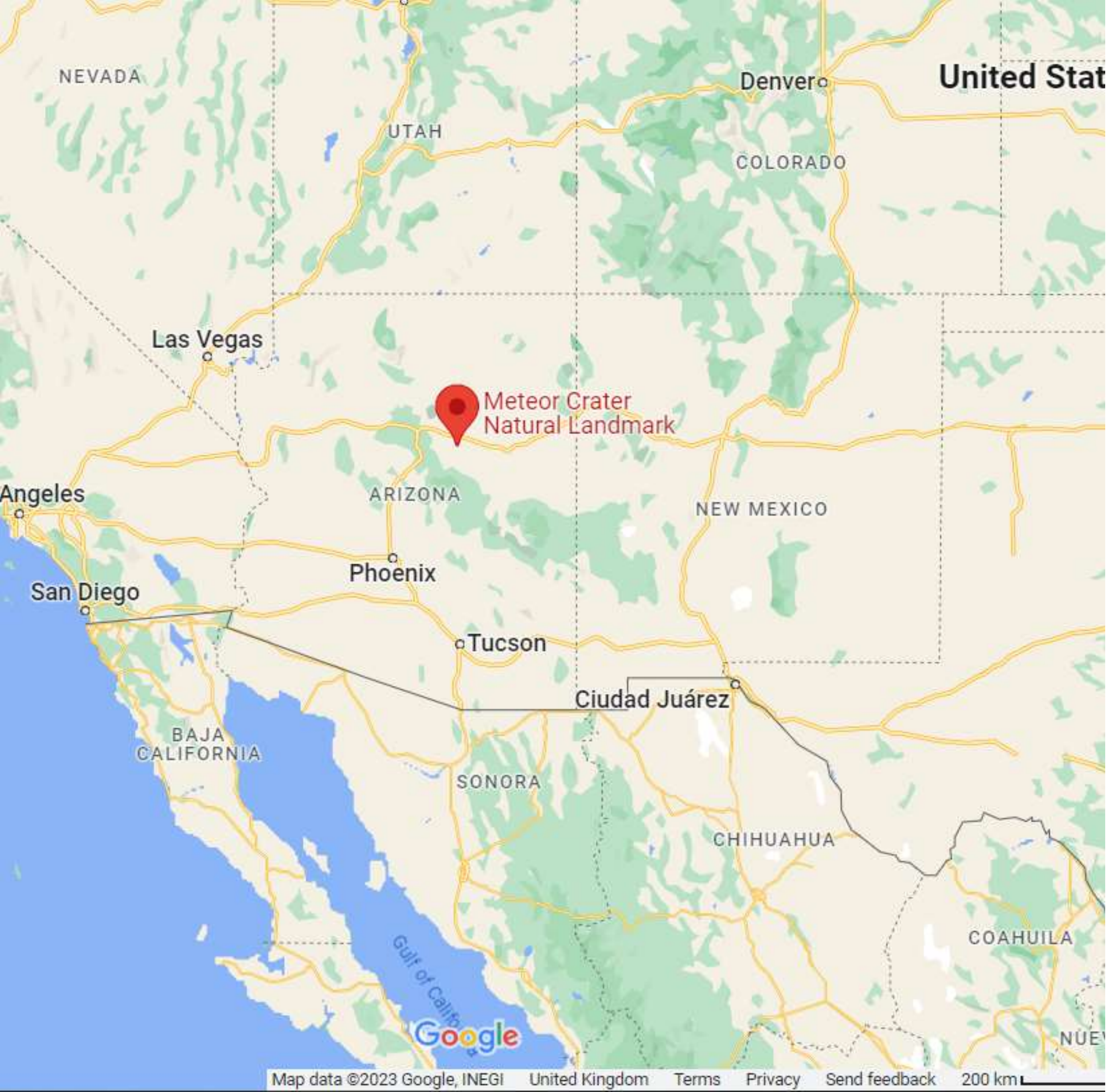
# The Barringer Meteor Crater Arizona

By

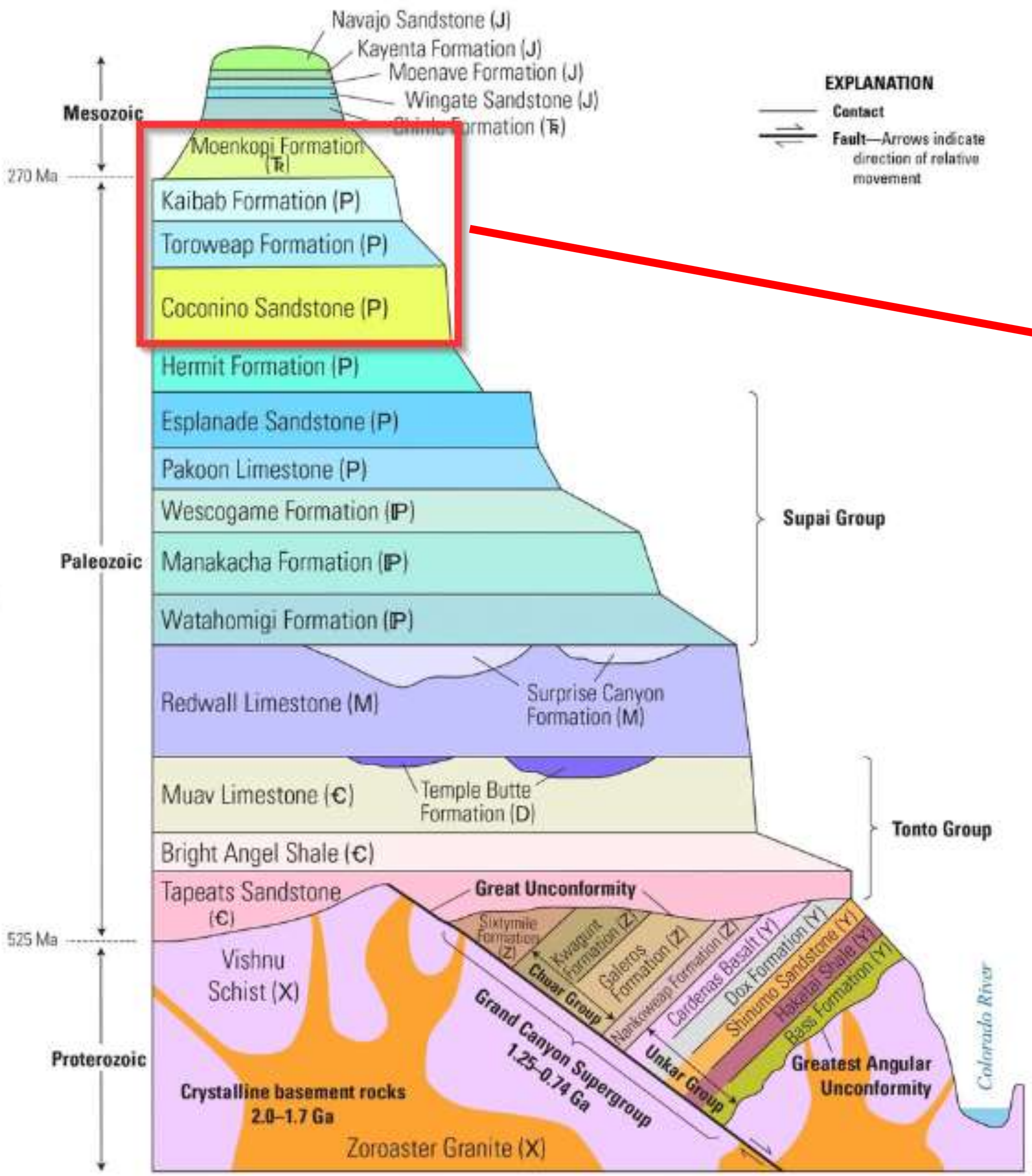
Mellissa Freeman

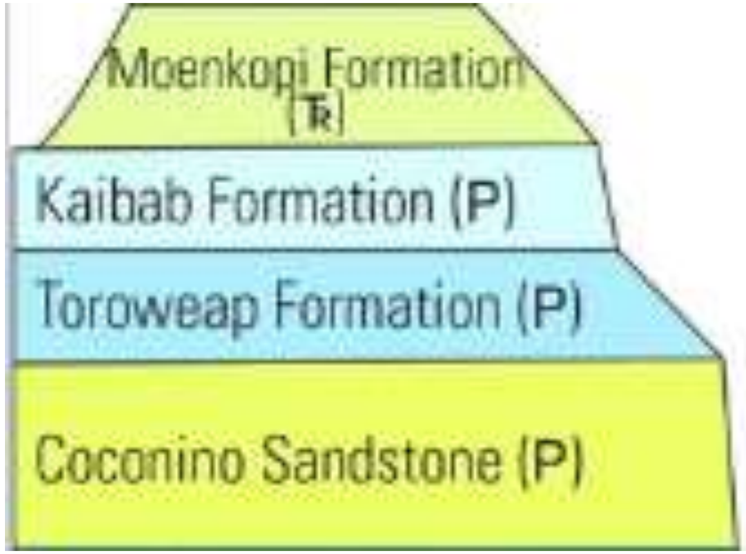



# Location

Colorado Plateau

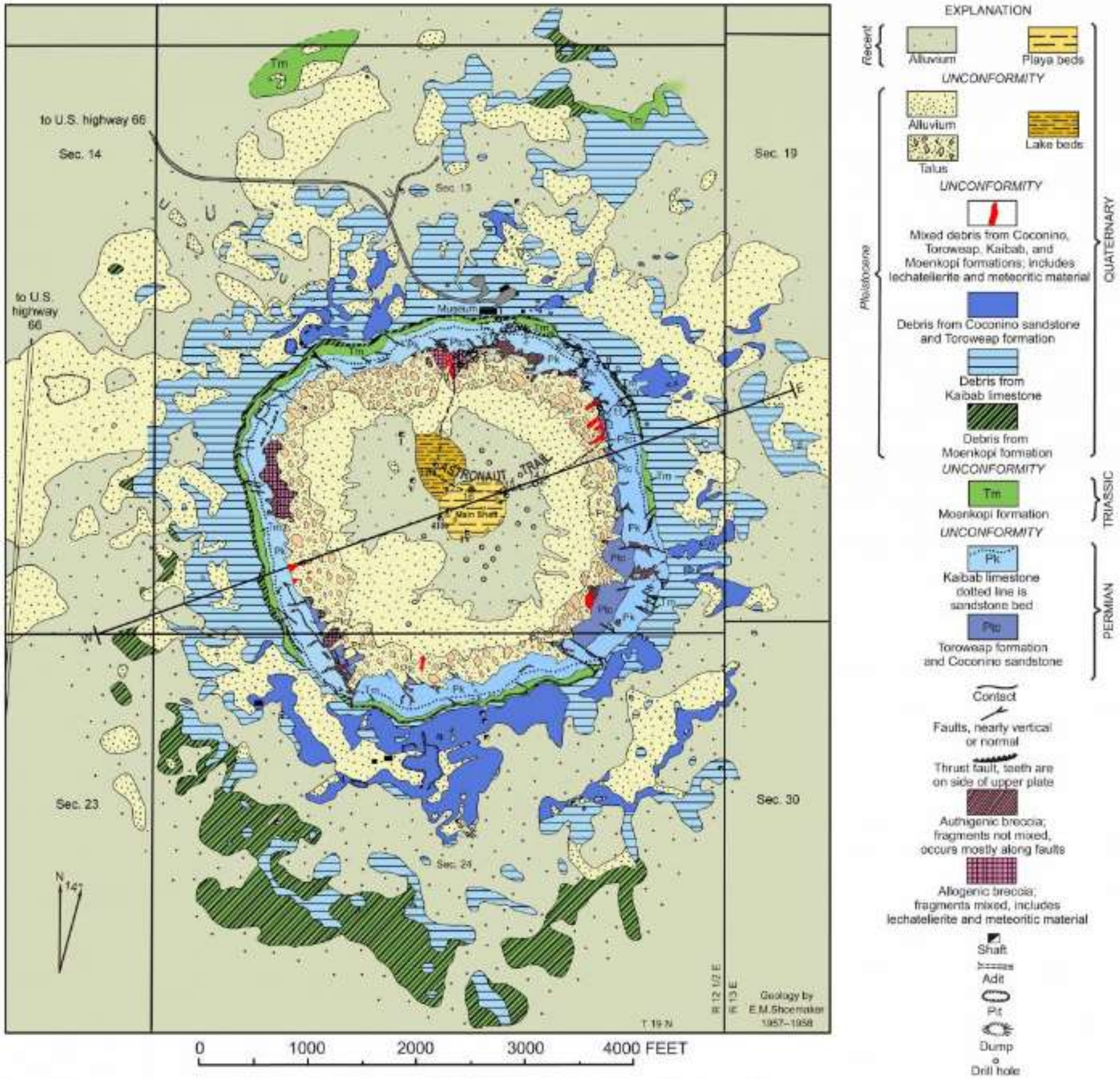
# The geology


Navajo Sandstone (J)
Kayenta Formation (J)
Moenave Formation (J)
Wingate Sandstone (J)
rmation (Ŧ)
Mesozoic
270 Ma
Moenkopi Formation (Ŧ)
Kaibab Formation (P)
Toroweap Formation (P)
Coconino Sandstone (P)
Hermit Formation (P)
Esplanade Sandstone (P)
Pakoon Limestone (P)
Wescogame Formation (IP)
Manakacha Formation (IP)
Watahomigi Formation (IP)
Supai Group
Paleozoic
Redwall Limestone (M)
Surprise Canyon Formation (M)
Muav Limestone (Є)
Temple Butte Formation (D)
Tonto Group
Bright Angel Shale (Є)
Tapeats Sandstone (Є)
Great Unconformity
525 Ma
Vishnu Schist (X)
Sixtymile Formation (Z)
Kwagunt Formation (Z)
Galeros Formation (Z)
Chuar Group
Nankoweap Formation (Z)
Cardenas Basalt (Y)
Dox Formation (Y)
Shinumo Sandstone (Y)
Hakatai Shale (Y)
Bass Formation (Y)
Unkar Group
Grand Canyon Supergroup 1.25–0.74 Ga
Proterozoic
Crystalline basement rocks 2.0–1.7 Ga
Zoroaster Granite (X)
Greatest Angular Unconformity
Colorado River
EXPLANATION
Contact
Fault—Arrows indicate direction of relative movement


Moenkopi Formation (Ŧ)
Kaibab Formation (P)
Toroweap Formation (P)
Coconino Sandstone (P)

# Geological Map of Meteor Crater Arizona

- Created by Gene Shoemaker, 1960



GEOLOGIC MAP OF METEOR CRATER, ARIZONA

# The history

- Impact happened approx. 50,000 years ago
- 1871 - The first written report was by a man by the name of Franklin
- 1886 – iron-nickel meterorites were found by a sheep herder
- 1891 – site visited by USGS who deemed it to be volcanic
- 1903 – site was purchased by Daniel Moreau Barringer
- 1941 – the Barringer family entered into a lease with Bar T Bar Ranch Company and formed the Meteor Crater Enterprises Inc which is still running today.

