SELECTING SITES FOR A DEMONSTRATION OF THE "GEOTHERMAL VILLAGE" CONCEPT

VARET JACQUES
WP 11 GV1 GÉO2D

Work under progress *with Peter Omenda, Yves Géraud, Pascal Tarits, Walter Whealer, Susan Onyango, Fabio Lannone, Isabella Nardini and other partners to LEAP-RE, WP11, GV1 Project…*

LEAP-RE STAKEHOLDER FORUM
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Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

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Introduction

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Context

Within climate friendly, Renewable Energy options, Geothermal Energy appears as one of the most promising solutions in Eastern Africa. This, due the general advantage of a resource available 24/24h and 7/7d, independently of climatic conditions, compared with Solar, Wind or Hydro, and to the exceptional geodynamic condition prevailing along the East African Rift System (EARS).

Relevance of your study

Along the EARV which extends from Eritrea to Mozambique, the progressive separation of the Arabian, Nubian and Somalian plates (Fig.1) provide telluric conditions allowing for exceptional high geothermal heat flow otherwise available only in deep sea conditions along the Mid Oceanic Ridges (MOR), with the exception of Iceland (where geothermal is known to cover a large part of the energy demand of the country).

Work under progress under the coordination of University of Lorraine, with Yves Géraud, Peter Omenda, Pascal Tarits, Walter Whealer, Susan Onyango, Fabio Lannone, Isabella Nardini and other partners to LEAP-RE, WP11, GV1 Project…

Geodynamic context favors geothermal solutions

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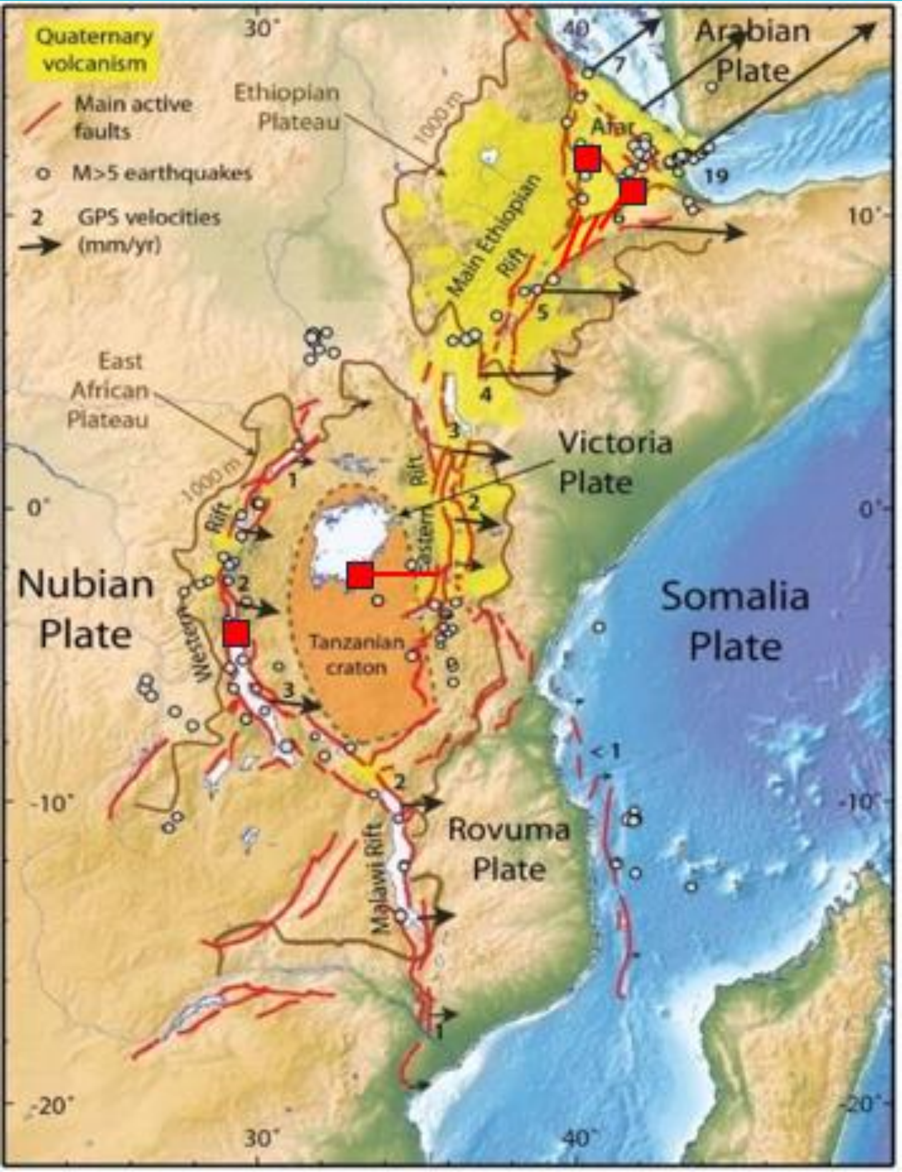

