The Republic of Djibouti

DATA COLLECTION SURVEY ON GEOTHERMAL DEVELOPMENT IN THE REPUBLIC OF DJIBOUTI

FINAL REPORT

Executive Summary

DECEMBER, 2014

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT

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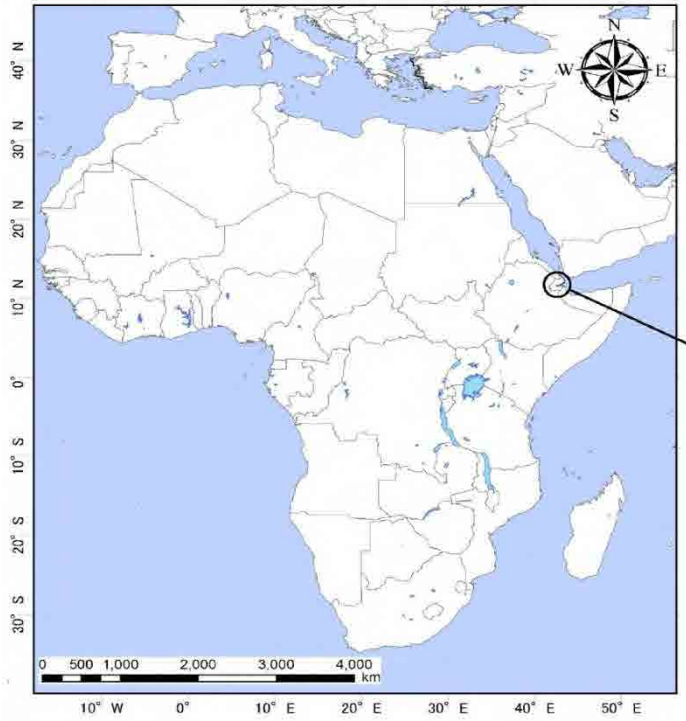
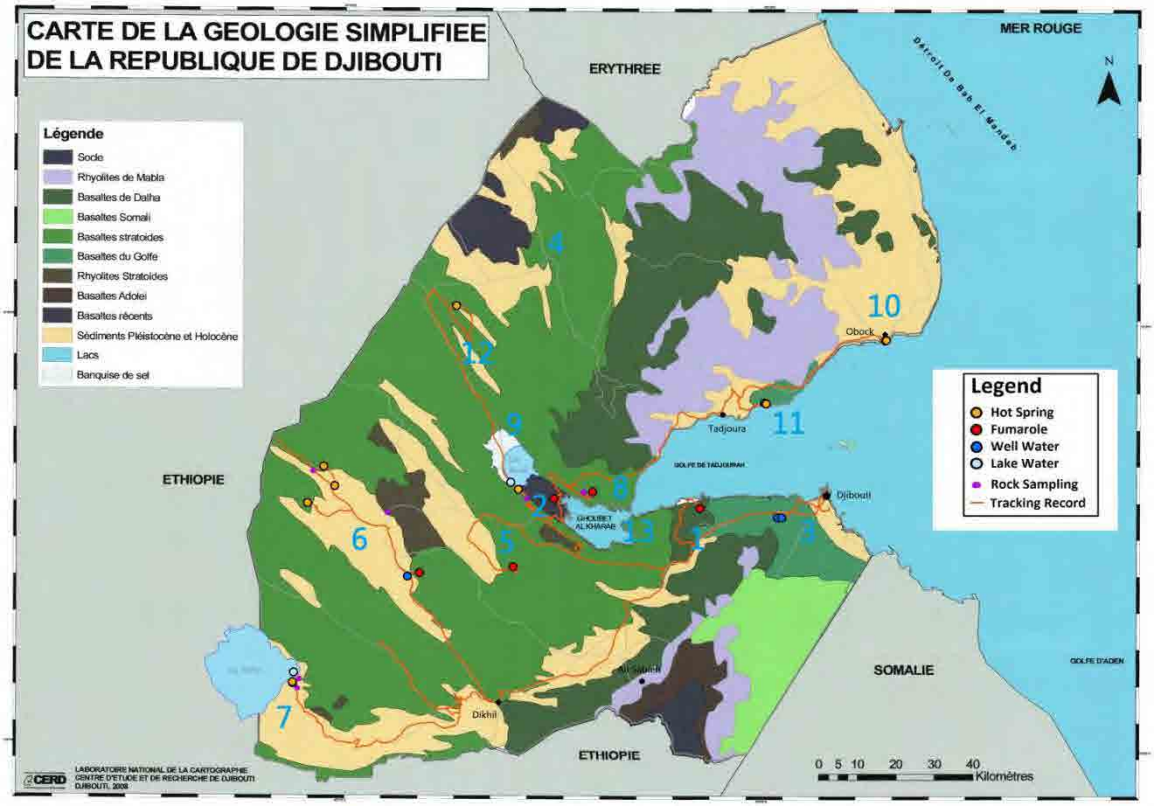


No.	Site	No.	Site
1	Arta	8	Nord Goubet
2	Asal Rift	9	Nord Lac Asal
3	Djibouti	10	Obock
4	Dorra	11	Rouweli
5	Gaggade	12	Sakalol
6	Hanle	13	Sud Goubet
7	Lac Abhe		



Location Map

Abbreviations

ADDS	Djibouti Social Development Agency
ADME	Djiboutian Agency Control of Energy
AFD	Agence Française de Développement (French Development Agency)
AFDB-ADF	African Development Bank
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AUC	African Union Commission
BOP	Blowout Preventer
CERD	Centre for the Study and Research of Djibouti
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DoE	Department of Environment in Ministry of Home, Urbanism, Environment and Land Planning
E/S	Engineering Service
EC	Electrical Conductivity
EdD	Electricité de Djibouti
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ESMAP	Energy Sector Management Assistance Program
EUEIPDF	EU Energy Initiative Partnership Dialogue Facility
F/S	Feasibility Study
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographical Information System
GPS	Global Positioning System
GRMF	Geothermal Risk Mitigation Fund
ICEIDA	Iceland International Development Agency
IPP	Independent Power Producer
ISERST	Institute of Higher Studies and Research Science and Engineering
ISOR	Iceland Geosurvey
JICA	Japan International Cooperation Agency
Ma	Million Age
MENR	Ministry of Energy Responsible for Natural Resources
MER	Main Ethiopian Rift
MESR	Ministry of Higher Education and Research
MT	Magnetotelluric Method

NDF	Nordic Development Fund
NUB	Nubian Plate
ODDEG	Djiboutian Office for Development of Geothermal Energy
OFID	OPEC Fund for International Development
ONEAD	National Office for Water and Sanitation in Djibouti
OPEC	Organization of the Petroleum Exporting Countries
ORC	Organic Rankin Cycle
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PPA	Power Purchase Agreement
ppm	parts per million
SAGS	Steamfield Above Ground System
SEFA	Sustainable Energy Fund for Africa implemented by AfDB
SWIR	Short Wave Infrared Radiometer
TAS	Total Alkali-versus-Silica
TDEM	Time-Domain Electro Magnetic Method
TIR	Thermal Infrared Radiometer
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNU-GTP	United Nations University – Geothermal Training Programme
VES	Vertical Electric Sounding
VNIR	Visible and Near-infrared Radiometer
WB	World Bank
WHO	World Health Organization
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

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1. Background of the Survey

Electricity in Djibouti had been produced by diesel engine power generation system of 137 MW installed capacity that requires oil to be all imported, because there is not indigenous energy identified by today for power generation in the country. In November 2011, the country started importing electricity generated at hydropower stations in its neighboring country Ethiopia, which has contributed drastically to reduction of energy costs, but in turn, increased its power generation dependency to Ethiopia by 80% in 2013. The Government of Djibouti considers this situation should not contribute to its energy security policy, and thus places high priority on geothermal energy development in the country as one of the national development targets.

2. Purpose of the Survey

The Survey was executed to collect data necessary for analysis of geothermal development in the Republic of Djibouti. The Survey was carried out through the collection of existing documented information, analysis of satellite images, geological and geochemical field survey, and laboratory analysis. With the information collected, prospective geothermal sites were evaluated for consideration of cooperation from Japan on geothermal development in Djibouti.

3. Present Conditions of Electricity in Djibouti

3.1. Demand and Supply

Electricity demand in Djibouti has steadily been increasing from about 50 GWh in the 1970s to 355 GWh in 2013. Electricité de Djibouti (EdD) with its diesel engine power generation facility, together with hydropower-generated electricity imported from Ethiopia since 2011, has been supplying the electricity in the country. While the installed capacity and available capacity of the diesel-powered facility are 135 WM and 101 MW respectively, Djibouti is able to import a maximum of 700 GWh a year according to a contract with Ethiopia, the energy corresponding to 80 MW of installed capacity. This makes its energy self-sufficiency rate extremely low at 19%.

3.2. National Development Plan, Electric Development Plan

In June 2014 the Government of Djibouti announced "Vision Djibouti 2035", that targets its vision to be realised by 2035. One challenging target stated in Vision Djibouti 2035 is for Djibouti to transform its power generation energy from 100% fossil fuel in 2010 to 100% renewable energy by 2020.

Among the targets and actions stipulated in the national five-year development plan (2011–2015) is the 'confirmation of geothermal energy available' as a target, and 'development of geothermal energy' as an action.

The electric development plan of EdD aims to have its installed capacity at 236 MW in 2020 when 100% of energy demand shall be supplied with renewable energy. Geothermal energy shall cover 50 MW of the 236 MW in 2019.

4. Organization for Geothermal Development

4.1. Djiboutian Office for Development of Geothermal Energy (ODDEG)

The Government of Djibouti has established ODDEG under the Presidential Office in 2014 to specialise in geothermal development. The relevant decree defines that all resources available for geothermal energy development in Djibouti shall be concentrated to ODDEG. While the staff, facilities and/or tools and equipment are limited at present, various activities are being performed, such as purchasing of a drilling rig, constructing of the new office building, assigning of researchers and reservoir engineers from the Centre for the Study and Research of Djibouti (CERD) for geophysical survey, in order to enhance ODDEG's capacity.

4.2. Study and Research Center of Djibouti (CERD)

CERD, formerly the Institute of Higher Studies and Research Science and Engineering (ISERST), was established in 1979 as a scientific and engineering research center. Professionals of geology, hydrogeology, geochemistry, among other scientific fields, are working for the center. Facilities for these specialties are available, but deemed insufficient. CERD has conducted pre-feasibility survey of three geothermal sites (Nord Goubet, Lac Abhe, and Obock) using its own research resources. Professionals for geophysical survey were transferred to ODDEG in July 2014 in accordance with the decree, whereas professionals of geochemistry and geology still belong to CERD including equipment and facilities for analysis, which shall be used for geothermal survey works in the future. The role of CERD in geothermal development is yet to be clarified.

4.3. Evaluation on Present Capacity of ODDEG and CERD

【1】 Geology：

ODDEG is in a close relationship with the Ministry of Energy and Natural Resources, that have mining geologists. There are also geologists in CERD. However, CERD is not sufficiently equipped with tools and/or equipment for geological survey and analysis.

【2】 Geochemistry：

ODDEG officers assigned as geochemists conducted the Survey together with the JICA Survey Team. There are seven researchers and staff in charge of geochemical survey and analysis in CERD, and most of the necessary equipment are available though some of analyzing tools and equipment for geothermal survey still need to be acquired.

【3】 Geophysical Survey：

Two sets of magnetotelluric method (MT) survey equipment are available at CERD as of June 2014 and are expected to be transferred to ODDEG. The equipment is usually used for academic purposes and are not so familiar to experts in the industry. CERD conducted magnetotelluric method (MT) survey for three geothermal sites. As the reports are confidential, the JICA Survey Team is not in a position to make comments on this, but the interpretation of the MT survey may has to be refined because a 2D inversion analysis software is not available.

5. International Assistance

5.1. World Bank and Other Financial Institutes

The Government of Djibouti is in the process of receiving financing from the World Bank (WB) and other six financial institutions for test well drilling in Asal-Fiale. In Asal-Fiale, test wells had been drilled in the 1980s that produced geothermal fluid of high salinity at over 100,000 ppm. More recently, another geophysical survey was conducted from October 2007 to March 2008. The results suggest the existence of low salinity zones, WB and other institutions expressed interest for assistance to the test drillings.

5.2. ICEIDA:

The Icelandic International Development Agency (ICEIDA) started their assistance programme in Arta and Gaggade.

5.3. UNU-GTP:

The Geothermal Training Programme of the United Nations University (UNU-GTP) has been training geothermal engineers from Djibouti since 1989.

5.4. GRMF:

Djibouti submitted applications to the Geothermal Risk Mitigation Fund (GRMF) to request financial assistance to drill test wells in Nord Goubet and to conduct surface exploration in Hanle.

6. Result of Site Survey

6.1. Geological Setting-East African Rift Zone

The Survey area is located in the northern area of the East African Rift Zone. The regional geology of Djibouti is generally characterised by intermittently active volcanic activities from the Oligocene to the Quaternary periods.

6.2. Satellite Imagery Analysis

Satellite imagery analysis was conducted using Japanese satellite products ASTER and PALSAR. The target sites are classified into the following two groups according to the results:

【1】 Areas where acid-neutral alteration zones are identified. These zones are generally associated with fault systems or basaltic composition of alkaline rock series.

Arta, Asal, Gaggage-Taassa, Hanle-Garabbayis, Lac Abhe, Nord Goubet, Nord Lac Asal, Rouweli, and Sud Goubet

【2】 Areas where alteration zones are not observed in the satellite images.

Djibouti-Awrofoul, Dorra, Obock, and Sakalol-AsbouDara

6.3. Geological Survey and Analysis

During the site survey, the JICA Survey Team visually confirmed the location and characteristics of fumaroles, rock outcrops, alteration clays, and fracture zones as necessary. They also collected rock samples and clay samples for analysis.

【1】 Microscopic Observation and X-Ray Fluorescence (XRF) Analysis

From the results of observation of rock sample thin sections by polarisation microscope, low-grade alterations were identified for all rock samples.

According to the bulk chemical composition analysis by XRF, most rock samples are classified in the basalt group, that is generally confirmed as the geological background of the alkaline rock series in Djibouti. Most of the primary rock forming minerals are present forming such ferromagnesian minerals as olivine, pyroxene, plagioclase, k-feldspar and/or magnetite/ilmenite. Ferromagnesian minerals are associated mostly with basaltic rocks and k-feldspar is associated with the intermediate rocks such as dark trachyte and trachybasalt.

【2】 XRD Clay Mineral Analysis

As a result of XRD analysis, alteration minerals such as nacrite, smectite, smectite-mixture, chlorite, and sericite indicate various grades of alteration. In particular, nacrite is a good indication of high-grade alteration, whereas smectite–chlorite is an indication of fairly high-grade alteration. The formulation temperature of clay minerals are estimated as (a) 100 ºC–150 ºC, (b)150 ºC–200 ºC, and (c) 200 ºC–250 ºC, as shown in Table 1 below.

Among the sites surveyed, geothermal activities in Gaggade-Taassa, Hanle-Garabbayis, and Nord Goubet-Anaale are considered to be still active because of geothermal manifestations identified in the field.

Table 1 Summary of XRD Analysis

Site Name	Rock Name	Clay Mineral				Zeolite group			others			Notes	Clay mineral Formaion Temperature (℃)
		Sme	Mix.	Chl /Ser	Kao /Nac	Sti	Nat	Lau	Gyp	Cal	Qz		
N. Goubet	Calcite									○		Cal. only	-
N. Goubet	calcite									○		Cal. only	-
Arta	Gypsum	○		○					○	+	+	Smc-Chl, Gyp (vein)	150-200
Arta	Rhyolite?	○	○							○	+	Smc-Mix, Chl	100-150
Arta	White clay				○						○	Nac.	200-250
Arta	White clay		○		○						○	Nac. & mix.	200-250
Arta	Gypsum								○			Gyp. only	-
Asal (2km east)	White clay, layered			○						○		Chl-Cal	150-200
Lac Asal	White clay								○			Gyp. only	-
N. Goubet_Anaale	Andesitic	○									+	Smc-Qz	100-150
N. Goubet_Anaale	White vein, calcite	○								○	+	Smc-Cal	100-150
Hanle-Garabbayis	Basalt	○	○	○		○	○	○				Smc-Chl + Gyp	150-200
Hanle-Yoboki (hill)	Rhyolite	○	○	○							○	Smc-Mix-Chl-Qz	150-200
Hanle-Yoboki (hill)	Rhyolite									+	○	Qz-Cal	-
Gaggade-Taassa	Reddish clay				○						○	Nac.	200-250
Gaggade-Taassa	Rhyolite	○								+	+	Smc-Cal-Qz	100-150

Smc: Smectite, Chl: Chlorite, Ser: Sericite, Sti: Stilbite, Lau: Laumontite, Gyp: Gypsum, Qz: Quartz, Cal: Calcite, Mix: Mixed layer minerals

(Source: JICA Study Team)

6.4. Geochemical Survey and Analysis

Geochemical characteristics of hot springs and gases are evaluated by analysis of water and gas chemistry and isotopes.

【1】 Geochemical Analysis

Water samples collected in this Survey are meteoric water and there is no obvious indication of mantle-originated fluid. Most of the water samples are of Na-Cl type.

【2】 Evaluation of Reservoir Temperature

High temperature areas identified by Na-K geochemical thermometer, high temperature areas revealed by CO_2/Ar and CH_4/CO_2 analysis, and areas with evidence of mantle gas are shown in Table 2 below.

Table 2 Summary of Geochemical Analysis

	Na-K Thermometer >190 °C	Gas Thermometer	Mantle Gas
Hanle-Garabbayis	-	☑ 159 °C～266 °C	☑
Arta	-	*(Weak Fumamoles)*	
Nord Goubet	-	☑ 228 °C～323 °C	☑
Gaggade Taassa	-	-	☑
Obock	☑	-	-
Djibouti Awrofoul (No.2)	☑	-	-
Asal – Fiale	-	-	☑
(-: No samples or analysis)			

Source：JICA Survey Team

6.5. Geothermal Potential Sites Identified by Survey Results

According to the results of satellite image, geology and geochemistry analyses, the following sites have been identified as potential geothermal sites:

- Arta
- Gaggade-Taassa
- Hanle-Garabbayis
- Nord Goubet- Anaale
- Obock
- Djibouti-Awrofoul-No.2

7. Social Environmental Survey

7.1. Objective

In order to assess socio-environmental conditions of the target sites, the Team collected information regarding relevant lows/regulations, protected/designated natural areas and the procedure of environmental impact assessment.

