Annex-2-1 The Evaluation Sheet of the Aluto Langano (Ethiopia) Geothermal Field (1)

Field Name	Aluto Langano
Country	Ethiopia
Province/Location	Lake District
Location	The Aluto-Langano Geothermal field is located in the Lakes District, Ethiopian Rift Valley, about 220 Km South of Addis Ababa. Aluto Volcanic Center covers an area of about 100km2 between Lakes Langanao and Ziway and rises about 600m abouve the surrouding Adami-Tulu Plain which has an elevation of abouto 1600m a.s.l. The broad truncated base and a summit caldera 6km by 9km elongated in a WNW direction has formed a basion of internal drainage.
Resource Characteristics	
Geology	
Volcanic activity	Volcanic activity at the Aluto volcanic center was entirely contained in the Quaternary and has been initiated with a rhyolite dome building phase intervened by explosive pyroclastic pumice eruptions. There are thick pyroclastic flows and recent lava flows. The hydrothermal mineral assemblage identified in the Aluto-Langano Geothermal wells indicate a high temperature active sustem which correlates with the present measured temperature range from 220 to 300°C.
Geological Structrure	The Aluto-volcanic complex is mainly affected by NNE-SSW trending Wonji Fault Belt (WFB). Amajor fault passed through LA-3 and LA-6 extends from lake Langano (south) and lake Ziway (north) and along which there are several surface manifestations (fumaroles, hot and warm springs, altered ground). this fault controls the circulation of the deep geothermal fluid and minor permeable zones occur along thin contacts.
(Past Geological Studies included)	Inventory of hydrothermal features, geological mapping and Petrographic studies, Logging of down hole geology, petrochemical and XRD analysis of surface and subsurface alteration
Geochemistry	The altering fluid is of near neutral alkali-chloride bicarbonated type water. Aluto-Langano is water dominated gas-rich geothermal field having areservoir temperatures in excess of 340oC ad estimated by various geothermometers. The general lack of O isotope shifting in rift hydrothermal systems suggests a high water-rock ratio, with the implication that these systems are mature. Similarly, the studies on Carbon isotope on the predominantly bicarbonate waters of the rift in general and in the Aluto-Langano geothermal system in particular show the evolution from dilute meteoric recharge (essentially from the eastern escarpment).
Work done so far	Surface geochemical exploration (solute, istopic, gas geochemistry), surface manifestations and water points and geothermal field geochmecial monitoring have been done.
Geophysics	Gravity survey, Electrical resistivity survey and Temperature survey have been done in A luto-Langano.
Gravity	Recently, GSE has conducted gravity measurements in the rift valley including Aluto-Langano areas as a part of the regional gravity mapping of the country. The residual gravity fields show the occurrence of high anomalies in the aluto volcanic complex, indicating the existence of relativeyly denser mass at shallow depth than the surrouding rock masses. Presumably the heat source is then a magma chamber found at deeper level as detected by low Bouguer gravity anomaly field at Aluto vocanic complex.
Resistivity	Dipole-dipole data coveres a large area from south of Lake Ziway, following the infereed west Langano fault zone and ending at Lake Shalla. The Schlumberger low resistivity on the foothill sides of Aluto indicates the presence of hot geothermal fluid infiltration in the area. Results of TB wells and deep exploratory holes in the west (LA-2) and southern part (LA-1) reflect that this infiltration to be the effect of a lateral flow from the area under the Aluto-volcanic complex. MT survey conducted in 2009 covers the central portion of Aluto Langano volcanic complex and depicted three streaks of resistivity discontinuities line and relatively high resistivity zone of the depth
Well Drilling	36 thermo-gradient wells and 8 deep exploratory wells have been drilled at the Aluto Langano geothermal field.

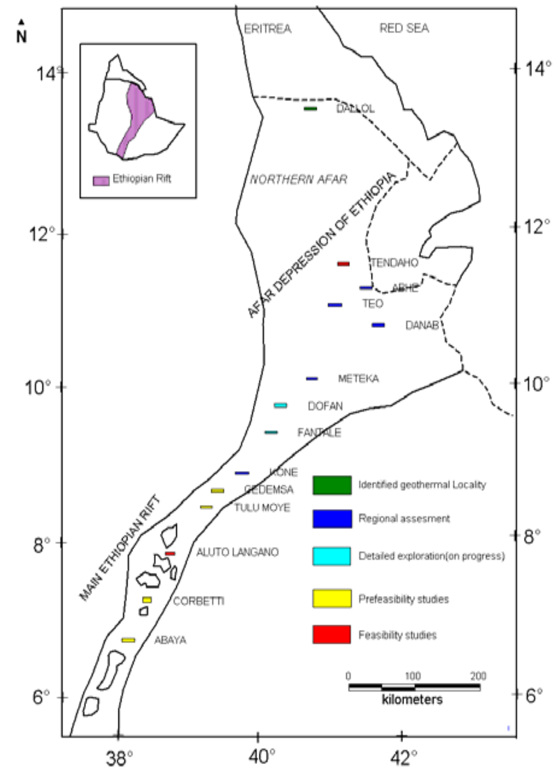


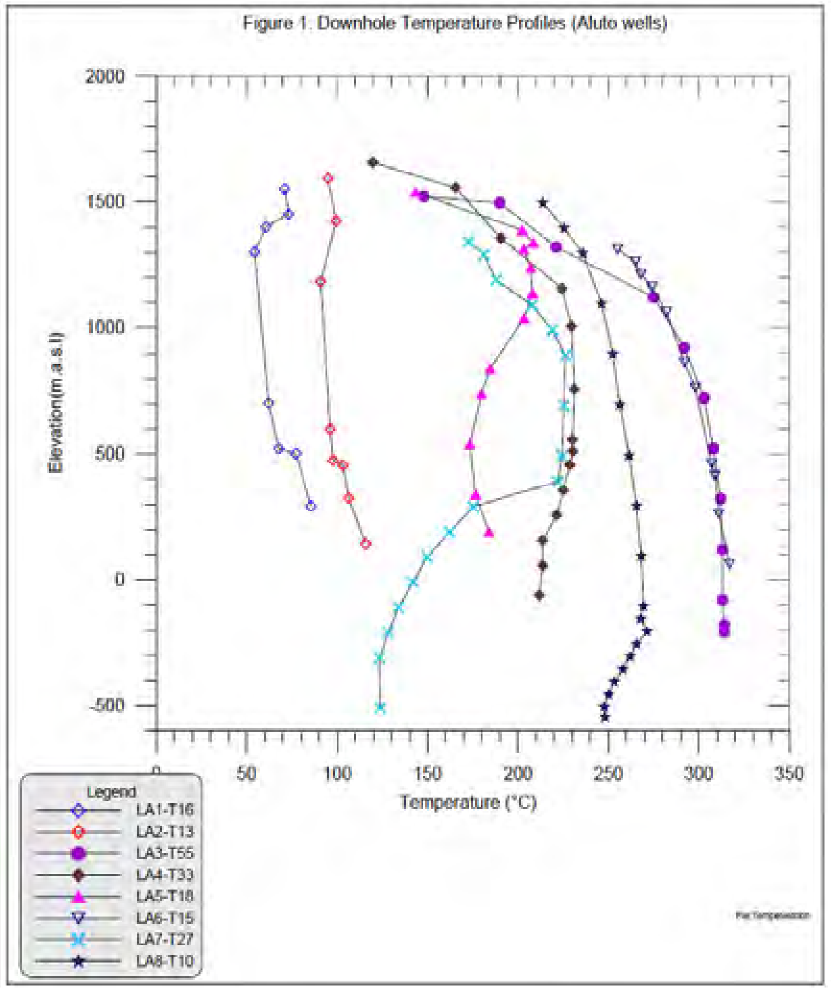
Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley

Appendix 1: Project Schedule and total cost breakdownfor the Expansion and Development of the Aluto Langano Geothermal Field

ID	ACTIVITY	Cost(USD)	Year1	Year2	Year3	Year4	Year5	Year6
I.	**Activities related to steam field**							
1.	Detailed surface Exploration	$240,000						
2.	Go/No Go	$0.00						
3.	Appraisal Drilling (6 wells), well testing, & Roads, pads	$12,250,000.00						
4.	Feasibility study and EIA	$100,000.00						
5.	Go/No Go							
6.	Production drilling & testing	$16,200,000.00						
7.	Go/No Go							
8.	Feasibility study and EIA	$100,000.00						
II.	**Phase I (35MW power plant construction)**							
9.	Design of power plant & Tendering	$650,000.00						
10.	35 MW power plant construction	$75,000,000.00						
11.	Transmission line Upgrading & plant commissioning	$1,500,000.00						
III.	**Phase II(40MW plant construction)**							
12.	Design of power plant & Tendering	$650,000.00						
13.	40 MW Plant construction & commissioning	$84,000,000.00						
	Total	190,690,000						
	Contingency (10%)	19,069,000						
	Grand Total	$209,759,000						

Annex-2-1 The Evaluation Sheet of the Aluto Langano (Ethiopia) Geothermal Field (2)

Temperature Survey	The comparison of down-hole temperatures led to the condlusion htat the up-flow zone is somewhere under the Aluto-volcanic complex and lateral flows feed the aquifer under the foothills. The highest temperature gradient observed was found to be in the eastern and northeastern part of Aluto volcanic complex near wells LA-3 and LA-6.
Well testing	Out of the eight deep wells, 5 are produceres. Subsurface tempertures as high as 335oC have been measured in the deep wells. The maximum recorded temperature wo the well (LA-3: 315oC, LA-6: 335oC) indicates production of a two-phse mixture form the reservoir. The thermodynamic conditions in the reservoir suggest that the primary upflow zone in the system is in the vicinity of wells LA-3 and LA-6. The two moderate enthalpy wells LA-4 and LA-8 produce fluids with a nearly constant enthalpy, roughly corresponding to saturated water at the maximum temperature measured int eh well. LA-7 is poor producer. Flow rates from Aluto wells are generally low indicating a low permeability resource
Conceptual Model	Aluto-Langano is water dominated gas-rich geothermal field having a reservoir temperatures in excess of 340oC. The deep water flows mainly towards the south, southwest and southeast, but also towards the east migrating through the Wonji Fault Zone, supplying the springs and shallow temperature gradient wells and fumaroles at lower and higher elevations, respectively.
Present Status of Development	A pilot power plant of 8.2MW gross has been installed in 1998. Due to some prolems, it was not possible to operate the plant without interruptions. It is necessary to examine production test after drilling of new deep wells and compare with previous tests.
Natrural/Social Environmental Condition	Possible geothermal reservoir area is not within any National Parks.
Power Sector Situation	Estimated T/L length from the field to the Adami-Tulu S/S is about 18km. Direct connection with 132kV to the Adami-Tulu S/S is recommendable. Electrification ratio in this area reachs only??.??%.
Power Output Potential	
Resource Potential	75MW, but according to the recent numerical 3D reservoir simulation, the geothermal resource capacity for the Aluto-Langano field was estimated to be at least 35MW.
Restrictted by National Park	None
Restricted by Power Demand	
Rank of Development Priority	A
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	
Outline for Power Development	The 75MWe power generations will be conducted in two phases (Phase-I: 1x35MWe, Phase-II: 1x40MWe). The possible development site in this field is located between Lake Ziway and Lake Langano. The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	Power Plant Capacity: 75MW (Phase-I: 35MW x 1unit, Phase-II: 40Mw x 1unit) Plant System: Single flashed steam cycle with condencing turbine Explor.+Production Well: approx. 8 wells (only in case of Phase-I) Reinjection Well: less than 4 wells (only in case of Phase-I) Transmission Line: 132kV, around 18km in length Connection: National Gridding Line in Adami-Tulu
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	



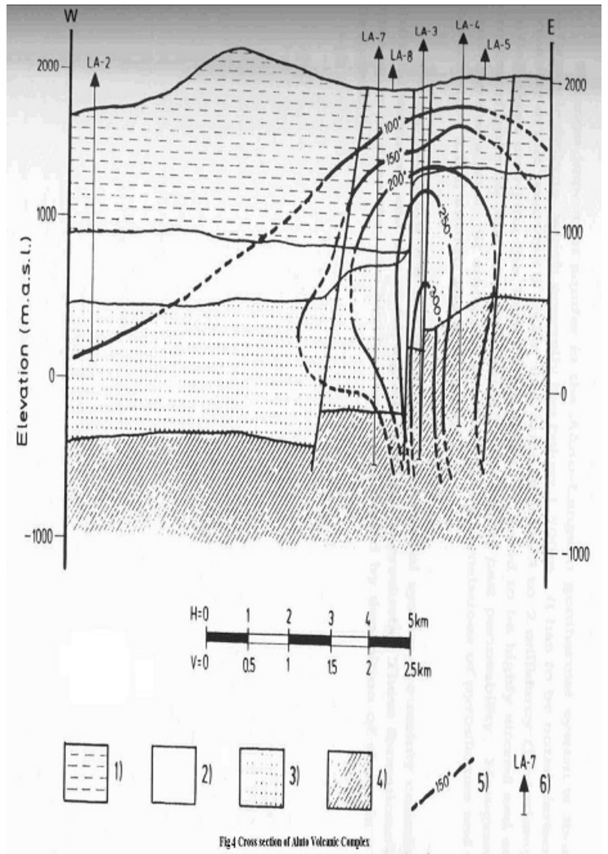


Table 1 An Over View Of The Aluto-Langano Geothermal Wells.

Well Drilling Date	LA1	LA2	LA3	LA4	LA5	LA6	LA7	LA8
From	7 Nov 1981	6 Jul. 1982	21 Jan 1983	6 Jul. 1983	15 Nov. 1983	24 Mar. 1984	11 Jul. 1984	28 Oct. 1984
To	11 June 1982	7 Nov. 1982	14 Jun. 1983	12 Oct. 1983	11 Mar. 1984	2 Jul. 1984	17 Oct. 1984	9 Mar. 1985
Location								
East (m)	474047	469849	477401	478300	478742	477649	476296	476946
North (m)	853808	861501	860723	860800	859427	861278	860832	862374
Elevation (m.a.s.l)	1601	1724	1921	1956	2038	1962	1891	1896
Total Depth (m)	1317	1602	2144	2062	1867	2202.8	2448.5	2500
Well Design Casing Depth (M)								
20"	57	45	41	40	29	41	39.3	40.
13 3/8 "	203	299	233	226	274	233	263	294
9 5/8 "	702	892	748	774	752.	754	956	721.
7 " Liner Top	690	887	723	726	---	728	941	666
7 " Liner Top Of Slots	800	901	1035	746	—	1499	1788	1867
7 " Liner Bottom	1317	1602	2140	2035		2201.	2449	2464
Status Of Well	Non-Productive	Non-Product-Ive	Productive	Productive	Non-Productive	Product-Ive	Product-Ive	Productive
Permeable Zone (m)	—	—	2000- 2121.5	1445-1800	—	2000-2200	2100-2300	2300-2500
Maximum Down Hole Temperature (°C)	—	—	315	230	—	>320	228	268

Annex-2-2 The Evaluation Sheet of the Tendaho (Ethiopia) Geothermal Field (1)

Field Name	Tendaho
Country	Ethiopia
Province/Location	Dubti Wereda, Afar
Location	The Tendaho geothermal field is located in Dubti wereda (district), Afar region in the NE part of Ethiopia, some 600 kms from the capital city, Addis Ababa.
Resource Characteristics	
Geology	
Volcanic activity	A sequence of basaltic lava flows outcrops on the graben bounding escarpments. These rocks form part of the Afar Stratoid series, a Pliocene to early Pleistocene (<4 million years) formation consisting mostly of basalts of fissural origin, with minor rhyolitic bodies in its upper part. The extensive fissural volcanism is believed to have remenants of magma injected along crustal separation zones to serve as heat source for the geothermal system. The stratigraphy under the graben floor was revealed by drilling, and the rock units were grouped into: Upper Unit: Thick sedimentary sequence consisting of fine to medium grained sandstone, siltstone and clay, probably intercalated by basaltic lava sheets; and Lower Unit: Basaltic lava flows of the Afar Stratoid Series.
Geological Structure	The geological work, so far discerned the detailed structural setting and fabric of the area. Tendaho lies within a NW-SE trending graben, part of the southeastern en-echelon extension on land of the Red Sea rift entering Afar to join the Lakes District and Gulf of Aden rifts at a triple junction located in the graben. Normal and strike-slip faults as well as open fissures characterize the graben.
(Past Geological Studies included)	Inventory of hydrothermal features, geological mapping and Petrographic studies Logging of down hole geology, petrochemical and XRD analysis of surface and subsurface alteration
Geochemistry	The isotopic information highlights that the recharge of the geothermal reservoir(s) in Tendaho graben originate(s) in the western escarpment and plateau at elevations above 2000 m and excludes local recharge. The residence time of the water from the recharge area for instance to the Dubti reservoir does not exceed 7000 years (from C14 dating). The water discharged from the Dubti exploratory wells is the sodium chloride type. Reservoir equilibrium temperatures and CO2 partial pressures of discharges from Deubti shallow geothermal wells, TD1, TD2, and TD4) are 260-278°C (1.3 Mpa), 220-225°C (0.35) and 235-240°C (0.4 +/ 0.1), respectively.
Work done so far	• Surface geochemical exploration (solute, isotopic, gas geochemistry) • Drilling geochemical logging (logging selected chemical parameters of the returned fluid during drilling) • Surface manifestations and water points; and geothermal field geochemical monitoring (monitoring physical and chemical parameters of the geothermal well discharges)
Geophysics	During the study of Aquater, a semi-detailed geophysical survey, consisting of electrical resistivity, gravity, magnetic and micro-seismic methods were conducted over an area of 2300 km2.
Gravity	Currently GSE is carrying out a national gravity survey at a nominal station spacing of 5 km along roads and accessible tracks. Homogenization of these data with previous gravity survey is underway. These data may be used to have an insight into the regional overview and aid in survey design. During the feasibility study, Aquater collected gravity data at 2086 stations and used them for model interpretation. Infill-gravity survey undertaken by the survey in 2004 at Dubti over localized thermal manifestation provided useful subsurface information.
Resistivity	Later in 1996, the EIGS carried out resistivity profiling using Schulmbeger array and head on profiling method along 55.3 and 43.5 line km covering 72 and 70 km2 respectively. Geological Survey of Ethiopia (GSE) and the German Geological Survey (BGR) in 2007 carried out electrical surveys consisting of Transient Electro-magnetic Method (TEM) & Magneto-telluric Method (MT) under Geotherm Program. The TEM was applied to remove static shift in MT data. Dubti fault inferred from the geological bore hole (TD-1, TD-2 & TD-4) section and alignment of surface geothermal manifestations is in agreement with the linear feature interpreted based on the geophysical data.

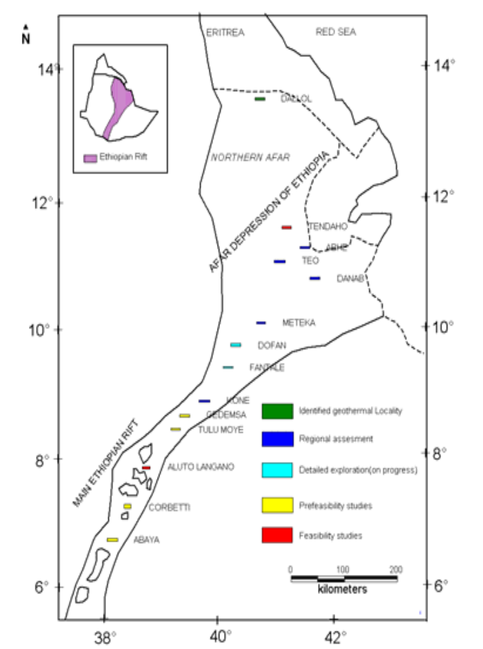
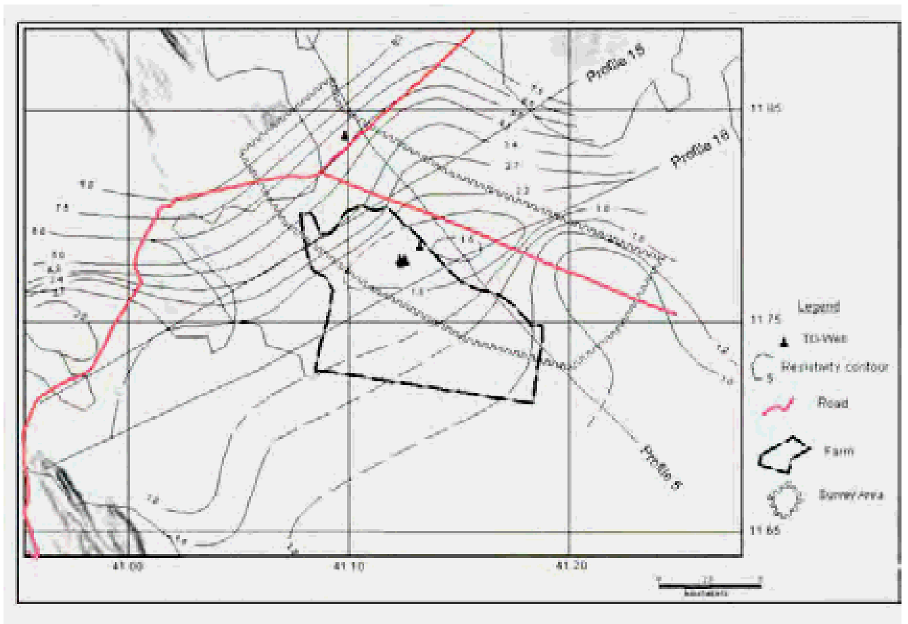


Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley



Annex-2-2 The Evaluation Sheet of the Tendaho (Ethiopia) Geothermal Field (2)

Well Drilling	3 shallow wells and 3 deep exploratory wells have been drilled at the Tendaho geothermal field.
Temperature Survey	The deep and shallow exploratory wells drilled in Tendaho have proved the existence of a commercially attractive geothermal resource at shallower level. Surface and sub-surface measurements conducted so far have determined that the shallow reservoir's temperature is 220-250°C.
Well testing	The permeability is relatively high (3-10Dm). Salinity and non-condensable gas contents of the fluid are low. About 3 MW electric powers can be generated from the existing shallow wells employing back pressure turbine.
Conceptual Model	The system is water dominated and has one or more reservoirs with temperatures exceeding 230°C. and with faults and fractures; and NW-SE strike-slip faults with tensional components in NE-SW direction and dip-slip rupture mechanism.
Present Status of Development	Aquater conducted a pre-feasibility study and BGR has done a feasibility study in the Tendaho geothermal prospect. Pre drilling work for well site selection and then deep drilling are necessary for the next procedure. Geoscientific and reservoir engineering information showed that the central part of the NE Dubti reservoir is situated about 2 km to the southeast of the area drilled by TD-2, while all the explored shallow wells tap from the outflow zones. Although the surface evidence available seem strong, discovering the geothermal reservoir can only be proved by actual deep drilling on the proposed "upflow zone", which has not yet been done.
Natrural/Social Environmental Condition	Possible geothermal reservoir area is not within any National Parks.
Power Sector Situation	Estimated T/L length from the field to the ???? S/S is about ????km. Electrification ratio in this area reachs only ??.??%.
Power Output Potential	
Resource Potential	100MW (Phase-i: 50MW X 1 unit, Phase-II: 50MW X 1unit)
Restrictted by National Park	None
Restricted by Power Demand	
Rank of Development Priority	A
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	
Outline for Power Development	The 100We power generations will be conducted in two phases (Phase-I: 1x50MWe, Phase-II: 1x50MWe). The possible development site in this field is located at ?????. The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable.
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	Power Plant Capacity: 100MW (Phase-I: 50MW x 1unit, Phase-II: 50MW x 1unit) Plant System: Condencing type Explor.+Production Well: approx. 9-11 wells (only in case of Phase-I) Reinjection Well: several wells (only in case of Phase-I) Transmission Line: ???kV, around ???km in distance Connection: National Gridding Line in ?????
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	