Figure1: The East African Rift System (EARS), extending from Mozambique (S) to Eritrea (N), with major fault systems (in red), main earthquake location (white dots for M> 5), manifestations of Quaternary volcanism (in yellow) and plate-motion vectors with GPS velocities (black arrows, with numbers in mm/y). Observe the progressive increase of the spreading rate from South to North along the EARS (from 2mm/y in the KRV, 5 to 7 mm/y along the MER and up to 2 cm/y in Afar).

The 4 sites studied are pictured with red square (from N to S):

- *Era Boru (EB) in Ethiopia with plate motion of 20 mm/y.*
- *Abhé Lake (AL) in Djibouti with both plate motions of Arabia (a few mm) and Somalia (6mm)*
- *Homa Hills (HH) in Kenia on the transverse (E-W) very slow Nanzia rift*
- *Bugarama in South Rwanda (less than 2mm/y)*

The base map is modified from Calais (2016)

Context Analysis

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- **Previous Studies on the subject & Context of Application**

In Africa, and particularly in East-Africa where the geodynamic context of the rift (EARS) favors geothermal solutions, the development is still rather low (with the noticeable exception of Kenya), and presently considered for large size projects serving electricity through the national grid.

Local solution, off-grid are still unknown, when the geological solutions allow for developments at local level. A first paper was published by Varet et al. (2014) presenting the Geothermal Village" concept (Fig.2), however it was not implemented yet due to lack of demonstration based on sufficiently convincing research. A regional Survey was engaged with the support of USAID & US Academies in Ethiopia, Kenya and Tanzania showing that numerous sites would suit the social demand and geothermal local potential (Mariita et al. 2016), and ad-hoc community based entities were established in Ethiopian Afar and Western Kenya (Nebro et al., 201-; Onyango & Varet, 2018).

The « Geothermal Village » concept

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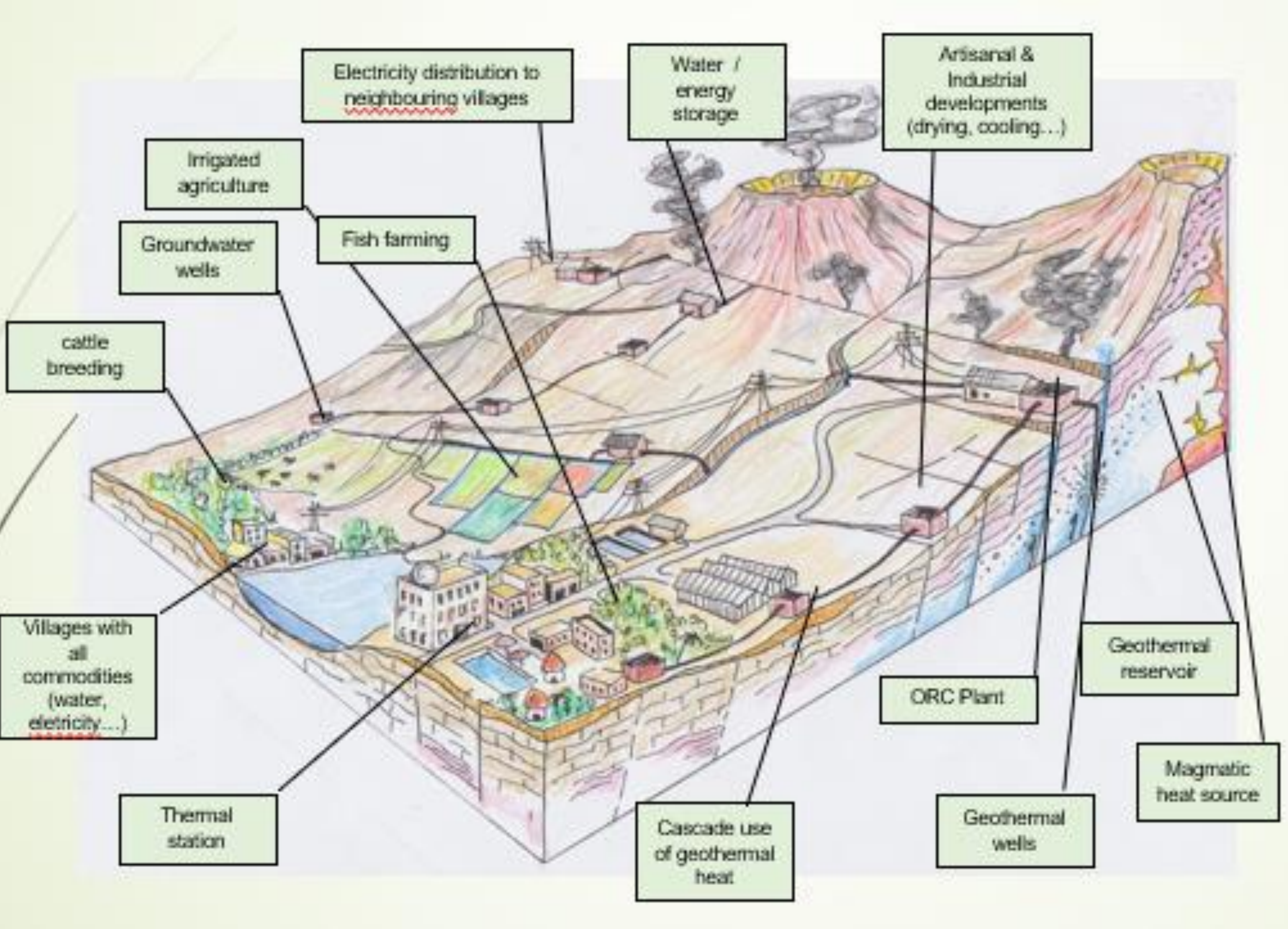