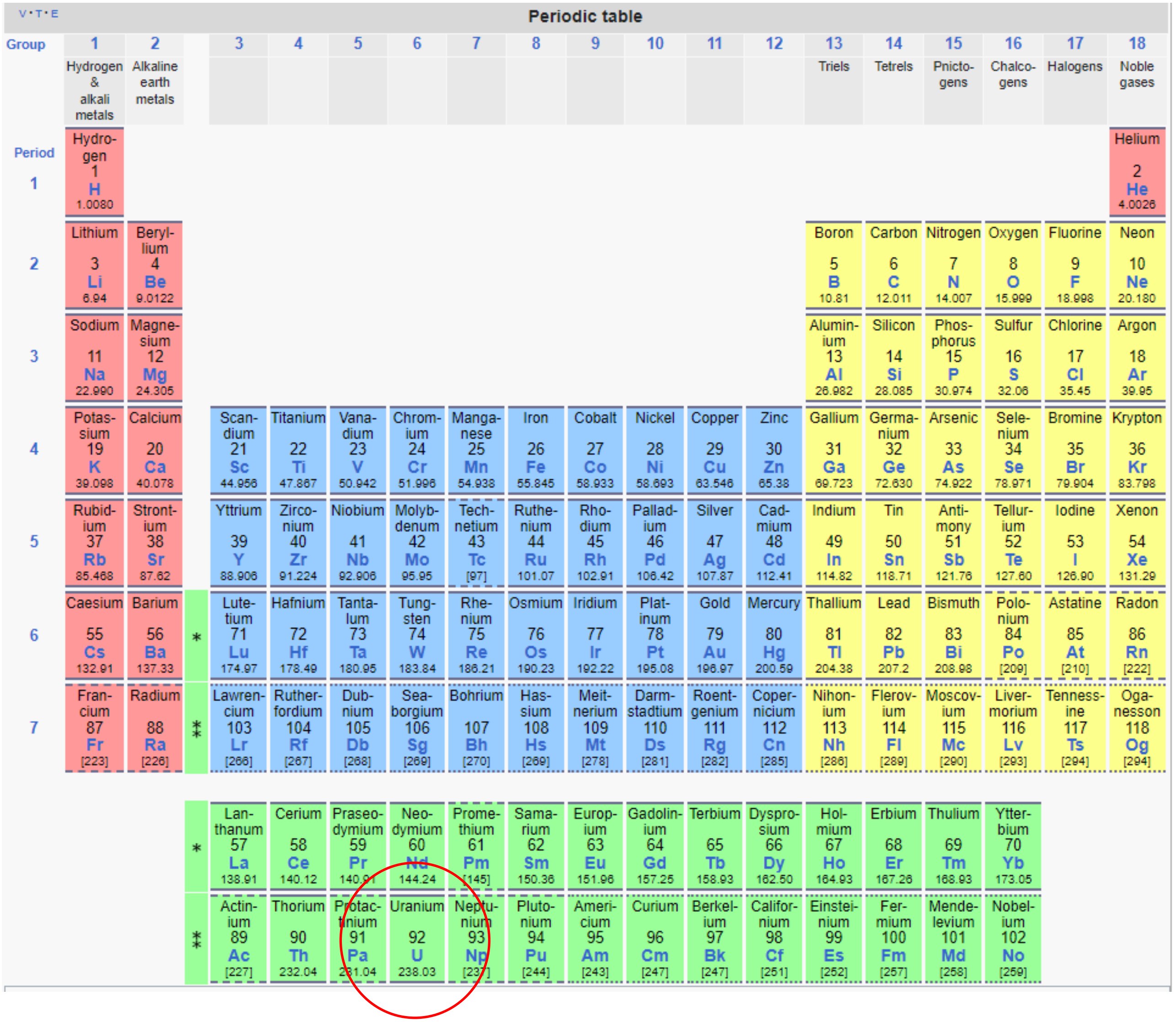
THE END OF PART 1….

# A brief look at naturally occurring fission reactors

Anne Hunt

# Uranium

- Actinide
  - Atomic number 92

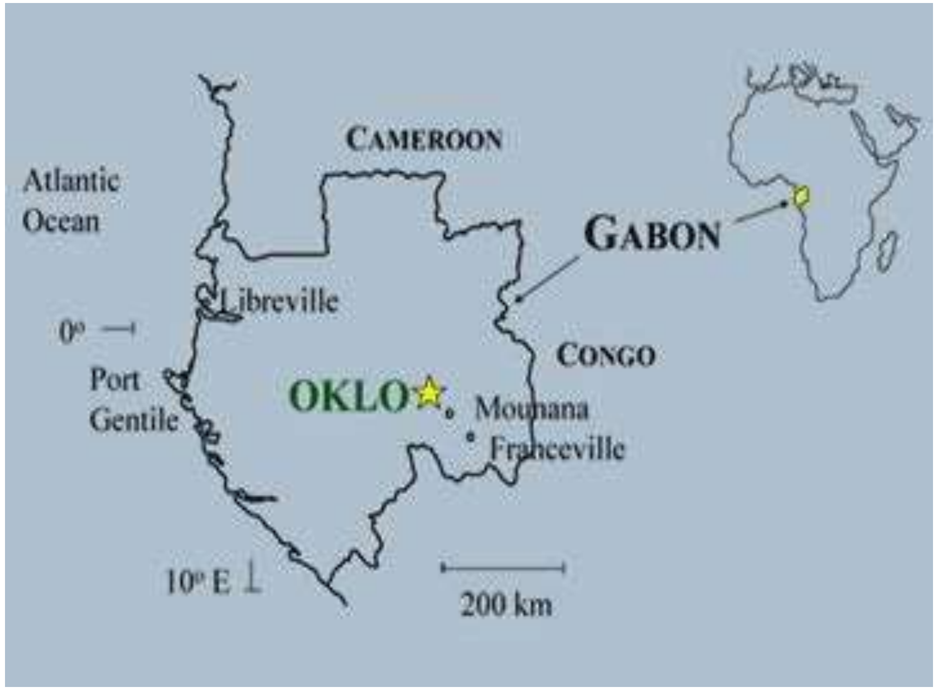


# Uranium

- 2 isotopes
  - $^{235}U$
  - $^{238}U$
- Both radioactive but half lives differ
  - $^{235}U$: 700 million years
  - $^{238}U$: 4.6 billion years
- Natural relative abundance
  - $^{235}U$: 0.72%
  - $^{238}U$: 99.28%
  - Relative adundance is remarkably consistent worldwide…

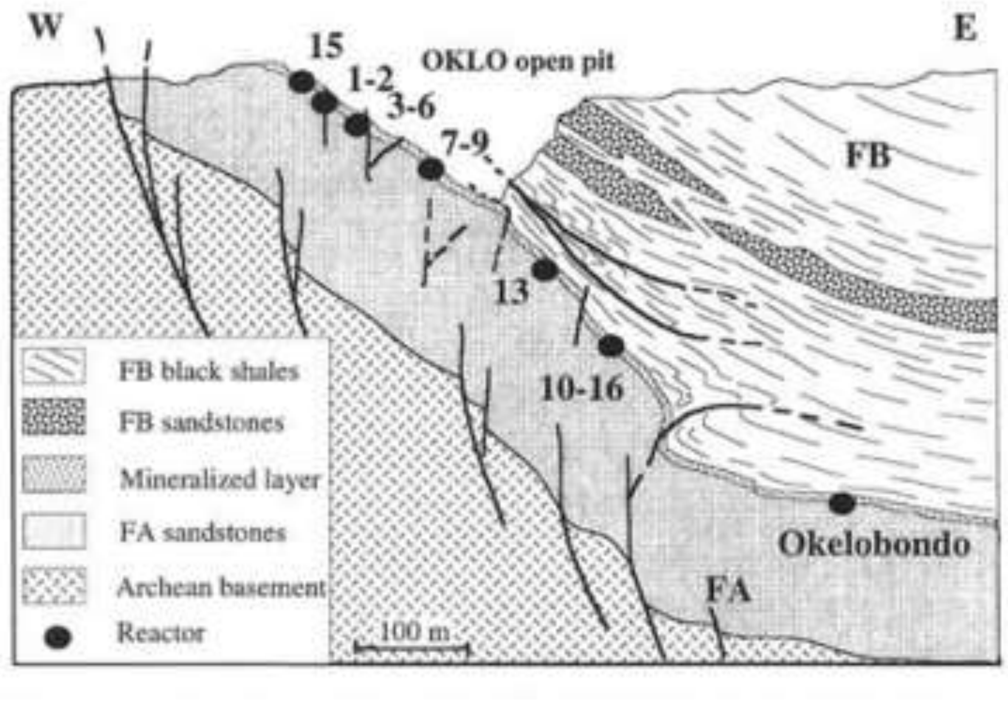
# Relative abundance

- …except in zones in the uranium mines at Oklo, Okelobondo and Bangombé in the Franceville Basin, Gabon
- In these zones
  - $^{235}U$ is low as 0.38 %
  - an assembly of the end-member fission products which result from sustained nuclear reactions in a nuclear reactor



# Geological setting

- Uraninite deposits
  - located near the top of a succession of sandstones and conglomerates
- Uraninite deposits
  - Formed by dissolution-precipitation processes
  - From which approximately 28,000 tonnes of uranium ore have been mined
- Age: 1950 ± 40 Ma - Proterozoic




*Gauthier-Lafaye et al 1996*

# Geological setting

- U-bearing conglomerates
  - Buried by deltaic marine deposits of Upper FA formation and FB shales
  - U(VI) oxides
- Shales were rich in organic matter
  - Burial at depths of up to 4 km
  - Temperature and pressure conditions of “oil window” causing conversion to hydrocarbons
  - Hydrocarbons
    - migrated to the FA sandstone reservoir rock
    - Accumulated in structural traps

# Geological setting

- Uranium mineralisation
  - fluids containing U(VI) oxides meet fluids bearing hydrocarbons
  - hydrocarbons reduce U(VI) oxides to U(IV) oxides
- Uranium is precipitated as uraninite ($UO_2$) in the sandstone in
  - pores
  - fractures
- Zones
  - uraninite seams are depleted in uranium but contain fission products

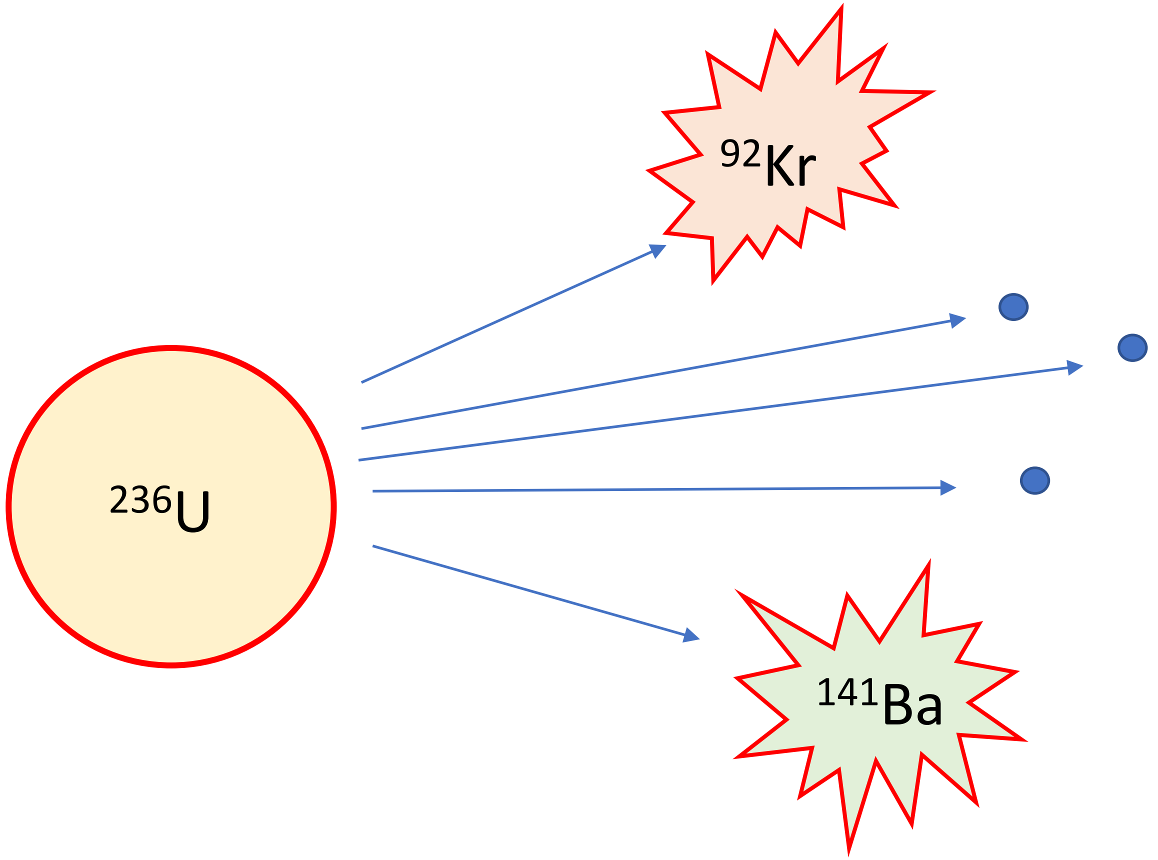
# Nuclear fission

- Inherently unstable nuclei of radioactive isotopes “decay” spontaneously emitting a neutron
- Decay occurs more readily if provoked by disturbance of the structure of the nucleus
- Most readily caused by the absorption of a neutron
- Certain isotopes, termed “fissile”, will absorb a neutron
  - $^{235}U$ is fissile
  - $^{238}U$ is not fissile

$$^{235}U + n = {}^{236}U$$

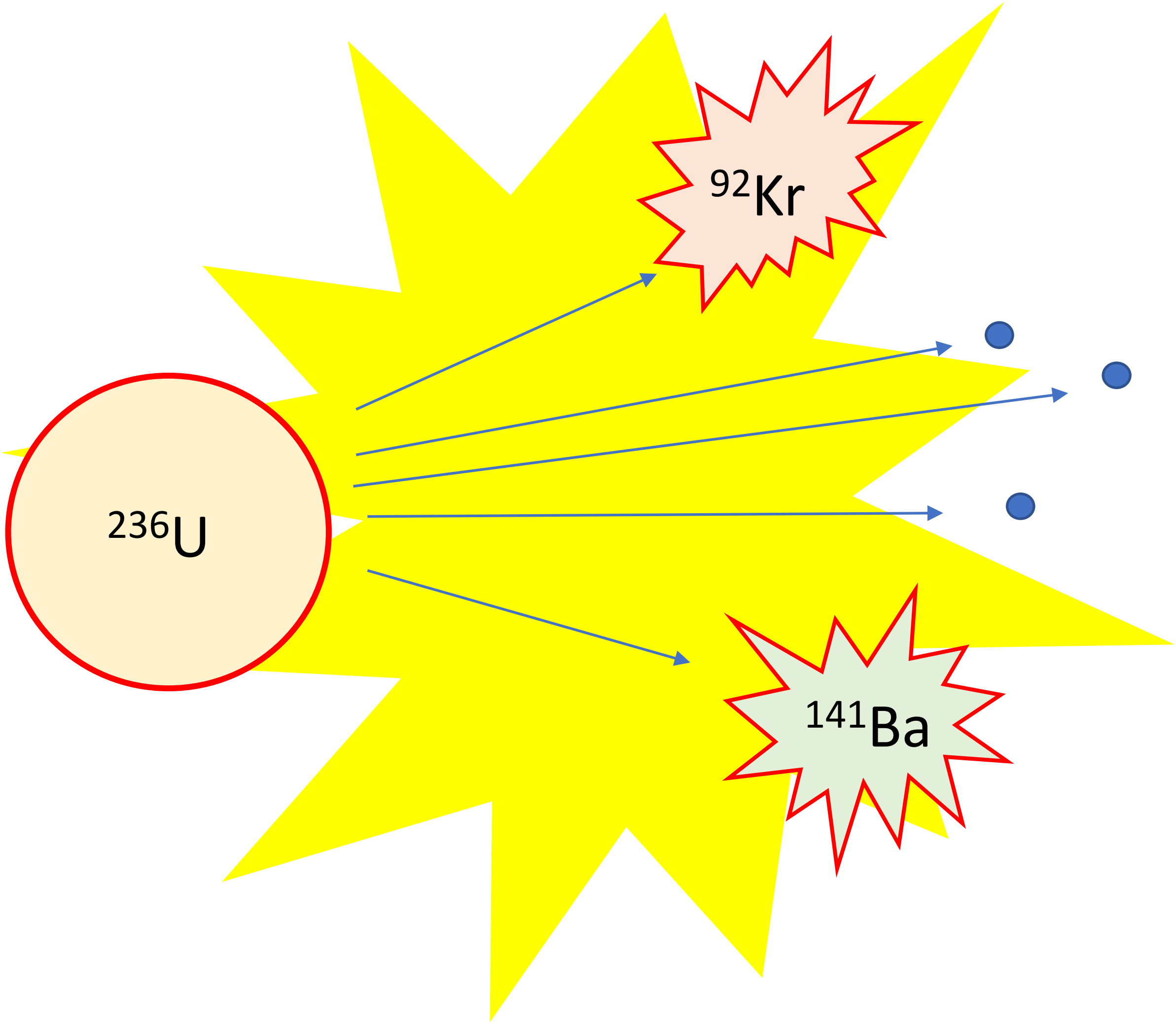
# Nuclear fission

- The fissile nucleus becomes even more unstable and splits into
  - 2 fission nuclei
  - 2 to 3 free neutrons travelling at high speed