7.2. Results

There are nine environmental protection areas in Djibouti. Zoning in the protection areas has not yet been established; the possibility for development not prescribed; or clear boundaries of the environmental protection areas not yet been decided, except the Djalélo and Addaoua Bourale mountain areas.

Among the geothermal prospects surveyed in the Survey, the area near Lac Abhe is possibly included in a protection area. Consultation with the Department of Environment is required in case of developing the area.

8. Proposal for Development of the Priority Sites

The following factors have been considered for the prioritisation of geothermal development sites:

- Geothermal resources
- Access conditions
- Working space and drilling water
- Socio-environmental conditions
- Related information
  - ① Distance to the existing/plane transmission line or nearest trunk roads

The proposed priority sites are shown in Table 3 below.

The most prioritised site is Hanle-Garabbayis, and the second most prioritised sites are Arta and Nord Goubet. Gaggade-Taassa is ranked at third because of poor accessibility.

Obock is ranked at a lower priority because of the limited geothermal manifestation and its long distance from the national grid. However, in order to secure the base load demand in the remote area, investigations for small-scale geothermal development would be recommended.

For other sites in Djibouti Awrofoul, water of high geochemical temperature and low conductivity waters were identified. It would be worth conducting MT surveys for future development.

Table 3 Proposed Priority Sites for Cooperation

Site name	Geothermal Resources		Workability			Socio -Environment		Reference	Priority rec'nded	
	Resources	CL (mg/L)	Accessi-bility	Landform	Well Drilling Water	Natural conditions	In-habitant	Distance to transmission line		Survey for the next stage
Garabbayis	☑ A-1	±1,000	C Fair	B Plain -ragged hill	☑ A Ground water in Hanle Plain	☑ A Barren	A none	45 km to Dikhil	**1**	MT survey with geological and geochemical survey
Arta	☑ A-3	☑ D ±15,000	B Good	B Plain - ragged hill	C Sea	☑ A Out of a registered protection area	B a few	6 km to N.1	**2**	MT survey with geological and geochemical survey
Nord Goubet	☑ A-2	☑ D ±15,000	C-D Poor-fair	C Plain - ragged hill	C Sea	☑ A Barren, Desolate	B a few	50 km to P.K. 51	**2**	Review of Pre-Feasibility Study of CERD
Gaggade	☑ A-1	±5,000	☑ D Poor	☑ D Ragged hill	☑ A Ground water in Hanle Plain	☑ A Barren	A none	40 km to P.K 51	**3**	MT survey
Obock *	B	5,000 - 40,000	A Excellent	A plain, costal	C Sea	B Coastal	near town	Isolated	**4***	Review of Pre-Feasibility Study of CERD
Djibouti	C	±5,000	A Excellent	A Plain	C Sea	-	-	-	**5**	MT survey
Lac Abhe	-	±5000	C Fair	A Plain	C Lac Abhe	☑ D Registered	B a few	75 km to Dikhil	**-**	Review of Pre-Feasibility Study of CERD

☑: Conditions that special considerations are given for prioritization

Obock *: Survey of a next stage, separately from survey for a flash type may be recommended if a binary type is considered.

Source：JICA Survey Team

9. Proposed Directions of Cooperation for the Geothermal Development

9.1. Long-Term Cooperation for Geothermal Development

The main tasks of ODDEG are drilling works and related testing and analysis such as well logging, production tests, and interference tests. The general direction of long-term cooperation with ODDEG is summarised in Table 4 below.

Table 4 General Direction of Long-term Cooperation for Geothermal Development

Milestone	Tasks	Cooperation Items
Pre-Survey	Data collection, Inventory Nation wise Survey Selection of Promising Area EIA and Necessary Permits Planning of Exploration	• Additional technical cooperation (T/C) after this survey
Exploration	Surface (Geological, Geochemical survey)	• Technical cooperation (T/C) • Facility procurement（Laboratory analysis equipment for geological and geochemistry analysis）
	Sounding (MT/TEM)	• T/C for site survey • T/C for 2D inversion analysis with soft ware procurement
	Gradient and Slim Holes	• Financial cooperation for drilling • T/C for well drilling • T/C for observation and data analysis of well geology and well geochemistry • T/C for well logging test and data analysis • Procurement of well logging tools • T/C for well testing and data analysis
	Seismic Data Acquisition	•（Not necessary）
	Pre-feasibility Study	• T/C for data analysis and reporting
Test Drilling	Slim holes Full-size wells Well Testing and stimulation Interference test	• Financial cooperation for drilling • T/C for well drilling • T/C for observation and data analysis of well geology and well geochemistry • T/C for well logging test and data analysis • T/C for well testing and data analysis
	First Reservoir Simulation	• Procurement of computer software for analysis • T/C for simulation analysis
Project Review and Planning	Evaluation and decision making Feasibility study and Final EIA	• T/C for F/S preparation • T/C for EIA preparation
	Drilling Plan	• T/C for plan making for well drilling
	Design of Facilities, Tender Process	• Loan Project（E/S：detailed design, Tender process）
	Financial Closure/PPA/IPP	• T/C for policy making
Field Development (ODDEG)	Production wells Reinjection Wells Cooling water wells Well stimulation Reservoir simulation	• Technical cooperation Project • T/C for well drilling • T/C for well testing and data analysis • T/C for well logging and data analysis
Construction (Contractor)	Steam/hot water pipelines Power plant and Cooling Substation and transmission	• Loan Project（E/S：Supervision） • Loan Project（Construction of Power plant and SAGS）
Start up and commissioning		• Loan Project（Defect liability period）
O&M		• Follow-up by a Technical Cooperation Project
T/C: Technical Cooperation, E/S: Engineering Service in a loan project, O&M: Operation and Maintenance		

Source：JICA Survey Team

9.2. Cooperation Approaches before Test Well Drilling

【1】 Approach-1 Cooperation for Flash-type Development

The JICA Survey Team confirmed that the four priority geothermal sites (i.e., Hanle-Garabbayis, Nord Goubet, Arta, and Gaggade-Taassa) have the most potential in terms of geothermal resources. It is considered that these four sites have almost equal potential although the grade of geothermal manifestations are slightly different. It is therefore a prudent approach that at least the three sites, namely, Hanle-Garabbayis, Nord Goubet, and Arta, where accessibility are relatively good shall be further compared after conducting geophysical MT survey with additional geological and geochemical survey in order to determine the most promising site for the costly test well drilling. Among these three sites, CERD had already conducted a MT survey in Nord Goubet; thus the other two sites (Hanle-Garabbayis and Atra) shall be the target for the MT survey to be conducted in the next step. However, if the MT survey in Hanle-Garabbayis should show very good results, the test well may be drilled in Hanle-Garabbayis. As for Gaggade-Taassa, where accessibility is not so preferable, the JICA Survey Team expects ODDEG to conduct the MT survey when necessary in the future.

【2】 Approach-2 Geothermal Energy Development in Obock

There is a possibility that a flash type power system may be developed in Obock according to geochemical thermometer data of 197 ºC. However, no other geothermal manifestations were identified in Obock, thus the JICA Survey Team ranked it at lower priority. The approach on Obock's geothermal resources should depend on the purpose of geothermal development in Obock.

(a) Considerations on development for flash type power system in Obock

CERD had already conducted a pre-feasibility survey including MT survey in Obock. The JICA Survey Team is not in a position to review the report as it is confidential, but they were informed that no remarkable anomalies have been identified in the MT survey result. The MT survey of the ground surface might not be capable enough to identify any anomaly that may be present near or under the sea, because the hot springs are usually under the sea level and become visible only during the lowest tide of a day. For geothermal development of a flash type power generation system, more precise survey results are necessary, and for this reason an MT survey from the sea surface or other technique may be required. However, since experience of conducting such survey is limited, applicability both from technical and cost performance point of view will have to be examined. Furthermore, if the flash type power system should be connected to the national grid, the distance will also have to be considered. It is 150 km from Asal.

From the above, the JICA Survey Team considered that Obock should not be at a high priority for development of a flash type geothermal power generation system.

(b) Development of a binary type geothermal power generation system in Obock

On the other hand, the JICA Survey Team identified that the base load electricity demand would be about 500 kW in Obock. If this base demand should be covered, a small-scale power station constructed within a reasonable amount of investment may be sufficient. In this case, a binary type geothermal power development is worthy of considering, as it may not require large-scale and costly exploration. This approach would then be taken separately from the approach for the development of flash type geothermal development for national grid connection.

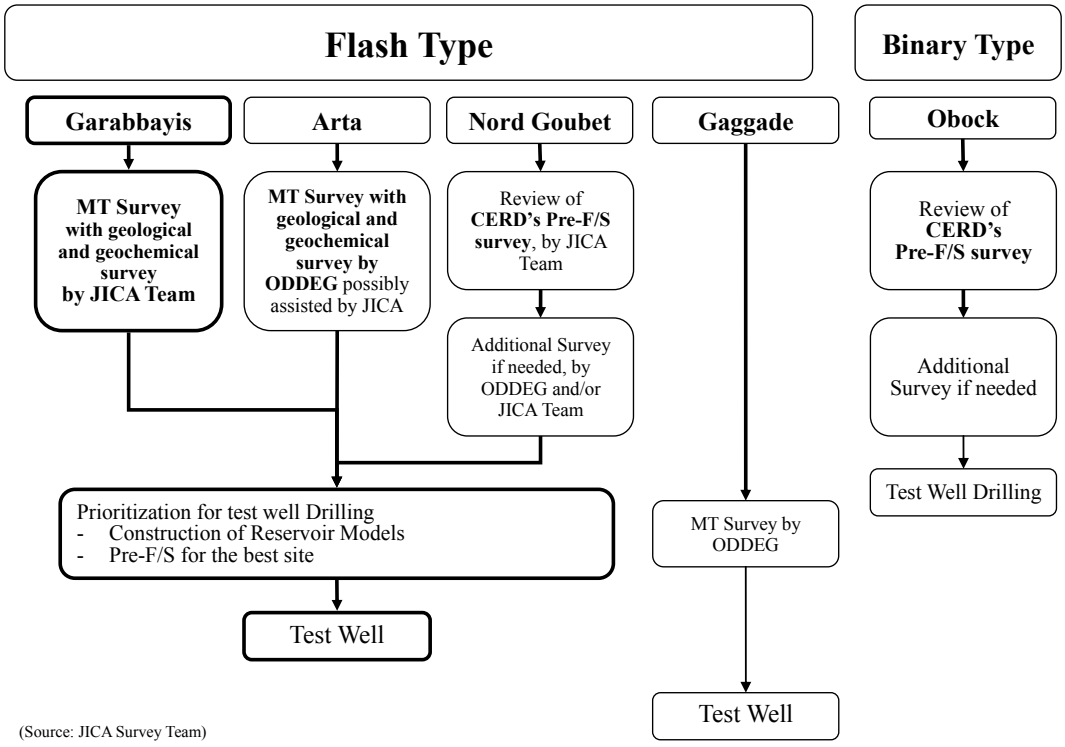


Figure 1 Approaches of Cooperation up to Test Well Drilling

【3】 Cooperation for Flash type geothermal Power Generation

(a) Exploration in the first priority site - Hanle-Garabbayis

The JICA Survey Team has selected Hanle-Garabbayis site as the first priority site based on potential resource assessment, access conditions, and others. The JICA Survey Team proposed the following surveys to determine the drilling target:

- Detailed Geological and Geochemical Survey

  The published geological map shows that there are some other fumarole points near and around the site the JICA Survey Team visited. In the next stage of exploration, a broader area than the one covered by this Survey should be surveyed, and rock samples, alteration clay samples and/or fumarole samples should be collected wherever necessary to determine the distribution of hydrothermal alteration minerals. The proposed direction of cooperation for geological and geochemical survey was described in Sections 3.3.2(5) and (6).

- Geophysical Survey (MT/TEM Survey)

  Geophysical survey is to be conducted for the purpose of investigating geological structure and reservoir structure. The type of geophysical equipment of ODDEG is usually used for academic purposes. Most of private consulting companies do not use this type of equipment and therefore they may not be operated effectively. For this reason, the JICA Survey Team proposed that the geophysical survey in Hanle-Garabbayis should

be ,conducted by a Japanese team with equipment to be brought in from Japan. should JICA consider technical cooperation.

(b) Geophysical Survey in Arta and Nord Goubet

As mentioned above, the other three sites (Arta, Nord Goubet and Gaggade) would be similarly prospective to Hanle-Garabbayis, therefore it would be a prudent approach that at least the three sites (i.e., Hanle-Garabbayis, Arta, and Nord Goubet) should be compared by the results of the MT survey, to finally determine the most promising site for test well drilling.

Cooperation from Japan thus shall include the Arta site where no MT survey has been conducted so far. If cooperation resources for a full size assistance should be limited within the coming fiscal year, financial assistance may be helpful for ODDEG to start the survey earlier.

On the other hand, CERD already conducted a pre-feasibility survey in Nord Goubet. For this site, a review of the CERD study that is kept confidential at this moment be conducted. If deemed necessary, additional survey should be recommended in the form of either technical assistance or financial assistance, as necessary.

As for Gaggade-Taassa where relatively strong geothermal manifestations are observed, the JICA Survey Team expects the ODDEG to conduct the survey using its own resources in the future when necessary.

(c) Cooperation for the three sites (Hanle-Garabbayis, Arta and Nord Goubet)

- MT data analysis with a 2D inversion software

  At present, a 2D inversion software is not available in ODDEG or CERD. Cooperation shall be made to analyse MT data collected from the three sites using a 2D inversion software that should be procured for technical cooperation with Japanese experts.

  In addition, recommendations for cooperation direction of geophysical exploration were made as discussed in Sections 3.3.1 (4) and (5).

- Geothermal Reservoir Modeling

  Based on the abovementioned survey, a preliminary geothermal reservoir model shall be created for the three sites. With the creation of the model, the following works shall be conducted:

  ✧ Preliminary assessment of geothermal resources; and

  ✧ Proposal for well siting and well drilling method including the methodology of well testing and well logging

- Pre-Feasibility

  Based on the preliminary assessment of geothermal resources, a pre-feasibility study shall be conducted for the best recommended site.

- Best season for site survey

  The average monthly temperature in Djibouti from May to September exceeds 30 °C, and reaches over 35 °C in July. Therefore, field surveys are usually conducted during the period from October to April in the following year when the average monthly temperature is below 30 °C. Therefore, field surveys in Djibouti is recommended to be conducted

particularly in December to February, when the average monthly temperature is below 25 °C.

【4】 Cooperation for Development of a Binary Geothermal Generation System in Obock

As mentioned above, the JICA Survey Team considered that large-scale geothermal development would not be required in Obock. Instead, small-scale geothermal power development that could satisfy a base load demand of 500–600 kW shall be considered. The JICA Survey Team recommends the following approaches:

(a) Review of the CERD pre-feasibility report

The report, which is currently kept confidential, shall be reviewed first.

(b) Proposal for exploration planning

The JICA Survey Team proposed the following approaches:

- MT survey of the sea surface may be necessary with a combination of additional MT survey of the ground surface, if judged so after the review of the CERD report. Cost effectiveness shall be considered because such survey from the sea may be costly as compared with the effectiveness of power generation for Obock.
- Drilling of slim hole is recommended from the coast in order to explore temperature gradient, and availability/volume of hot water. The slim hole shall be directional toward the sea. It is confirmed that the Ministry of Agriculture possesses a drilling rig capable of drilling down to ca. 500 m. Countermeasures against hot water or blowout preventer (BOP) shall be necessary.

(c) Issues

There will be issues arising from the expected high salinity even if sufficiently high temperature and abundant discharge should be confirmed, because the hot water samples showed similar salinity as seawater, and that isotope analysis indicated that the hot water may be of seawater origin.

- Scale problem in hot water circulation system
- Scale problem in cooling water (seawater is assumed) system

【5】 Djibouti-Awrofoul No. 2 (Well for Drinking Water Supply)

The well is located near PK20 relatively close to Djibouti City and adjacent of the existing substation. The hot water from the well indicated about 73.6 °C, and alkaline geochemical thermometer indicated 191 °C. Also, the electric conductivity is as low as 1,400～1,080 μS/cm. Although the other geothermal manifestations were not confirmed at this site, it may be worthwhile to conduct MT/TEM survey in order to investigate the possibility for geothermal development.

End of document

Attachment to the Executive Summery

Draft Final Report

Presentation Material

ODDEG's Comments reflected (02 Dec. 14)

DATA COLLECTION SURVEY ON GEOTHERMAL DEVELOPMENT IN DJIBOUTI

Draft Final Report Presentation

November, 2014
Sheraton Hotel, Djibouti

JICA Survey Team

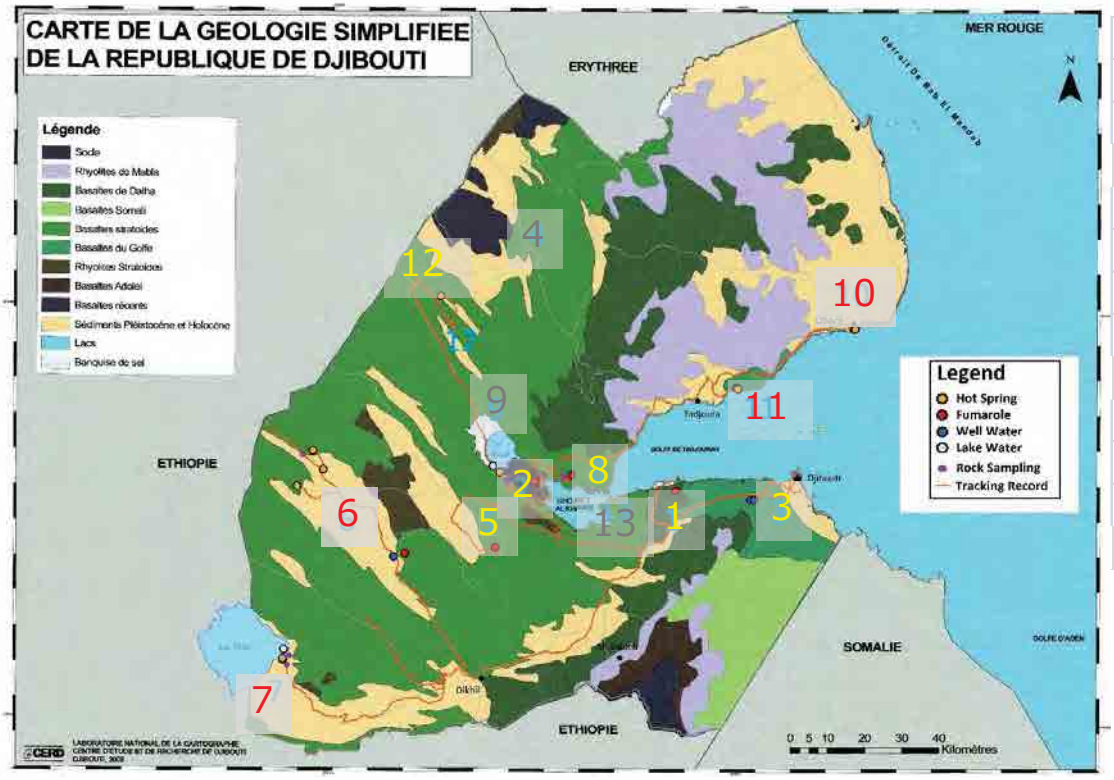
- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

Acknowledgement

- The field survey was conducted jointly with the ODDEG and CERD in the hottest months of May and June, 2014.

