

**Technical Workshop on the Geologic Development and
Geophysics of the Western Branch of the Greater East
African Rift System with Emphasis on Factors that
Control the Development of their Geothermal Systems**

CONCEPT NOTE AND WORKSHOP AGENDA

Kigali, Rwanda

9-11 March 2016

January 2016

EXECUTIVE SUMMARY

The Workshop on ***“Technical Workshop on the Geologic Development and Geophysics of the Western Branch of the Greater East African Rift System with Emphasis on Factors that Control the Development of their Geothermal Systems”*** is planned for 9-11 March 2016 at Gisenyi, Rwanda to discuss the geologic setup and conditions that would support the development of geothermal systems in the countries of the western branch of East African Rift System (EARS) which include Burundi, Rwanda, Uganda, Zambia, Tanzania, Malawi and Mozambique. The workshop that is sponsored by UNEP, ICEIDA/NDF, Energy Development Corporation Limited of Rwanda (EDCL) and EU will be held at Gisenyi in Rwanda.

Geothermal exploration in the western branch of EARS has so far not succeeded in discovering utilizable geothermal resources. Part of the reasons are that (i) the systems in the west are not (or not clearly) associated with a magmatic geologic conditions, (ii) the nature and characteristics of the systems are not fully understood, (iii) experiences and research methods for geothermal exploration used in the eastern branch of EARS have been inappropriately applied to systems in the western branch. It is therefore essential that a full understanding of the occurrences of the geothermal systems in the region, more so, this time when funding from support programmes and donor community are ready to fund projects in both eastern and western branches of the rift.

The workshop will be facilitated by international resource persons with wide experience in academic research as well as in the geothermal industry. These include:

Resource persons

Prof. Cynthia Ebinger, University of Rochester, USA

Dr. Wendy Nelson, Towson University, USA

Mr. Getahun Demissie, Consultant, Ethiopia

Dr. Peter Omenda, Geothermal Development Company, Kenya

Prof. Abdulkarim Mruma, Geological Survey of Tanzania

Dr. Damien Delvaux, Royal Museum for Central Africa, Belgium

Dr. Sæmundur Halldórsson, University of Iceland

Dr. Jacques Varet, Consultant, France

Mr. William Cumming, Consultant, USA

Dr. Luigi Marini, Consultant in Applied Geochemistry, Italy

Mr. Knútur Árnason, ISOR, Iceland

Dr. David Bjarnason, ICEIDA, Iceland

Dr. Bjorn S. Harðarson, ISOR, Iceland

Dr. Meseret Teklemariam, UNEP

Mr. Geoffrey Muchemi, Consultant

Prof. Georg Rumpker, Goethe University, Frankfurt

Mr. Keg Alexander, Consultant, New Zealand

In addition, twenty two geoscientists will be sponsored by UNEP and ICEIDA/NDF to attend from the western branch countries (14) and eastern branch countries (8). ***Participation in the workshop is by invitation but there are limited opportunities for self- sponsored participants from Africa and worldwide to attend. No fee will be charged for all participants of the workshop; and so interested self-sponsored participants are kindly requested to contact the organizing committee as soon as possible to reserve a slot.*** It is expected that the workshop will be attended by a total of seventy (70) international geoscientists.

The presentations will include issues concerning deeper understanding of the tectonic development of the region with focus on mantle plume and rifting, magmatism, and heat flow as evidenced from geophysics and study of mantle/crustal xenoliths. Detailed structural analyses will be presented to aid in the understanding of controls on geothermal development and storage. Case studies that include typical geothermal systems in the eastern branch and results of studies at Karisimbi, Kibiro and Ngozi area will also be presented alongside worldwide examples.

Expected Outcomes

The main outcome of the workshop will be the knowledge gained by the region's geoscientists concerning the heterogeneous geologic conditions in the western branch of EARS that determine the possible generation and storage of the region's geothermal resources. The newly gained understanding will be expected to allow them to more accurately explore geothermal systems in the region using more adopted integrated multidisciplinary exploration methods. A proceedings volume of the workshop will be produced as a reference material. A long term measure of success of the workshop will be initiation of successful projects funded by the private and public sectors in the western branch of EARS countries.

