Technological considerations in establishing direct use projects

The Geothermal Village concept

Jacques Varet Géo2D

Powering Agri-food value chains with geothermal heat to enhance food security and drive climate action

Pre-Conference Short Course, 9th African Rift Geothermal Conference
Djibouti Palace Kempinski, 1st November – 2nd November 2022

Technological considerations in establishing direct use projects

The Geothermal Village concept

Jacques Varet Géo2D

Powering Agri-food value chains with geothermal heat to enhance food security and drive climate action

© KCC Photo/Sylvain Liechti

The « Geothermal Village » project Presentation frame

1. Introduction : presentation Dr. Jacques Varet, Géo2D
2. Aim of the “Geothermal village” project; development of the concept
3. Status of the 4 sites selected for a demonstration project
4. R&D engaged: methodology and Feasibility expected
5. Time frame

The « Geothermal Village » project

1.Introduction : Géo2D

- **SME based in France,** R&D, expertise, advices, capacity building
- **Specialized in geothermal, mainly in the EARV,** long experience, particularly Afar triangle (CNR-CNRS since 1967)
- **Géo2D created 2011 by J.Varet,** IAVCEI prize winner, former Head BRGM geothermal, French Geological Survey director, Eurogeosurveys President with experience in Ethiopia, Kenya, Djibouti, Eritrea, Rwanda & Tanzania
- **Launched** the Geothermal Village concept in 2014 (in a first EU/ACP Facility proposal)
- **Developed the concept since** on geoscientific (1km3 approach), engineering (ORC + steam condensing for water production) & social sciences
- **Engaged a PhD** with EHESS (Paris) on social approach to geothermal development serving local needs for indigenous people (Susan Onyango)
- **Published** several papers on the issue (see references); **A guidebook** on Direct Uses in the EARV is under edition with UNEP (cf. Meseret's presentation)
- **The GV1 R&D project** is financed under EU/AU **LEAP-RE**, involving 15 partners from 4 EU and 4 AU countries

Looking for **GRMF** support for **demonstration sites** being studied (Ethiopia, Kenya, Rwanda, Djibouti)

INTRODUCTION

- Africa - in particular all along the East African Rift System - has geothermal resources of high value (shallow volcano-tectonic related).
- Nevertheless, the resource – even if exceptional with steam available at the surface - is essentially untapped, particularly in the remote and arid areas where the societal needs are highest.
- This due largely to a lack of reference (demonstration) projects when relatively inexpensive boreholes can tap quite hot fluids (up to 150°C).
- R&D (producing know-how) is required to implement at the local level, African solutions as the nature of the resource and of the energy demand significantly differs from existing scheme.

The « Geothermal Village concept

The Geothermal Village concept relies upon geothermal fluids obtained from moderate depth boreholes :

- used first for small-size electricity production devices (portable ORC's)
- then in a cascade of increasingly lower temperature for direct uses (DU)
- such as drying crops/fish/meat, cooking and baking, fish farms and greenhouses, pasteurizing (dairy),
- bathing and washing, supply drinking water, provide cooling and freezing, including eco-tourism based on hot-springs resorts.

Diversifed EARS

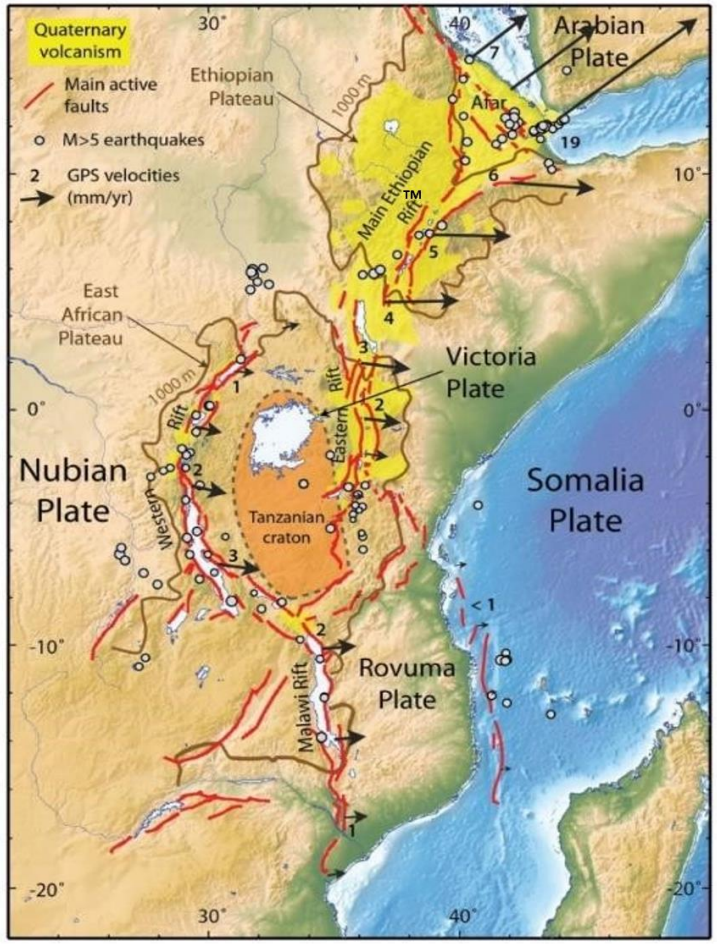


Fig. 2.1: The East African Rift system, with major fault systems (in red), major earthquake location (white dots for M> 5), manifestations of Quaternary volcanism (in yellow) and plate-motion vectors with GPS velocities (black arrows, with numbers in mm/y). Observe the progressive increase of the spreading rate from South to North along the EARV (from 2mm/y in the KRV5 to 7 mm/y along the MER and up to 2 cm/y in Afar). Calais (2016)

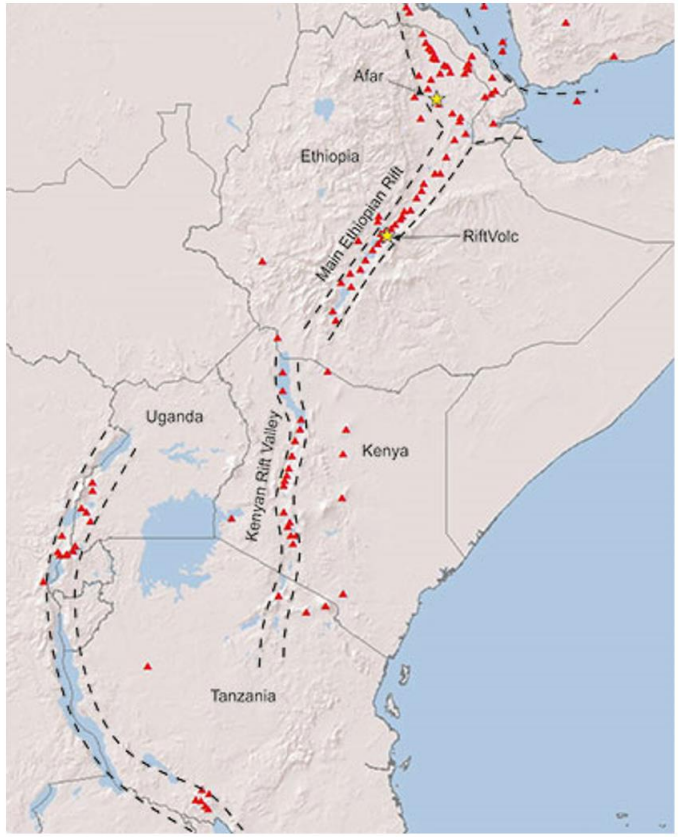
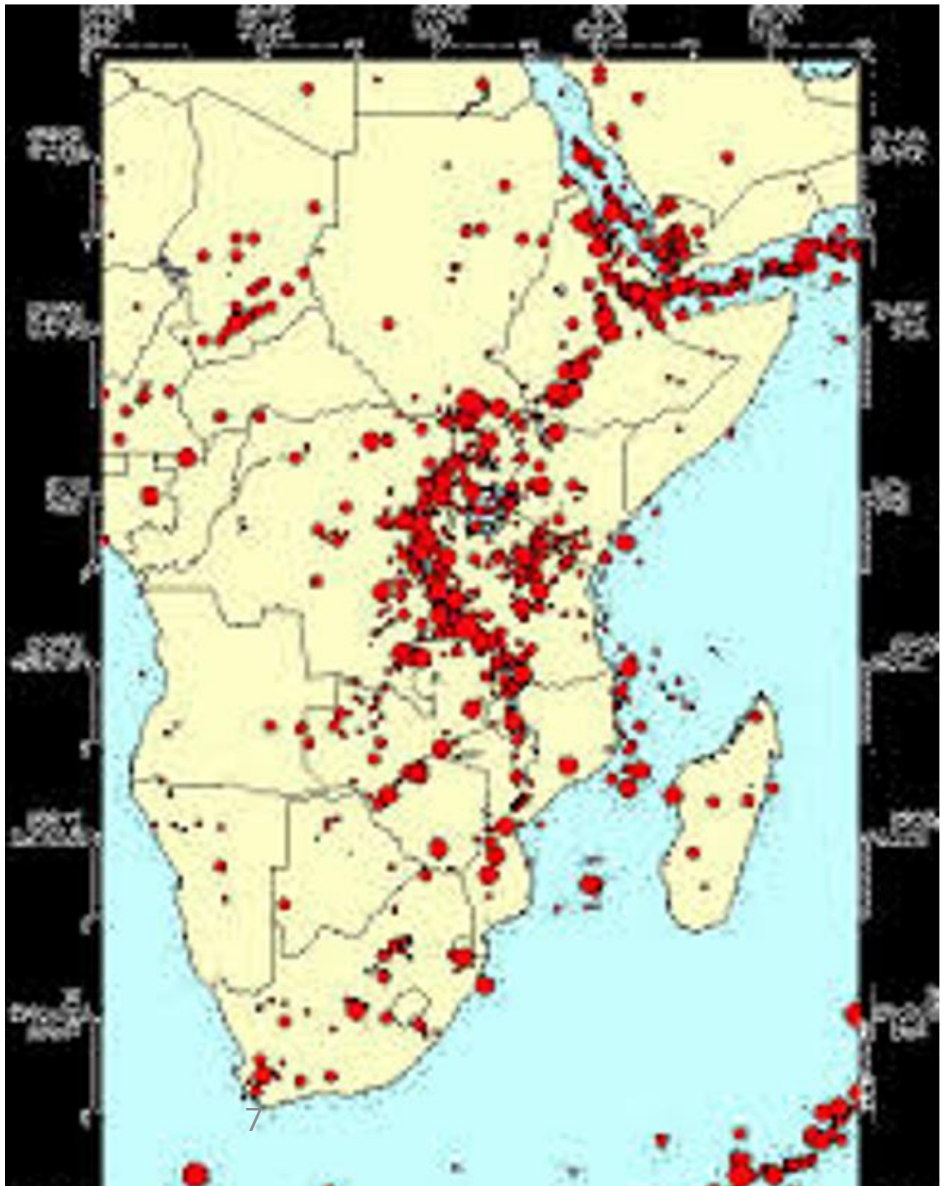
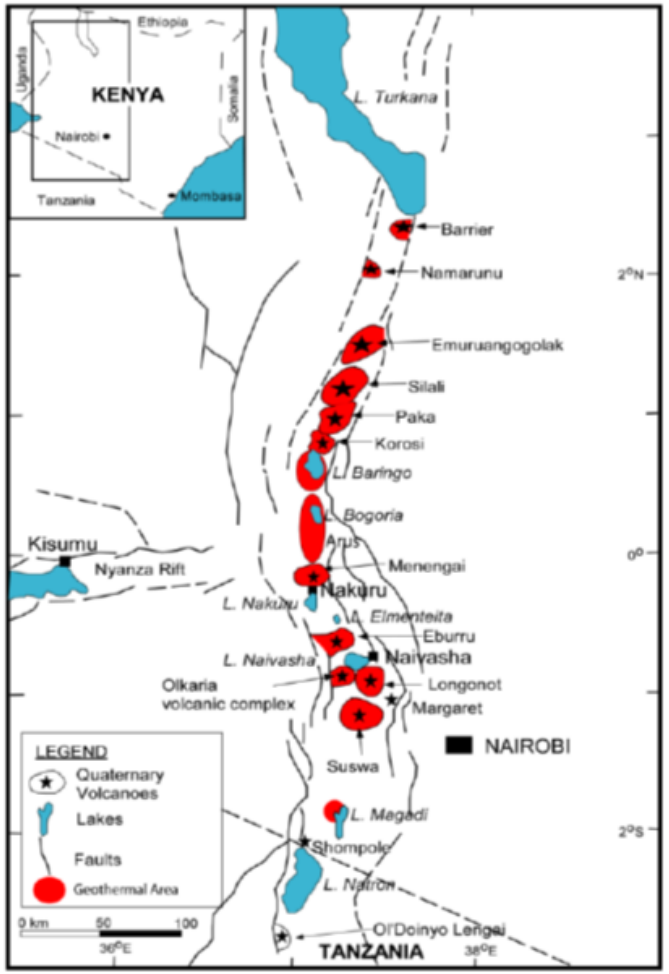


