Geothermal Outlook in East Africa:

Perspectives for Geothermal Development

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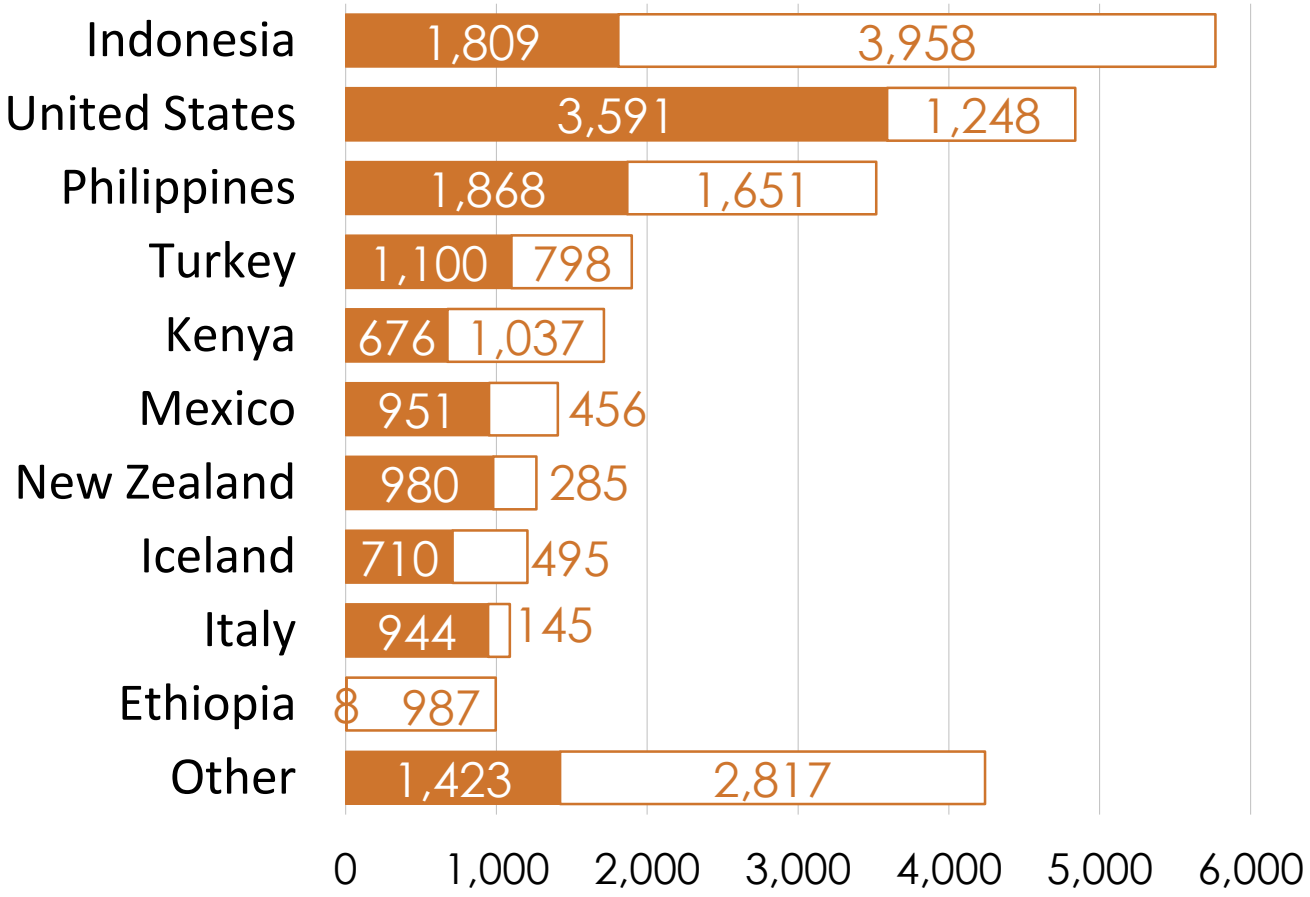
INTERNATIONAL GEOTHERMAL ASSOCIATION

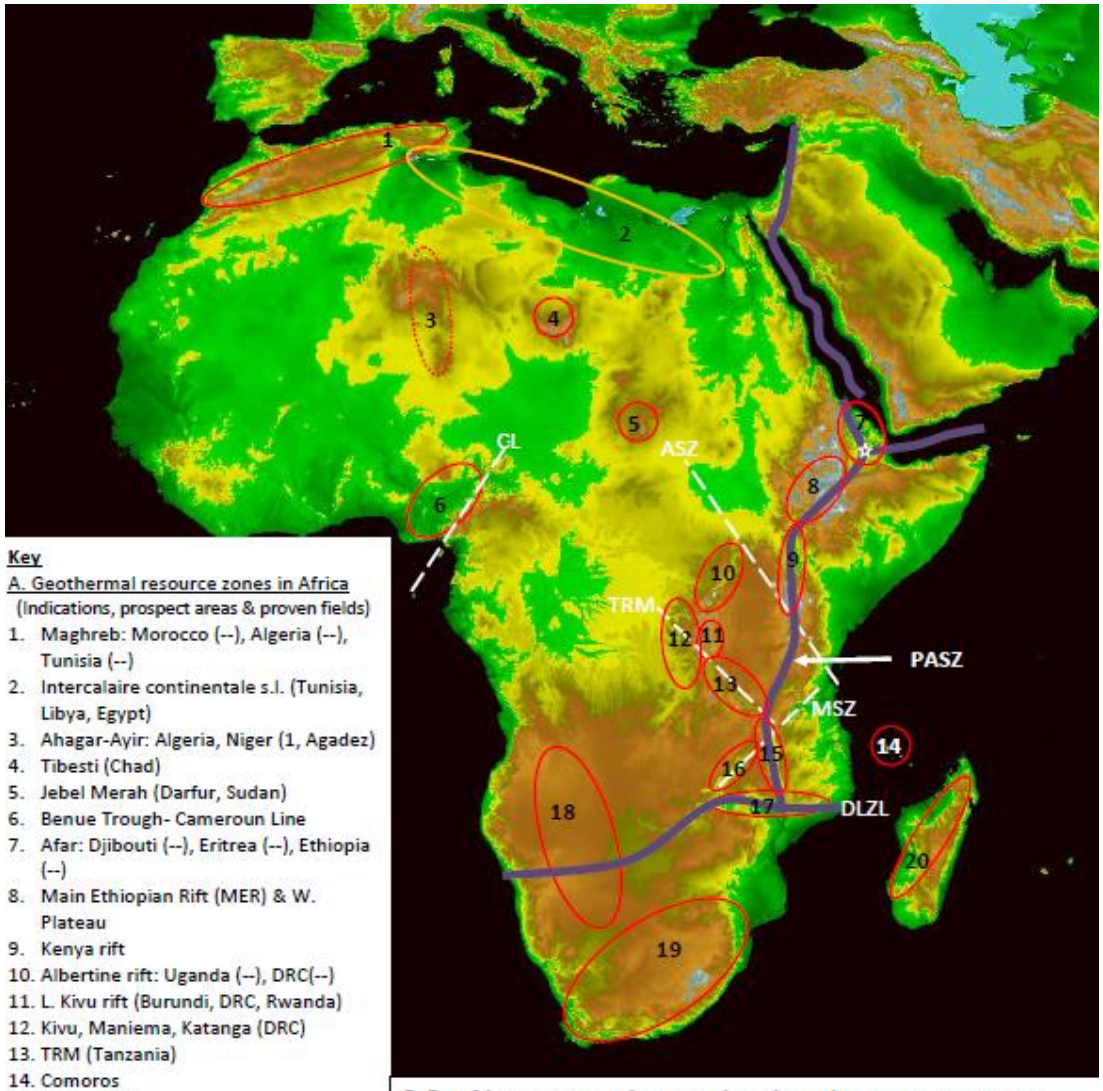
- Scientific, educational and cultural organization with 5,000+ members in over 65 countries.
- Non-political, non-profit, non-governmental organization with consultative status to the UN and special observer status to the Green Climate Fund – Partner to the Global Geothermal Alliance
- Objectives:
  - Encouraging **research, the development and utilization** of geothermal resources worldwide through the publication of scientific and technical information among the geothermal specialists, the business community, governmental representatives, UN organisations, civil society and the general public.
  - **Encourage, facilitate and, promote** the coordination of activities related to worldwide research, development and application of geothermal resources.
- Founded in 1988, IGA Secretariat is located in Bochum, Germany at the International Geothermal Centre of the Bochum University of Applied Sciences.