Considering that numerous villages remain at present – and in foreseeable future – off-grid, geothermal local solutions are justified. Prevailing geodynamic conditions allow for steam to be available at the surface, and unexpensive energy production systems for both Electricity and Direct Uses (DU) as well as water answering the needs of local communities, severely affected by increasingly arid conditions climate change.

Geothermal hence appears as a solution for circular economy (cascade use of energy and water) and climate resilience at local level :

this is the Geothermal Village (GV) concept (Varet et al., 2014)

The 4 sites selected for the GV project

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The sites selected for GV project based on specific, different geodynamic location

Answering the call of the EU, at least 3 sites were requested in 3 different countries,

- but 4 sites were in fact selected (seen in Fig.1), in order to increase the diversity and the variety of possible duplications of the systems, mobilizing relevant partners from each African country

- Sites implemented based on both the geological resource conditions (determining the geothermal production system), and social demand (governing the various kinds of applications, surface engineering and local distribution networks).

Methodology - 1

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- Scientific Methodology Adopted in the Study

4 selected sites were subject to multidisciplinary studies including: geosciences, social sciences, engineering, aiming at selecting one of them for a demonstration.

This implies in particular the quality of the resource, the social demand and organization on site, the technology choices and technical capacity in the country, and the fulfillment of administrative conditions (leasing of the site by concerned authorities f.i.).

Unfortunately, the safety conditions (Tigray war) did not allow to complete yet the work in Ethiopia at Era Boru, but this will be engaged in the last month of the year 2023 and early 2024, while on the Rwanda site, the field work, well advanced at present, should be completed end of October 2023.