Fig. 2.2: Map of the volcanoes along the EARS. While only a few are located along the western branch, the eastern branch is characterized by the high number of volcanic centres (red triangles are quaternary volcanoes). Map from; www.riftvolc.geos.ed.ac.uk.



Kenya, Ethiopia, Djibouti (major/local sites)



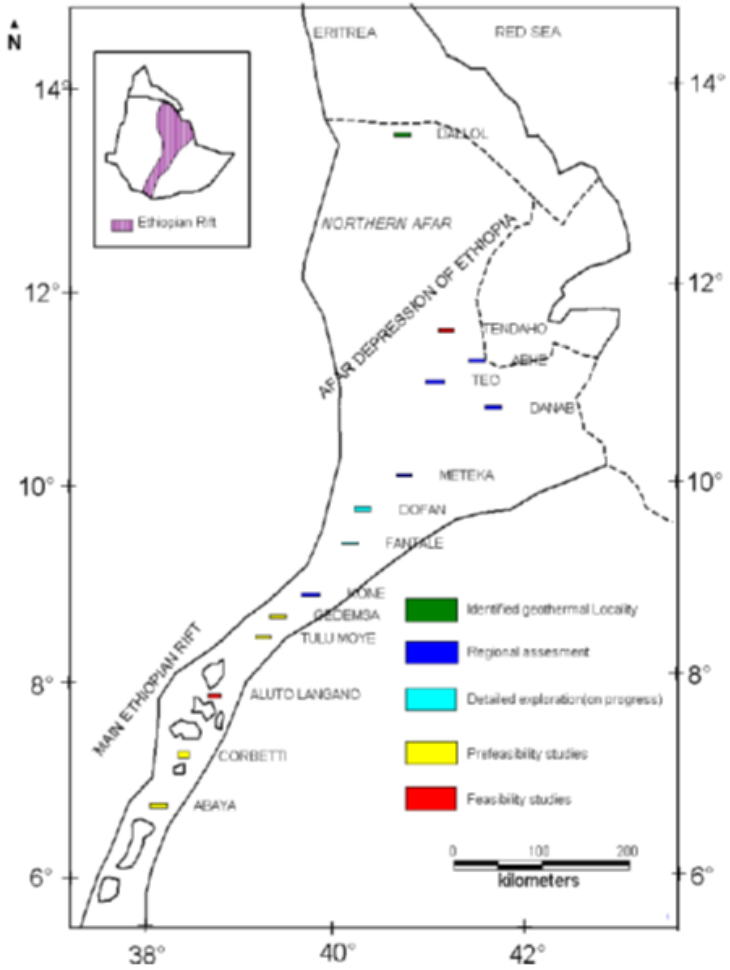


Fig. 2.3: Geothermal resource sites for electricity production identified (A: Left) in Kenya and (B: Right) Status of Geothermal Exploration and Development in Ethiopia (from Omenda, 2012, 2018).

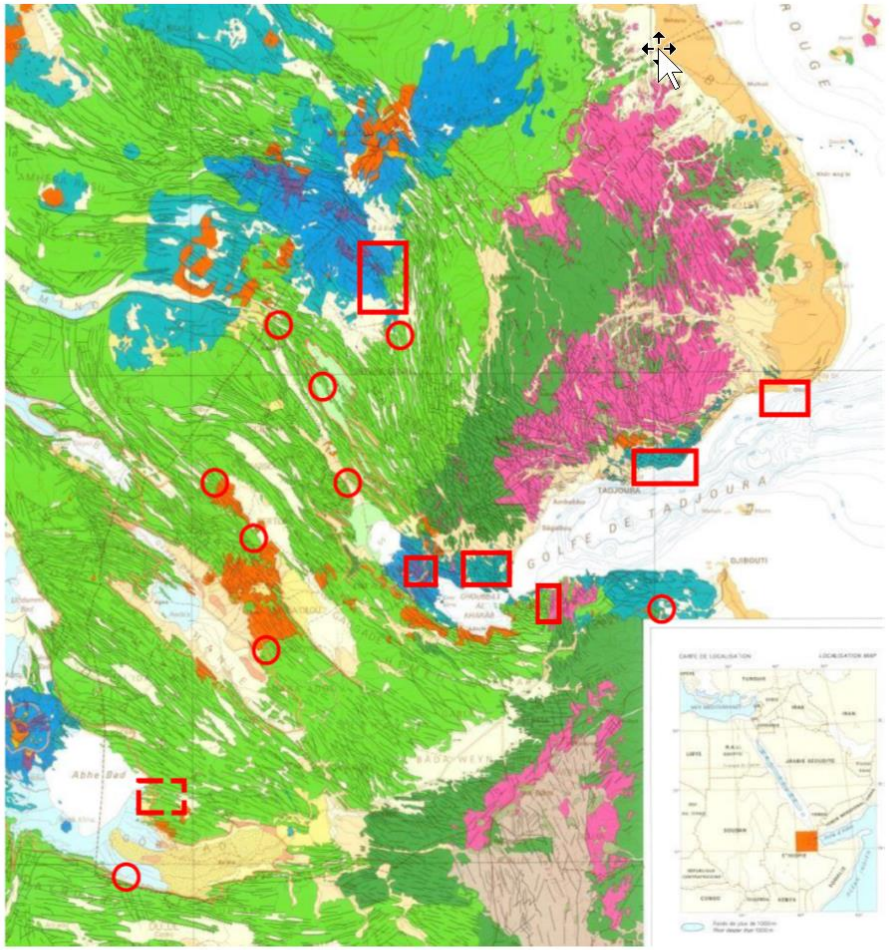


Fig. 2.14: Geothermal sites in the Republic of Djibouti. Magmatic sites located along active spreading axis, whereas a-magmatic sites are shown with circles. The base map is the Geological Map of Central and Southern Afar (Varet, 1975), The two magmatic sites of Manda Inakir (North) and Abhé (South) could benefit from a joint investigation with Ethiopia as they extend on both sides of the border. But on Djibouti side alone, possibilities of DGUD exist. Map established by Géo2D for ODDEG (2018).