TOP 10 GEOTHERMAL COUNTRIES

Installed capacity 2018 (MWe) & Projects by 2020



Source: TGE Research (2018), GEA (2016), IGA (2015), JESDER (2018) Enerji Atlasi (2018)



Key

A. Geothermal resource zones in Africa
(Indications, prospect areas & proven fields)

1. Maghreb: Morocco (--), Algeria (--), Tunisia (--)
2. Intercalaire continentale s.l. (Tunisia, Libya, Egypt)
3. Ahagar-Ayir: Algeria, Niger (1, Agadez)
4. Tibesti (Chad)
5. Jebel Merah (Darfur, Sudan)
6. Benue Trough- Cameroun Line
7. Afar: Djibouti (--), Eritrea (--), Ethiopia (--)
8. Main Ethiopian Rift (MER) & W. Plateau
9. Kenya rift
10. Albertine rift: Uganda (--), DRC(--)
11. L. Kivu rift (Burundi, DRC, Rwanda)
12. Kivu, Maniema, Katanga (DRC)
13. TRM (Tanzania)
14. Comoros
15. Malawi (--)
16.
17. Zambezi basin: Mozambique (--) Zambia (, Zimbabwe(26)
18. Namibia (32), RSA (3), Botswana)
19. RSA (79)
20. Madagascar (28)
21. Isolated thermal spring areas

B. Panafrican structures that control geothermal resource occurrences

Suture zones that rifted during the Neogene-Quaternary by normal faulting:

EARS: Suture zones that controlled EARS development during the Neogene to Quaternary

DLZ: Damara-Lufillian-Zambezi(-Lurio) shear zone originally a suture zone

Transverse structures, lines of recurrent crust breakup by shear faulting

CL: Cameroun Line

ASZ: Aswa Shear Zone

TRM: Tanganyika-Rukwa-Malawi sinistral fault/ SE arm of Western rift

DLZ: Damara-Lufillian-Zambezi(-Lurio) shear zone originally a suture zone

Map of Africa Showing Geothermal areas

Geothermal areas are associated with various tectonic regimes

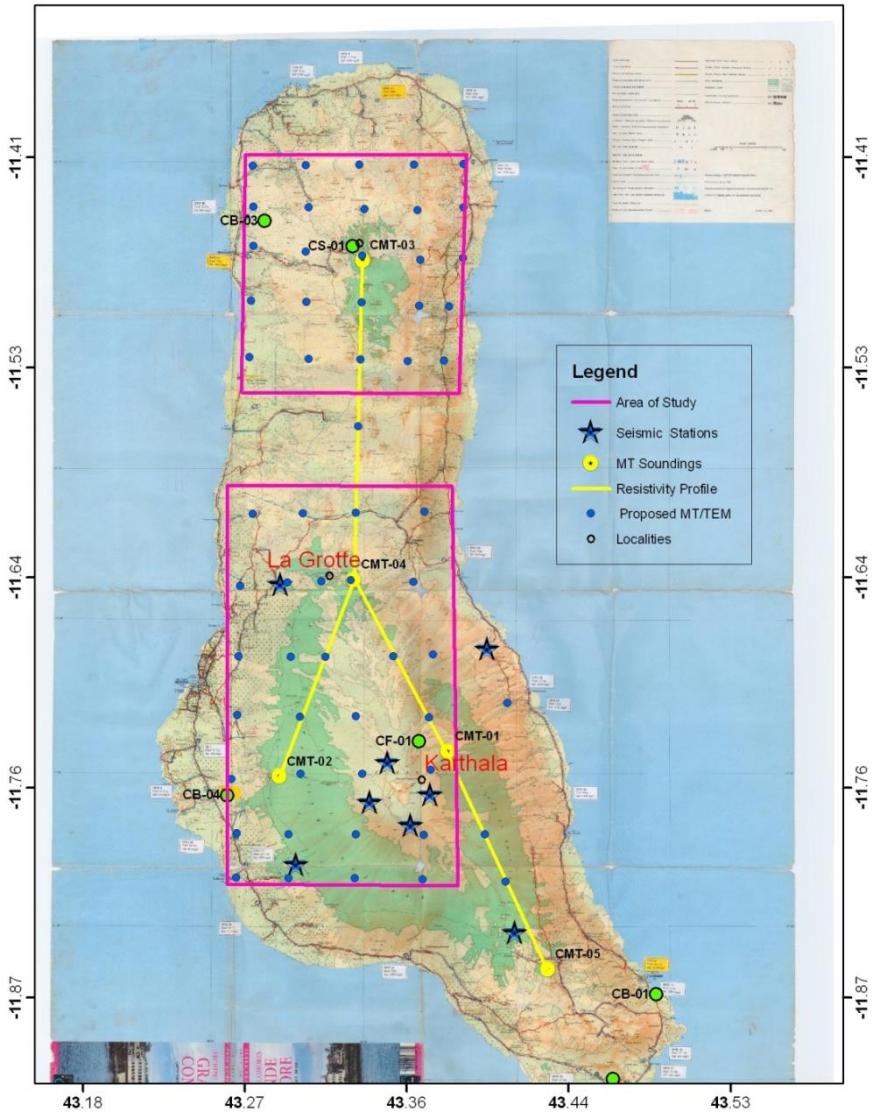
Geothermal Potential in E. Africa

- Africa's geothermal potential in the Eastern Africa Rift > 20,000 MWe
- Currently (2018) only Kenya has operational geothermal power stations
- There are plans to increase geothermal installation in Eastern Africa by over 4,000MW over the next 10 years
- Geothermal energy in North African countries is mainly for direct applications