# Nuclear fission

- Total mass of parts is very slightly less than original atom
- Missing mass has been converted into energy (released in the form of heat)
  - $E = mc^2$



# Nuclear fission

- These neutrons may go on to trigger fission of neighbouring fissile isotopes – a chain reaction
- A chain reaction may be
  - Uncontrolled – runaway nuclear reaction – basis of atomic weapons or
  - Controlled (“moderated”) - basis of nuclear power
- For a controlled nuclear reaction, neutron speed is crucial
  - Too fast – will go through nuclei = no neutron capture – chain reaction shuts down
  - Too slow – insufficient energy = no neutron capture – chain reaction shuts down
  - Goldilocks speed = neutron capture followed by fission

# Nuclear fission

- High speed neutrons
  - inelastic collisions with things of similar mass will slow down neutrons emitted by fission
  - In liquid form, some water molecules dissociate into hydrogen ions and oxygen ions
  - A hydrogen ion has the same mass as a neutron
  - Water is a good moderator

# Criteria for self-sustaining chain fission reactions i.e. a nuclear reactor

1. Sufficient fuel
2. Sufficiently high ratio of $^{235}U$: $^{238}U$
3. Containment
4. Moderator

# Conditions at Oklo

1. Sufficient fuel
   - U ore seams are at least 0.5 m and typically contained in layers 2m thick
   - Sufficient concentration of uranium-bearing minerals
     - Minimum requirement of 10%
     - In reactor zones, typically 20 to 87%

Remains of reactor at location 2

# Conditions at Oklo

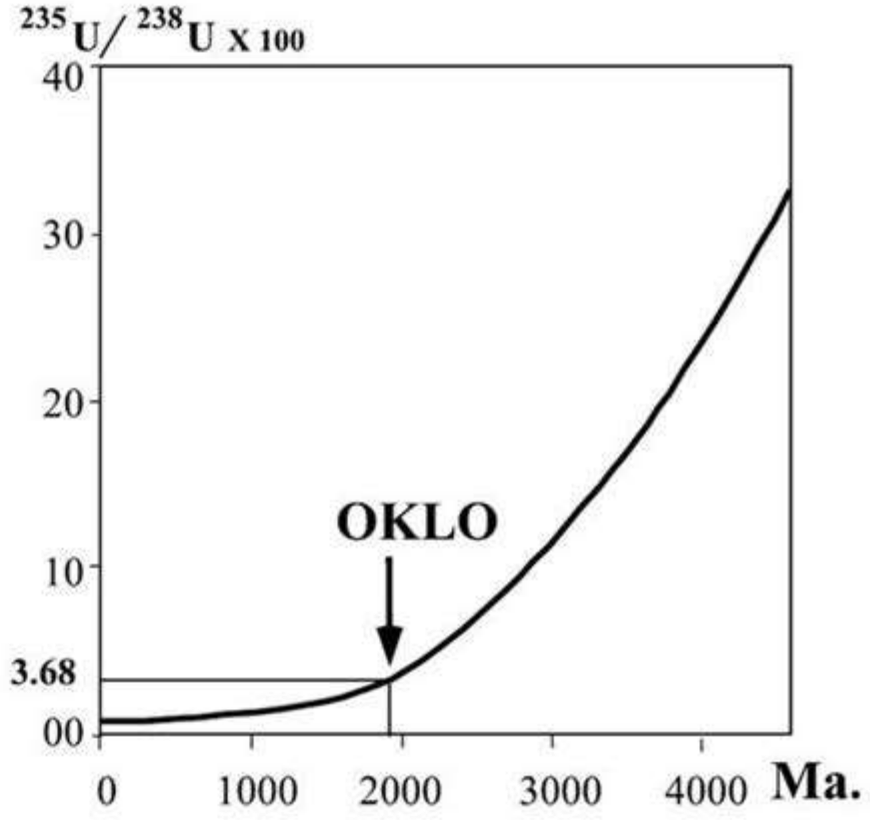
2. Sufficiently high ratio of $^{235}U$: $^{238}U$

- Based on the half lives, extrapolation backwards to nearly 2Ga indicates that the relative abundance was approximately

  U – 235: 3.68%

  U – 238: 96.32%

- Fuel for nuclear power plant: approximately U – 235: 3 to 5%

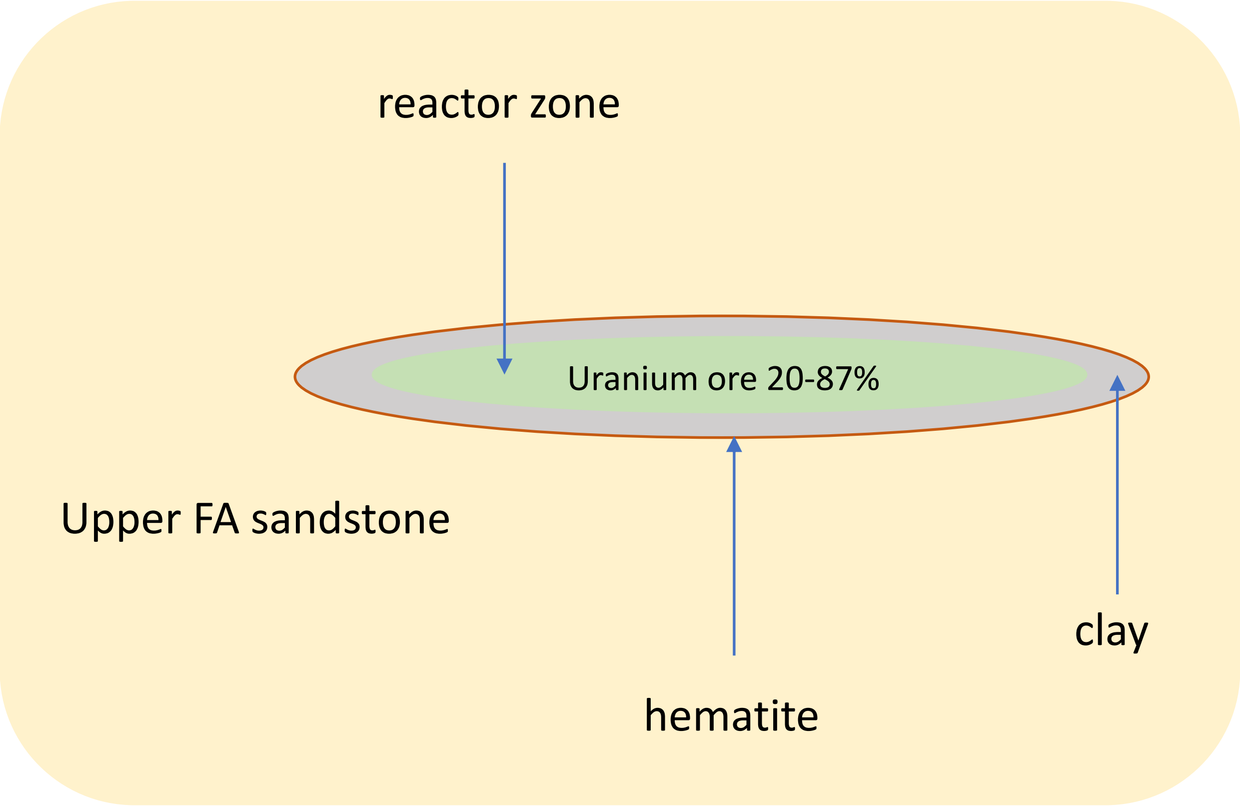



*Gauthier-Lafaye 2002*

# Conditions at Oklo

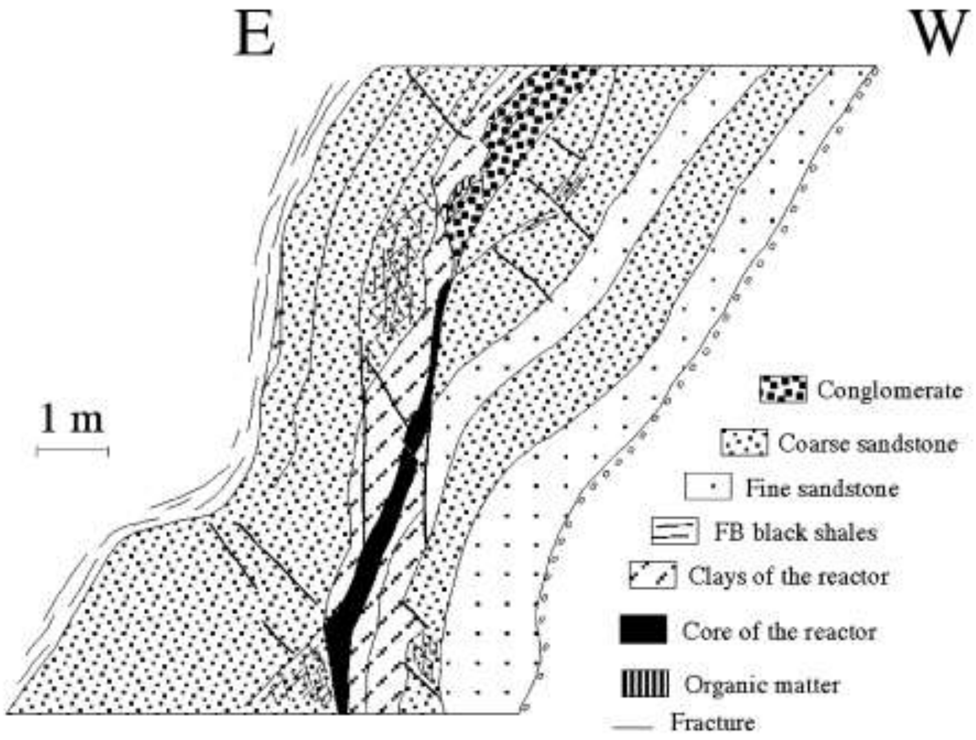
3. Containment

- Enveloped by clay minerals
  - e.g. illite
- Quartz-rich sandstone are natural neutron reflectors
- Sharp boundary between reactor zone and underlying sandstone
  - often with a thin layer of hematite ($Fe_2O_3$)



# Conditions at Oklo

4. Moderator
   - Meteoric water seeping down through porous rocks and faults




Rector 9 from earlier figure *Gauthier-Lafaye et al 1996*

# Duration of Oklo fission reactors

- Short-term
  - Heat generated by the fission reactions caused the water to boil away
  - Without a moderator, the chain reactions shut down
  - When cooled sufficiently for water to flow back, neutron speed is moderated again and chain reactions recommence
  - Calculations indicate
    - Activity – approximately 30 minutes
    - Shut down – approximately 2 hours 30 minutes
    - i.e. a 3 hour cycle
- Long-term
  - Differs between reactor sites – approximate range 62,000 to 270,000 years
  - Analyses of abundances of fission products

# Depleted Uranium

- Research into current conditions at Oklo - useful analogue in connection with disposal of nuclear fuels

# References


- *A. P. Meshik, C. M. Hohenberg, and O. V. Pravdivtseva "Record of Cycling Operation of the Natural Nuclear Reactor in the Oklo/Okelobondo Area in Gabon," Phys. Rev. Lett.* ***93****, 182302 (2004).*
- *Janeczek, J. Mineralogy and Geochemistry of Natural Fission Reactors in Gabon. Reviews in Mineralogy Volume 38 p.321*
- *Meshik, A. P. (November 2005). "The Workings of an Ancient Nuclear Reactor". Scientific American.* ***293*** *(5): 82–6, 88, 90–1. Bibcode:2005SciAm.293e..82M. doi:10.1038/scientificamerican1105-82. PMID 16318030.*
- *Gauthier-Lafaye, F.; Holliger, P.; Blanc, P.-L. (1996). "Natural fission reactors in the Franceville Basin, Gabon: a review of the conditions and results of a "critical event" in a geologic system". Geochimica et Cosmochimica Acta.* ***60*** *(25): 4831–4852. Bibcode:1996GeCoA..60.4831G. doi:10.1016/S0016-7037(96)00245-1.*
- *Davis, E. D.; Gould, C. R.; Sharapov, E. I. (2014). "Oklo reactors and implications for nuclear science". International Journal of Modern Physics E.* ***23*** *(4): 1430007–236. arXiv:1404.4948. Bibcode:2014IJMPE..2330007D. doi:10.1142/S0218301314300070. ISSN 0218-3013. S2CID 118394767.*
- *Gauthier-Lafaye, F. (2002). "2 billion year old natural analogs for nuclear waste disposal: the natural nuclear fission reactors in Gabon (Africa)". Comptes Rendus Physique.* ***3*** *(7–8): 839–849. Bibcode:2002CRPhy...3..839G. doi:10.1016/S1631-0705(02)01351-8.*

