DJIBOUTI GEOTHERMAL DEVELOPMENT

CEO of EDD

Mr Djama Ali Guelleh

Global Geothermal Development Plan

The Hague - 19 November 2013

Outline

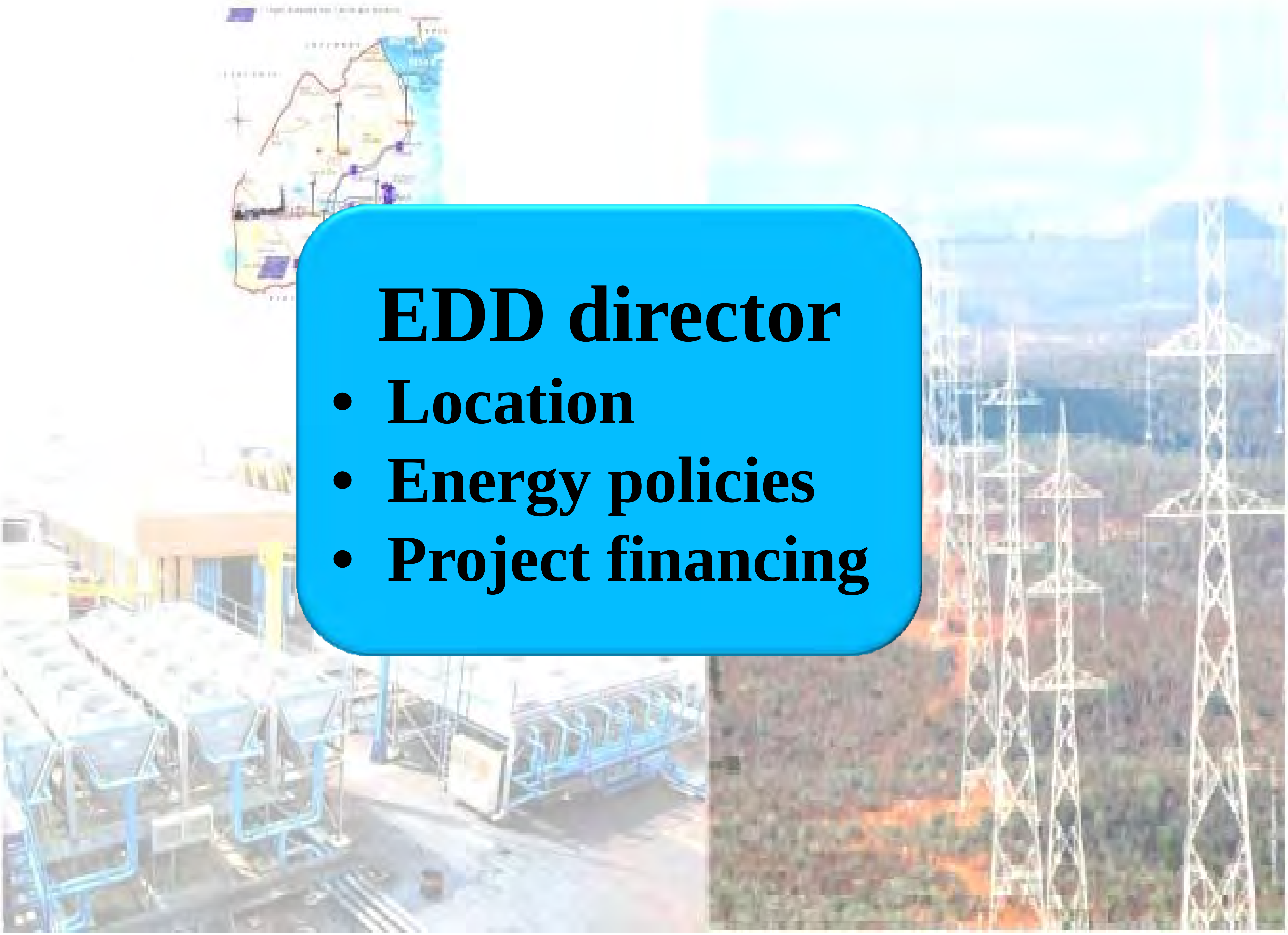
- Geographycal location
- Energy policies
- History of Geothermal Exploration in Djibouti
- Geothermal prospects
- Actual project « Fialé »
- Requirement to build 3D stochastic model in Assal geothermal field
- Project financing
- Project description
- Conclusion