1. Introduction

The geologic makeup of the East African Rift System (EARS) region is heterogeneous in its eastern, western, southern and southwestern branches (Figure 1). This has caused wide diversity in the mode of occurrence, characteristics, potential grades and end-use possibilities of its geothermal resources. In terms of the generation and characteristics of its geothermal resources, the geologic makeup and structures of most of the EARS region are not as well-known as in its northern and eastern sectors. There is thus a lack of clarity in the geologic conditions that would allow the targeting of the prospective areas by exploration in the western and southern branches of the Greater EARS region. This contrasts with the situation in the northern and eastern sectors where the presence of evolved volcanic eruptive centres facilitates reliable exploration target area determination.

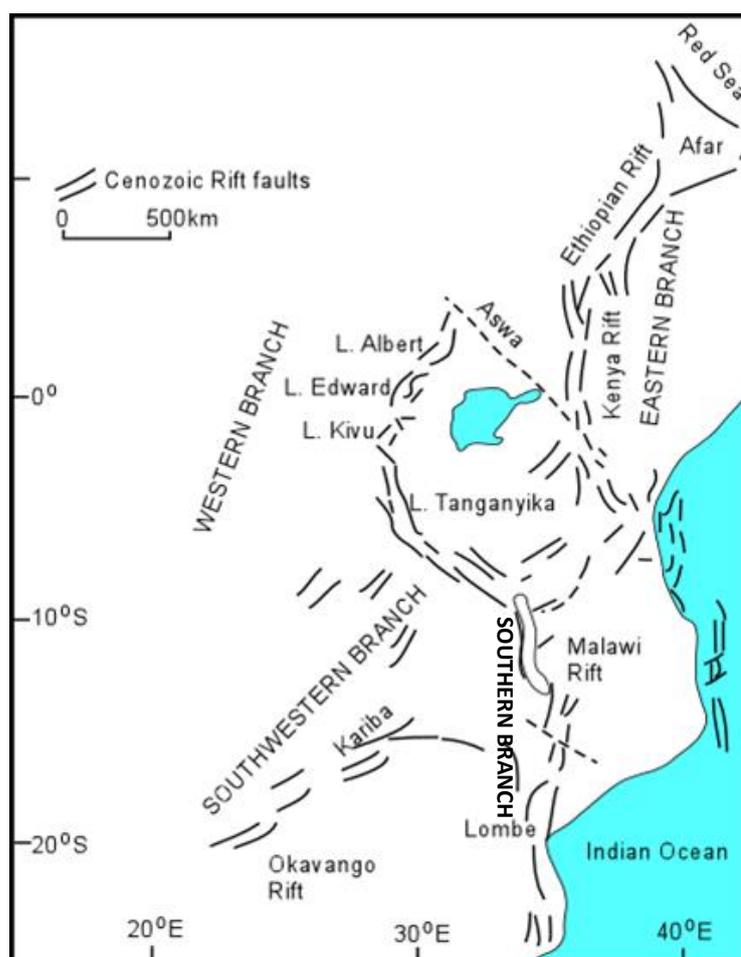


Figure 1: Structural map of eastern Africa showing EARS rift sectors

It is thus essential that a deeper understanding of the geologic development and geophysical character of the diverse geothermal provinces of the region as well as of the geochemical characteristics of the thermal fluids discharged at the surface is gained by the groups that are engaged in their exploration. This understanding can then be interpreted in terms of how the geothermal systems are developed and hosted in the different geologic provinces. Exploration would then be aimed at testing and improving the interpretations for efficient discovery and definition of the geothermal resources. It would also enable the countries in the region to predict the potential grades and possible uses of their geothermal resources, thus, rationalizing their expectations. The need for dealing with this issue is felt in the countries in the region in light of the non-discovery of the resources by exploration drilling carried out to date. This need

is now further amplified by the expansion of African Rift Geothermal Development Facility project (ARGeo) into new and diverse geologic terrains.