African Countries with Geothermal Resources

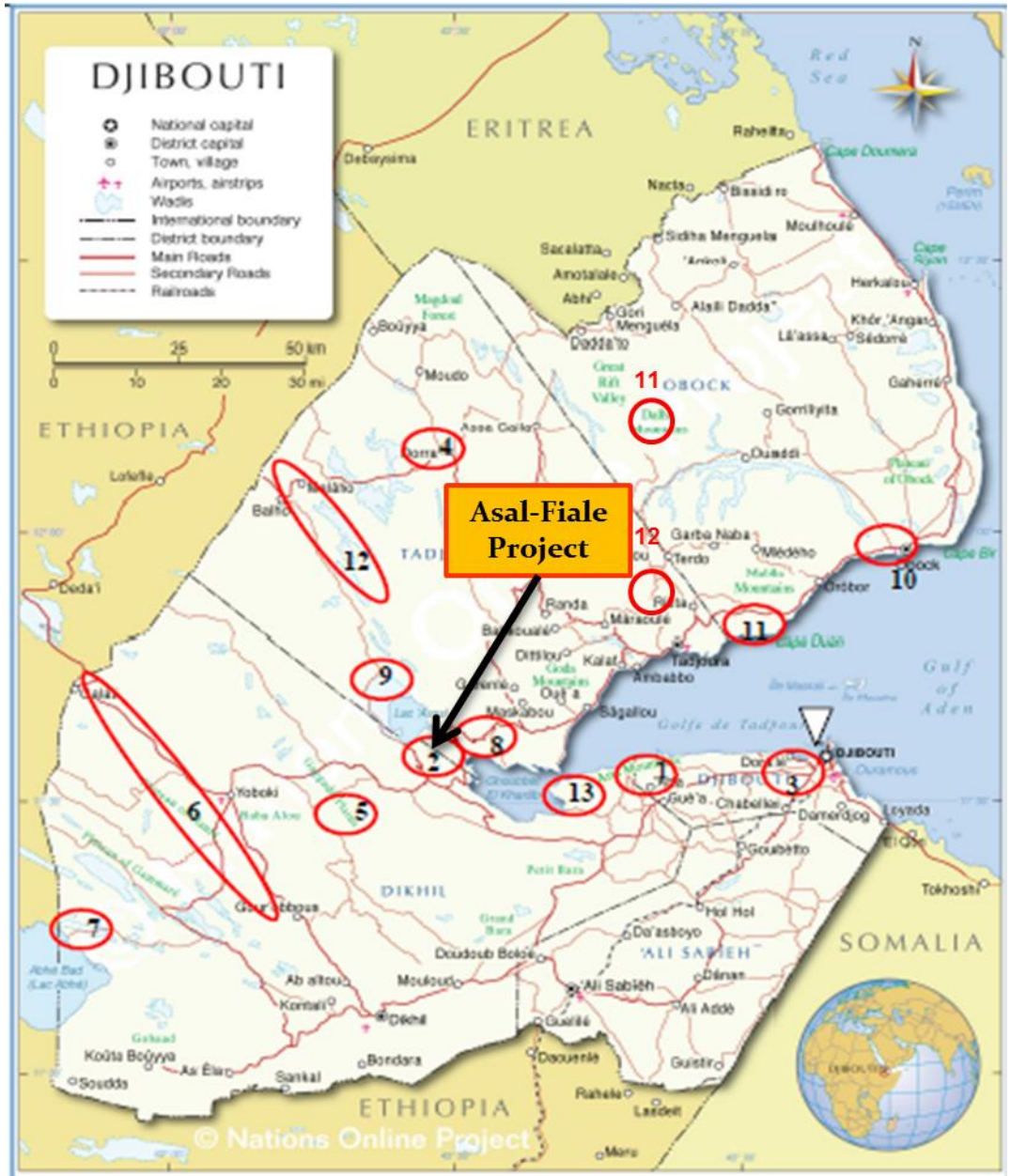
- Algeria
- Burundi
- Comoros
- Djibouti
- DRC
- Egypt
- Eritrea
- Ethiopia
- Kenya
- Madagascar
- Malawi
- Morocco
- Mozambique
- Nigeria
- Rwanda
- South Africa
- Sudan
- Tanzania
- Tunisia
- Uganda
- Zambia

COMOROS



- Geothermal potential highest within the Grand Comoro Island
- Further studies planned at Karthala and La Grille volcanoes
- Potential is estimated at >30 MWe
- Exploration drilling planned is supported by AUC-GRMF, NZ Govt.