Geothermal at the surface: steam or hotspring

Fig. 2.7: Steam vents along a fault affecting basaltic lava flows in central Afar (Ethiopia), a kind of manifestation that is quite frequent along the East African Rift Valley, and Afar in particular, where these have a local name: "boina". A shallow geothermal resource presently essentially untapped (Photo J.Varet 1969).

Fig. 2.5: hot-springs along a fault affecting trap-basalts North of Fantale volcano in Awash National Park Filowa resort, southern Afar Regional State, Ethiopia (Photo J.Varet, 2014)

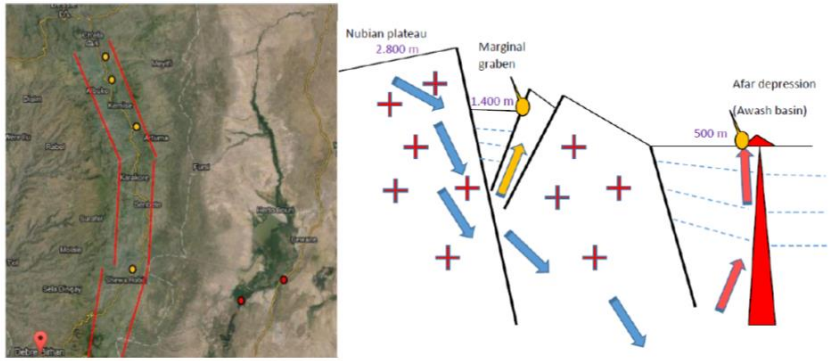


Fig. 2.9: Left: Google map showing the limit of the Nubian plateau: on the right (West) the Nile hydrographic basin, on the left (East) the Afar depression and the Awash River basin (Ethiopia), Marginal grabens developed along the escarpment. Location of major hot-springs sites, circa 100°C (from North to South: Harbu, Shekla, Borkena and Shewa Robit) are shown in yellow. Also shown the nearest steam vents s2.9 ex.ites in the Afar depression (in red). The limit of the Amhara and Afar regional states is also drawn (white dotted lines). Right: Geological interpretative section of the hydrogeological system feeding the geothermal systems (respectively hot-springs and steam vents) in the marginal graben - affecting the pre-Miocene "basement" made here of trap-basalts prom the Nubian plateau - and Southern Afar volcanic ranges built along faults and dikes of NNE-SSW (MER) direction. Appropriate geophysical methodology are being developed to properly map in 3D the convective geothermal plumbing system to be tapped by shallow drilling for local developments.

Fig. 2.8: Steaming fault affecting a rhyolite flow near Olkaria, Kenya (Photo J.Varet, 2014)

Fig. 2.6: hot-springs along fault bordering lake Bogoria (Kenya), the site, where hydrothermal deposits developed, attracts fishes and flamingos (Photo J.Varet, 2013)

Ex.: fault systems ; sedimentary basins

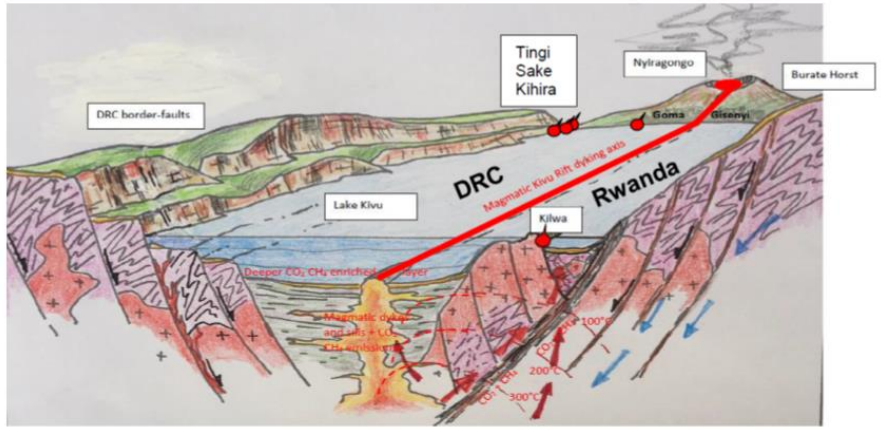


Fig. 2.24: Block diagram showing the hypothetical Northern Kivu Rift geothermal conceptual model (J.Varet, 2018).

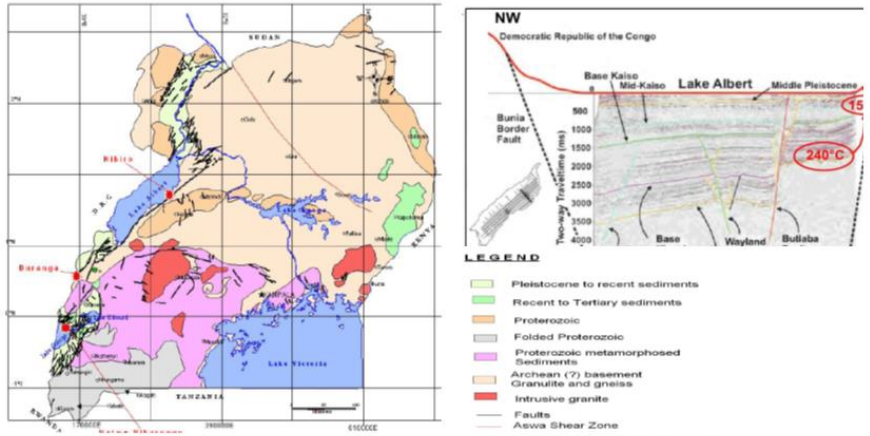


Fig. 2.25: (A) Geological map of Uganda showing the main surface surface thermal manifestations of Katwe (70°C), Kibiro (86°C) and Buranga (98°C) with its legend (B – down). From G.Bahati & A. Alaba (ARGeo, 2008) and (C - up) section through Lake Albert showing the geothermal model derived from seismic profiles and hydrochemical studies (Kato, 2017)

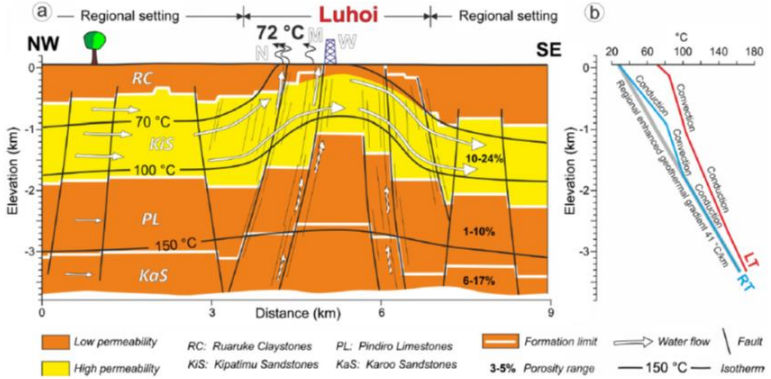


Fig. 2.26: Conceptual model of the Luhoi geothermal system in Eastern Tanzania shown with an idealised NW-SE section showing the Kipatimu sandstone host of the geothermal reservoir, with a horst structure which controls the hydrogeology and consequent thermal convection. The diagram on the right show how the convection increase the geothermal gradient in the first kilometre at depth. (Armadillo et al. 2020).

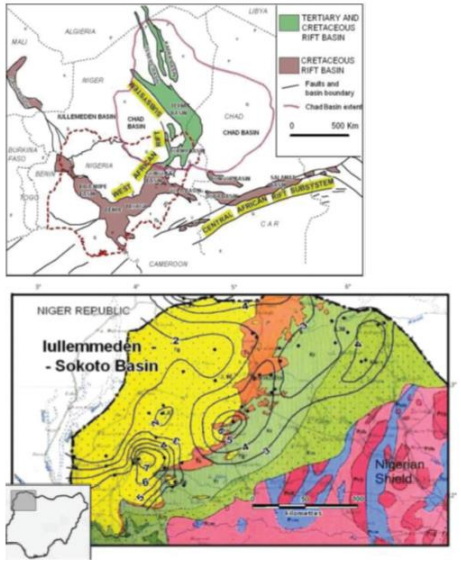


Fig. 2.27: Some geological characteristics of the sedimentary basins in Nigeria and surrounding countries showing the structures at depth, particularly the underlying tertiary and cretaceous rifts determining the thermal gradients (A: left) and some details of the Nigeria part of the Sokoto basin (B: right) showing the resulting thermal gradients on a simplified geological base map (from Kwaya et al., 2019).