EDD director
- Location
- Energy policies
- Conclusion

Abdou Mohamed
- History
- Geothermal prospects
- Actual project

Kayad Moussa
- 3D model
- Preliminary result

Saida Omar
- Project description
- Project finance



EDD director

- Location
- Energy policies
- Project financing

Geographical location

Volcanoes with known or inferred Holocene eruptions
Source: http://www.volcano.si.edu/gvp/

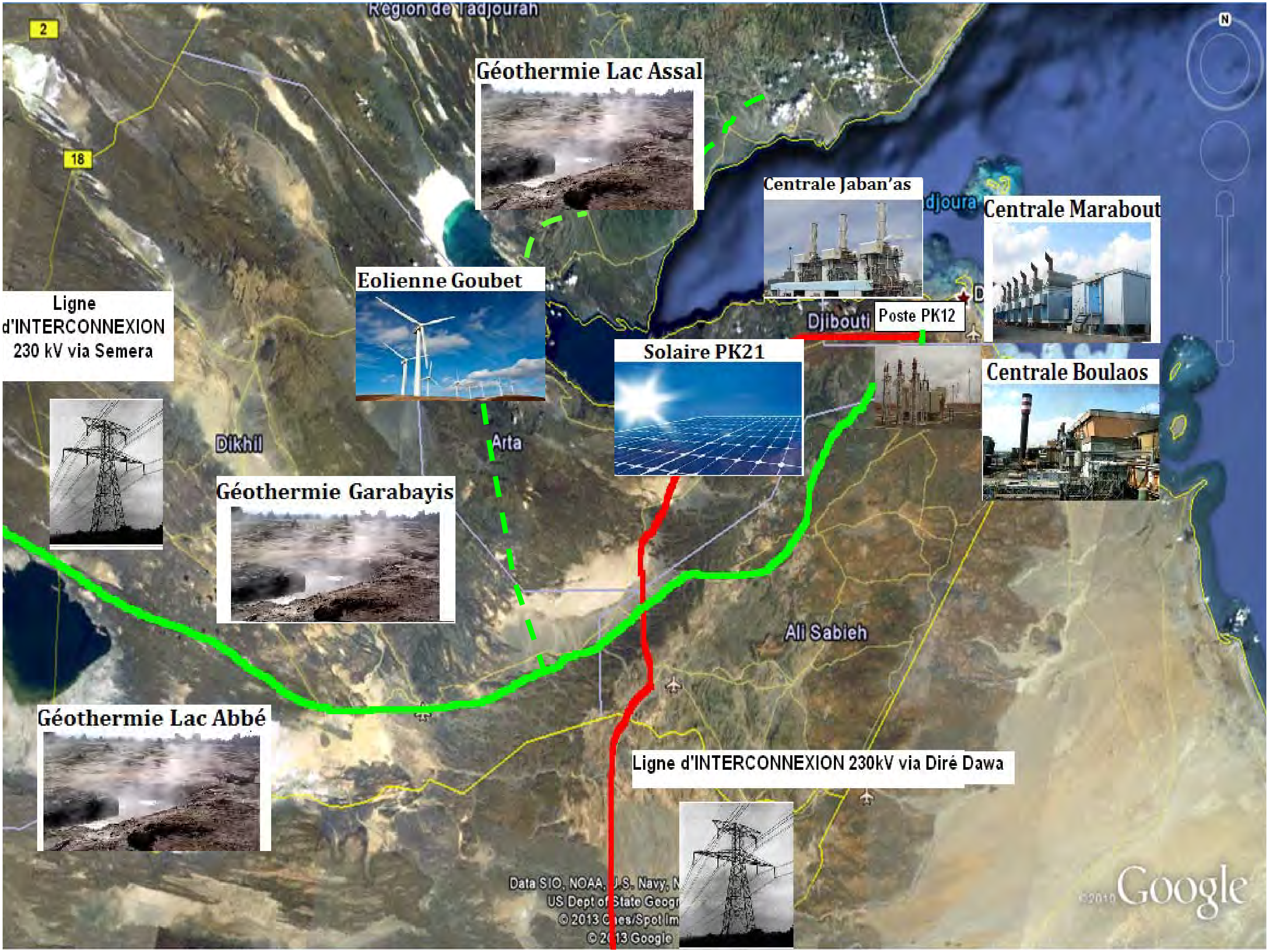
The Geologic characteristics of the territory of the Republic of Djibouti are exceptionally favorable for the development of Geothermal Energy.