- Our greatest thanks to be directed toward the ODDEG, who made various arrangements, as the counterpart.
- The same thanks directed to the CERD, who conducted geochemical analysis and useful technical communications also.
- We would also appreciate all the other Djiboutian officers who provided us with kind cooperation.

Location Map



1	Arta
2	Asal
3	Djibouti
4	Dora
5	Gaggade
6	Hanle
7	Lac Abhe
8	Nord Goubet
9	Nord Lac Asal
10	Obock
11	Rouweli
12	Sakalol
13	Sud Goubet

Contents of the Presentation (1/2)

1. Background, Purpose
2. Background Information
   1. Present Situation of the Electric Sector
   2. National Development Strategy
3. Institutional Set-up: Our understandings
   - ODDEG
   - CERD
4. Donors' Assistance
5. Reconnaissance Survey and Analysis Conducted
   a. Remote Sensing
   b. Geology – Rock thin sections, XRD, XRF
   c. Geochemistry

Contents of the Presentation (2/2)

1. Back Ground, Purposes

- Background
  - ① Djibouti imports more than 80 % of electric energy from Ethiopia as of 2013;
  - ② No indigenous energy is available at present, except geothermal energy for electric generation;
  - ③ Geothermal development is a top priority.
- Activities and Purposes
  - ① To collect existing information and its review,
  - ② To conduct a reconnaissance survey,
  - ③ To analyze the data collected for consideration of Japanese assistance approach on geothermal development

Background Information

- Why is geothermal energy to be developed in Djibouti?

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

Present Situations of the Electric Sector

- Installed capacity:
  - Diesel engine generation system
  - Rated: 135 MW, Operational: 101 MW
- Energy supply and self-sufficiency

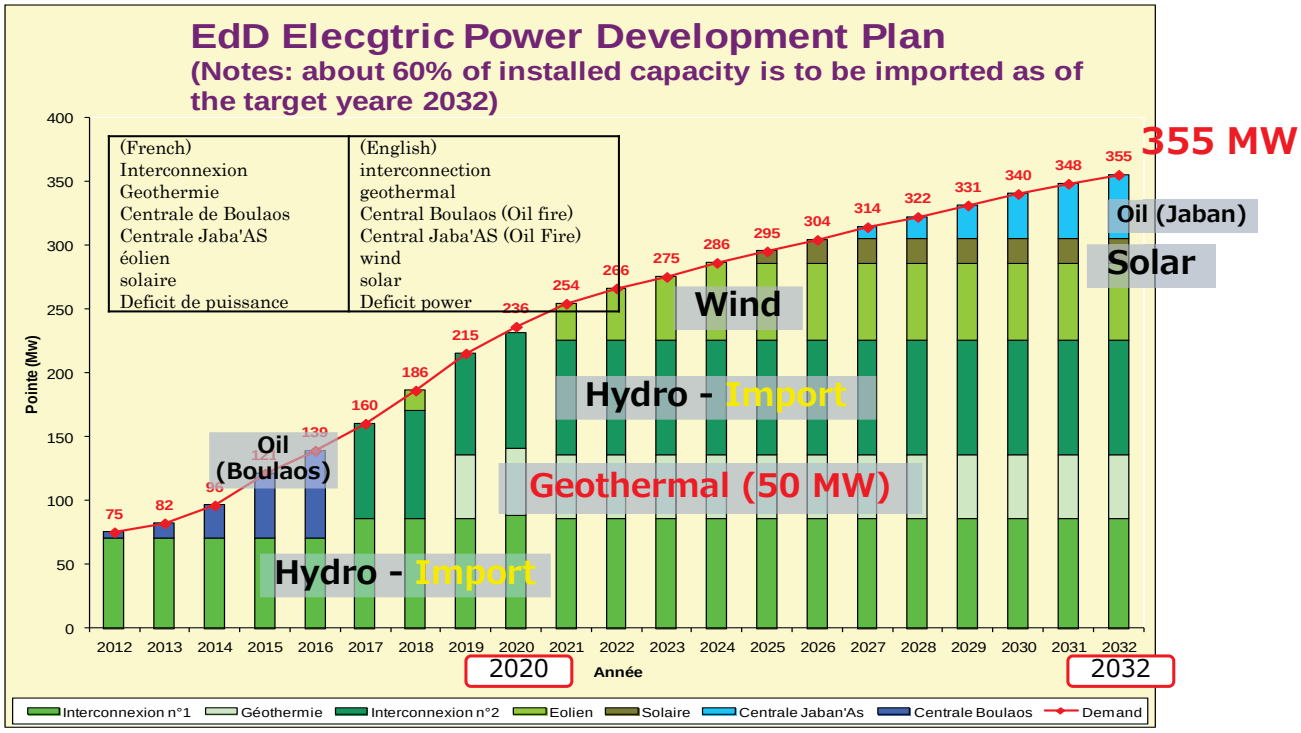
	2011	2012	2013
(a) Total Supply (GWh)	232.0	387.0	354.9
(b) Self Supply (GWh)	77.0	24.0	67.5
Self- Sufficient Ratio (%)	33.2	6.2	19.0

Source: EdD

- Note: Djibouti started to import Electric energy *from Ethiopia* in November 2011

National development strategy

- VISION Djibouti 2035
  - The Djiboutian country revolutionizes 100% of thermal power generation dependence of 2010, for 100% of renewable energy use by 2020.



Institutional set-up: Our understanding

1. ODDEG
2. CERD

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

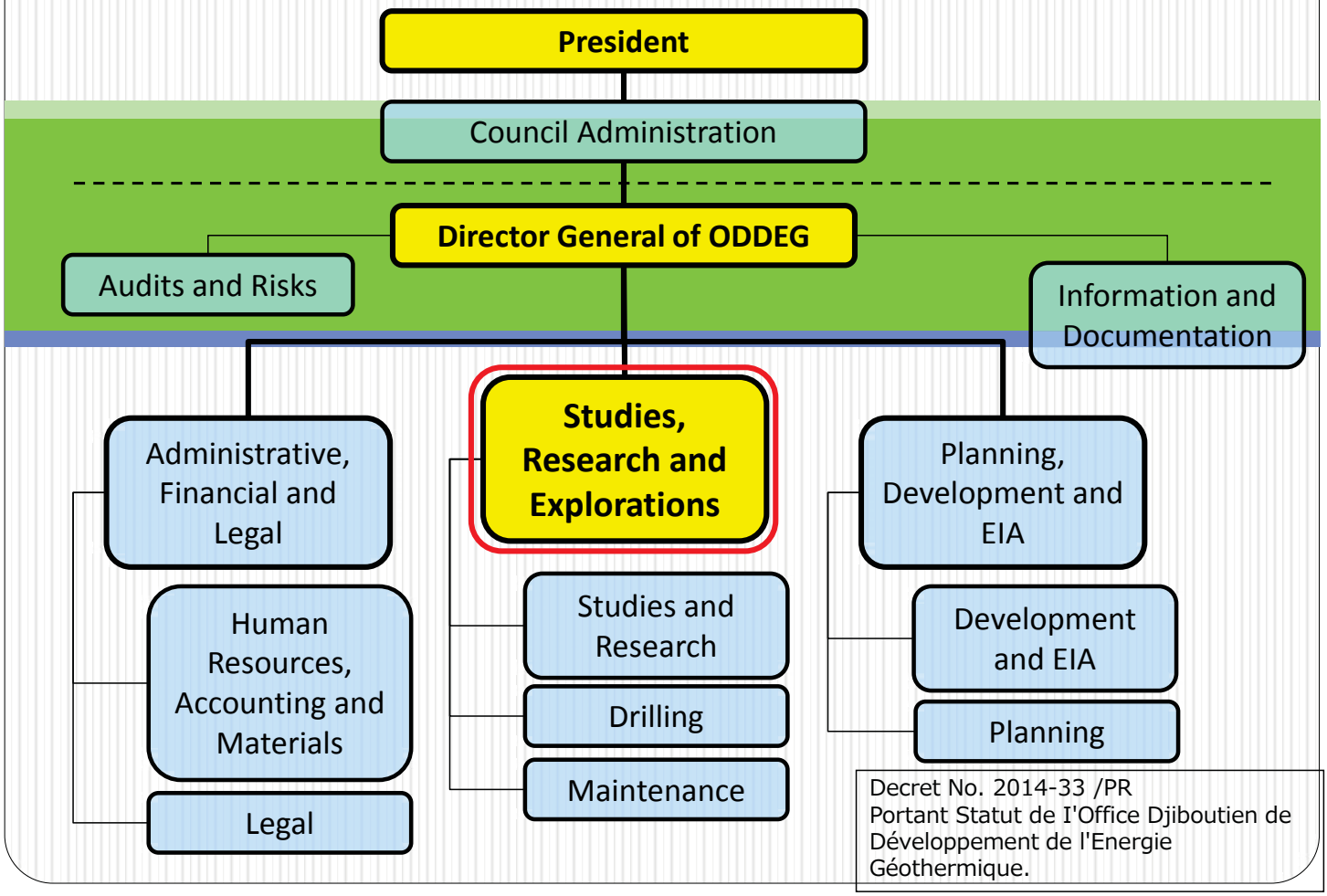
JICA-TEAM: NK, Geo-E, SRED

Institutional set-up: ODDEG

Organization in charge of Geothermal Development:

- ***ODDEG (Djiboutian Office for Development of Geothermal Energy) was newly established in 2014***
- Task: Up to resource confirmation (test wells), thereafter IPP is to be introduced.

ODDEG Organization, Decret No. 2014-33 /PR



Decret No. 2014-33 /PR
Portant Statut de I'Office Djiboutien de Développement de l'Energie Géothermique.

Officers already assigned to ODDEG

Officers of ODDEG (as of July 2014)

ODDEG	Former assignment	Person
Director	ISERST→ EdD	1
Geophysicist (Ph.D)	CERD	1
Geophysical Engineer	CERD	1
Physicist	CERD	1
Reservoir Engineer (Ph.D)	CERD	1
Technician	CERD	1
Drilling Engineer	MENR	3
Planning	MENR	1
Development	MENR	1
total		11

Corrected

ODDEG: Major Activities being conducted

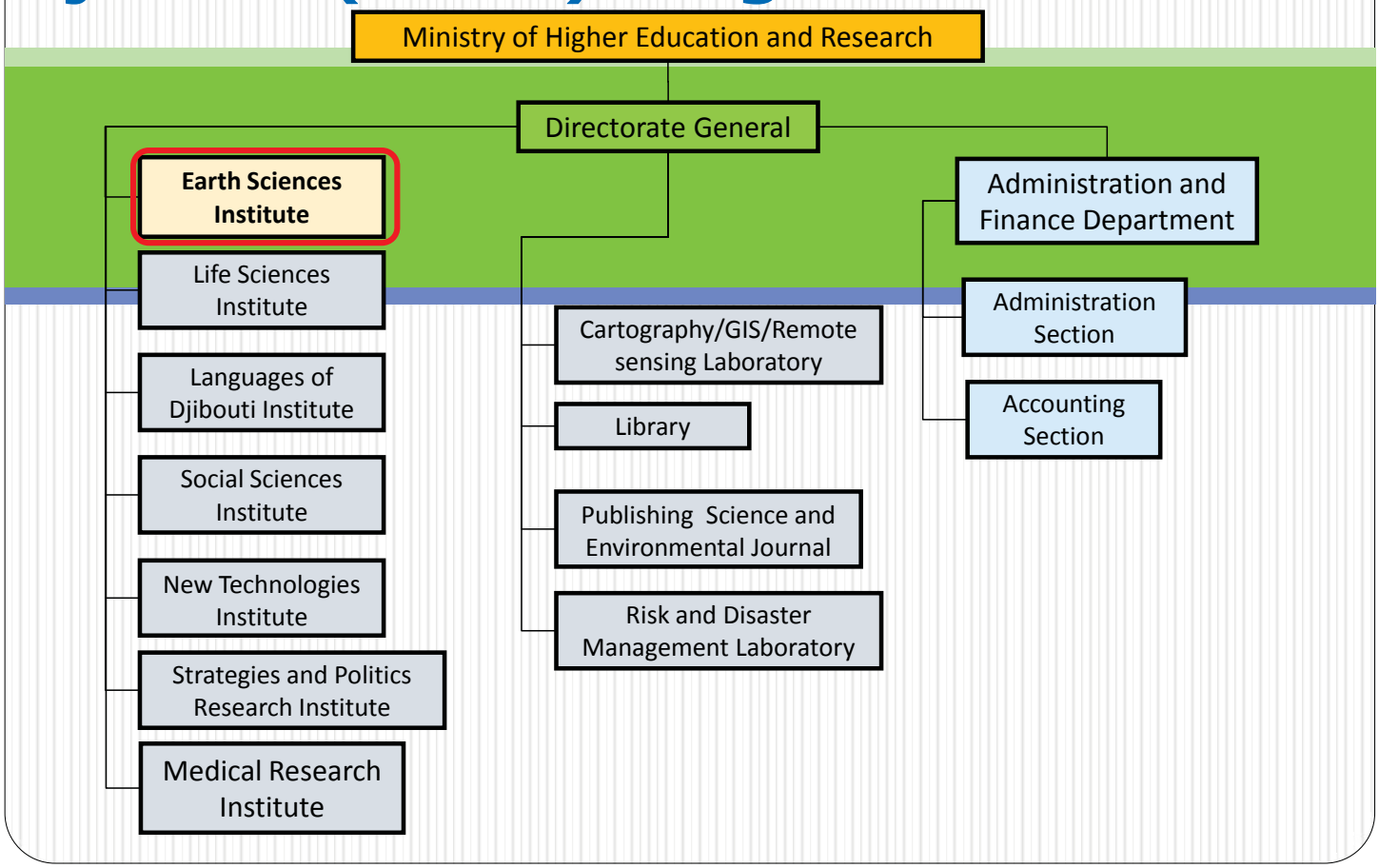
Major Activities being conducted:

- The ODDEG handles the preparation work for the Assal test well drilling project.
- Ten 10 officers were officially transferred to ODDEG (July, 2014). Among those, **five professionals were from CERD.**
- The new office of ODDEG is now being constructed at P.K. 20, where then "Agriculture zone" was located.
- A set of drilling rig is being procured from Turkey.

Institutional set-up: CERD

- ISERST was first established in 1979.
- ISERST was re-organized to CERD in 2001.
  - CERD is **the Djiboutian national researching center** consisting of seven (7) research institutes.
  - **Earth Science Institute** is the one that conducts scientific researches on earth sciences.

Center of Study and Research of Djibouti (CERD): Organization



CERD: Earth Sciences Institute

Earth Sciences Institute

- Hydrogeology
- Geology
- Geochemistry
- Geothermal
- Applied Geophysics
- New Energy and Energy Management
- Geophysical Observatory Of Arta

AS of June, 2014

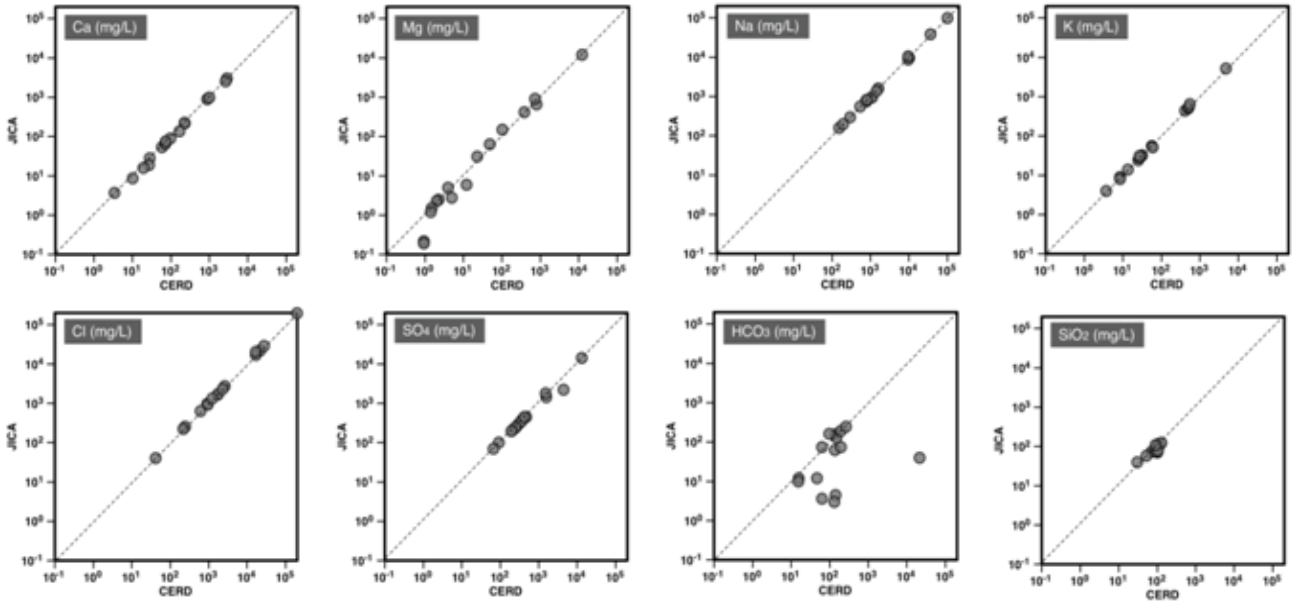
	PhD	Master	Bachelor	others	Subtotal
Geology	2		1		3
Geothermal	1				1
Metallogeny	1				1
Geophysics	1	2			3
Cartography		3			3
Risk Management		1			1
Hydrogeology	1	1		3	5
Geochemist	1	4		2	7
Seismology		1		3	4
Drilling				2	2
Total	7	12	1	10	30

CERD: Geochemical Equipment Available

	Equipment	Model	Nos.	Notes
1	GC-MS (Gas chromatography-mass spectrometry)	Agilent Technologies 7890A&5975C	1	
2	ICP-OES (Inductively coupled plasma optical emission	HORIBA AS500	1	
3	HPLC (High performance liquid chromatography)	DIONEX ICS3000	1	Ion chromatography
4	Spectrophotometer (UV-VIS)	Lab Medic UV-VIS 1129	1	
5	Spectrophotometer (VIS)	JENWAY 6310	1	
6	Spectrophotometer (FT-IR) (Fourier-Transform-InfraRed-spectroscopy photometer)	BRUKER ALPHA-P	1	
7	FL-AAS (Flama Atomic absorption spectrometer)	AGA LABS 1381	1	Na and K only measurable
8	FL-AAS (Flama Atomic absorption spectrometer)	GBC SB-906	1	Not operational (Hollow cathode lumps N/A)
9	pH. Conductivity meter	-	1	
10	Microscope	-	1	
Others available				
Muffle Furnace (1), Electric Balance (2), Ball Mill (1), Incubator for BOD (2), Oven (2), Deionizer (1), Ultra Wter Purifier (1)				

Major items of water analysis: Generally operational
Gas analysis: Not available
FL-AAS: Hollow cathode lumps not available
Consumables (gas, reagents, glassware): running short

Counter-checking: Lab analysis results of CERD and JICA



Most of analysis results are in good agreement.

