabian–Nubian Shield (ANS):

✓ In the north, its composed largely of juvenile Neoproterozoic crust (Stern, 1994; Johnson et al. 2011), and

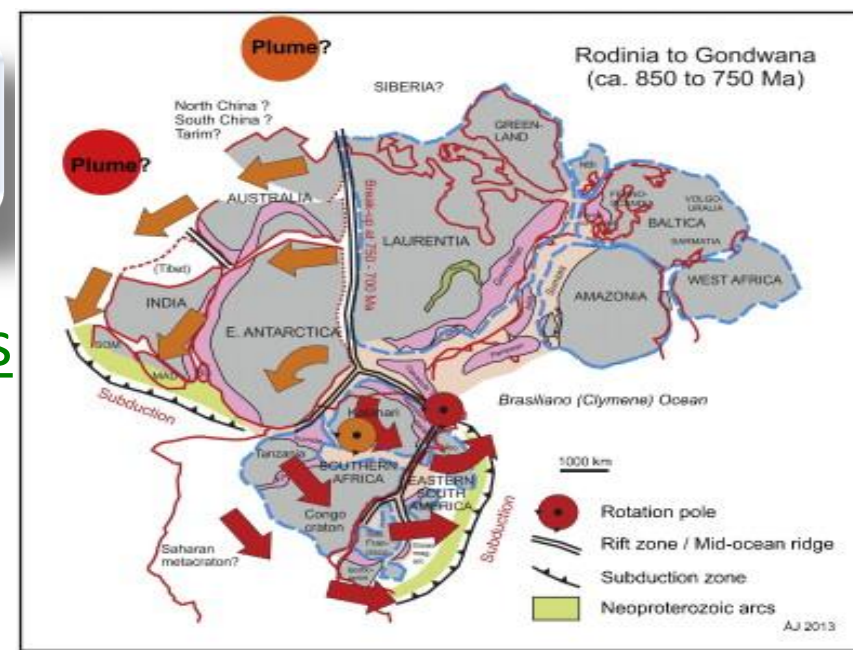
✓ In the south; the Mozambique Belt (MB) comprising mostly Pre-Neoproterozoic (Metamorphic rocks) crust with a Neoproterozoic – early Cambrian tectono-thermal overprint.





# IV. The Gondwana Supercontinent Evolution

- The Gondwana was assembled by continental collisions in the Late Precambrian ,by plate tectonic evidence (about 1 billion or 950 Ma +/- 50 Ma. to 542 million years ago).
- Gondwana then collided with North America, Europe, and Siberia to form the supercontinent of Pangea.
- The breakup of Gondwana occurred some about 180 million years ago, in the Jurassic Period.



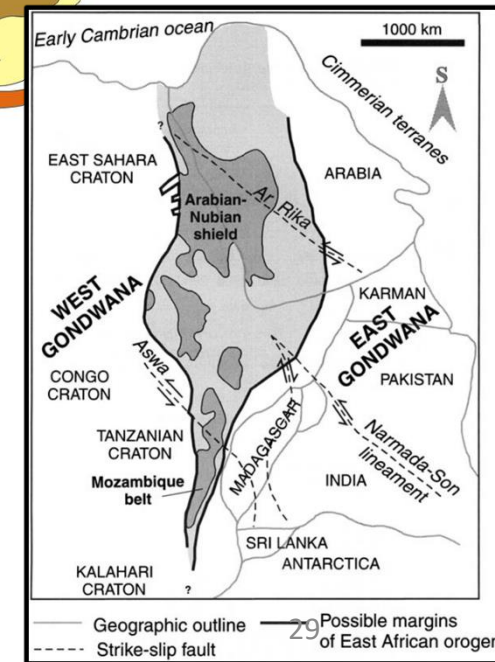
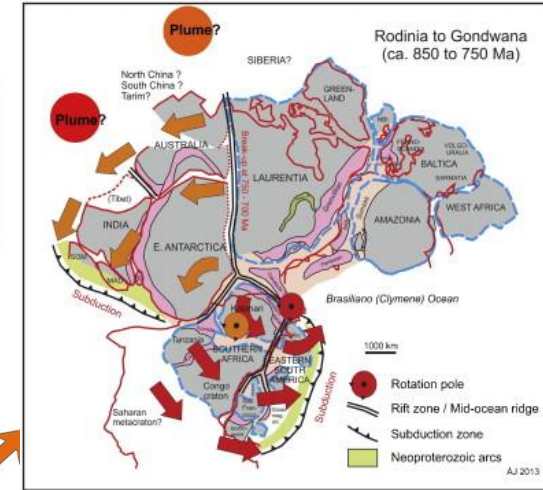
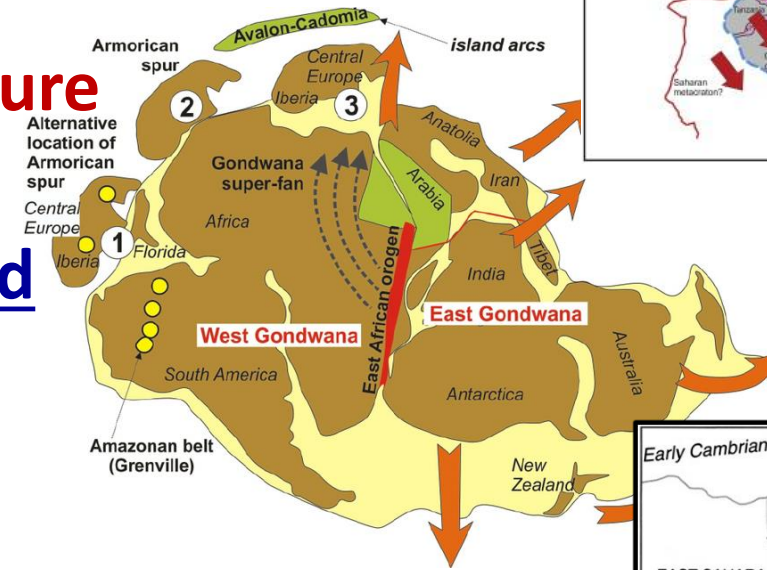
## Cont'd: The Gondwana Supercontinent evolution

- That's leading, The Gondwana supercontinent, to be formed by the closure of the Mozambique Ocean, and the
- Amalgamation (Accretion) of the East and West Gondwana around the end of Neoproterozoic time,

