Research on the Tectonic and Magmatic Development of the Ethiopian Rift System

and

its Contributions to Geothermal Resource Exploration and Development.

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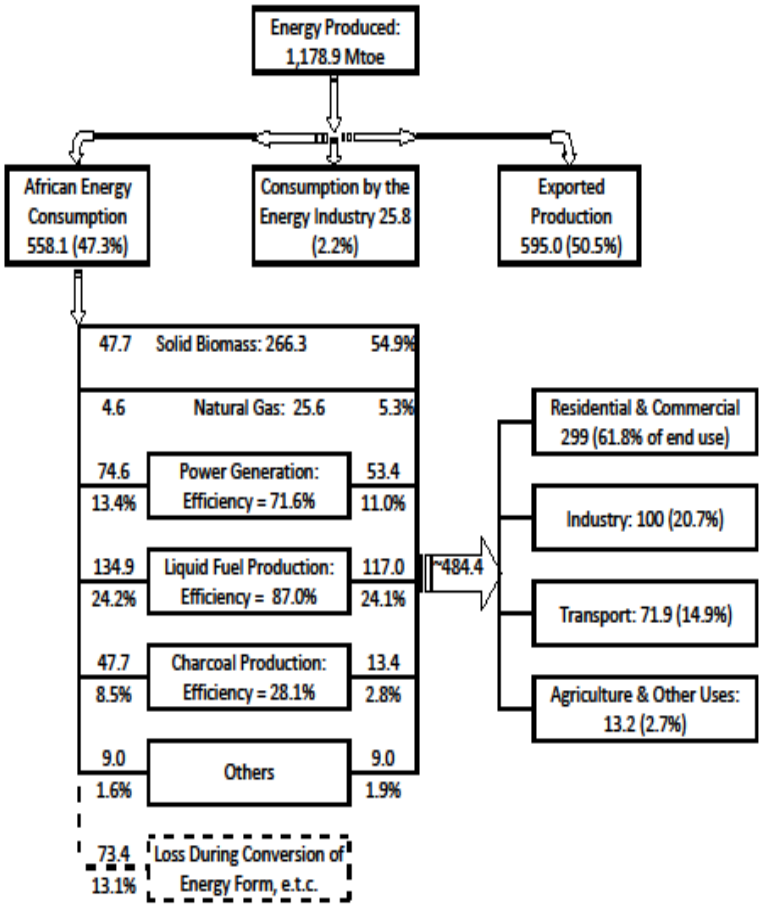
Outline

- Why the need for geothermal energy development?
  - Electricity supply in Africa
- What has been, and is being done?
  - Synoptic case histories & prospects
- What contributions did Afar research make?
  - N.E. Africa, extrapolations

1. THE DARK CONTINENT

HAKUNA MATAA: No light



The African energy system, 2008, figures in Million tons of oil equivalent (Mtoe). (based on IRENA, 2010).

A number of things are wrong here:

- Production: About 1 Toe/yr per capita, 51% exported, 47% consumed
- Consumption: 60% biomass, 34% Fossil fuels, 6% renewables
- Use in economic production 34%
  - Low energy use & poor structure

The Paradox: Energy Poverty in the middle of plenty

Considering only the renewable energy sources, Africa's potential, in TWh (from IRENA, 2010)

- Wind power: 5,000 – 7,000
- Solar Energy: 155,000 -170,000
- Geothermal energy: >125
- Hydropower: 1,844
- Bagasse: 3.0 - 13.6

❖Of the non-intermittent sources, 9% of the hydro and 1% of the geothermal potentials have been developed by 2011

Electricity is a good energy form: Easy to produce, transport and use, but ……..

Sources	Capacity, GW	%
Non-renewable	**104.7**	**84.0**
Coal	52.4	42.0
Natural Gas	34.9	28.0
Oil	15.0	12.0
Nuclear	2.5	2.0
Renewable	**24.3**	**16.0**
Hydro	21.2	14.0
Wind	1.7	1.1
Biomass (bagasse)	1.1	0.7
Geothermal	0.2	0.2
Totals	**129.0**	**100.0**

- Africa has small power generation capacity .
  - Only 20% Africans have electricity access (World average 86%)
  - Average African consumes 124KWh/yr (World average 2,784)
- Africa needs to increase capacity 33-fold to serve all Africans
- The present system is too dependent on fossil fuels.
- Africa needs to use its abundant renewable energy sources:
  - For additional generation capacity, and,
  - To replace thermal generation and expand