EXPLORATION METHODS FOR SHALLOW GEOTHERMAL RESOURCES

Table 3.1. Examples of explorations methods for the three play-types for DU in Africa
Source:

Play-type	Volcano-hosted	Fault-controlled	Sedimentary
Area	**Eastern Rift branch**	**Western Rift branch**	**Basin areas**
Characteristics	Volcano-hosted, magma heat sources, distributed heat, deep anomalies, shallow out-flows.	Fracture/fault- controlled, deep circulation, convective systems, localised anomalies	Commonly low to medium temperature resources controlled by fault or folds systems
DU targets	Shallow out-flows with fumaroles /steam vents	Productive fault near surface spring	Near hot-springs geological discontinuities
Geological Methods	Volcanology and structural mapping and fault kinematics	Detailed structural and litho-stratigraphic mapping	Structural and litho-stratigraphic mapping based on previous oil explo. & existing wells
Geochemical methods	Fluid (hot-spring), gas (fumaroles), soil gas (radon & CO_2)	Fluid analysis (hot- springs), soil gas (radon & CO_2)	Soil gas (CO_2 and Radon surveys); fluid sampling and analysis
Geophysical methods	Gravity, seismics, MT, TEM, heat flow, occasional TGH	Gravity, seismics, TEM, (optional MT), heat flow, TGH	Existing gravity, seismic surveys; TEM, heat flow eventually TGH
Conceptual geothermal modeling	Based on high-temp. exploration results, determine shallow out-flows	3D mapping of fault systems and related convective up-flow	Anomalous thermal gradient allowing to catch shallow reservoir

EXPLORATION METHODS FOR SHALLOW GEOTHERMAL RESOURCES
data handling

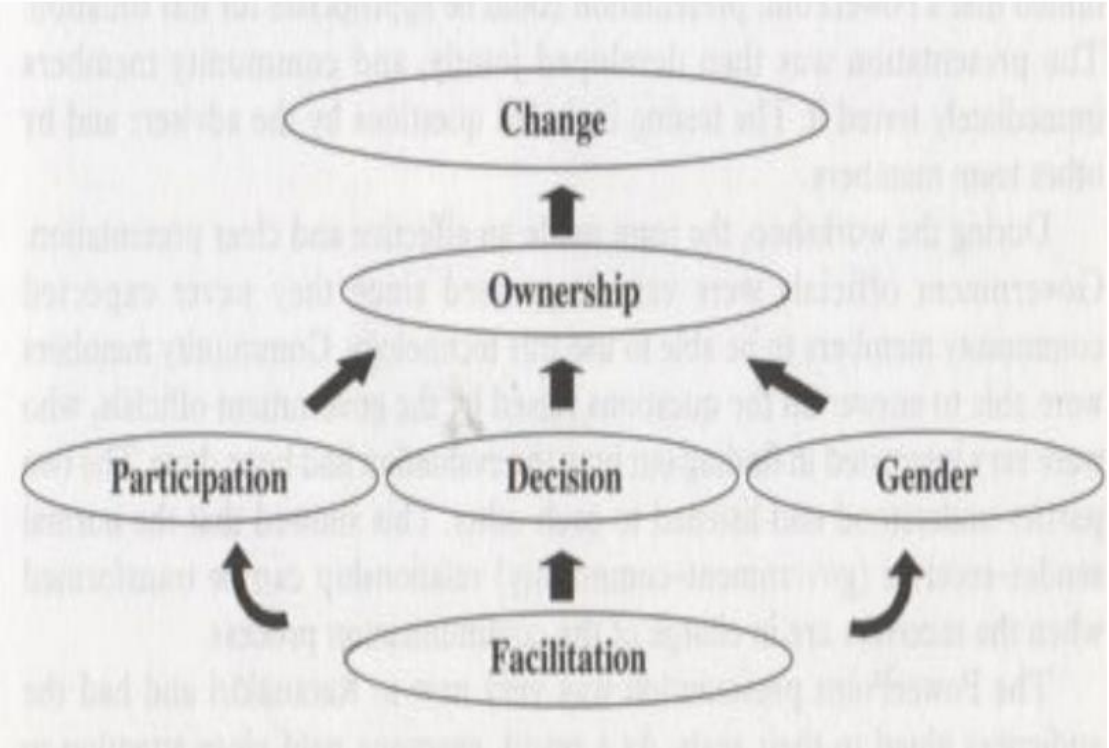
Table 3.2: Example of data sheets for DUGD initial investigations

Geography & geology		Fluid sample characteristics		Socio-economic data	
1.	Name	1.	Sampling feature	1.	Official name of resource
2.	County, State	2.	Specimen description	2.	Local language name
3.	Lat & Long Degree	3.	Fluid temperature (°C)	3.	Community on site
4.	Elevation	4.	Discharge	4.	Local language
5.	Topo environment	5.	Analysis type, date	5.	Population on site
6.	Satellite image	6.	Laboratory	6.	Population 5 km radius
7.	Air photograph	7.	pH	7.	Sex ratio (male: female)
8.	Geological map	8.	Specific conductance	8.	% children, %elders
9.	Tectonic setting	9.	Total dissolved solids	9.	% educated persons
10.	Volcanic environment	10.	Ca, Mg, Na, K, Fe	10.	Main production
11.	Reservoir rock	11.	SiO2_mgL	11.	Income (GDP/head)
12.	Reservoir extension	12.	Cl, F, SO_4_mgL	12.	Distance to access road
13.	Hydrological context	13.	Bicarbonate_mgL	13.	Distance to electric grid
14.	Hydrothermal products	14.	Isotopic analysis	14.	Telecom (phone access)
15.	Surrounding features	15.	Hydrothermal mineral deposits	15.	Water access, quality
16.	Geophysical data	16.	Hydr. min. alteration	16.	Organisation structure
17.	Surrounding wells	17.	Geothermometres	17.	Religion/belief
18.	Geothermal concept	18.	Bibliography	18.	Contact person
19.	Bibliography			19.	Possible management

Social approach

Fig. 3.3: Ismael Ali Gardo and AGAP-Géo2D team meeting with elders in Teru (Photos Varet, 2016)

Fig. 3.4: Social Scientist (Susan Onyango, Géo2D & EHESS) meeting women and girls at Badlands, Kenya under GP A project. (Photo J.Varet, 2016)



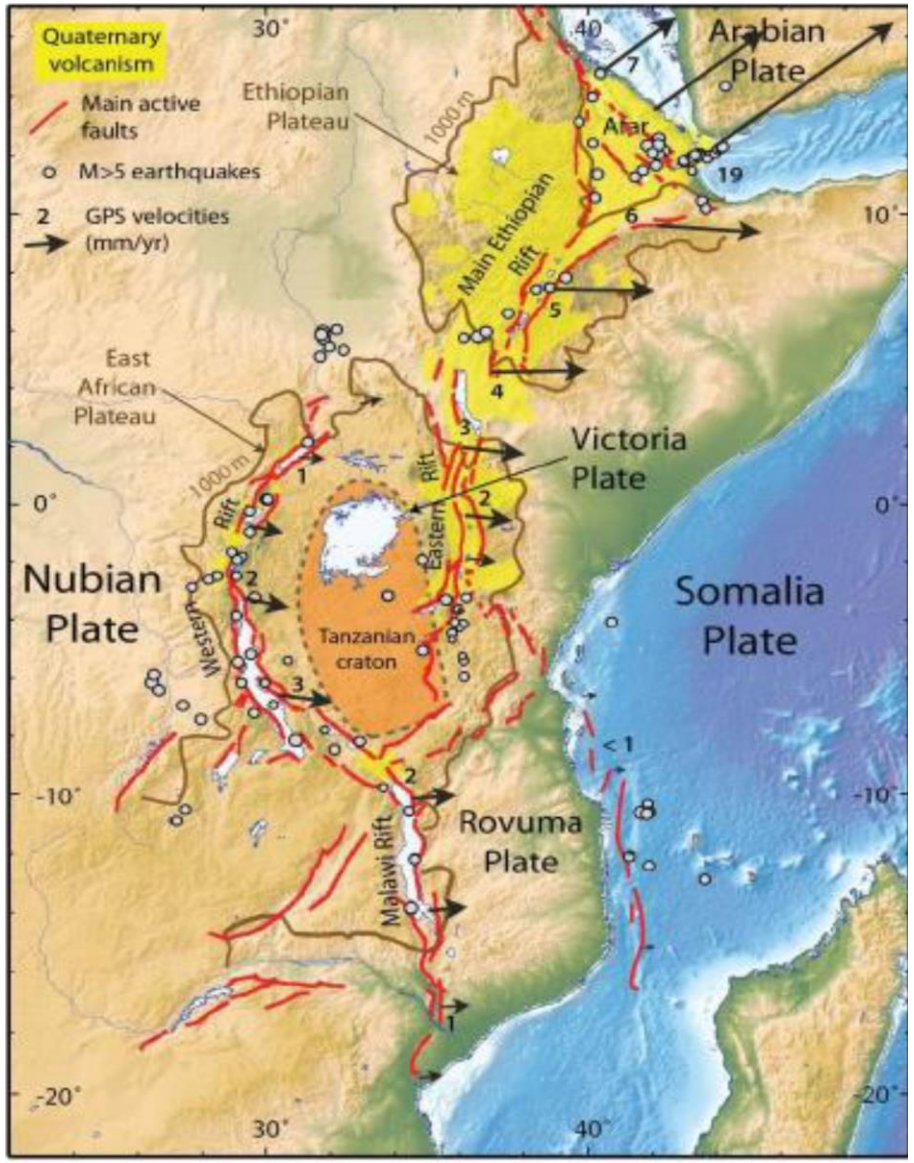
The « Geothermal Village concept

The LEAP-RE EU-AU R&D program

- First investigations show that hundreds of sites along the EARS have the resources appropriate for such developments, each installation allowing modular expansion.
- The GV project, supported by the EU-AU LEAP-RE program mobilize interdisciplinary teams from both Europe and Africa to develop a few relevant demonstration systems, adapted to the specific socio-economic needs of the local community, at an appropriate technology level.

Geothermal Village LEAR EU project

The GV project is a close collaboration between East African and European countries.
The GV project will carry out a feasibility analysis of such a system.
The objective is the development of demonstrators in the frame of a succesive project within the framework of Green Deal, with GRMF support.