Countries of the western and southern branches of the Greater EARS region propose to organize a workshop, with the support of UNEP and ICEIDA/NDF. The workshop is sought to provide an understanding of the geologic conditions that control the occurrence of geothermal resources in the region. This is required for carrying out geothermal exploration projects that are well-founded on reliable geoscientific bases. The organizers will marshal specialized resource persons from among the large international community that is engaged in geoscientific research in the western and southern branches of the Greater EARS region with particular focus on the western branch, in fields that are relevant to the understanding the occurrences of the geothermal systems. Selected resource persons that have extensive experience in geothermal exploration in the region will also participate in the workshop. Geoscientists that are engaged in carrying out geothermal exploration in each of the western branch countries will attend the workshop. UNEP-ARGeo and ICEIDA/NDF will sponsor the participation of the above in the workshop.

The expected outcome of the workshop is a detailed understanding of the geologic conditions of occurrence of geothermal resources in the western branch of the Greater EARS region that is expected to be gained by the geoscientists of the region. This will be a basis for the western branch geoscientists to build their capabilities regarding the determination of the approaches that should be followed and the methods that should be applied in exploring for the resources. Proceedings of the workshop will be compiled and will include extended abstracts, power-point presentations and summary of the workshop resolutions. These will form important reference materials for geoscientists of the region.

2. ARGeo and the Workshop

The number of countries that are subscribed to African Rift Geothermal Development Facility (ARGeo) in terms of its two project components (i) Technical assistance for surface exploration studies, and (ii) Regional networking, information systems, capacity building, policy advice presently stands at 13. This number includes the six countries that were subscribed to it until recently (Eritrea, Ethiopia, Kenya, Rwanda, Tanzania and Uganda) and the seven others that have recently joined (Burundi, Comoros, Djibouti, Democratic Republic of Congo (DRC), Malawi, Mozambique and Zambia). The ARGeo region encompasses the region of the EARS proper that include eastern, southern and western rift branches, and the Comoros volcanic islands of the Western Indian Ocean.

3. Relevance

Most of the ARGeo countries are traversed by the various sectors of the EARS. The EARS is highly magmatic in some of these countries (Djibouti, Eritrea, Ethiopia and Kenya), i.e. in those that share its northern and eastern sectors, while in the others it exhibits little volcanism (Uganda, North-eastern DRC, Rwanda and, northern and south-western Tanzania) or none at all (Malawi, Zambia and Mozambique). The Burundi part of the Western rift has lava flows that originated in volcanic eruptions from outside the western border of the country but none within itself. Zambia and eastern and south-eastern DRC have long-lived and repeatedly activated tectonic structures that lie in adjacent flank regions of the EARS that are undergoing tectonic extension and exhibit anomalous surface hydrothermal activity, but are devoid of Quaternary volcanism. Grande Comoro Island is situated in an area of hotspot activity in the Western Indian Ocean, outside the EARS realm and has active volcanism. There is, thus, a great degree of geologic diversity in the newly expanded ARGeo region. Thus there is a wide diversity

in the occurrences of potential geothermal systems in the region in terms of their heat sources, reservoir characteristics, resource grades and potential end-uses.

Experience gained from the exploration of some of the EARS region's geothermal prospect areas has shown that the working geothermal models that have guided successful exploration in the northern and eastern EARS sectors cannot be wholly applied to the exploration of prospect areas in the Western branch (rift). The fundamental reason for this is that the tectonic and magmatic states of the different rift sectors are not the same and the bases of exploring for their geothermal resources are not directly replicable.

Presently, an even greater degree of diversity is being added to the ARGeo region with the inclusion of the entirely non-magmatic southern parts of the EARS and its adjacent regions, and of the independent tectonic setting of volcanism in the Comoros. It is thus evident that the successful exploration, discovery and characterization of geothermal reservoirs in the newly expanded ARGeo region require that its geologic diversity, and that of its geothermal systems, are well understood. More efficient exploration programs can then be designed and executed by accommodating the peculiarities of each geothermal resource province.