Regional differences exist

- S. & N. Africa:
- 70% of Africa's generation capacity:
  - Attributed to Coal in S. & natural gas in N.
- 1.617 & 739 KWh per capita in S & N
- Access to Electricity: >70%
- SSA Less privileged: Access 20%, per capita consumption 107 KWh/yr.
  - Oil & gas in Gulf of Guinea area help
- Eastern Africa fares least: 15% access & 68 KWh/yr per capita consumption
- Each Eastern African could have a 60W light bulb to light for about 3 hours/day, but….
- There is no equity: the cities get 9/10th of the electricity

The reasons ?

1. Low African purchasing power.
   - ➢ Economies grow 5%/yr. 7%/yr electricity demand growth promises more growth
2. High generation cost: Small power plants; Average hydro-plant size= 46MW
   - ➢ Develop large hydro, 2-6 GW: a 10-fold capacity increase halves the unit cost
3. Small markets can not accommodate large plant additions
   - ➢ Interconnect national power supply systems to create larger regional markets &power trading
4. Large electricity consuming industries are in the cities, other power supply is unprofitable;
   - ➢ Electricity is and essential social and economic infrastructure, do rural electrification schemes
   - ❖ So there are the regional power pools which are addressing these issues.

The EAPP Plan to 2020

- HV transmission lines connect Egypt, Sudan, Ethiopia-Kenya, Tanzania, Uganda, Rwanda, Burundi, Uganda, East DRC (Kivu)
- Generation capacity from renewables increases energy supply by 40%
- Thermal generation will be phased out, except from coal .
- Unified electricity system will be regulated by a singly organization

❖ New Generation: 82.5% hydro, 13% geothermal, 4.5% wind

❖ Role of geothermal power is to support mainly hydo-based regional electricity system by base-load power supply.

2. GEOTHERMAL EXPLORATION AND DEVELOPMENT IN ETHIOPIA

1. **MER**

- 1969-71: 24 month reconnaissance covered 150,000 sq km ERS
- 1972: Inventory in the highlands

➢ Over 600 hydrothermal features associated with about 20 heating systems located

- 1973-80: Detailed surveys by Geology, Geochemistry,, geophysics at Langano, Corbetti, Abaya
- 1981-84: Exploration drilling of Alutu, 8 wells, 1,100-2.500m depth, T_{max}= 320^{O}C