That

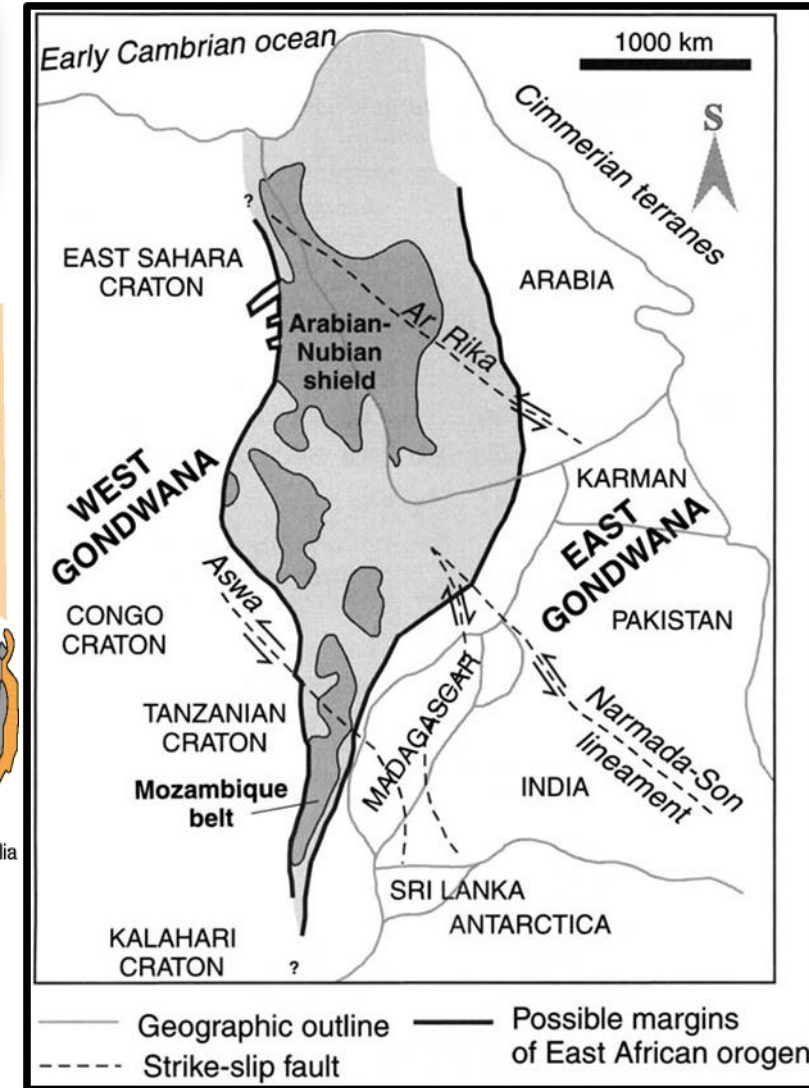
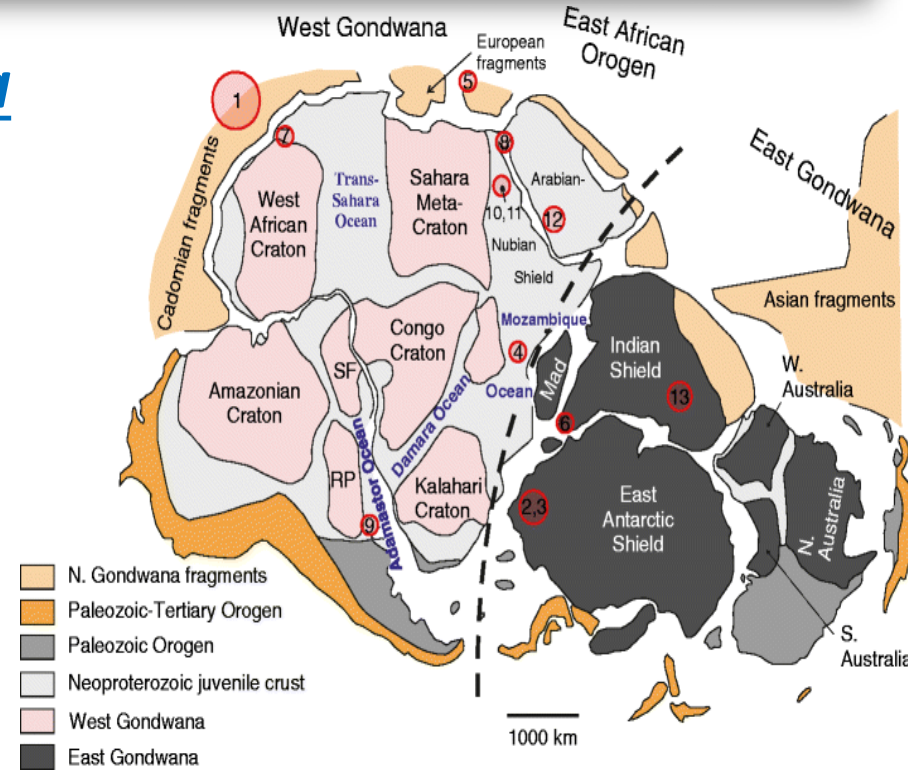
led to the formation of the East African Orogeny (EAO).

- i.e. the EAO extends from southern Israel, Sinai and Jordan in the north to Mozambique and Madagascar in the south.



# The Gondwana Supercontinent

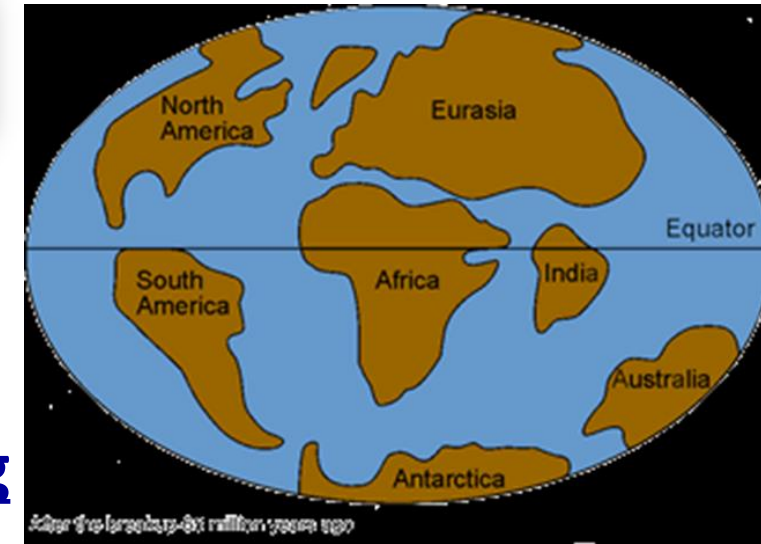
- The western Gondwana comprises Africa and South America,
- and the eastern half of Gondwana contains (Madagascar, India, Australia, and Antarctica).





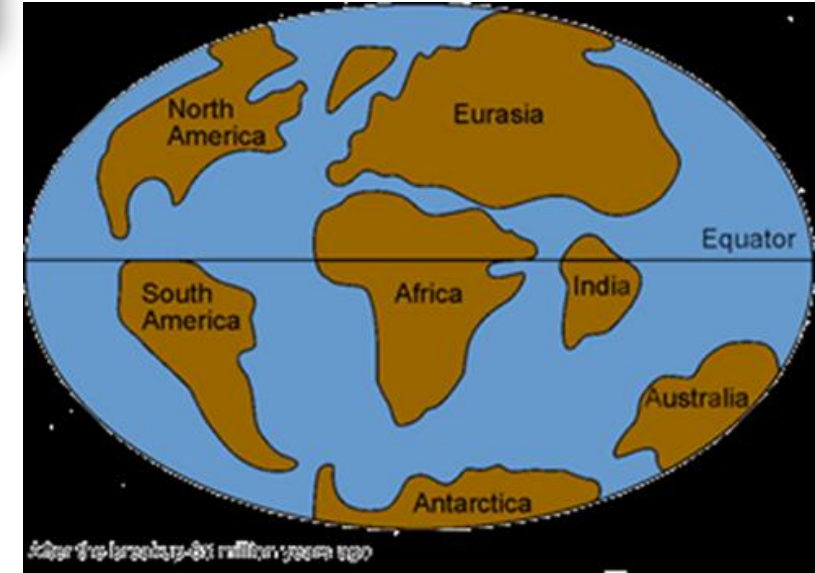
# The Gondwana Supercontinent

- The South Atlantic Ocean opened at about 140 million years, as Africa separated from South America.
- At about the same time, India, which was still attaching Madagascar, separated from Antarctica and Australia, causing opening the central Indian Ocean.
- During the *Late Cretaceous Period*, India broke away from Madagascar.
- Australia slowly rifted away from Antarctica.