# THE END OF PART 2…..

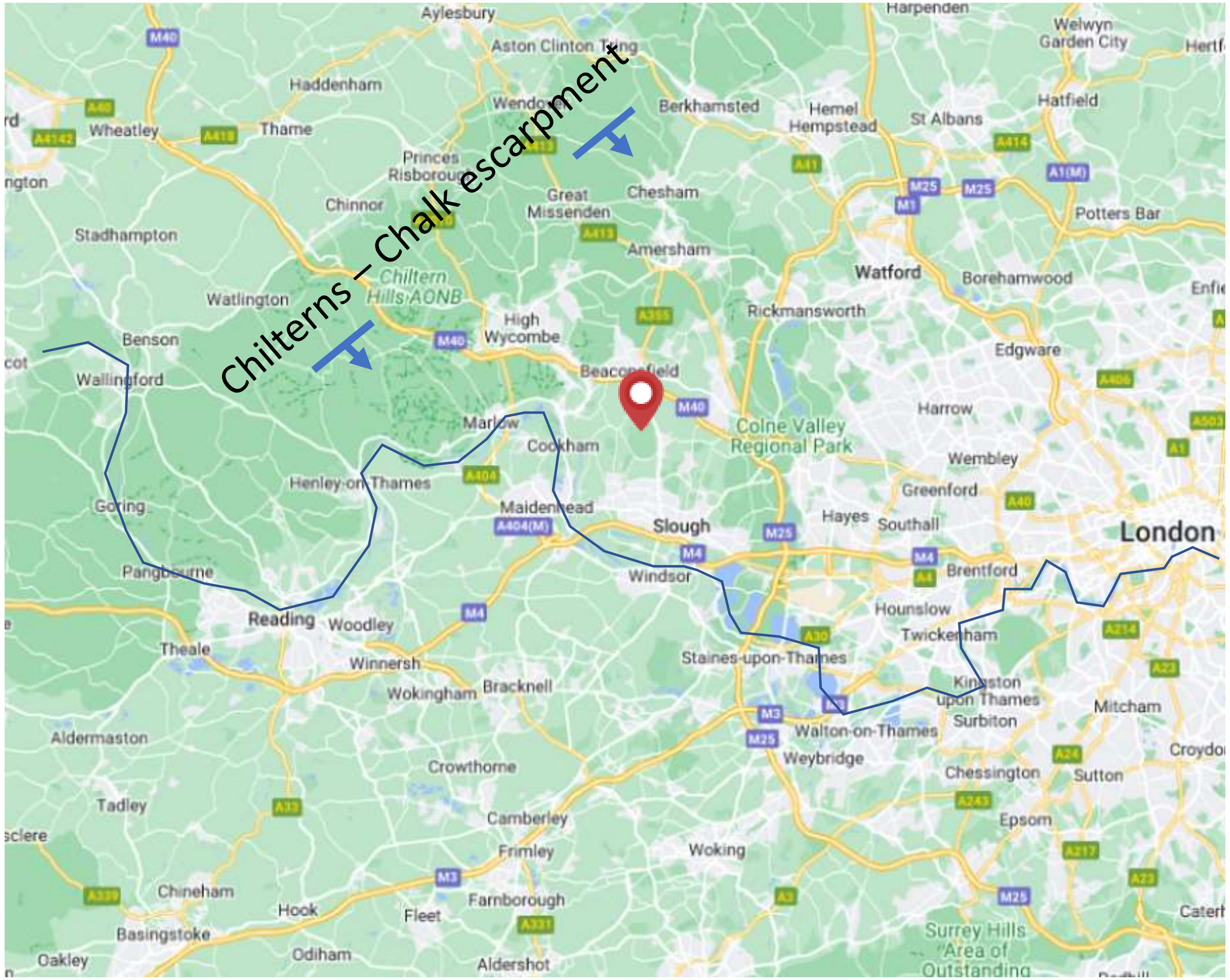
# Burnham Beeches Hydrology

Bath Geological Society

Graham Hickman

May 2023

# Burnham Beeches – 25miles west of London



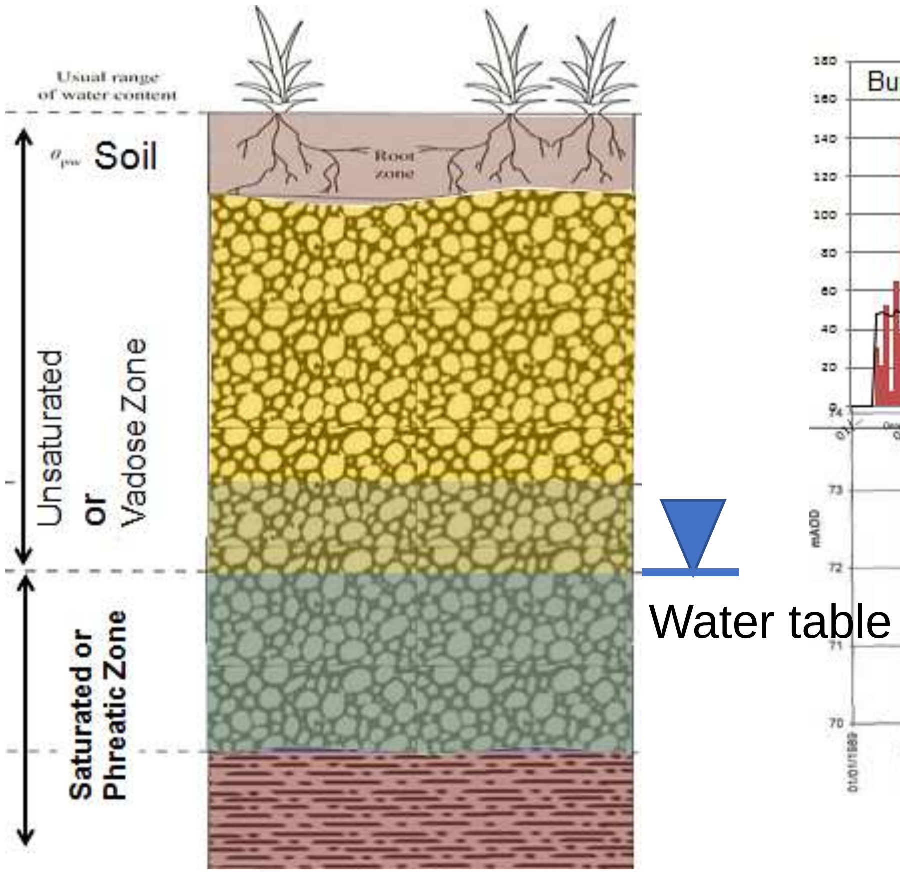

River Thames

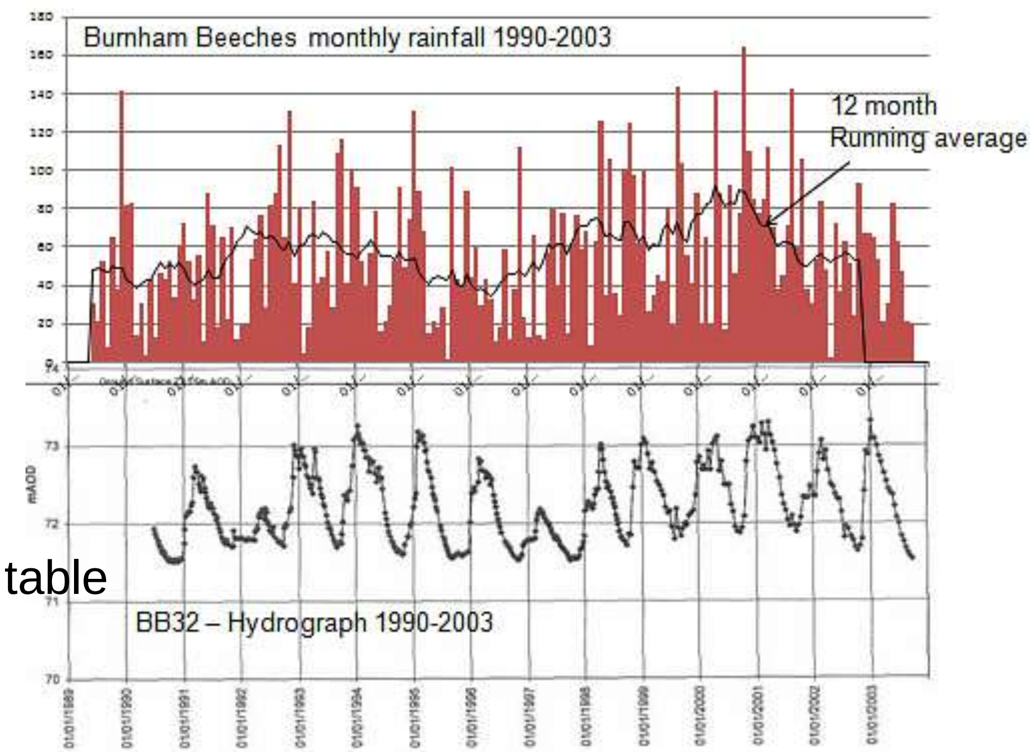
Northern Edge of Thames Valley, Western Edge of London Basin


Ancient Beech Pollards – SSSI, thin sandy soils


# Water observation bore holes

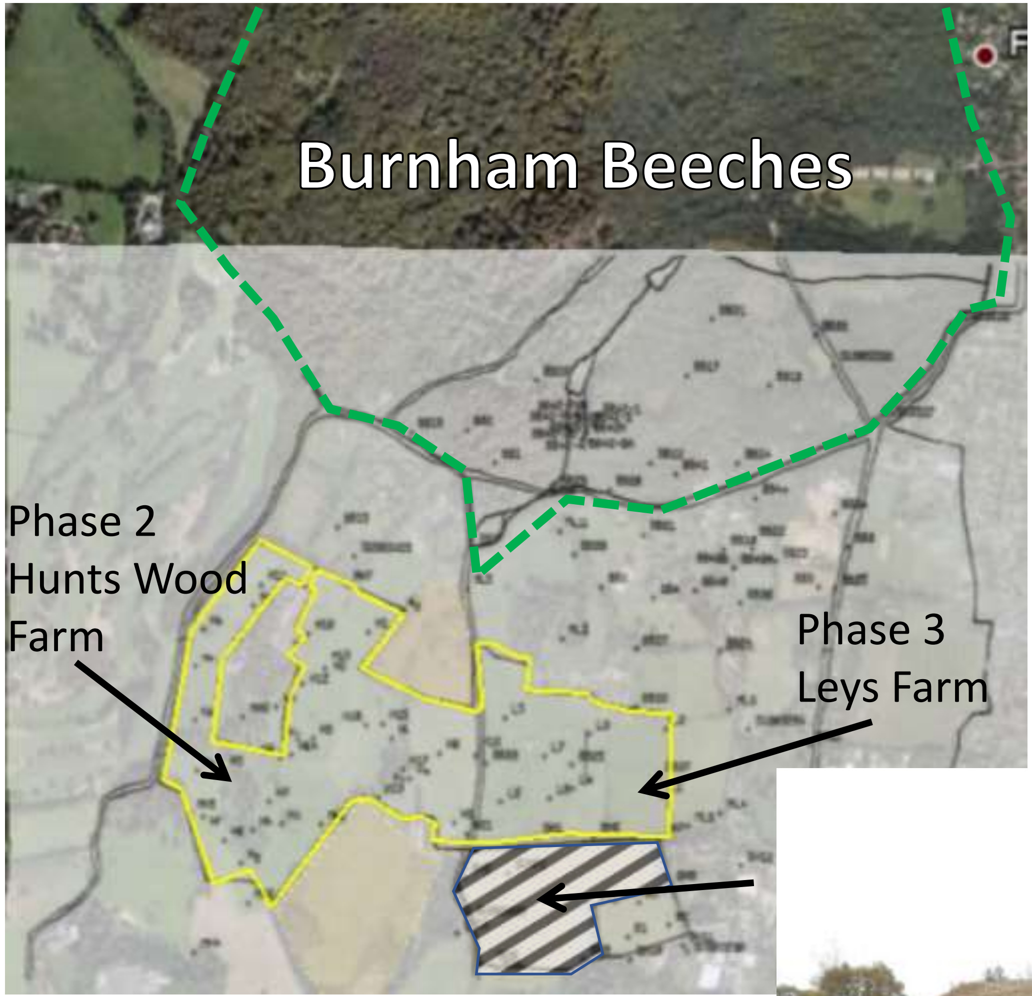
# Hydrology the Basics




During summer – less rain, more evaporation, take-up by plants – water levels fall

During winter – more rain, less evaporation, reduced plant take-up – water levels rise
more run-off, bogy areas and springs more active



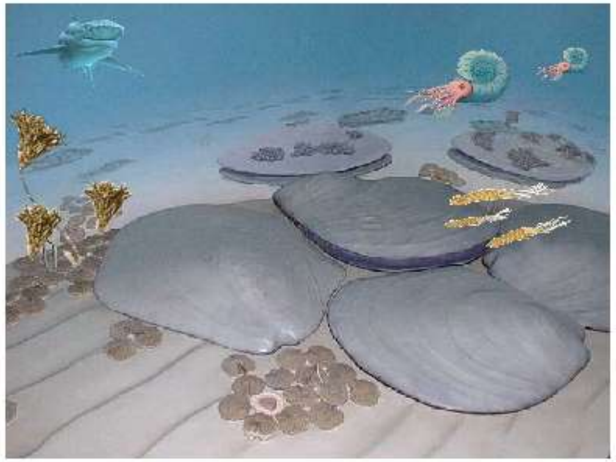

Despite strong opposition, in 1982 permission was given to extract gravels from a lower Terrace (Boyn Hill) south of Burnham Beeches.

Concerns about impact on Burnham Beeches by lowering water table. If a hydraulic connection exists. In 1988 this resulted in a program of boreholes being drilled and monitored.