It follows from the above that a deeper understanding of the geologic development and geophysical character of the diverse geothermal provinces as well as of the geochemical characteristics of the thermal fluids discharged at the surface should be gained by the groups that are engaged in their exploration. This understanding can then be interpreted in terms of how the potential geothermal resources are generated and hosted in the different environments. Exploration can then be aimed at testing and improving geo-scientific methods and interpretation, enabling more efficient discovery and reliable characterization of the subsurface resources. This will also enable the countries of the region to predict the potential grades and possible uses of their geothermal resources, and thus rationalize their expectations. The required knowledge of the geologic conditions that control heat sources and development of geothermal reservoirs is largely available through international geoscience research undertaken in the region and the rest of the world.

The EARS is a unique natural laboratory where the processes that are involved in ocean basin initiation and development are understood, thanks to the output from international academic research. An understanding of the processes involved in the creation and growth of the continents has benefitted from research in the evolution of the African landmass since Archean times. It is an advantage to the ARGeo region that this wealth of knowledge can allow it to execute geothermal research starting at high levels of knowledge of the gross geologic and geophysical conditions that determine the generation and storage of the resources in the different tectonic provinces of this diverse region. The interpretation of the existing knowledge in terms of the probable modes of generation and storage of geothermal resources should enable the adoption of approaches in integrated multidisciplinary exploration that are appropriate to each case.

However, awareness of the existing geoscience knowledge and its relevance to the creation and maintenance of the geothermal resources of the region is not sufficiently widespread within the geoscience community that is engaged in exploring for them. There is also much relevant experience that can be derived from the case histories of geothermal resources that have been discovered and developed in diverse geologic provinces in the rest of the world.

4. Scope

Geographic scope: The proposed workshop is aimed at satisfying a need that is felt in the part of the ARGeo region that comprises Burundi, DRC, Malawi, Mozambique, Rwanda, Tanzania, Uganda and Zambia. The geothermal resource prospect areas in these countries have either low or no Quaternary volcanism. This contrasts with the situation in the rest of the ARGeo countries that share the northern and eastern EARS sectors where magma bodies are the heat sources of their high enthalpy geothermal systems. Thus, the workshop is planned for the benefit of geoscientists that are engaged in geothermal resource exploration in the region of present interest that encompasses the above countries.

Geoscientific scope: The proposed workshop is intended to provide an understanding of the geologic processes and current state of the region that account for the creation and sustenance of its geothermal resources.

5. The Proposed Action

In order to close the above described knowledge gap, ARGeo countries of the region, with the support of UNEP and ICEIDA/NDF, propose to organize a workshop to take place in Gisenyi, Rwanda, on 9 to 11 March 2016. The organizers plan to invite, through UNEP-ARGeo, specialized resource persons from among the large international community that is engaged in geoscience research in the Greater EARS region, and selected senior geoscientists from within the ARGeo region. The experts will speak at the workshop on various geoscience topics that are relevant to the understanding of the geologic and geophysical conditions of occurrence of the region's geothermal resources. The number and identity of the resource persons will be determined following the determination of the scope and orientation of the topics to be addressed. UNEP and ICEIDA/NDF will sponsor two geoscientists that are engaged in the planning and execution of geothermal exploration projects in each of the eight countries of the subject region to attend the workshop. Further, one geoscientist from each of the eastern branch countries that comprise Djibouti, Eritrea, Ethiopia and Kenya will be sponsored to participate in the workshop

6. Expected Outcome

The main outcome of the workshop is expected to be the understanding that will be invested in the region's geoscientists regarding the heterogeneous geologic conditions that determine the generation and storage of the region's geothermal resources. Their newly gained understanding is expected to allow them to determine the geologic and structural features that are most likely to host geothermal resources, and thus, those where integrated multidisciplinary exploration should focus. The geochemistry and geothermometry of thermal fluids discharged at the surface may also provide fundamental clues on the presence and characteristics of local geothermal resources.

A second output will be the Proceedings of the workshop. It is intended that the lectures and the communications during the question-and-answer/discussion periods of the workshop will be recorded for later transcription. After validation by their authors, the transcriptions and the presentations will be compiled into a proceedings volume of the workshop. This is intended to serve as a basis for the work of the technical meeting referred to below.

During this workshop, there will be a technical discussion with the purpose of translating the understanding gained from the workshop into knowledge of the geologic and geophysical settings of the region's geothermal resources and, based on data on the surface hydrothermal manifestations, infer the physical and chemical characteristics of the potential resources. This

should enable the priority ordering and proper targeting of resource prospect areas by exploration in each country.