CERD Geochemistry: Issues identified

- **Budgetary constraints** partially due to free-services to other governmental organizations,
- **Techniques to be enhanced**, using updated analysis technologies, and
- Technical supports was requested to JICA

CERD(➔ODDEG?): Geophysical survey equipment available

Survey	Type	Producer	Quantity	Status	Installed Year
MT	ADU-07e (Receiver)	Metronix	2	Good	2010, 2012
	MFS-06e (Induction Coil)	Metronix	6 (2 sets)	Good	2010, 2012
	EFP-06	Metronix	18 (3 sets)	Good	2010, 2012, 2014
TEM	Terra TEM	Monex GeoScope	1	Good	2012
Gravity	CG-5 Autograv	Scintrex	1	Good	2013
Electric	McOHM Profiler-4	OYO	1	Good	2014

"Metronix" is usually used **for academics purposes**.
Few Japanese industrial practitioners are familiar with it.

CERD: Geophysical survey conducted for geothermal

Survey	Type	Producer	Quantity
N. Goubet	TDEM	2010	32
	MT		30
Lac Abhe	TDEM	2011	35
	MT		34
	Gravity	2012	85
Obock	TDEM	2013	46
	MT		46
	Gravity		122

- **Pre-feasibility studies** were conducted for these prospectives.
- The studies were not made available for the JICA Team for review.

CERD (➔ODDEG) Geophysical: Issues identified

- Not sufficient computer software available for TEM and MT data analysis: i.e. computer software for 2D analysis not available,
- Review of the existing MT-survey results to be needed for further capacity enhancement,

Note: Japanese Consultants are not familiar with the Metronix MT survey equipment; for rather academic use than practical use.

CERD Geology: Requests to JICA

- CERD wishes to have the following equipment for geological analysis
  - Rock thin section making facility
  - Polarized microscope
  - Stereo microscope
  - XRD equipment
  - XDF equipment
  - Fluid inclusion analysis equipment

Donors' Assistance

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

JICA-TEAM: NK, Geo-E, SRED

Other Donors' Assistance

Organization	Programs		
UN-GTP	1. Past Record (1989 - 2013):		
		Short Course	20 person
		Six months Trainings	9 person
		Master degree course	1 person
		PhD	1 person
	2. This Year (2014)		
		Short Course	3 person
		Six months Trainings	2 person
		Master degree course	-
ICEIDA	1. Technical Training for drilling Supervision (2014 - 2016)		
	2. Knowledge improvement of geothermal exploration and review of studies at Arta and Gaggade		
	3. Improvement of management capacity of geothermal development		
GRMF	Application was submitted to GRMF for confirmation drilling at Hanle and the Nord Ghoubbet, but not accepted due to clerical reasons.		
WB, AfDB-ADF, SEFA, GEF, OFID, AFD, ESMAP	Test drilling at Asal-Fiale site - Project Managing Director - Engineering Consultant for technical supervision - Drilling contractor		

1. WB: World Bank
AfDB: African Development Bank
2. ADF: African Development Fund (AfDB)
3. SEFA: Sustainable Energy Fund for Africa implemented by AfDB
4. GEF: Grobal Environment Facility
5. AFD: Agence Francaise de Developpemet
GGDP: Global Geothermal Development Plan through ESMAP
6. ESMAP: Energy Sectore Management Assistance Program
7. OFID: OPEC Fund for Internationla Development

SEFA: A joint initiative of the Danish government and the Energy, Environment and Climate Change Department (ONEC) of AfDB
ADF: the concessional window of the AfDB Group.

Reconnaissance Survey and Analysis Conducted

General Purpose:

Verification/Confirmation of the existing data as a base data for possible future JICA assistance

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

Remote sensing

Photo: a giant travertine in Lac Abhe

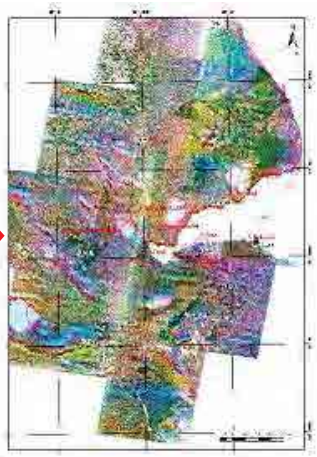
Remote Sensing Analysis
Analysis process (ASTER Image, PALSAR Image)

ASTER (RGB=B3, B2, B1)

+

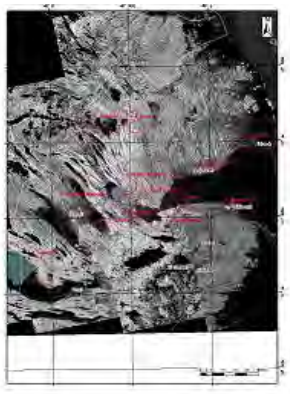
ASTER (RGB=B4, B6, B8)

⇒



ASTER (RGB=BB4/B6, B5/B6. B5/B8

Information on Alterations



PALSAR
(single polarized wave HH)

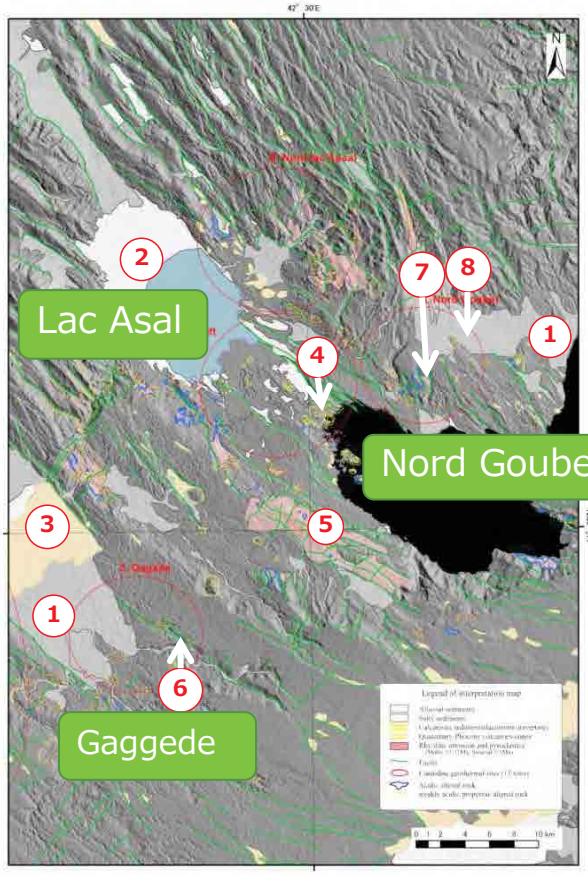
Information on Geo-morphology

Analyzed Images

DEM Relief

Geo-E, SRED

Remote Sensing Analysis

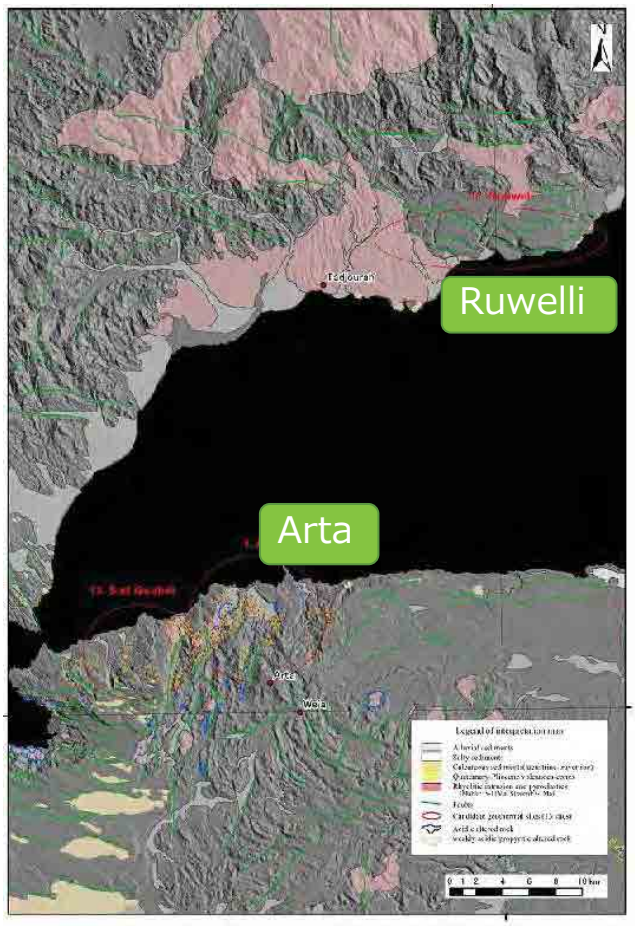


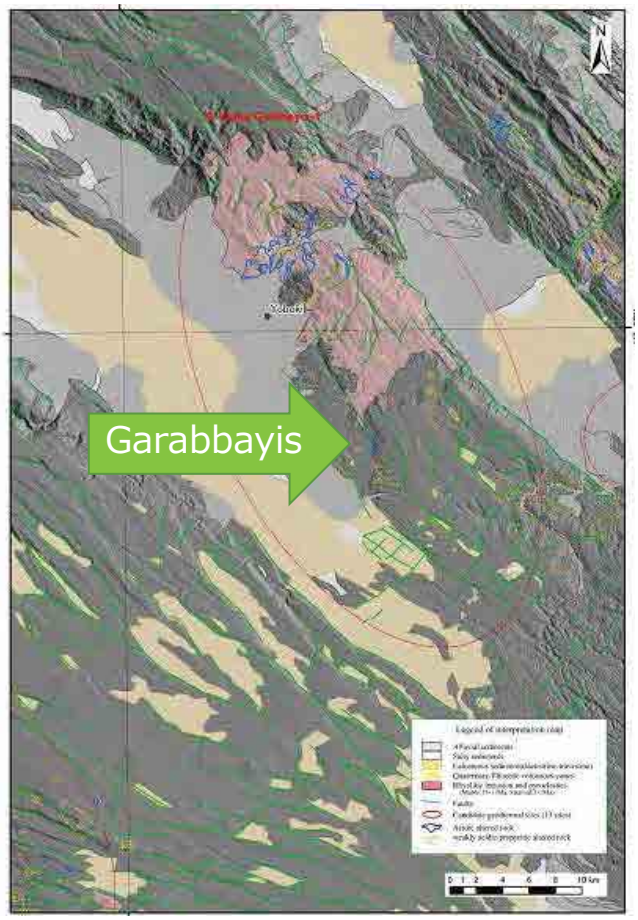
What are identified?

① Alluvial sediments
② Salty sediments
③ Calcareous sediments (Lacustrine-travertine)
④ Volcanic cones
⑤ Rhyolitic instruction and/or Pyroclastic
⑥ Faults
⑦ Acidic Altered spot
⑧ Weakly acidic propylitic altered spot

JICA-TEAM: NK, Geo-E, SRED

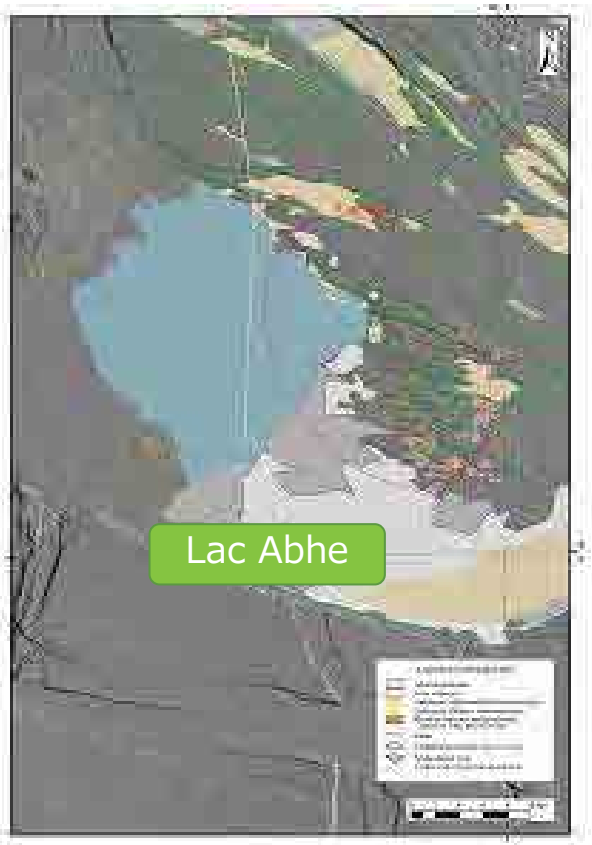
Remote Sensing Analysis





JICA-TEAM: NK, Geo-E, SRED

Remote Sensing Analysis



JICA-TEAM: NK, Geo-E, SRED

Remote Sensing
Summery of the Results

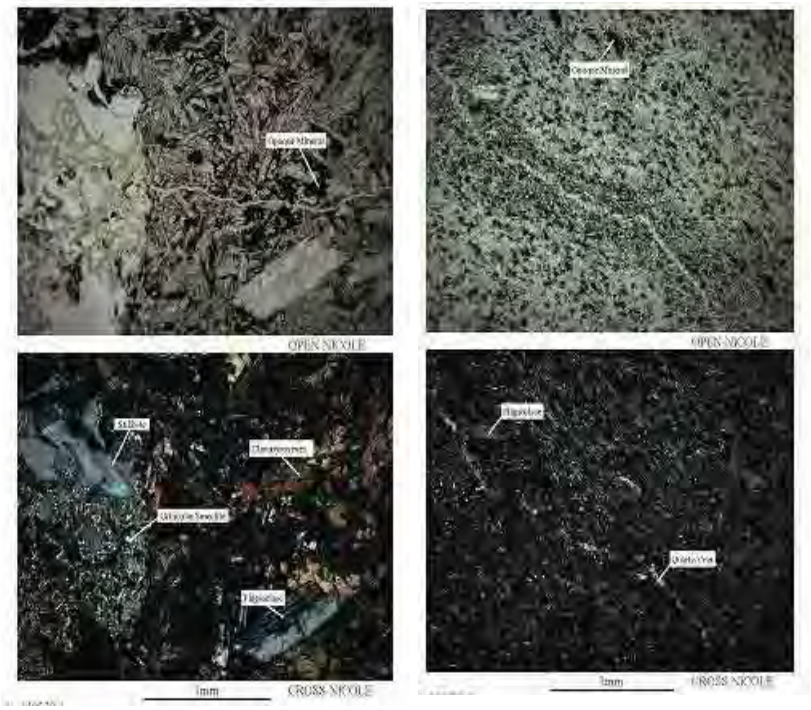
Acidic altered rock, or Weakly acidic altered rock;	Not particular alteration identified
Arta Asal Gaggade-Taassa Hanle-Garabbayia Lac Abhe Nord Goubet Nord Lac Asal Rouweli Sud Goubet	Djibouti-Awrofoul Dorra Obock Salalol-AsbouDara

Geology-Rock thin sections, XDR, XRF

Purposes:

- Observation of rock thin sections
  - Visual observations of rock minerals/textures
- XRF: X-Ray Fluorescence analysis
  - Rock classification (TAS: Total Alkaline-Silica)
- XRD: X-Ray Diffraction analysis
  - Alteration clay mineral identifications

Rock thin sections



- Left: Course grained Basalt (Garabbayis)
- Right: Andesite (N. Goubet-Anaale)

Visual observation of rock forming minerals/textures under polarized microscope

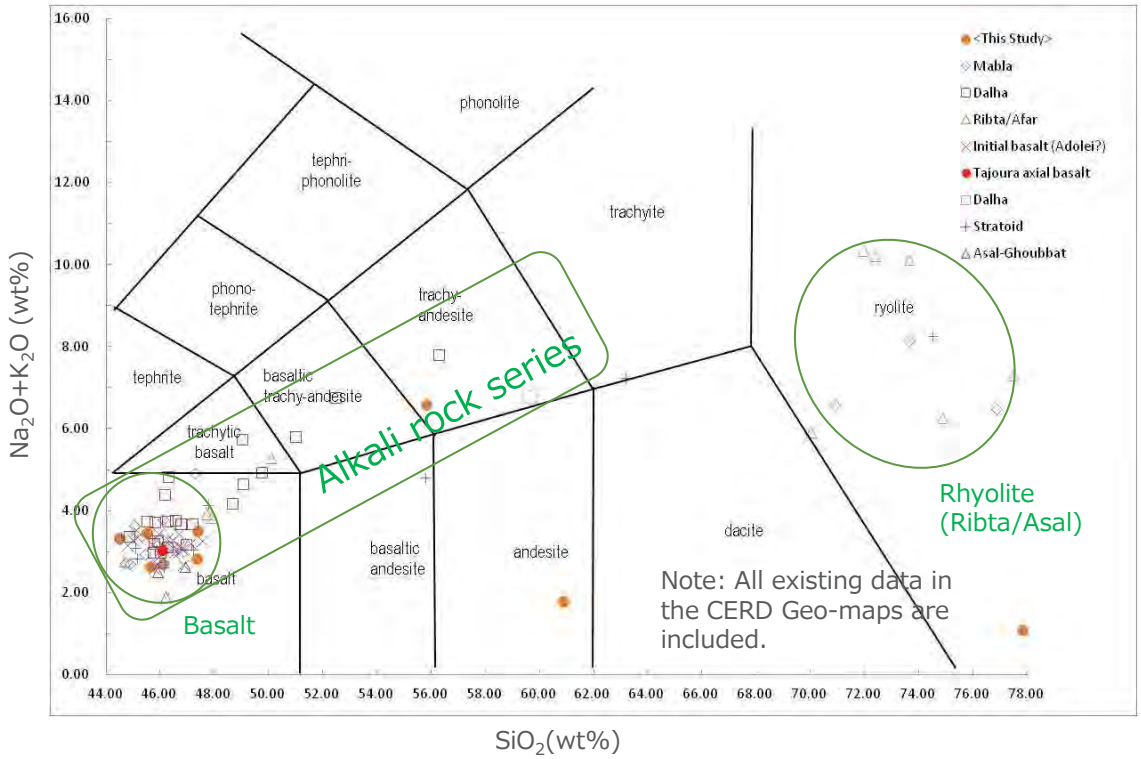
General Observations

- Alteration minerals are observed: such as Secondary Qz, Calcite, Zeolite, clay and others.