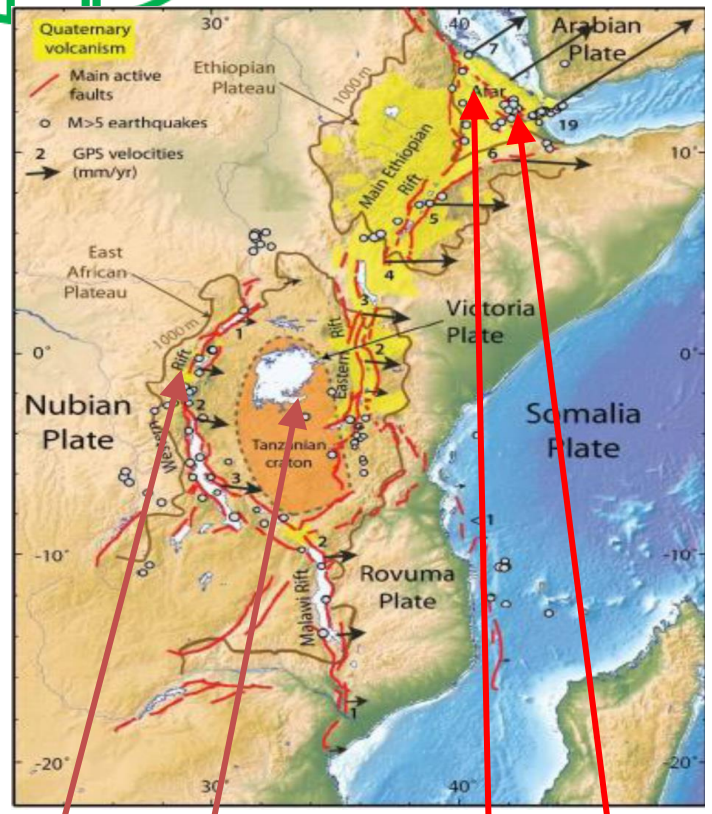
The «Geothermal Village» (GV) project at a glance

- **Duration**: M8-M45
- **Partners involved**: UL, AAU, UoN, SSSA, UNiTO, Fraunhofer IEG, Géo2D, ODDEG, UBO, NORCE, EDCL, SEPCO
- **Main objectives**:

- *Introduce geothermal-based stand-alone electric and thermal energy systems to off-grid African communities*
- *Providing **template case-studies** on adapting GV concept to different socio-eco contexts*
- *Demonstrating **feasibility** to public and private investment organizations*
- *Keeping the **technology level appropriate for local** operation and maintenance*
- *Capacity Building to ensure **local empowerment and mastering** (sciences, technical, admin., etc.)*

Djibouti, Ethiopia, France (3), Germany, Italy (2), Kenya (2), Norway, Rwanda

Structure of the Project



(From Calais, 2016)

Low temperature
Direct use

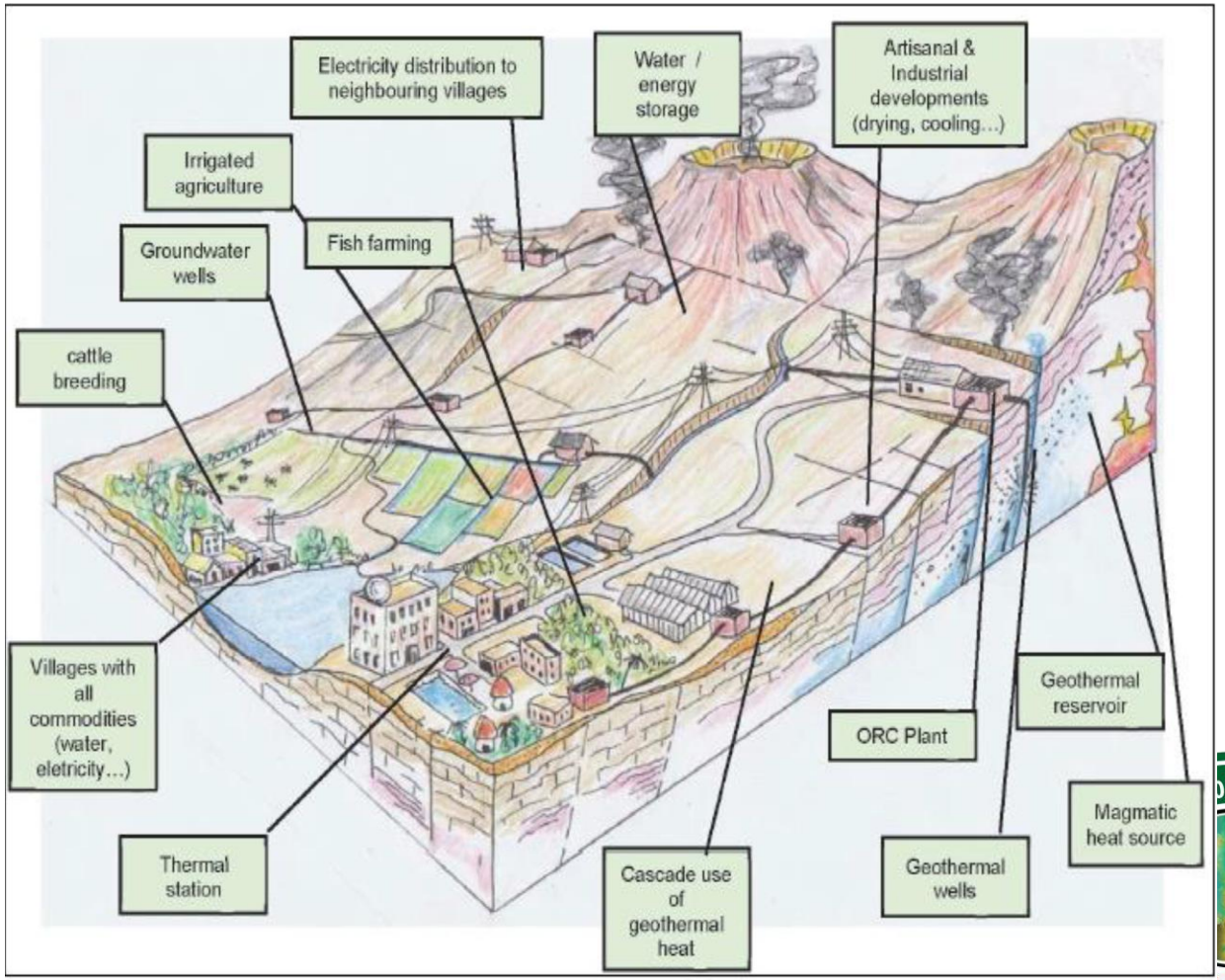
High temperature
Electricity prod.

Geothermal specificity of the EARS:

- ❑ High geothermal heat flow inducing shallow resource
- ❑ Geodynamics allowing for :
  - high temperature (electricity generation) in the Easter Branch and Afar
  - Medium temperature in the western branch and southern rift (direct uses applications)
- ❑ Social and economic demand vary due to climate and anthropology
- ❑ Wide range of contexts and applications but same challenge of:
  - Shallow resources implying specific approach & technologies
  - Local management capacities off-grid systems

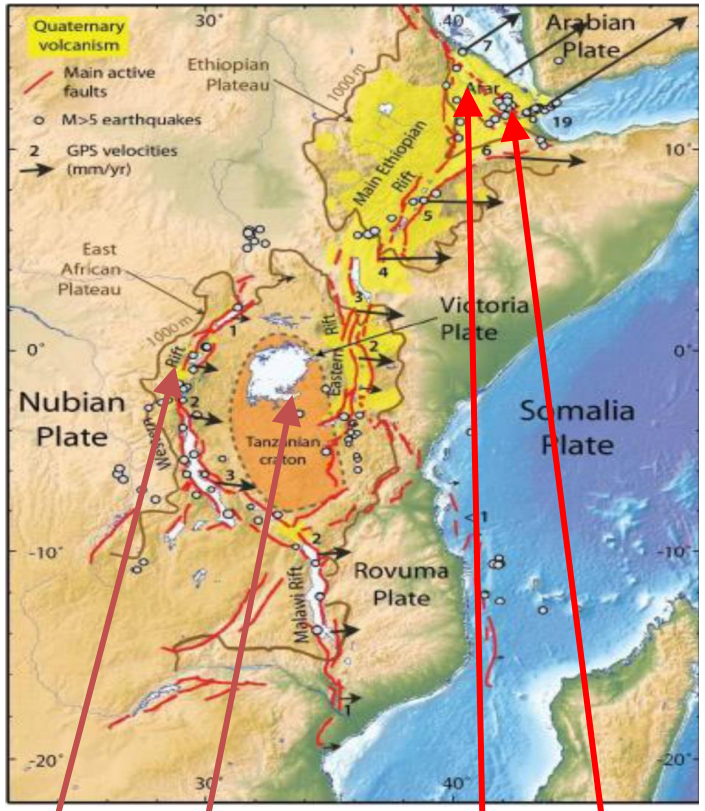
2. Aim of the project; development of the concept

- A project to build geothermal-based stand-alone electric and thermal energy systems to off-grid African communities.
- A project that brings together skills across the entire geothermal value chain with 7 WP:
  1. Geoscience (geology, geochemistry, geophysics, conceptuel modeling)
  2. Social Sciences (local demand, organisation, empowerment…)
  3. Conceptual design and engineering
  4. Feasibility study
  5. Research mobility & Capacity building
  6. Project management
  7. Preparation for demonstration



Geothermal Village

3 A variety of sites representative of the diversity of the EARS



(From Calais, 2016)

Low temperature
Direct use

High temperature
Electricity prod.