7. Sustainability

The active participation of the region's geoscientists and the technical discussion during the workshop are expected to provide them with the knowledge and understanding that should enhance the sense of country's geothermal project ownership which is essential for ensuring progression toward resource development in their countries for appropriate uses. They will be expected to be able to advocate on geothermal resource development and to effectively engage in it. They should also be able to use their newly gained knowledge assets in the formulation of well-grounded projects and in the acquisition of support from their home-institutions and governments for the execution of the resource exploration, development and utilization schemes.

8. Replicability

The understanding of the geologic conditions of occurrence of geothermal resources in the ARGeo region, and the successful use of the resources, can promote similar undertakings in countries in adjacent regions. There is geologic and geophysical continuity between the ARGeo and the adjacent regions and the use of the gained knowledge, skills and experiences are thus replicable.

9. Collaboration

Rwanda and Uganda during the 1st UNEP Geothermal Technical Review Meeting held in Nairobi, Kenya, in June 2014 proposed the idea of organizing a workshop to address the challenges experienced while exploring for geothermal resources in the western branch of EARS. Rwanda, through EDCL, further expressed an interest to host the workshop in Gisenyi.

The meeting resolved that the workshop should be held as proposed and that UNEP in consultation with ICEIDA/NDF and the host country to coordinate the preparation for the meeting including documentation that is planned to be derived from it. UNEP and ICEIDA/NDF will further sponsor the resource persons and workshop participants (geoscientists) from the beneficiary countries to participate in the workshop. Other participants are expected to be sponsored by their countries or institutions while other participants will come from development partners and private sector.

WORKSHOP PROGRAMME

Tuesday, 8 March 2016: ARRIVAL OF DELEGATES		
DAY ONE: 9th of March 2016		
OPENING SESSION		
TIME	TITLE	PRESENTOR
08.00-09.00	Registration of Delegates	All
09.00-09.30	Short speeches from: EDCL, ICEIDA/NDF, AUC, UNEP.	
GLOBAL PERSPECTIVE: AN INTRODUCTION		
09.30-10.15	Global occurrence of geothermal systems in different geologic settings: their identification and utilization.	W. Cumming
10.15–10.45 Coffee Break and Group Photo		
TECHNICAL SESSION 1: REGIONAL GEOLOGICAL SETTING		
TIME	TITLE	PRESENTOR
10.45-11:30	The Geologic and Tectonic Evolution of the Greater East African Rift System and controls on occurrences of known geothermal systems	G. Demissie
11:30-11:45	Questions and Answers	
11.45–12.15	Structural development and fault kinematics of the Western Branch of the EARS and their controls on geothermal resources	D. Delvaux
12.15-12:30	Questions and Answers	
12:30-13:00	Geodynamic setting and thermomechanical models – context for western rift geothermal studies	C. Ebinger
13:00-13:15	Questions and Answers	
13:15-14:15 LUNCH BREAK COURTESY OF EDCL		
TECHNICAL SESSION II: TECTONIC DEVELOPMENT OF EARS RIFT SECTORS		
TIME	TITLE	PRESENTOR
14.15–14.45	The tectonic development of Lakes Tanganyika-Rukwa-Malawi (TRM) rift basins and Incipient Rifts in the SW branch of EARS in Zambia and Mozambique	A. Mruma
14.45-15.00	Questions and Answers	
15:00-15:30	Tectonic development of Rungwe volcanic province in Tanzania, the Kivu rift, the Upemba graben in SE DRC and some insights into the Albertine rift relevant for the geothermal exploration	D. Delvaux
15.30-15.45	Questions and Answers	
15.45 – 16:15 Tea/Coffee Break		
16:30-17:30	Open discussions on the day's sessions	
17.30-18.00	Summary of Day's presentations on key lessons learnt	G. Demissie and P. Omenda