Methodology – 2 Time frame and Work packages

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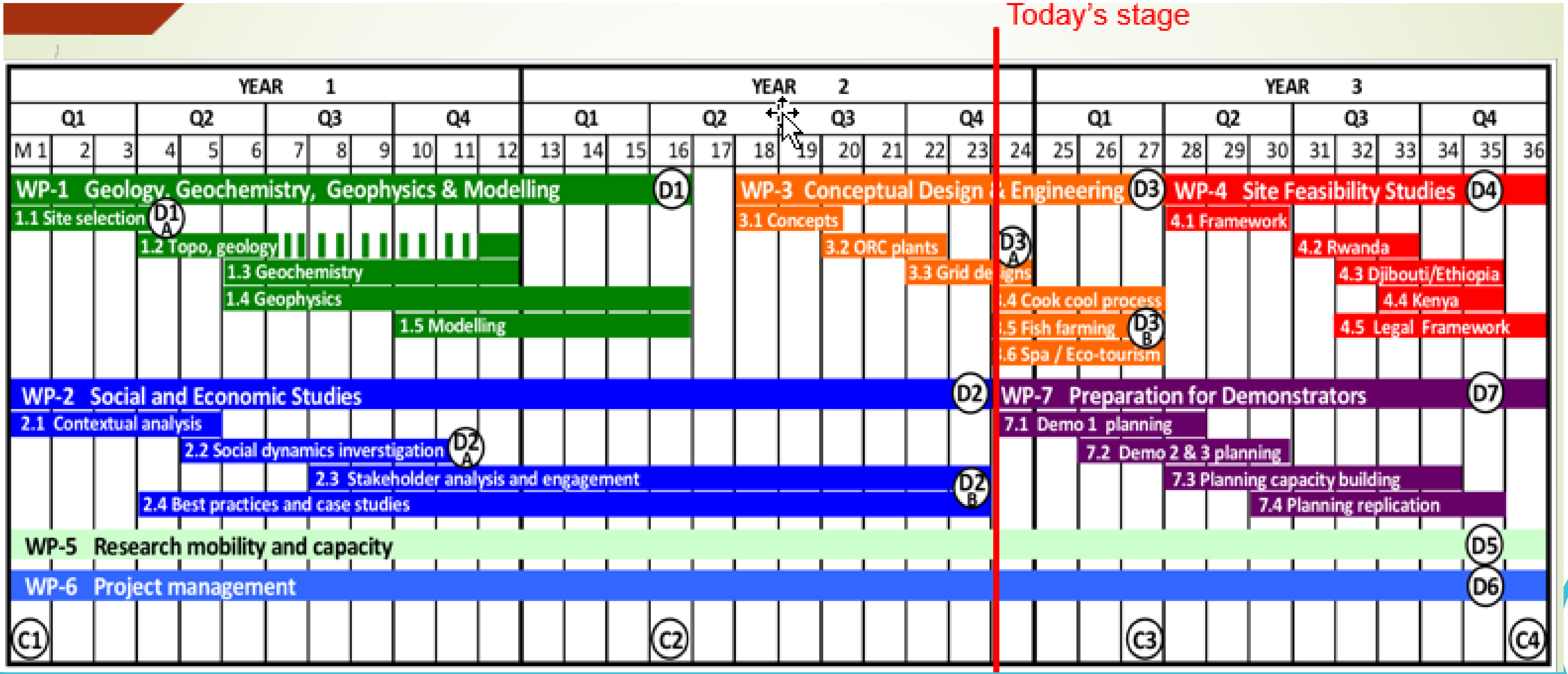
- **Scientific Methodology Adopted in the Study: a multidisciplinary approach**



Eraboru GV site (Afar regional State, Ethiopia)

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Feeding herds (goats, sheeps, donkeys, camels, cows) with distlled water form engineered steam vent at Era Boru

Era Buru in North-Central (Teru Woreda) Ethiopia's Afar Regional State is located on the northern extremity of the most active spreading segment : Manda Harraro axial volcanic Range (Barberi & Varet, 1977), which was affected by a spectacular opening over 70Km long and up to 8cm large in the years 2005-2010, well documented by various geophysical studies (Ebinger et al., 2010).

The area is affected by numerous stream vents along N-S faults at the foot of Dabbahu volcano topped by pantelleritic obsidian domes derived from the fractionation of transitional parent basalts (Barberi et al, 1975), hence forming an important shallow magmatic heat source which developed along a transverse fracture zone, in a context analogue to Olkaria (Varet and Omenda, 2020),

with a "geothermal civilization exploiting artisanally this steam field (Gardo & Varet, 2022). Located at the foot of the intensively faulted Nubian escarpment, the system benefits from a good groundwater recharge (Varet, 2010).

Abhé GV site, Djibouti

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Abhé in the SW extremity of the Djibouti Republic, on the Easter border of this salty lake extremity of the Awash Endoreic basin. Spectacular travertine chimneys are steaming at the top with thermal springs at their foot. No recent volcanic activity is observed on site, but the Dama Ale shield volcano on the western side of the Lake in Ethiopia display a complete magmatic sequence of tholeiitic affinity from basalts to rhyolites (Varet, 2019).

Its location is clearly controlled by the intersection of the WNW-ESE Red Sea – Aden Rift system, with the Northern end of the ENE-WSW Main Ethiopian Rift 6mm. The site was already well studied by ODDEG, but requested complementary investigations engaged in 2021 .