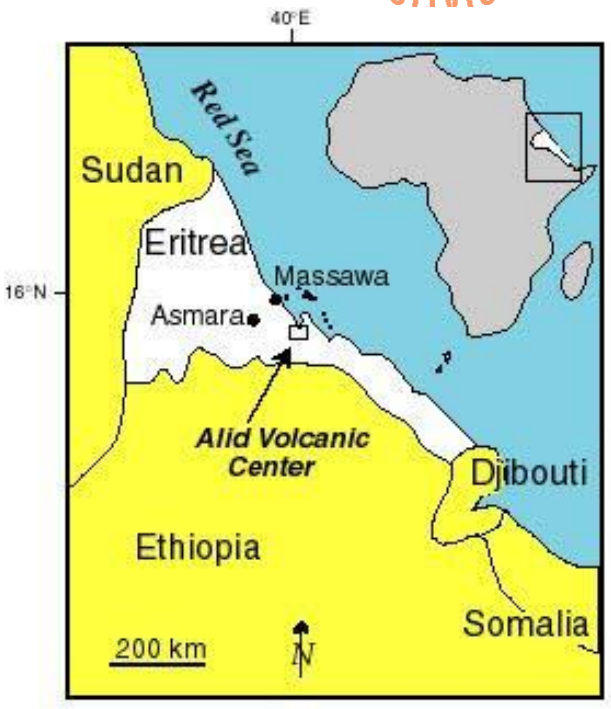
DJIBOUTI



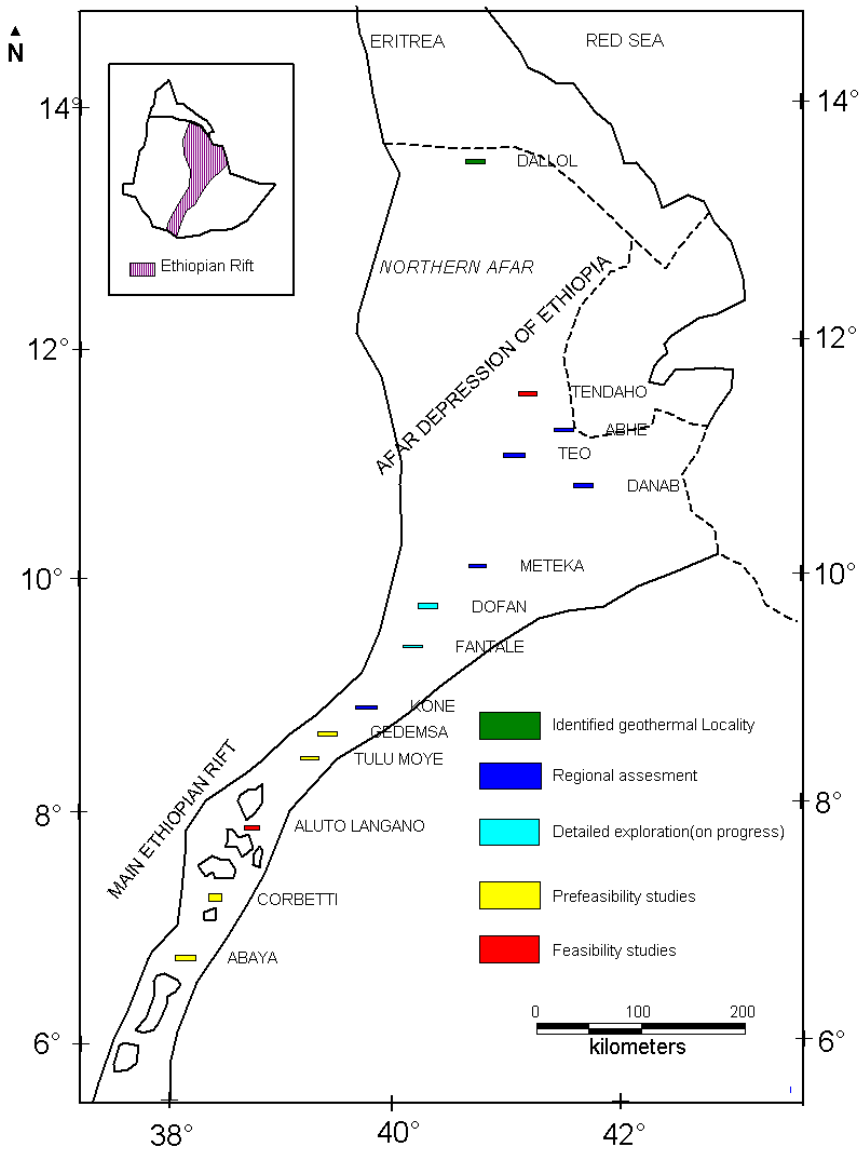
- The geothermal potential of Djibouti has been estimated to be about 1,000 MWe.
- Plans are to drill wells and develop 30 MW Geothermal Plant in the Lake Assal Region
- Studies are ongoing in other prospects

ERITREA

- An active crustal spreading center characterized with numerous NW trending fissures , faults, felsic volcanoes and thinned crust.
- Alid identified as the most promising high enthalpy prospect for geothermal exploitation.
- Detailed studies planned for 2015 in Alid and supported by UNEP and ICEIDA was suspended due to extreme field conditions
- Detailed surface studies of the other prospects are planned.



ETHIOPIA



- Ethiopia has actively been exploring for its geothermal resources since 1969
- Over 23 high temperature geothermal potential areas identified
- Estimated potential of more than 10,000 MWe
- A larger number of areas have potential for medium to low temperature resources

Aluto-Langano Field

- The 7.2 MWe Geothermal Combined Cycle Unit was commissioned in 1998.
- The plant had intermittent operation between 1998 and 2014 with challenges of maintenance
- The plant is currently not in operation due to maintenance challenges

Ethiopia - Aluto

- Drilling is underway to allow for expansion of the field for 70 MWe
- Financing for drilling is from World Bank, Iceland, JICA and Government of Ethiopia
- Two wells were drilled between 2013 and 2015
- Progress has slowed since 2015 due to various challenges

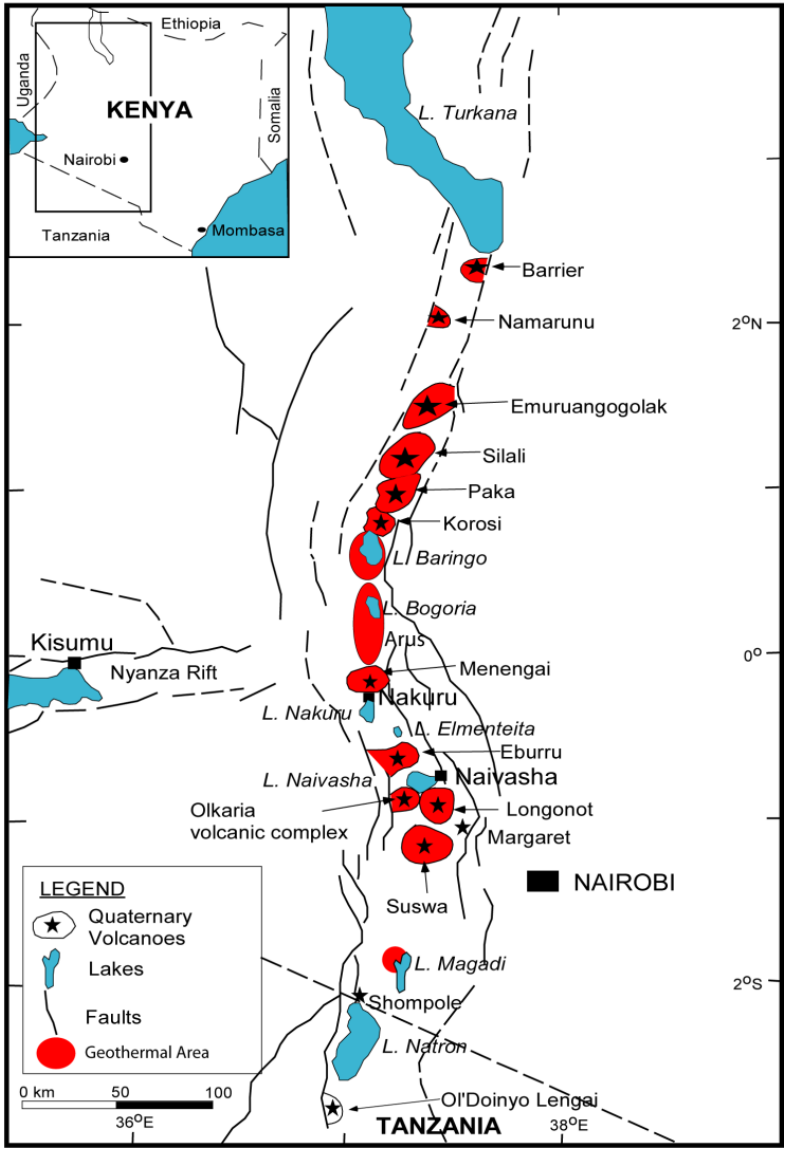
Ethiopia – Tendaho-Alalobeda

- Six exploration wells drilled between 1993-1998 confirmed presence of geothermal resources
- A mix of shallow and deep appraisal wells are planned for year 2018/2019
- Tendaho-Alalobeda is being evaluated for development of a 12 MWe pilot plant in phase one
- Expansion to 100 MWe in subsequent phases