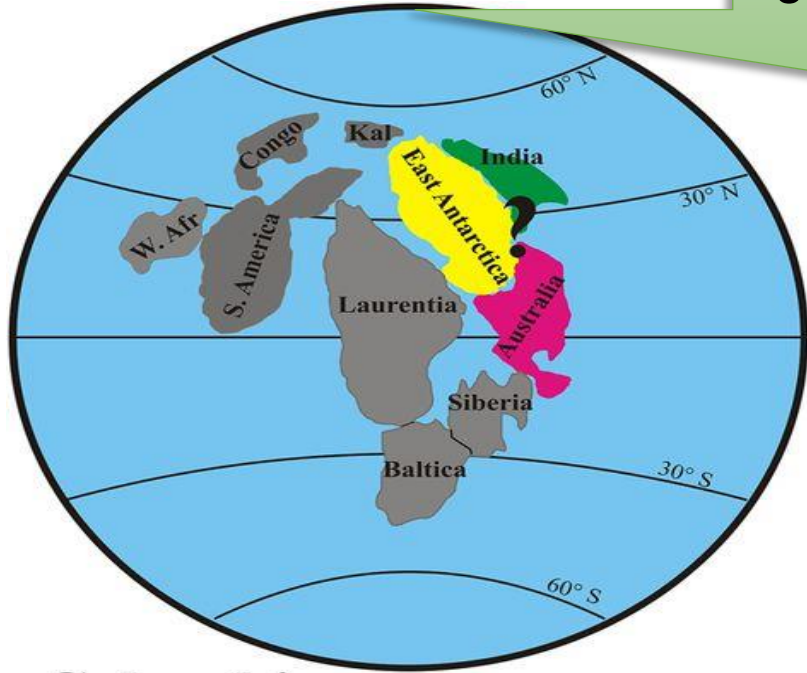
# The Gondwana Supercontinent

- India eventually moved and collided with Eurasia at some about 50 million years ago, forming the Himalayan mountains,
- At the same time the Australian Plate is moving-northward , and by just begun its collision along the southern margin of Southeast Asia. This collision is still under its way today

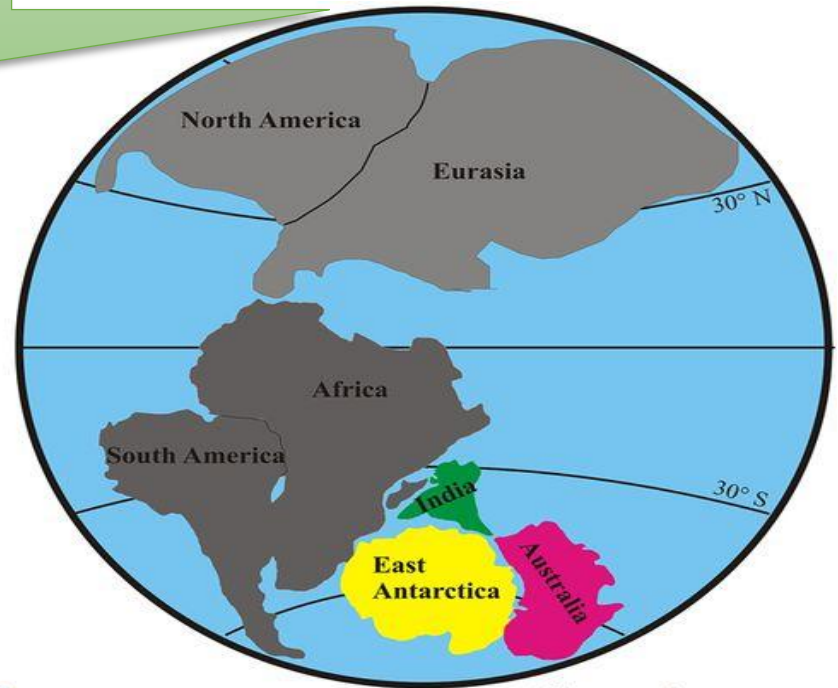
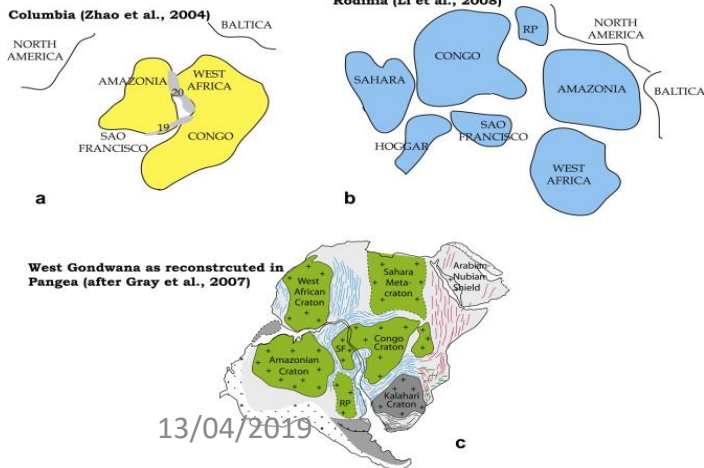




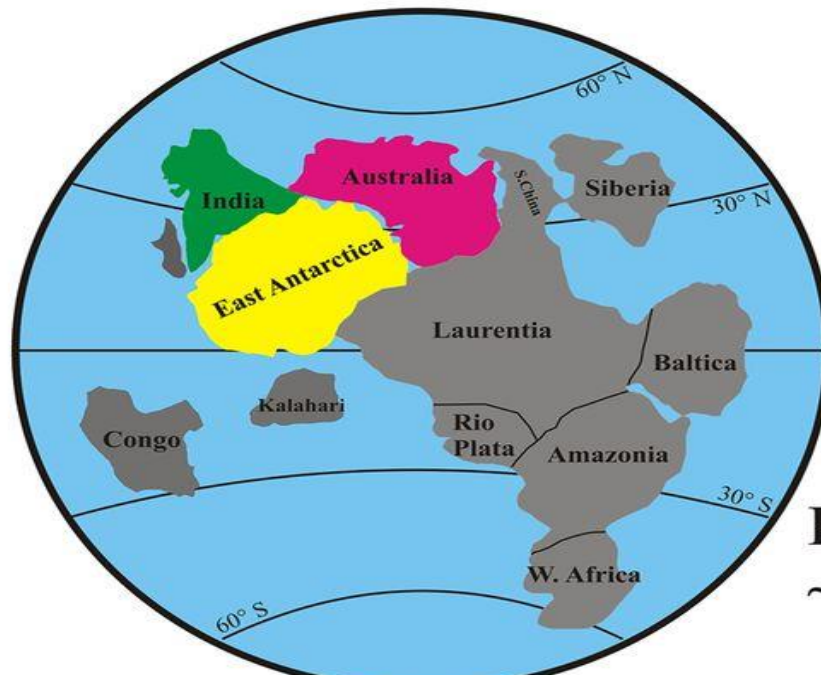
Thus, the crustal Evolution  
of the Supercontinents is  
viewed hereunder



