Second International Conference on the Geothermal Resources of the East African Rift Region

Entebbe,

November 24-28, 2008

Geologic Conditions of Hydrothermal Feature Occurrence in Africa: Some Heating Mechanisms

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1. Why address this issue?

Hydrothermal features = the most OBVIOUS and EASILY ACCESSIBLE surface manifestations of subsurface geothermal resources.

The FEATURES are SAMPLES of the RESOURCES;
NON-REPRESENTATIVE, MODIFIED SAMPLES but still samples.

A good understanding of surface features is essential for gaining a first reliable appreciation of the characteristics of the related underground resources & their potentials for economic exploitation.

Most geothermal prospects in Africa are not systematically explored

The Very first need in such cases: Understanding the gross geotectonic setting of hydrothermal feature occurrence and of the immediate geologic conditions which govern the heating and circulation of the fluids which issue at the surface.

This can create a reliable basis for successful resource exploration and development

A by-product: We can escape being haunted by magma body heat sources which may be lurking at depths which we cannot anyway reach by drilling to prove them

Singer (Sewing Machines) **Corporation** once illustrated a simple basic tenet of Exploration Philosophy. They did not exactly say it, but might have said

"***If you know what whatever you are looking for looks like, you will find it if it is there***".

Here we will try and see if we can know what we are looking for. The observable heating mechanisms that give rise to hydrothermal activities in selected regions of Africa.

2. Outline

- where does the heat at the surface come from?
- Where does it go?
- Tectonic features of Africa
- The distribution of known hydrothermal activity
- Examples of a variety of the heating and circulation mechanisms

3. Data sources

Innumerable publications;

On hydrothermal features, mainly:

Domestic publications from the EARS & Maghreb regions

Waring (USGS) 1965

Zarubezhgeologia, Moscow, 1981

4. The Earth's Heat

4.1 Heat Flow: Average for continental Africa= c51 mWatt m^{-2}

4.2 Heat Sources:

- C 2/3 of heat flow is of crustal origin: radioactivity, compressive crustal processes, diagenesis; mostly diffuse
- The rest is of sub-crustal origin: Conducted through the crust or convected along breaks in crust; the later, focused heat flow

4.3 Heat sinks:

- Primary: Energy dissipated in transporting lithosphere plates: driving continetal drift
- Secondary: fold mountain building, earth quakes, lithosphere uplift lithosphere melting; mostly concentrated along breaks in crust

IMAGINE: The thermal energy involved in transporting Africa northward before 30 Mya

IMAGINE: Heat energy not dissipated after Africa stopped moving at 30 Mya; Where is that energy going?

It has been and still is being dissipated in;

- heating and uplifting Africa to a much higher average elevation than any other continent of analogous tectonic nature.
- constructing the Atlas fold mountains
- generating and erupting the largest volume of magma since c270 Mya
- fragmenting Africa along the EARS,
- creating earthquakes;
- Creating geothermal systems: magma generation and transport at depth, hydrothermal fluid convection in the upper crust.

Some of us could starve if the last did not happen

5. The tectonic features which emanate from above:

5.1 The signs:

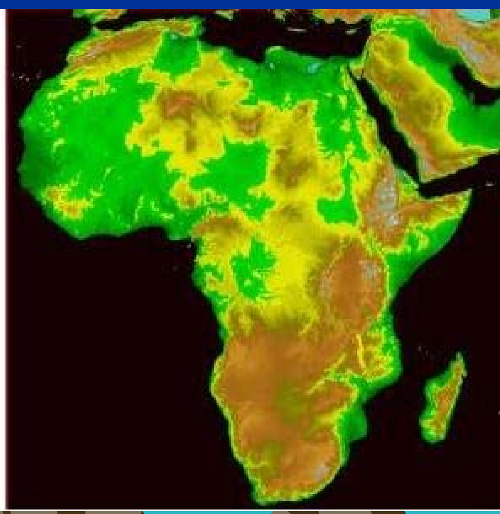
- Physiography (USGS & NOAA)

Unique feature: African super-swell

- The gravity field (Fairhead, 1979)

Unique feature: Large amplitude and wave length of negative anomaly matching the physiography

Interpret^{n}: Light weight African lithosphere



5.2 Cause and effect

- Seismic shear wave velocity tomography (Ritsema, 2004):