➔Rock samples have generally undergone alteration process.

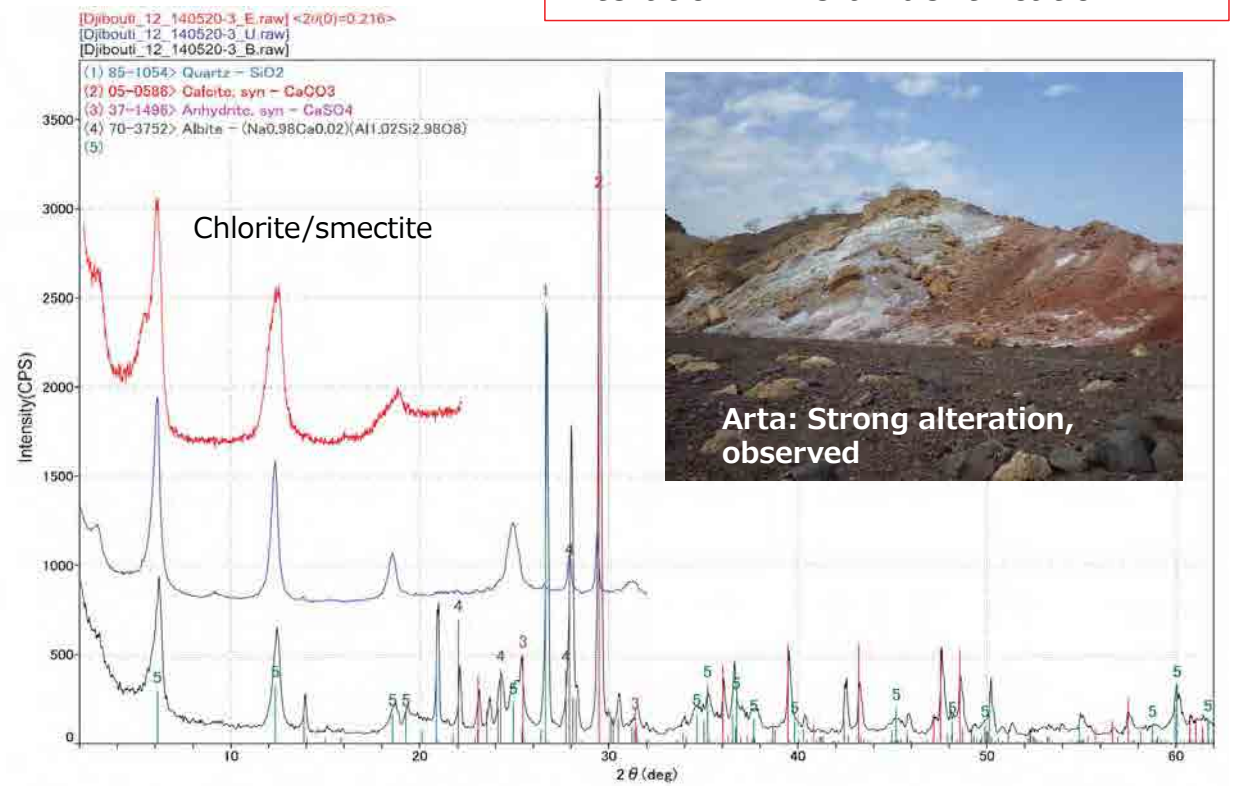
XRF : TAS Diagram

Rock Classification

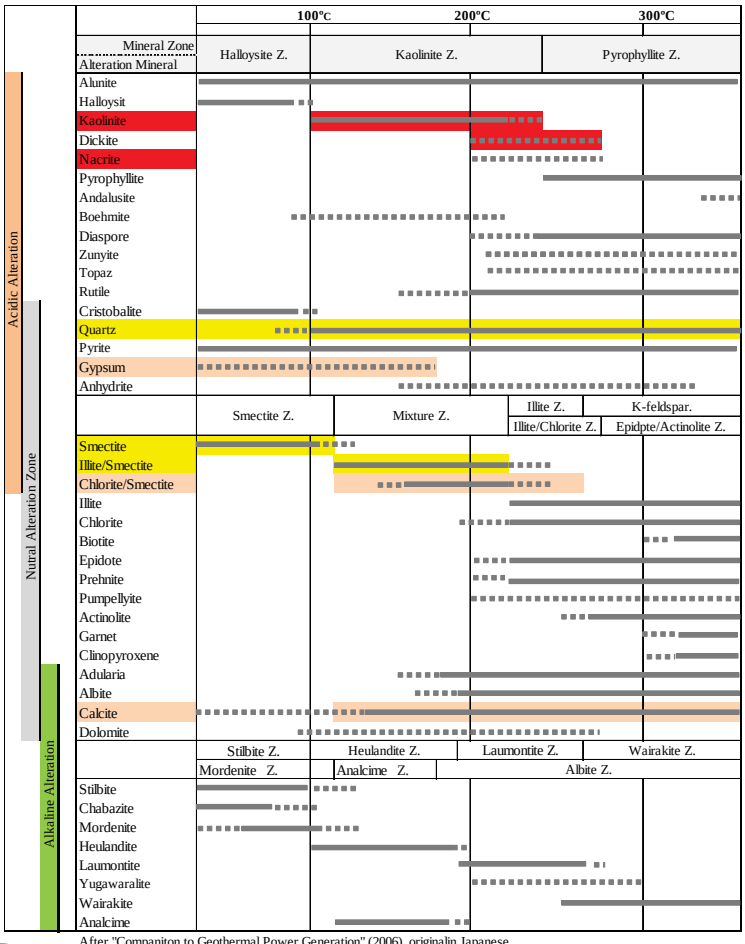


XRD: An example (Arta)

Alteration mineral identification



JICA-TEAM: NK, Geo-E, SRED



After "Companiton to Geothermal Power Generation" (2006), originalin Japanese

Geothermometer

Hydro-thermal alteration clays:

➔ a guide of past-underground temperatures under which the clays formed.

Clays Identified:

Kaolinite, Nacrite, Quartz, Smectite, Illite/Smectite, Gypsum, Calcite Chlorite/Smectite,

JICA-TEAM: NK, Geo-E, SRED

Summary – Clay Geothermometer

Site Name	Rock Name	Clay Mineral				Zeolite group			others			Notes	Clay mineral Formaion Temperature (℃)
		Sme	Mix.	Chl /Ser	Kao /Nac	Sti	Nat	Lau	Gyp	Cal	Qz		
N. Goubet	Calcite									○		Cal. only	-
N. Goubet	calcite									○		Cal. only	-
Arta	Gypsum	○		○					○	+	+	Smc-Chl, Gyp (vein)	150-200
Arta	Rhyolite?	○	○							○	+	Smc-Mix, Chl	100-150
Arta	White clay				○						○	Nac.	200-250
Arta	White clay		○		○						○	Nac. & mix.	200-250
Arta	Gypsum								○			Gyp. only	-
Asal (2km east)	White clay, layered			○						○		Chl-Cal	150-200
Lac Asal	White clay								○			Gyp. only	-
N. Goubet_Anaale	Andesitic	○									+	Smc-Qz	100-150
N. Goubet_Anaale	White vein, calcite	○								○	+	Smc-Cal	100-150
Hanle-Garabbayis	Basalt	○	○	○		○	○	○				Smc-Chl+Zeolite	150-200
Hanle-Yoboki (hill)	Rhyolite	○	○	○							○	Smc-Mix-Chl-Qz	150-200
Hanle-Yoboki (hill)	Rhyolite									+	○	Qz-Cal	-
Gaggade-Taassa	Reddish clay				○						○	Nac.	200-250
Gaggade-Taassa	Rhyolite	○								+	+	Smc-Cal-Qz	100-150

Smc: Smectite, Chl: Chlorite, Ser: Sericite, Sti: Stilbite, Lau: Laumontite,
Gyp: Gypsum, Qz: Quartz, Cal: Calcite, Mix: Mixed layer minerals

(Source: JICA Study Team)

Arta, Gaggade ➔ max. 200 – 250 ºC
Garabbayis ➔ max. 150 – 200 ºC

An evidence of hydro-thermal activities in the past.

Geochemistry

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

List of Samples

No.	Sampling location	Fumarolic gas	Hot spring	Well	Lake
1.	Arta	1	0	0	0
2.	Asal	1	1	0	1
3.	Djibouti	0	0	2	0
4.	Dorra	Failed to sample due to road damage			
5.	Gaggade	1	0	0	0
6.	Hanle	1	3	1	0
7.	Lac Abhe	0	2	0	1
8.	Nord Goubet	1	1	0	0
9.	Nord Lac Asal	Failed to sample due to no access way			
10.	Obock	0	2	0	0
11.	Rouweli	0	1	1	0
12.	Sakalol	0	1	0	0
13.	Sud Goubet	Failed to sample due to no access way			
Number of samples		5	11	4	2

Chemical Analysis Items

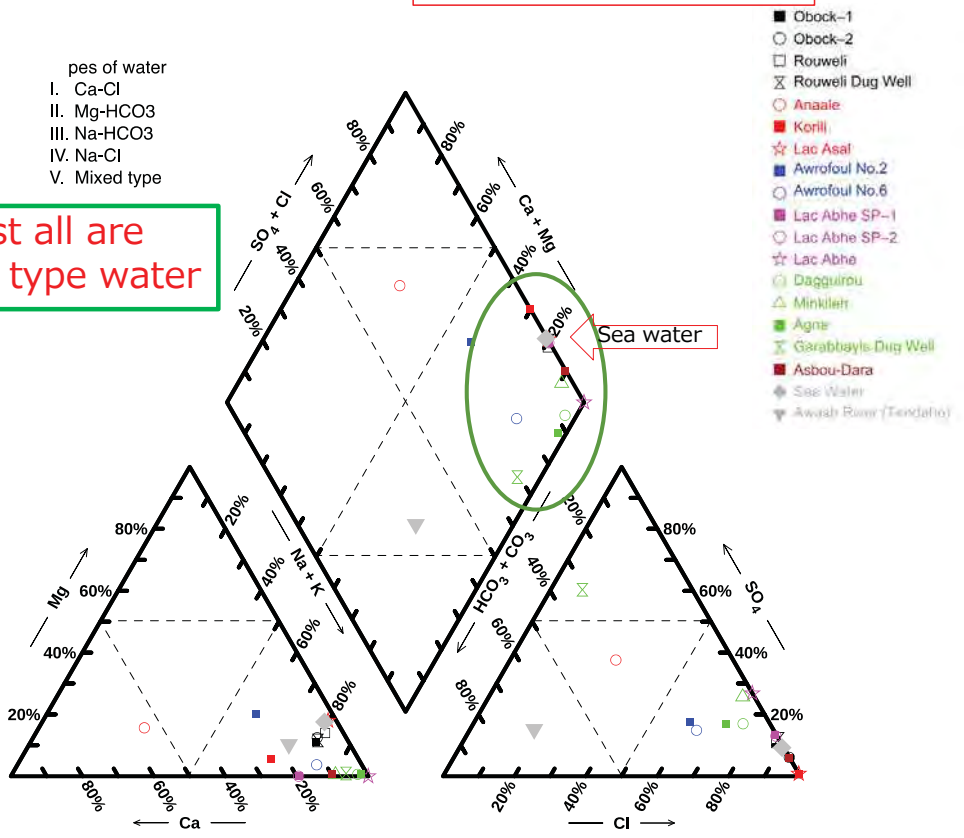
Fumarolic gas samples	H_2O, H_2S, CO_2, H_2, N_2, CH_4, O_2, He, Ar, $^3He/^4He$, $^4He/^{20}Ne$, and $\delta^{13}C(CO_2)$
Water samples	pH, Conductivity, Li, Na, K, Ca, Mg, Cl, SO_4, CO_2, H_2S, SiO_2, B, Fe, Al, As, Hg, δD, and $\delta^{18}O$

Trilinear Diagram

Water Classification

pes of water
I. Ca-Cl
II. Mg-HCO3
III. Na-HCO3
IV. Na-Cl
V. Mixed type

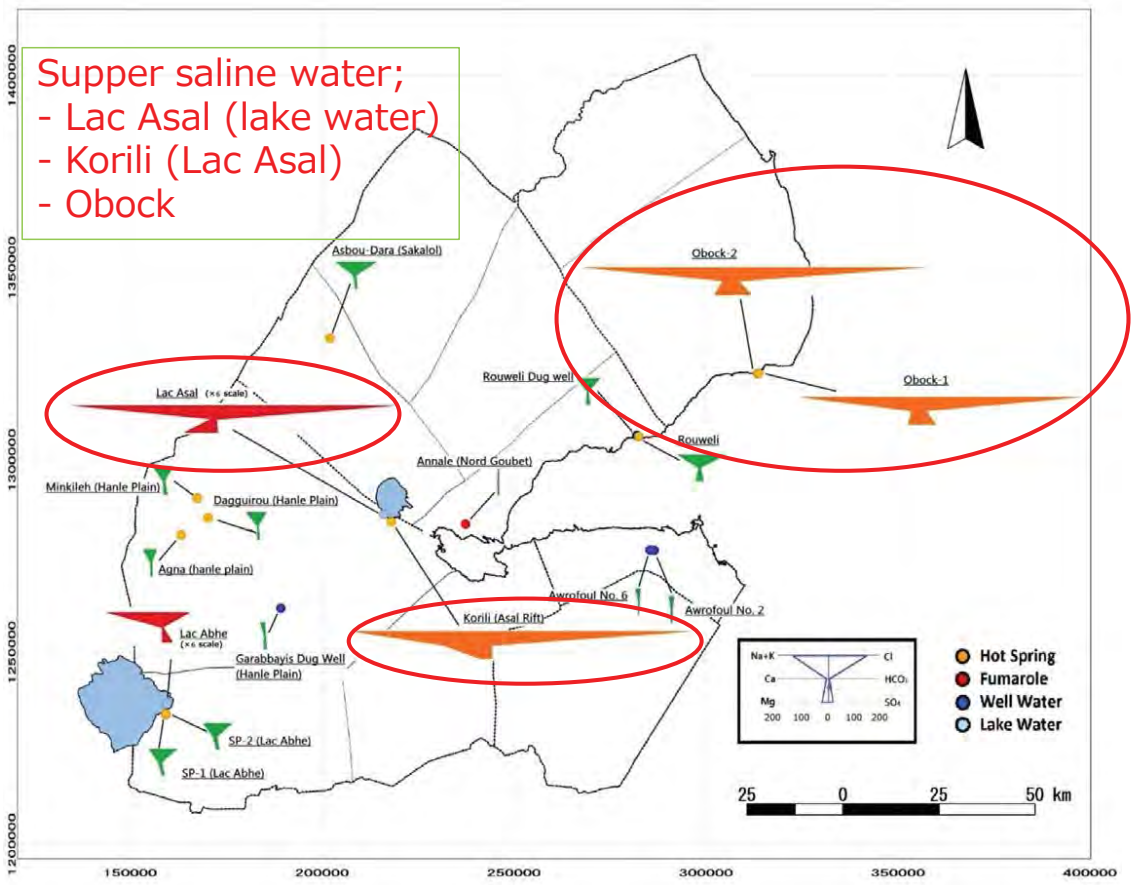
Almost all are Na-Cl type water



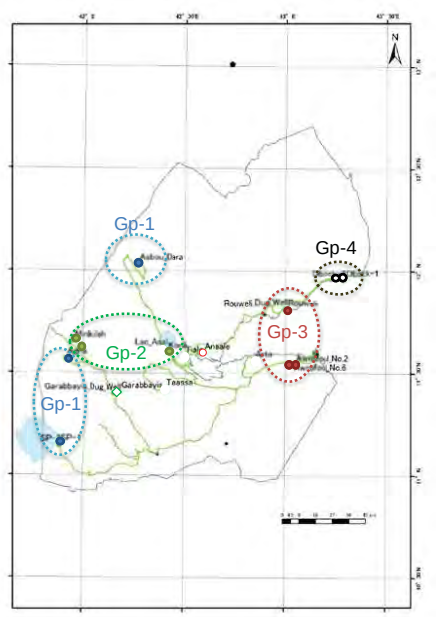
Stiff Diagram

Water Classification

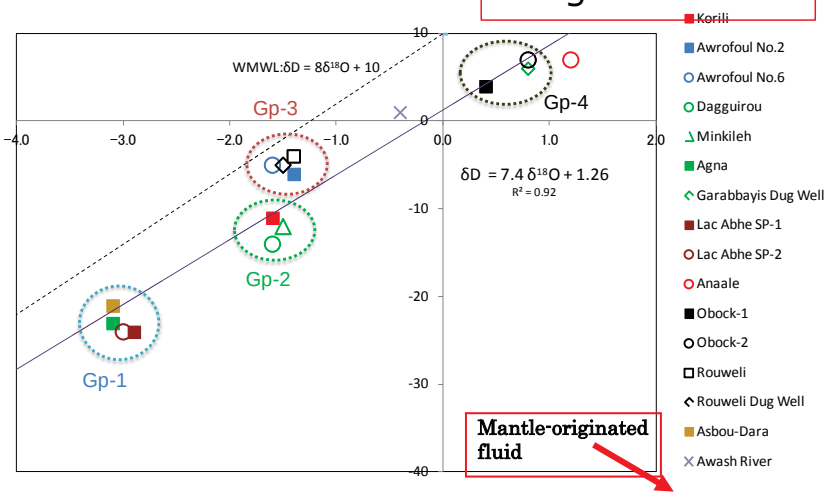
Supper saline water;
- Lac Asal (lake water)
- Korili (Lac Asal)
- Obock