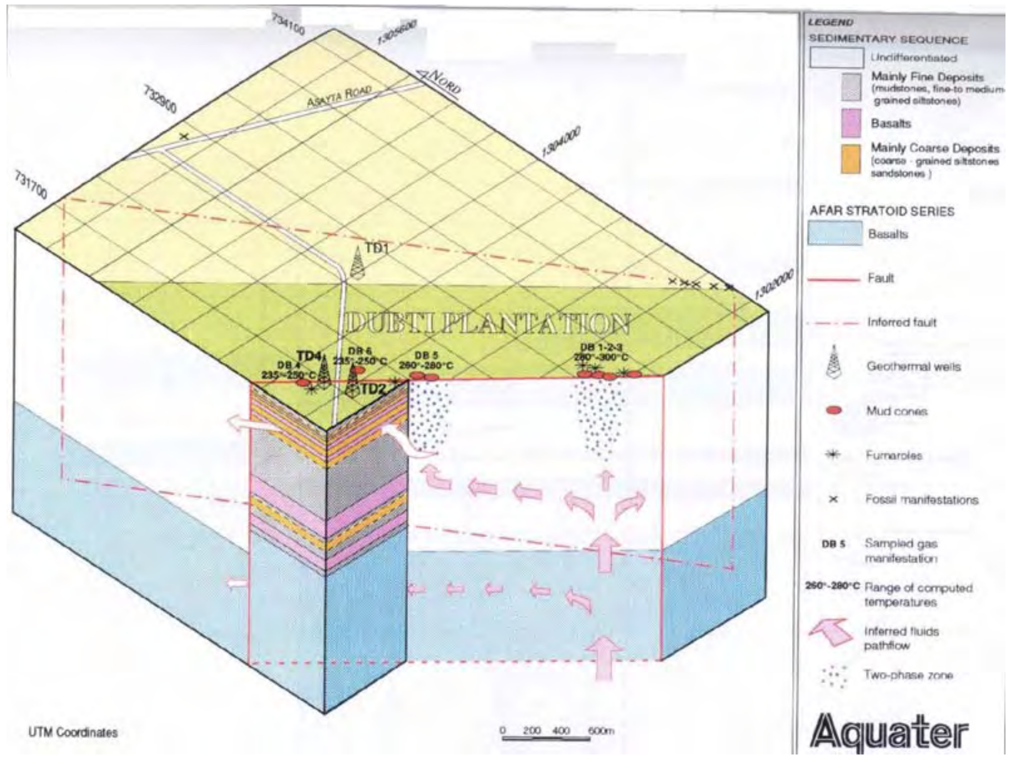


TABLE 1: Salient data on the exploratory wells drilled at Tendaho

Well No.	TD1	TD2	TD3	TD4	TD5	TD6
Drilling period	20/10/93 - 27/02/94	13/03/94 - 10/05/94	07/09/94 - 19/10/94	27/04/95 - 09/05/95	20/12/97 - 14/012w/98	01/02/98 - 20/02/98
Drilled depth (m)	2196 (1550*)	1811	1989	466	516	505
Elevation (m.a.s.l)	365.9	365.7	366.8	365.2	366.3	366
Permeable zones	400-600** 1200-1300	220-500** 1200-1300	50-200**	220-466	220-516	220-505
Maximum Down-hole Temp. (°C)	278	245	198	245	253	245
Status of the well	Non-productive	Productive	Non-productive	Productive	Productive	Productive

Note: * re-drilled current depth
** Cased

Annex-2-3 The Evaluation Sheet of the Abaya (Ethiopia) Geothermal Field (1)

Field Name	Abaya
Country	Ethiopia
Province/Location	Lake District
Location	Abaya geothermal prospect is located on the northwest shore of Lake Abaya, about 400kms south of Addis Ababa, seated of the Southern Ethiopia regional state and located on the Addis Ababa-Nairobi highway.
Resource Characteristics Geology	The local stratigraphy in the area includes both volcanic and continental sedimentary rocks. The exposed volcanic units are ignimbrites, pumiceous pyroclastics, rhyolites, basalts and rhyo-obsidian flows. The pyroclastics and basaltic lava flows form flat lying layers in the faulted terrain while the more silicic lavas form high standing volcanic eruptive centers. The sedimentary units include Pleistocene volcano-sediments, Holocene lake sediments and recent alluvium and fluviatile deposits. The youngest basalts occur along the Wonji Fault Belt which at these latitudes is located on the western rift margin.
Volcanic activity (heat source)	The overall characteristics and distribution of hydrothermal activity is related to the different rhyolitic central volcanoes and suggests the existence of a number of heating systems within the greater Abaya prospect area.
Geological Structrure	Both the eastern and western escarpment areas have high precipitation; and are sources for the deep recharge of the Abaya geothermal systems. The channels of this recharge system are regarded to be the NNE-SSW and the transverse NW-SE tectonic structures mapped in the area. Most hydrothermal features in the study area are found along tectonic lines of the WFB and in association with volcanic centers.
(Past Geological Studies included)	Inventory of hydrothermal features, geological mapping and Petrographic studies, petrochemical and XRD analysis of surface
Geochemistry	The hot spring waters in all the geothermal areas of the MER, amongst which this prospect area is one, are of mixed origin. As a result, the estimates based on mixing models is in excess of 300°C for the Northwest Abaya area springs, which is in good agreement with the results of the CO2 gas and Sulphate-water isotopic temperatures suggesting the presence of a sufficiently high temperature system underneath. The hot water at depth probably flows to the north, northwest and northeast and mixes with shallow low chloride groundwater.
Work done so far	Geochemical studies were carried out on the fumaroles; and the waters from surface water points such as springs, rivers and lakes. These included major element chemical analyses on liquid phase samples; gas analyses on samples from fumaroles; and isotopic determinations on all fluid sources in the area have been done.
Geophysics	Lake District Geothermal Exploration project in 1983 conducted a gravity survey along 130 line km, VES observations at 58 stations and 30 line km self potential survey on the northwestern shore of Lake Abaya. Under Abaya-Tulu Moye geothermal project, at north-west Abaya VES data at 14 stations along three profiles, and a 21 km resistivity profiling data were collected. Gravity and magnetic data were also collected covering a length of 138 Km.
Gravity	Regional gravity field shows low gravity zone, hosting three circular features aligned in NE-SW direction along Wonji fault belts. The zone is flanked by high gravity values on both sides and the middle low encompasses Duguma – Fango volcanic complex. The Bouguer gravity map reveals high gravity anomalous zone straddling the eastern part of the map from south to north. It follows the strike of Wonji fault belt along river Bilate.
Resistivity	For VES data collections Schlumberger array with a maximum current electrode spacing (AB) of 2 km was used. From the integral analysis, two geothermal areas stand-out as a vital geothermal prospects for further detailed investigations including drilling. These are the northwestern shore of Lake Abaya and the area extending from Bilate manifestations up to Anka Dugna manifestation & alteration zone, including the vicinity of Dunga-Fango

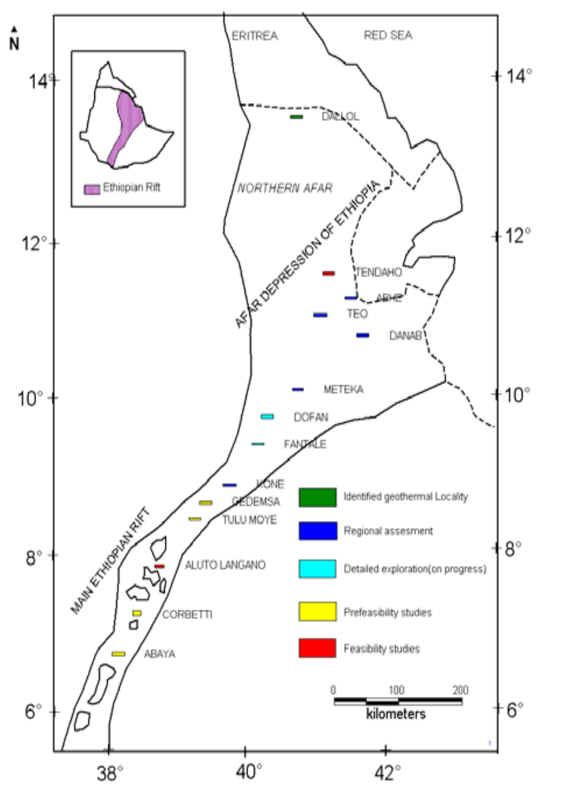
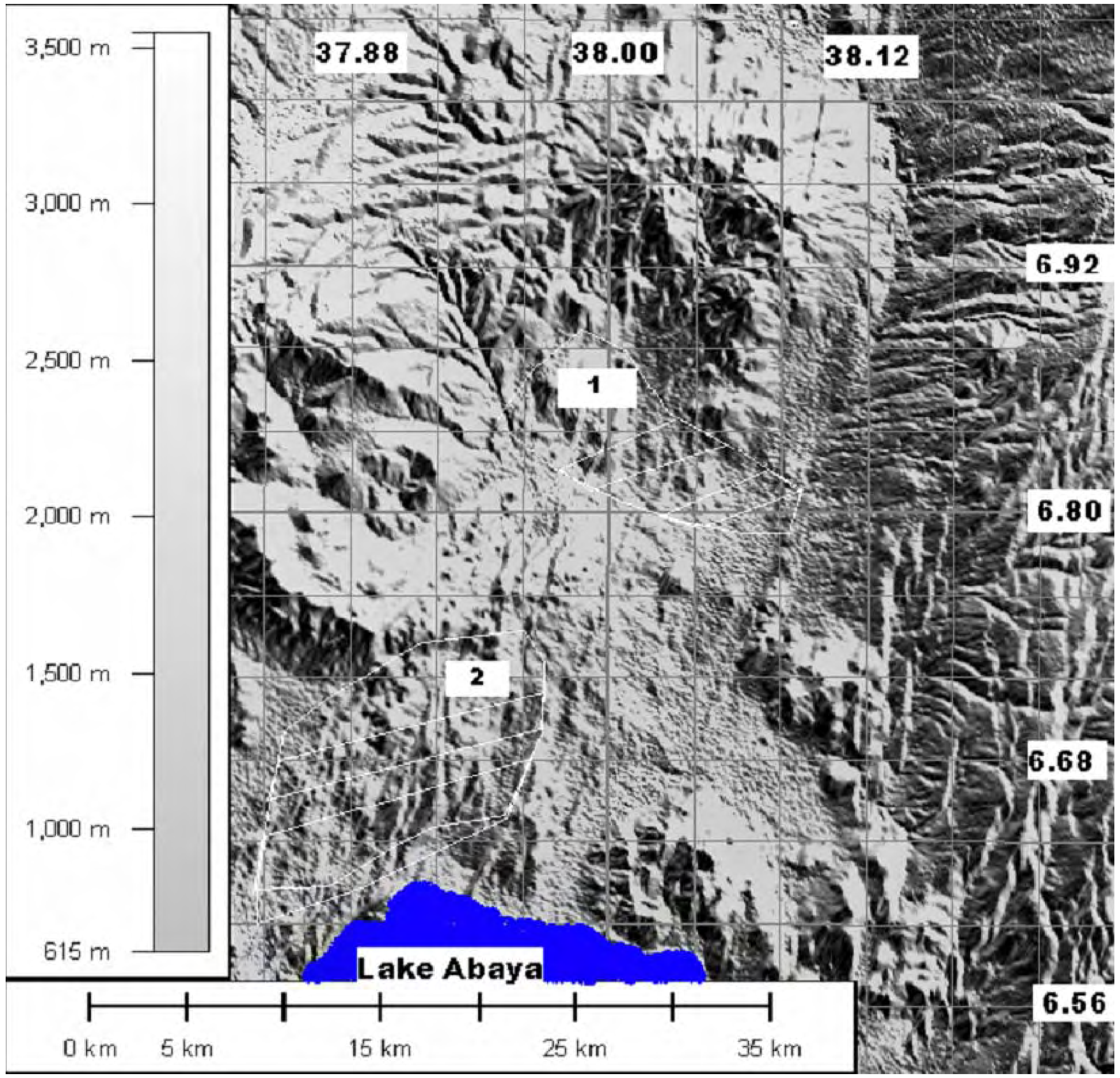


Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley

Annex-2-3 The Evaluation Sheet of the Abaya (Ethiopia) Geothermal Field (2)

Well Drilling	None
Temperature Survey	
Well testing	
Conceptual Model	The waters in the Abaya area have near neutral pH and are primarily of the sodium bicarbonate type like that of the Aluto-Langano geothermal system.
Present Status of Development	Based on geoscientific studies of the Abaya prospect, three areas stand out as being more prospective, northwest shore of Lake Abaya, Anka-bilbo and tobacco plantation of Bilate. As the geothermal reservoir system at Abaya is mainly structure controlled, it is necessary to conduct detailed structural analysis of the prospect to help in locating the more permeable zones of the deep reservoir area. Pre drilling work for well site selection and then deep drilling are necessary for the next procedure after implementation of the high resolution geophysical survey (gravity, magnetic, TEM and MT).
Natrural/Social Environmental Condition	Possible geothermal reservoir area is not within any National Parks.
Power Sector Situation	Estimated T/L length from the field to the ???? S/S is about ????km. Direct connection with 132kV to the ???? S/S is recommendable. Electrification ratio in this area reachs only ??.??%.
Power Output Potential	
Resource Potential	100MW (Phase-i: 50MW X 1 unit, Phase-II: 50MW X 1unit)
Restrictted by National Park	
Restricted by Power Demand	
Rank of Development Priority	B
Potential (Expected) Developer	
Proposed Geothermal Development Plan	
Outline for Power Development	The 100We power generations will be conducted in two phases (Phase-I: 1x50MWe, Phase-II: 1x50MWe). The possible development site in this field is located at northwest shore of Lake Abaya, Anka-bilbo and/or tobacco plantation of Bilate. The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable.
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	Power Plant Capacity: 100MW (Phase-I: 50MW x 1unit, Phase-II: 50MW x 1unit) Plant System: Condencing type Explor.+Production Well: approx. 9-11 wells (only in case of Phase-I) Reinjection Well: several wells (only in case of Phase-I) Transmission Line: ???kV, around ???km in distance Connection: National Gridding Line in ?????
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	



Shaded Relief Elevation Map of Abaya

Annex-2-4 The Evaluation Sheet of the Corbetti (Ethiopia) Geothermal Field (1)

Field Name	Corbetti
Country	Ethiopia
Province/Location	Lake District
Location	Corbetti geothermal prospect is located about 250 km south of Addis Ababa and 20kms from Awasa, seat of the Southern Ethiopia regional state and located on the Addis Ababa-Nairobi highway.
Resource Characteristics	
Geology	Corbetti is a silicic volcanic system similarly to Alutu volcano, except for it's being a well developed resurgent cauldron system. Corbetti caldera has an irregular elliptical outline, elongated in the east-west direction and measuring 10 and 15 km along its two axes.
Volcanic activity	The volcanic products at Corbetti are very young. The repeated cycle of volcanism forming the present morphology of Corbetti system normally shall have remnant magma intruded at shallow depth. This young and shallow magmatic chamber at shallow depth is providing the heat to the Geothermal System at Corbetti.
Geological Structrure	Corbetti has a similar geological set up with that of Aluto-Langano. The caldera-forming volcano developed on terrain made up of late Tertiary ignimbrites which are the main reservoir rocks at Aluto-Langano. The annular structural configuration of the caldera is complicated by the existence of a dense set of the rift forming faults in the NNE-SSW direction. Transversal E-W oriented fissures and the NNE-SSW rift forming faults control the occurrence of hydrothermal features. This relatively pronounced structural fabric system compared to Aluto-Langano is expected to form relatively high secondary permeability in the Tertiary ignimbrites.
(Past Geological Studies included)	Inventory of hydrothermal features, geological mapping and Petrographic studies, petrochemical and XRD analysis of surface
Geochemistry	The chemistry of samples from the shallow wells indicates that the fluids are sodium bicarbonate types. The isotopic composition of the steam from fumaroles lies on the meteoric water line. The 18O enrichment of TG2 is probably due to steam heating whereas the isotopic composition of TG3 falls on the evaporation line. The ground water flow direction in the Awasa-Corbetti-Shalla area is dominantly from south to north as evidenced from piezometric information while the isotopic and chemical data suggest that the system is recharged from the eastern escarpment.
Work done so far	Geochemical studies were carried out on the fumaroles and the waters from the shallow drill holes including major element chemical analyses on liquid phase samples; gas analyses on samples from fumaroles; and isotopic determinations on all fluids in the area.
Geophysics	Geophysical survey had followed different stages of geophysical studies starting from a semi-detailed exploration by dipole-dipole electrical and gravity surveying, through the execution of a detailed electrical resistivity method, to the point of citing thermal gradient (TG) wells in order to establish the existence of geothermal steam resources.
Gravity	A circular low Bouguer gravity anomaly having steep gradient at its outskirt has outlined the geologically inferred Corbetti caldera. A high residual gravity anomaly greater than 10 mGal located between Corbetti and Lake Shalla was interpreted as caused by a dense intrusion.
Resistivity	Electrical surveys comprising of self-potential (SP) and resistivity methods provided useful subsurface information. Positive SP anomaly that is as high as 190 millivolts within the caldera was interpreted as an indication of up flow zones. An elongated low resistivity anomaly, as mapped by Dipole-Dipole electrical survey, opens towards Lake Shalla. Its cause is the subsurface movement of hot geothermal fluid from Corbetti to Lake Shalla, and this interpretation is supported by the local hydogeological gradient. The assumption of horizontal stratification is not valid for VES interpretation. Though the data was interpreted, it can be reliable. Resistivity or density structure of Corbeti caldera are not well defined in terms of caldera collapse, faulting and the reservoir is not located by the previous survey.

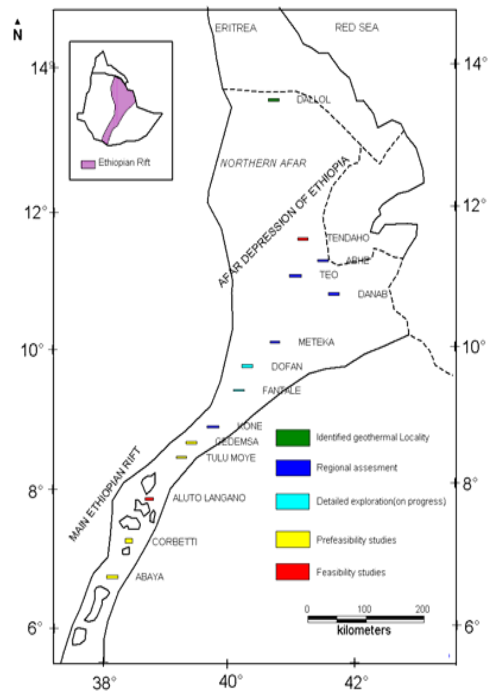


Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley

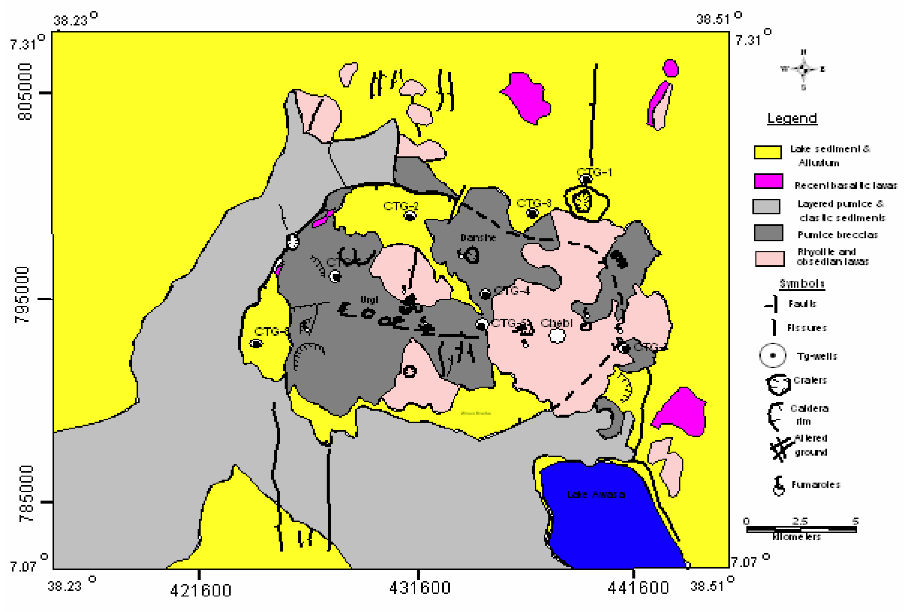
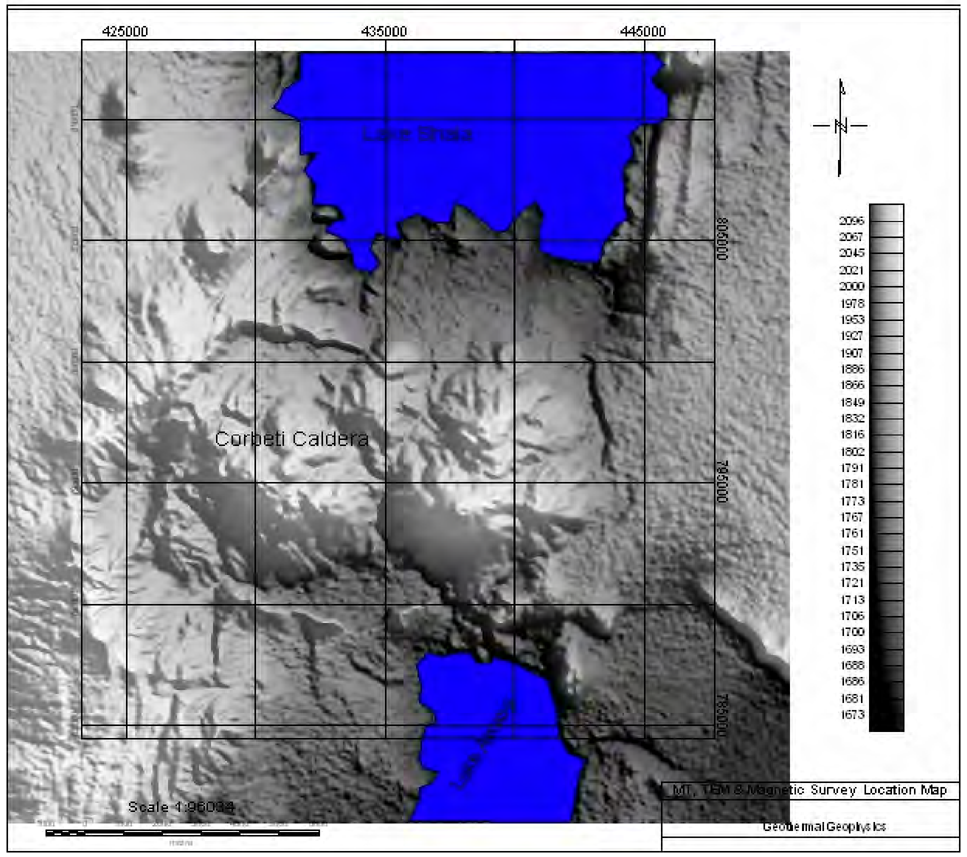


Figure 11, Geological map of Corbetti geothermal prospect (GSE, 1987)

Annex-2-4 The Evaluation Sheet of the Corbetti (Ethiopia) Geothermal Field (2)

Well Drilling	7 thermo-gradient wells have been drilled at the Corbetti geothermal field.
Temperature Survey	
Well testing	
Conceptual Model	The system is a high temperature field, with subsurface temperatures in excess of 300ºC, and the chemistry similar to that of the Aluto-Langano geothermal field.
Present Status of Development	GSE conducted a pre-feasibility study. As the geothermal reservoir system at Corbetti is mainly structure controlled, it is necessary to conduct detailed structural analysis of the prospect to help in locating the more permeable zones of the deep reservoir area. The Caldera and its vicinity with average an area of 100km2 will be desired to explore using TEM, MT and Magnetics. Pre drilling work for well site selection and then deep drilling are necessary for the next procedure.
Natrural/Social Environmental Condition	Possible geothermal reservoir area is not within any National Parks.
Power Sector Situation	Estimated T/L length from the field to the ???? S/S is about ????km. Direct connection with 132kV to the ???? S/S is recommendable. Electrification ratio in this area reachs only ??.??%.
Power Output Potential	
Resource Potential	75MW (Phase-i: 35MW X 1 unit, Phase-II: 40MW X 1unit)
Restrictted by National Park	None
Restricted by Power Demand	
Rank of Development Priority	B
Potential (Expected) Developer	
Proposed Geothermal Development Plan	
Outline for Power Development	The 75MWe power generations will be conducted in two phases (Phase-I: 1x35MWe, Phase-II: 1x40MWe). The possible development site in this field is located the south of Lake Shalla. The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable.
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	Power Plant Capacity: 75MW (Phase-I: 35MW x 1unit, Phase-II: 40Mw x 1unit) Plant System: Condencing type Explor.+Production Well: approx. 8 wells (only in case of Phase-I) Reinjection Well: several wells (only in case of Phase-I) Transmission Line: 132kV, around ????km in distance Connection: National Gridding Line in ?????
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	



Shaded Relief Elevation Map of Corbetti

Annex-2-5 The Evaluation Sheet of the Tulumoye (Ethiopia) Geothermal Field (1)

Field Name	Tulumoye
Country	Ethiopia
Province/Location	
Location	Tulumoye geothermal prospect is located about 200km south east of Addis Ababa, close to Koka hydro power station and the natioanl grid system.
Resource Characteristics	
Geology	Volcanism in the area involved the extrusion of peralkaline felsic lava associated with young tensional and transverse tectonic features dating from1.2 to 0.1 million years (Di Paola, 1976). Fissural basalt flows followed during the late Pleistocene and further eruption of silicic lava and pyroclastics. The prospect area itself is characterized by volcanism dating from less than 0.8 million years ago and continuing intermittently into historic times. The occurrence of fresh obsidian flows attests to the youth of volcanism in the area. Basalt flows make up the low lying area at an altitude of 1,900m asl while the central silicic eruptive centers rise to up to 2,300m asl.
Volcanic activity (heat source)	The history of periodic eruptions from the young eruptive centers (0.07 My), the presence of highly differentiated intermediate to silicic rocks (rhyolitic, ignimbritic, etc.), the existence of numerous active faults, the widespread occurrence of steaming ground and hydrothermal alteration, and of a young phreatic explosion crater indicated the probable existence of an active heat source, a shallow magmatic chamber. The study of alteration minerals indicated the occurrence of both acid sulfate and alkaline types of alteration. The widespread distribution of chalcedony deposits in the studied area indicates a deep reservoir temperature in excess of 150oC.
Geological Structrure	The main ground water recharge into the Tulumoye subsurface is from the eastern rift escarpment area. Ignimbrites outcropping tho the east of the prospect are are affected by rift forming and transverse faults. These older rock untis mayserve as reservoir rocks. The presence of numerous NNE-SSW trending, rift forming faults and the NNS-SSE oriented transverse faults intersecting them as well as the open fissures are believed to create high secondary permeability in these deep-seated rocks. The fractures created as a result of the intersection of the above sets of faulting in the east and northeast of the prospect area may serve as channels for the infiltration of meteroric water into the zone.
(Past Geological Studies included)	- Inventory of hydrothermal features, geological mapping and Petrographic studies, - Petrochemical and XRD analysis of surface alteration minerals - Geological and alteration studies in shallow drill holes
Geochemistry	In Tulumoye area, as is the cases in most of the MER prospect areas, meteoric waters which infiltrate the shallow aquifers acquire first a dilute alkaline-earth bicarbonate composition, but with deeper penetration and further leaching, their compositions vary to alkaline bicarbonate types with higher total dissolved solids (TDS). Thermal waters related to deeper and hotter aquifers have extreme Na-HCO3 compositions, TDS higher than ground waters and very low Ca and Mg contents. The Tulumoye area, where numerous gaseous manifestations with significant H2 content are found and where the only water sample collected showed anomalous values of both NH3 and CO2 is considered as one of the priority areas of the MER for further detailed investigation.
Work done so far	Geochemical studies were carried out on the weak fumaroles; and steaming ground and the the waters from the near by possble sources. These included major element chemical analyses on liquid phase samples; gas analyses on samples from fumaroles; and isotopic determinations on all fluid sources in the area have been done.