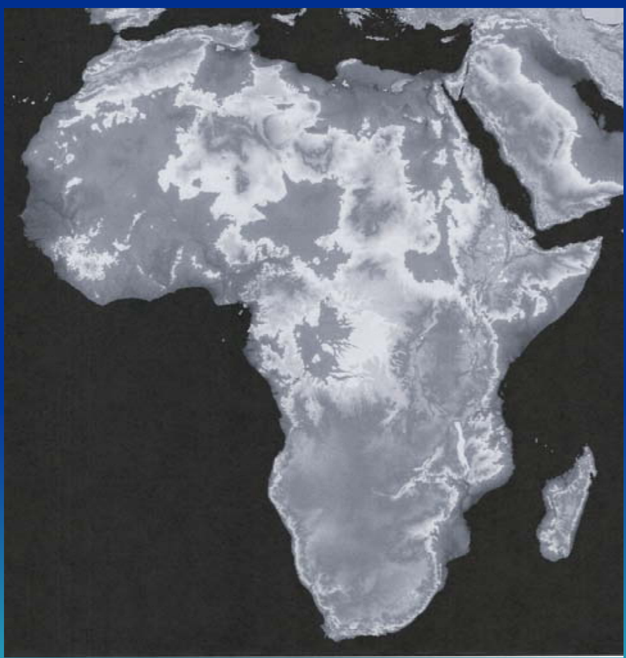
There is widespread low velocity in asthenosphere (i.e. higher than normal temperatures beneath Africa)

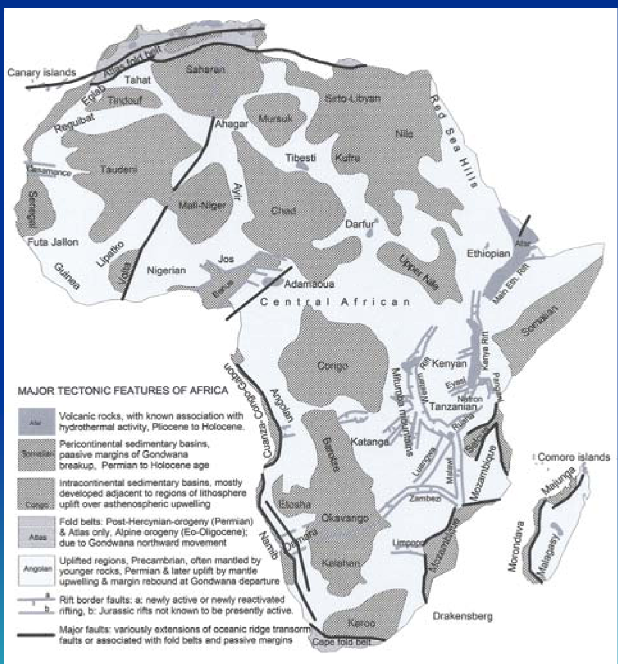
Interpret^{n}: Thermal expansion caused light weight African lithosphere

Effect

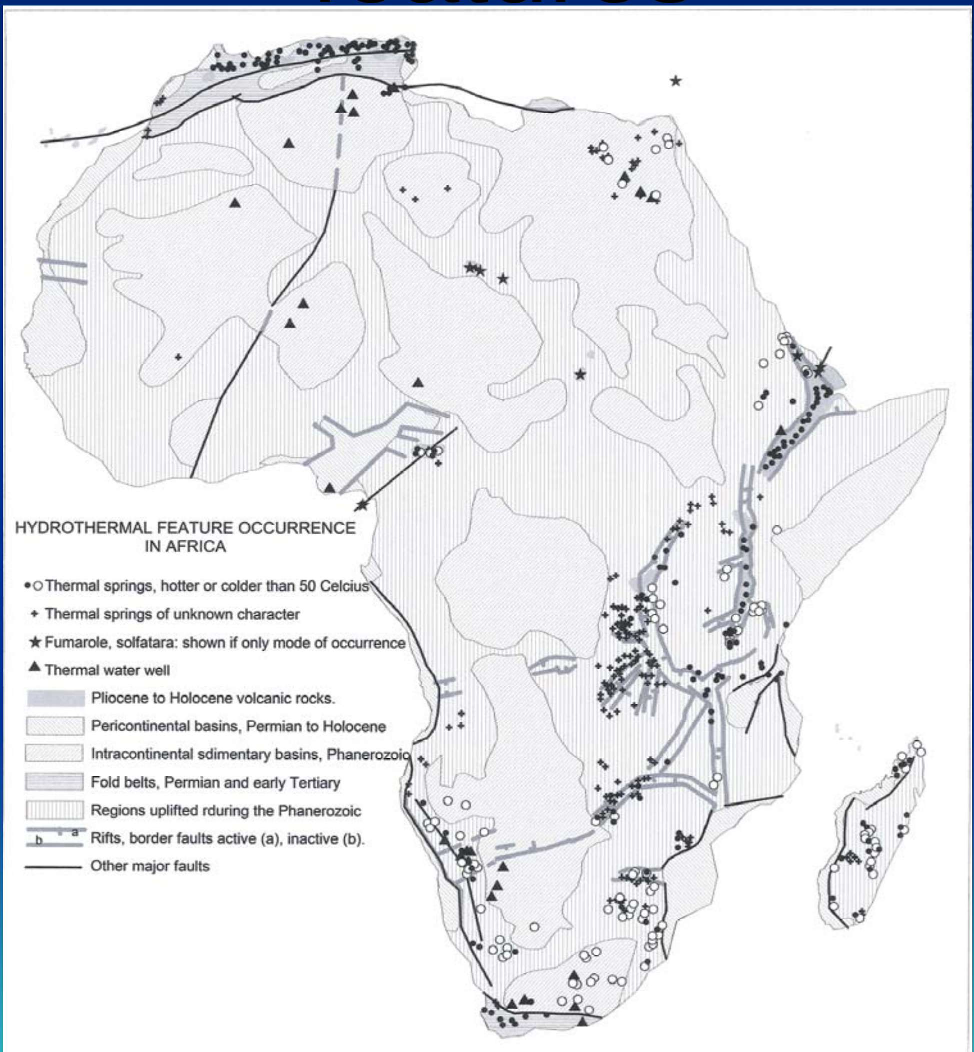
Characteristic tectonic features:

- high plateau topography
- Juxtaposed basins and uplifted plateaus
- lithosphere breakup to the extent of the effect of asthenospheric temperature anomaly





6. This tectonic outcome controls the occurrence, dynamism and heating of most hydrothermal features



A number of heating processes are recognizable: We will consider a few in the EARS

A. Heating by shallow magma chambers

Known key geologic conditions:

High energy plumes (Afar and Samburu) rise from broad asthenospheric tumescence

Resulting volcanic rock suites typical of partial lithosphere melting, differentiation from long lived magma chambers

Hydrothermal fluids: High temperature, Chloride types

Preponderance of the conditions: Axial zones of the EARS in Djibouti, Eritrea, Ethiopia, Kenya

B. Heating in the upper mantle

Known Geologic conditions:

Volcanic provinces located on the outskirts of regions affected by high energy plumes, but in region of high asthenosphere tumescence

Volcanic rock characters show magma generation by metasomatic melting in asthenosphere, rapid direct ascent to surface, close association with carbonatite magmatism preponderance of calc-alkaline rock compositions; Magma ponding in the classic magma chamber not applicable

hydrothermal fluids: Commonly dominant fumarolic activity, Thermal springs with high CO_2 output;

CO_2 & juvenile water vapor principal heat transporters to surface

Preponderance of the conditions: Northern sector of Western and southern sector of Eastern rifts: Uganda, Rwanda, Burundi, N.Tanzania

C. Intermediate between A & B

C1: Regions affected by less energetic mantle plumes

Known geologic conditions:

No rift development; extensive volcanism on plume driven uplifted plateaus; caldera formation with resurgent volcanism common

Volcanic rock chemistries progression from initial strongly alkaline to bimodal –acidic-basic affiliations, indicating shallow magma bodies

Parent geothermal fluids: strong dominance of fumarolic activity; derivations of thermal waters uncertain, condensates?

Preponderance: Zones of thermal uplift in Eastern Sahara: Volcanic fields of Tibesti (Chad), Jebel Merah (Darfur, Sudan)

C2. Rungwe: SW Tanzania

Known geologic conditions:

No plume

Volcanism in triple junction setting (Ruaha, Ruakwa and Malawi rift arms) promoted enhanced magma generation by anatexis or by pressure release melting in lower crust: Result “silicic products make up about 50% of the volcanic rocks”: Harkin 1960 Shallow silicic magma body possible heat source.

Hydrothermal fluids: Fumaroles on eruptive centers; site of old hugh temp thermal spring activity on Embaka fault; several low temp springs at points of hydrologic discharge.

The catch: Songwe spring activity very similar to those discussed under “B”

D. Amagmatic rift zones with high energy hydrothermal activity

These make up the western branches of EARS

D1: Rifts in partially cratonized terrains, no magmatism

Known Geologic conditions:

Current rifts developed as reactivations of Jurassic rifts. Seismicity indicative of incipient rifting in partially cratonized Mio-Proterozoic terrains,

East DRC and NW Zambia rift zones located in main zone of negative gravity anomaly but with rifting hindered by cross-cutting rock fabrics of the Lufilian Arc

Hydrothermal fluids: Large number of thermal springs with temperatures commonly exceeding 90^{O}*C. Many with large flows. Silica sinter deposition In Zambezi rift.*

Preponderance: Zambezi rift branch on Zambia-Zimbabwe border, and Mweru, Mweru Wantipa and Bangweulu rift branches in the DRC-Zambia border area

D2. Damara belt of Namibia: Probable incipient rifting in young Panafrican terrain exhibits a number of thermal springs at higher that 80^{O}*C. Genetic similarity believed to thermal spring activity in Zambezi rift zone*

Conclusion

The SW rift branches illustrate that magma heat sources are not essential for dynamic hydrothermal activity to occur.

Heating is attributable to deep circulation of meteoric waters in region of high underground temperatures.

The amagmatic sectors of the Basin and Range tectonic province of the western United States house high and medium temperature geothermal resources which support more than a dozen power generating facilities.

No need for magma heat source for exploitable geothermal systems to exist.

Do we need to invoke magma heat sources for hydrothermal features in the Western Rift ?

I think not, in the face of both the theoretical and field evidence.

Thank you for your attention