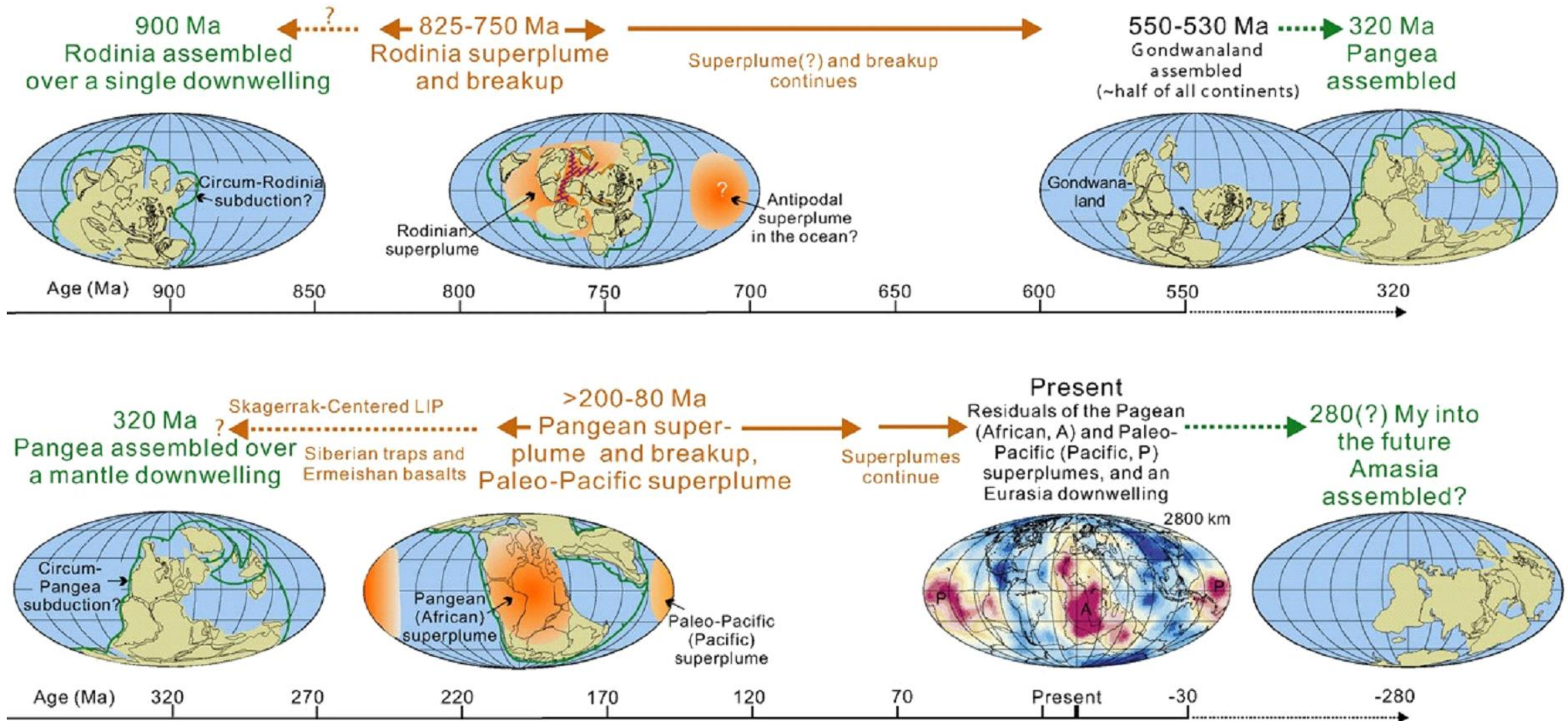
**Columbia**  
**~1.5 Ga**



**Gondwana**  
**~ 0.5 Ga**



**Rodinia**  
**~ 1.0 Ga**



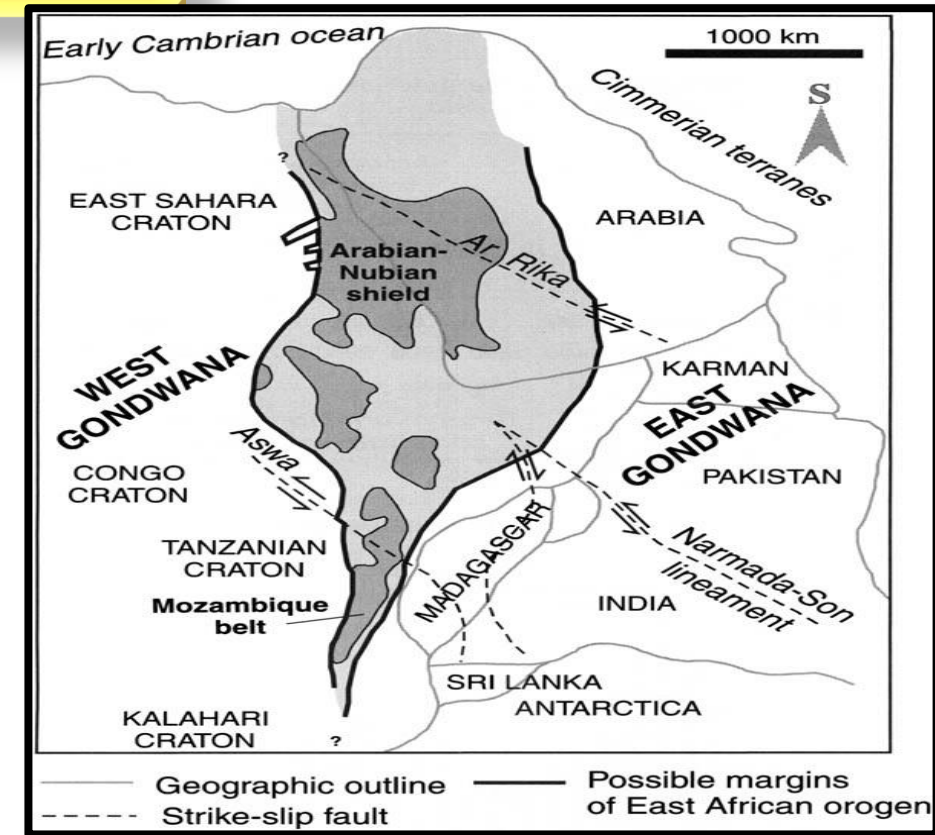
**Fig.** Illustration of supercontinent–superplume coupling in the past 1000 Ma, and the possible presence of a ~600 My supercontinent–superplume cycle. Sources for (paleo-) geographic maps: 900–320 Ma (Li et al., 1993, 2008), 200 Ma (Scotese, 2004), present with SMEAN shear wave velocity anomalies near the core–mantle boundary (Becker and Boschi, 2002; Burke and Torsvik, 2004), and 280 My into the future (S. Pisarevsky, personal communication).



# Development of the Arabian-Nubian Shield (ANS)

The Arabian-Nubian Shield forms as a plate boundary

or as suture zone formed between East and West Gondwana at the northern end of the East African Orogen (EAO).

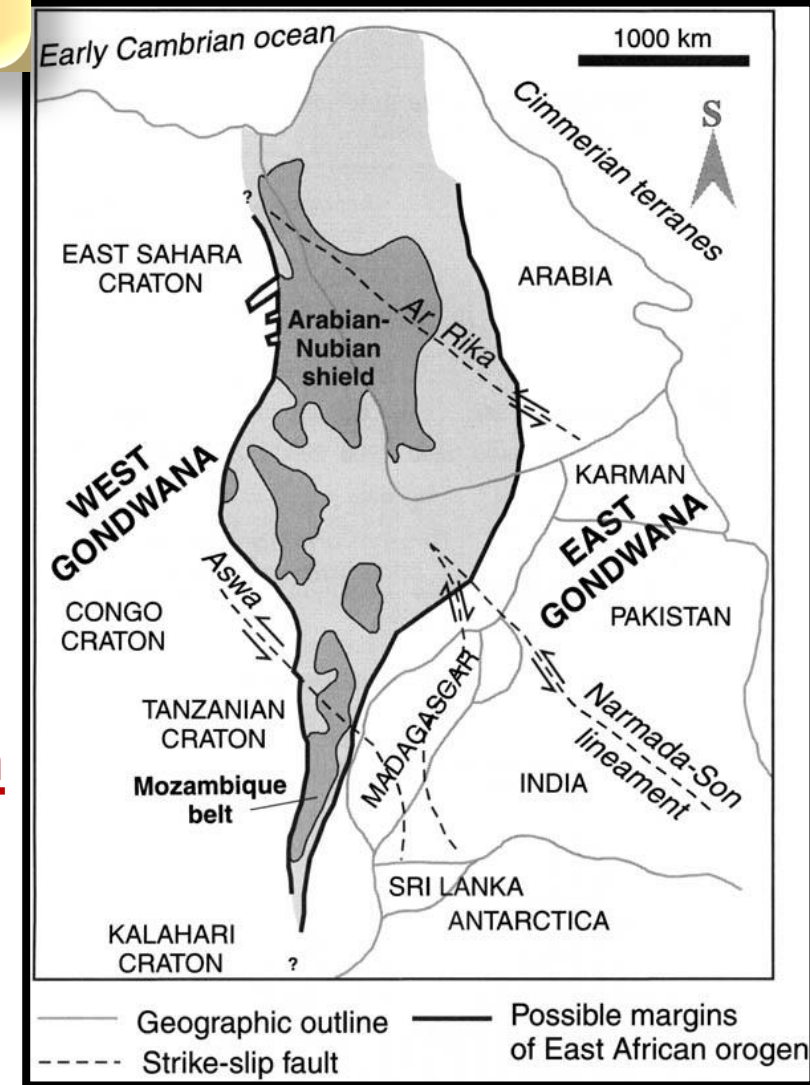


**Fig. 1: Sketch map of the East African Orogen showing the location of the Arabian-Nubian Shield relative to the Mozambique Belt and adjacent cratonic margins (after Stern 1994). Note the orientation shown as at the end of the Precambrian**