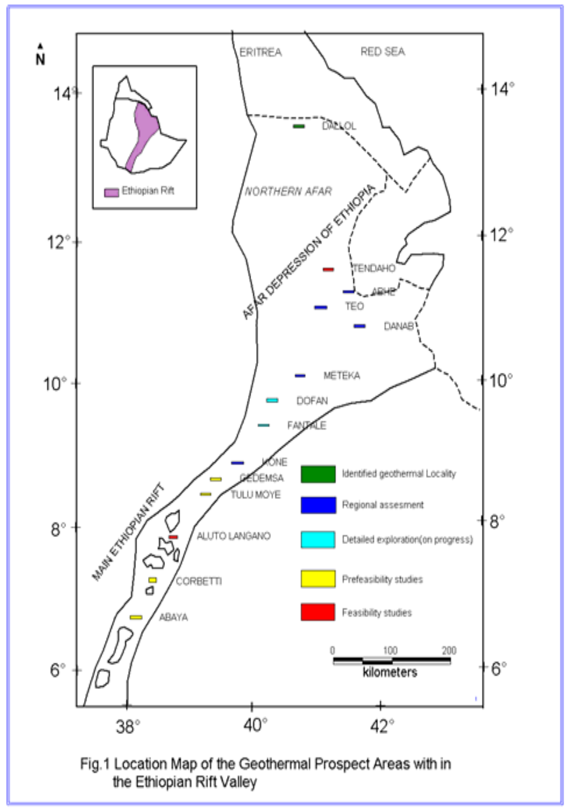
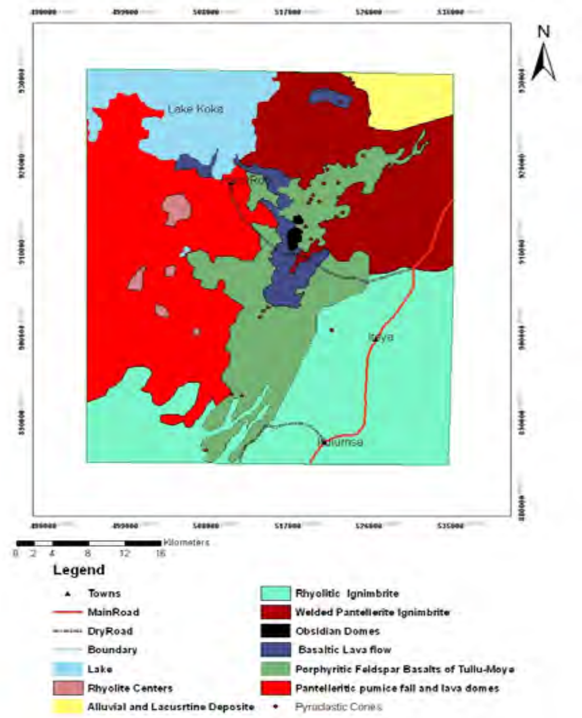
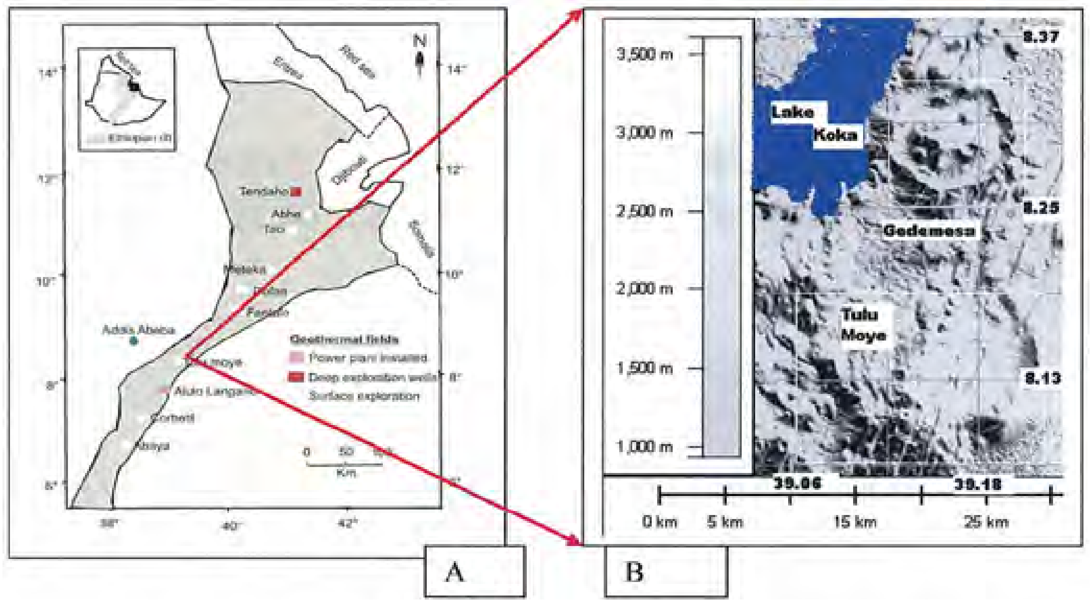


Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley

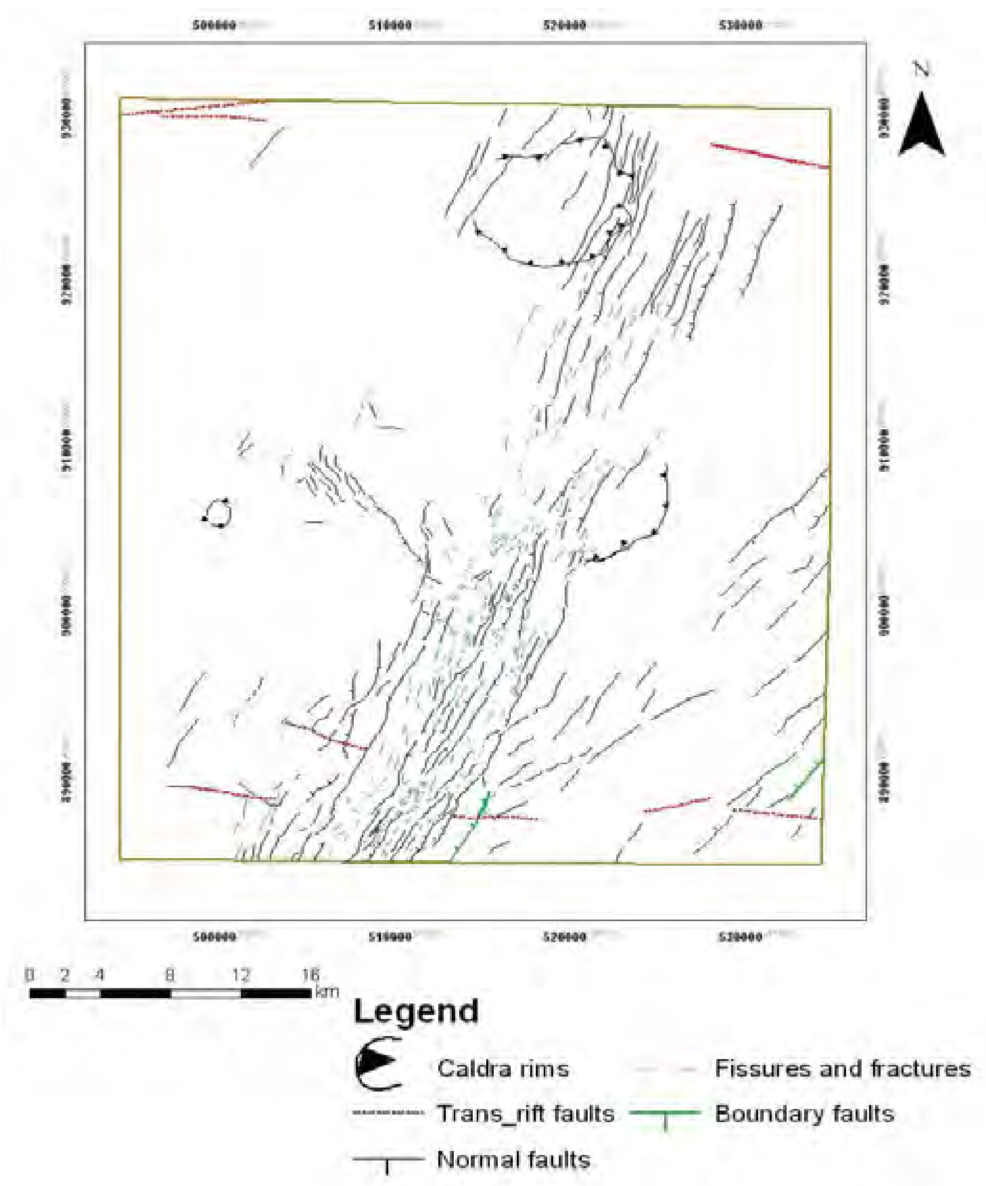


Geologic Map of the Tulumoye and Gedemsa Geothermal Areas



Annex-2-5 The Evaluation Sheet of the Tulumoye (Ethiopia) Geothermal Field (2)

Geophysics	Elecgtroconsult (ELC) and GSE collected resistivity data on 51 and 69 VES station in Tulumoye and Gedemsa prospect areas respectively. Gravity data reading was taken on 147 at Tulumoye and on 304 at Gedemsa prospects.
Gravity	Both the graviy and magnetic data revealed a NW-SE structures that traverse the Wonji Fault belt. The traversing structure covers the area from Tulumoye in the southest through the Mt. Dima & Mt. Jimma volcanic centers to Bite village in the northwest. The wide spread alteration and fuming ground, which coincide with the low resistivy zone, occupy these crisscross structures which provided conduit for geothermal fluid circulations.
Resistivity	Most sounding reached the top of resistivity basement at Tulumoye and Gedemsa areas, ecxept few of them. Three resistivity layers at Tulumoye and four at Gedemsa were identified. A very thin surfacial layer, not every where encountered is the extra layer which is higly variable in resistivity values.The resistive basement is attributed to basalts of the rift floor, on the basis of their resistivity characteristics and of regional geological considerations (outcriops observed at a fault scarp near the Kulumsa river fall, and presence of basaltic zenoliths of deep origin at Mt. Cheka). The resistive basement has undulating surface: where there are pronounced up-rises, the layer above it shows an increase in resistivity and these markded up rises were interpreted as due to intrusive and or the up pushing of a shallow magma chamber. Overlying the basement is a low resistivity of conductive layer attributed to Nazeret group, a pyroclastic wequence mainly composed ignimbrites. It occurs everywhere and its resistivity and thickness varies. In Tulumoye, low resistivity anomaly, below 20 ohm-meters is gound at the southeast sector fot the prospect and see
Well Drilling	Several TG wells
Temperature Survey	Data from some of the TG wells yielded conductive gradients of 60 and 40oC/100m depth respectively which is indicative of the existnence of a high enthalpy geothermal system at shallow depth.
Well testing	
Conceptual Model	
Present Status of Development	As the geothermal reservoir system at Tulymoye is mainly structure controlled, it is necessary to conduct detailed structural analysis of the prospect to help in locating the more permeable zones of the deep reservoir area. Pre drilling work for well site selection and then deep drilling are necessary for the next procedure after implementation of the high resolution geophysical survey (TEM and MT).
Natrural/Social Environmental Condition	Possible geothermal reservoir area is not within any National Parks.
Power Sector Situation	
Power Output Potential	
Resource Potential	40MW (Phase-i: 15MW X 1 unit, Phase-II: 25MW X 1unit)
Restrictted by National Park	None
Restricted by Power Demand	
Rank of Development Priority	B
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	
Outline for Power Development	The 40We power generations will be conducted in two phases (Phase-I: 1x15MWe, Phase-II: 1x25MWe). The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable.
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	



Tectonic Map of the Tulumoye and Gedemsa Geothermal Areas

Annex-2-6 The Evaluation Sheet of the Dofan (Ethiopia) Geothermal Field

Field Name	Dofan
Country	Ethiopia
Province/Location	Southern Afar
Location	The Dofan (Fantale) geothermal prospect is located about 200km northeast of Addis Ababa in the central part of the Ethiopian Rift.
Resource Characteristics Geology	Dofan is a rhyolitic volcano with its initial phases of activity started erupting at about 1.7My. Subsequent eruptions continued between 0.5-0.2 My with a considerable volume of peralkaline rhyolitic and trachytic lava from numerous eruptive centers. Tectonic activity of MER orientation dissected the volcano into two peaks forming a NNE-SSW trending graven along the faults of which some historical fissural basaltic lava are reported to have erupted. Plio-Pleistocene continental sediments cover the surroundings of Dofan volcano and may form an impervious cap rock for any reservoir that may exist at depth. There are several hydrothermal manifestations (fumaroles and hot springs) within the prospect area. Hydrologic recharge is from the rift marginal highlands situated immediately to the west of the prospect area.
Volcanic activity (heat source)	Possible heat sources could be a shallow magma chamber which gave rise to voluminous eruption of volcanic products namely rhyolite, obsidian, trachyte, pumice and ignimbrite. The reservoir rocks are assumed to be at intermediate depth Dino Ignimbrite and Bofa basalt and Alaji basalt (rift margin basalt) at deeper level.
Geological Structrure	Tectonic activity of MER orientation dissected the volcano into two peaks forming a NNE-SSW trending graben along the faults of which some historical fissural basaltic lava are reported to have erupted.
(Past Geological Studies included)	Inventory of hydrothermal features, geological mapping and Petrographic studies Petrochemical and XRD analysis of surface alteration minerals
Geochemistry	The chemistry of the waters in Dofan (Fantale) area indicates the presence of three families of ground waters. The first exhibits a composition ranging from alkarine-earth-bicarbonate to alkarine-bicarbonate, which is essentially a result leaching of volcanic rocks by locally infiltrated meteoric waters. The second groundwater family displays a chloride composition, with relatively high content of sulphate, which is most likely a result of leaching of evaporite deosits. The third family is that of thermal waters, which are characterized by very low contents of Mf (and Ca), high contents of other dissolved substances, typical Na-HCO3 composition and relatively high pH (from 8.2 to 8.8). Isotopic data suggest the occurrence of steam loss in a temperature range of 100 to 200oC. In the prospect area, only ammonia anomalies have been identified, the most important being in the area between Fantale and Dofan volcano. However, this was not accompanied by a boron anomaly. The fumaroles have emission temperatures of about 100oC. Their gas contents are primarily composed of CO2, but significant quantities of H2, CH4 and occasionally CO, have been detected. The study of chemical equilibria in the gas phase allowed the estimation of underround temperatu
Work done so far	Geochemical studies were carried out on the fumaroles; and the waters from surface water points such as springs and rivers. These included major element chemical analyses on liquid phase samples; gas analyses on samples from fumaroles, isotopic determinations on all fluid sources in the area and soil survey have been done.
Geophysics	While ELC-GSE (1986-87) executed the Reconnaissance Geothermal Resource Exploration project, electrical resistivity and gravity surveys were carried out over Dofan and Fantale prospects. The collected 52 VES data are located outside Dofan volcano north, west and southwest vicinities, along eight profiles oriented E-W and NW-SE. In addition, 188 gravimetric stations were unevenly distributed over the Difan Volcano and its surrounding. Between 2003 and 2005, Dofan-Fantale geothermal exploration project carried out geophysical survey consisting of gravity, magnetic and electrical resistivity methods. It was a continuation of the previous reconnaissance work of ELC-GSE.
Gravity	From the Bouguer Map the high is observed to occur over Dofan volcanic product and fussural lava flows. Gravity data modeling, constrained by interpreted resistivity layers, resulted in five density layers. The basement basalt occurs at an average depth of 1km with a density of 2.8 gm/cc. Faulting affects it and form minor graben and horst structures. Two types of lavas, one with larger lateral extent and the other with minor extent have density of 2.7 gm/cc and 2.6 gm/cc respectively. Sediments with ignimbrites have variabe densities varying from 2.1 to 2.25 gm/cc.
Resistivity	Three to five resistivity layers were identified, four layers in the west, five in the north and three in the south west of Dofan. The resistive basement corresponds to the rift floor basalts belonging at least in part to Afar stratoid series. It is characterized by a medium to high resistivity and irregular configuration. Overlying the basement is a conductive unit (as the third layer) tentaively attributed to sedimentary sequence and nazret group. The second layer composed of the intercalation of lavas of the Dofan volcano products consisting of basalts and rhyolites with conductive units. It has intermediate resistivity values. The first layer is recent alluvial roducts characterized by a resistivity variation mainly due to the difference in clay content.
Present Status of Development	As the geothermal reservoir system at Dofan-Fantale is mainly structure controlled, it is necessary to conduct detailed structural analysis of the prospect to help in locating the more permeable zones of the deep reservoir area. Pre drilling work for well site selection and then deep drilling are necessary for the next procedure after implementation of the high resolution geophysical survey (TEM and MT).
Natrural/Social Environmental Condition	Possible geothermal reservoir area is not within any National Parks.
Power Sector Situation	
Power Output Potential Resource Potential	50MW (Phase-i: 25MW X 1 unit, Phase-II: 25MW X 1unit) in Dofan-Fantale prospect
Restrictted by National Park Restricted by Power Demand	None
Rank of Development Priority	B
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan Outline for Power Development	The 50We power generations in Dofan Fantale prospect will be conducted in two phases (Phase-I: 1x25MWe, Phase-II: 1x25MWe). The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable.

Proposed Geothermal Development Plan Outline for Power Development	The 50We power generations in Dofan Fantale prospect will be conducted in two phases (Phase-I: 1x25MWe, Phase-II: 1x25MWe). The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable.
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	

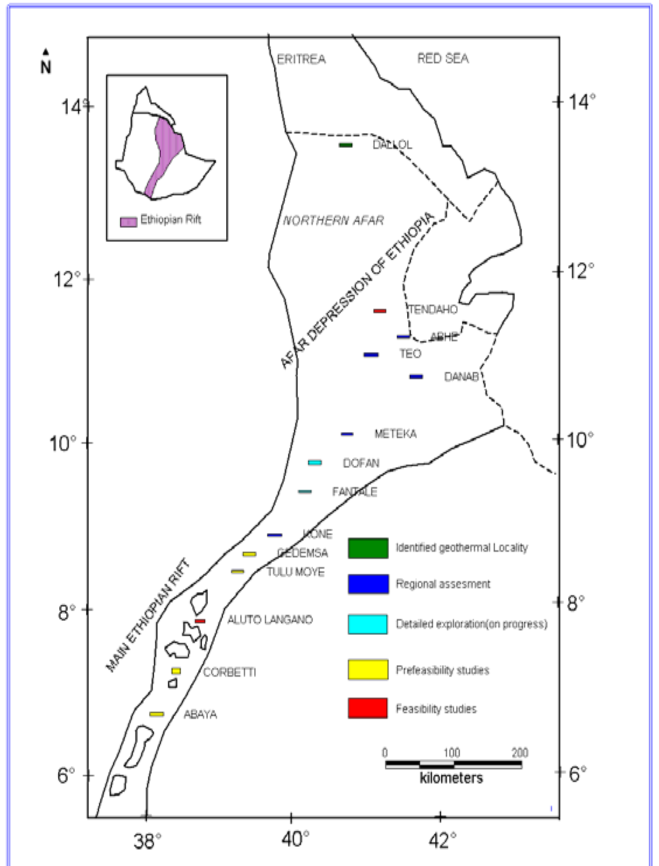
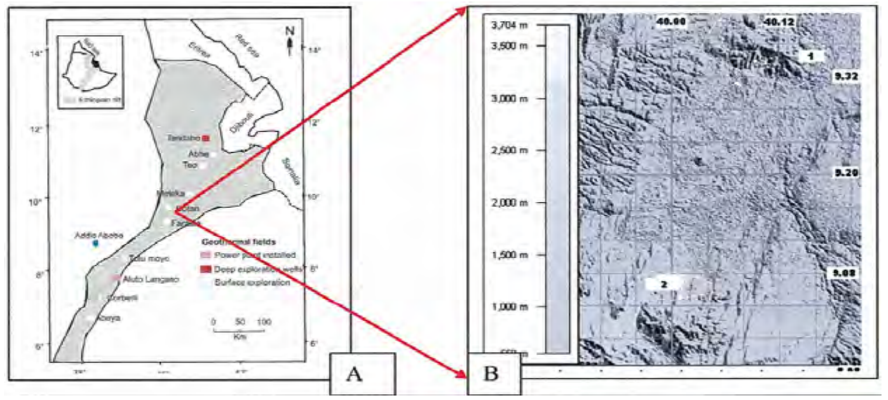


Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley



Annex-2-7 The Evaluation Sheet of the Fantale (Ethiopia) Geothermal Field

Field Name	Fantale
Country	Ethiopia
Province/Location	Southern Afar
Location	The Fantale (Dofan) geothermal prospect is located about 200km northeast of Addis Ababa in the central part of the Ethiopian Rift.
Resource Characteristics	
Geology	Fantale volcano stands on terrain at 1,000m altitude, made up of ignimbrites of the Nazret group. It is a silicic volcano of Pleistocene age with a summit caldera. The volcano is characterized by felsic lava extrusions on the caldera floor and fumarolic activity. Its peak is at 2,000m altitude. Very young obsidian flows high on its southeastern flank attest to the youth of itsu activity. However, it is presently at the fumarolic stage. The immediate area of Tedecha is made up of ignimbrite faulted in the NNE-SSW. A spouting thermal spring issues at boiling temperature at Artu Habilo in Tedecha area. The springs do not have any obvious immediate association with young volcanic activity. It is not certain if they constitute outflow from Fantale volcano situated about 7 km to the southeast.
Volcanic activity (heat source)	Possible heat sources could be a shallow magma chamber which gave rise to voluminous eruption of volcanic products namely rhyolite, obsidian, trachyte, pumice and ignimbrite. The reservoir rocks are assumed to be at intermediate depth Dino Ignimbrite and Bofa basalt and Alaji basalt (rift margin basalt) at deeper level.
Geological Structrure	Tectonic activity of MER orientation dissected the volcano into two peaks forming a NNE-SSW trending graben along the faults of which some historical fissural basaltic lava are reported to have erupted.
(Past Geological Studies included)	Inventory of hydrothermal features, geological mapping and Petrographic studies Petrochemical and XRD analysis of surface alteration minerals
Geochemistry	The chemistry of the waters in Dofan (Fantale) area indicates the presence of three families of ground waters. The first exhibits a composition ranging from alkarine-earth-bicarbonate to alkarine-bicarbonate, which is essentially a result leaching of volcanic rocks by locally infiltrated meteoric waters. The second groundwater family displays a chloride composition, with relatively high content of sulphate, which is most likely a result of leaching of evaporite deosits. The third family is that of thermal waters, which are characterized by very low contents of Mf (and Ca), high contents of other dissolved substances, typical Na-HCO3 composition and relatively high pH (from 8.2 to 8.8). Isotopic data suggest the occurrence of steam loss in a temperature range of 100 to 200oC. In the prospect area, only ammonia anomalies have been identified, the most important being in the area between Fantale and Dofan volcano. However, this was not accompanied by a boron anomaly. The fumaroles have emission temperatures of about 100oC. Their gas contents are primarily composed of CO2, but significant quantities of H2, CH4 and occasionally CO, have been detected. The study of chemical equilibria in the gas phase allowed the estimation of underround temperature whic
Work done so far	Geochemical studies were carried out on the fumaroles; and the waters from surface water points such as springs and rivers. These included major element chemical analyses on liquid phase samples; gas analyses on samples from fumaroles, isotopic determinations on all fluid sources in the area and soil survey have been done.
Geophysics	While ELC-GSE (1986-87) executed the Reconnaissance Geothermal Resource Exploration project, electrical resistivity and gravity surveys were carried out over Dofan and Fantale prospects. 53 VES data were collected over, two stripes located in the plain bordering the south and west of Fantale volcano. Between 2003 and 2005, Dofan-Fantale geothermal exploration project carried out geophysical survey consisting of gravity, magnetic and electrical resistivity methods. It was a continuation of the previous reconnaissance work of ELC-GSE.
Gravity	The survey area covered by the gravity and magnetic method is about 1,435 km2 in the Fantale prospect. The long wavelength, high anomaly, trending in NE-SW direction occurs over the axial rift zone and has a funnel shape, widened towards the northeast. The regional gravity field dominates the Bouguer gravity anomaly and both show similar patterns. short wavelenth, high Bouguer gravity anomalies are observed to be superimposed on the long wavelength Bouguer gravity field. They occur over Fantale volcano at Sabure, southeast of Lake Metehara, around Habilo, and at the northeast corner of the map.
Resistivity	Four resitivy units were recognized in both areas but resistivity values differ being lower in the south. The resistivity basement (4th layer) corresponding to Alaji basalt of the trap series has resitivity values in excess of 100 ohm-meters. The conductive resitivity layer (3rd layer) was interpreted to be paused by the Nazret group, consisting of a thick sequence of ignimbrites and ash flows. The 2nd layer overlying the conductive unit has relatively higher resistivity and corresponds to Dino ignimbrite which is less altered. The shallowest layer is composed of alluvium, Fantale ignimbrite and lava products of the Fantale volcano itself with a thickness of a few tens of meters to a maxumum of 130m.
Well Drilling	
Temperature Survey	
Well testing	
Conceptual Mode	
Present Status of Development	As the geothermal reservoir system at Dofan-Fantale is mainly structure controlled, it is necessary to conduct detailed structural analysis of the prospect to help in locating the more permeable zones of the deep reservoir area. Pre drilling work for well site selection and then deep drilling are necessary for the next procedure after implementation of the high resolution geophysical survey (TEM and MT).
Natrural/Social Environmental Condition	Possible geothermal reservoir area is not within any National Parks.
Power Sector Situation	
Power Output Potential	
Resource Potential	50MW (Phase-i: 25MW X 1 unit, Phase-II: 25MW X 1unit) in Dofan-Fantale prospect
Restrictted by National Park	None
Restricted by Power Demand	
Rank of Development Priority	B
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	
Outline for Power Development	The 50We power generations in Dofan Fantale prospect will be conducted in two phases (Phase-I: 1x25MWe, Phase-II: 1x25MWe). The demand of electricity in Ethiopia is large, so a large scale power plant development as far as resource available is recommendable.
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	