In particular, Djibouti includes Afar depression, also called the “Danakil depression”, located at the intersection of three important tectonic structures

GOVERNMENT ENERGY POLICY

The Ministry of Energy in charge of natural Resources is responsible for overall policy formulation in the energy sector

- ✓ Make available a sustainable energy for economic growth
- ✓ Avoid any imported HFO in the future and produce more clean energy
- ✓ The government's aim is to develop all available alternative and renewable energy resources whereby the priority goes to geothermal resources for which the country has a very good potential.


Région de Tadjourah
Géothermie Lac Assal
Centrale Jaban'as
Centrale Marabout
Eolienne Goubet
Ligne d'INTERCONNEXION 230 kV via Semera
Djibouti
Poste PK12
Solaire PK21
Centrale Boulaos
Dikhil
Arta
Géothermie Garabayis
Ali Sabieh
Géothermie Lac Abbé
Ligne d'INTERCONNEXION 230kV via Diré Dawa
Google

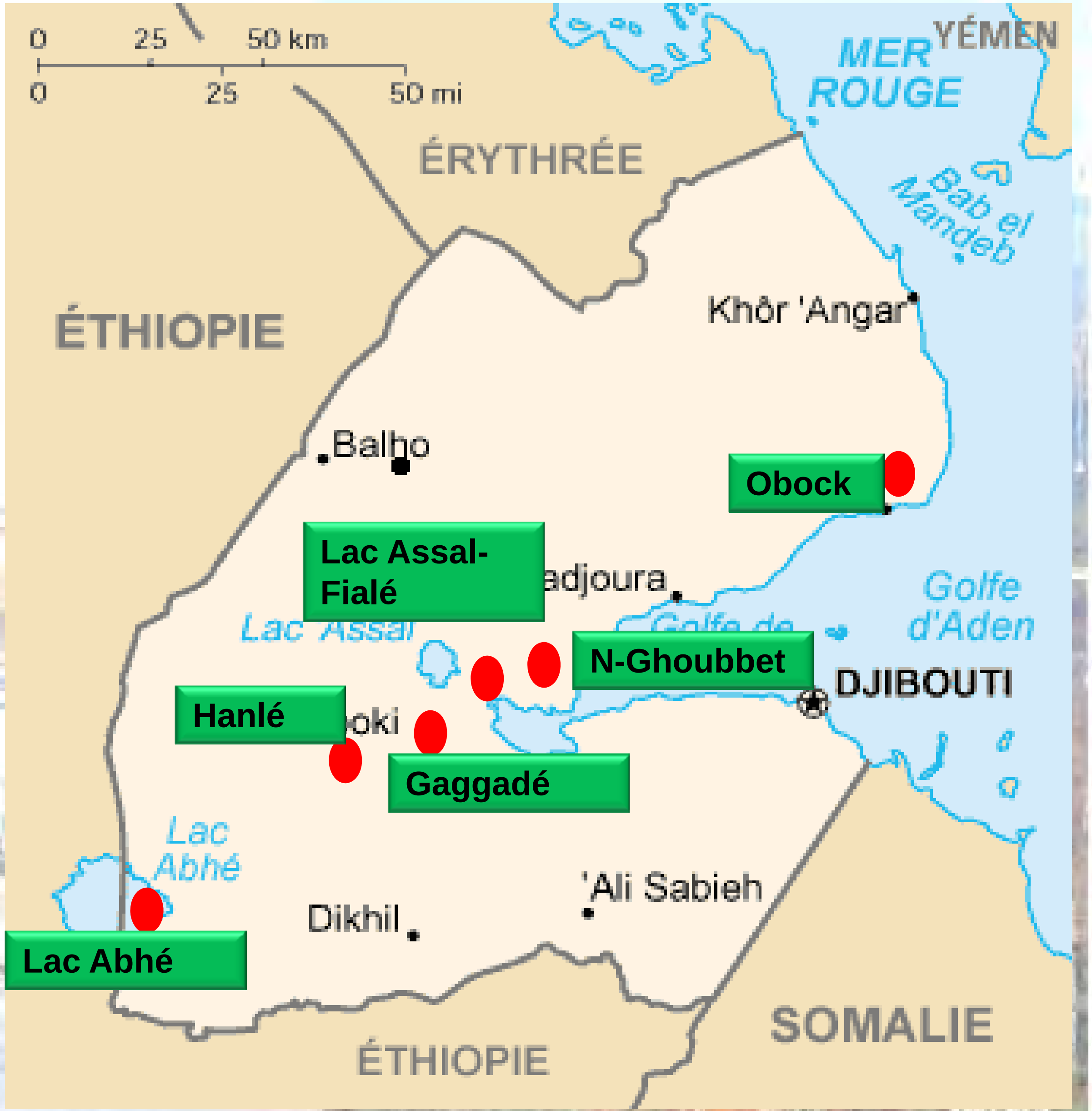
Geothermal resources could reduce energy dependency & electricity costs