# Development of the Arabian-Nubian Shield (ANS)

► THE ANS TECTONIC FRAME WORK AND EVOLUTION HAS BEEN RECOGNIZED WITHIN THE LAST 20 YEARS BY APPLYING GONDWANA TERM ON THE BASES OF:

1. Paleo-magnetic pole studies of rocks in Craton areas, and
2. Due to isotopic data along the eastern margin of Africa and part of India, and Madagascar in the Orogenic movement that formed Mozambique Belt



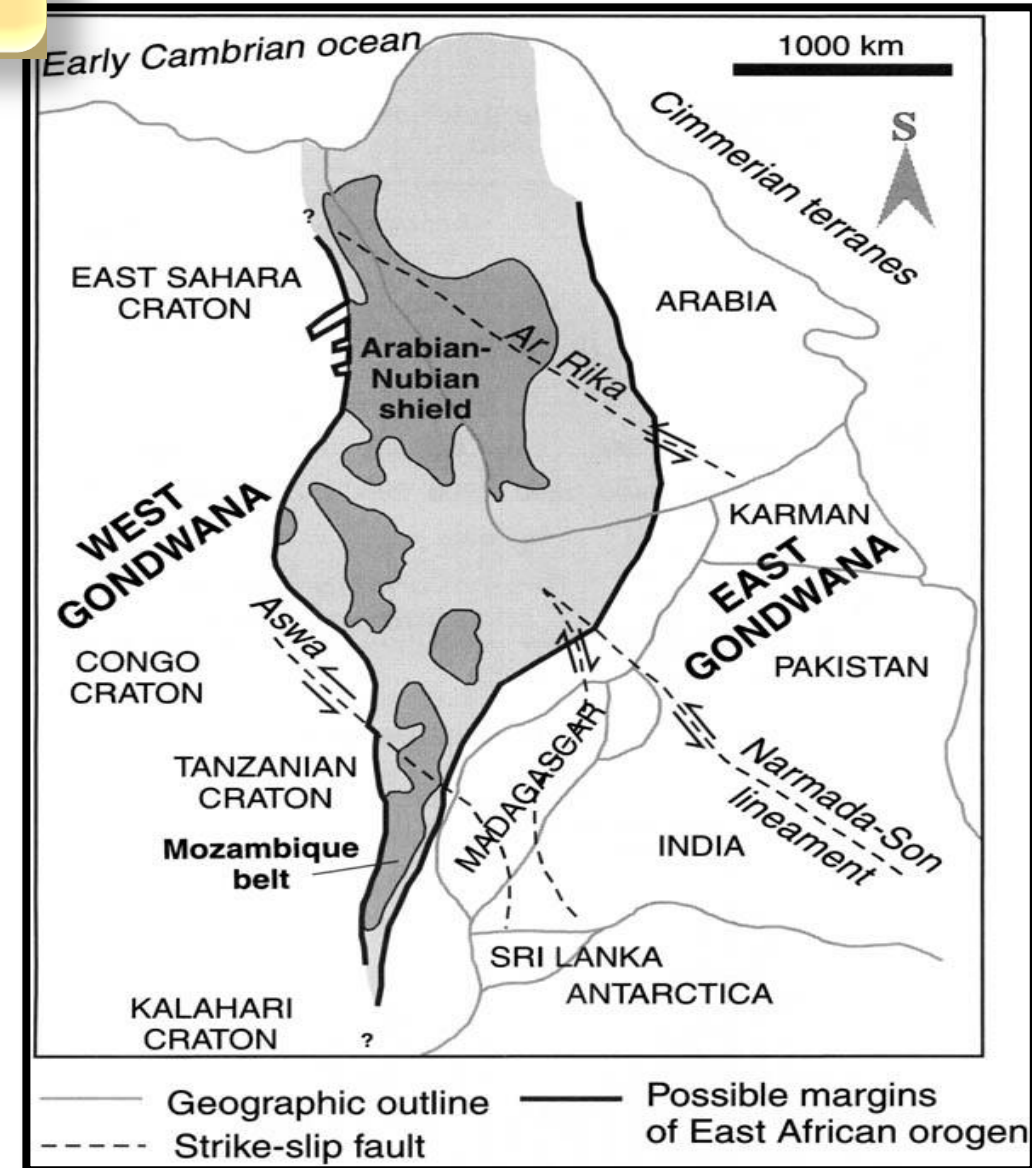
# Development of the Arabian-Nubian Shield (ANS)

## ➡ Consequently:

In reference to depositional Studies, magmatism, structure, history and Geochronologic data  
redefined and showed that:

- ✓ The Arabian shield is equivalent to the Nubian Shield in the NE Africa Part of the Mozambique rocks' belt,
- ✓ Where the rocks deformed, metamorphosed from southern Africa to the Arabia-Nubian Shield.

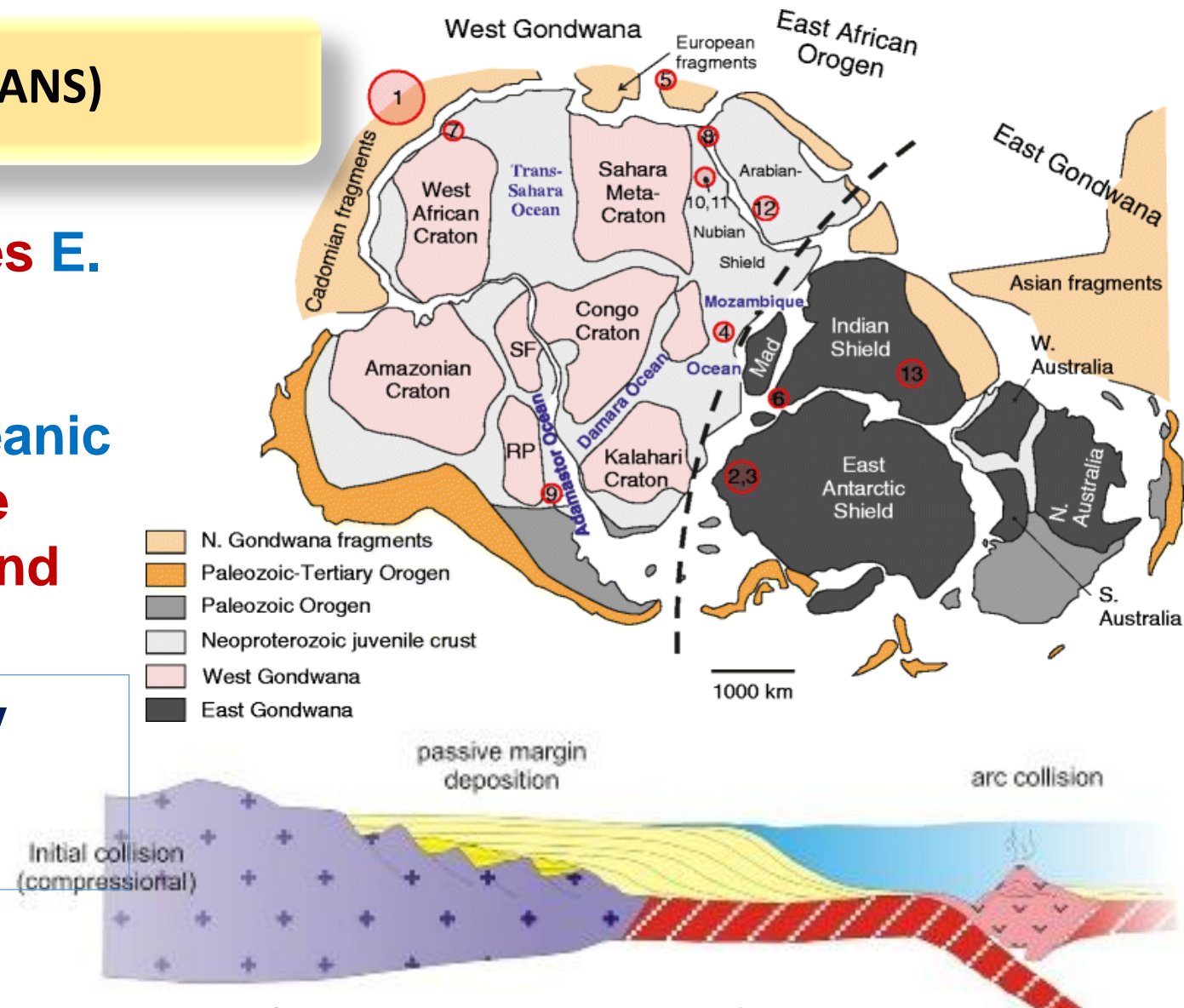
So,





# Development of the Arabian-Nubian Shield (ANS)

- The **Mozambique Ocean Separates E. & W. Gondwana.**
- Beside, it is considered as an oceanic basin where the early rocks of the Arabian-Nubian Shield evolved and formed)
- **Passive margin** meta-sedimentary succession located in Kenya and Sudan
- **A Passive Margin** is considered as a transition zone between oceanic and continental lithosphere which was not an active plate margin.