Corbeti Geothermal

- Concessioned to Coberti Geothermal Ltd
- PPA signed for 500 MWe
- Exploration Drilling to start in 2018
- US$ 2billion committed

KENYA



- All high enthalpy fields are located within the axis of the Kenya rift valley
- Geothermal potential is estimated at more than 10,000 Mwe
- Operating power plants are located at Olkaria and Eburru
- Geothermal system has been confirmed at Menengai

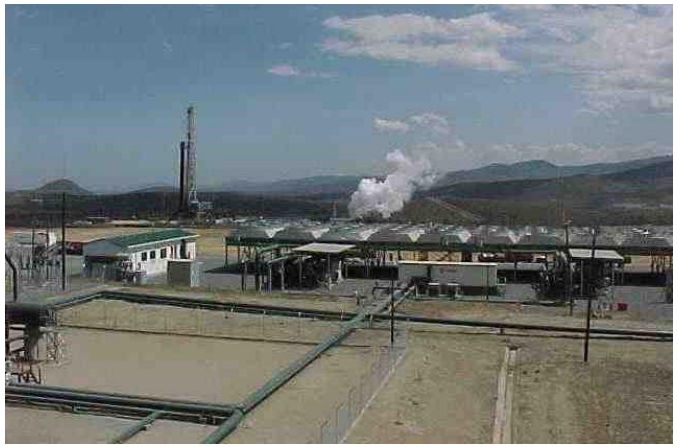
Developments in Kenya

- **Olkaria 1 field (215MWe):**
- Olkaria I: 45 MWe commissioned in 1981-1983
- Olkaria I AU: 140 MWe commissioned in 2014
- Olkaria I AU unit 6 – 70 MWe under development
- >30MWe of wellhead power generation

- **Olkaria II (105 MWe)**
  - 70 MWe flash plant commissioned in 2003
  - 35 MWe commissioned in 2009

Developments in Kenya

- **Olkaria III field (140 MWe):**
- ORC plants of 5 Mwe developed in phases from 2003 to 2014
- Plants are owned and operated by Orpower4, Inc.



- **Olkaria Central (4.3 MWe)**
  - 2MWe ORC plant commissioned in 2004
  - 2.3 MWe back pressure plant commissioned in 2006
  - The plants are owned and operated by Oserian Dev Co.

Developments in Kenya

- **Olkaria IV (140 MWe):**
- 2 x 70 MWe flash plants commissioned in 2014
- About 51 MWe wellhead units
- Plants are owned and operated by KenGen
- **Olkaria V (154 MWe)**
- Civil works are under way for the 154 MW Olkaria V geothermal power project of Kenya Electricity Generating Company (KenGen) in Olkaria, Kenya.
- **Akiira Geothermal Proj (70 MWe)**
- Drilling of third well due to start in April 2018
- IPP

Developments in Kenya

- **Eburru Pilot (2.52 MWe)**
  - Flash condensing pilot plant commissioned in 2011

Developments in Kenya

- **Menengai 1**
- 3 x 35 MWe units under development by three IPPs, namely, The three Orpower 22 Limited, Sosian Menengai Geothermal Power Limited (SMGPL) and Quantam East Africa Power Limited.
- Steam gathering system under construction
- Production drilling is ongoing for additional 60 MWe plant

DIRECT UTILIZATION

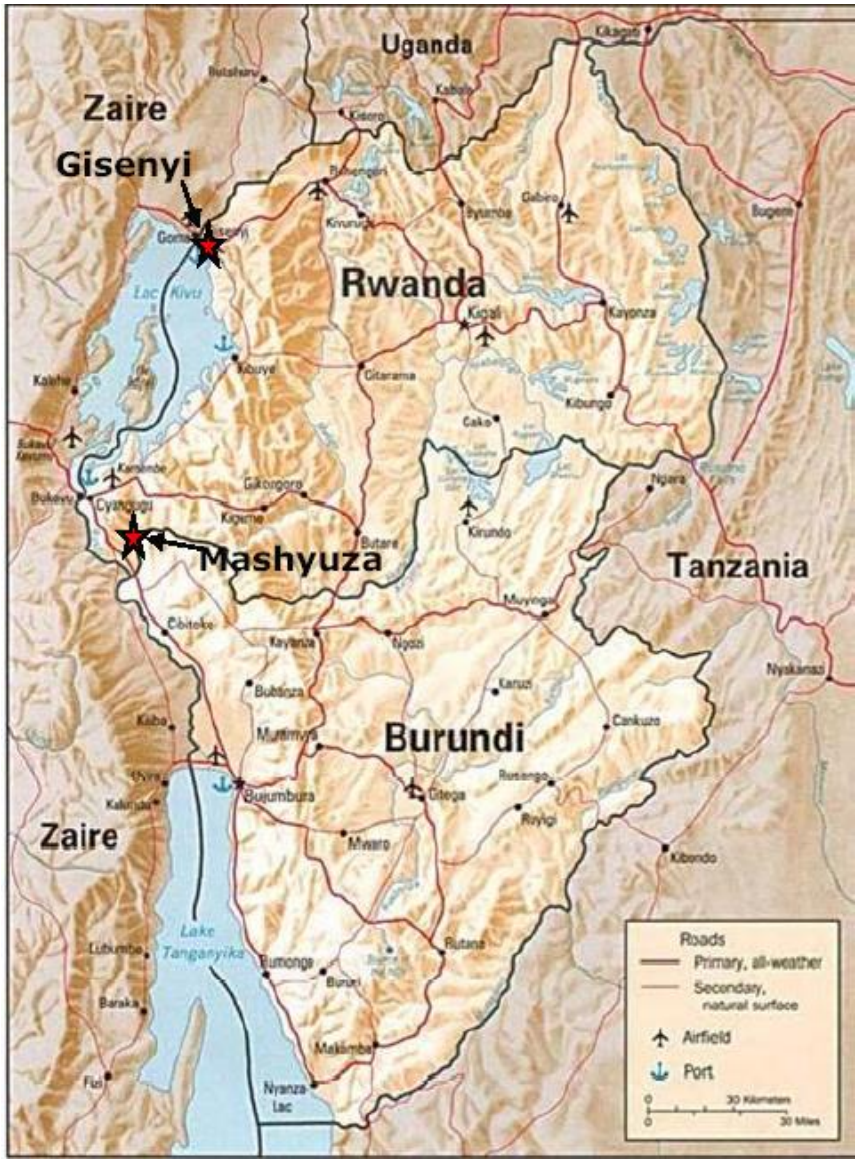
- Cut roses green house heating and soil fumigation of 100 hectares at Oserian farm and spa at Olkaria
- Eburru crop drying project
- Pilot Laundromat, milk processor, aquaculture and greenhouse at Menengai

Other Projects in Kenya

Detailed surface studies have commenced in the following prospects:

- Baringo – Silali block
- Barrier
- Homa Hills
- Namarunu
- Magadi

RWANDA



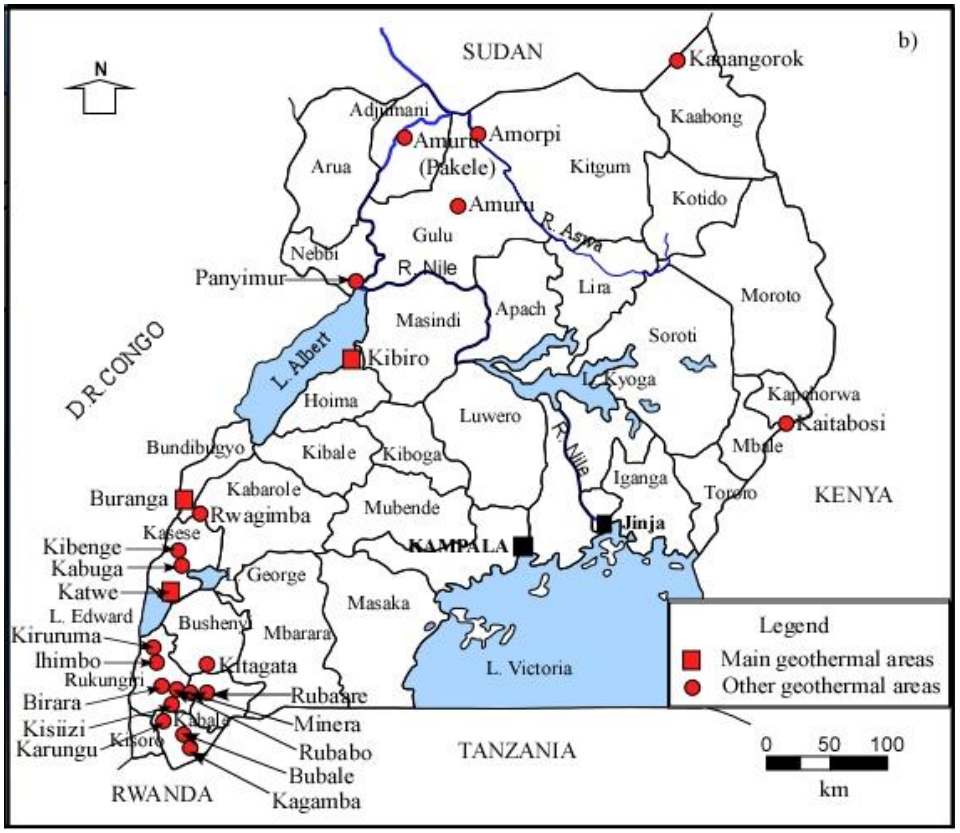
Geothermal Prospects in Rwanda are associated with Virunga volcanic complex:

- Gisenyi
- Mashyuza

- All the resources in Rwanda are classified as medium to low temperature
- Deep exploration drilling in Karisimbi did not intersect a geothermal system.
- Gisenyi and other areas are being evaluated for potential direct use applications

UGANDA

- Most of the geothermal potential areas are associated with the western rift
- The four major geothermal areas are:
  - Katwe-Kikorongo,
  - Buranga,
  - Kibiro and
  - Panyimur
- Estimated potential in Uganda is 450 MWe



Kibiro

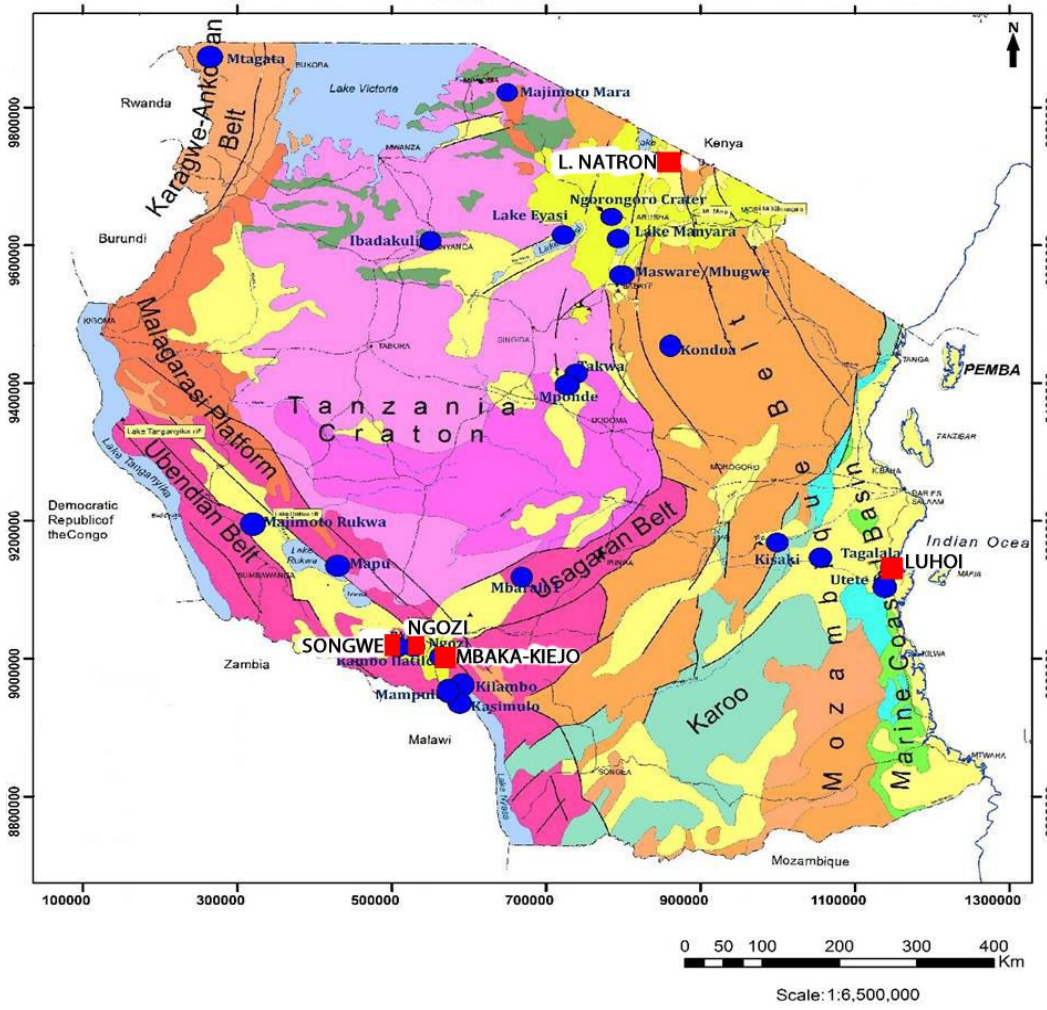
- Geothermometry indicates reservoir temperatures >150°C
- The geothermal system is modeled as fault controlled
- Drilling of TG holes is planned for Kibiro

Buranga

- The prospect has the largest geothermal manifestation in Uganda – hot springs, mud pools, fumaroles, etc
- The prospect is located at the foot of the Ruwenzori mountain
- Fracture controlled system