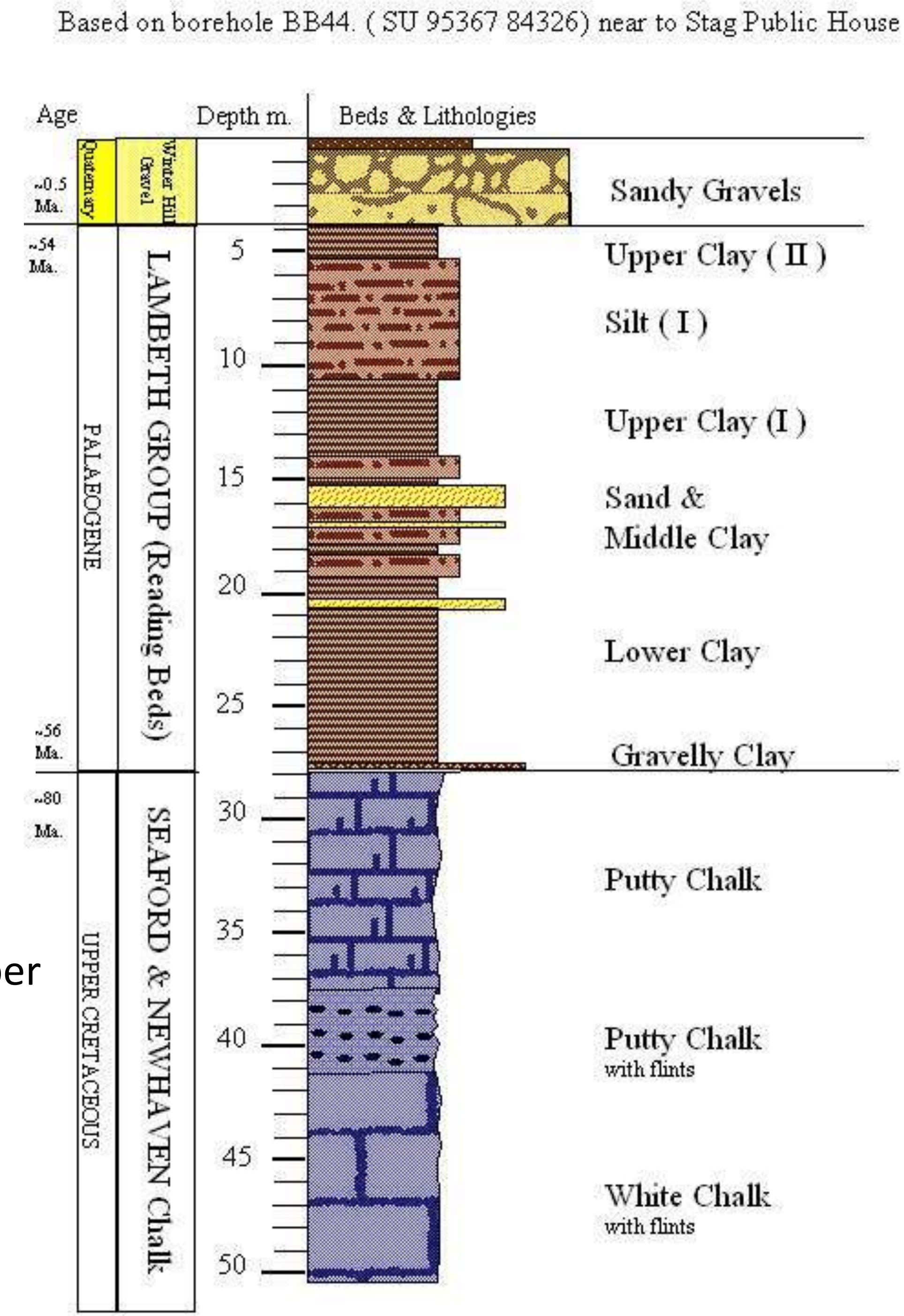
# East Burnham Quarry

Winterhill Terrace Quaternary ~0.45Ma

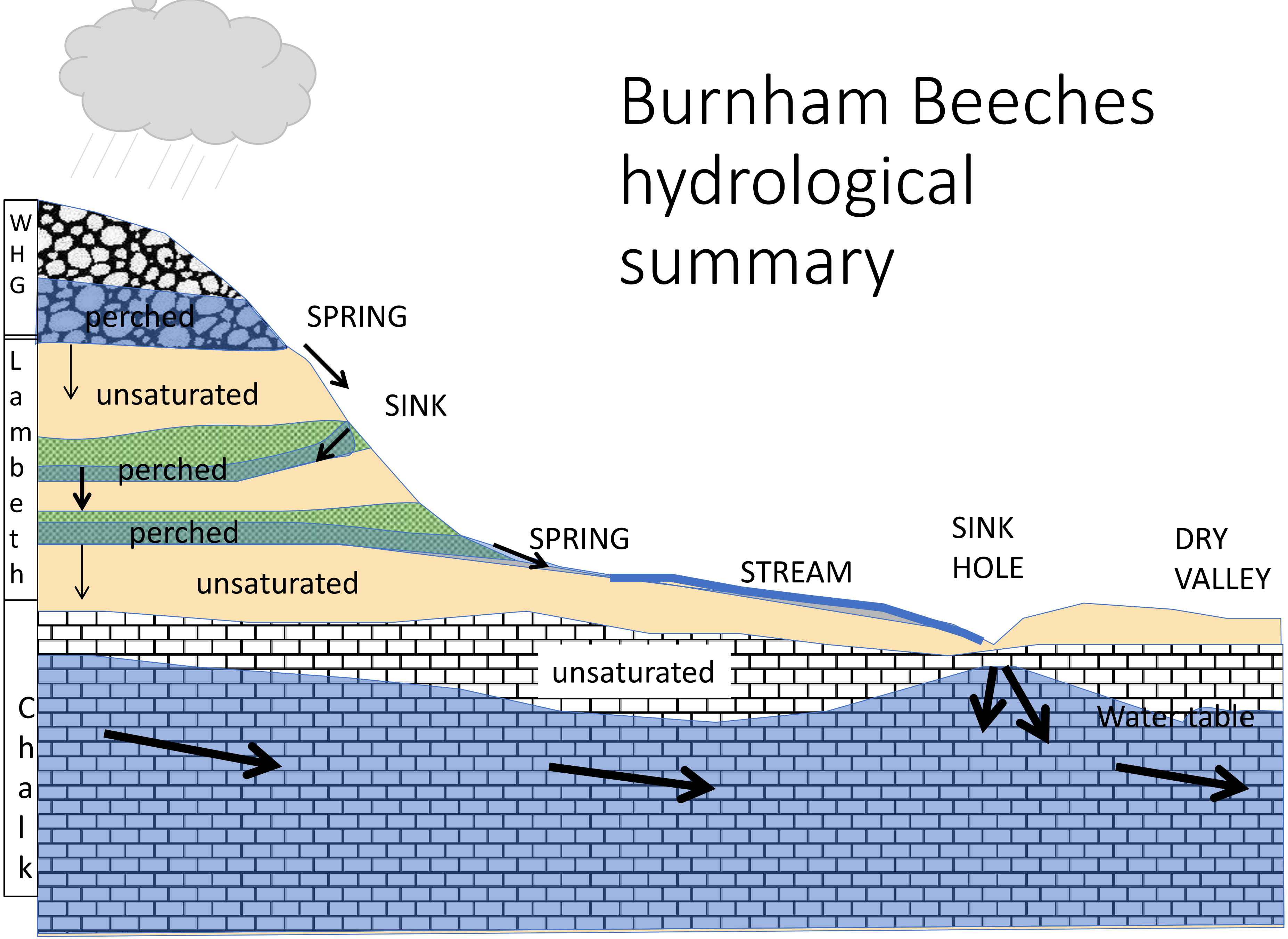
Lambeth Group Palaeocene 56-54Ma



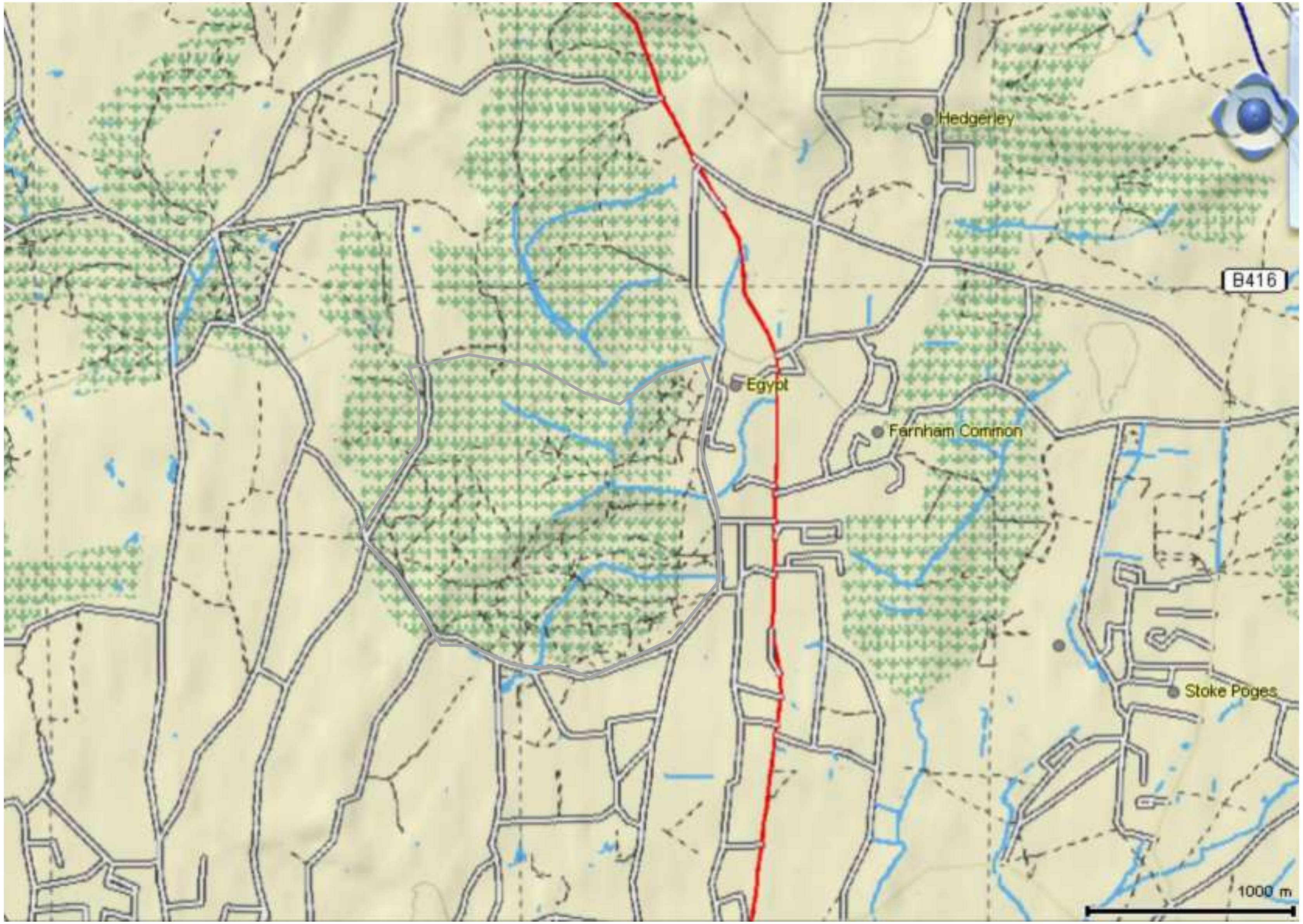
Chalk – Upper Cretaceous ~80Ma

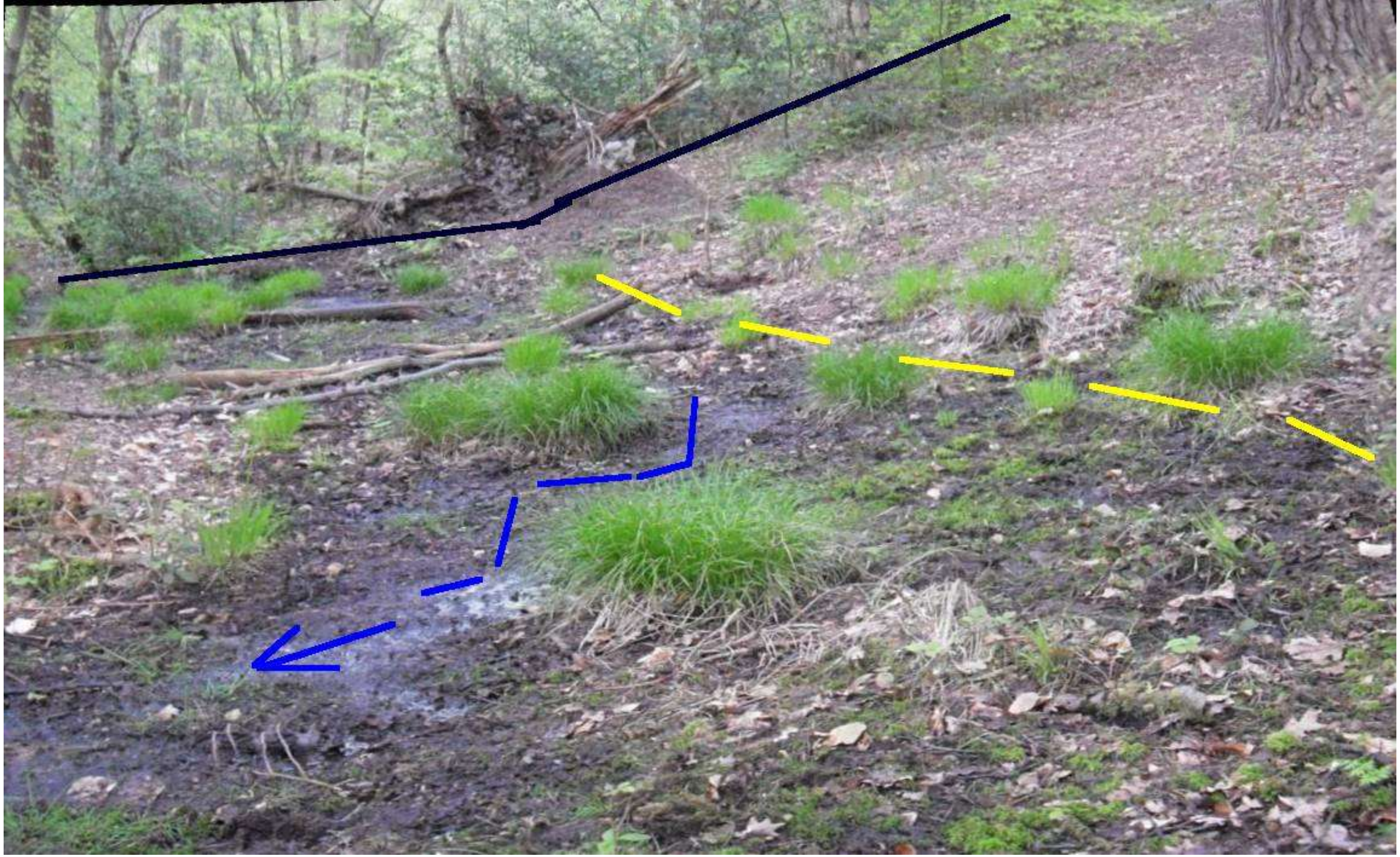


# Burnham Beeches hydrological summary



# Streams in and around Burnham Beeches





Springs develop at interface between gravels and clays, notice also break in slope

Clays and silts – springs, mires, streams.


Swilly Pond May 9th 2010


# Swilly pond Jan 3rd 2010


I hope this talk has inspired you to visit

THE END OF PART 3…..

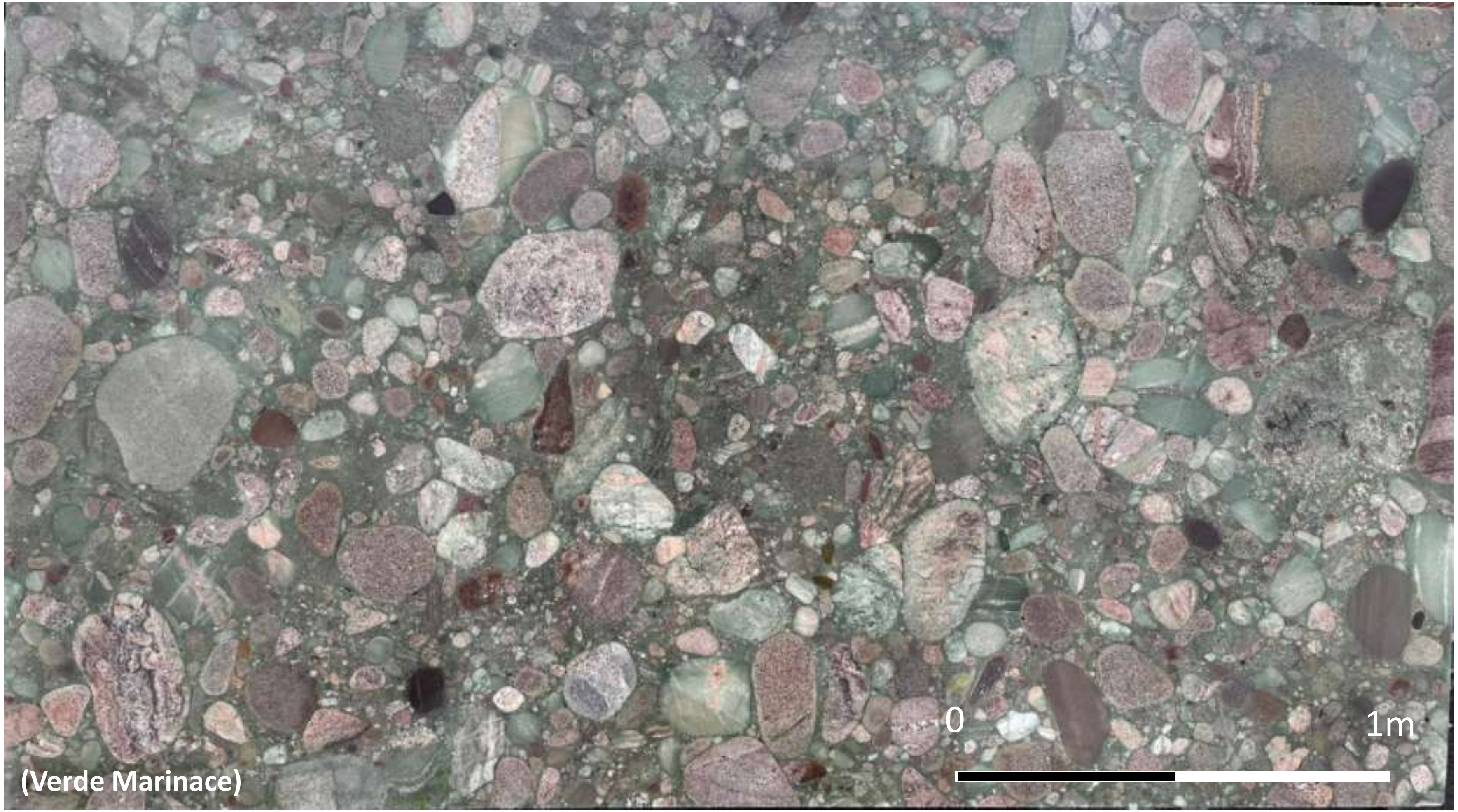
# A Bit of Brazil In Bath

Bath Christmas Social 2021 (Geology of Kitchen Worktops).

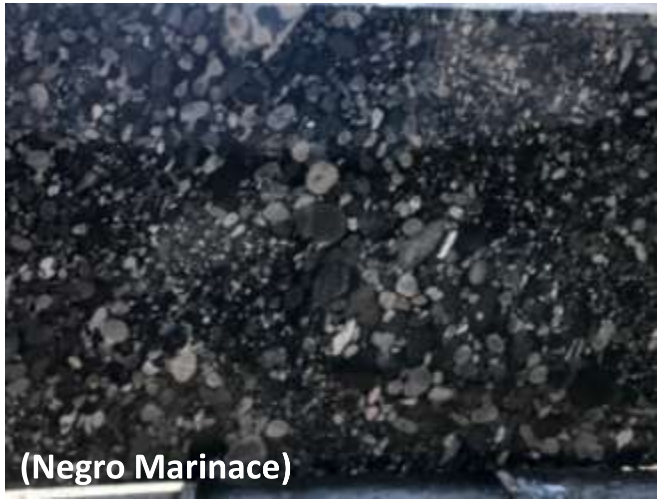

★ Star of The Show….

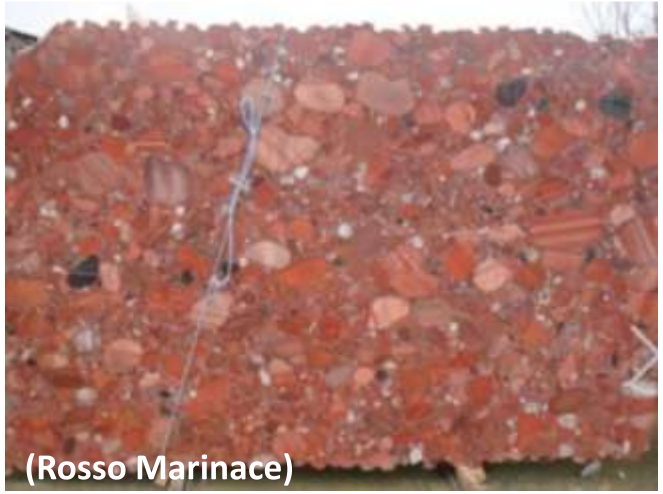
Paleoproterozoic polymict metaconglomerate (Eastern Brazil)

On public display in Bath…..