➢ 2 wells cold, 4 wells produced, one was lost

➢ 1996-99 Pilot plant installed: 7.3MW

- 210-2110 Further geophysical surveys: MT

❖ Present: Financing acquired for production drilling and 50MW power plant

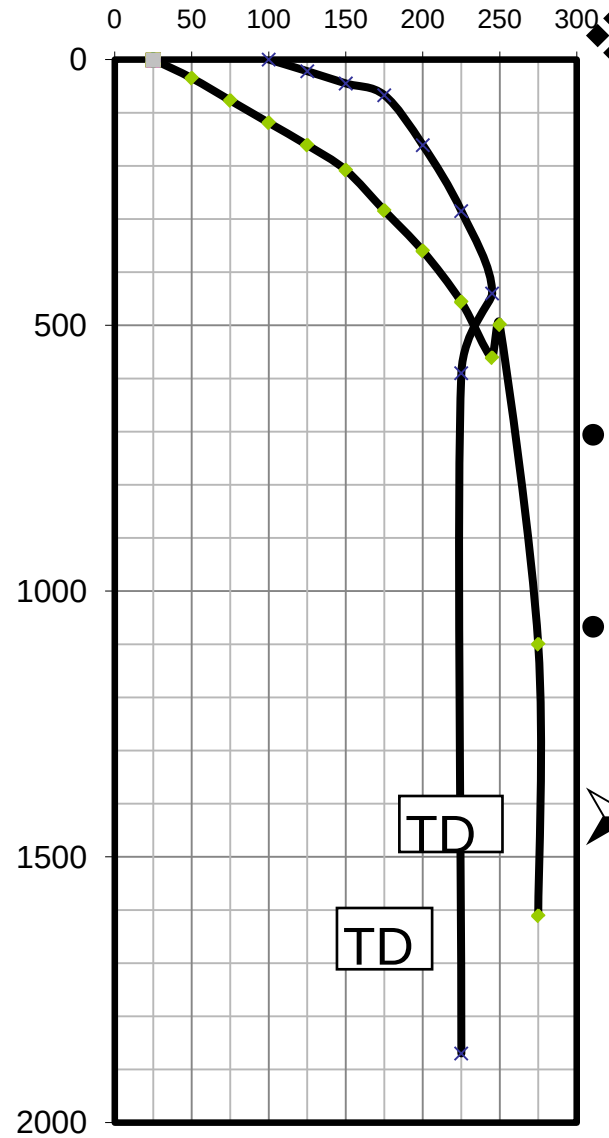

08.07.2006


06.23.2006

2. Tendaho

- 1978-80: Detailed exploration of Tendaho graben
- 1993-95: 3 deep & 1 shallow exploration wells drilled to depths of 2196 & 466 m

➢ Deep wells: T=278^{O}C, but impermeable



❖ 200-400m depth in Quaternary sediments 245^{O}C geo-fluid 1,000 kJ/kg, 100 tph, 27% dry

- 1997-98: Drilled 2 wells to ~500m, same result
- Geophysical survey ongoing;

➢ plan developing for drilling 3,000 m wells to find deep resource

3. **S. Afar-N. MER Surveys**

- **No more drilling finance: US$ 3-4 million/well**
- **Semi-detailed surface exploration of 10 areas, to minimize pre-drilling surface exploration work.**

➢ **Tulu Moye, Gedemsa, Dofen & Meteka have good prospects for yielding >250^{O}C geo-fluids.**

- **No more than one year of surface exploration is needed at each to ready them for drilling**
- **IPP now exploring Tulu Moye and Gedemsa, as well as Abaya and Corbetti.**

- **THE FUTURE?**

❖ **Regional geothermal programmes becoming active to support 7 EARS countries to explore and develop their geothermal resources: UNEP-ARGeo & AUC-RGP**

3. HOW DID AFAR RESEARCH CONTRIBUTE TO GEOTHERMAL EXPLORATION?

- In the beginning there were or maps, geologic or topographic, only good aerial photographs
- The rift floor was covered by the “Aden series” of Blanford from a century earlier. The Oligocene flood basalts were also thought to outcrop .

MER:

- First clue: P. Mohr’s perception of the “Wenji Fault Belt”, Still used, even if since found to have been a bit enthusiastic,
- The interpreted high “reservoir temperatures” were from thermal springs associated with rhyolite centers in the fissure lava field of the WFB.
- Rift transverse structures favor positioning of silicic centers:
- Why all this rhyolite, crust anatexis or differentiation? what does it mean in terms of geothermal resource generation?

AFAR Rift

Enigmatic at first

- Allalobeda thermal springs & Magenta fumaroles occur in block faulted basalt terrain, but
  - what and where is the heat source?
- Dubti farm mud volcanoes lie on SE trajectory of Manda-Hararu range faults.
  - what and where is the heat source?

➢ CNR-CNRS research explained Afar tectonic and magmatic development in terms of Plate Tectonics

- Manda Hararu : youngest microplate boundary
- Tectonic setting and interpreted high “reservoir temperature” ranked Tendaho high as a prospect area
- Geophysics by German universities showed crustal attenuation and deep temperature structures

Key Lessons Learned

- Where late Pleistocene rhyolites and co-occurring fissure basalts are known to be differentiation products, the most common case:
  - Long lived shallow magma body heat sources should be expected
- Rift transverse faults are micro-plate boundaries.
  - Positioning of silicic centers is favored where they cross WFB in MER and rift margin fault in N. Afar rift
- Calderas focus heat flux and geo-fluid upwelling & are easy to explore
- Allalobeda and the Dubti mud volcanoes could occur due to shallow ground water table supported by Awash River
  - Other “axial zones” in N. & Central Afar can be predicted to have blind geothermal systems due to paucity of shallow ground water

In ERS, there are only a small variety of tectonic and magmatic associations. A few geothermal models can describe a large number of geothermal areas

Young bimodal volcanic rock occurrences situated on micro[plate boundary structures are sure to be good geothermal targets.

Research generated knowledge of this association in Ethiopia.

Geothermal exploration could start at a higher level of knowledge and go further to “prove steam” than many

Thank you for your kind attention