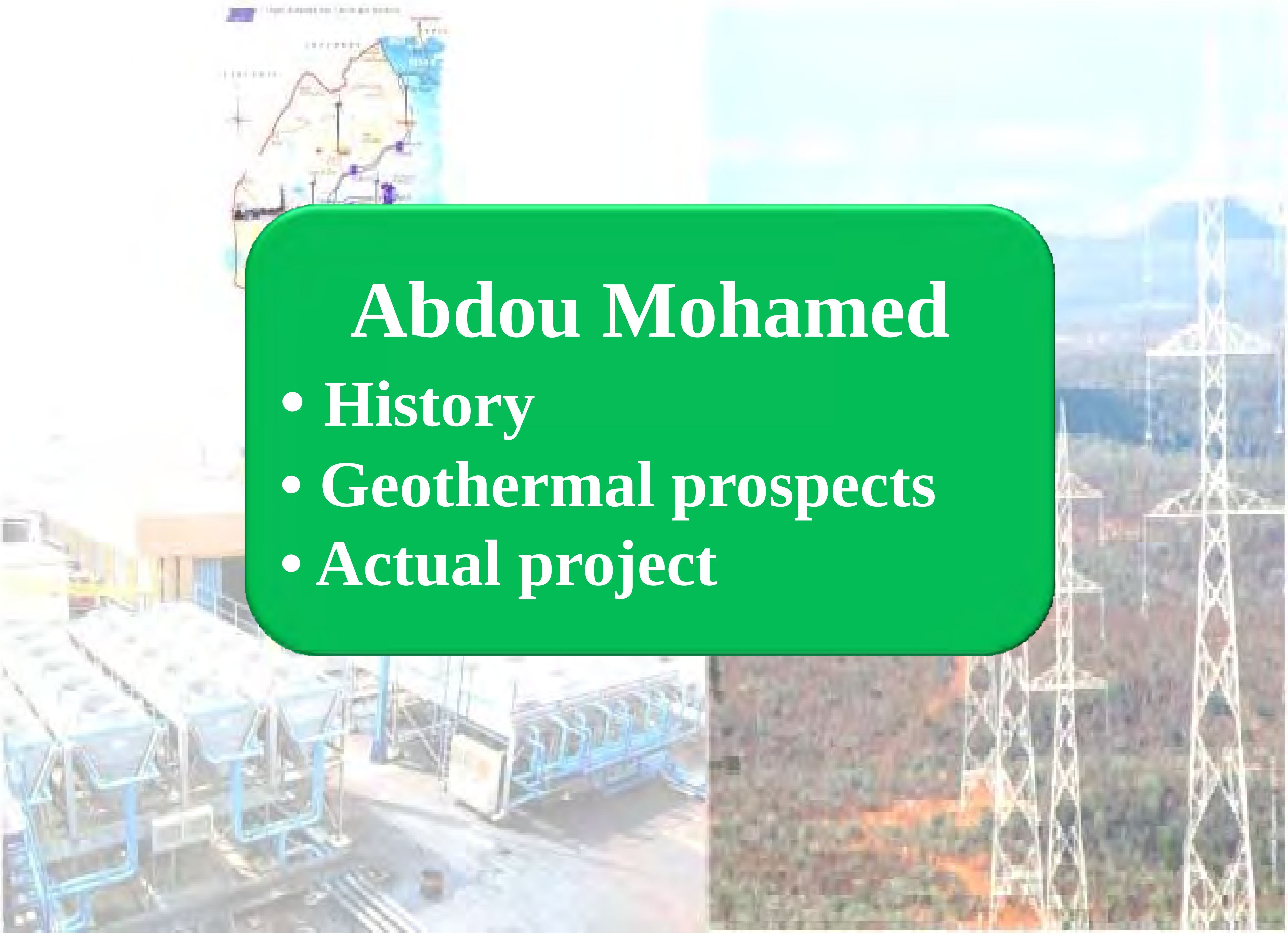
- Djibouti is 100 % energy dependent (imports HFO for diesel production and hydroelectricity imported from Ethiopia)
- Djibouti has a strong geothermal energy potential
  - At least 10 geothermal prospects areas.
  - And in six of them there are enough available data