High geothermal heat flow inducing shallow resource

- Geodynamics allowing for :
  - high temperature (electricity generation) in the Easter Branch and Afar
  - Medium temperature in the western branch and southern rift (direct uses applications)
- Social and economic demand vary due to climate and anthropology
- Wide range of contexts and applications but same challenge of:
  - Shallow resources implying specific approach & technologies
  - Local management capacities off-grid systems

4 sites selected: Ethiopia, Djibouti, Kenya, Rwanda

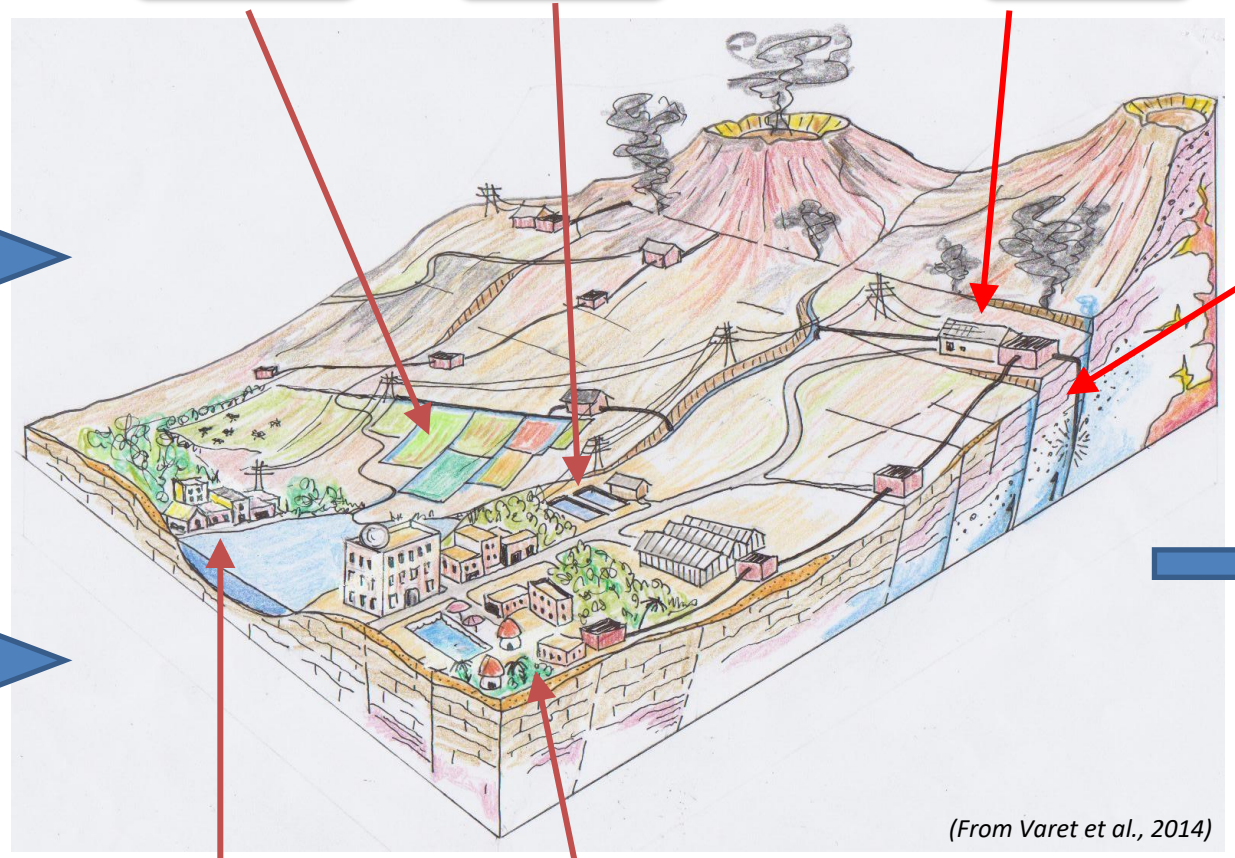
Geothermal Village
Srtucture of the Project - Methodology

Analysis of **site characteristics**

- Geosciences
- Social-eco. sciences

Assessment of **available resources and needs**

- Social-eco. sciences
- Engineering sciences



(From Varet et al., 2014)

Outcome :

- **Feasibility studies**
- **Implementation strategies**

Based on critieria:
- Local communitiy needs, lifestyle & capacities
- Type of income sources ;
- Appropriate level of technology, etc.

Geothermal Village

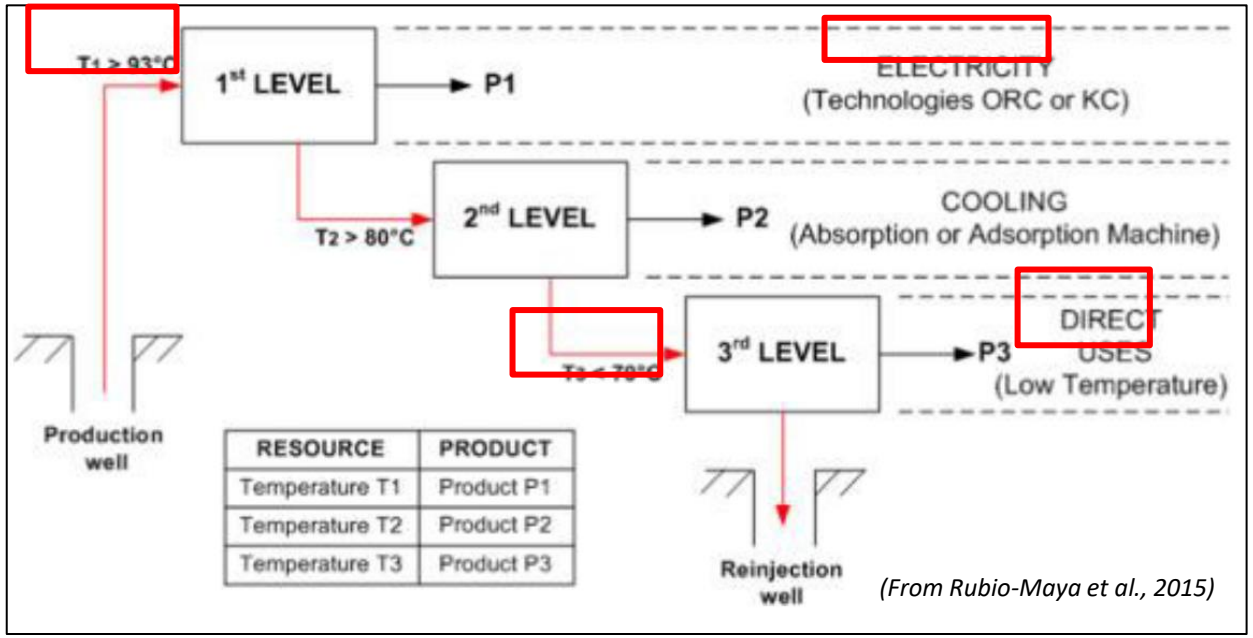
Structure of the Project - Technology

→ Cascade use **geothermal energy** combining various technologies

→ **ORC** : stand-alone, flexible and portable production modules for small applications, in the range of 20 to 200 kWe, a size **adapted to the needs and production expected**

→ Selection & adaptation of African technology and local (regional) engineering solutions (drilling, pipes, heat exchangers, etc.)

180 kW ORC plant by Enogia
https://enogia.com/wp-content/uploads/2021/10/180LT-EN.pdf



(From Rubio-Maya et al., 2015)

→ Wide array of applications:

- Electric production ; Cooling
- Fish & agri. product drying -> *Kenya, Rwanda*
- Domestic water production -> *Ethiopia Djibouti*
- Balneology -> *Djibouti, Kenya*

Structure of the Project – Capacity Building

Research mobility & partnership :

- Involvement of Master and PhD students in the project
- Summer schools/workshops about RE, in synergy and coordination with the other LEAP-RE WPs

Capacity building :

- Based on needs assessments, training for local communities **to ensure proper mastering of the whole chain** of basic knowledge (from technology and financial handling to administrative and social management) → *This should guarantee maintenance, extension and replication of such community-based geothermal projects.*
- Trainings through CBOs and NGOs involved in the GV (e.g. Kenya -> **HHCBO** ; Ethiopia -> **AGAP**)

→ Vote on the status of the newly created (2015) Afar Geothermal Alternative Power Company (AGAP), an Ethiopian CBO.

