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Gross Crustal Structural Setting of Geothermal Resources in Africa

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1. Why consider the matter?

Thanks to Dr. Lund, and the Lindal diagram, we now know of the variety of uses of geothermal fluids in virtually the whole range of enthalpies above ambient

- Excellent examples exist in Africa in use of low enthalpy resources: E.g. Kenya, Tunisian Sahara!
- Our interest in the resource should thus expand beyond high enthalpy resources & the electricity objective
- Interest should expand beyond the magmatic northern part of EARS
- That way, Africa can increase its usable geothermal resource base

2. Outline

- Intro.: where does the heat at the surface come from?
- Tectonic state of Africa
- The Platform region (extensional tectonics)
  - Regions of uplift
    - Rifted zones
    - Zones of thinned lithosphere
  - Regions of subsidence
    - Intracontinental basins
    - Marginal basins
- The fold mountain regions (compressive tectonics)
- Distribution of known hydrothermal activity

3. Where does the heat at or near the surface come from?

a. Radio-activity, mainly in the crust: U, Th, K

b. Conduction of mantle heat through the crust

c. Mass movement in the solid crust:

- Compression
- Shearing

d. Basin subsidence & diagenesis:

- Sediment compaction
- Clay dehydration

e. Mass transport at plate margins:

- Magma rise from deep sources
- Hydrothermal activity in upper crust

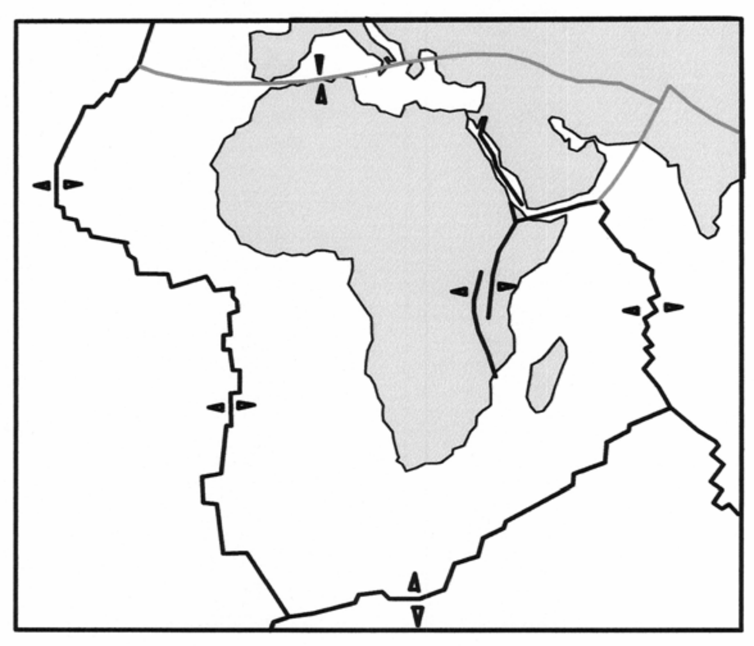
a & b: regionally near uniform: diffuse

c – e: localized: mostly concentrated

4. Gross tectonic state of Africa

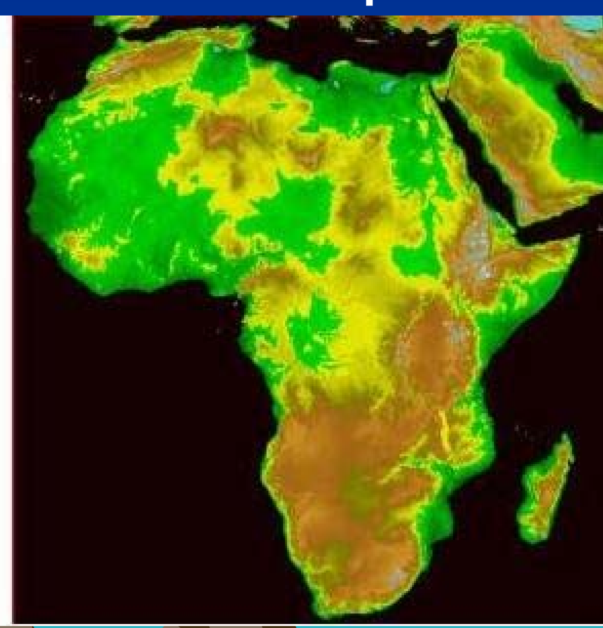
- Africa pressed from all sides; Far field stretching cannot account for rifting
- Its fragmentation through rifting must have an internal energy source
- Imagine: Africa moved rapidly north till about 40 mya; then it became much slower: Europe got in the way.
  - What happens to the energy saved?