Local geothermal generation could enable Djibouti to meet demand at least cost

Sites already prospected

Geothermal sites that get geosciences data
All these sites are ready for exploration drilling





Abdou Mohamed

- History
- Geothermal prospects
- Actual project

Djibouti's geothermal potential is still untapped

- Geothermal exploration programs in Djibouti started in the 70s

1970s:	1980s:	2000s:
French BRGM drills 2 deep wells	Multi-donors project, 4 deep wells drilled	Pre-feasibility study performed by an Icelandic company

- Confirmation of the geothermal resource was stopped because of:
  - technical difficulties, including high levels of salinity and scaling.
  - financing constraints and insufficient implementation capacity.

A LONG GEOTHERMAL HISTORY

1970 to 1975: The two wells have good temperatures only one of them has produced geothermal fluid (Asal 1) with high salinity.

1980 to 1985: The Djibouti government has conducted a detailed general inventory of geothermal resources and more areas of interest were identified

1987 to 1990: The deep geothermal exploration has been the completed :

- two drilling wells in Hanle (Hanle 1 and 2)
- four other wells in the Asal Rift (Asal 3, 4, 5,6).
- A scaling and corrosion study was performed on the well Asal 3.

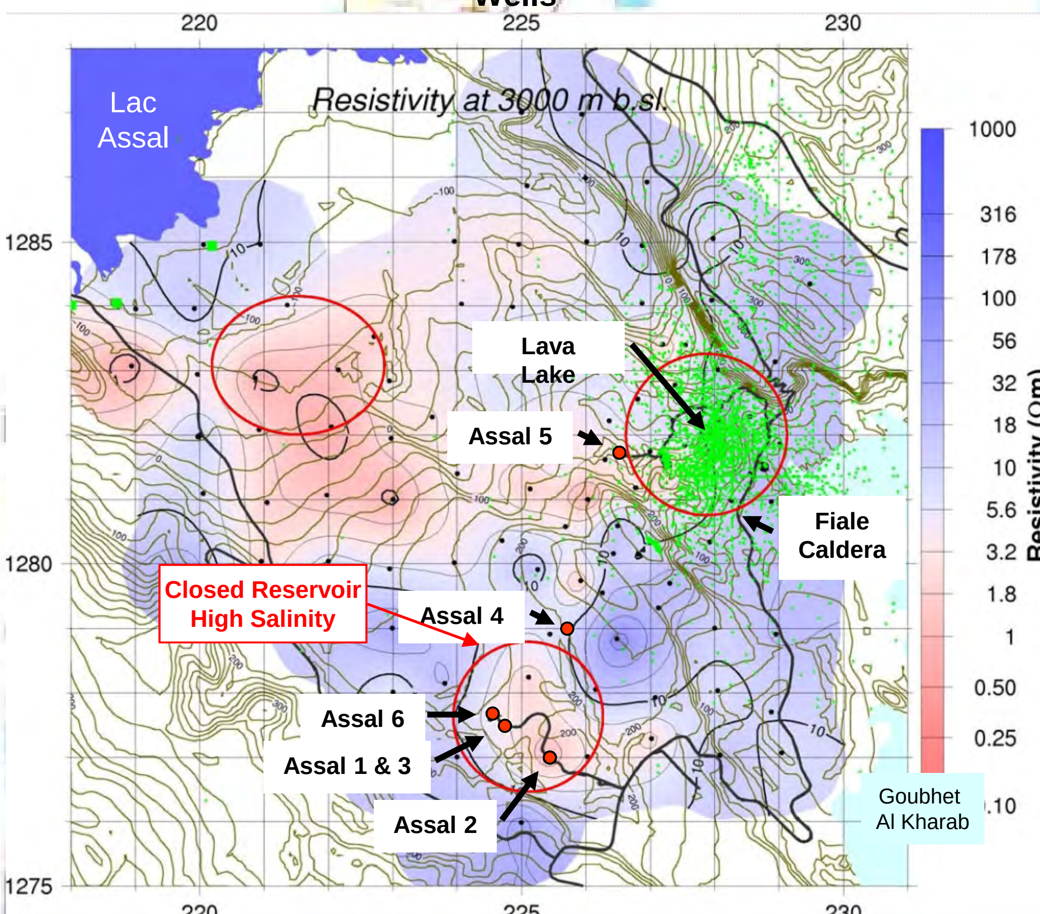
Target area « Fialé »

The objective :

- Confirmation of the resource in order to mitigate any risk for future developpment
- To drill 4 deviated wells and produce 50 to 100 MW in the first phase

Lake Assal, Fiale Caldera Drilling Target

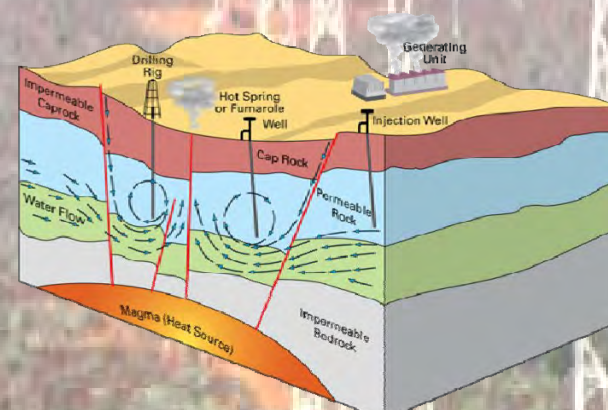
Geothermal Sectors and Location of Assal Exploratory Wells



Potential Geothermal Sectors Seismic Activity

Prefeasibility Study Promises:

- Magma Chamber Heat Source Located 3000 M under Lava Lake
- Underground Seawater Flow Between Goubhet Al Kharab and Lac Assal Provides Geothermal Fluid Recharge
- Vertical Fracturing for Improved Permeability
- Seawater Recharge Expected to Reduce Salinity when Compared to Closed Reservoir Encountered with Assal 1,3 & 6