## Varieties...

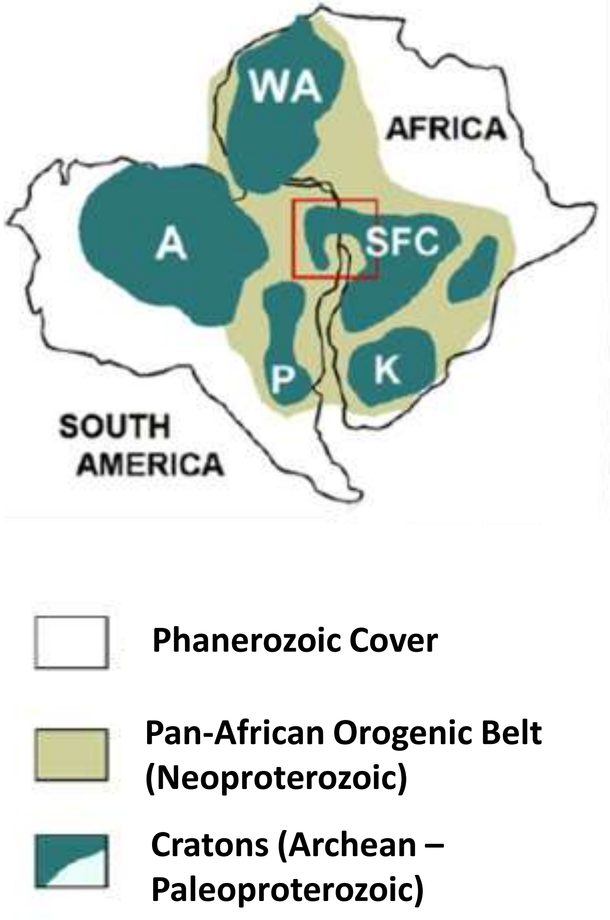


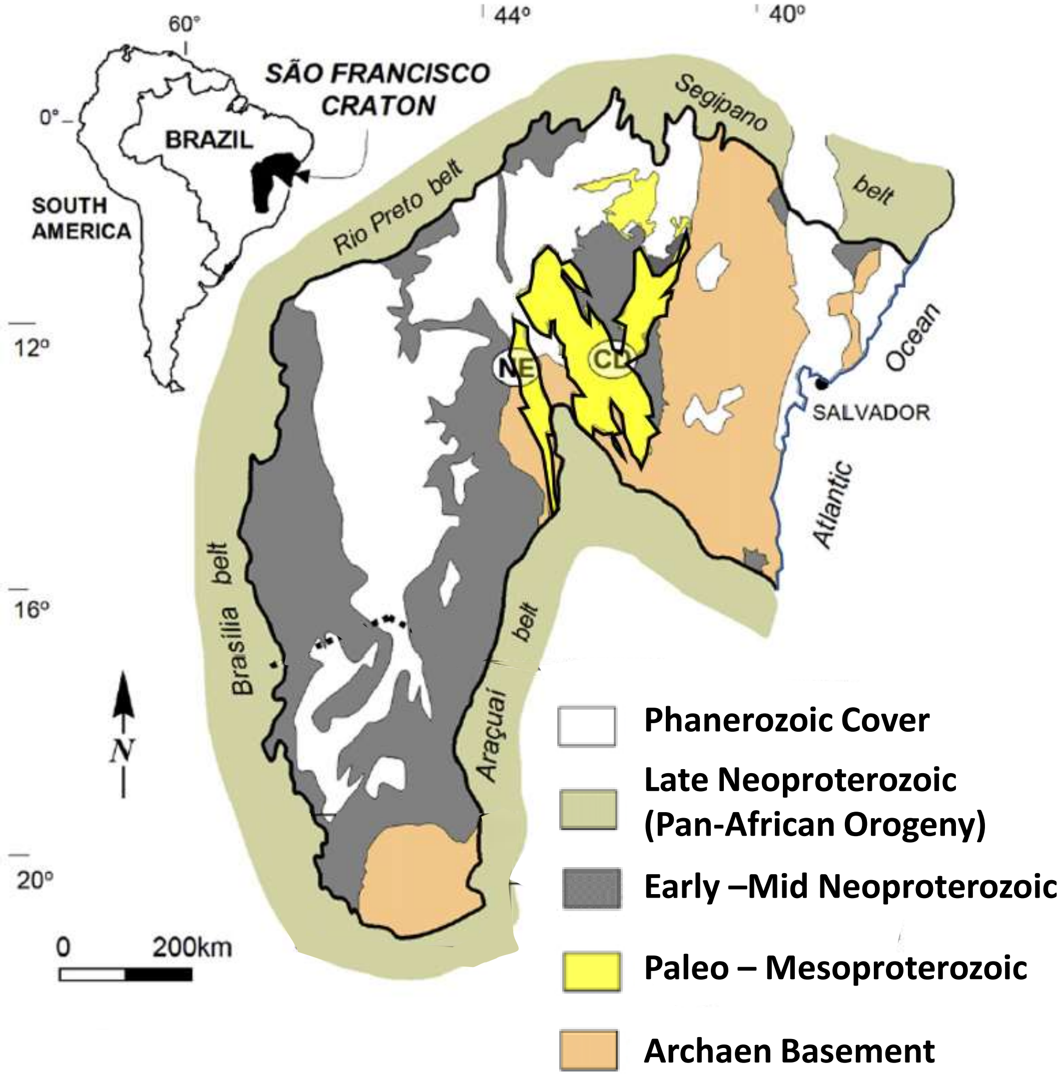





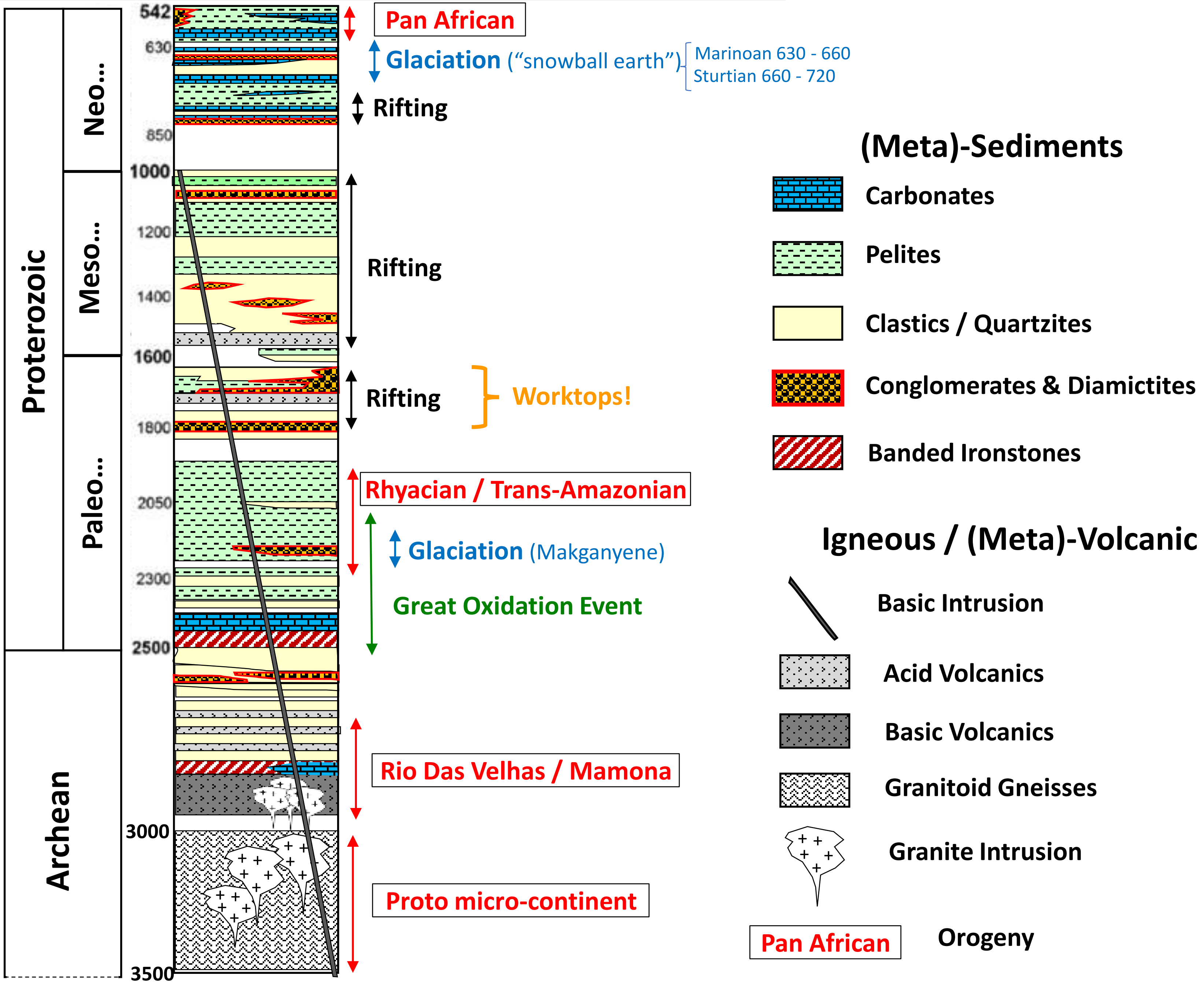
## University College Hospital London (Monolith and Shadow sculpture by John Aitken)

# Geological Context

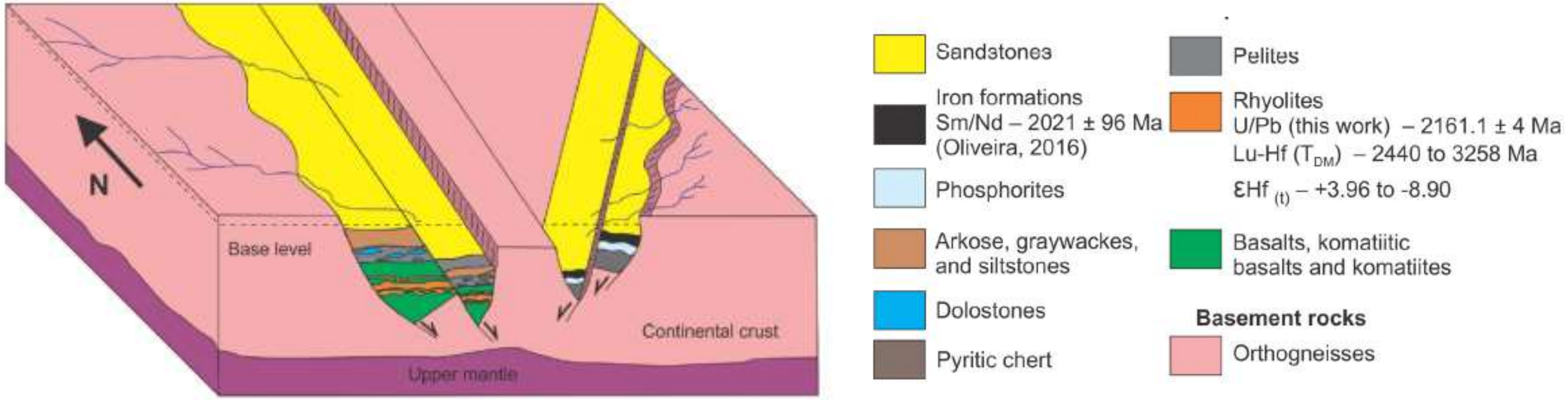


# Sao Franciso Craton : Precambrian Sequence (simplified)



# Paleoproterozoic Rift Geometries (schematic)



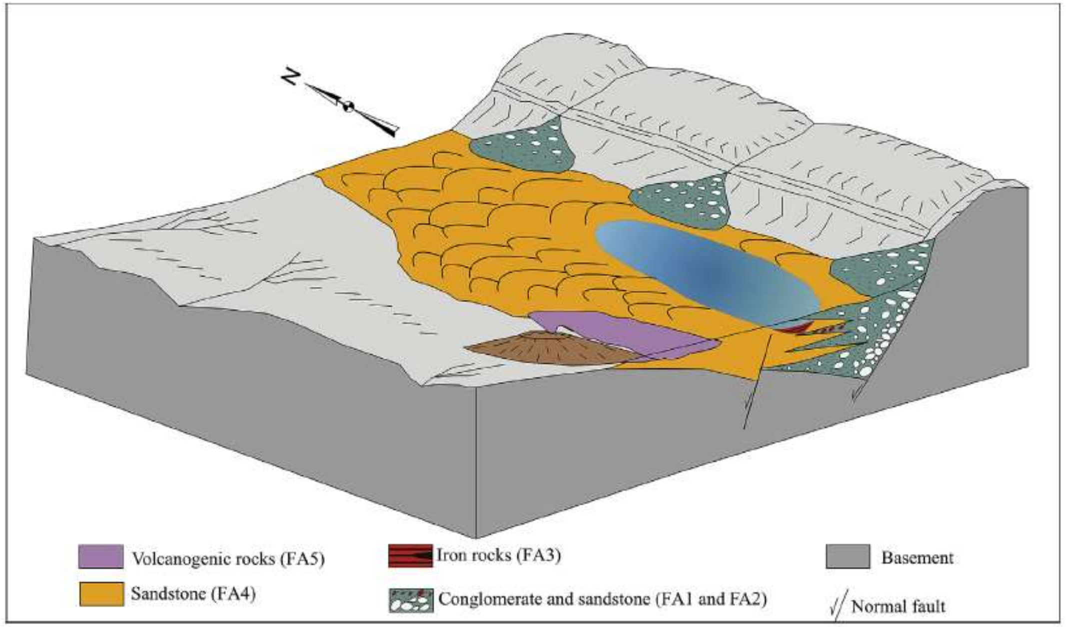
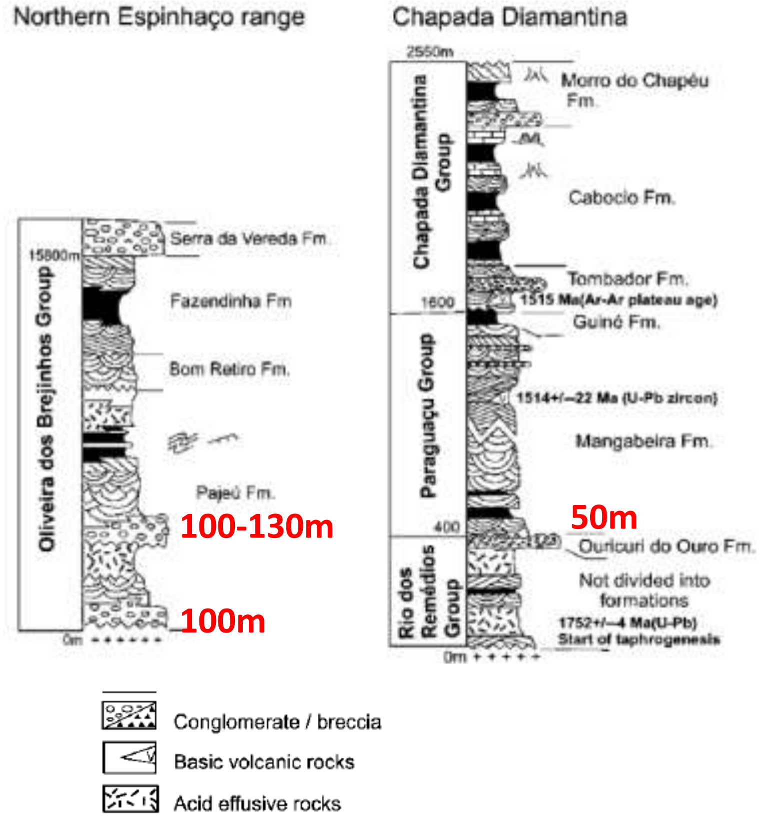




**Fig. 16.** Schematic illustration of the basin-fill evolution for the Terra Vermelha Group and related facies association.