δD-δ^{18}O Relationship (water samples)



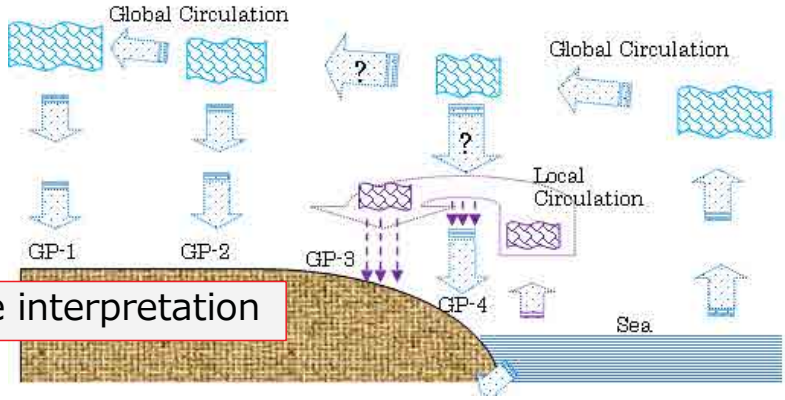
Origin of Water



Conclusions:

-- No mantle-origin

- Global and Local meteoric circulation ➔ One interpretation



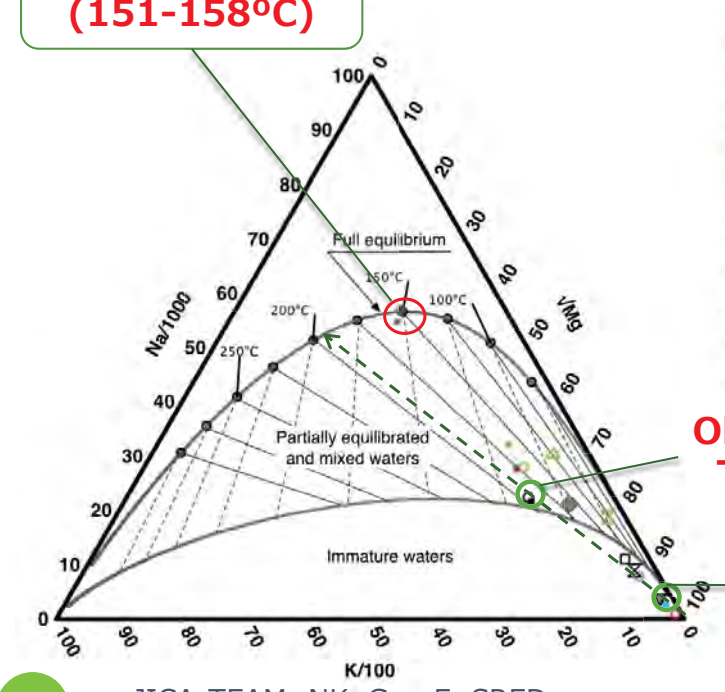
JICA-TEAM: NK, Geo-E, SRED

Na-K-Mg Ternary Diagram

Geochemical thermometer

Lac Abhe (151-158ºC)

Lac Abhe hot water:
Full equilibrium
➔Shallow source?
➔(Similar Temp. in depth)



- Agna
- Anaale
- Asbou-Dara
- Awrofoul No.2
- Awrofoul No.6
- Daggouirou
- Ethiopia_Awash R
- Grabbayis Dug Well
- Korili
- Lac Abhe SP-1
- Lac Abhe SP-2
- Minkileh
- Obock-1
- Obock-2
- Rouweli Dug Well
- Rouweli
- seawater

Obock, Awrofoul:
Partially equilibrium
➔ Deeper source?
➔ Higher Temp. in depth

Obock
T. Na-K: 195-197ºC

Awrofoul No.2 (Djibouti)
T. Na-K: 191ºC

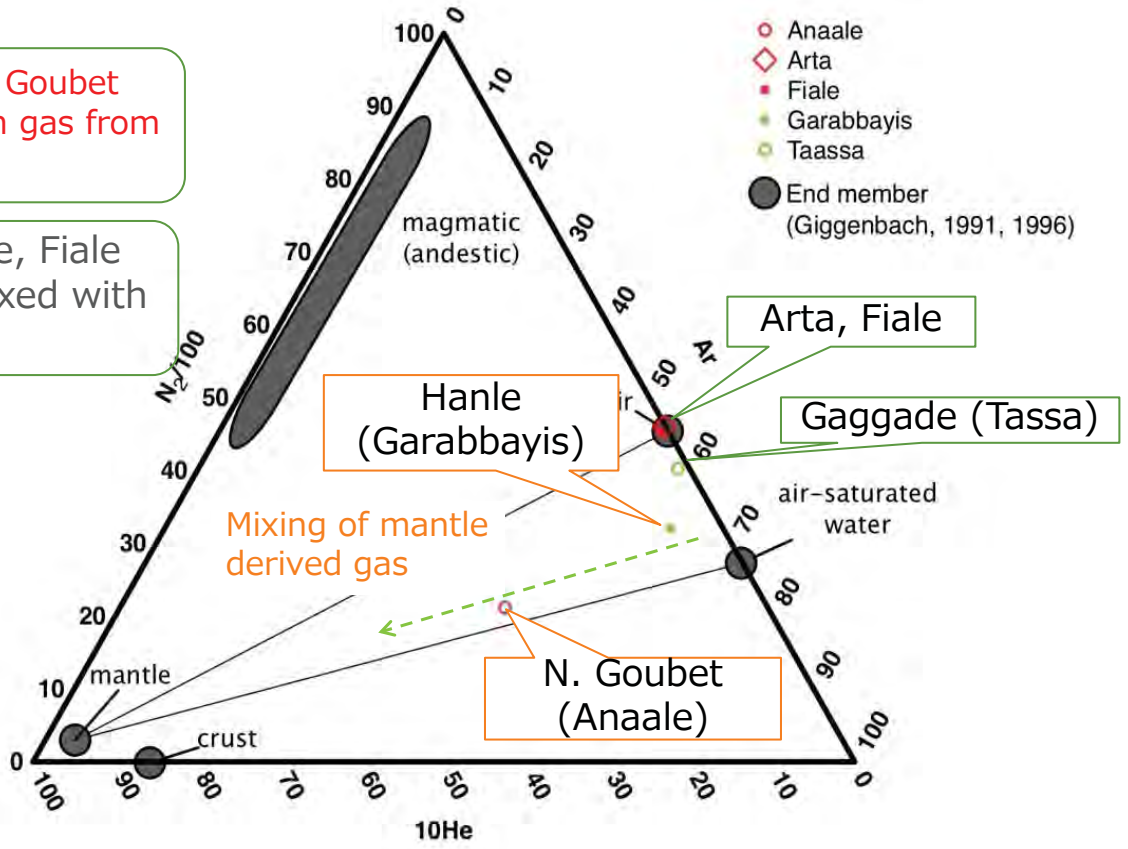
JICA-TEAM: NK, Geo-E, SRED

He-Ar-N_2 Ternary Diagram for Fumarolic Gas Samples

Mixture with mantle gas

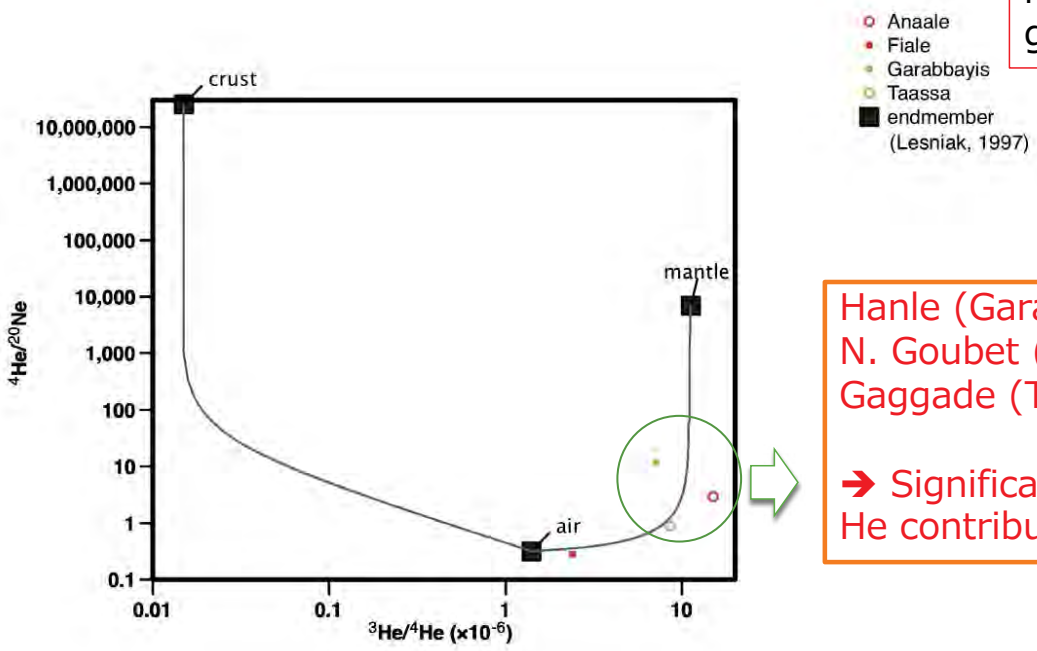
Garabbayis, N. Goubet
➔ mixture with gas from mantle

Atra, Gaggade, Fiale
➔ Largely mixed with air



Correlation of $^3He/^4He$ and $^4He/^{20}Ne$ for Fumarolic Gas Samples

Mixture with mantle origin gas



Hanle (Garabbayis),
N. Goubet (Anaale),
Gaggade (Tassa)

➔ Significant Mantle He contribution.

➔ Gas Geothermometer (T-CO_2/Ar, T-CH_4/CO_2)

Hanle(Garabbayis): 159-266ºC, N.Goubet (Anaale): 228-323ºC

Summary of Geochemical Survey

No.c	Sampling location	Fumarole		Water					Evaluation
		Feature	T CH_4/CO_2	Feature	Cond. (mS/m)	T chalcedony	T Na-K	T Na-K-Ca	
1.	Arta	Very weak (Air mixed)	-	-	-	-	-	-	-
2.	Asal	Slightly mixed with Mantle derived gas	-	Na-Cl, Meteoric	5,050	96	177	167	Prospective
3.	**Djibouti**	-	-	Na-Cl, Meteoric	121 -156	103 -119	169 -191	136 -143	Probability
5.	**Gaggade**	Significantly mixed with Mantle derived gas	-	-	-	-	-	-	Prospective
6.	**Garabbayis**	Significantly mixed with Mantle derived gas	266	-	-	-	-	-	Prospective
	Hanle	-		Na-Cl, Meteoric	283 -396	92 -103	126 -173	116 -165	
7.	Lac Abhe	-	-	Na-Cl, Meteoric	581 -582	115 -124	151 -158	130 -136	
8.	**Nord Goubet**	Significantly mixed with Mantle derived gas	323	-	-	-	-	-	Prospective
10.	**Obock**	-	-	Na-Cl, Meteoric	4,150 -4,820	90-93	195 -197	192 -193	Probability
11.	Rouweli	-	-	Na-Cl, Meteoric	896	79	160	152	
12.	Sakalol	-	-	Na-Cl, Meteoric	750	115	164	150	

Selection of Prospective Sites

- Survey on Natural Conditions Explained
  - Satellite Image Analysis
  - Geological Reconnaissance
    - Site survey
    - Rock Thin Section Observation
    - XRF
  - XRD analysis for Alteration Clay Identification
  - Geochemical Analysis

➔ Selection of prospective sites for a next step of survey.

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

Comparison of the Sites Surveyed

No.	Survey Site	Regional Gelogy	Geoth.l Alteration		Fumarolic Gas	Geochemical therm.	Evaluation	
		Geological Characteristic	Intensity	Temp. (℃)		Alkali Temp. (℃)		
1	Arta	Associated with Rhyolite	severest	max. 200-250	(Air mixed)	-	★Good	A-3
2	Asal_Fiale	Recent basaltic lava	-	-	Mixed with mantle origin gas	--	(★Good)	(Not for evaluation
	Asal_Koril		-	-	-	116-177	poor	-
3	Djiboubi_Awrofoul_No.2	Basalt	-	-	-	52-191	(★Fair)	C
4	Dorra	Basalt	Not accessible				(Not accessible)	
5	Gaggade_Taassa	Associated with Rhyolite	severest	Max. 200-250	Mixed with mantle origin gas	-	★good	A-1
6.1	Hanle-Garabbayis	Neighboring larger scale Rhyolite	severe	150-200	Mixed with gas of mantle origin $T(CH_4/CO_2)$=266	-	★good	A-1
6.2	Hanle-Dagguirou	Basalt	-	-	-	113-170	Poor	-
6.3	Hanle_Minkileh	Basalt	-	-	-	91-126	Poor	-
6.4	Hanle-Agna	Basalt	-	-	-	107-173	Poor	-
7	Lac Abhe	Basalt and lake deposit	-	-	-	136-158	Poor	-
8	Nord Goubet	Dotted rhyolite and andesite	fair	100-150	Mixed with gas of mantle origin $T(CH_4/CO_2)$=323 ℃	-	★good	A-2
9	Nord Lac Asal	Basalt	Not accessible				(Not accessible)	
10	Obock	Calcareous deposit	-	-	-	115-197	(★Fair)	B
11	Rouweli	Basalt	-	-	-	75-160	poor	-
12	Sakalol_Asbou-	Basalt	-	-	-	116-164	poor	-
13	Sud Goubet	Basalt	Not accessible				(Not accessible)	

WB

Prospective Sites Selected by Natural Conditions – 6 Sites

No.	Site	Regional Gelogy	Geoth.l Alteration		Fumarolic Gas	Geochemical therm.	Evaluation	
		Geological Characteristic	Intensity	Temp. (℃)		Alkali Temp. (℃)		
1	Arta	Associated with Rhyolite	Sever-est	max. 200-250	(Air mixed)	-	★Good	A-3
3	Djibouti_Awrofoul_No.2	Basalt	-	-	-	52-191	(★Fair)	C
5	Gaggade	Associated with Rhyolite	Sever-est	Max. 200-250	Mixed with mantle origin gas	-	★good	A-1
6.1	Garabbayis	Neighboring larger scale Rhyolite	Severe	150-200	Mixed with mantle origin gas $T(CH_4/CO_2)$=266℃	-	★good	A-1
8	Nord Goubet	Dotted Rhyolite and andesite	Fair	100-150	Mixed with mantle origin gas $T(CH_4/CO_2)$=323 ℃	-	★good	A-2
10	Obock	Calcareous deposit	-	-	-	115-197	(★Fair)	B

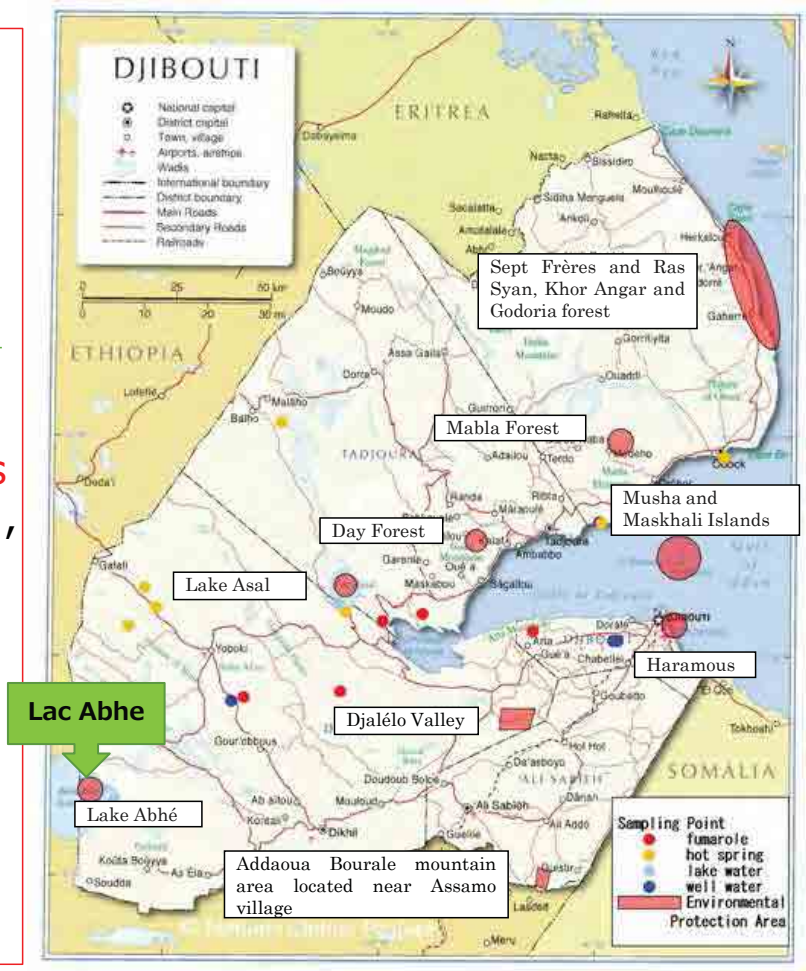
Socio-Environmental Review

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

Protected Area

- Nine (9) Protected Areas
- Demarcation of the protected areas is not established (except Djalélo Valley & Addaoua Bourale mountain area).
- Exploitation to be allowed in the protected areas depends on local conditions (types of zone in the area) , the zoning is now on preparation.
- Discussions with the Dept. of Environment are requested to confirm the possibility of the exploitation to be conducted.



EIA condition

- Procedure of EIA is written in Decree 2011-029/PR/MHUEAT,
- Drilling is a target of the EIA study,
- No Environmental Standards (currently they follow the international standards),
- No environmental consultant firm in Djibouti (there are a few individual experts) .