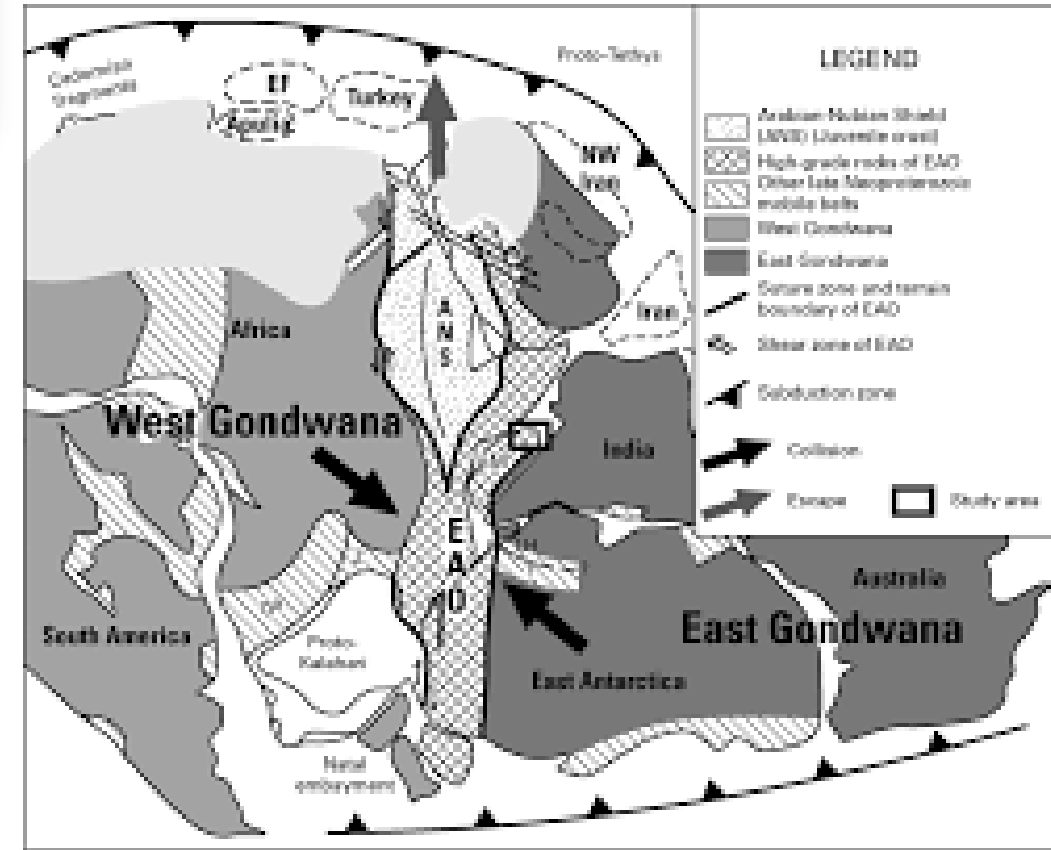


## Development of the Arabian-Nubian Shield (ANS)

**The ANS convergence (assemblage) forms super continental (EAO) at the Tethyan Sea margin, it :**

- **Exposed as the initial time of Mozambique belt.**
- **developed at the final contact between E & W Gondwana at an assembled stages (suture zone) .**

**Therefore**



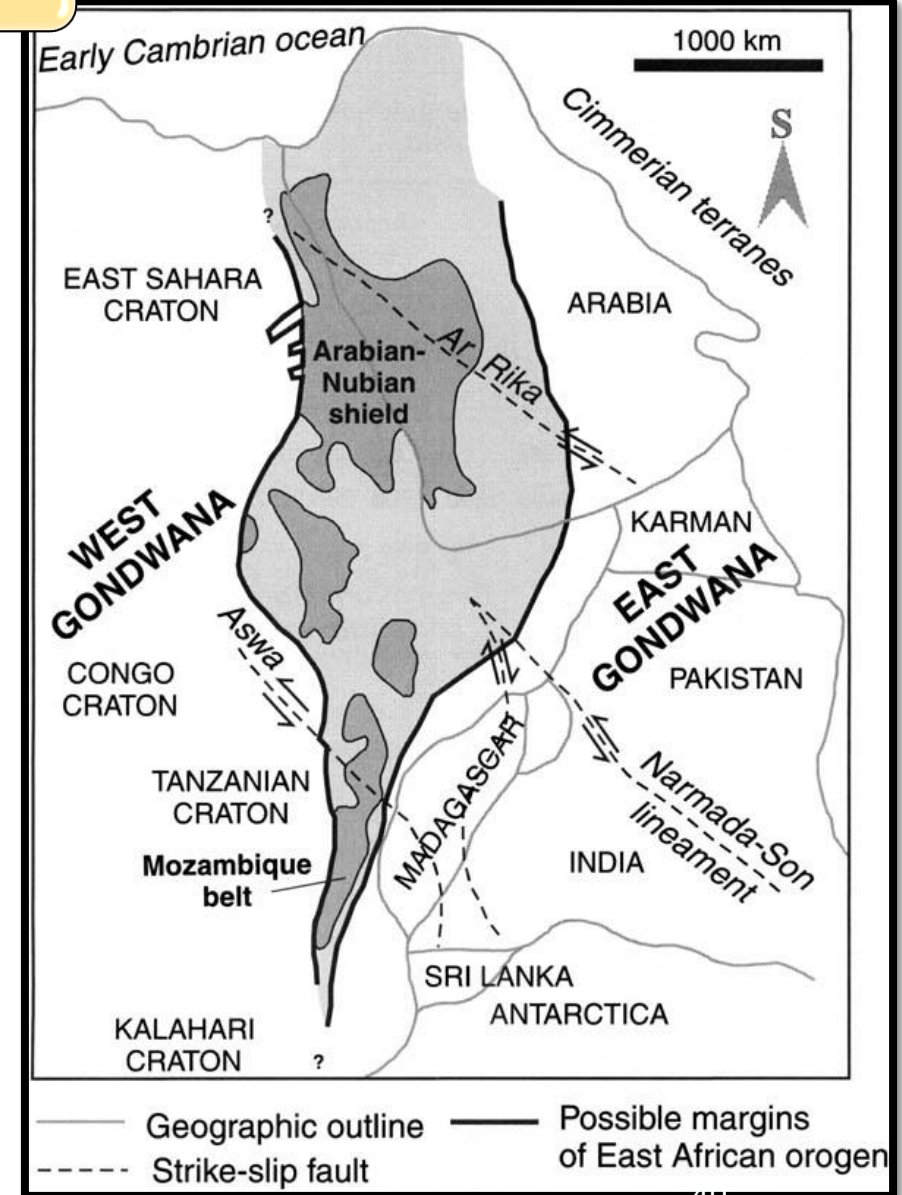
# Development of the Arabian-Nubian Shield (ANS)

- **East Gondwana involves** the Cratonic (fragments) of Kalhari, East Antarctica, Madagascar, India and Australia

for the meantime

- **West Gondwana** fragments (CRATON) comprises Congo, East Sahara, Tanzanian and west Africa cratons.