Homa Hills GV site, Nyanza Rift, W. Kenya

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Geochemical sampling for geothermal gas analysis at Homa Hills by Université de Lorraine / CNRS team (LEAP-RE WP11 GV project)

Homa hills in western Kenya, on the SE shore of Lake Victoria belongs to the E-W Nyanza Rift, perpendicular to the main KRV. Along this rather slow but still active rift segment, magmas of carbonatitic composition erupted in Mio-Pliocene with Homa Hills as the most spectacular volcano.

Hot springs and steam vents are found in the central part and northern slope of the volcano, which is intensively dissected by erosion since it was built, due to the solubility of the volcanic products, with intrusive in the central part, and effusive, pyroclastic layers and reworked lahars along the slopes.

In such environment, the hot-springs are highly carbonatitic, whereas surface water is generally salty. As a result, the demand for unsalty water is high, with at present the Lake Victoria as only solution.

Mashyuza geothermal site, Southern Rwanda

Mashyuza, between Lakes Kivu and Tanganyika belong to a N-S linear tectonic depression (Rusizi river flowing from N to S). Two fault trends are observed pattern: NW-SE and NE-SW of the Kivu rift segment, cut by the most recent N-S faults with an E-W extension reaching 2Km width. It acts as an accommodation zone linking Lake Kivu and Lake Tanganyika rift systems. Two Mio-Pleistocene units (1) Sedimentary lacustrine terraces related to former lake levels (up to 160-200 meters above the present level) at the end of the Pleistocene period; (2) Volcanic tholeiite dated 11 to 9 My and alkali-olivine basalts dated 8-5 My. If these products are too old to allow for a magmatic heat source, they are of interest as they may control the reservoir conditions in the graben in-fillings. The most recent seismo-tectonic studies indicate a stress tensor with a nearly horizontal extension oriented in the E-W direction, coherent with the plate motions measured from GPS (Fig.1). The thermal springs are all located along the same recent N-S (to N20°E) fault zone resulting from this extension under progress. Even if inherited from the same long lasting still active tectono-magmatic history, the site has to be considered as fault-related, amagmatic system.
I.e.representative of a dominant type in the western rift system (Omenda et al., 2016), a good reason for selection in the frame of the GV project. Geophysical investigations are under progress.

Results / Preliminary Results - 1

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Results & Expected Results of the study

All sites were subject to multidisciplinary studies including: geosciences, social sciences, engineering, aiming at selecting one of them for a demonstration.

This implies in particular the quality of the resource, the social demand and organization on site, the technology choices and technical capacity in the country, and the fulfillment of administrative conditions (leasing of the site by concerned authorities f.i.).

Unfortunately, the safety conditions (Tigray war) did not allow to complete yet the work in Ethiopia at Era Boru, but this will be engaged in the last month of the year 2023 and early 2024, while on the Rwanda site, the field work, well advanced at present, should be completed end of October 2023.

Box Style 2

Results / Preliminary Results - 2

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The quality of the resource – and the resulting energy production - appears quite variable:

1. at **Abhé**, where numerous steam vents and thermal springs are found, we have the possibility to produce a fluid allowing for electricity production from an ORC, and also hot water for direct uses, as well as drinking water, highly demanded on site (desertic conditions).
2. At **Homa Hills**, in a rather different social environment, geological conditions determine a highly salty fluid, raising costly productive conditions, but despite this difficulty, the feasibility of the demonstration should allow to propose a cascade use of the resource answering the demand of the community, organized in specific CBO.
3. At **Mashyusa**, the high flow rates but limited temperature (52°C at the surface) is suitable for a variety of direct uses but would not allow for electricity production: preheating of limestones for the cement factory, industrial rice drying and implementation of a bathing and SPA resort, already popular but need should reach international sanitary and medicinal standards. Offering community run facilities for drying and preservation of vegetables and fruits from plantations around peasant’s houses surrounding the village is also considered.
4. **EraBoru** should provide the most effective demonstration of the GV concept, with its well-developed easy-to-reach geothermal resource (shallow steam to be produced from shallow wells), and the high local demand for water and energy of a community already organized for engaging, managing, and promoting such resilient developments in the region and all along the EARV.

Conclusion

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As a whole, on all 4 sites, the choice should also allow to demonstrate the best technical options and economic conditions, for the project construction and the resulting advantage for the concerned population.

The feasibility studies should allow for demonstrations representative of the variety of resource type and demand conditions prevailing in Africa along the EARS.

One of the site will be selected for a real-size demonstration.

Hoping LEAP-RE will allow for a next round with the EU allowing for this demonstration

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