Proposed Site selection for A next step of JICA's assistance

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

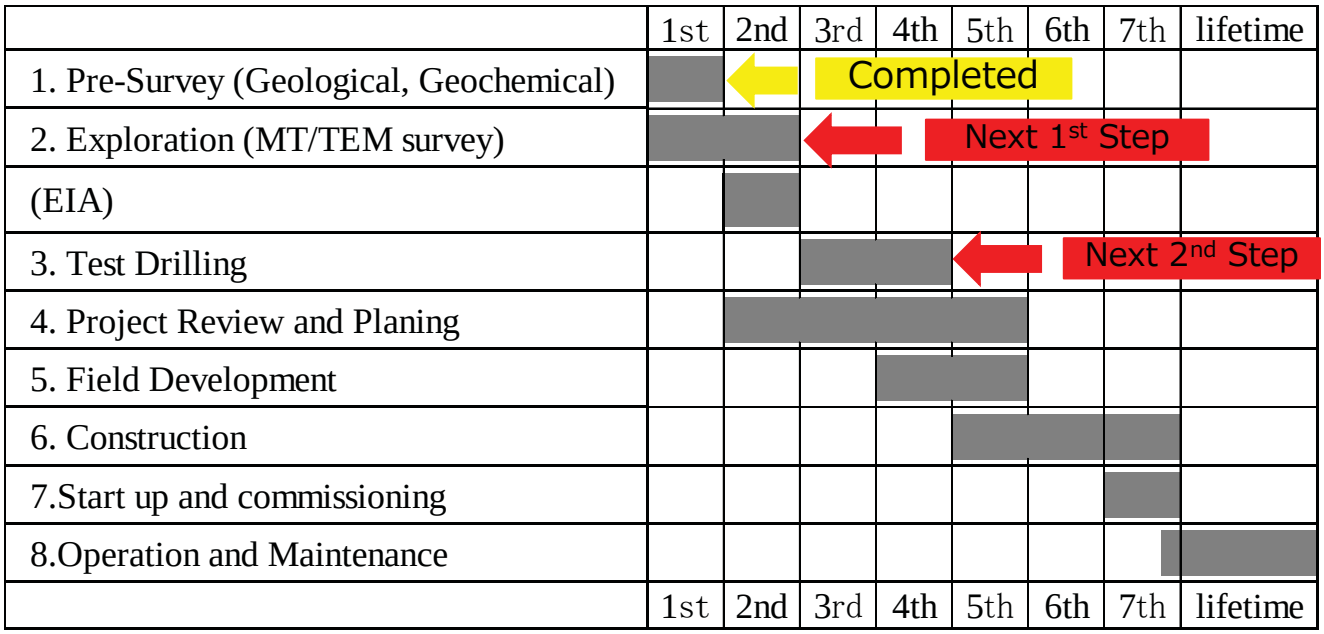
Site Selection for JICA Assistance

Site name	Geothermal Resources		Workability			Socio -Environment		Reference	Priority rec'nded
	Resources	CL (mg/L)	Accessi-bility	Landform	Well Drilling Water	Natural conditions	In-habitant	Distance to transmission line	
Garabbayis	☑ A-1	±1,000	C Fair	B Plain -ragged hill	☑ A Ground water in Hanle Plain	☑ A Barren	A none	45 km to Dikhil	**1**
Arta	☑ A-3	☑ D ±15,000	B Good	B Plain - ragged hill	C Sea	☑ A Out of a registered protection area	B a few	6 km to N.1	**2**
Nord Goubet	☑ A-2	☑ D ±15,000	C-D Poor-fair	C Plain - ragged hill	C Sea	☑ A Barren, Desolate	B a few	50 km to P.K. 51	**2**
Gaggade	☑ A-1	±5,000	☑ D Poor	☑ D Ragged hill	☑ A Ground water in Hanle Plain	☑ A Barren	A none	40 km to P.K 51	**3**
Obock *	B	5,000 - 40,000	A Excellent	A plain, costal	C Sea	B Coastal	near town	Isolated	**4***
Djibouti	C	±5,000	A Excellent	A Plain	C Sea	-	-	-	**5**
Lac Abhe	-	±5000	C Fair	A Plain	C Lac Abhe	☑ D Registered	B a few	75 km to Dikhil	**-**

☑: Conditions that special considerations are given for prioritization

Obock *: Survey of a next stage, separately from survey for a flash type may be recommended if a binary type is considered.

Overall time schedule up to Start up – 6 years at least

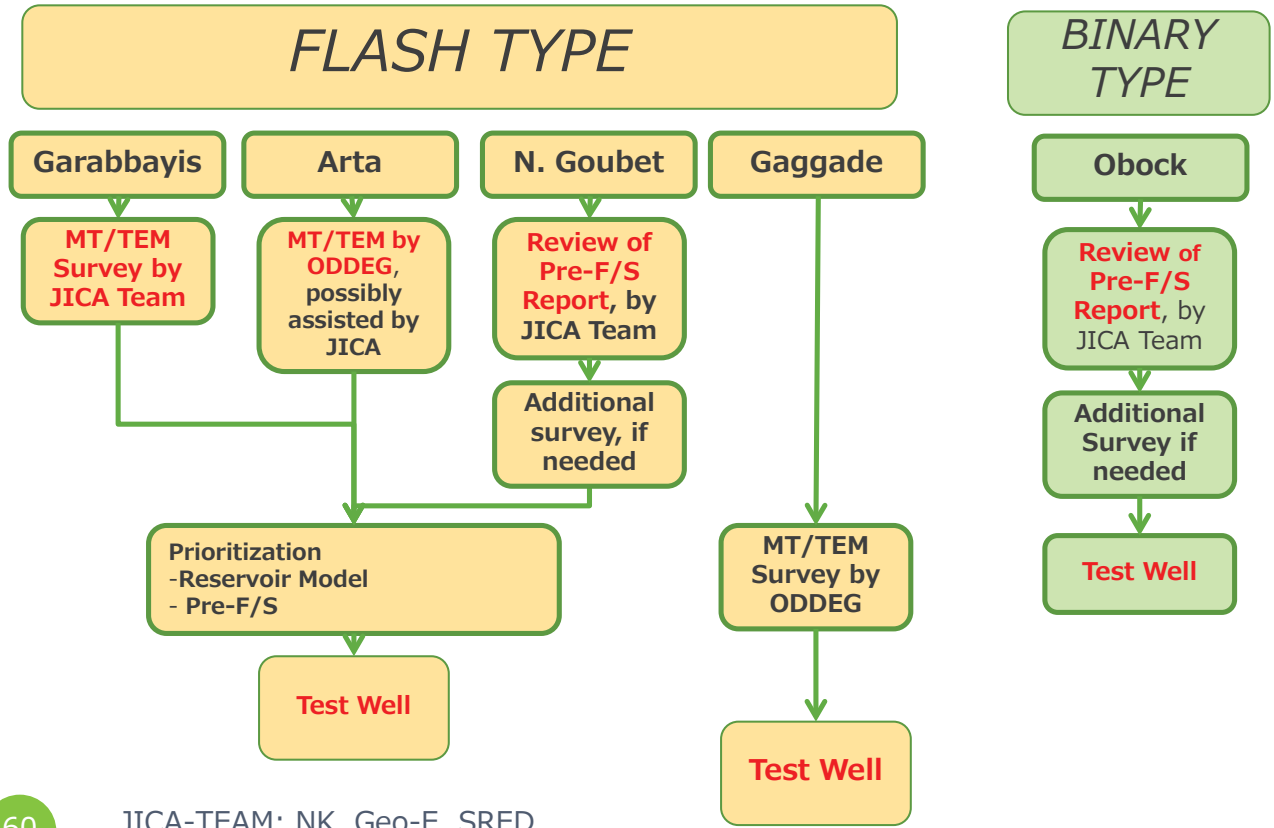


Proposed Approach up to Test drilling

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

Proposed approach up to test well drillings



Recommendations

1. In **Garabbays** and **Arta**, **MT/TEM survey** shall be conducted, ASAP;
2. For **N. Goubet**, the **Pre-feasibility study** shall be reviewed for comparison with Garabays and Arta, ASAP;
3. In **Gaggade**, **MT/TEM survey** may be conducted, thereafter;
4. For **Obock**, the **Pre-feasibility study** shall be reviewed for consideration of Binary development, ASAP;
5. In *(a)* priority site/*s*, **test well drillings** shall be implemented, ASAP

Way Forward: General Issues

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

Overall time schedule up to commissioning – 6 years at least

ODDEG

	1st	2nd	3rd	4th	5th	6th	7th	lifetime
1. Pre-Survey (Geological, Geochemical)								
2. Exploration (MT/TEM survey)								
(EIA)								
3. Test Drilling								
4. Project Review and Planing								
5. Field Development								
6. Construction								
7.Start up and commissioning								
8.Operation and Maintenance								
	1st	2nd	3rd	4th	5th	6th	7th	lifetime

IPP ?

General issues for geothermal development – Capacity required

- **Exploration stage, and Test Well drilling stage**
  - **MT/TEM survey (ODDEG)**
    - Field survey, 2D analysis
  - **Gradient/slim holes and test wells**
    - Drilling supervision
    - Well geology
    - Well geochemistry
    - Well logging
    - EIA
  - **Reservoir modeling**
  - **Reservoir potential assessment**
  - **(Pre-)feasibility study**
- **Procurement of contractors (ODDEG):**
  - Drilling
  - Civil work
  - Material supply
  - Supervisory consultant

Recommendations

1. **Institutional set-up shall be addressed with;**
   1. Clearer goal of ODDEG,
   2. Clearer work allocations among governmental organizations,

To attract subject-focused donors' attentions, particularly for capacity building!

Urgent Requirement of Personnel for ODDEG (Suggested)

Urgent requirement of Personnel for ODDEG (Suggested)

	Position	Assigned	Desirable	Balance
1	Director General	1	1	0
	(Acting Director)	0	1	1
2	Information and Documentation	0	2	2
3	Audits and Risks	0	1	1
4	Study, Research and Explorations			
	Studies and Research			
	Geologist	0	3	3
	Geophysicist (Ph.D)	1	1	0
	Geophysical Engineer	1	1	0
	Physicist	1	1	0
	Reservoir Engineer (Ph.D)	1	1	0
	Reservoir Engineer	0	1	1
	Geochemist	0	2	2
	Technician	1	3	2
	Drilling			
	Drilling Engineer	3	3	0
	Civil Engineer	0	2	2
	Maintenance			
	Mechanical Engineer	0	2	2
5	Administrative, Financial and Legal			
	Human Resources, Accounting and Materials			
	Human Resources	0	1	1
	Accounting	0	1	1
	Material	0	1	1
	Legal	0	1	1
6	**Planning, Development and EIA**			
	Development and EIA	**1**	**2**	**1**
	Planning	**1**	**2**	**1**
	Total	11	33	22

Corrected

Data base

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

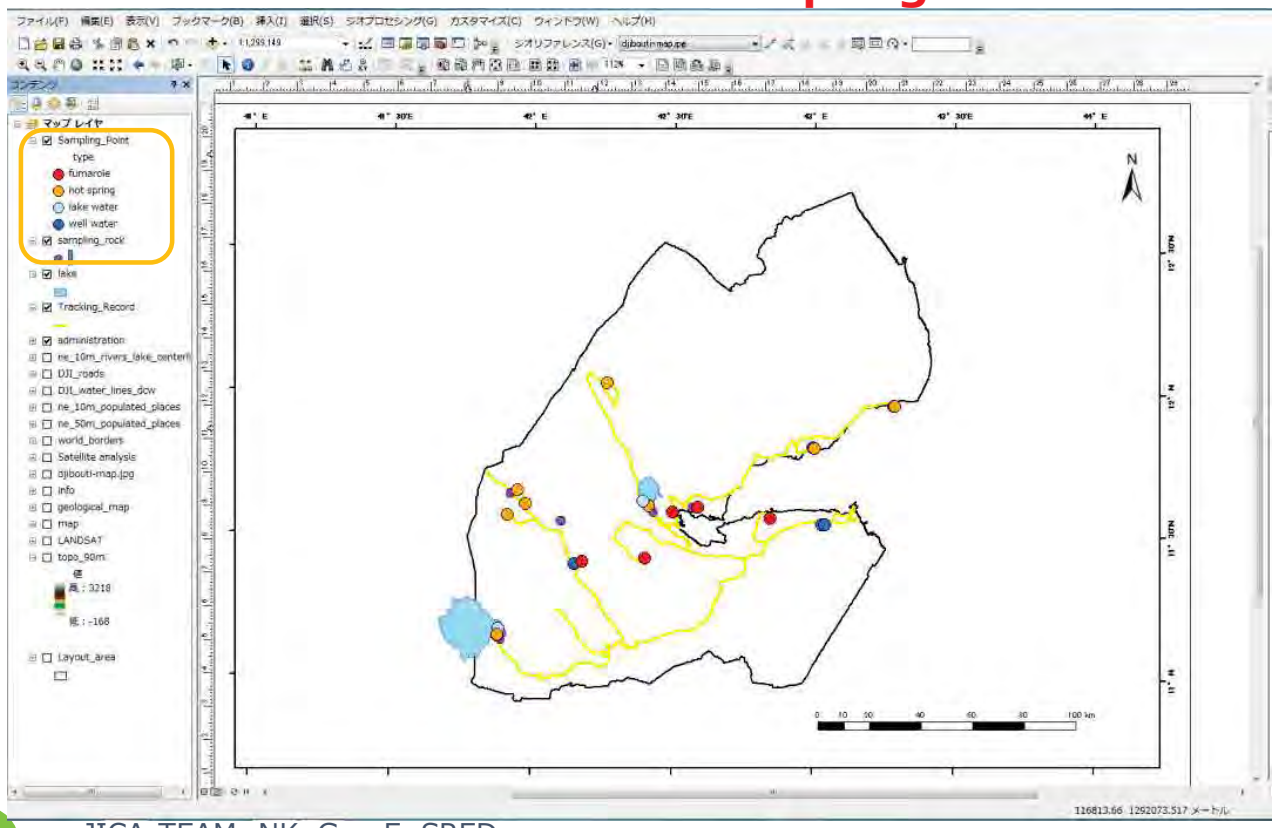
Data Information

The following information was compiled for GIS database.

- **Site survey information**
  - Sampling points, Track record of the survey, Delineation of protection zones.
- **Information from in-door analysis and laboratory analysis**
  - Satellite Imagery analysis, Geochemical analysis and geological analysis.
- **Existing information**
  - Figures (Geological maps, Rainfall distribution map, etc) and Positional information with attribute data
- **Basic information**
  - International borders, district boarders, topographic map (90 m mesh), etc.