Subsequently





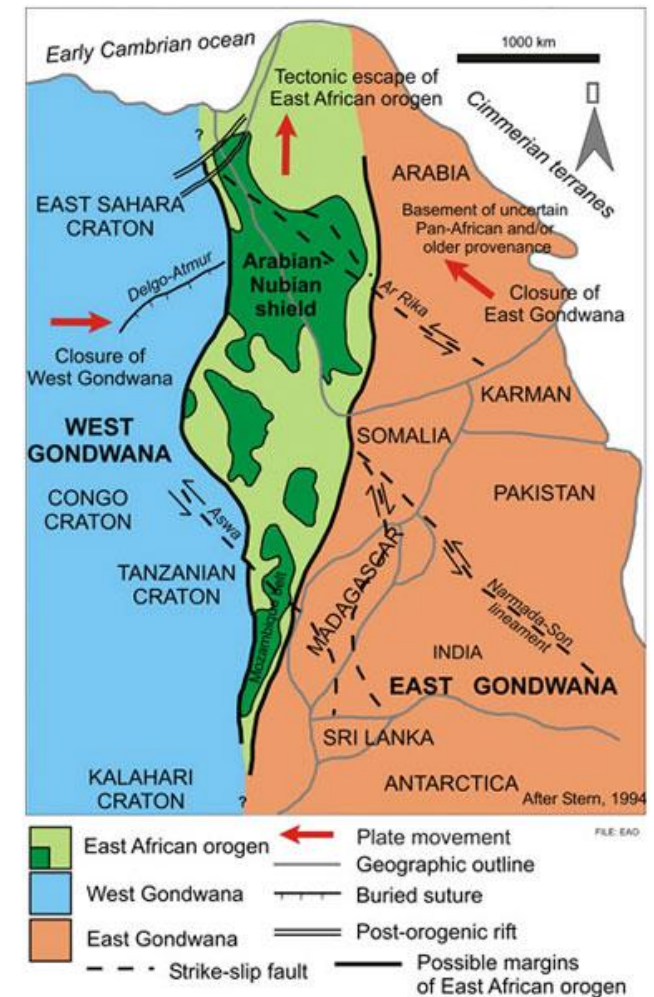
# Development of the Arabian-Nubian Shield (ANS)

- The ANS tectonic outlines evolved in the Mozambique Ocean between the convergent blocks of the East and West Gondwana

But,

- The representative rocks of west Gondwana outcrops are poorly exposed, and form in the East Saharan Craton.
- Meanwhile the representative rocks of the Eastern Gondwana in Arabia are unknown

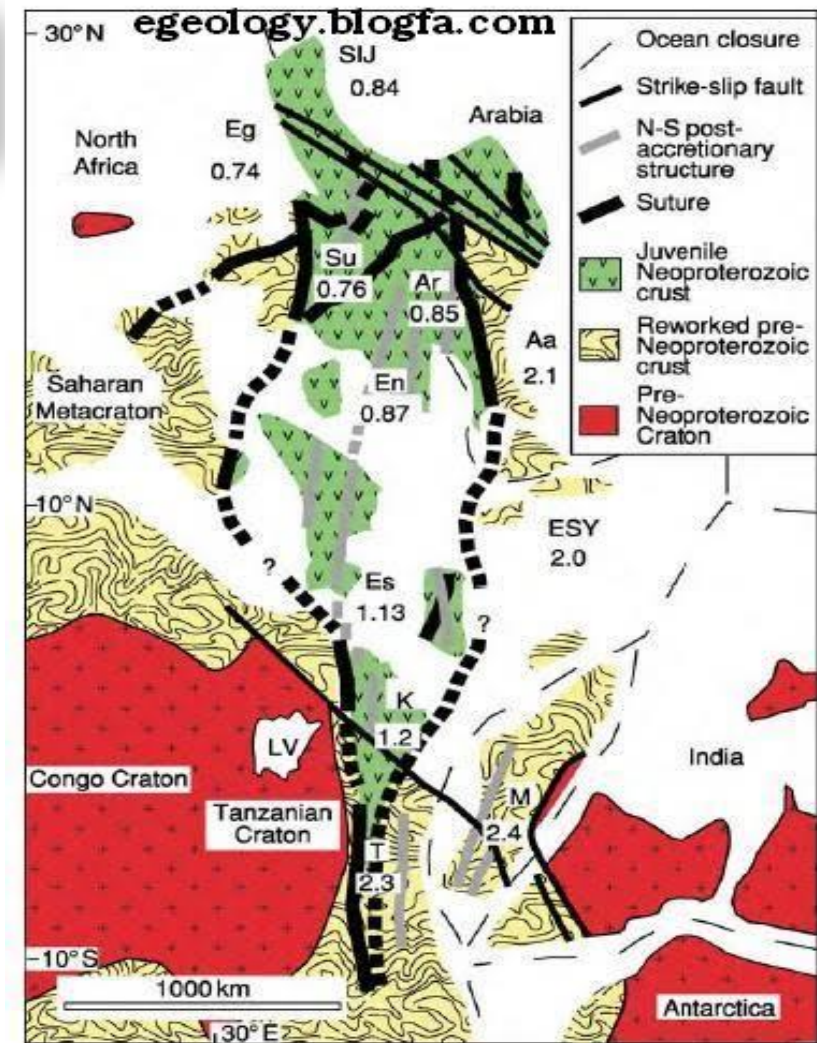
So,



For that  
reason

# Arabian-Nubian Shield (ANS)

- ANS is exposing and comprising a large area of mostly juvenile Neoproterozoic crust.
- ANS abounds the abundance of island-Arc rocks, and ophiolites rocks appears as sutures zones.
- The ANS makes up the northern half of the East African Orogen (EAO) and
- The ANS extends from southern Israel and Jordan to the south as far as Ethiopia and Yemen, where



**Figure 2** Pre Jurassic configuration of elements of the East African Orogen in Africa and surrounding regions. Regions include Egypt (Eg), Sudan (Su), Sinai Israel Jordan (SIJ), Afir ter rane, Arabia (Aa), rest of Arabian Shield (Ar), Eritrea and northern Ethiopia (En), southern Ethiopia (Es), eastern Ethiopia, Somalia, and Yemen (ESY), Kenya (K), Tanzania (T), and Madagascar (M). Numbers in italics beneath each region label are mean Nd model ages in Gy.

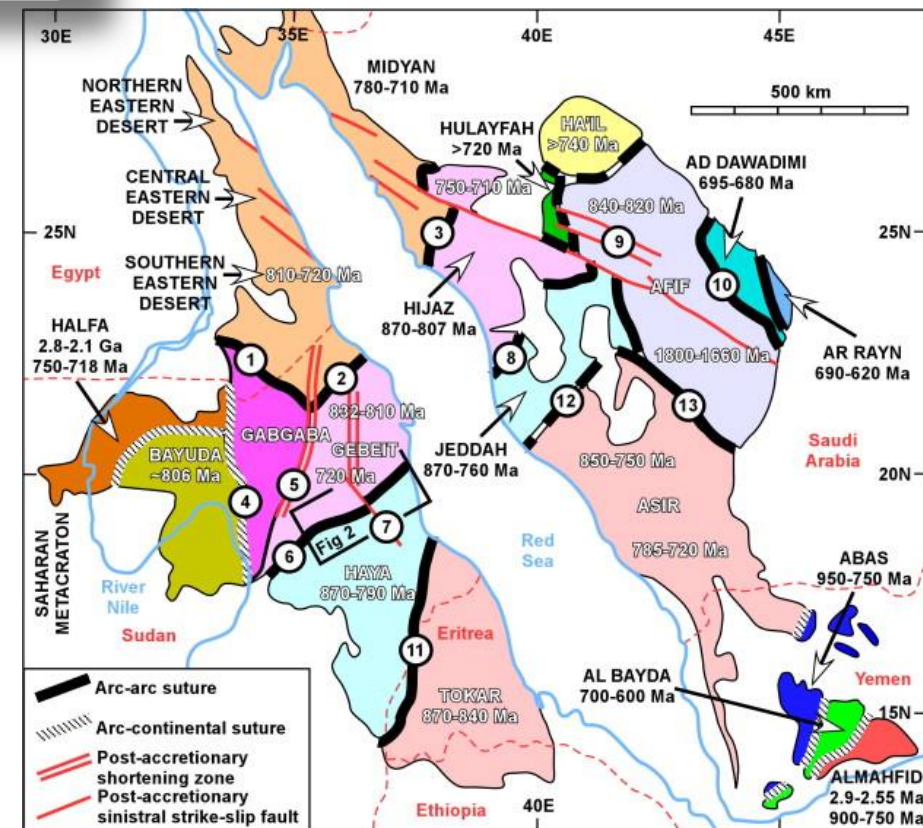
# Arabian-Nubian Shield (ANS)

## ➤ The ANS evolved as a Mozambique Belt

- Mozambique Belt, on its the north portion, dominant with a juvenile nature rocks, with low grade of metamorphism forming ANS,
- And in its southern part the belt shows metamorphic.