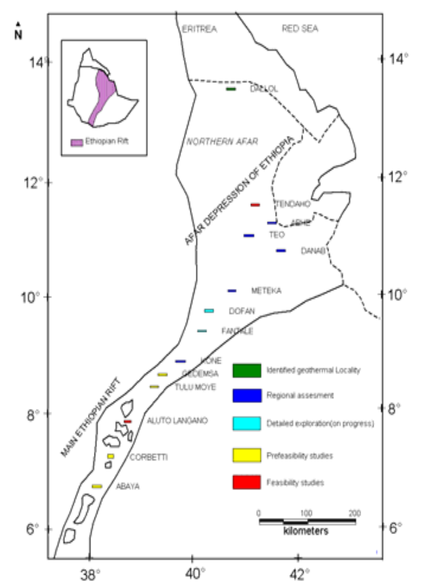
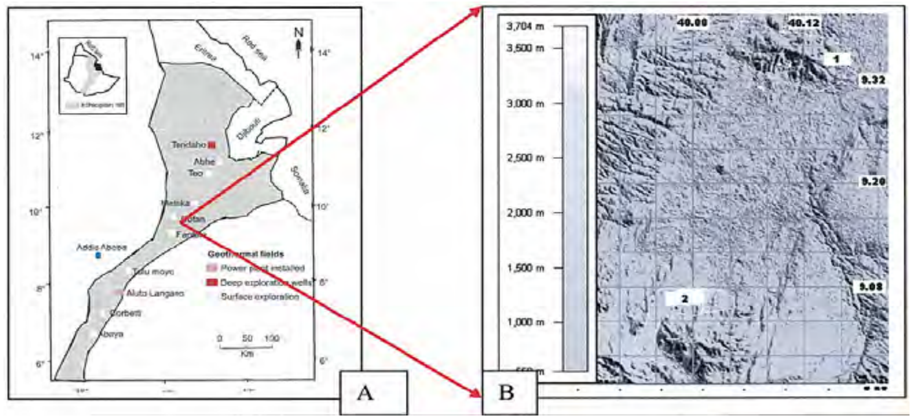


Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley



Annex-2-8 The Evaluation Sheet of the Gedemsa (Ethiopia) Geothermal Field

Field Name	Gedemsa
Country	Ethiopia
Province/Location	Lake District
Location	Gedemsa geothermal prospect is located about 175km south of Addis Ababa in the central sector of Main Ethiopian Rift (MER). It lies between 500000-530000E and 885000-930000N UTM coordinates covering about 900km2. The area is situated within the central sector of the Main Ethiopian Rift (MER) characterized by active tectonism and related volcanism. This part of the rift manifests faulted blocks with relatively steep scarps that form local horst and graben structures, long and narrow open fissures and cinder cones which constitute the very rough topography. The prospect is bounded by two main Asphalted Roads namely; Nazreth- Asella and Mojo- Ziway, neither of them is helpful to reach the area. However, there are two dry weather roads both crossing the area, one from Kulumsa through Olgocho to Meki; the other from Dera to Haro Robi, which has been useful to access important geologic outcrops, structures and representative sites for this study.
Resource Characteristics	
Geology	The geologica map of the area is produced mainly from earlier geological maps of Lake Ziway-Asela and Nazreth-Dera regions (Alula et al.,1990; Abebe et al., 1998), recent studies (Abebe et al., 2007; Bocaletti et al., 1998), and interpretation of Landsat TM with field observations. The map is presented in broad sense. For example, the western part of the area is mapped broadly as pantelleritic pumice fall and lava domes, but many lithologies like rhyolites, lava domes and pumice falls are contained in it.
Volcanic activity (heat source)	
Geological Structrure	
(Past Geological Studies included)	
Geochemistry	
Work done so far	
Geophysics	Elecgtroconsult (ELC) and GSE collected resistivity data on 51 and 69 VES station in Tulumoye and Gedemsa prospect areas respectively. Gravity data reading was taken on 147 at Tulumoye and on 304 at Gedemsa prospects.
Gravity	Most of the faults recognized by the resistivity model that have surface expressions are step like forming horst and graben. Gravity modeling of Gedemsa caldera has identified three density layers and interpretation has indicated a collapse structure of the caldera.
Resistivity	Most sounding reached the top of resistivity basement at Tulumoye and Gedemsa areas, ecxept few of them. Three resistivity layers at Tulumoye and four at Gedemsa were identified. A very thin surfacial layer, not every where encountered is the extra layer which is higly variable in resistivity values.The resistive basement is attributed to basalts of the rift floor, on the basis of their resistivity characteristics and of regional geological considerations (outcriops observed at a fault scarp near the Kulumsa river fall, and presence of basaltic zenoliths of deep origin at Mt. Cheka). The resistive basement has undulating surface: where there are pronounced up-rises, the layer above it shows an increase in resistivity and these markded up rises were interpreted as due to intrusive and or the up pushing of a shallow magma chamber. Overlying the basement is a low resistivity of conductive layer attributed to Nazeret group, a pyroclastic wequence mainly composed ignimbrites. It occurs everywhere and its resistivity and thickness varies. The upper highly resistivity layer in Gedemsa corresponding to recent basaltic flows probably of fissural type is miss Tow major lows are recognized from resistivity mapping of Gedemsa prospect. The first one occurs at the western
Well Drilling	
Temperature Survey	
Well testing	
Conceptual Model	
Present Status of Development	
Natrural/Social Environmental Condition	
Power Sector Situation	
Power Output Potential Resource Potential Restrictted by National Park Restricted by Power Demand	
Rank of Development Priority	
Potential (Expected) Developer	
Proposed Geothermal Development Plan Outline for Power Development	
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	

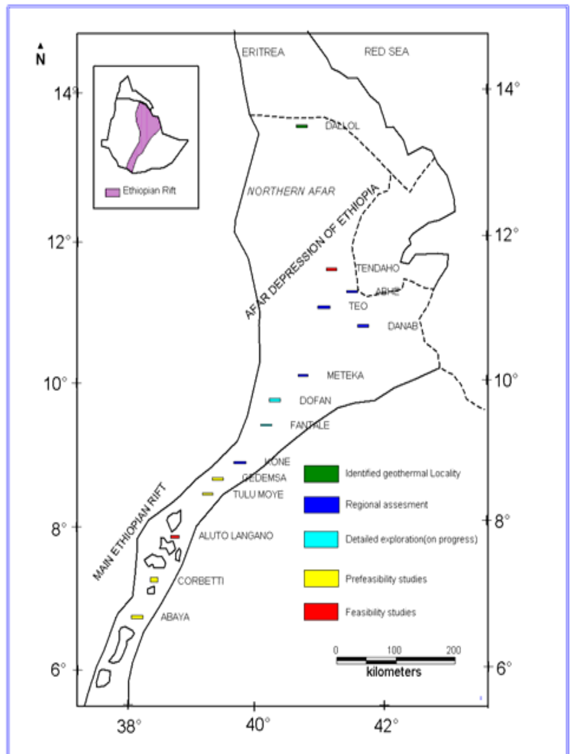
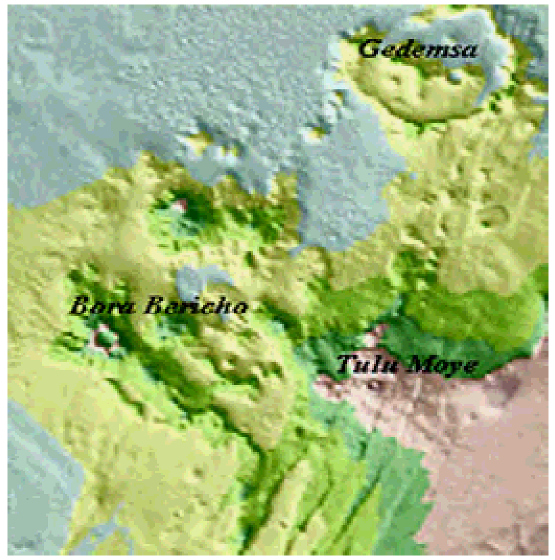
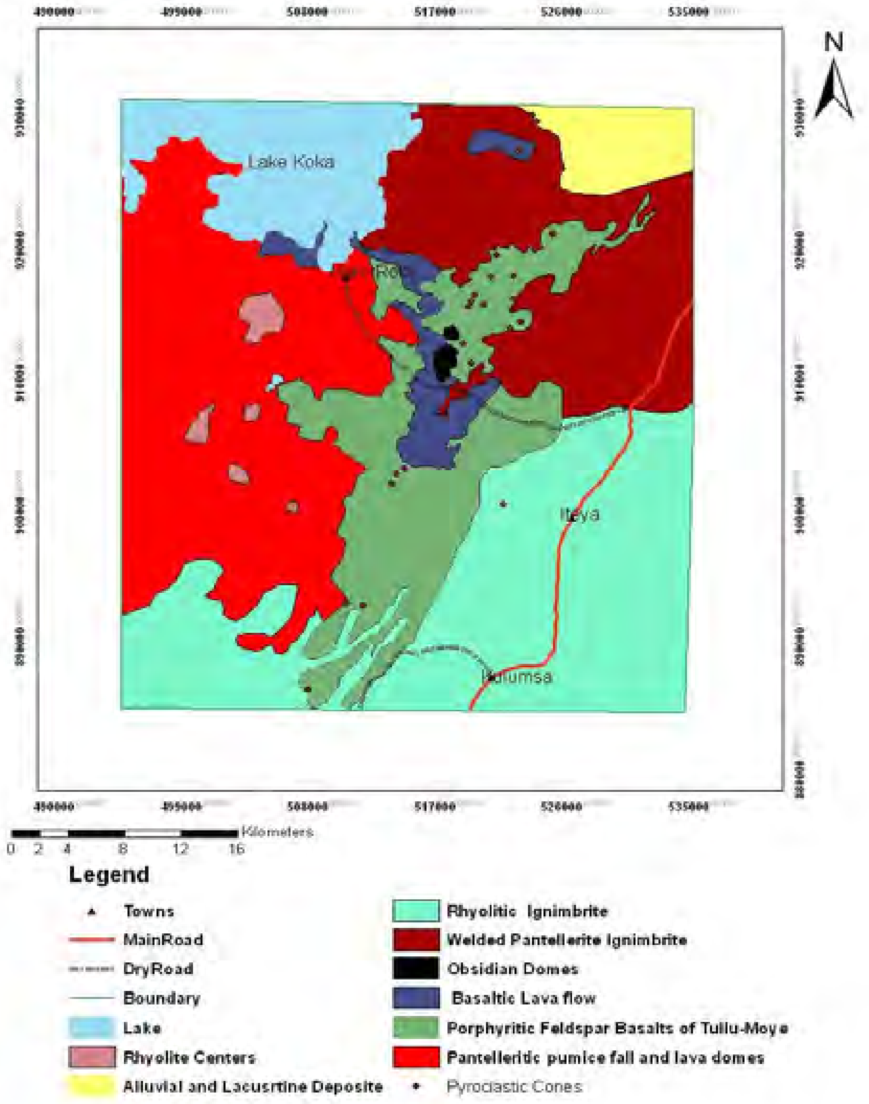


Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley

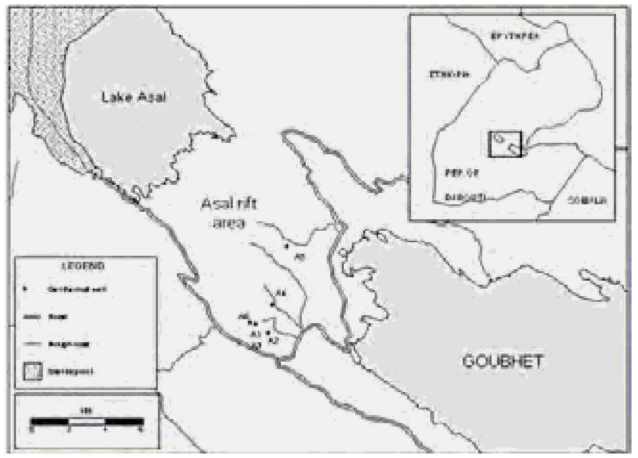




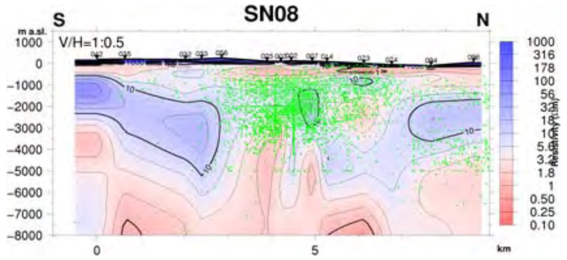
Geologic Map of the Tulumoye-Gedemsa area

Annex-3-1 The Evaluation Sheet of the Asal (Djibouti) Geothermal Field (1)

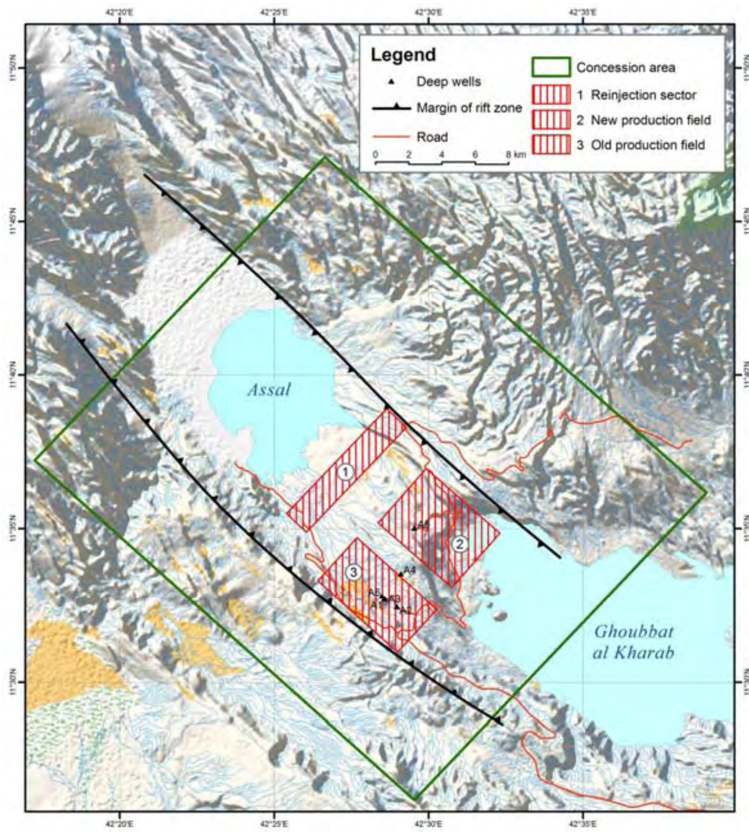
Field Name	Asal
Country	Djibouti
Province/Location	The Asal geothermal system is located in the isthmus between Lake Asal and Ghoubet al Kharab.
Accessbility	About 120 km from Djibouti city. Altitudes range from -151 m at Lake Asal to +300 m at the highest point of the rift valley floor. The area is bounded by the high plateaus of Dalha to the north (above 1000 m high) and by 400 to 700 m high plateaus to the south.
Resource Characteristics	
Geology	
Hydrogeology	The region is arid with an average rainfall of 79 mm per year. Hydrogeological studies of the region show a general groundwater flow toward Lake Asal, which is the lowest point of the area and is occupied by a salt lake saturated in sodium chloride and calcium sulphates. The area is controlled by faults of tectonics, still active at present.
Geological Structrure	The volcanic series overlie the basement rocks (Jurassic limestones and Cretaceous sedimentary rocks) as a result of the Red Sea, Aden gulf and East African rifts triple junction system, related to plate tectonic movements.
(Past Geological Studies included)	From November to December 2007, a field survey consisted of geological and geophysical studies were done in Asal area. The survey was led by ISOR, Icelandic Geosurvey a consulting and research institute. Finally a preliminary conceptual model by combining with the old data available (geochemistry, geology, drilling wells) is proposed. It revealed the presence of three geothermal independent reservoirs called for simplification Fiale, Gale le Goma and South of Asal Lake.
Geochemistry	Several groups of springs are identified in the Asal area: Manda springs are located on the Eastern side of lake Asal where Korili spring is considered separately, wadi Kalou springs in the Southern part of lake Asal, Alifita and adkorar springs on the Northern side of the lake. All the springs chemical composition analysis show a sea water relationship except one, located in the Kalou waddi in the Southern part of the lake Asal. The latter would have a continental water that has reacted with basalts. The geothermometer gives a maximum of 100°C very close to the emergence temperature. Other springs from Kalou and Korili show also a mixing with lake Asal and sea water. The degre of interaction with basalt is more or less intensive for each groups. This is accordingly to the advancement of the reaction or to the mixing of variable proportion between a water that has reacted intensively and a sea water that has poorly reacted with basalts. It has been shown that the hypersaline water of lake Asal contribute also to the reservoir fluids
Work done so far	Several geochemical studies were undertaken in Asal rift zone to understand the origine of the numerous springs and the geothermal reservoirs fluids (San Juan 1990; Fouillac et al. 1983; Fontes et al. 1980, 1989).
Geophysics	
Gravity	Gravimetric survey points out several heavy body anomalies having different dimensions (CFG 1993). Those located in the central part of the rift are correlated with the injection of magmatic chamber and the collapse of the ground. Localy small anomalies could be the result of an intensively fractured zone. The comparison with the aeromagnetic data and the gravimetric modeling, with the help of geothermal data, demonstrate the existence of a basement represented by the old Dalha basalt series, splitted in several compartments delimited by intensive fractured zones.
Resistivity	The survey was mainly focusing on the Eastern-central part of the Asal rift in the continuation of the well Asal 5. Results presented here are from the interpretations of ORKUSTOFNUN and BRGM. An "upflow" has been demonstrated in the "lava lake" area based on a supposed hydrostatic level higher than sea level and the absence of high resistivities in depth.
Well Drilling	A total of six deep wells (Asal 1 to Asal 6) have been drilled in the area, the first two in 1975 and the last four in 1987 and 1988.
Temperature Survey	Well Asal 2 was damaged, wells Asal 4 and Asal 5 were impermeable although very hot, but wells Asal 1, 3 and 6 have produced extremely saline fluids from 1000-1300 m depth where the aquifer temperature is about 260°C (Daher, 2005). Downhole temperature found in excess of 360°C in Max.



Asal Geothermal area with six wells drilled



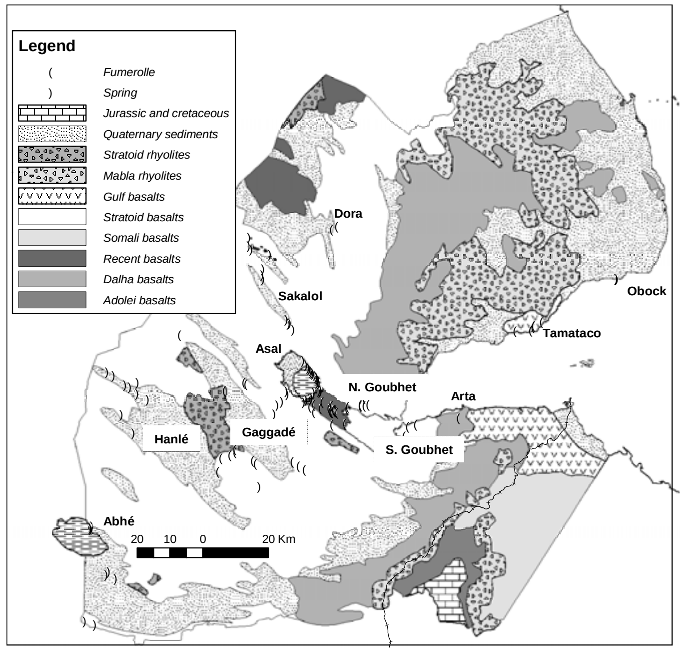
Seismicity and Resistivity S-N Section



Current Exploration in the Assal Rift

Annex-3-1 The Evaluation Sheet of the Asal (Djibouti) Geothermal Field (2)

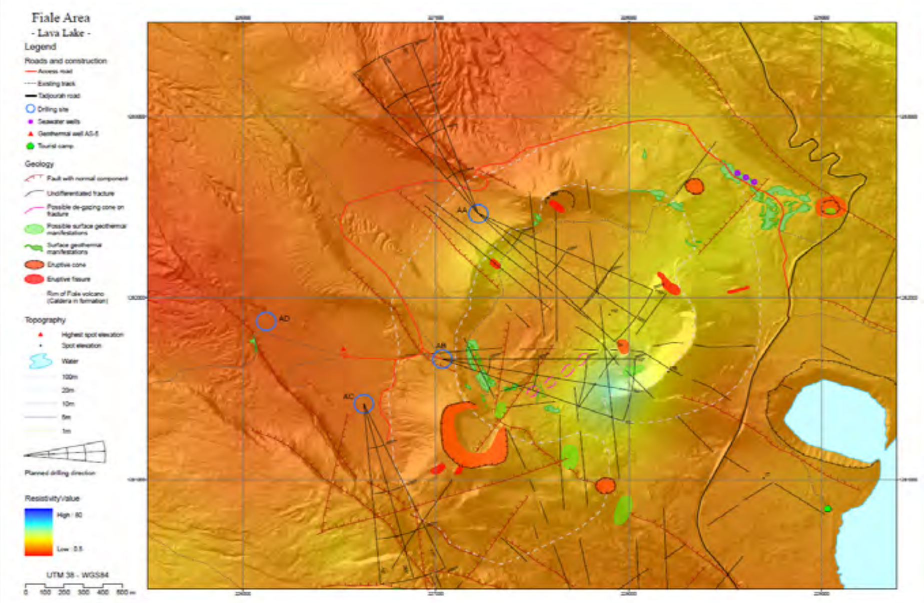
Well testing	Well test data from wells Asal 3, 4 and 6, including injection test data, draw-down test data, pressure build-up data and pressure interference data have been analyzed in order to estimate the reservoir properties of the Asal geothermal system. The permeability thickness of the deep geothermal reservoir is estimated to be about 4-8 Dm (Daher, 2005). During long-term exploitation a large pressure draw-down is observed in the reservoir. Wells Asal 3 and Asal 6 produce highly saline (120 g/l) reservoir fluid and the scaling of galena at high pressure reduces the discharge rate (Virkir-Orkint, 1990). Extensive exploration and field tests need to be performed to accurately estimate the actual size and capacity of the Asal reservoir.
Conceptual Model	Of the three identified up flow zones the Fiale area is considered most attractive for development. The research indicates that the chemistry of the Fiale area is more benign than at the old well field. Well sites have been chosen to reach specific drilling target identified by the first conceptual model. Actually Reykjavik Energy is more focused on Fiale zone because it seems to have higher resistivity than the two others areas. Fiale is located in the central part of the rift and according to the seismicity data, it is the more active. Then the sea water is recharging and reducing the salinity concentration around 50 g/l. By comparing the two others fields the total dissolved solid TDS is 116 g/l.
Present Status of Development	- A contract granting a temporary exclusive license for geothermal utilization in the Assal Rift area between the --Government of the Republic of Djibouti and Reykjavík Energy was signed on 29 February 2007. - An exploration permit was issued by the Djibouti Minister of Energy and Natural Resources on May 23rd 2007 - The concession area covers 750 km2.
Natrural/Social Environmental Condition	
Power Sector Situation	
Power Output Potential	
Resource Potential	Favorable geological setting plus a 3-4 km2 reservoir with temperatures above 240 °C indicates a generating capacity at least 50 Mwe and up to 150 MWe.
Restrictted by National Park	None
Restricted by Power Demand	
Rank of Development Priority	A
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	
Outline for Power Development	Drilling of three exploration wells to to confirm the power potential in 3D numerical simulation.
Possible or Recommended Multi-purpose Geothermal Heat Use	
Scope for Power development	From the actual Fiale geothermal reservoir project development managing by Reykjavik Energy Invest in order to build a power plant of 50 MWe at 2012 in the first phase, and later extension to 100- 150 MWe.
CO2 emmission Reduction ('000 tonne/year)	
Proposed Geothermal Development Schedule	
Location Map	
Other Figures	