(From Varet et al., 2020)

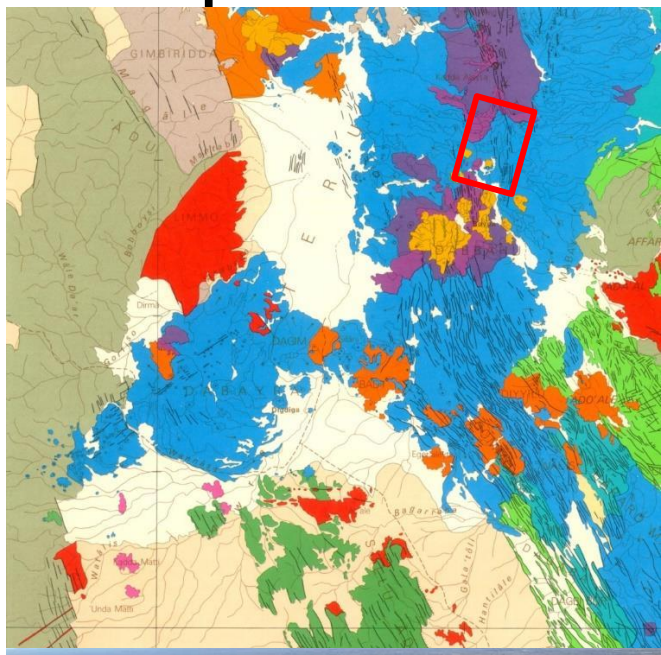
Sites selected : (1) Era Boru, Afar Regional State, Ethiopia

Geographic Coordinates 12°40'N – 40°20' E; *Altitude* : 700m

Surface thermal manifestations are numerous (steam vents) and well known by the Afar pastors, as they are engineered to condensate the steam and produce water that is used for both livestock's and human consumption

- digging holes in the fumarole site,
- use the clay (red kaolin-iron hydroxides mixtures) produced by the hydrothermal decomposition of the volcanic rock to create an impermeable basin for condensate water collection,
- close the system with a chimney made of blocks of lava covered by branches (acacias trees) that will allow to condensate the steam (as in condensation towers of thermal plants).
- Example of such devices, are quite common all over Afar particularly at Era Boru where 150 families live from this resource

The project – delayed due to Tigray war - will allow to identify shallow drilling targets and answer the needs of the communities on site (energy and water production)



Geothermal Village

Sites selected : (2) Djibouti, Lac Abhé

Georgaphic Coordinates: 11°09’16 N; 41°53’00 E *Altitude* : 245-313 m

Geosciences :

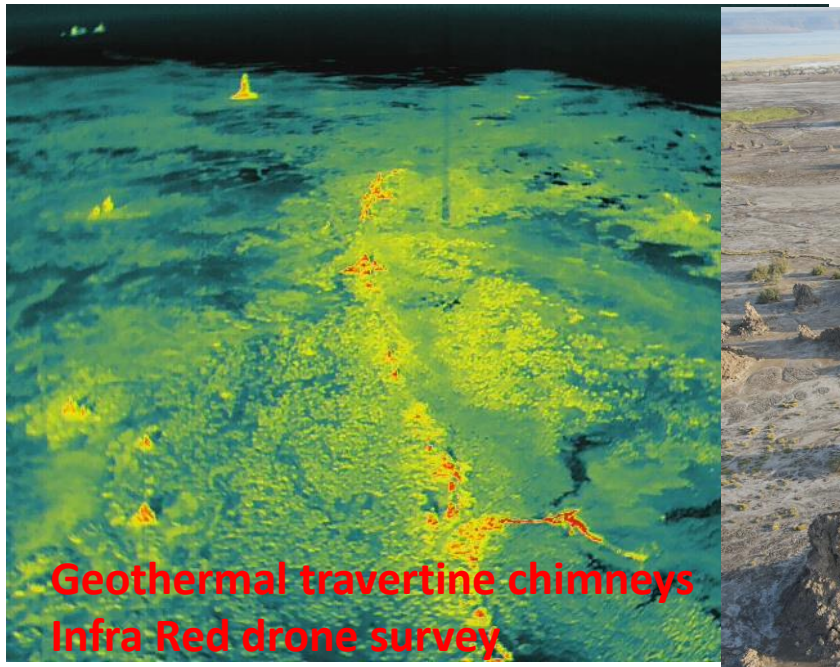
Successful geosciences field work in the Lac Abhé area (Oct. – Nov. 2021)

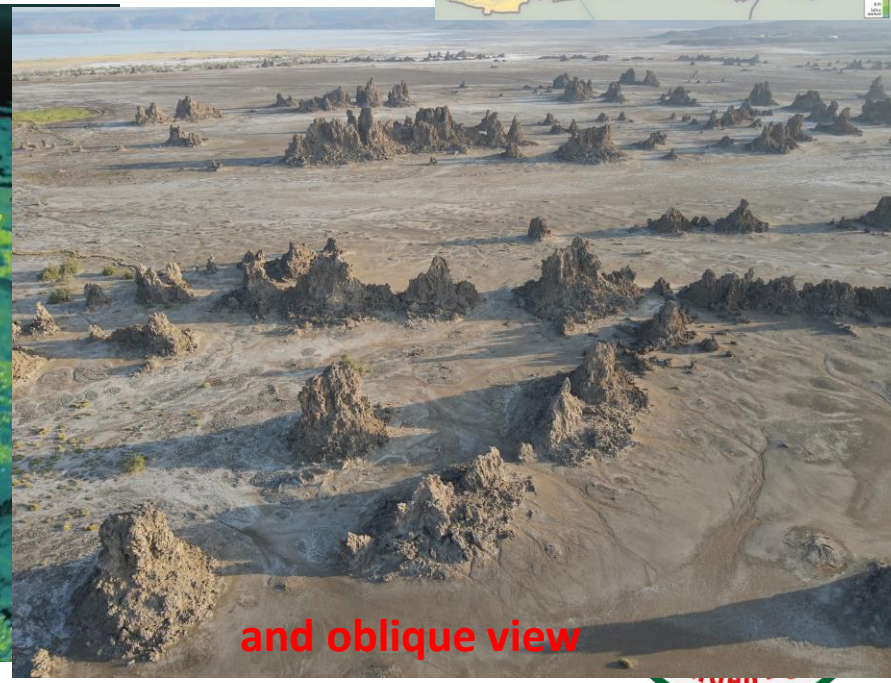
- *Gelogy*
- *Geochemistry*
- *Geophysics*
- *Characterization of the potential drilling site and of the geothermal reservoir*
- Starting of data processing with all the involved partners

Social sciences : Preliminary survey

- 70 families near the site;
- a school just built and started operating
- More families will join the village that the geothermal resource will power,
- also providing water

The detailed social study will be engaged in the coming months





Geothermal Village

Sites selected : (3) Bugarama, southern Rwanda

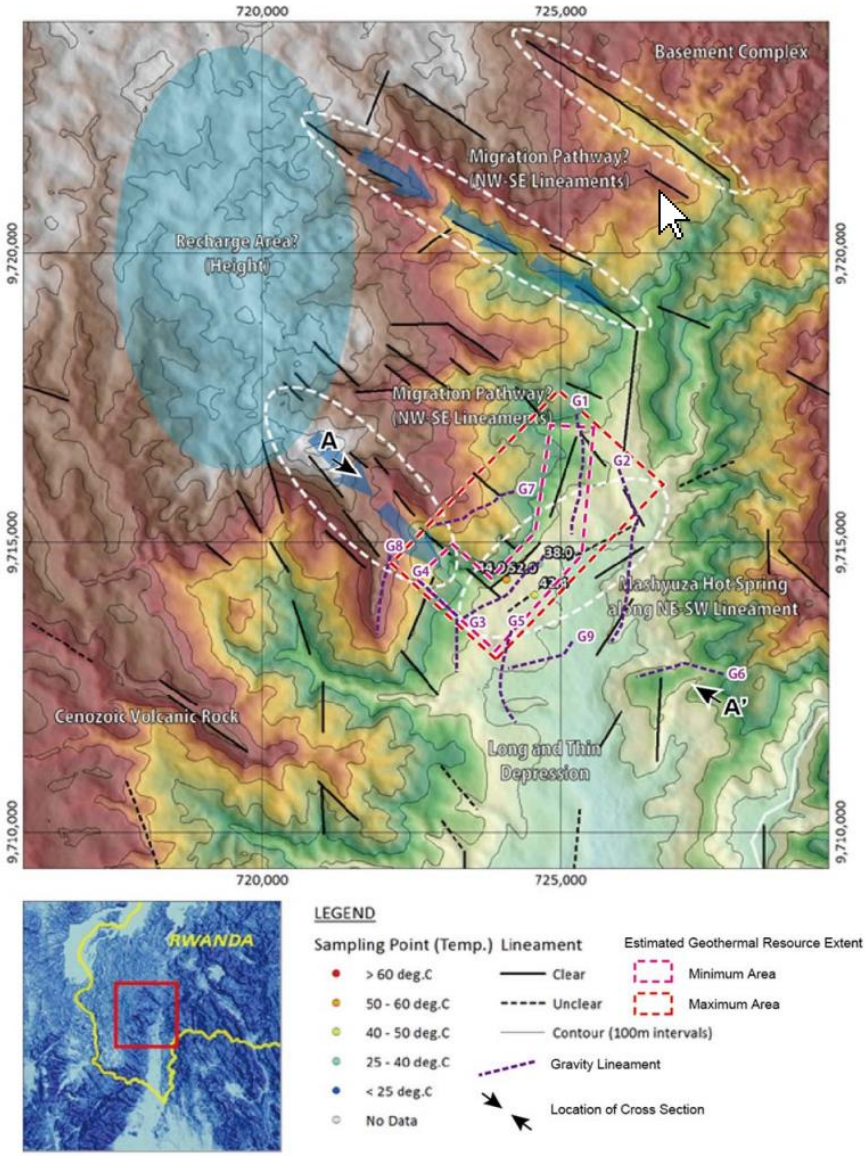
Coordinates: 2°42’ S ; 25°01 E *Altitude*: 956m

Access (distance & time): 288km from Kigali, 6 hours drive

Bugarama, is rather rich in thermal manifestations. At least 3 sites are gifted with hot springs, with characteristics not suitable for electricity production. One of them will be selected in the frame of GV project in February 2022;

Given the local economy based on agriculture, Direct Uses (DU) applications will be studied in the area (crop drying and fish farming in particular),

Further exploration works to be engaged with EDCL late 2022, implying both earth science and social science teams, followed by technology assesments.