$E = {}^{1}/_{2} mv_1^2 - 1/2 mv_2^2 /$ unit time (Emiliani, 1997)



5. Plateau topography is characteristic of Africa

- Plateau is coincident with large negative Bouguer gravity anomaly
- Topographic swell due to uplift in zones of thinned lithosphere overlying region of anomalous temperature in asthenosphere
- Africa is blistering over a huge mobile hot plate at about 100km depth



Result:

- The “standard African Lithosphere” (Girdler 1982) is 100km thick; instead of 120-130 km for continental lithospheres
  - This raises the temperature gradient in the solid outer layer of the earth under Africa
- In regions of up-swelling the lithosphere is still thinner and lower mantle rises to shallow levels:
  - Regions of normal mantle melting: < c35km (Girdler 1982)
  - Regions of metasomatic mantle melting: c40km (Wilson 2001)
  - Thicker lithosphere: little of no magmatism, but hot plate working

This is believed to account for differences in character of EARS magmatism & hydrothermal activity

- Nevertheless uplifted regions (mapped by strong negative gravity anomaly) have anomalous upward heat transport:
  - Where fractured including by incipient rifting high hydrothermal heat transport
  - explaining high incidence and vigor of hydrothermal activity in: E.g.: DRC, Zambia, Zimbabwe, Namibia, Drakensberg mountains

Regions of Subsidence:

a. Intracontinental basins in areas of thinned lithosphere:

- Cont. crust sagging into stretched & thinned mantle
  - Heated underneath

Central & Southern African sedimentary basins may have low to medium enthalpy geothermal prospects:

Karoo, Okavango, Barotse

b. Marginal basins

- Subject to thermal subsidence following E & W Gondwana departure, especially E. Gondwana:
  - Some have high temperature hydrothermal activity: E.g. Rufuji basin, Tanzania
  - Others may include W. Malagasy basin

May be useful to consider analogy with Gulf Coast of U.S.A (minus salt diapirs)

c. Sedimentary basins in regions of "standard lithosphere"

- Near-normal conductive heat flow through crust
  E.g. Saharan basin of Algeria, Tunisia & Libya: Intercalaire Continentale artesian aquifer, $70^{o}C$, 600-2800m, 1 million sq. km. of connate water: mined
- Another e.g.: Nile basin, Egypt

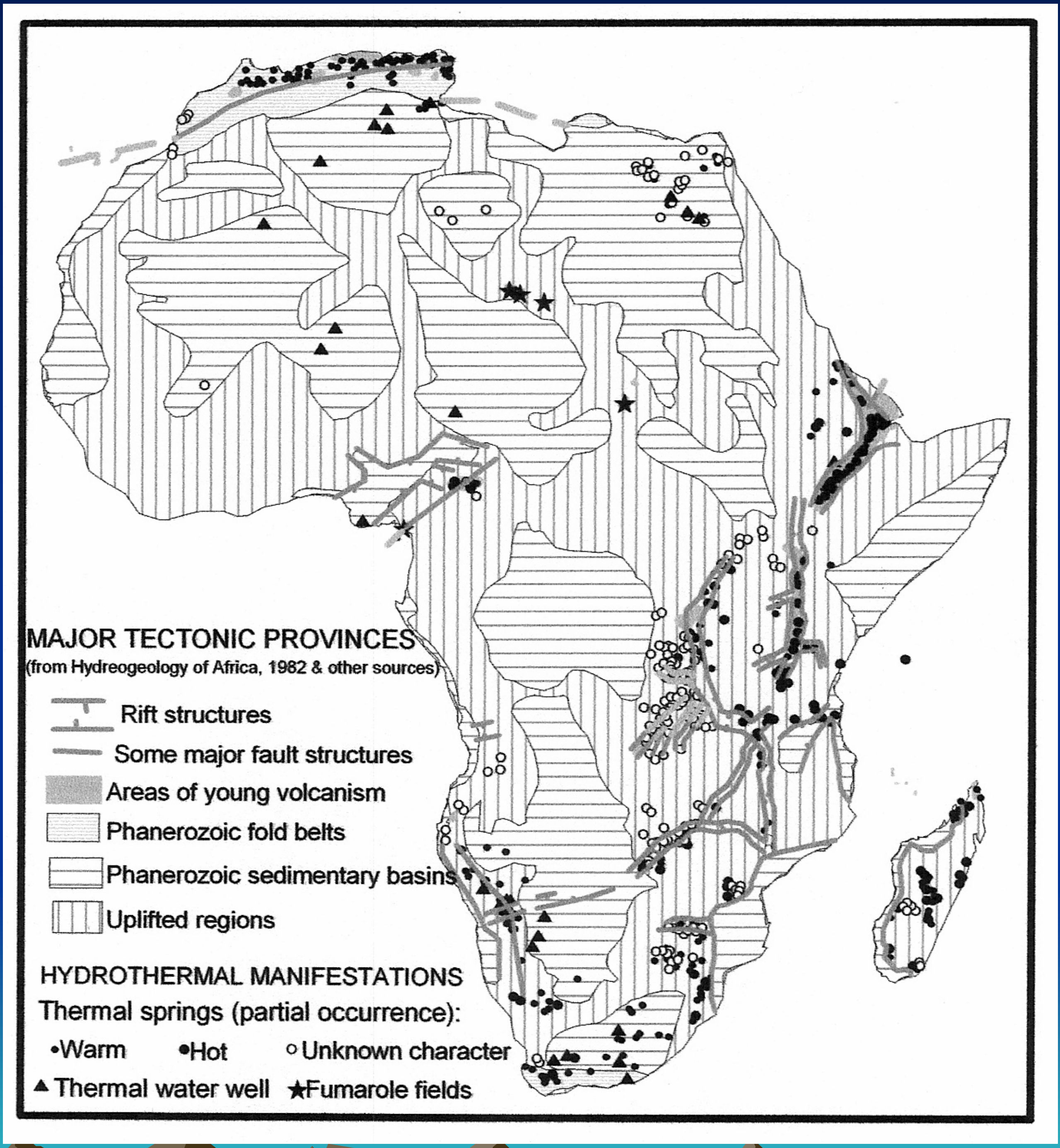
N.B. All deep sedimentary basins may also be heated through exothermic diagenetic processes:

- – Sediment compaction
- – Clay mineral dehydration

Fold Mountain belts

- Both are regions of negative gravity anomaly:
  - Atlas: deep mantle plume due to regional fault from the Canary Islands hot spot
    - c90km lithosphere also from seismic velocity studies (Rimi 2005)
  - Cape: Southern lobe of gravity anomaly due to deep mantle plume
- Both regions have low to medium temperature springs

Known Distribution of Hydrothermal Activity



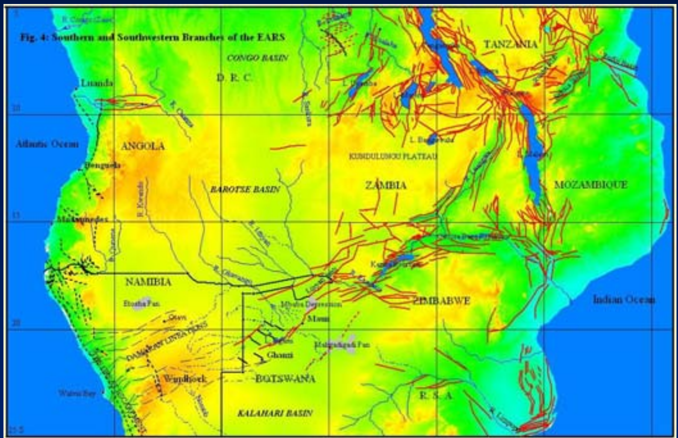
CONCLUSIONS

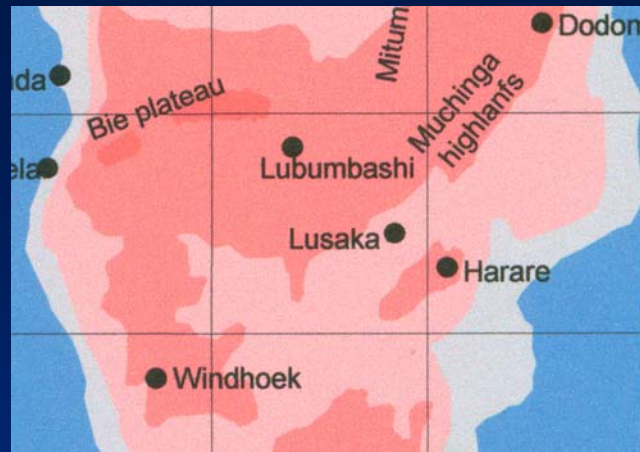
- Virtually all grades of geothermal resources have use where resource occurrence & opportunity of economic use coincide: Interest should broaden to exploit this.
- Best starting point is carrying out reliable & complete inventory, first stage geological & geochemical characterization of hydrothermal features, inventory of use opportunity, matching & ranking: There is much to be done in this.
- Oil exploration drilling provides useful data for sedimentary basins: It should be accessed and analyzed; learn from the Maghribi, they are good at it

LET US CONGRATULATE UGANDA GEOLOGICAL SURVEY
FOR JUST COMPLETING THE NATIONAL INVENTORY OF HYDROTHERMAL FEATURES

ASANTE SANA

This preliminary work was encouraged by UNEP (Nairobi)





Many thermal springs but slow rifting; among other reasons?:

Rifting favors not yet cratonized rocks with consistent rock fabrics

Above region:

Proterozoic folded formations with Archean cores, complex fold axes

Not easy to break?