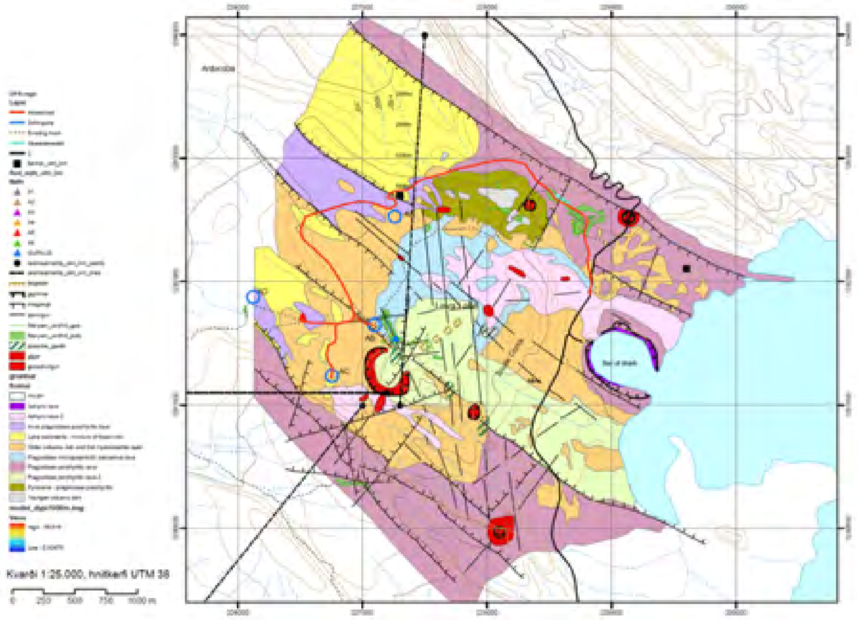
Geologic Map of the Republic of Djibouti

Surface Exploration Carried out in Djibouti

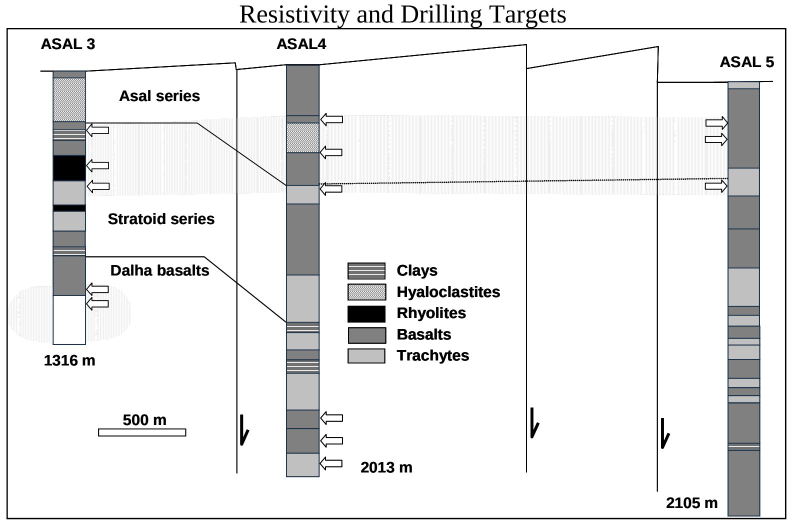
Area	Exploration stage: Geology	Geochemistry	Geophysics	Exploration drilling	Surface manifestations: Hot springs	Fumaroles
Lake Asal	+++	++	+++	++	++	+
North Goubbet	++	++	++		+	+
Gaggade	++	++			+	+++
Hanle	++	++	++	+		++
Lake Abbe	++	+			++	++
Arta	++	++	++			+
Obock		++			+	+
Alol	+	+			++	+



Resistivity and Drilling Targets



Detailed Geologic Map of the Asal Geothermal Field



Interpretated cross-section in the Asal rift zone

Annex-3-2 The Evaluation Sheet of the Hanle-Gaggade (Djibouti) Geothermal Field

Field Name	Hanle-Gaggade
Country	Djibouti
Province/Location	The prospect site is located in the South-Western region of the country where stratoid basalts circumscribe a succession of high plateaus and sedimentary plains between lake Abhé and lake Asal.
Resource Characteristics	
Geology	The volcanic series overlie the basement rocks (Jurassic limestones and Cretaceous sedimentary rocks) as a result of the Red Sea, Aden gulf and East African rifts triple junction system, related to plate tectonic movements. Within the plains of Hanlé and Gaggadé, several fumerolles and hot springs are identified in lake Abhé area, Galafi plain, Eastern site of the rhyolitic Baba Alou mountain and along the Northern border of the Gaggadé plain. Temperature of the hot springs can exceed 60°C.
Geochemistry	Geochemical studies undertaken by AQUATER (1981) recognized 5 hydrochemical groups that can be related to the different aquifers or can show mixing between them. The group 1: Bicarbonated-earth-alkaline and exhibit low mineralisation. It corresponds to the low depth waddi bed alluvium aquifers and is characterized by direct recharge from intermittent stream waters. The group 2: Chlorinated-alkaline and represents all the boreholes catching the regional volcanic aquifer. Several springs located in Hanle plain at the contact of sedimentary rocks and basalts fault scarps fall also among the same group 2. The group 3: The springs in lake Abhe area (Gobaad Plain) are characterized by chlorinated-alkaline-earth-alkaline type of waters. The group 4: Sedimentary aquifers which waters type is chlorinated-bicarbonated-sulfated-alkaline. The group 5: The mixing of waters between goup 1 and group 4, streambed alluvium and sedimentary aquifers. The geochemical anomalies in CO2, NH3 and H3BO3 allowed to define the ascending fluids mechanisms.
Geophysics	Geophysical prospection has been mainly based upon geoelectrical method (AQUATER 1981) to assess the top of the stratoïd basalts and the sedimentary filling thickness. Previous aeromagnetic data has been also considered and a seismic network was implemanted to determine the seismic activity. The sedimentary filling, identified by low to very low electrical resistivities due to clays, has important variable thickness probably mainly controlled by the underlying Afar stratoïd basalts faults system.
Well Drilling	The first part of the exploration began with three gradient wells of about 450 meters depth in Hanlé plain (Teweo1, Garabayyis 1 and Garabayyis 2) in order to confirm the hydrogeological settings and to assess the temperature gradients before carrying on with the deep drillings (GEOTHERMICA 1985; GENZL 1985). They showed heterogeneous sedimentary sequences comprising sandy aquifers overlying stratoid basalts aquifer. . Two deep wells (Hanlé 1 and Hanlé 2) realized in Hanlé plain reached respectively 1623 m and 2038 m (AQUATER 1989). After the lacustrine deposits the well crosses a rhyolitic complex between 94 m and 307 m overlying a monotonous sequence of basaltic flows. Permeable zones are encountered in the rhyolitic complex, at the contact with the basalts and in the scoriaceous layers. The well is impervious below 800 m.
Temperature Survey	Temperature measurements gave a maximum of 87°C on Garabayyis 2 (gradient well) and the estimated temperature gradients are between 1.3°C/100m and 2°C/100m. Hanlé 1 recorded a maximum of 72°C at 1420m.and the maximum temperature in Hanlé 2 is 124°C at 2020 m. The lithological sequence is represented mainly by basalts. Highly permeable levels are found down to 450 m (fluid TDS 2 g/l) and the rest of the well remains impervious (AQUATER 1989; Jalludin 2003). On the basis of these results on permeability and temperature the ongoing programme in Hanlé was revealed not satisfactory for geothermal purposes.
Conceptual Model	
Present Status of Development	
Rank of Development Priority	
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	- Field geological reconnaissance - Preparation and realization of surface studies program - Exploration wells location - Exploration drilling

Annex-3-3 The Evaluation Sheet of the Nord-Goubhet (Djibouti) Geothermal Field

Field Name	Nord-Goubhet
Country	Djibouti
Province/Location	The Nord-Goubhet area is located North-Eastward but close to the Asal rift. Goda mountain and Makarassou region are found in the Northern part and the study zone is limited by the sea in the South. Compared to the Asal rift, the area is elevated up to 500 to 600 meters of altitude.
Resource Characteristics Geology	The geology is marked by the Dalha basalts outcrops covered by the more recent Gulf basalts and pleistocene sediments. The fracture network is well developped. The area is situated between different zones of different tectonic pattern and therefore is affected by several tectonic trends: Asal rift NW-SE faults, Makarassou N-S trends (Tapponnier et Varet 1974) and old trends identified in the Goda mountain. As a consequence, the area is tectonicaly active, confirmed by some faults in the recent sediments and large panels of steep cliffs formed of Dalha basalts.
Geochemistry	Along the scarped valleys of the wadis several fumaroles and one boiling spring are found at the bottom of the volcanic cliffs. Different methods applied to the chemical data from the condensate of the fumaroles give estimations for the possible reservoir temperature: 220°C and 170°C (Geothermica 1987). Stable isotopes analysis of the fumaroles describe an assumption of the origine of the waters. Compared to the fumaroles of the Asal rift zone, Nord-Goubhet fumaroles have significantly lower delta-D and delta-18O. It is suggested that no primary steam from undiluted or diluted deep water exist in this zone. Fumaroles would be more likely the result of a secondary steam from previously condensated steam or boiling groundwater (Geothermica 1987).
Geophysics	Three geophysical surveys were conducted in the area of Nord-Goubhet: gravimetry, AMT and electric (rectangle method) (BRGM 1983). The gravimetric results point out several heavy and light anomalies not distributed regularly. Although these anomalies are of low amplitudes they are more or less clearly delimited by the different linear trends, correlated to the tectonic of the area. From their analysis, BRGM retain three main guidelines. First, the Southern Asal rift system delimits light anomalies. Parallel to it and Northward, a large axis comprises a succession of heavy and light anomalies. In the central part, a similar axis is identified along a NNW-SSE trend. It can be noticed that the major part of the hydrothermal activity is located between these two axis. Finaly, light anomalies cover the Eastern part of the prospect. The geoelectrical survey shows globaly low resistivities and three main zones can be observed. The first one is located on the Eastern part of the prospect. The second low resistivty area is located on the South-Westrn zone but higher resistivities are found along a NNW-SSE axis. The last and very conductive area is located in the Nort
Well Drilling	
Temperature Survey	
Conceptual Model	
Present Status of Development	
Rank of Development Priority	
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	- Field geological reconnaissance - Preparation and realization of surface studies program - Exploration wells location - Exploration drilling

Annex-3-4 The Evaluation Sheet of the Arta (Djibouti) Geothermal Field

Field Name	Arta
Country	Djibouti
Province/Location	This geothermal prospect zone is located on the Southern shore of the Gulf of Tadjourah and 45 km West from the town of Djibouti.
Resource Characteristics	
Geology	The geological formations are mainly represented by the miocene Dalha basalts and the other units comprise Mabla rhyolites, stratoide basalts and Gulf basalts. The plain is filled with coarse quaternary sediments. The zone shows a particularly intensive fracture network controled by strike slip faulting and recently by normal faults (Arthaud et al. 1980). This geological situation implies the existence of a volcanic and tectonic activity in the area with the presence of a close magmatic chamber, however this activity would have stopped over the last 2 My ago (Geothermica 1982). This past activity has probably been at the origin of the past hydrothermal activity recognized on the field by the altered areas. The interest for the geothermal development remains as the fractured Arta zone is located close to the Gulf of Tadjourah ridge and there exist surface hydrothermal manifestations.
Geochemistry	Geochemical studies of shallow wells and springs determine two main chemical types. One is alkaline-bicarbonated characterizing superficial groundwaters with typical recharge from wadi beds during run off. The geochemical temperature is slightly under 75°C (Geothermica 1982). The second type is alkaline-chlorine in relation with sea water intrusion and probably in relation with underlying high TDS waters as it has been demonstrated in the country (Bouh 2006; Jalludin et al. 2006). The geochemical temperatures range from 75 to 95°C. Likely, these waters do not exhibit any anomaly corresponding to a possible geothermal reservoir. This fact might be explained by the insulation of the geothermal reservoir by the existence of a cap rock zone. However, the ammonia content in the fumaroles could be the results of the boiling at 100°C of a reservoir of pure alkaline-chloride type (Geothermica 1982).
Geophysics	Two geophysical methods explored the Arta area with gravimetry and electric. The gravimetric survey delineates an upwelling zone with positive anomaly that would be represented by a rhyolitic dôme. The underground structures showed by the mapping of the anomalies seem to corroborate one of the main fracture trends, NE-SW. The main findings from the geoelectrical soundings are constituted by the presence of a several hundreds meters thick conductive layer. Within the scope of the geological situation of the area, this might be related to highly altered volcanic rocks, most likely Dalha basalts, as it is observed also in the field elsewhere. Consequently, from the geothermal reservoir standpoint, this analysis sustain the existence of a cap rock of relatively elevated thickness.
Well Drilling	
Temperature Survey	
Conceptual Model	In order to fulfill the geothermal reservoir exploration and to construct the conceptual mosdel in the Arta region, Geothermica (1982) suggest that the objective would not be at shallow depth and drilling exploration might cover two thousands of meters to possibly tap a deep geothermal reservoir.
Present Status of Development	
Rank of Development Priority	
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	- Field geological reconnaissance - Preparation and realization of surface studies program - Exploration wells location - Exploration drilling

Annex-3-5 The Evaluation Sheet of the Obock (Djibouti) Geothermal Field

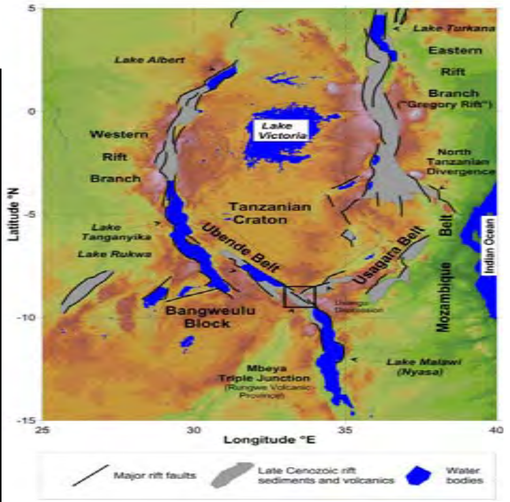
Field Name	Obock
Country	Djibouti
Province/Location	The Obock prospect zone is close to the town of Obock located on the Northern shore of the Gulf of Tadjourah on its Eastern limit.
Resource Characteristics	
Geology	This geothermal site is based on the resurgence of several hot springs and one fumarole on the beach. Some hot springs can be identified only during low tides. The outcrops close to the hydrothermal manifestations are formed of quaternary madrepores covered by the alluviums all over the wide Obock plain. In the upstream part, are found the volcanic rocks dominated by the intensively fractured Mabla rhyolites in forms of mountains and scarped reliefs. The fractures on the quaternary plain area are observed exclusively close to the shore as E-W open fissures in the madrepores.
Geochemistry	Geochemical analysis give an alkaline-chloride dominated waters in relation with sea water. Geothermometers found a possible reservoir temperature of 210°C (Houssein 1993).
Geophysics	Based upon marine geophysical and tectonic studies, the surface hydrothermal activity appear to be related to the near Gulf of Tadjourah ridge which fault system reaches the Obock site (Manighetti 1993). Some geophysical prospections were undertaken for the purpose of groundwater development and also for the geothermal development, but their outcomes are not significant as they are limited in investigation depth or not complete. These are electrical soundings with short AB lenghts (CGG 1965) and magnetic survey with insufficient points (Essrich and Brunel 1990).
Well Drilling	
Conceptual Model	
Present Status of Development	
Rank of Development Priority	
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	- Field geological reconnaissance - Preparation and realization of surface studies program - Exploration wells location - Exploration drilling

Annex-3-6 The Evaluation Sheet of the Lake Abhe (Djibouti) Geothermal Field

Field Name	Lake Abhe
Country	Djibouti
Province/Location	Lake Abhé zone is located in the South-Western region of the country, on the border with Ethiopia. This hypersaline lake is the Western end of the Gobaad plain and the Eastern end of the dowstream valley of Awash river coming from the Ethiopian plateau.
Resource Characteristics	
Geology	The geology is characterized by the stratoid basalts plateaus limited by E-W faults configuring the Gobaad plain, filled by quaternary and probably late pliocene sediments.
Geochemistry	The lake area is particularly rich of surface hydrothermal manifestations with fumaroles and hot springs but also travertine constructions, some of them being elevated at more than 60 m above ground level. The travertines are aligned on the main fracture trends. Fumaroles are located on those travertines and the hot springs occur at the bottom of these travertine chimneys. The temperature of resurgence of the hot springs is generaly higher than 90°C. Only geochemical preliminary studies cover this prospect and give mainly two types of waters. Most of the hot springs are alkaline-chloride-sulfated and few of them present also a bicarbonated type as a result of surface water mixing. The surface hydrothermal manifestations are spread over an area of about one hundred square kilometers. This observation suggest that in lake Abhé zone there exist an important thermal anomaly representing potential geothermal reservoir.
Geophysics	
Well Drilling	
Conceptual Model	
Present Status of Development	
Rank of Development Priority	
Potential (Expected) Developer	Central Government (or Private Company)
Proposed Geothermal Development Plan	- Field geological reconnaissance - Preparation and realization of surface studies program - Exploration wells location - Exploration drilling

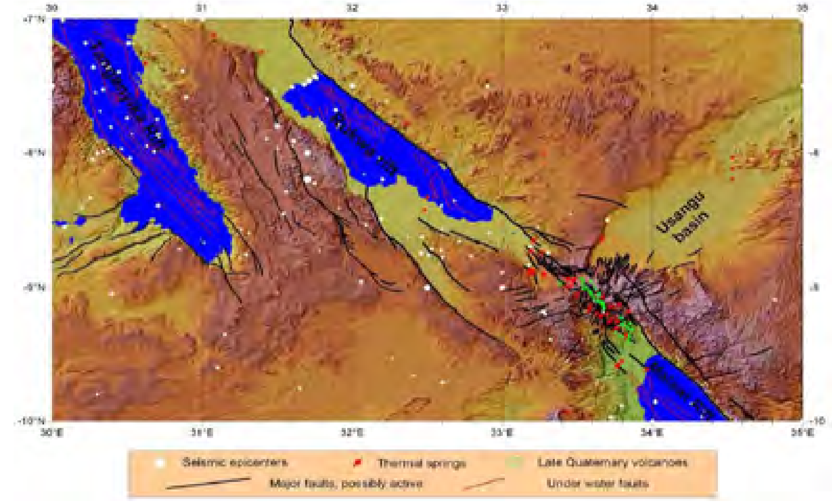
Annex-4-1 The Evaluation Sheet of the Mbeya (Tanzania) Geothermal Field (1)

Field Name	Mbeya
Country	Tanzania
Province/Location	Mbeya region, Rungwe Volcanic province
Accessibility/Communication	The area is accessible by railway or roads from Dar Es Salaam to Zambia and roads from Mbeya to Malawi. For field measurements, with exception of the paved roads, the accessibility is difficult towards Ngozi and Rungwe volcanoes due to rugged and steep terrain (BGR, 2008).
Resource Characteristics Geology	
Volcanic activity (heat source)	A detailed investigation combining SRTM DEM90, referenced aerial photographs, topographical and geological maps and field observations allow refining the knowledge of the tectonic architecture. The RVP is currently affected by a strike-srip to extensional type of tectonic stress regime with both horizontal ENE-WSW maximum compression and NNW-SSE minimum compression (extension) axes. Deformation localises mainly along high-angle faults that cross-cut the whole volcanic massif and along which significant strike-srip to oblique-slip movements occur. These faults often reactivate older basement structures and/or normal fault systems within Late Quaternary rift sediments and volcanics. They exert strong control on the volcanic vent location and also on the discharge of many hot springs, CO_2, gas vents, bubbling hot springs and cold springs. K-Ar dating of young volcanic rocks and U-Th dating of the Songwe travertine shows that the Ngozi geothermal system started to be active around 360 Ka ago (Delvaux et al., 2010).
Geological Structrure	The area of investigation belongs to the Rungwe Volcanic Province (RVP) near Mbeya which is located at the intersection between the western and eastern branches of the East African Rift System, forming the triple junction between the South-Rukwa, North-Malawi (Nyasa) and Usangu rift basins. Its present-day architecture is the product of a long-term rift evolution into several successive stages. The Neotectonic period in that area represents the second- and still active stage of the Late Cenozoic rifting history, and is constrained by dated volcanics from the Rungwe massif, to have started 1.5- 1 Ma ago. Tectonic investigations in the area show that fluid flow is controlled by fracture permeability along active faults. Most thermal springs are aligned along the major NW-SE rift trend that controlled the long-term development of the Rukwa and North-Malawi (Nyasa) rift basins. During the last 0.5Ma, the local fault kinematics is dominated by NW-SE horizontal extension and NE-SW horizontal compression leading to a new network of conjugated strike-slip faults (Delvaux et al., 2010).
(Past Geological Studies included)	
Geochemistry	Strong indications for mixing processes of hot asending fluids with e.g. cold groundwater were revealed from fluid chemistry. (e.g. REE patern, Sr/Cl and Li/Cl linear correlations). Geochemical evolution of Lake Ngozi water is influenced by additional process taking place in the lake environment. Neary all fluid samples plot in the field of "peripheral waters". Only sample Ngozi (and Ivuna) plots close to the field of "geothermal waters". A linear trend in the ternary Na-K-Mg diagrams is defined by diluted Lake Ngozi water (=> partially equilibrated field) and diluted hot springs of Songwe and Mahombe (immature water field). This trend is interpreted as genetic relation of those fluids pointing to reservoir temperatures of >200^{0}C from slow equilibrating Na/K geothermometer. Most distant fluids of Ibayi and Udindilwa hot springs seem to be partialy reequilibrated within local reservoirs. A similar ternd for the Southern system defined by hot springs Mampulo, Kasimulo and Mbaka (partly equilibrated field) as well as Kilambo (immature water field) gives maximum reservoir temperatures significantly below 200 ^{0}C (Delvaux et al., 2010).
Work done so far	
Geophysics	All TEM resistivity curves within the entire survey area feature a decrease towards later times, indicating lower resistivities at greater depths (BGR, 2010).
Gravity	None



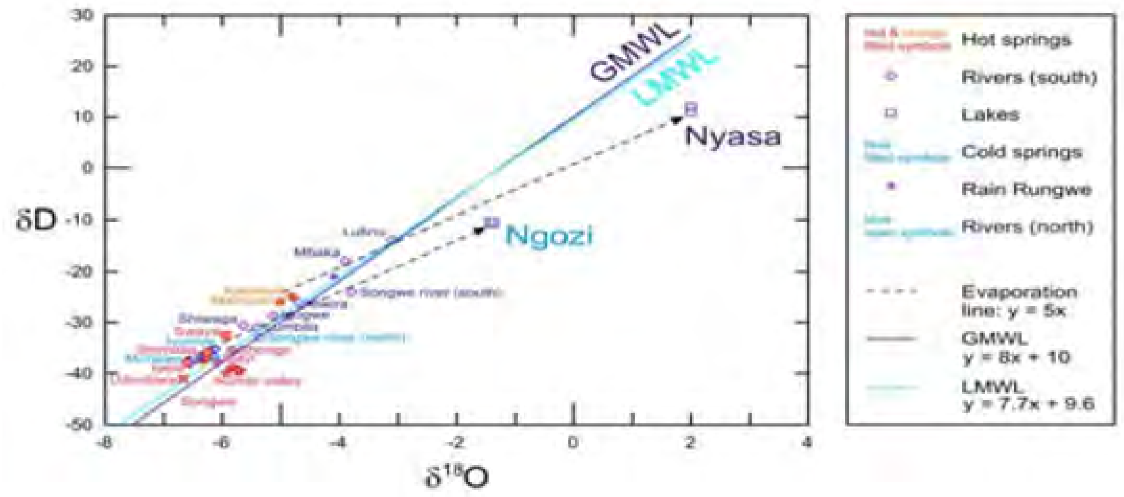
(Source) (Delvaux et al., 2010)