# Metasediment Outcrops

a) Actinolite Marble

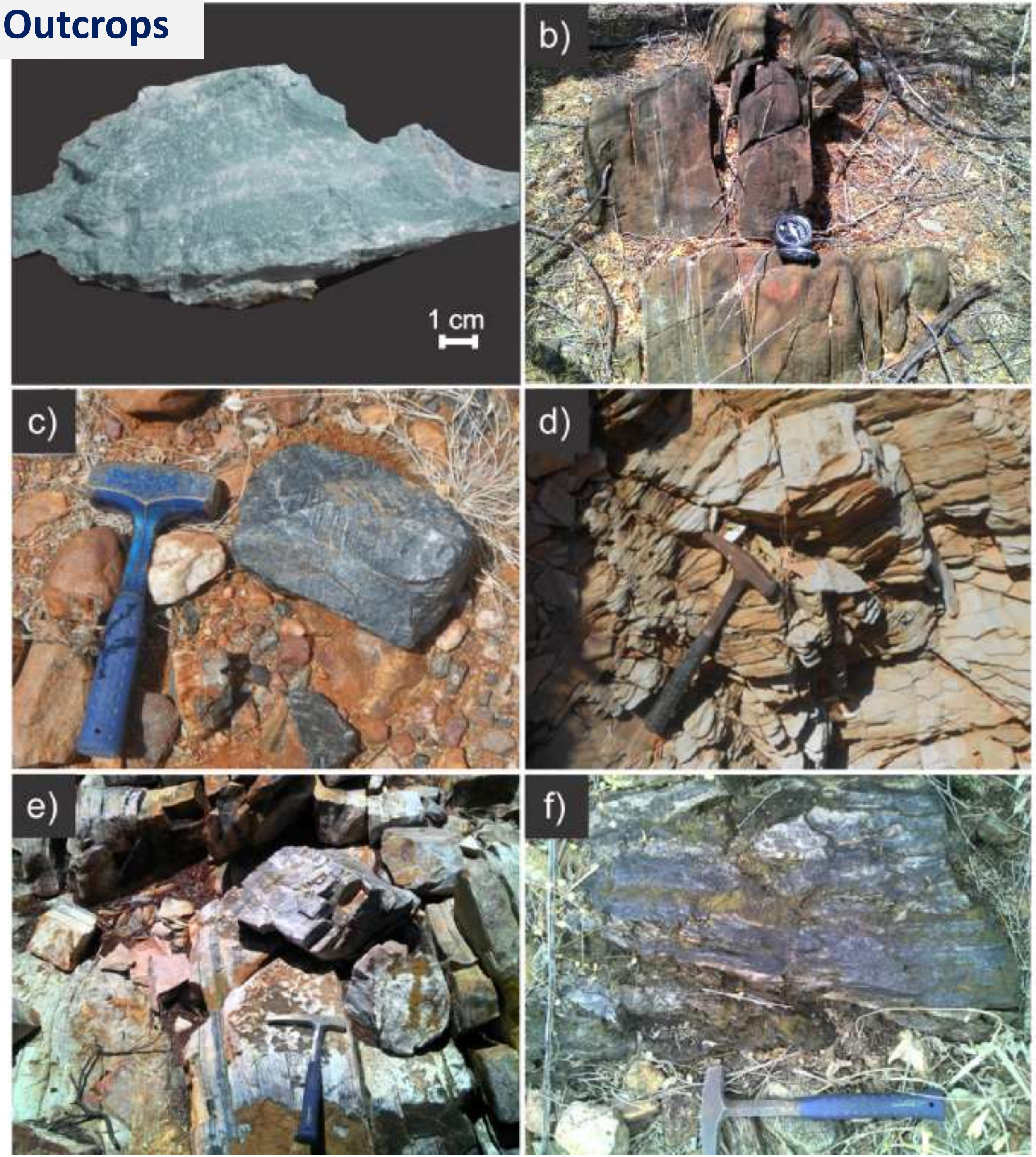
b) Metadolostone (showing bedding)

c) Metachert (pyritic massive)

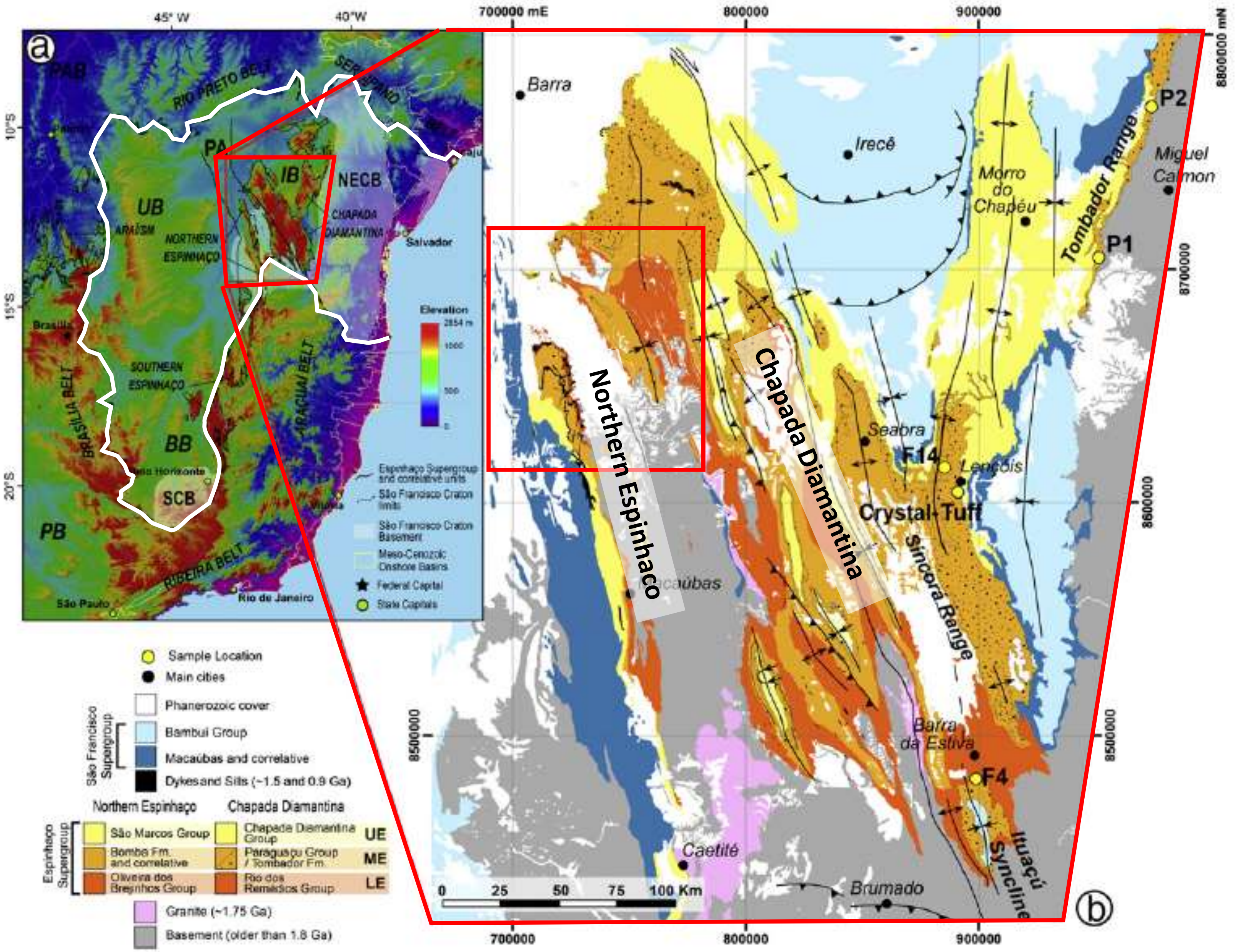
d) Phyllite

e) Quartzite with depositional with light (quartz-rich) and dark (tremolite & tourmaline-rich) layers

f) Magnetite-bearing banded iron formation



# Area of Interest (Northern Espinhaco & Chapada Diamantina)




F. Guadagnin et al. / Gondwana Research 27 (2015) 363–376

# Surface Geology / Quarries

Neoproterozoic (635 My – 1 By)

Mesoproterozoic (1.0 By – 1.6 By)

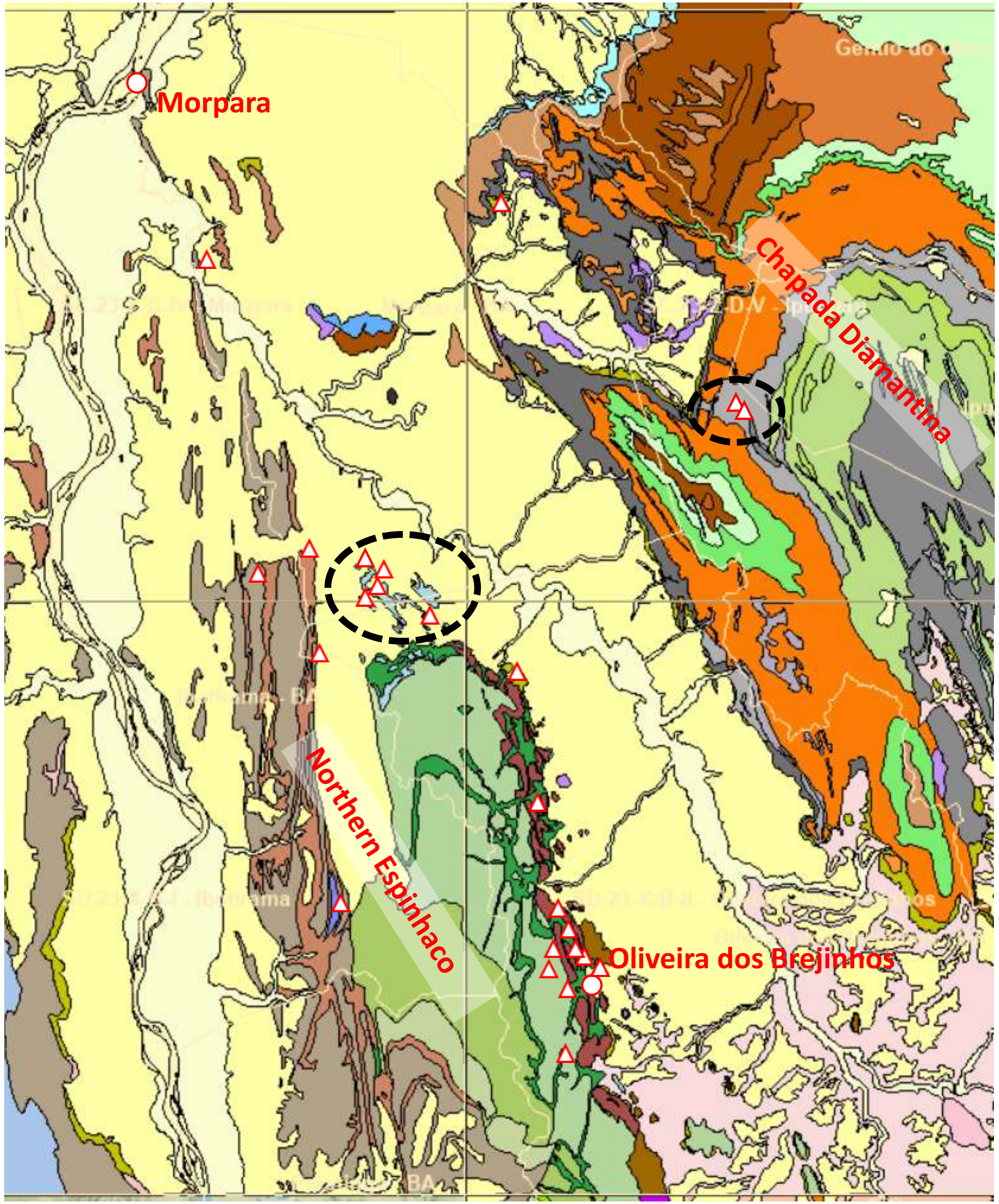
Paleoproterozoic (1.6 By – 1.8 My)

Archaean (> 2.5 By)

Basic Intrusives (circa 850 My)

Ornamental Stone Quarries

Metacongolmerate Quarries



## A bit of Brazil In Bath can be found at....

BATH PIZZA CO

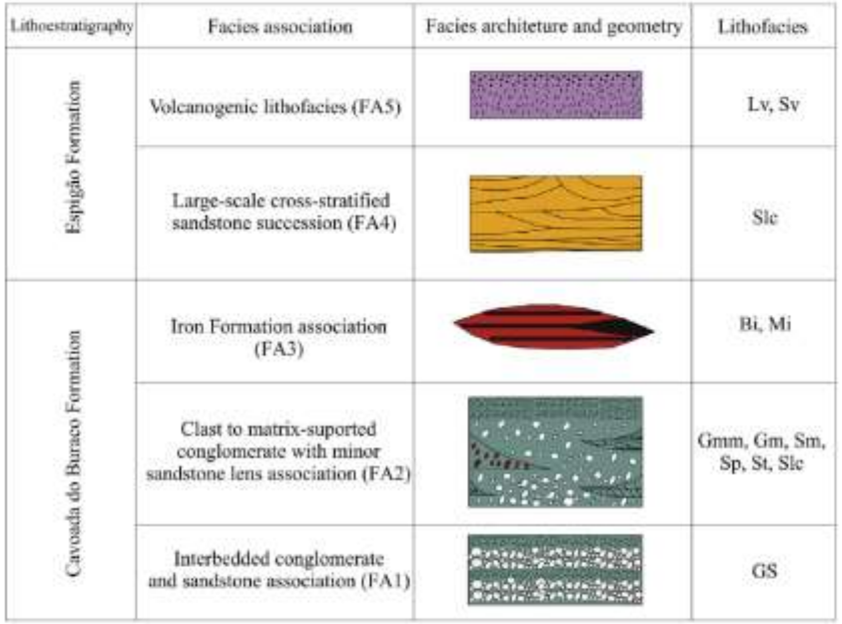


LHS


RHS

# Extras….

Record of a Statherian rift-sag basin in the Central Espinhaço Range: Facies characterization and geochronology. Alice Fernanda de Oliveira Costa (2018)



| Lithoestratigraphy | Facies association | Facies architeture and geometry | Lithofacies |
|---|---|---|---|
| Espigão Formation | Volcanogenic lithofacies (FA5) | | Lv, Sv |
| | Large-scale cross-stratified sandstone succession (FA4) | | Slc |
| Cavoada do Buraco Formation | Iron Formation association (FA3) | | Bi, Mi |
| | Clast to matrix-suported conglomerate with minor sandstone lens association (FA2) | | Gmm, Gm, Sm, Sp, St, Slc |
| | Interbedded conglomerate and sandstone association (FA1) | | GS |

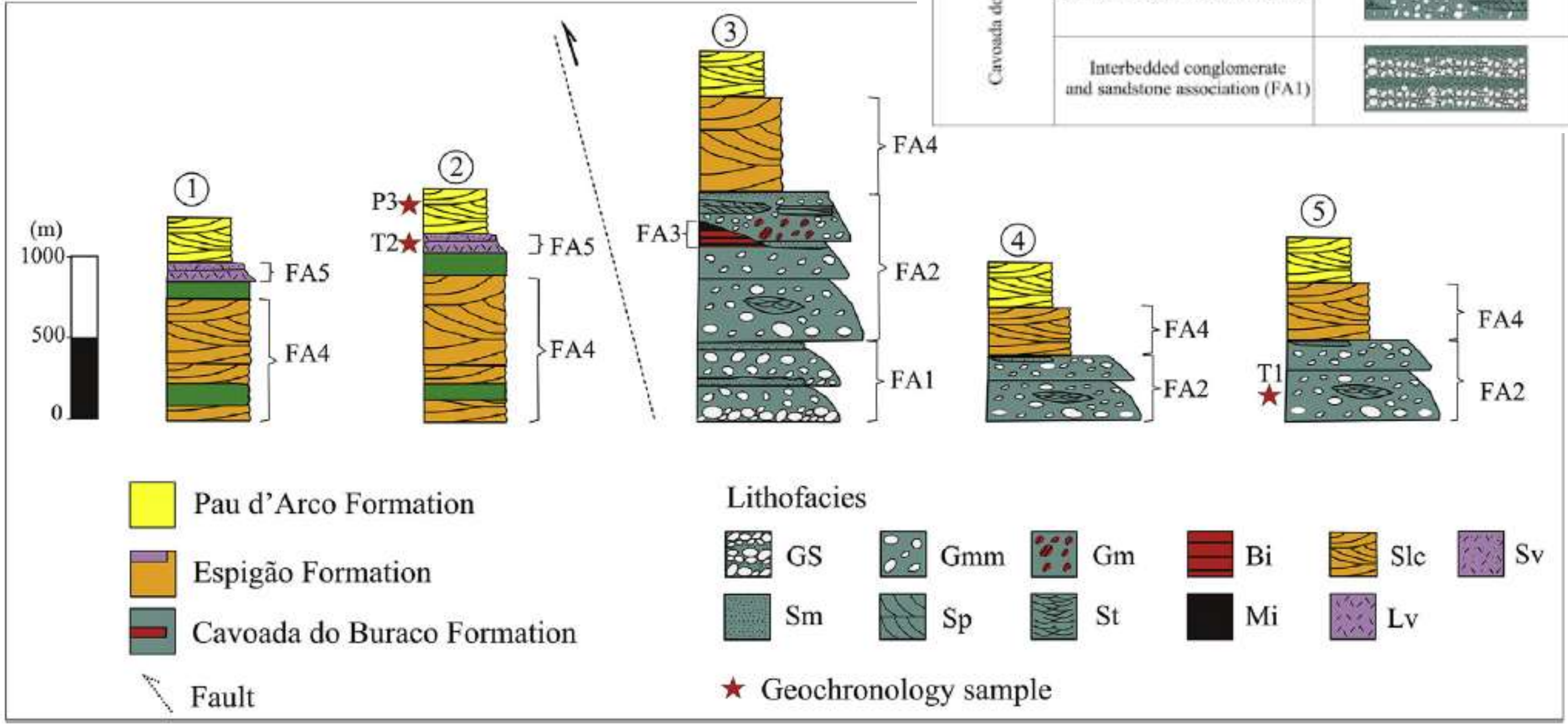



**Fig. 3.** General stratigraphic columns showing disposition of the different facies association and stratigraphic units.