GIS Data base

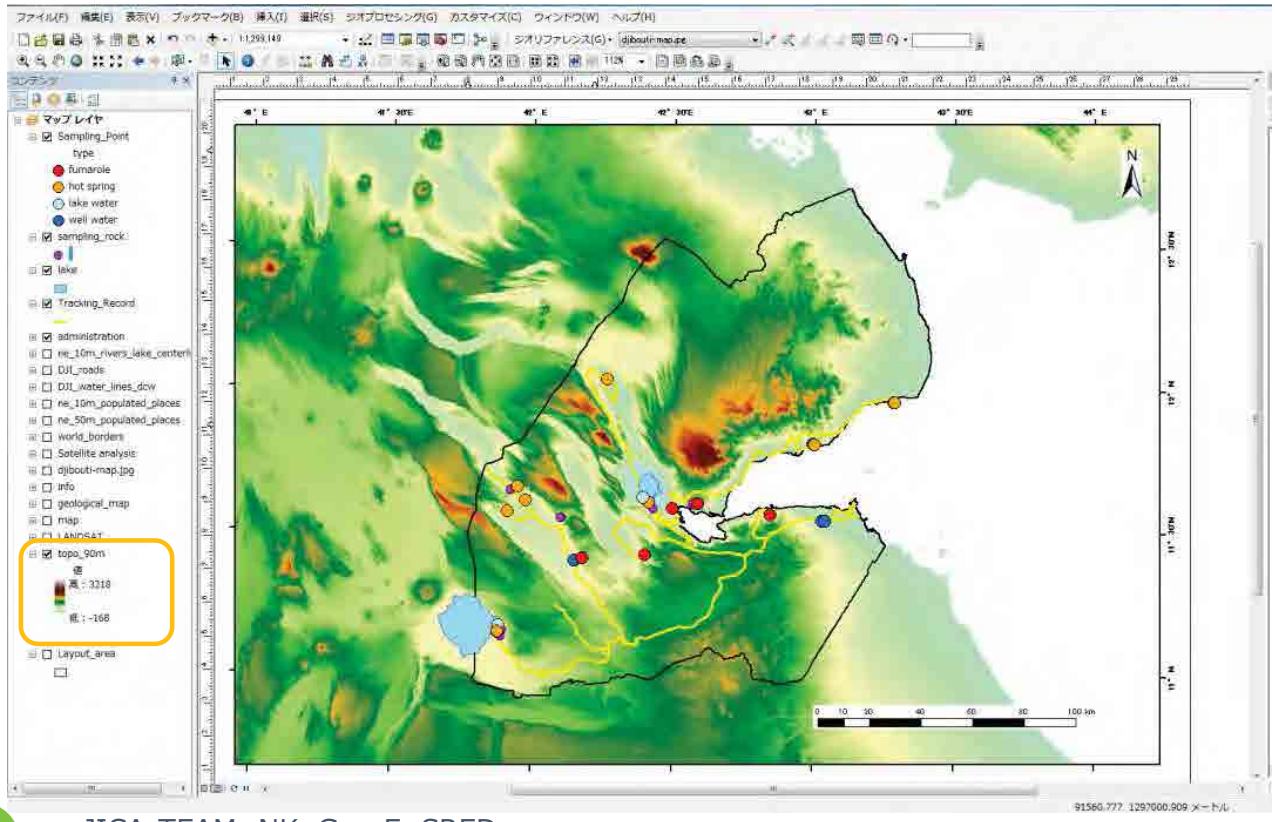
Sampling Information



JICA-TEAM: NK, Geo-E, SRED

GIS Data base

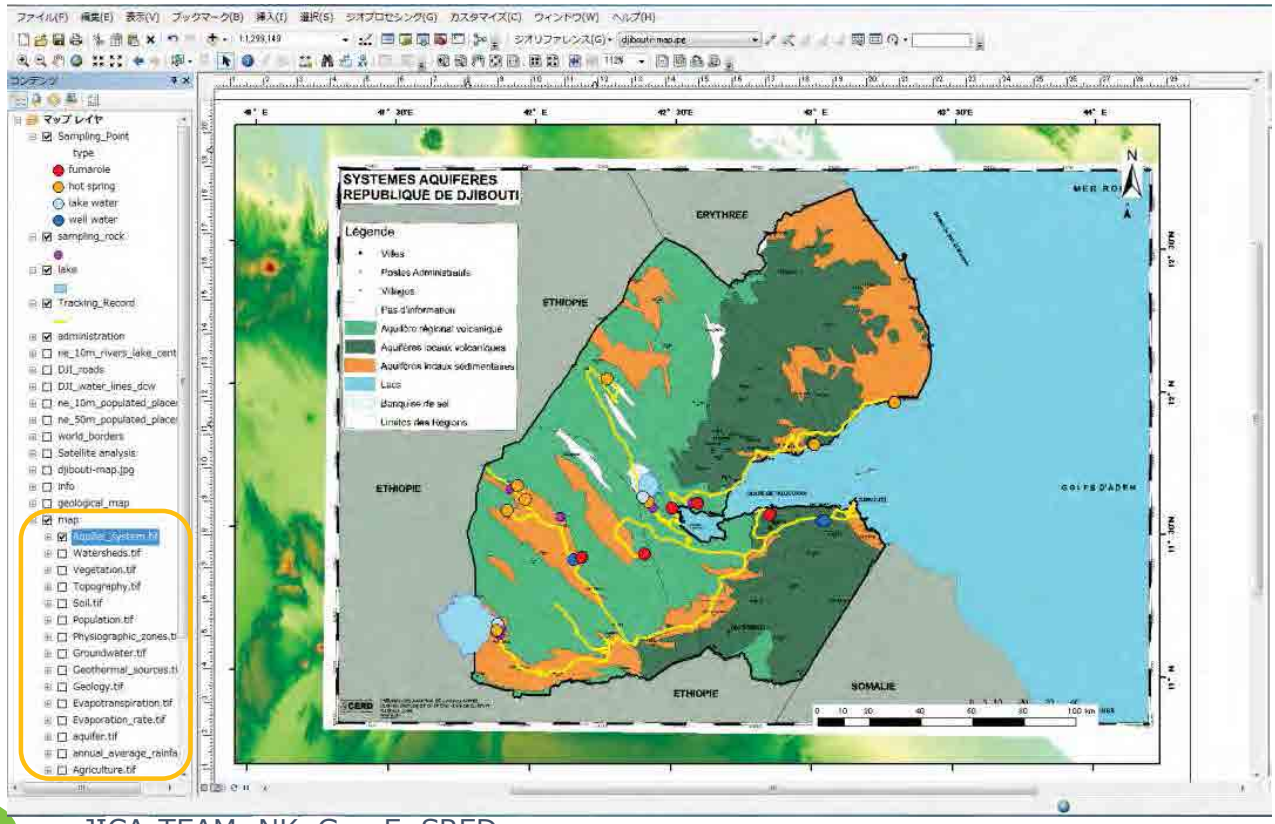
Topographical Information



JICA-TEAM: NK, Geo-E, SRED

GIS Data base

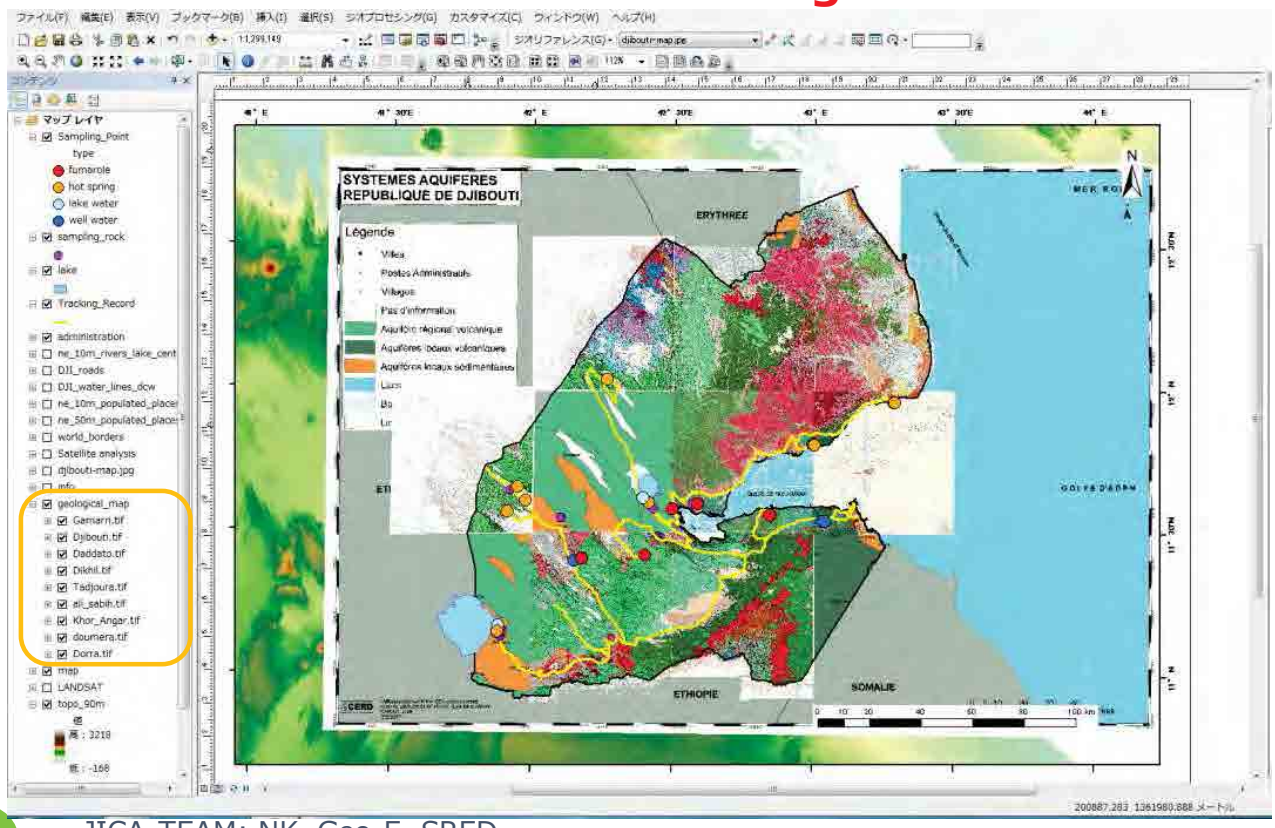
Collected Information



JICA-TEAM: NK, Geo-E, SRED

GIS Data base

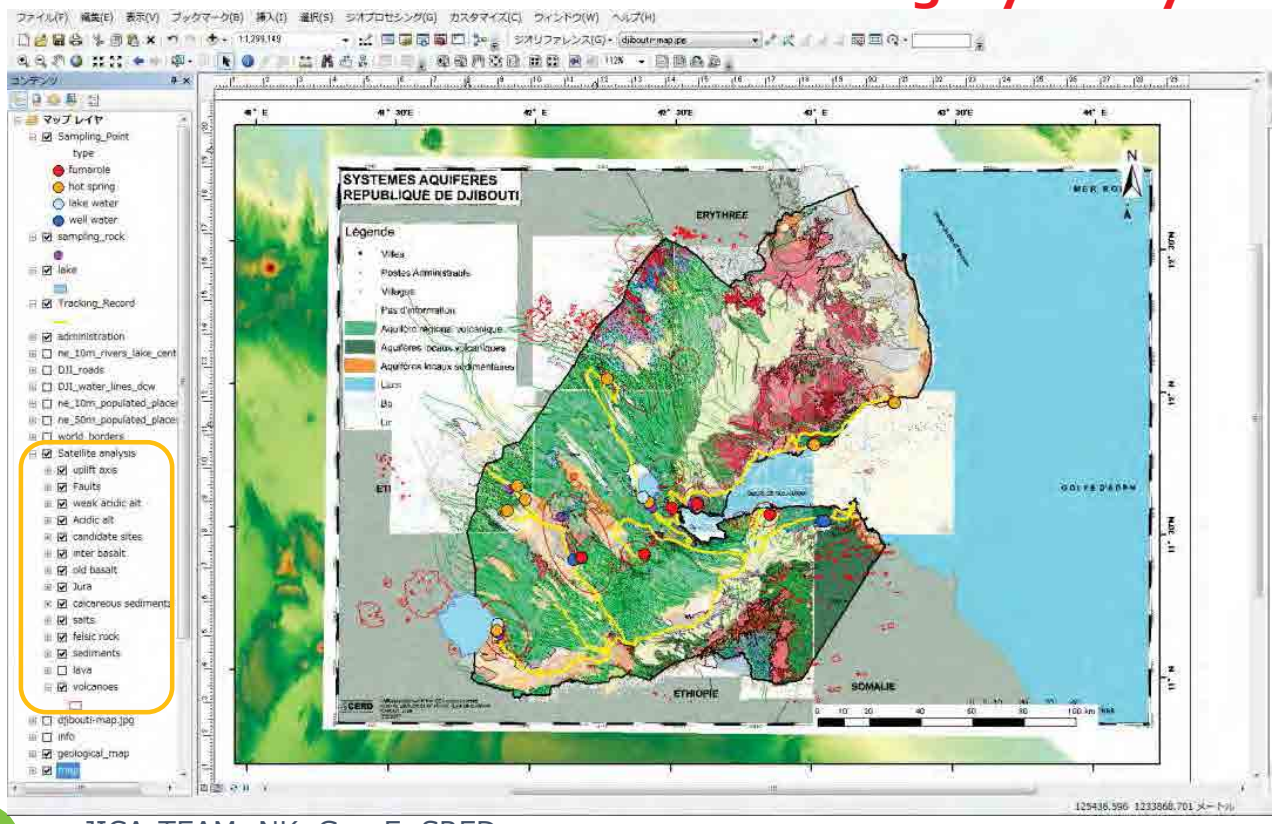
Geological Information



JICA-TEAM: NK, Geo-E, SRED

GIS Data base

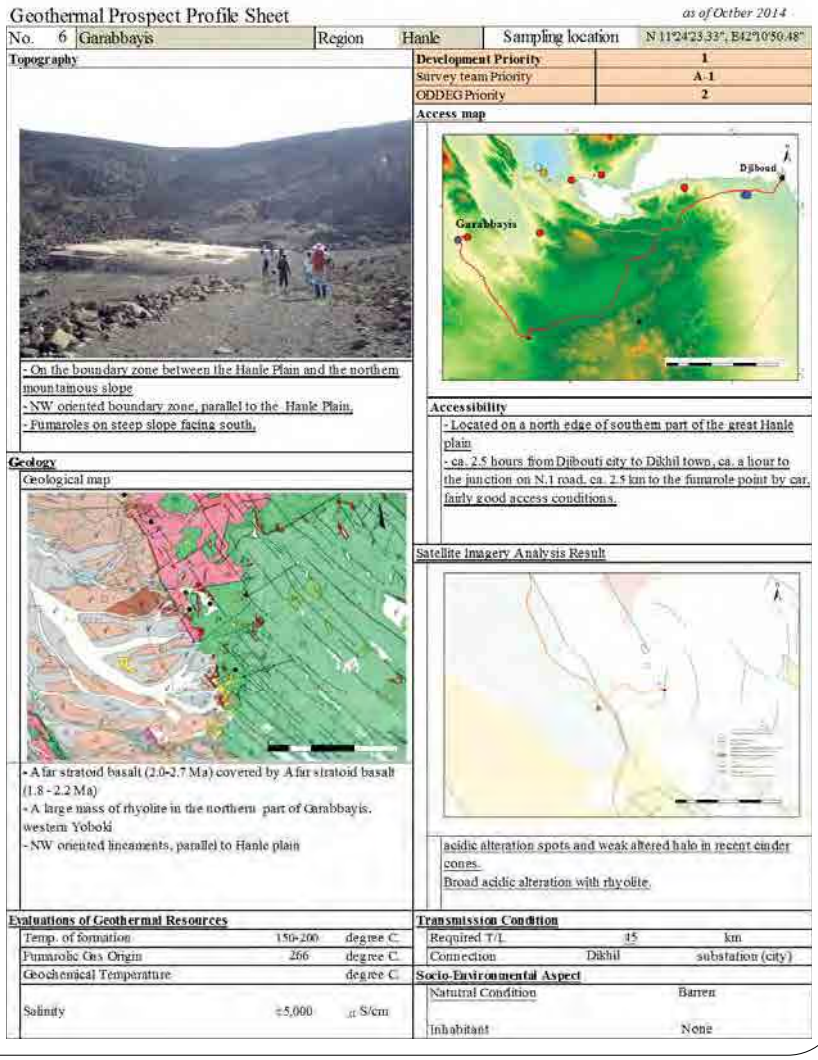
Satellite Imagery Analysis



JICA-TEAM: NK, Geo-E, SRED

Geothermal Profiling Sheet

- We prepared the profiling sheets based on the GIS database and the results of the priority selections.



Geothermal Prospect Profile Sheet — as of October 2014

No. 6	Garabbayis	Region	Hanle	Sampling location	N 11°24'23.33", E42°10'50.48"

Topography

- On the boundary zone between the Hanle Plain and the northern mountainous slope
- NW oriented boundary zone, parallel to the Hanle Plain.
- Fumaroles on steep slope facing south.

Development Priority	1
Survey team Priority	A-1
ODDEG Priority	2

Access map

Djibouti
Garabbayis

Accessibility

- Located on a north edge of southern part of the great Hanle plain
- ca. 2.5 hours from Djibouti city to Dikhil town, ca. a hour to the junction on N.1 road, ca. 2.5 km to the fumarole point by car, fairly good access conditions.

Geology

Geological map

- A far stratoid basalt (2.0-2.7 Ma) covered by A far stratoid basalt (1.8 - 2.2 Ma)
- A large mass of rhyolite in the northern part of Garabbayis, western Yoboki
- NW oriented lineaments, parallel to Hanle plain

Satellite Imagery Analysis Result

acidic alteration spots and weak altered halo in recent cinder cones.
Broad acidic alteration with rhyolite.

Evaluations of Geothermal Resources

Temp. of formation	150-200	degree C.
Fumarolic Gas Origin	266	degree C.
Geochemical Temperature		degree C.
Salinity	÷5,000	μ S/cm

Transmission Condition

Required T/L	45	km
Connection	Dikhil	substation (city)

Socio-Environmental Aspect

Natutral Condition	Barren
Inhabitant	None

JICA-TEAM: NK, Geo-E, SRED

Photographs

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)

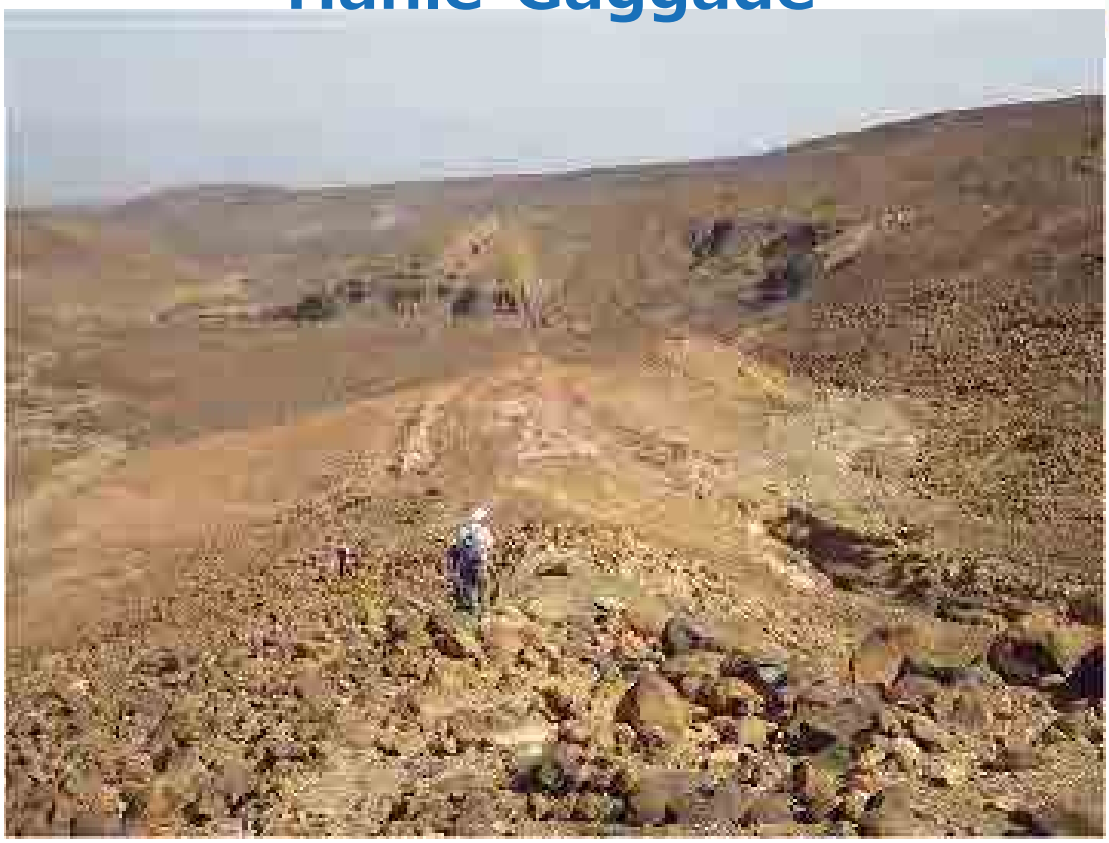
Hanle-Garabbayis

Photo: Base concrete of an old test well

Arta

Nord Goubet

Hanle-Gaggade



Obock

Lac Abhe

Sakalol

Djibouti-Awrofoul

Merci à ODDEG et CERD

JICA-TEAM: NK, Geo-E, SRED

DATA COLLECTION SURVEY ON GEOTHERMAL DEVELOPMENT IN DJIBOUTI

Thank you, Merci and Arigatoh!

To discussion session

November, 2014
Sheraton Hotel, Djibouti

JICA Survey Team

- Nippon Koei co. Ltd.,
- Geothermal Engineering Co. Ltd.
- Sumiko Resources Exploration and Development Co. Ltd. (SRED)