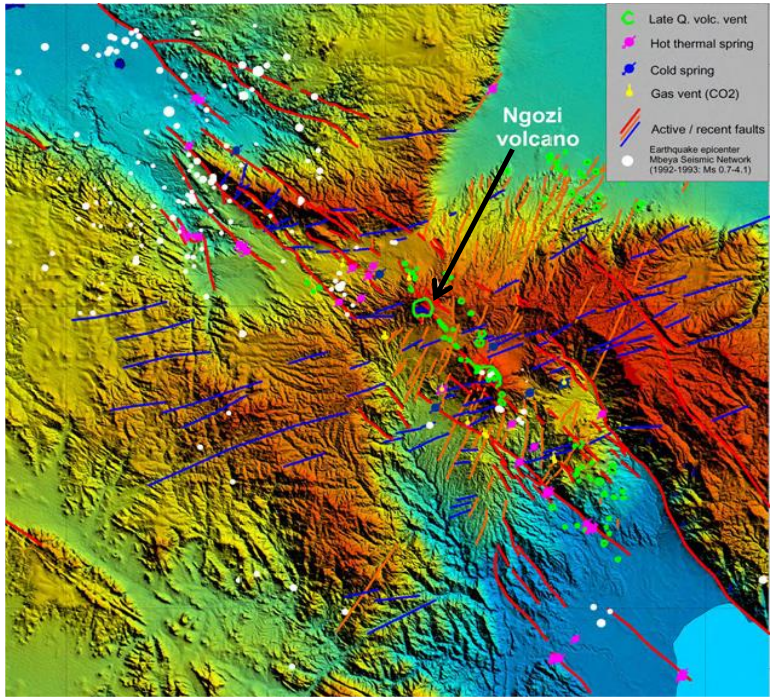
TANZANIA

- Geothermal systems in Tanzania are mainly associated with the western and eastern rift branches
- 5 prospects are prioritized:
  - Ngozi
  - Songwe
  - Kiejo-Mbaka
  - Luhoi
  - Natron
- Over 500 MWe estimated



Ngozi-Songwe-Mbaka

- Ngozi is a Potential high temperature geothermal resource
- Under development by TGDC
- Slimhole drilling to be done in Ngozi in 2018
- Project to be financed by AUC-GRMF, AfDB
- Detailed surface studies and TGH planned for Songwe and Mbaka prospects in 2018



ZAMBIA

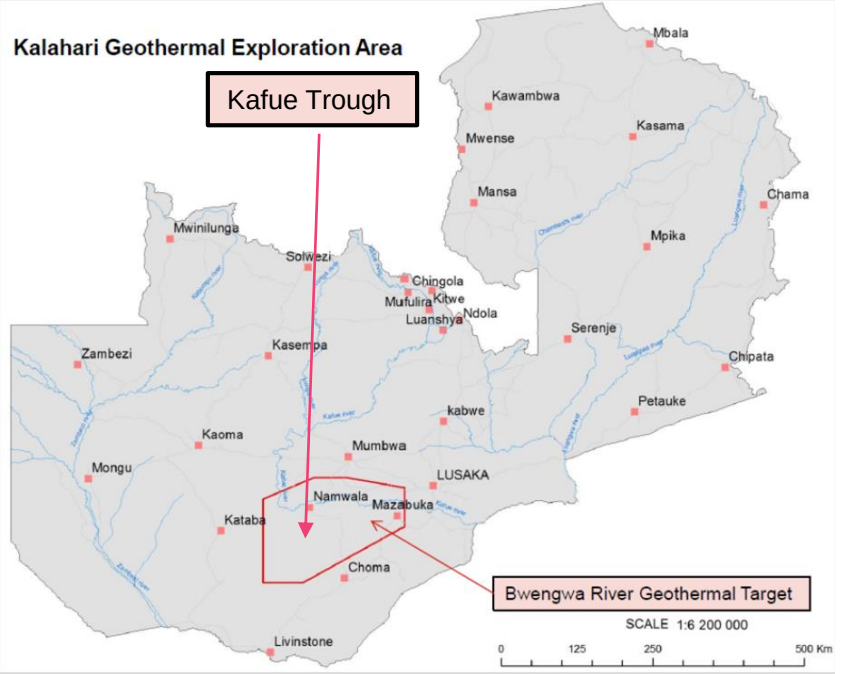

Kapisya Prospect
Lake Tanganyika
TANZANIA
Lake Mweru
Mpulungu
Sumbu National Park
Kasama
Isoka
D. R. CONGO
Mansa
Bangweulu Floodplains
MALAWI
North Luangwa National Park
Mpika
Luambe National Park
ANGOLA
Solwezi
Kitwe
Ndola
Kasanka National Park
South Luangwa National park
Chipata
Mkushi
Kapiri Mposhi
Liuwa Plains National Park
Kafue National Park
Z A M B I A
MOZAMBIQUE
Mongu
Lusaka
Lower Zambezi National Park
Lochinvar National Park
Chirundu
Siavonga
Lake Kariba
ZIMBABWE
Sioma Ngwezi National Park
Livingstone
NAMIBIA
Victoria Falls
BOTSWANA