Geothermal Village

Sites selected : (4) Homa Hills, E. Lake Victoria, Kenya

Geographic Coordinates: 0°20’20 N ; 34°31’ E ; *Altitude* : 1131-1180 m

Previous investigations confirmed:

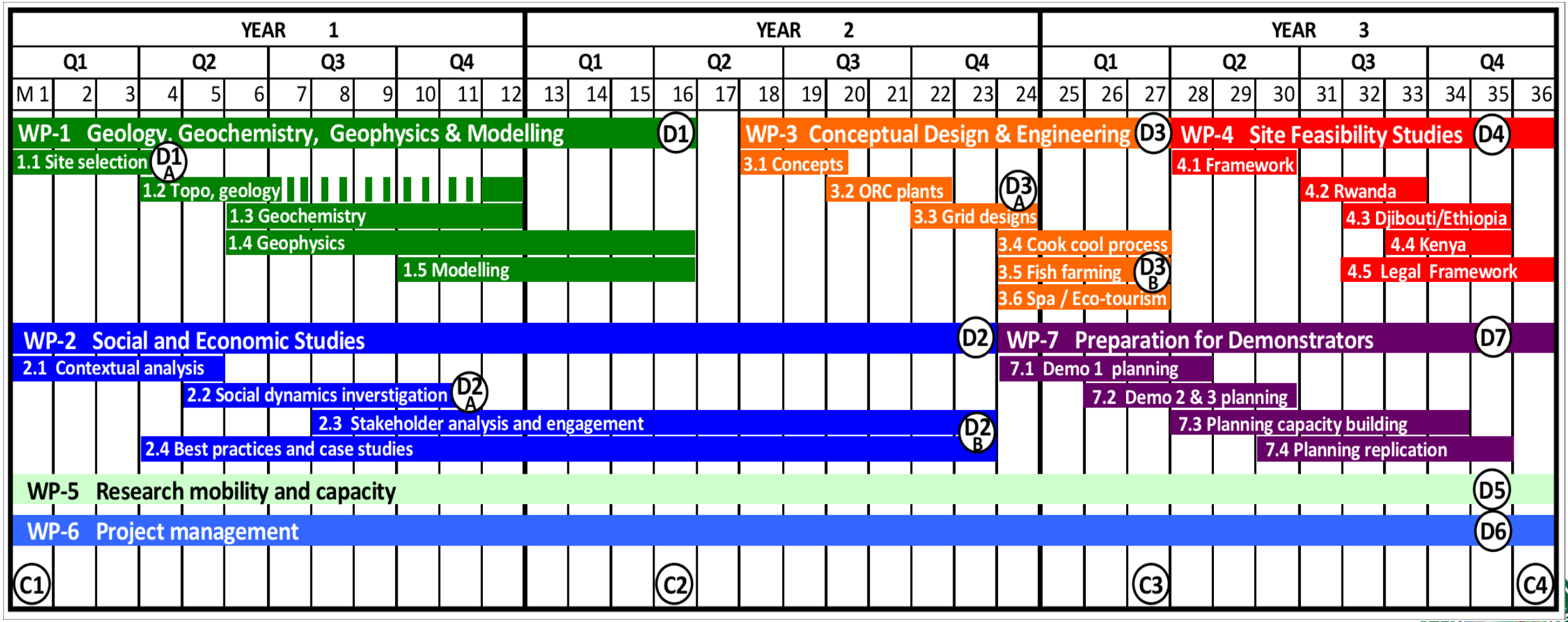
- Low to intermediate temperature geothermal system in the prospect.
- Heat source associated with magmatic intrusive.
- Estimated reservoir geothermometry from 160ºC to 235ºC.
- A resource to be utilized both for electricity generation (using ORC) and direct uses (fish drying, thermalism).

Field works (geoscience and social sciences) to be engaged march 2022

- structural geology, geochemistry geophysics to establish a 3D picture of the hydrothermal system plumbing at 1 Km3 scale.
- Anthropological study & analysis of the local socio-economic demand (present and future) being quantified.

Geothermal Village

5. Time frame & work packages



GV Relevant pblications

Onyango, S. & Varet, J. (2014): For a new social gender-based approach to geothermal development. *Proceedings 5th African Rift geothermal Conference, Arusha, Tanzania, 29-31 October 2014.* http://theargeo.org/fullpapers/fullpaper/For%20a%20new%20social%20gender-based%20approach%20to%20local%20geothermal%20development.pdf

Nebro, A., Gardo, I.A., Varet, J. & Onyango, S. (2016) Community-based geothermal development perspective in Afar: a new player Afar Geothermal Development Company (AGAPI) *Proceedings, 6th African Rift Geothermal Conference, Addis Ababa, Ethiopia, 2nd –4thNovember 2016* http://theargeo.org/fullpapers/COMMUNITY-BASED%20GEOTHERMAL%20DEVELOPMENT%20PERSPECTIVE%20IN%20AFAR.pdf

Onyango, S., & Varet, J. (2016) Future Geothermal Energy Development in the East African Rift Valley through local Community Involvement: Learning from the Maori's experience. *Proceedings, 6th African Rift Geothermal Conference, Addis Ababa, Ethiopia, 2nd –4thNovember 2016*

http://theargeo.org/fullpapers/FUTURE%20GEOTHERMAL%20ENERGY%20DEVELOPMENT%20IN%20THE%20EAST%20AFRICAN%20RIFT%20VALLEY%20THROUGH%20LOCAL%20COMMUNITY%20INVOLVEMENT.pdf

Omenda, P., Ebinger, C., Nelson, W., Delvaux, D., Cumming, W., Marini, L., Halldórsson, S., Varet, J., Árnason, K., Ruempker, G., Alexander1, K., Zemedkum, M.(2016) Characteristics and important Factors that influence the Development of Geothermal Systems in the western branch of the East African Rift System. *Proceedings, 6th African Rift Geothermal Conference, Addis Ababa, Ethiopia, 2nd –4th November 2016* http://theargeo.org/fullpapers/CHARACTERISTICS%20AND%20IMPORTANT%20FACTORS%20THAT%20INFLUENCE%20THE%20DEVELOPMENT%20OF%20GEOTHERMAL%20SYSTEMS%20IN%20THE%20WESTERN%20BRANCH%20OF%20EAST%20AFRICAN%20RIFT%20SYSTEM.pdf

Mariita, N., Onyango, S. & J. Varet, J. (2016) Potential for Small Scale Direct Applications of Geothermal Fluids in Kenya's Rift Valley – An Update from GeoPower Africa Project *Proceedings, 6th African Rift Geothermal Conference, Addis Ababa, Ethiopia, 2nd –4th November 2016*

http://theargeo.org/fullpapers/POTENTIAL%20FOR%20SMALL%20SCALE%20DIRECT%20APPLICATIONS%20OF%20GEOTHERMAL%20FLUIDS%20IN%20KENYAS%20RIFT%20VALLEY%20%E2%80%93%20AN%20UPDATE%20FROM%20GEOPOWER%20AFRICA%20PROJECT(1).pdf

Varet, J. (2016) Perspectives et Initiatives en géothermie dans la vallée du Grand Rift Est-Africain. *Géosciences*. 21, 39.

Gardo, I.A. & Varet, J. (2018) Dabbahu (Teru Woreda) in Northern Afar. A major Ethiopian Geothermal Site Leased by AGAP *Proceedings, 7th African Rift Geothermal Conference Kigali, Rwanda 31st October – 2nd November 2018.* 14 p.

http://theargeo.org/fullpapers/C7/Dabbahu%20-Teru%20Woreda%20in%20Northern%20Afar.pdf

Gardo, I.A. & Varet, J. (2018) Ta'Ali geothermal site, Afdera Woreda, Northern Afar, Ethiopia *Proceedings, 7th African Rift Geothermal Conference Kigali, Rwanda 31st October – 2nd November 2018*. 14 p.

http://theargeo.org/fullpapers/C7/Ta%20Ali%20geothermal%20site,%20Afdera%20Woreda,%20Northern%20Afar,%20Ethiopia.pdf

Onyango, S. (2018) The dynamic landscape of geothermal development adressing Gender, local community participation and environment in Easter Africa. *7th African Rift Geothermal Conference Kigali, Rwanda 31st October – 2nd November 2018*. 14p. http://theargeo.org/fullpapers/C7/The%20Dynamic%20Landscape%20of%20Geothermal%20Development%20in%20Addressing%20Gender%20along%20the%20African%20Rift%20Valley.pdf

Onyango, S. & Varet J. (2018). Proposing a New, Specific Methodological Approach to Medium Enthalpy Shallow Geothermal Resources for Africa's Rift Valley. *Proceedings, 7th African Rift Geothermal Conference Kigali, Rwanda 31st October – 2nd November 2018.* 14 p.

http://:theargeo.org/fullpapers/C7/Proposing%20a%20new%20specific%20methodological%20approach%20to%20development%20of%20medium%20enthalpy%20shallow%20geothermal%20resources.pdf

Varet, J., Y. Géraud, P. Tarits, A. Sciullo, M. Contini, I. Nardini, W.H. Wheeler, S. Onyango, U. Rutagarama, B. Atnafu, J. Onjala, K. Moussa, P. Omenda, I. A. Gardo, Z. Change* (2020). The Geothermal Village Project (GV1) Supported by the LEAP-RE Research ProgrammeLaunched by the EU in Partnership with the AU. *Proceedings, 8 th African Rift Geothermal Conference Nairobi, Kenya: 2 – 8 November 2020*. 11p.

http://theargeo.org/C8/final/Varet%20et%20al.%20-%202020%20-%20The%20Geothermal%20Village%20Project%20(GV1)%20Supported%20by%20the%20LEAP-RE%20Research%20Programme%20Launched%20by%20the%20EU%20in%20Partnership.pdf

Thank you

Merci!

Jacques Varet Géo2D
www.geo2d.com
j.varet@geo2d.com
+33 6 18 07 22 27