Location map of Mbeya field



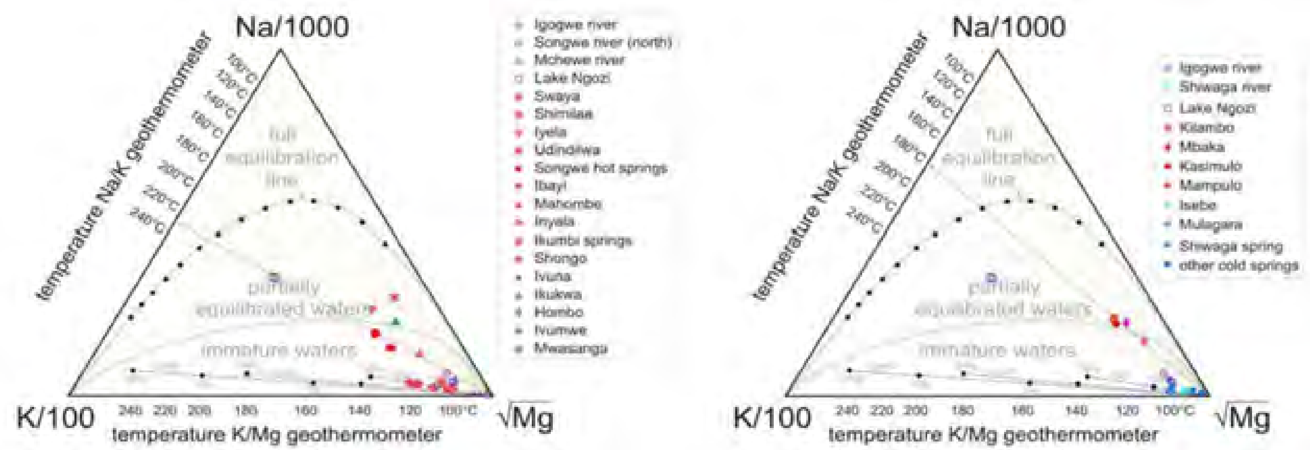
(Source) (Delvaux et al., 2010)

Distribution of faults, hot springs and volcanos in the Mbeya region



(Source) (Kraml et al., 2010)

Delta-D / Delta ^{18}O diagram of hot spring water in Mbeya region

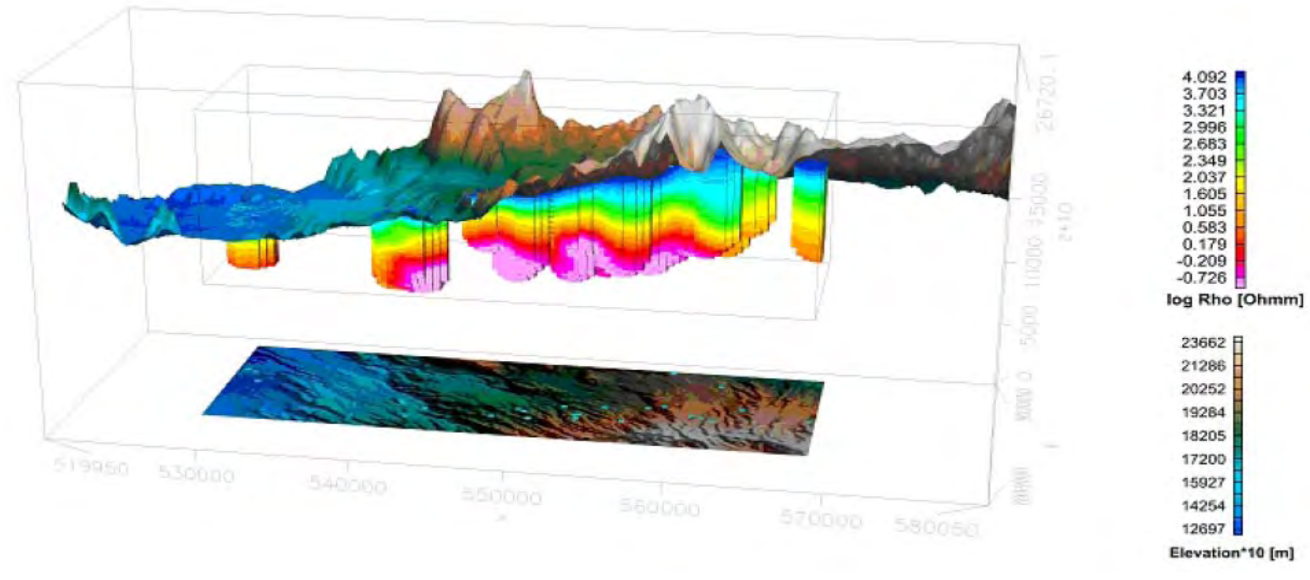


(Source) (Kraml et al., 2010)

Trilinear diagram of Na-K-Mg of hot spring water in Mbeya region

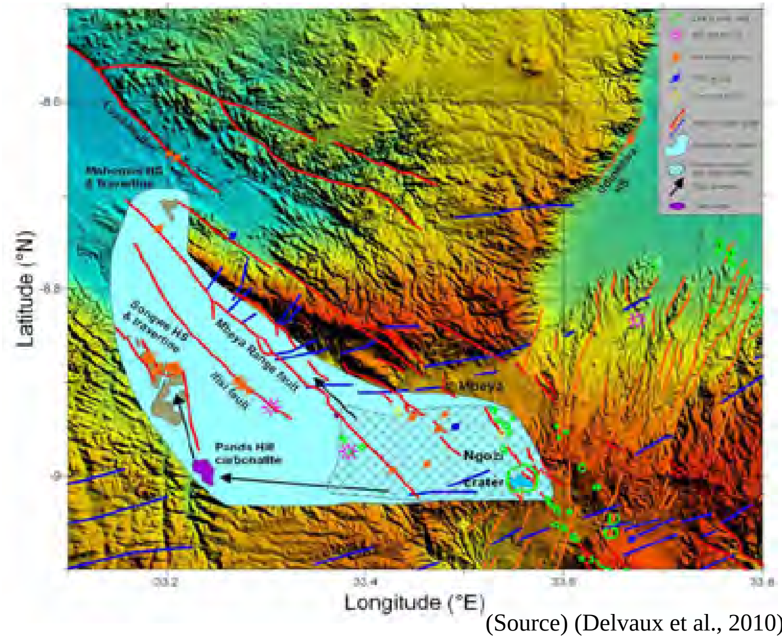
Annex-4-1 The Evaluation Sheet of the Mbeya (Tanzania) Geothermal Field (2)

Resistivity	The sounding locations have been assigned to three profiles, all of them being oriented NE-SW, I.e. roughly perpendicular to the strike of the Rukwa Rift structure. All low resistive areas and border areas close to the Ngozi volcano are of utmost interest (BGR, 2010).
Well Drilling	None
Temperature Survey	None
Well testing	None
Conceptual Model	The geothermal reservoir, which receives its recharge mainly from high elevated areas in the Poroto Mountains including Ngozi volcano, is located between the Ngozi crater and Mbeya town. The fluids are flowing through the faults of the major Rift trend (fracture permeability) towards the discharge areas mainly in the Songwe valley, following the natural hydraulic gradient (Kalberkamp et al., 2010).
Present Status of Development	Geology: Reconnaissance, Geophysics: Pre-F/S, Geochemistry: Pre-F/S (TANESCO, 2009).
Natural/Social Environmental Condition	Unknown
Power Sector Situation	None
Power Output Potential Resource Potential Restrictted by National Park Restricted by Power Demand	Unknown
Rank of Development Priority	Unknown
Potential (Expected) Developer	Unknown
Proposed Geothermal Development Plan Outline for Power Development	Structural geology, MT/TEM, shallow exploratory well followed by deep exploratory
Possible or Recommended Multi-purpo	Drying of agricultural products and cement slabs (Kraml et al., 2010)
Scope for Power development	Unknown
CO2 emission Reduction ('000 tonne/ye	Unknown
Proposed Geothermal Development Sc	Unknown
Location Map	
Other Figures	



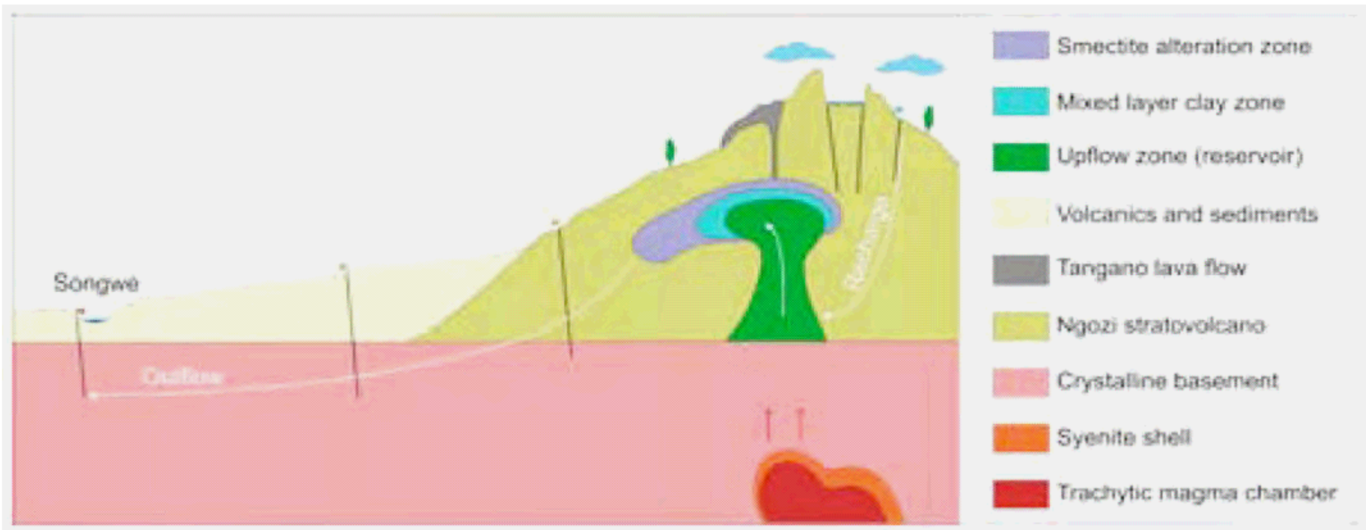
(Source) (Kalberkamp et al., 2010)

TEM survey result in Mbeya region



(Source) (Delvaux et al., 2010)

Fluid flow model (plain) of Mbeya region



Geothermal conceptual model (section) in Mbeya region

(Source) (Kalberkamp et al., 2010)

Annex-4-2　The Evaluation Sheet of the Rukwa (Tanzania) Geothermal Field

Field Name	Rukwa block
Country	Tanzania
Province/Location	near Lake Rukwa
Resource Characteristics Geochemistry	A few small thermal springs occur near Lake Rukwa, the Ivuna springs, c. 85 km NW from the Songwe springs. These springs discharge c. 2.5 kg/s of NaCl water at T= 60ºC (pH = 8.0) associated with c. 0.3 MW heat discharge. The springs have been diverted into evaporation ponds which sustain a small, local salt industry. Minor gas is discharged which, according to James (1967), contains almost no CO2 but consists mainly of N2. The chemical data allow the following interpretation: The fast equilibrating constituents in the water point to underground temperatures of c. 110ºC, as given by T(CH). However, it is not likely that the thermal water derives from a deeper, high temperature reservoir because of the absence of CO2. Since saline deposits do not occur in the Rukwa sediments, the cause of the salinity of the water remains unclear. (Hochstein et al., 2000)
Well Drilling	None
Present Status of Development	Reconnaissance (TANESCO, 2009).

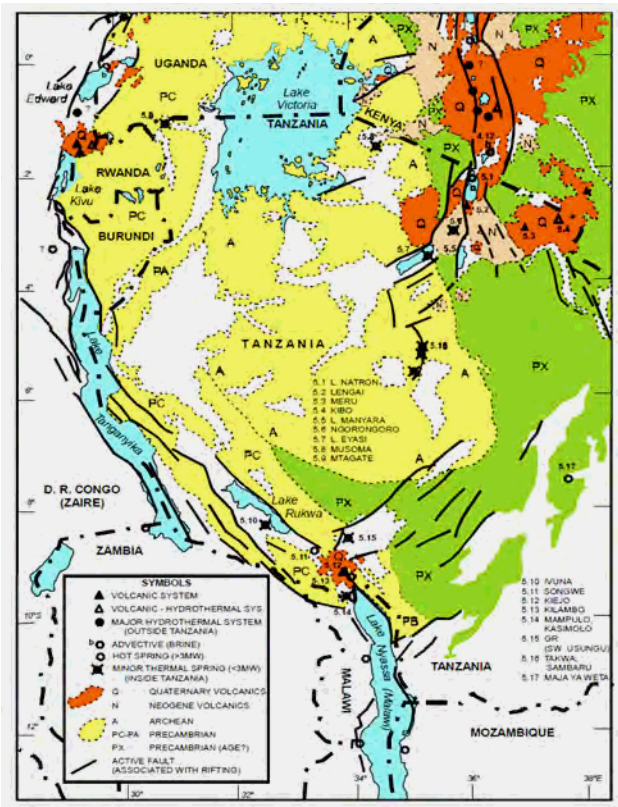
Chemical analysis data of hot spring in Tanzania

(mg/kg)

Area (see Fig.1)	pH/T C	Na	K	Ca	Mg	Cl	HCO3	SO4	SiO2	F	source
L.Magadi (4.12)	9.9/34	7000	75	0.6	<0.4	3550	13000	52	36	70	a.
L.Natron (5.1)	8.9/38	230?	56	2	1	940	3800	145	30	24	b.
L.Manyara(5.5)	9.9/69	580	?	2	2	235	>1100?	30	98	n.d.	c.
L.Eyasi (5.7)	9.3/42	5450	50	1	1	4800	3400	680	44	60	b.
Musoma (5.8)	9.4/60	1980	33	1	1	1150	2280	445	98	20	b.
Songwe (5.11)	6.9/73	790	102	49	19	185	1990	160	85	7	d.
Kilambo (5.13)	c.7/58	1240	60	54	34	400	2600	255	151	3	d.
Kasimolo(5.14)	c.7/58	1330	74	63	19	220	3010	260	150	2	d.
Mampulo(5.14)	7.2/63	910	n.d.	36	18	135	1425	230	125	-	e.
Mtagate (5.9)	8.1/53	20	3	13	1	14	44	18	50	1	f.
Ivuna (5.10)	8.0/60	1320	76	78	17	2040	200	225	100	7	d.
Takwa (5.16)	8.5/38	815	?	20	4	555	290	400	n.d.	5	f.
M.Ya W. (5.17)	8.5/38	815	?	40	32	160	750	300	65	-	f.

Sources: a. Clarke et al. (1990), #15　b. SWECO (1976)　c. Harris (1951)
d. Makundi and Kifua(1985)　e. Harkin (1960)　f.Walker (1969).

(Source) (Hochstein et al., 2000)



(Source) (Hochstein et al., 2000)

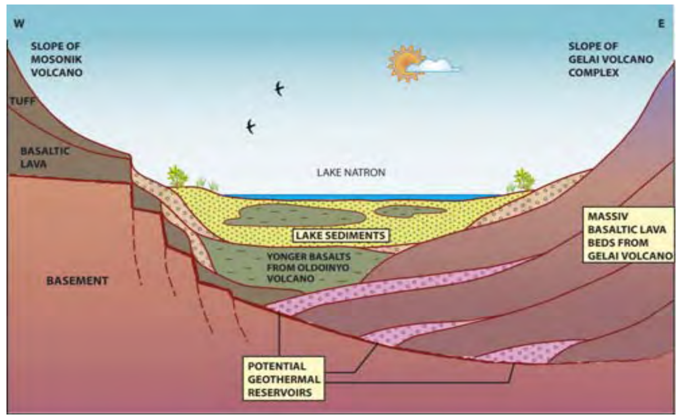
Location map of geothermal area of Tanzania

Annex-4-3 The Evaluation Sheet of the Kisaki & Rufiji (Tanzania) Geothermal Field

Field Name	Kisaki & Rufiji block
Country	Tanzania
Province/Location	
Resource Characteristics Geochemistry	At the E margin of a broad, c. 300 km wide strip of Precambrian rocks, folded against the Tanzanian Craton, occur the Maja ya Weta thermal springs. These discharge c. 25 kg/s of Na-bicarbonate-sulfate water at T = 72ºC. Their heat loss of c. 5 MW is the highest of all thermal springs which issue from the Archean-Precambrian rocks in Tanzania. The thermal energy at Maja ya Weta could be exploited by smaller, direct utilization schemes. Further to the SE, c. 140 km from Maja ya Weta, one can find the Utete hot springs (T max = 55ºC) which discharge c. 1.5 MW heat with little development potential. These springs occur over a thick wedge of Neogene-Cretaceous sediments which covers the Precambrian rocks in the east. (Hochstein et al., 2000)
Well Drilling	None
Present Status of Development	Reconnaissance (TANESCO, 2009).

Annex-4-4 The Evaluation Sheet of the Eyasi-Ngorongoro-Natron (Tanzania) Geothermal Field

Field Name	Eyasi-Ngorongoro-Natron
Country	Tanzania
Province/Location	along the shore of Lake Natron
Resource Characteristics	
Geology	The geology of the area around Lake Natron is dominated by Cenozoic volcanics, consisting of basalts lava flows and more viscous alkali volcanics. The walls of the rift valley are composed of a number of basalt flows, which are sub-vertical on the more recently faulted western margin. The western rift valley wall appears to consist of at least 10 distinct lava flows. The eastern basin margin has a gentler gradient and appears to be older than the western margin. The initial half-graben boundary fault was presumably on the eastern side of the rift and active faulting has now migrated to the western margin. The western margin boundary fault appears to be the locus of a number of recent volcanoes and volcanic complexes that are located directly over the boundary fault, suggesting that this is a deep crustal fault being a conduit for heat flow and lava. One of these volcanoes, Oldoinyo Lengai, is still active. Lava from this volcano actually overflows the fault escarpment showing that the lava flow from this volcano is younger than the fault. However, the displacement does not appear very large. This means that the bottom of the rift probably dips toward east where older and older sediments are likely to be found in a deeper and deeper position. The geological and structural settings in the area would lead to a conceptual model where the probability to find geothermal reservoirs increases towards the east. The model is illustrated as a cross section in Appendix A10 indicating possible reservoirs at the eastern and older slope of the current rift. Moreover, the conceptual model also suggests that potential deep reservoirs may be at hand in the vast volcanic area east of the current rift.(SWECO, 2005)
Geochemistry	The water chemistry of the springs is highly influenced by the carbonatite volcanism in the area. Hence, the spring water is characterised by an alkaline composition with a pH in the range of 9-10 and a $NaHCO_3$ content of several thousands mg/l. The composition indicates a meteoric origin with an advective flow system in a hot upper crustal where the water attains its mineral content by percolating through the basaltic volcanic sediments. At the outlets and further on in the lake, the caustic soda is precipitated by evaporation. However, in order to obtain a soda solution, there must be a CO_2 source. In this case it is suggested that there is a regional crustal CO_2 flux connected to the rifting processes enhancing the development of bicarbonate brine. The four analyses made indicate that Silica thermometers are in the range of 69-140°C, while the Na-K-Ca thermometers show values in the range of 159-257°C (for more details, see Appendix A8). It is of interest to notice that the highest thermometer value was obtained from a cluster of seeps in the central part of the valley (the Simba springs) and close to the lake, while the lowest value represents
Geophysics	
Gravity	In general, the measurements indicate a lack of mass in the investigated area. This is typical for rift systems, where the down-faulted high-density basement is replaced with less dense sediments. The results indicate that the deepest displacement of the basement is to be found at the SW corner of the lake and that higher levels are at hand towards the Oldoinyo Lengai volcano as well as at the eastern rift border slope. This indication looks controversial to the conceptual model but can be explained by extensive occurrences of high-density volcanic rocks close to the volcanoes. (SWECO, 2005)
Resistivity	
Well Drilling	None
Present Status of Development	Reconnaissance (TANESCO, 2009).



(Source) (SWECO, 2005)

Geological structure conceptual model of Lake Natron field

Spring Area	Temp. °C	pH F[1] pH L	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	F mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Si mg/l	SiO_2 mg/l	Ref.
Coastal Basin and Nothern Rift System													
Tanga													
Kidugaro	37	6.6/7.0	620	1,100	63	0.8	192	21	700	49	14	29	G
Lake Natron													
East	38-50	8.9	3,780	940	145	24	2	1	2,280	56	n.a.	30	D
Central	35	9.3/9.4	25,000	2,040	1,730	350	2	0.5	10,800	617	50	106	G
West	32	10/10	3,800	1,070	136	22	0.8	0.1	2,080	34	11	23	G
Ngorogoro	32	7.6	268	12	2	1.4	4.5	11	61	12	n.a.	110	D
Lake Manyara	69	9.9	>1,100	235	30	n.a.	2	2	580	n.a.	n.a.	98	A
Lake Eyasi	42	9.3	3,390	4,810	680	59	1	1	5,440	50	n.a.	44	D
Musoma													
Maji Moto	60	9.4	1,832	1,140	445	20	1	1	1,980	33	n.a.	98	D
West Lake													
Mtagate	53	8.1	44	14	18	1	13	1	20	3	n.a.	50	C
Central Cration Precambrium Terrain-Rufiji Basin													
Dodoma -	31-47	7.2-8.9	121-	48-	37-	0.8-	2.3-	0.1-	93-	2-	n.a.	29-	D
Singida -		7.5-8.9	590	770	360	9.5	110	27	915	49		56	
Kondoa	*Max-Min values from 8 analyses representing 7 different springs*												
Rufiji Valley													
Maji y Weta	70	8.5	750	160	300	n.a.	40	32	815	n.a.	n.a.	65	C
Utete	55	7.5	756	147	280	4.3	16	5.8	510	20	n.a.	40	D
Luhoi	50-75	na	na	na	na	na	22.4	na	2,472	176	15.3	n.a.	F
Southern Rift System													
Lake Rukwa													
Ivuna	60	8	200	2,040	225	7	78	17	1,320	76	n.a.	100	E
Songwe River													
Rambo	86	6,6/7,5	1920	215	170	9	23	8	840	93	n.a.	68	D
Main	72	6,7/7,4	2000	197	168	7.6	39	16	773	100	35	75	G
Marlo	53	6,7/7,2	2000	225	175	8.8	44	9	823	90	32	69	G

Note:

1) F= field analysed L= laboratory analysed

References: A. Harris 1951 – B. Harkin 1960 – C. Walker 1969 – D. SWECO 1978 – E. Makundi and Kifua 1985 – F. First Energy Company Ltd 1999 – G. SWECO 2004

Spring area Name	Temp °C	Silica °C	Chalcedony °C	Na-K °C	Na-K-Ca °C	F mg/l	Co_2[4] mg/l	Ref.
Coastal Basin and Nothern Rift System								
Tanga								
Kidugaro	37	78-83[1]	45	146-152[2]	167	0.8	<0.1	C
L. Natron								
East	38-50	80	46	n.a.	172	24	0	A
Central 1	35	136-140	113	127-134	257	350	<0.1	C
Central 2	28	81-85	48	114-122	210	27	<0.1	C
West	32	69-74	35	40-51	159	22	<0.1	C
Ngorogoro	32	143	115	279	215	1.4	12	A
(Caldera)								
L Manyara	69	107	n.a.	n.a.	n.a.	n.a.	n.a.	B
L Eyasi	42	55	85	n.a.	144	59	0	A
Musoma								
Maji Moto	60	123	95	n.a.	156	20	0	A
Central Cration Precambrium Terrain-Rufiji Basin								
Dodoma -								
Singida -	31-47	78-107	45-76	n.a.	58-116	1-10	1-21	A
Kondoa	*Max-Min values from 8 analyzes representing 7 different springs*							
Rufiji Valley								
Maji y Weta	70	91	58	136	177	7.2	74	A
Utete[3]	55	90-92	57-59	n.a.	154-157	4.3	69	A
Luhoi	50-75	n.a.	n.a.	140	210	n.a.	n.a.	D
Southern Rift System								
Songwe River								
Rambo 1	86	117	86	196	216	9	110	A
Rambo 2	83	111	81	189	213	9.1	222	A
Rambo 3	73	128	99	216	217	7.3	181	A
Main	72	120-121	91	216-217	219	7.6	<1	C
Marlo	53	117-118	87	195-198	209	8.8	94	C
Nyasa Basin								

Notes:

1) Higher ref C values represent adiabetic and lower values conductive conditions.
2) Higher ref C values according to White and Ellis and lower according to Fournier and Truesdell.
3) Analyses on duplicate samples.
4) CO_2 are all calculated values.