Zambia-Kapisya

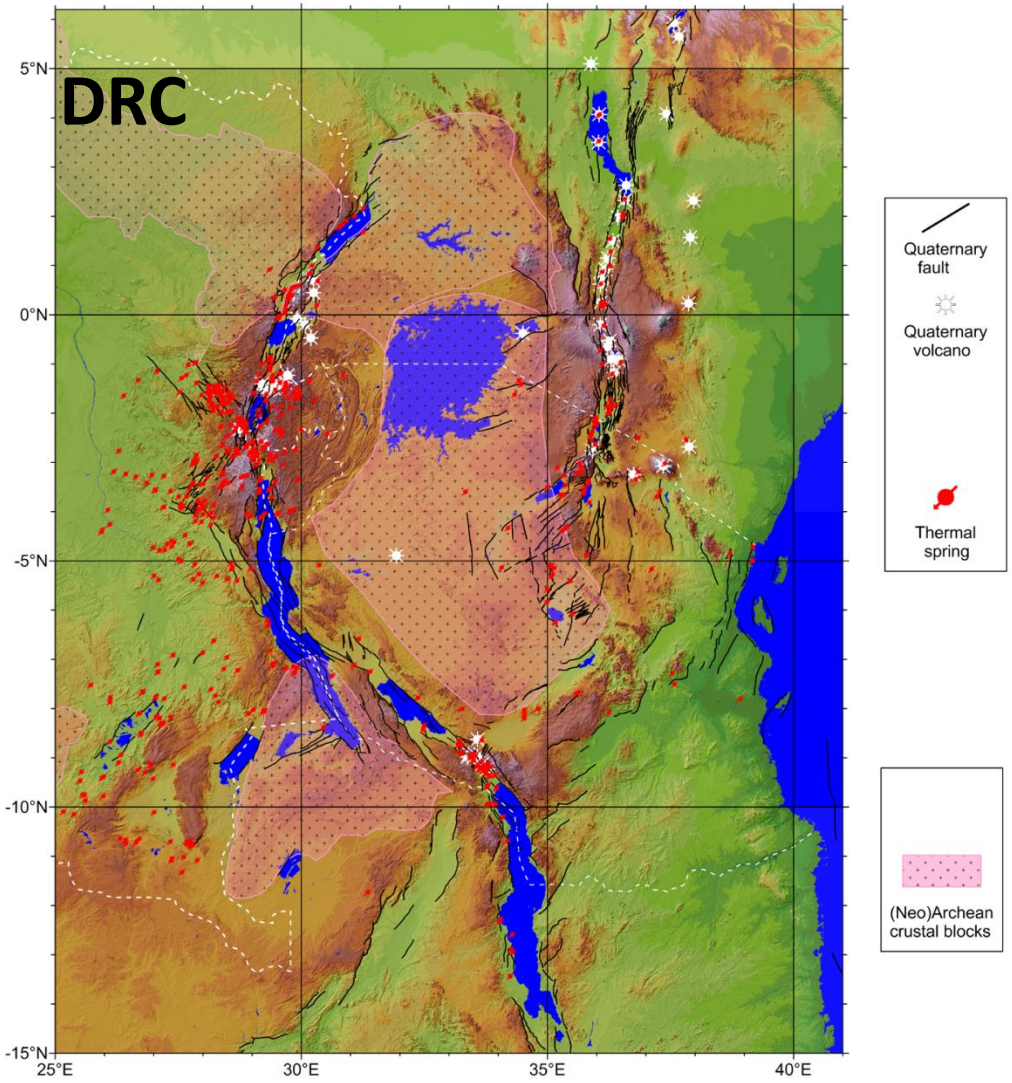
- Zambia has over 80 occurrences of hot springs
- In 1986, a pilot plant, Kapisya, was installed
- The plant was designed to use 15 pumped shallow wells,
    - 4 have submersible pumps.
    - The plant also has two (ORC) turbo-generators 200 kW.
    - The plant was never commissioned

Kafue Geothermal Area

- The Kafue Trough lies at the intersection of the Zambezi mobile belt and the Mwembeshi Shear Zone
- Kalahari Energy Limited is currently active in the Bwengwa River project with TGH drilled with positive results (T>130oC)



DEMOCRATIC REPUBLIC OF CONGO



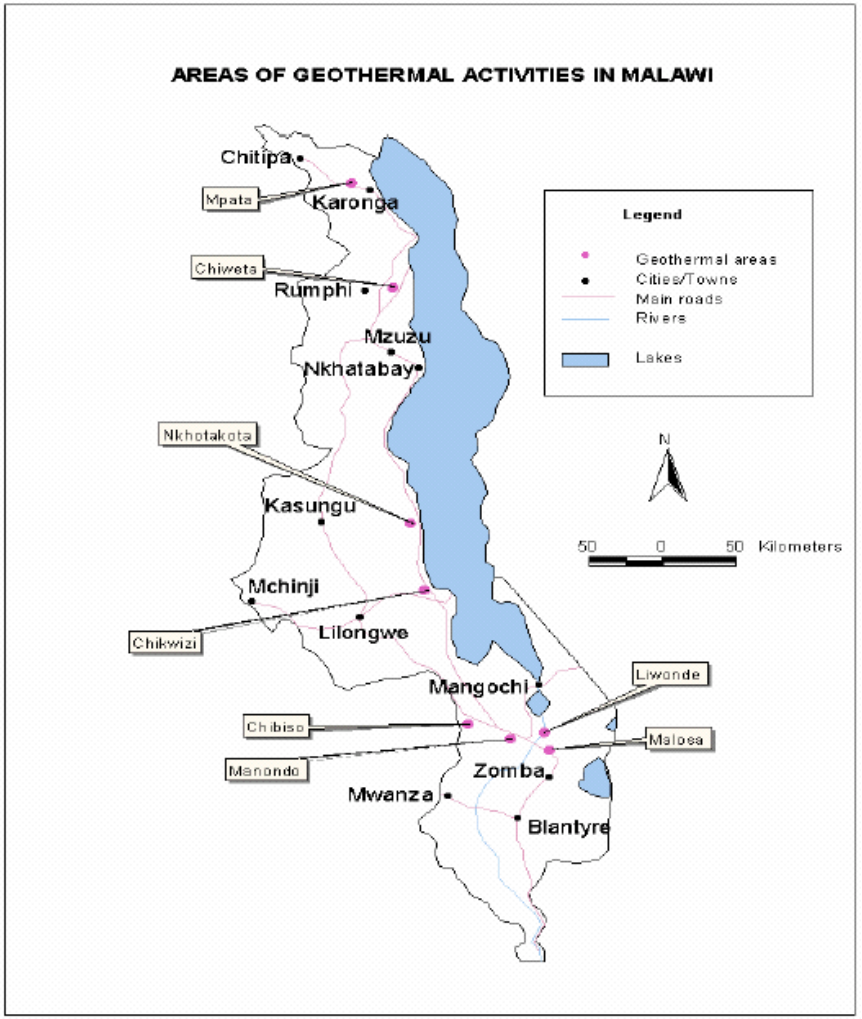
- All hot springs occur along faults
- Hot springs abundant in the Virunga volcanic area along faults

DRC

0.2 MWe Binary plant was installed in 1952 at Kiabukwa hot springs to support mining operations

MALAWI

- Springs discharge at T=40-80^{o}C
- Geothermal system is due to deep circulation along structures
- Detailed surface studies are ongoing in some prospects
- Low to medium temperature resources



GEOTHERMAL SUPPORT PROGRAMMES ACTIVE IN EAST AFRICA

- **ARGeo – UN Environment** - Capacity building and Technical Assistance
- **AUC – GRMF** – Grant for surface studies and drilling
- **BGR** - Capacity building and Technical Assistance
- **EAGER/DFID** - Technical Assistance
- **IADC – Italy** – Technical Assistance and loan for infrastructure developments and drilling
- **Iceland MFA –** Capacity building and Technical Assistance
- **JICA -** Capacity building and Technical Assistance
- **NDF -** Capacity building and Technical Assistance
- **NZ MFAT -** Capacity building and Technical Assistance
- **Power Africa/USAID** - Capacity building and Technical Assistance
- **UNU-GTP -** Capacity building

Banks Supporting Geothermal Projects in E.A.

- African Development Bank (ADB)
- Agence Française du Développement (AfD)
- EIB
- China Exim Bank
- IFC
- KFW
- OPIC
- World Bank

What is likely holding back Development?

- High upfront costs
- Inadequate grant support for exploration drilling
- DFIs and agencies reluctance to support exploration of low-medium temperature resources
- Commercial banks reluctance to participate in the exploration phase
- Inadequate trained human capacity

CONCLUSIONS

- Large potential exists for geothermal resources development and utilization in Eastern Africa
- Support is still required in the following areas:
  - Human capital development
  - Technical Assistance
  - Increased grant support for the exploration phase