Technical review of geothermal potential of Kibiro springs, Uganda


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Project background and organization

- In 2014, request for technical assistance submitted by Uganda Directorate of Geological Survey and Mines (DGSM)
- Funding by African Rift Geothermal Development (ARGeo)
- Implementation by UN Environment Programme (UNEP)
- Technical advice and equipment provided by Geothermal Development Company of Kenya (GDC)
- 3 advisors: Bill Cumming, Luigi Marini, Keg Alexander
Project objectives

- UNEP/ARGeo project initiated in Dec 2015
- Review data from existing surveys
- Collect new data
- Interpret geoscienctific data in coordination with DGSM (capacity building)
- Develop an integrated conceptual model including target sites for possible exploration wells
Kibiro – overview

- Kibiro hot springs located on SE shore of Lake Albert in Western Branch of EARS
- ~350-m SW-NE escarpment divides area into 2 entirely different geologic settings:
  - To the SE, the geology dominated by Precambrian crystalline basement
  - To the NW, the rift valley consists of sequences of sediments, up to 5.5 km thick

Source: Ring, 2008
Kibiro – Regional tectonic evolution

- Recent tectonic history
  - Rifting originated in late Oligocene or Early Miocene (~23 Ma)
  - Compression during mid-Miocene (~15 Ma)
  - Second phase of rifting during Pliocene (~2.6 to 5.3 Ma)
  - Compression during the Pleistocene (~0.01 to 2.6 Ma)
  - Present day: normal faulting regime (extensional)

- Lake Albert rift developed as a pull-apart in a sinistral-transtensional environment

- Complicates interpretation due to different stress regimes

Tectonic history source: Delvaux & Barth, 2010
Lake Albert

- Rift basin based on 2D reflection seismic data
- Depth to basement (blue is deepest)

Source: Uganda PEPD, 2004
Kibiro springs

- **Mukabiga**:  
  T = 57-86 °C  
  flow = 4 L/s,  
  gas bubbling,  
  oily odor

- **Mwibanda**:  
  T = 33-72 °C  
  flow = 2.5 L/s

- **Muntere**:  
  T = <39.5 °C  
  flow = seeps
Geochemistry summary

- Kibiro hot springs are high salinity Na-Cl water with average TDS of 4500 mg/kg
- Mixture of geothermal water and shallow, brackish water
- Gas chemistry dominated by methane (CH$_4$)
- Na-K geothermometry indicate deep reservoir T’s in range of 236-250 °C. However, Na and K not in equilibrium with low-albite and microcline resulting in suspect results
- Silica, K-Mg, and H$_2$-Ar geothermometer results indicate that deep reservoir T’s are in range of $\sim$150 °C, in a fault-hosted upflow with no direct magmatic heating
- Fluid from depth of 2-2.3 km flows up NTB to shallow reservoir below alluvial fan where 115 – 125 °C based on enthalpy-chloride relationship (due to mixing with cold brackish water).
MT results

- At 450 masl
- Lake Albert surface is ~620 masl
Rift Basin Sediments

Metamorphic Basement
TEM results

- At 200 m depth
Kibiro Geothermal Prospect

TEM GDC DGSM 2015-2016, 1D Inversion Cumming 08/2016
Profile 2c TEM Resistivity (1D smooth)
Kibiro conceptual model – fluid flow

- Fluids gain heat through deep circulation beneath Lake Albert
- Heat source is rock-to-water conductive heat transfer at considerable depths in the amagmatic Lake Albert rift basin
- Heated fluids rise to base of sediments in basin and then up deep-seated normal faults
- Heated fluids flow updip through sediments along Eastern platform towards NTB Fault
- Discharge at Kibiro springs at zone of enhanced permeability (intersection of NTB Fault and minor faults)
Kibiro conceptual model
Estimated extent of shallow geothermal reservoir:

- P90: 0.2 km$^2$
- P50: 0.9 km$^2$
- P10: 2.5 km$^2$
Power capacity estimates for Kibiro

Lognormal power density approach (Cumming, 2016)

- Range of estimated resource area: 0.2 to 2.5 km$^2$
- Assuming a resource T of 130 °C, power density (based on existing geothermal power plants): 0.4 to 7 MW/km$^2$
- Power capacity estimates (% confidence):
  - P90: 1 MWe
  - P50: 3 MWe
  - P10: 10 MWe
- If TGHs confirm 140-150 °C shallow reservoir at 150-200 m depth, then a 15 MWe development could be feasible
Next step: 4 temperature gradient holes
Muntere salt beds at Kibiro, Uganda

Thank you!