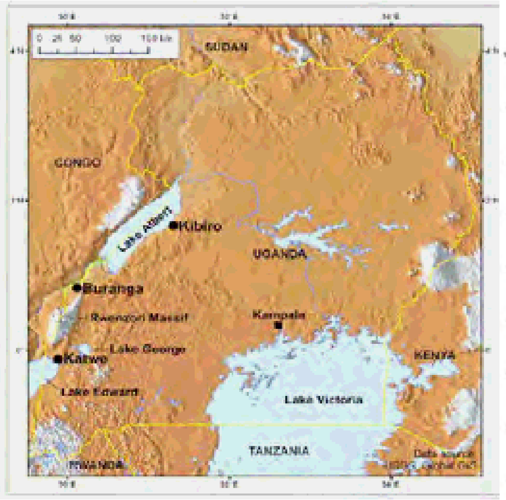
References: A. SWECO 1978 - B. Hochstein et al. 2000 - C. SWECO 2004 - D. First Energy Company Ltd 1999

Annex-4-5 The Evaluation Sheet of the Dodoma-Singida-Kondoa (Tanzania) Geothermal Field

Field Name	Dodoma-Singida-Kondoa
Country	Tanzania
Resource Characteristics	
Geochemistry	A group of widely scattered thermal springs with no thermal potential occurs in Archean gneisses c. 150 km SSW from Lake Manyara, the Takwa-Sambaru group. Here, small (< 1 to 2 kg/s) discharges of thermal Na-chloridesulfate water with moderate mineralisation (up to 2 g/kg TDS) and T of up to 40ºC occur. The surface is flat throughout; the mere existence of these springs points to freely convecting fluids within deep reaching, presumably young fracture zones which, in turn, are probably the result of the present-day, active tectonic deformation. Assuming a crustal temperature gradient of c. 15ºC / km for the craton, circulation depths of at least 3 km are indicated by the chalcedony geothermometer (T = 72ºC) of the Hika spring (Walker, 1969), the only spring in the Takwa-Sambaru group whose SiO_2 concentration is known. Another half a dozen of thermal springs with T < 40ºC can also be found over the craton; they all discharge little heat (<1MW) with almost no potential for development. (Hochstein et al., 2000)
Well Drilling	None
Present Status of Development	Reconnaissance (TANESCO, 2009).

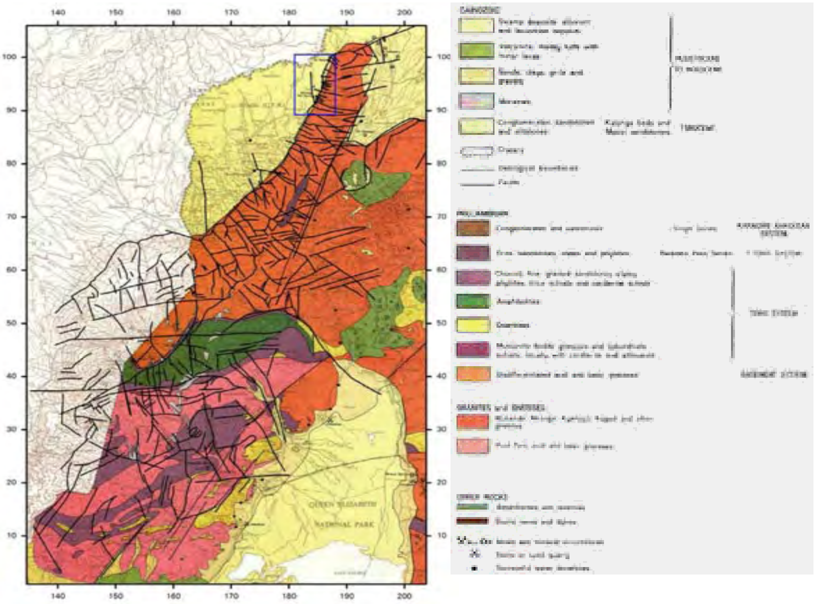
Annex-5-1 The Evaluation Sheet of the Buranga (Uganda) Geothermal Field (1)

Field Name	Buranga
Country	Uganda
Province/Location	Bundibugyo district The Buranga hot springs are situated in the Albertine Rift (western branch of the East African Rift) within the Semliki National Park in Bundibugyo district between Semliki River to the west (borderline to the Democratic Republic of Congo) and Rwenzori Massif to the east (BGR, 2007).
Accessibility/Communication	The survey area at the Buranga geothermal prospect is only partly accessible because of the terrain conditions with the steeply dipping escarpment of the Rwenzori Massif and dense tropical rain forest with creeks and swamps (BGR, 2007).
Resource Characteristics Geology	Buranga is located at the foot of the Rwenzori massif near the base of Bwamba escarpment and localized by the major Rift Valley faults. Buranga has no evidence of volcanism but is highly tectonically active. The hot springs emerge through sediments of Kaiso beds and peneplain gravels. The Kaiso beds and peneplain gravels consists of variable sands and gravels with irregularly distributed boulders containing sub-angular fragments. The Kaiso sediments are underlain by fine to mediumgrained, poorly consolidated sands and clays; some coated with calcareous material. Precambrian rocks of the main rift fault, which strikes N45^{0}E and dips N60-65^{0}E, underlie the sediments. The rocks form the northern half of Rwenzori massif and consists of mainly migmitites, gneisses and amphibolites. They strike N10-30^{0}E and have complex joint systems. The hot springs seem to lie on a fracture / fault line striking N40^{0}E parallel to main rift fault (Bahati et al., 2010).
Volcanic activity (heat source)	Because of the clear indications for an active magmatic intrusion which could serve as heat source for the hydrothermal system in the subsurface of the Buranga geothermal prospect, a magmatic body was included in the conceptual model. The model is integrated in a 3-D satellites image as vertical section along the Bwamba fault. It has to be considered that the section is vertical, although the fault has a dipping angle (60^{0}W at Buranga) (BGR, 2007).
Geological Structure	
(Past Geological Studies included)	
Geochemistry	The fluids are neutral with a pH of 7-8 and salinity of 14,000 – 17,000 mg/kg total dissolved solids. In the earlier study by Ármannsson (1994) a good agreement was obtained for all plausible solute geothermometers tested for several hot springs and pools in Buranga and it was concluded that the subsurface temperature was 120 - 150°C. The results from stable isotopes suggest that the geothermal water is from high ground in the Rwenzori Mountains like in Katwe. There is no tritium in the thermal water from Buranga which implies that it is not mixed with cold groundwater. The strontium ratios in rocks indicate that the geothermal water, most likely, interacts with granitic gneisses. The source of sulphate is minerals or rock (terrestrial evaporates) with a possible magmatic contribution. Studies by the Federal Institute for Geosciences and Natural Resources (BGR) of Germany and the Government of Uganda using helium isotopic ratio ($^{3}He/^{4}He$) in gaseous discharges from hot springs also suggest a magmatic source of solutes for Buranga (Bahati et al., 2010).
Work done so far	
Geophysics	None
Gravity	None
Resistivity	None
Well Drilling	four boreholes were drilled in 1953-1954.



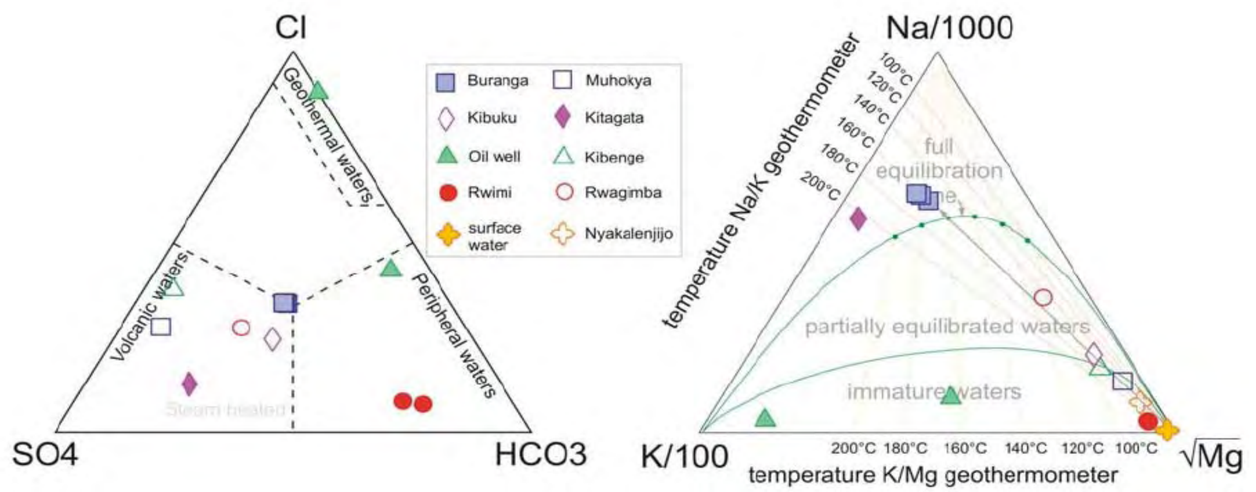
(Source) Bahati et al.(2010)

Geothermal areas of Uganda
(Katwe, Kibiro, Buranga)



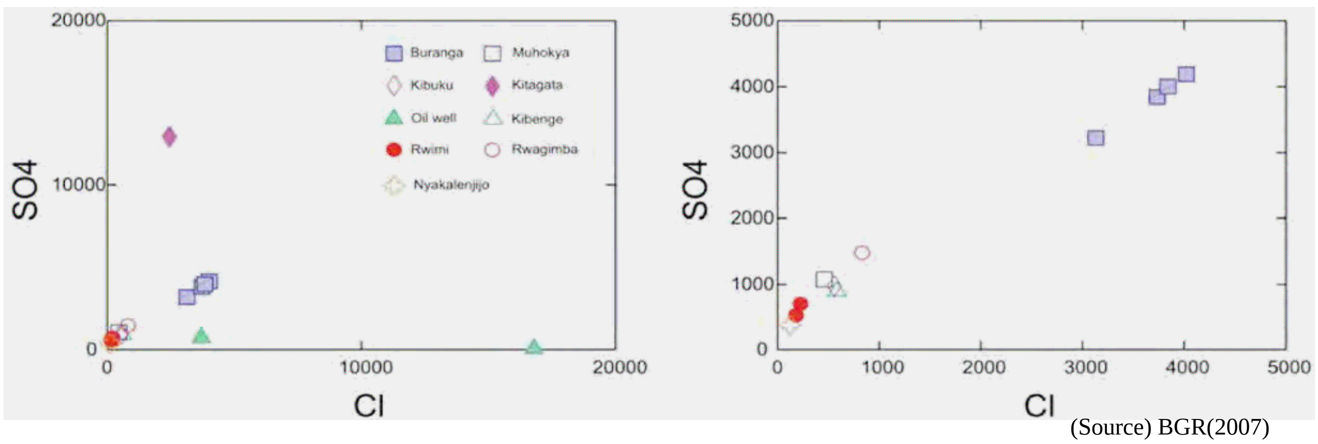
(Source) BGR(2007)

Geological map and lineament map of Buranga area



(Source) BGR(2007)

Trilinear diagram of the major anions and Na-K-Mg of hot spring water in the Buranga area



(Source) BGR(2007)

Cl-SO_4 diagram of hot spring water in the Buranga area

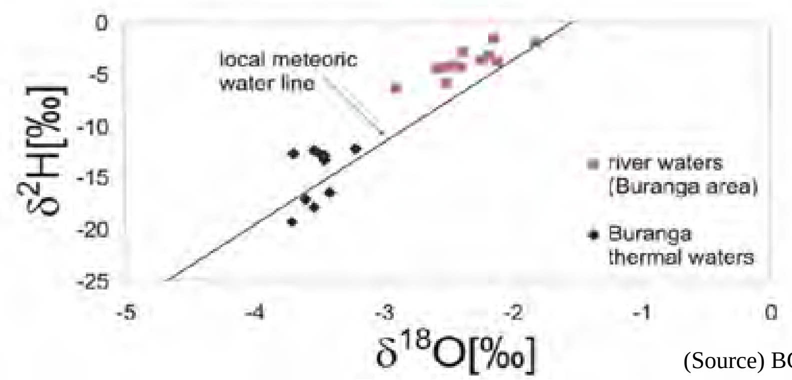
Annex-5-1 The Evaluation Sheet of the Buranga (Uganda) Geothermal Field (2)

Temperature Survey	In 1953/54 the Geological Survey of Uganda carried out a programme at Buranga to determine if geothermal power could be developed. Four boreholes were drilled in Buranga. Borehole No.1, which was sited near milestone 32 on the road to Bundibugyo, SE of the hot springs, was drilled down to a depth of 182 m. There the rift sediments consists of fine to coarse grained clastic deposits. The basement rocks were reached at 177 m, which are overlain by fault breccia and mylonite of 5 m thickness. The highest temperature in the borehole (58 ^{0}C) was observed in the fault breccia. Borehole No.2 was drilled 90 m west of the road, about 45 m south of track to Mumbuga, to the depth of 349 m. The borehole did not penetrate the sediments and the highest measured temperature was 66 ^{0}C. Borehole No.3 was sited 45 m west of Borehole No. 1 and drilled down to depth of 120 m. At the depth of 12m, a zone, reported as a steam zone, was hit. This resulted in a blow-out which lasted for 10 minutes. It is most likely that the blow-out was mainly due to gas rather than steam. No temperature log is available from drilling fluid was reported to have temperatures in the range of 49-72 0C. Borehole No. 3 is still flowing and the water has the temperature of 76 0C. Borehole No. 4 was planned and decided to drill but no documentation has been found (BGR, 2007).
Well testing	None
Conceptual Model	None
Present Status of Development	Pre-F/S
Natural/Social Environmental Condition	
Power Sector Situation	None
Power Output Potential	
Resource Potential	None
Restricted by National Park	(in the Semliki National park, but no restriction)
Restricted by Power Demand	
Rank of Development Priority	None
Potential (Expected) Developer	None
Proposed Geothermal Development Plan	None
Outline for Power Development	None
Possible or Recommended Multi-purpo	None
Scope for Power development	None
CO2 emission Reduction ('000 tonne/y	None
Proposed Geothermal Development Sc	None
Location Map	
Other Figures	

Chemical (mg/kg) and stable isotope (‰)analysis results for hot spring water in Buranga

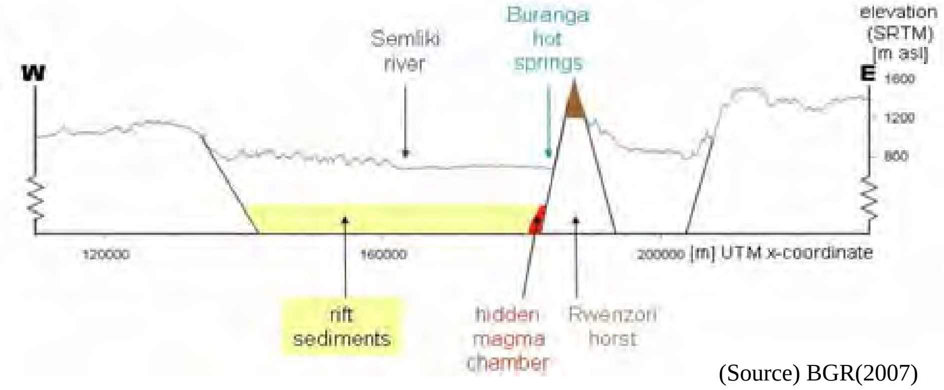
Location	Sample No.	Temp. (°C)	pH	CO_2	H_2S	SiO_2	Na	K	Ca	Mg	SO_4	Cl	B	Li	$\delta^{18}O$	δD	TDS
Mumbuga2	UG-93-09	93.4	7.87	2445	0	76.9	5320	195	2.45	2.13	3720	3580	4.3	1.34	-3.6	-17.1	14600
Mumbuga5	UG-93-10	93.6	7.73	2411	0	76.4	5160	190	2.56	2.27	3570	3490	4.2	1.3	-3.49	-12.8	14030
Nyansimbe9	UG-93-16	95.8	8.15	2638	0	87.7	5940	222	0.95	1.74	4180	4010	4.71	1.48	-3.21	-12.2	16250
Nyansimbe13	UG-93-11	80.3	7.61	2889	0	88.6	6160	230	2.1	2.63	4330	4160	4.96	1.51	-3.54	-12.4	17050
Nyansimbe17	UG-93-32	98.2	8.57	2635	0	85.1	6270	235	0.39	0.28	4400	4210	4.96	1.51	-3.45	-13.4	17080
Nyansimbe19	UG-93-13	85.8	7.81	2878	0	85.7	6300	234	2.04	1.98	4420	4240	4.8	1.54	-3.46	-12.9	17050
Kagoro20	UG-93-12	89	7.50	2798	0.3	81	5950	219	2.69	2.19	4160	4030	4.7	1.47	-3.69	-12.7	16400
R.Mungera	UG-93-15	21.8	7.52	57	0	37.2	11.1	3.7	11.2	3.61	1.7	1.8	0	0.008	-2.24	-3.7	74
Kyakatimba1	UG-93-17	23.8	7.54	197	0	36.3	21.2	8.1	54.7	14.3	27.6	2.1	0	0.034	-2.57	-4.6	208

(Source) Bahati et al.(2010)



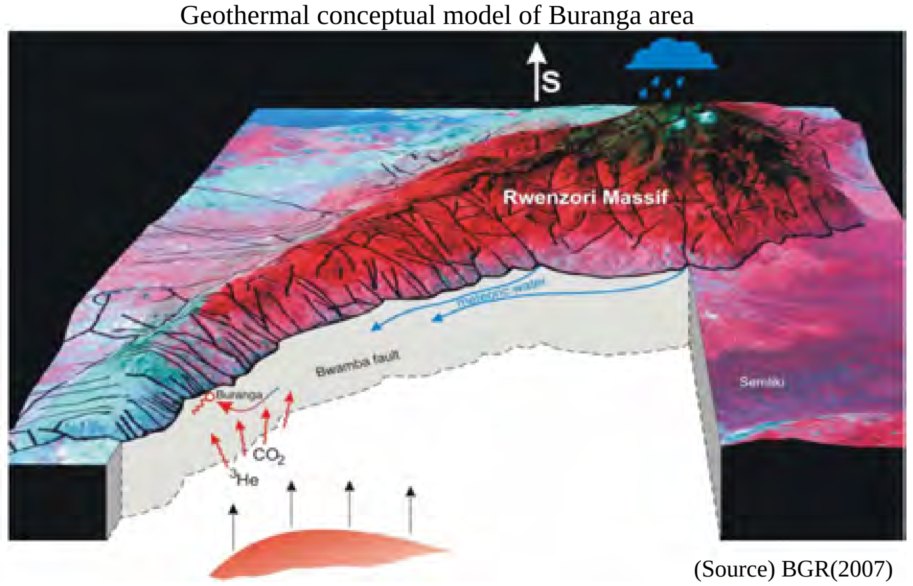
(Source) BGR(2007)

Delta-D-Delta ^{18}O diagram of hot spring and river water in the Buranga area



(Source) BGR(2007)

Geothermal conceptual model of Buranga area



(Source) BGR(2007)

3-D model of Buranga area

Geochemical temperature of hot springs other than major areas in Uganda

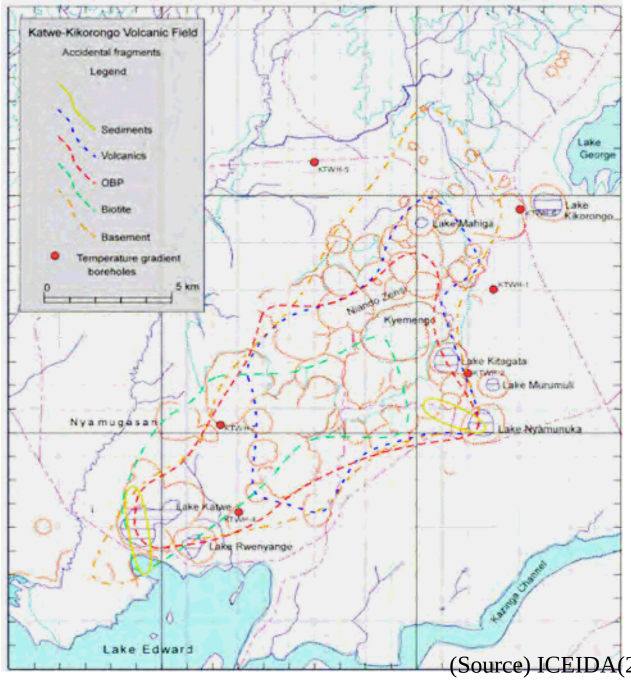
Area	Site	T_{qz}[a]	T_{KMg}[b]	T_{NaK}[c]	T_{NaKCa}[d]	$T_{S^{18}O_4 H_2 {}^{18}O}$[e]
Kibiro	Kibiro 5	160	148	217	220	137
	Kibiro 14	151	150	222	223	110
Katwe-Kikorongo	L.Kitagata 2	116[f]		145[f]		130
	L.Kitagata 5	134[f]		162[f]		140
Buranga	Kagoro 20	122[f]		111[f]		188
	Nyansimbe 17	104[f]		113[f]		189
	Mumbuga 5	117[f]		111[f]		212

[a] Fournier and Potter (1982).
[b] Giggenbach (1988).
[c] Arnórsson et al. (1983).
[d] Fournier and Truesdell (1973).
[e] Mizutani and Rafter (1969).
[f] Results from Ármannsson (1994).

(Source) Bahati et al.(2010)

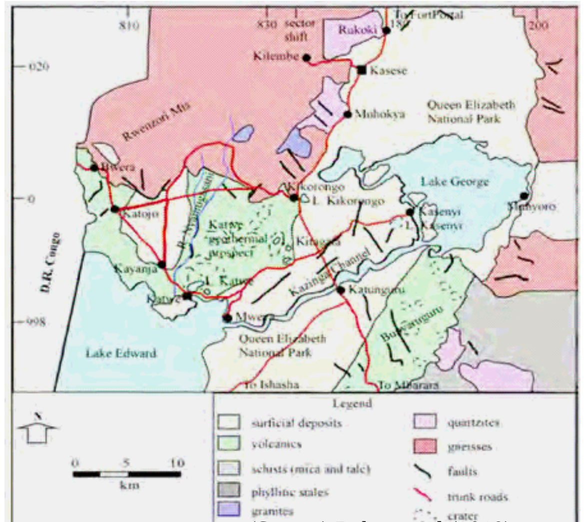
Annex-5-2 The Evaluation Sheet of the Katwe-Kikorongo (Uganda) Geothermal Field (1)

Field Name	Katwe-Kikorongo
Country	Uganda
Province/Location	district of Kasese
Accessibility	It is within the Queen Elisabeth National Park, south of the Rwenzori Massif and north of Lake Edward. Katwe is a volcanic area with many phreatic craters but very little lava on surface. Some of the craters have crater lakes. The most pronounced hot spring is on bottom of the crater lake in the Kitagata crater. As being in a national park, the Katwe area is mostly uninhabited, except for the Katwe village, south of the saline Lake Katwe. Considerable salt mining takes place in Lake Katwe（ICEIDA, 2010)
Resource Characteristics Geology	
Volcanic activity (heat source)	The results of geological surveys in the Katwe prospect indicate that explosion craters, ejected pyroclastics, tuffs with abundant granite and gneissic rocks from the basement dominate the area. The volcanic rocks, mainly composed of pyroclastics and ultramafic xenoliths, are deposited on the extensive Pleistocene lacustrine and fluvial Kaiso beds and in some places directly on Precambrian rocks. Minor occurrences of lava are found in the Lake Kitagata and Kyemengo craters. The age of the volcanic activity has been estimated as Pleistocene to Holocene. The deposit is greyish, generally coarse to fine-grained, calcareous and mixed with sand and silt of Pleistocene sediments. Travertine deposits have been found in Lake Katwe, Lake Nyamunuka, Lake Kasenyi, and Lake Kikorongo and in the vicinity of Lake Kikorongo at Kikorongo junction. The lava flows, craters and extinct hydrothermal deposits give an indication of a heat source for the geothermal activity. The prospect stretches from Lake Katwe to Lake Kikorongo an area of approximately 150 km2. Outside the crater area, the geology is characterised by surficial deposits to the east and the west, and to the north lie the Rwenzori Mountains whose geology is dominated by gneisses, granites, granulites, amphibolites, schists and in some places quartzites (Bahati et al.,
Geological Structure	The geological mapping of the Katwe-Kikorongo Volcanic Field under the present project is far from being complete. The geology of the area is very complex and the petrology is unique. The limited geological work carried out under the geothermal project concentrated solely on questions which could clarify the existence of the presumed geothermal reservoir. The presence of hot springs in the volcanic terrain in the Queen Elizabeth Park has for long interested scientist, and raised the question if an exploitable geothermal resource existed in the crater area. The current study has demonstrated that volcanic intrusions have occurred at relatively shallow depth and that the molten magma has interacted with groundwater resulting in phreatomagmatic eruption and production of maar type craters. The geological evidence indicates that the magma-water interaction takes place within the pre-Cambrian basement and that the forces of the eruption demand that the access to groundwater is considerable. The presence of ample water in pre-Cambrian granites and gneisses point to a secondary permeability caused by the brake-up of the older formation during evolution of the Rift Valley. The evidence gathered from the geological survey has shown that the three main criteria needed for the development of a geothermal reservoir might exist, namely a heat source, permeability and water. This is supported by the existence of hot spring right in the middle of the field, and where the geological evidence points to the highest magma production, an intersection of large tectonic system and therefore the highest permeability. Hot springs are few in the crater area, and their chemistry is difficult to interpret due to the high salinity of the shallow groundwater and lake water in the craters. The chemistry points though to temperatures as high as 200°C, which meets the requirements for an exploitable reservoir, but the interpretation of the chemical data indicates that the reservoir fluid has very high salinity. Although the geology work identified a possible heat source, the mode of eruption, i.e. phreatomagmatic, drains vast quantities of energy from the reservoir. A rapid cooling at depth and the eruption of most of the intruded magma to the surf leave the permeable reservoir cold. One observation to support this situation is the lack of geothermally altered accidental fragments and/or secondary minerals from a developed geothermal reservoir (ICEIDA, 2010).
(Past Geological Studies included)	