DAY TWO: 10th of March 2016		
TECHNICAL SESSION III: MAGMATISM AND HEAT FLOW IN THE GREATER EARS		
PART A: GEOLOGY AND GEOCHEMISTRY		
TIME	TITLE	PRESENTER
8.30–9.00	Dynamic Model of Lithospheric drip Magmatism in western arm of EARS and its Implication for Geothermal Occurrences	W. Nelson
9:00-9:15	Questions and Answers	
9:15-9:45	The Nature of Volcanism in the Environs of the Tanzanian Craton: case of Rungwe Volcanic Field	S. Halldorsson
9.45-10:00	Questions and Answers	
10:00-10:30	Heat sources for geothermal Systems in eastern branch of EARS in comparison to the western Branch of EARS	P. Omenda
10:30-10:45	Questions and Answers	
10.45-11.15 TEA BREAK		
Part B: GEOPHYSICS OF THE WESTERN BRANCH OF EARS		
TIME	TITLE	PRESENTER
11:15-11:45	Resistivity Structure of the Basement Terranes associated with the western arm of EARS and possible relationship with potential geothermal heat sources	C. Ebinger
11:45-12:00	Questions and Answers	
12:00-12:30	Seismic imaging of crustal magma chambers in western branch of EARS	G. Rumpker
12:30-12:45	Questions and Answers	
12:45-13:45 LUNCH BREAK COURTESY OF EDCL		
TECHNICAL SESSION IV: Case Studies		
TIME	TITLE	PRESENTER
13.45–14.15	Results of surface geothermal investigations in Karisimbi geothermal prospect	K. Arnason
14:15-14:45	Integrated Geothermal investigations of Gisenyi geothermal prospect: results of recent preliminary geological, geophysical and geochemical surveys	J. Varet
14:45-15:15	Geological characteristics of Kibiro and Ngozi geothermal prospects	K. Alexander
15.15-15.45	<i>Questions and Answers for above presenters</i>	
15.45–16.15 Coffee Break		
16:15–16.45	Geophysical characteristics of Kibiro and Ngozi geothermal prospects in relation to possible occurrence of geothermal systems	W. Cumming
16:45-17:15	Geochemical signatures of geothermal systems at Kibiro and Ngozi geothermal prospects	L. Marini
17:15-17.30	<i>Questions and Answers for above presenters</i>	
17.30-18.00	Summary of day's presentations	P. Omenda and G. Demissie

DAY THREE: 11th of March 2016		
TECHNICAL SESSION 5: METHODOLOGIES APPROPRIATE FOR GEOTHERMAL EXPLORATION IN WESTERN BRANCH OF EARS		
TIME	TITLE	PRESENTER
	Heat sources for the occurrence of geothermal systems in the western branch of EARS: Are magma chambers viable heat sources in Western branch? If so, what are investigative methods required to explore them?	
8.30-8.50	- Geological perspective	W. Nelson
8.50-09.10	- Geophysical perspective	C. Ebinger
09.10-09.30	- Seismic perspective	G. Rumpker
9:30-9:50	Comparison of selected geothermal systems in the Basin and Range geothermal systems in USA with Kibiro and Songwe geothermal areas.	N. Hinz and K. Alexander
09.50-10:10	Effective Geochemical methods for identifying geothermal systems in the western branch of the EARS	L. Marini
10:10-10:30	Effective Geophysical methods for identifying geothermal systems in the western branch of the EARS	W. Cumming
10.30–10.50 Coffee Break		
10.50-11.10	Potential for application of temperature gradient drilling or other temperature surveys in the western branch of the EARS – successful examples of structurally controlled resources in the Basin and Range, USA	N. Hinz
11.10-11.30	Critical datasets required for the successful development of integrated geothermal conceptual models: Summary of supportive information required before committing a prospect to exploratory drilling	J. Varet
11:30-12:15	Summary and Conclusions of the workshop	P. Omenda and G. Demissie
12.15-12.30	CLOSING SPEECHES - EDCL - UNEP - ICEIDA/NDF - AUC	U. Rutagarama
13:00-14:00 LUNCH BREAK COURTESY OF EDCL		
14:00 END OF THE WORKSHOP		

SESSION CO-CHAIRS: Dr. Meseret Teklemariam
Mr. Geoffrey Muchemi

RAPPORTEURS: Dr. Peter Omenda
Mr. Getahun Demissie