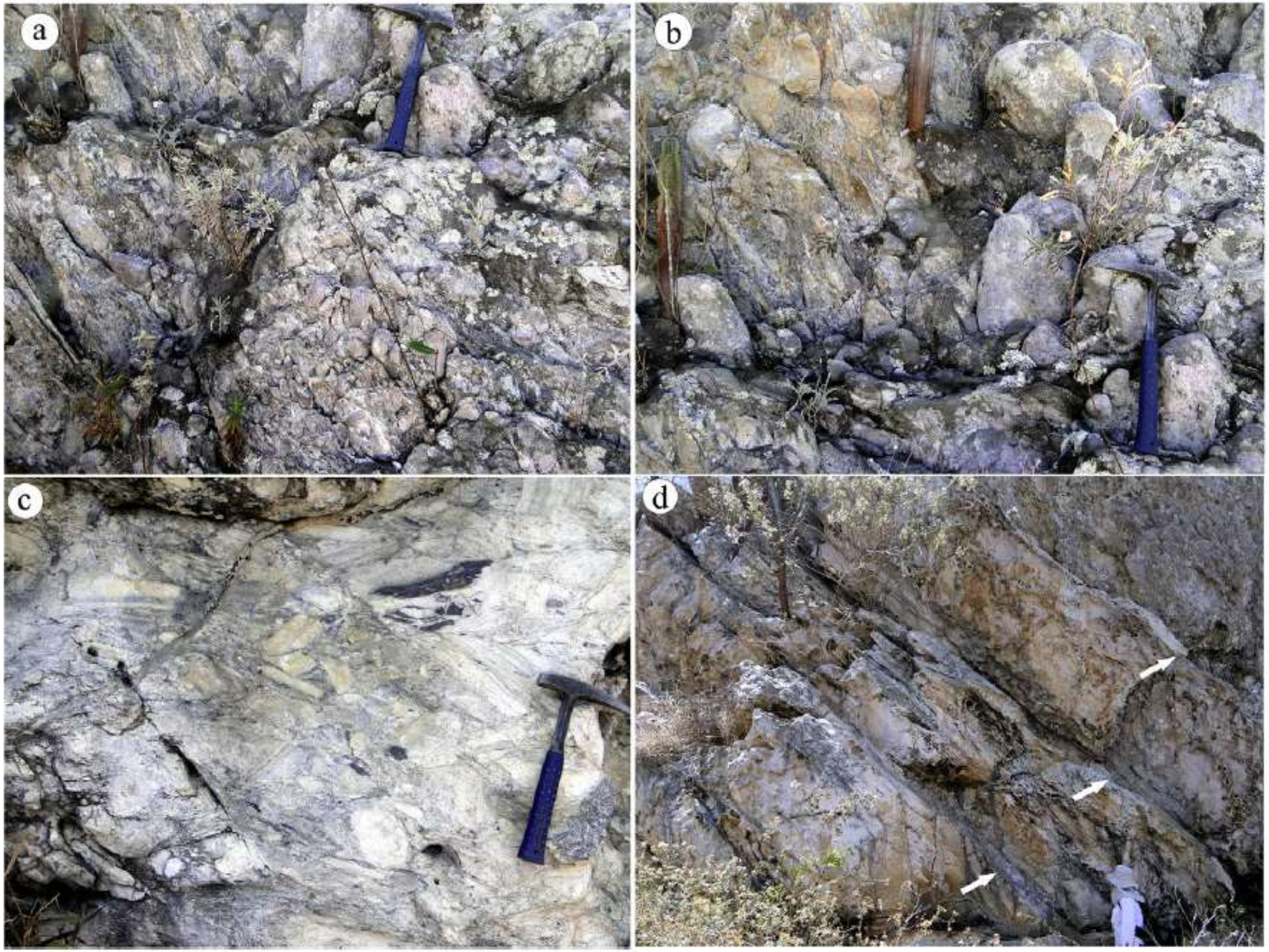


Fig. 5. Lithofacies from FA1 association: (a) Massive matrix-to clast-supported conglomerate with disorganized framework; (b) layer of matrix-supported with scattered boulders; (c) layer of clast-supported conglomerate with angular clasts; (d) matrix-supported conglomerate separated by thin layers of sandstone (Sm).

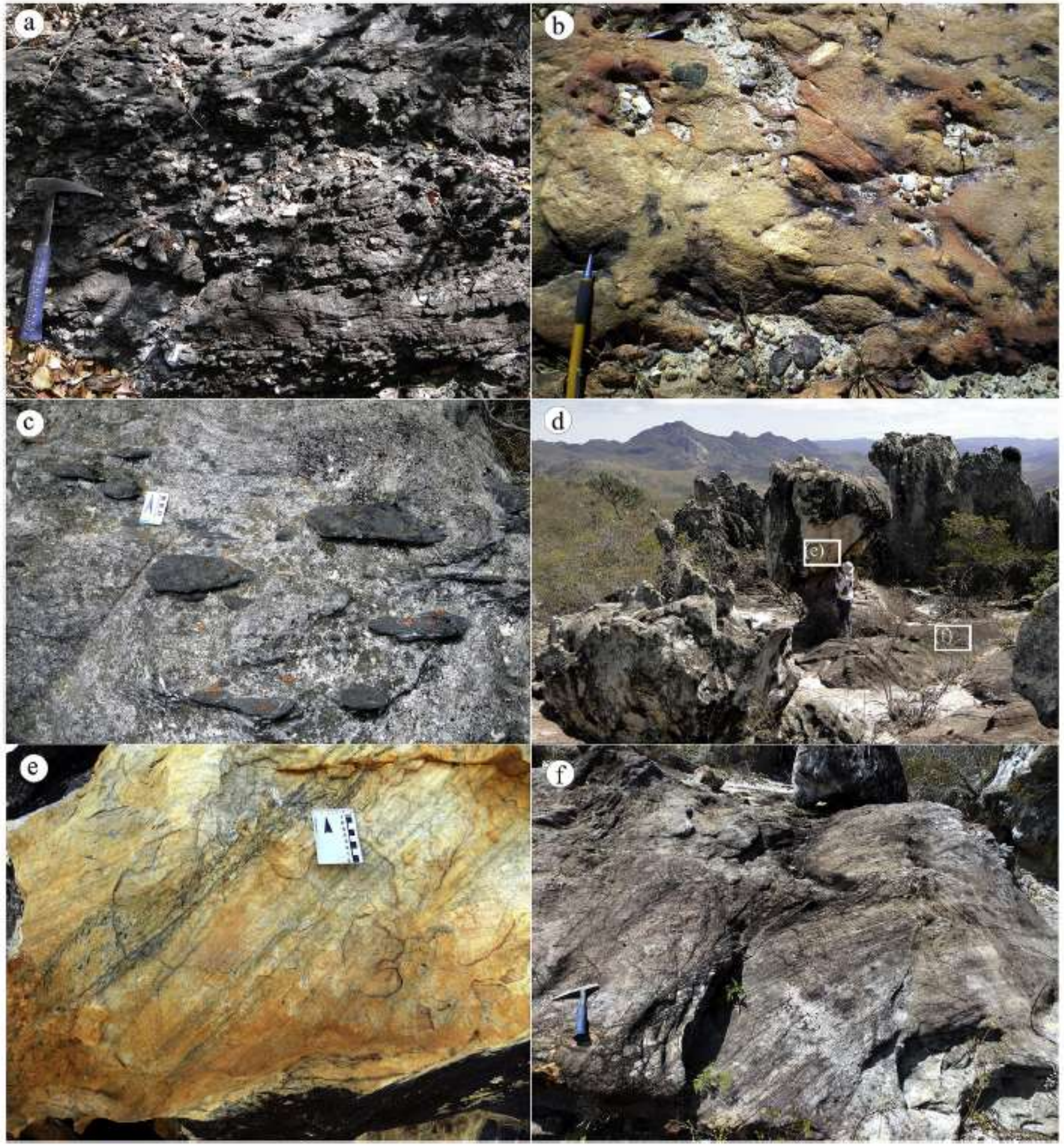
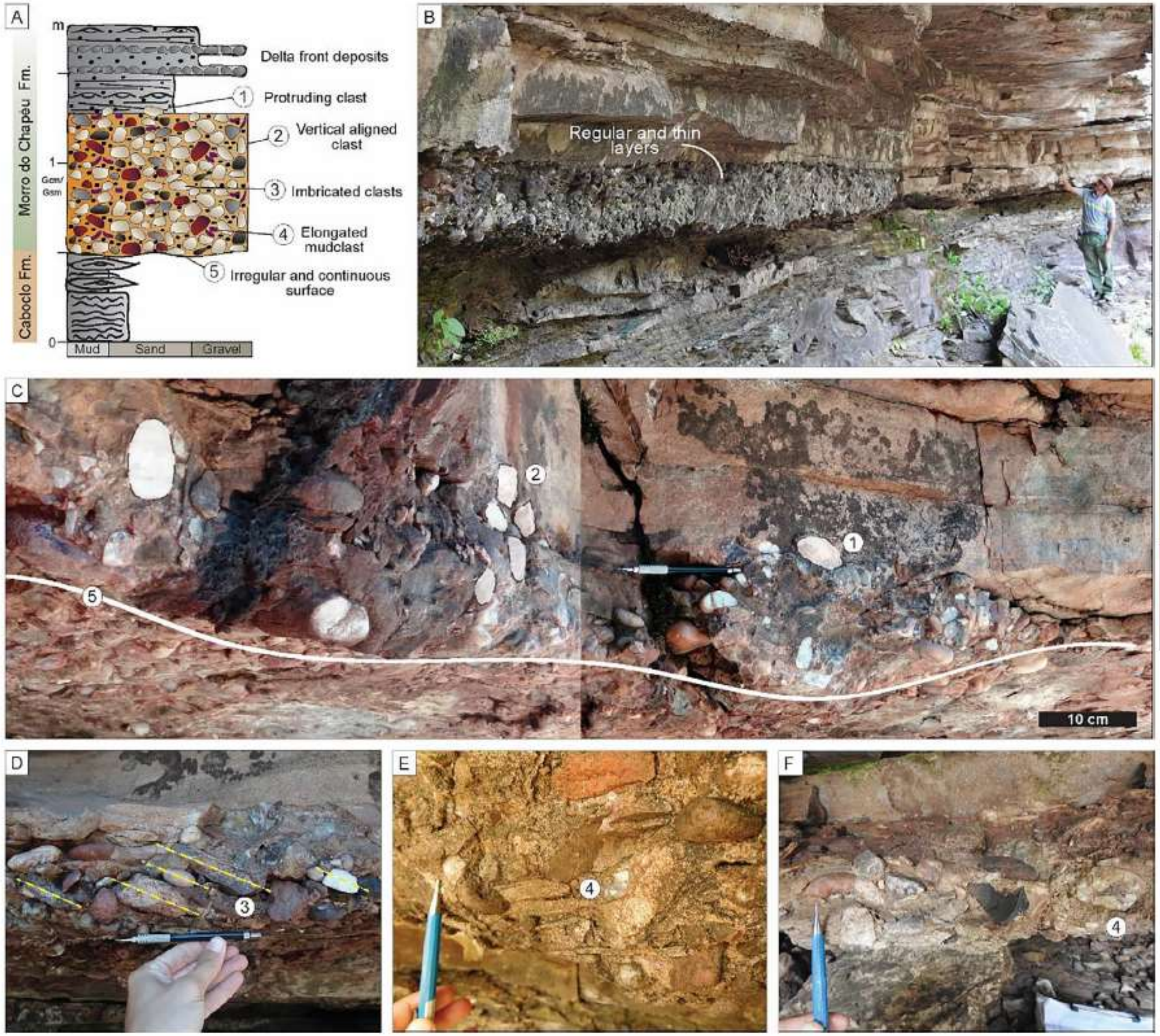



Fig. 7. Lithofacies from FA2 association: (a) Conglomerate Gmm with a sandstone St lens; (b) Matrix-supported polymictic conglomerate (Gm lithofacies); (c) Matrix-supported conglomerate with Bif's clasts; (d) Large-scale cross-stratified sandstone (Slc lithofacies) with planar-cross bedded sandstone bed (lithofacies Sp); (e) Enlarged view of lithofacies Sp marked by heavy minerals; (f) Enlarged view of lithofacies Slc.

Sequence stratigraphy of the mixed wave-tidal-dominated Mesoproterozoic sedimentary succession in Chapada Diamantina Basin, Espinhaço supergroup– Ne/Brazil E. G. de Souza (2019)




| Era | Tectonic environment | Supergroup | Group | Mega-sequence | Formation |
|---|---|---|---|---|---|
| | | | Fig. 1A | | Fig. 1B |
| | | | | | Phanerozoic cover |
| Neoproterozoic | Rift<br>1st-order | São Francisco | Una | | Salitre |
| | | | | | Bebedouro |
| Mesoproterozoic | Rift - Sag<br>1st-order | Espinhaço | Chapada Diamantina | Upper | Morro do Chapéu |
| | | | | | Caboclo |
| | Sag<br>1st-order | | 1st-order | Middle | Tombador |
| | | | Paraguaçu | | Açuruá |
| | | | | | Mangabeira |
| Paleoproterozoic | Rift<br>1st-order | | Rio dos Remédios | Lower | Lagoa de Dentro Ouricuri do Ouro |
| | | | | | Novo Horizonte |
| | | | | | Serra da Gamelera |
| | | | | | Basement |

Fig. 4. A) Main characteristics of alluvial deposits (see Table 2); B) The single occurrence as a regular and thin layer with wide lateral extent, bounded by continuous and undulated surfaces; C) Layer details and representation of main larger clasts with vertically orientation; D) Imbricated and parallel clasts with the major axis to NW; E and F) Wide variation of form and composition of clasts, where the larger are subrounded to rounded while smallers are angular and low sphericity.

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# THE END!