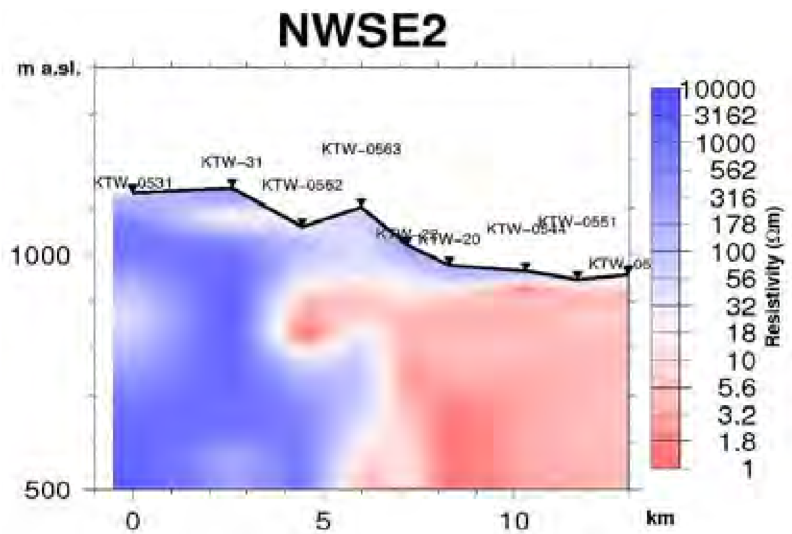
(Source) ICEIDA(2010)

Craters in the Katwe-Kikorongo volcanic area



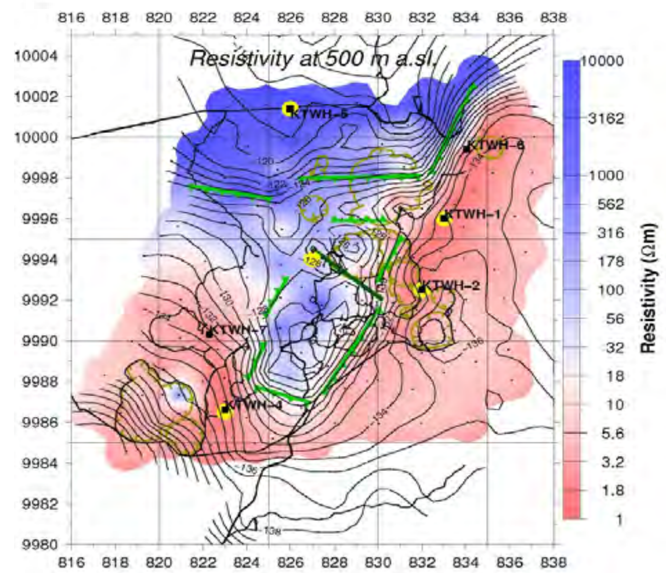
(Source) Bahati et al (2010)

Geological map of Katwe-Kikoro area



Resistivity map based on the TEM survey in the Katwe-Kikorongo area

(Source) ICEIDA(2010)

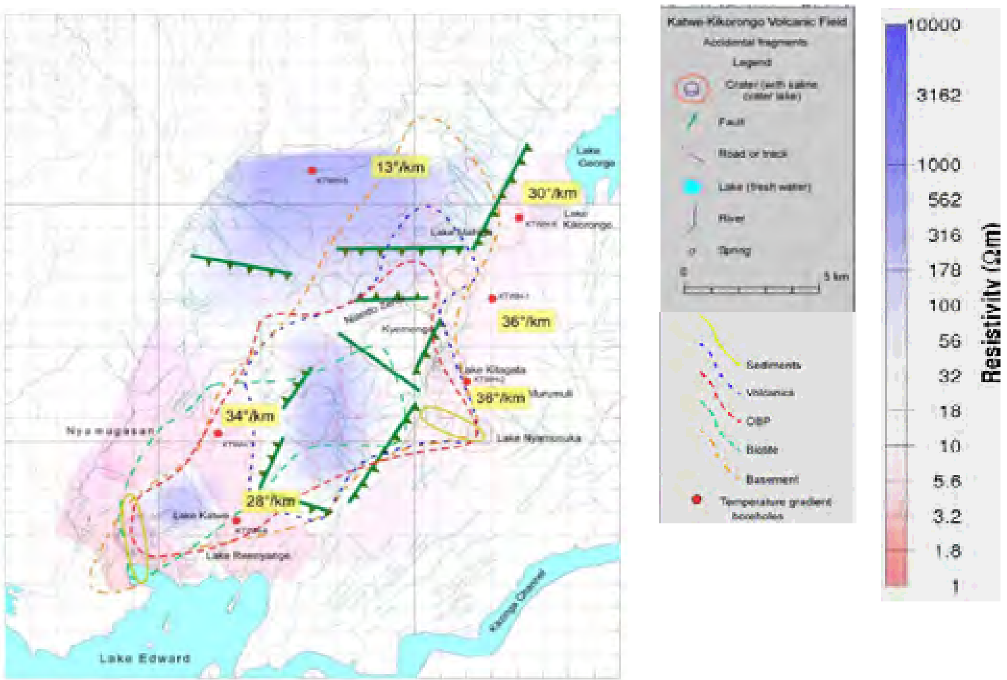


Chosen heat flow hole points（yellow） and actual drilled points（black squares） in the Katwe-Kikorongo area

(Source) ICEIDA(2010)

Annex-5-2 The Evaluation Sheet of the Katwe-Kikorongo (Uganda) Geothermal Field (2)

Geochemistry	The geochemistry results reveal the existence of a geothermal system in the Katwe prospect. The geothermal fluids are characterized by high carbonate contents and salinity two of the hot springs sampled in the Lake Kitagata crater. HS-02 and HS-05 have a salinity of 19,410 and 27,770 mg/kg total dissolved solids respectively. The high carbonate affects the concentrations of Ca and Mg which are less mobile and tend to precipitate out of solution as Ca and Mg carbonates rendering the geoindicators involving the two cations unreliable. Solute geothermometers have been difficult to use in Katwe due the high salinity of the fluid. The sulphate concentrations are relatively high and all indications suggest that the geothermal system is relatively old. Relatively low B values compared to Cl and Li suggest that the fluid are more likely to originate from volcanic basement rocks rather than from the young overlying sediments. Some indications of possible mixing with groundwater were inferred from log(Q/K) diagrams (Armannsson, 1994) predicting a temperature of 140- 160 ^{0}C. The NaK geothermo
Work done so far	
Geophysics	
Gravity/Magnetics	The gravity data agrees with the TEM resistivity data and indicates that the low resistivity anomalous areas are controlled by a N-S fault east of Lake Katwe and a NNE-SSW fault in the Lake Kitagata –Lake Kikorongo area (Bahati et al., 2010).
Resistivity (MT/TEM)	Geophysical surveys; Transient Electromagnetic (TEM) and Gravity were conducted in the Katwe geothermal prospect. The results indicate the existence of two low resistivity anomalous areas. The first one is located around Lake Katwe and the second stretches from Lake Kitagata to Lake Kikorongo (Bahati et al., 2010).
Well Drilling	
Temperature Survey	The drilling of six thermal gradient wells up to 300m depth in the volcanics did not show any indication of Olivine-Biotite-Pyroxene (OBP) series. This confirms that the depth to the intrusive source of heat is greater than 300m to which the wells were drilled. The results from the temperature gradient measurements give almost linear profiles indicating conductive heat transfer. However, the values between 30 and 36°C/km are slightly above the global average of 30°C/km suggesting that the
Well testing	None
Conceptual Model	None
Present Status of Development	Pre-F/S
Natural/Social Environmental Condition	It is within the Queen Elisabeth National Park.
Power Sector Situation	None
Power Output Potential	
Resource Potential	None
Restricted by National Park	
Restricted by Power Demand	
Rank of Development Priority	
Potential (Expected) Developer	
Proposed Geothermal Development Plan	
Outline for Power Development	None
Possible or Recommended Multi-purpo	None
Scope for Power development	None
CO2 emission Reduction ('000 tonne/y	None
Proposed Geothermal Development Sc	None
Location Map	
Other Figures	



(Source) ICEIDA(2010)

Geothermal structure of Katwe-Kikorongo area

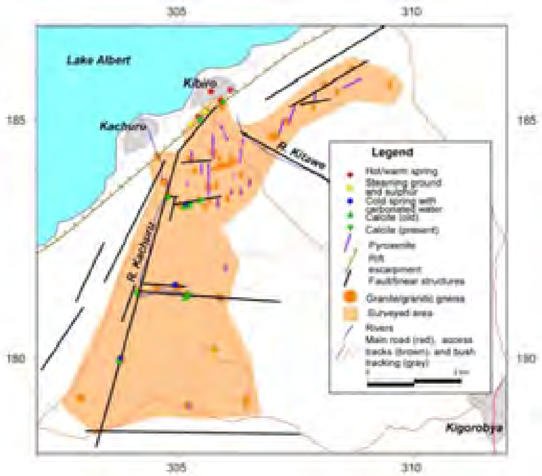
Chemical (mg/kg) and stable isotope (‰)analysis results for hot spring water in the Katwe-Kikorongo area

Location	Sample No.	Temp. (°C)	pH	CO_2	H_2S	SiO_2	Na	K	Ca	Mg	SO_4	Cl	B	Li	$\delta^{18}O$	δD	TDS
LKatwe13	UG-93-01	28.6	7.61	156	0	29.3	44.7	35.1	10.1	5.92	7.0	3.9	0	0.003	-3.52	-9	132
L.Katwe6	UG-93-02	28.5	9.64	11316	5.3	88.6	25600	3500	0.1	0.95	9940	19000	1.9	0.067	1.9	-6	72000
L.Nyamunu1	UG-93-03	27.5	9.42	5523	0	32.2	8950	722	0.13	0.49	6450	3340	0.27	0.025	1.12	9.1	24690
L.Edward1	UG-93-04	23.3	8.55	223	0	18.2	83.7	41.5	16.8	27.3	18	20.2	0	0.01	2.52	22.1	254
Katunguru1	UG-93-05	26.6	6.95	1000	0	53.7	952	89.7	296	232	1800	723	0	0.023	-1.88	-8	4870
L.Kitagata5	UG-93-06	66.6	8.41	3105	0	91	9310	644	0.6	0.85	13400	2430	0.82	0.063	-0.73	0.5	27770
L.Kitagata2	UG-93-07	56.6	8.03	2544	0	105	6510	523	1.45	6.27	8970	1770	0.59	0.031	-0.6	3.2	19410
KazingaCh1	UG-93-08	26.2	8.28	108	0	21.5	38.5	7.8	22.9	11.2	11	10.3	0.06	0.005	0.98	12.6	180
L.Kitagata1	UG-96-06	61.1	9.33	10350	19.4	210	33600	1840	4.1	2	44000	8370	2.77	0.16	2.2	0	99515
L.KitagataW	UG-93-28	36	9.57	19470	0.3	389	87300	4780	4.3	1.47	110300	22200	6.9	0.08	10	24	256000
L.KatweW	UG-93-29	28	9.55	9008	4.8	237.6	124500	22500	5.3	32.5	71300	86600	17.5	0.11	9.6	24.5	372000

(Source) Bahati et al.(2010)

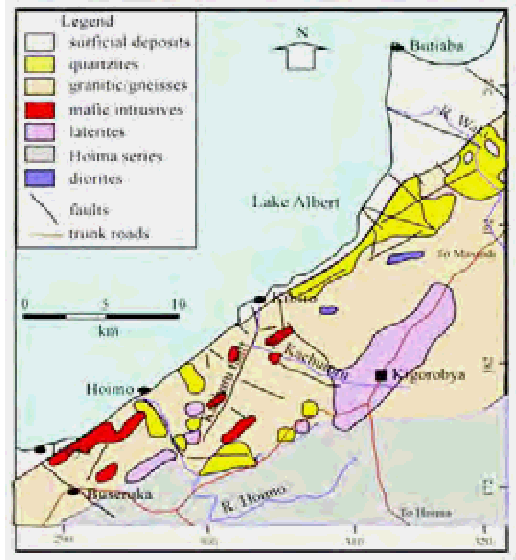
Annex-5-3 The Evaluation Sheet of the Kibiro (Uganda) Geothermal Field (1)

Field Name	Kibiro
Country	Uganda
Province/Location	Kibiro is situated in Hoima district, on the eastern shore of Lake Albert.
Accessibility	Kibiro is located at the foot of the escarpment of the western branch of the East African Rift System (EARS), and is connected by a rough but motorable track up the escarpment from Kigorobya township, which has road connection to Hoima in the south and Masindi to the north through Biiso. The escarpment, which rises over 300 m above Lake Albert, has a profound influence on land use in the area. Below the escarpment at Kibiro the main occupation is fishing and salt production, but the area around Kigorobya is a fertile agricultural land, where the main cash crop is tobacco and cotton. Closer to the escarpment there is less rainfall and cattle keeping is the main agricultural activity (ICEIDA, 2010).
Resource Characteristics Geology	The Albertine rift is located within the western branch of the East African Rift System, and is characterized by thick accumulation of sediments, at least 5.5 km, but absence of any volcanic rock on surface. The western rift is considered at an early stage in development, and is younger (late Miocene – Recent) than the more mature eastern branch. The Albertine rift is seismically active, characterized by deep-seated (27 – 40 km) large earthquakes. The rift cuts straight through the study area at N50°E, but immediately as one moves out of the escarpment region, this direction cannot be seen, neither in macro-structures, such as fault zones or lineaments, nor in finer structures, such as joints and fractures. In the granitic rocks outside the escarpment the main lineaments are the same in fault structures and in joints and fractures, the principal directions are N20°E and E – W, and a less prominent N120 – 130°E. In summary the tectonic pattern in the study area is governed by the formation of the rift. The same forces that are tearing the Archaean shield apart in SE – NW direction and forming the Albertine Rift have block-faulted the semi-brittle granitic baserock east of the escarpment. The fault system is most likely of the same age as the rift itself and results from the same forces (ICEIDA, 2010).
Volcanic activity (heat source)	The Kibiro geothermal prospect is divided into two entirely different geological environments by the escarpment, which cuts through the field from SW to NE.. To the east of the escarpment, the geology is dominated by Precambrian crystalline basement, characterized by granites and granitic gneisses that are mylonitic in the fault controlled valleys. To the west lies an accumulation of thick sequences of Rift Valley arenaceous Kaiso and argillaceous Kisegi sediments of at least 5.5 km thickness, but without any volcanic rocks on the surface (Bahati et al., 2010).
Geological Structure	The faults of the escarpment that strike N500E constitute the main structures in the tectonic environment. The forces causing the rifting of the Archaean plate have put stress on the granitic rocks resulting in block faults with two main directions, N200E and N900E. Crosscutting joints striking mainly E-W and N200E with vertical dips are found in all the rock types. A less common joint set of N1300E also occurs. Some joints are open while others are filled with secondary minerals commonly quartz or siliceous material and rarely by calcite. The faulting and jointing in the crystalline basement constitute high yielding aquifers as evidenced by the shallow thermal gradient wells drilled in the area. Recent geological and geophysical studies show anomalous areas that can be traced along faults in the block faulted granites to the east and away from the Rift escarpment (Bahati et al., 2010).
(Past Geological Studies included)	



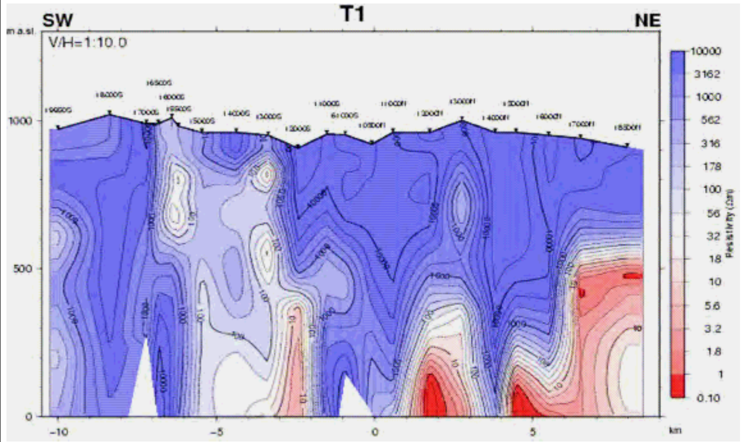
(Source) (Bahati et al., 2010)

Geology and geothermal manifestations in the Kibiro area



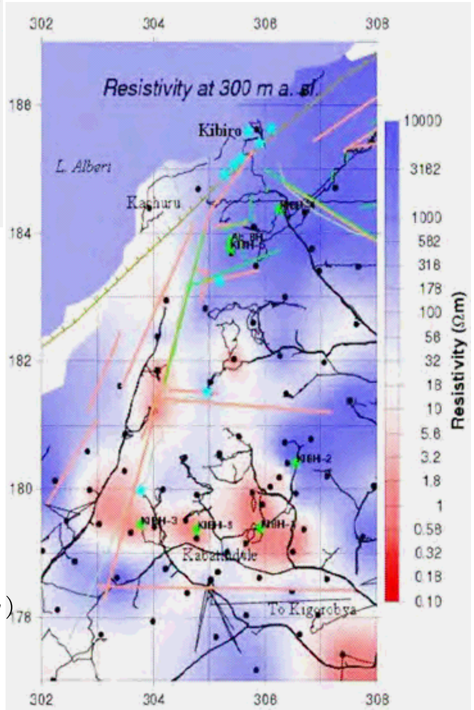
(Source) (Bahati et al., 2010)

Geological map of Kibiro area



(Source) (ICEIDA, 2004)

Resistivity map of the geothermal area based on the TEM survey in Kibiro

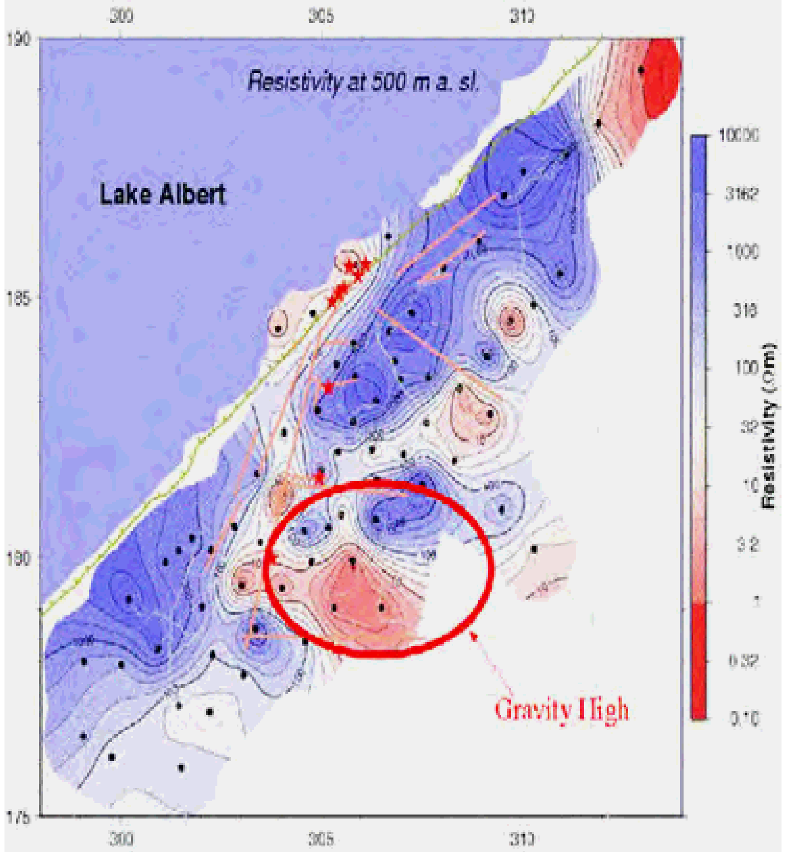


Resistivity map of the geothermal area based on the TEM survey in Kibiro
(Geothermal manifestation is marked as *star*)

(Source) (Bahati et al., 2010)

Annex-5-3 The Evaluation Sheet of the Kibiro (Uganda) Geothermal Field (2)

Geochemistry	The fluids are characterised by a neutral pH, and salinity of 4,000 - 5,000 mg/kg total dissolved solids. A subsurface temperature of 200 - 220°C is inferred by geothermometry and mixing models. Stable isotope results show that two groups of waters located east and south of Kibiro represent the groundwater that could be the source of recharge for the Kibiro hot springs. A massive flow of groundwater from a higher elevation than all the cold-water sampling points is also suggested. This high ground is represented by the Mukhihani-Waisembe Ridge in Kitoba subcounty, located 20 km southeast of Kibiro. The tritium concentration of the Kibiro hot spring water is 1.25 TU similar to that of the groundwaters (0 - 3.5 TU), and indicates that the hot spring water has cold groundwater contribution as suggested by geochemical modelling and is therefore a mixture of a hot water component and cooler water. However, it should be noted that the tritium background in precipitation for the area is rather low, up to a few tritium units only, and indications of mixing may not always be clear. The isotope composition of sulphur and oxygen in sulphates expressed in δ34S (SO4) and δ18O (SO4) suggest a magmatic contribution. Strontium isotopes in water and rock (87/86SrH2O, 87/86SrRock) indicate an interaction between the granitic gneisses and the geothermal fluids. The reservoir rock types in Kibiro are, therefore, granitic gneisses (Bahati et al., 2010).
Work done so far	
Geophysics	The results of the geophysical surveys indicate the existence of anomalous areas in the Kibiro prospect. A low resistivity anomaly trench was traced into the crystalline basement, following the fault lines of the blockfaulted granites, first to the SSW away from Kibiro and then following W-E fault lines toward Kigorobya Town (Bahati et al., 2010).
Gravity/Magnetics	The gravity data does not show any distinct density variations, except for the large density contrast between the sediments in the Rift Valley and the granites east of the escarpment. There is, however, an indication of a higher gravity field in an area roughly coinciding with the W-E low-resistivity anomalous area. This might indicate a deep higher density intrusive acting as a heat source for the geothermal activity producing the low resistivity anomaly. The cause of these low-resistivity anomalies can, at the moment, not be stated with certainty, but the most likely explanation is conductive alteration minerals in fractures in the otherwise resistive base-rock. Saline water in fractures could also be a possible candidate, but the relatively low salinity of the water discharges from hot springs at Kibiro and other cold springs in the area makes this rather unlikely (Bahati et al., 2010).
Resistivity (MT/TEM)	
Well Drilling	
Temperature Survey	Six thermal gradient wells were drilled up to 300 m in the geophysical anomalous areas in the crystalline basement. The lithological analysis and the temperature gradient results indicate absence of a geothermal gradient east of the escarpment (16°C/km) but slightly elevated towards the escarpment (31°C/km) (Bahati et al., 2010).
Well testing	
Conceptual Model	None
Present Status of Development	Pre-F/S
Natural/Social Environmental Condition	None
Power Sector Situation	None
Power Output Potential Resource Potential Restrictted by National Park Restricted by Power Demand	None
Rank of Development Priority	
Potential (Expected) Developer	
Proposed Geothermal Development Plan Outline for Power Development	None
Possible or Recommended Multi-purpo	None
Scope for Power development	None
CO2 emission Reduction ('000 tonne/ye	None
Proposed Geothermal Development Sc	None
Location Map	
Other Figures	



(Source) (ICEIDA, 2004)

Resistivity and gravity anomaly area map based on the TEM survey in Kibiro

Chemical (mg/kg) and stable isotope (‰)analysis results for hot spring water in Kibiro

Location	Sample No.	Temp. (°C)	pH	CO_2	H_2S	SiO_2	Na	K	Ca	Mg	SO_4	Cl	B	Li	$\delta^{18}O$	δD	TDS
Mukabiga2	UG-93-19	86.5	7.06	146	10.4	129	1530	169	62	8.14	46.7	2500	2.26	1.5	-2.01	-11.3	4576
Mukabiga5	UG-93-20	81.1	7.14	155	13	125	1490	164	62.9	7.96	26.4	2450	2.23	1.48	-2.08	-11.8	4436
Mwibanda14	UG-93-21	71.8	7.14	155	17.3	122	1480	165	65.7	9.21	15.4	2440	2.21	1.46	-1.98	-10.6	4384
Muntere15	UG-93-22	39.5	8.05	115	0	135	1570	182	75.9	8.71	49.9	2580	2.47	1.53	-1.01	-3.9	4548
L.Albert	UG-93-23	30	8.93	236	0	0.5	72.3	49.4	9.75	27.3	19.3	24.2	0	0.012	5.47	39.8	338
Wantembo	UG-93-24	29.8	6.89	367	0	90.5	87.5	7.7	75.8	39.5	139	31.2	0	0.016	-3.58	-15.2	662
Kiganja1	UG-93-25	23.6	6.26	130	0	70.8	12.4	2.6	14.8	8.03	5.3	5.2	0	0.003	-1.57	-4.1	124
Ndalagi1	UG-93-26	24.9	6.72	232	0	76.1	50.6	7.5	138	39.5	227	123	0	0.015	-2.08	-5.2	680

(Source) (Bahati et al., 2010)