Therefore,

- The ANS, thus defined, as an extended area of a about 3000 km length (north to south) and >500 km on either side of the Red Sea . It is flanked by the RED SEA to the West , and to the East.



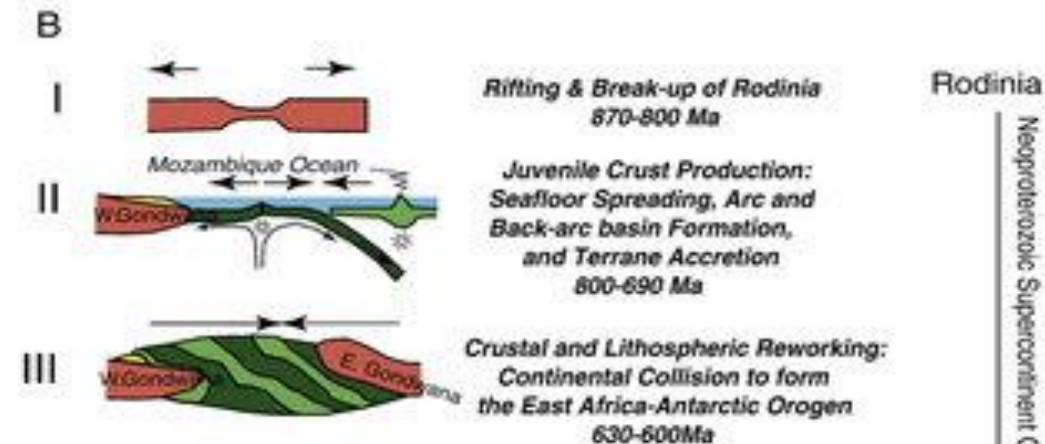
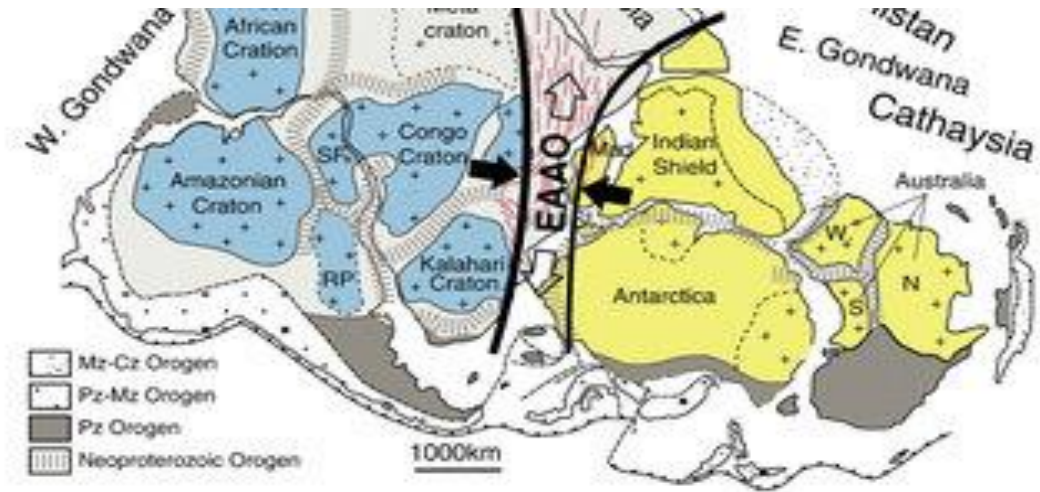


So, in view of that

- ❖ The ANS is convergence plates initiate as super continental assembled at the Tethyan Sea at the north margin of Gondwana

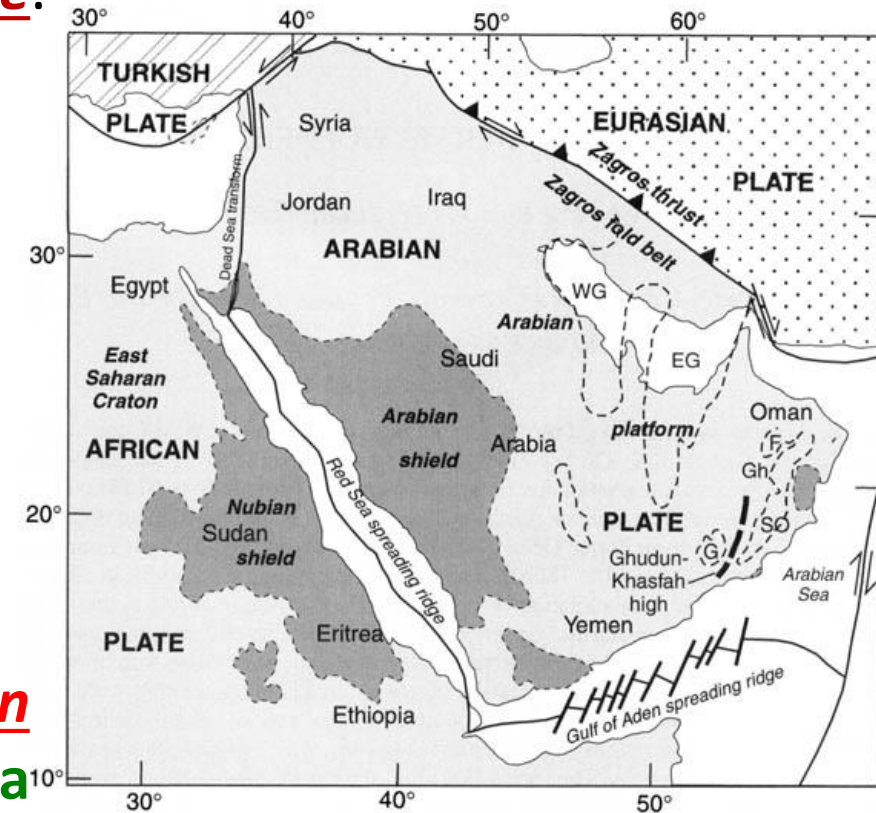
And then,

- The ANS as an initial convergence stage launched between the East and the West Gondwana at Mozambique ocean floor, and
- This tectonic activity ceased (ended), by the Accreted (assembled) of both E & W Gondwanas land creating the ANS.



## Tipoff (Summary)

- The eastern part of the AN Shield is now pre-served in the Arabian Plate, and the western segment of the African Plate.
- The ANS is placed at north end of eastern African Orogen (EAO)
- and it is interpreted as it's a development in terms of the Rodinia rifted tectonism, affecting & causing,
- the closure of the ensuing (belong to) Mozambique Ocean, Arc collision, orogeny ... etc.
- The Arabian-Nubian Shield (ANS) consists of Precambrian rocks exposed on either side of the Red sea are having a deformational events and is discontinuously occurred in the western part of Arabian plate and northeastern Africa



➤ **I.e. the Arabian Shield is representing part of the eastern Gondwana plate.**