Exploratory Drilling Technical Program

- Four Full Size 9 5/8 inch Geothermal Production Wells

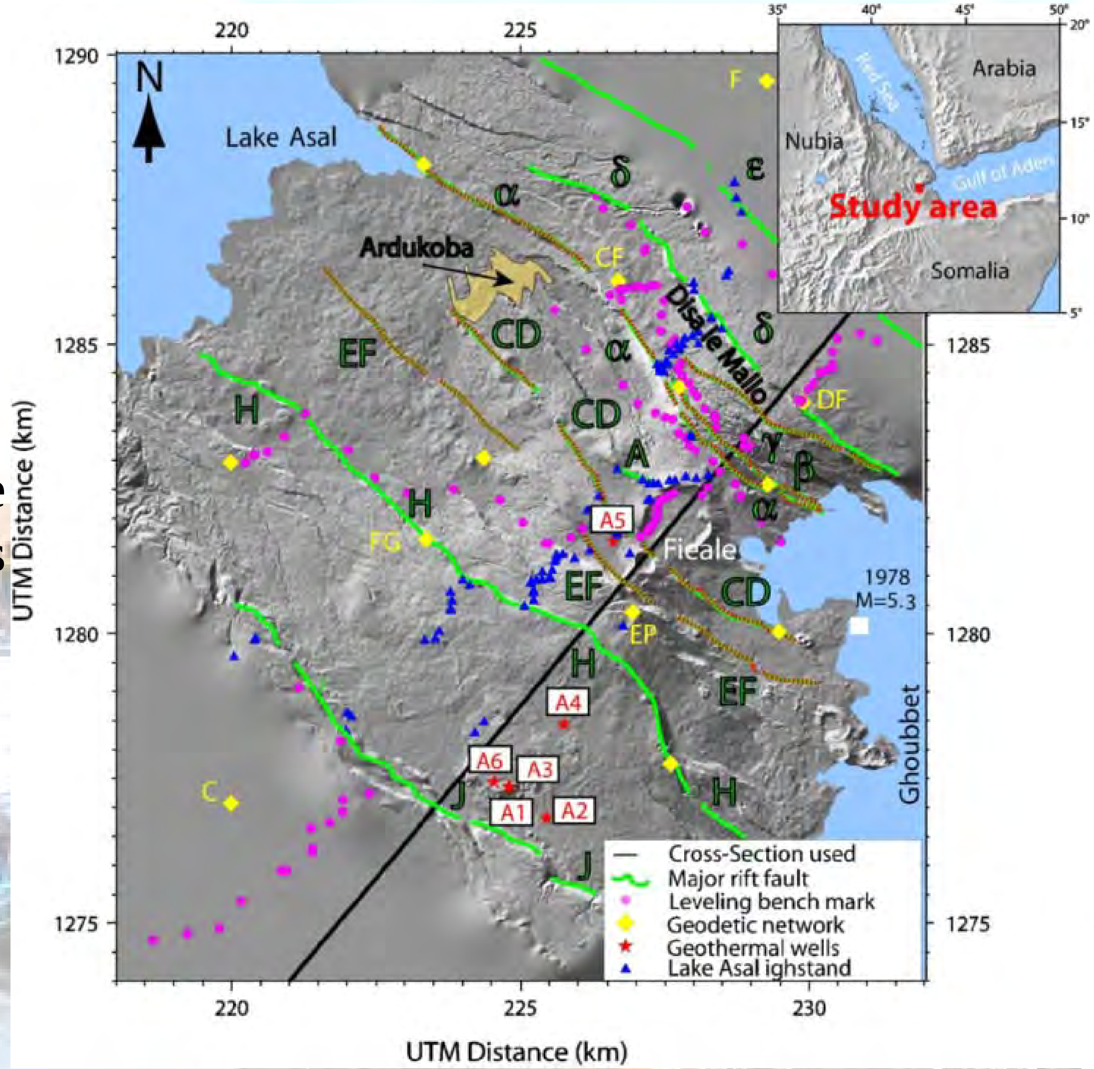
- Average Well Depth of ~ 2,500 Meters

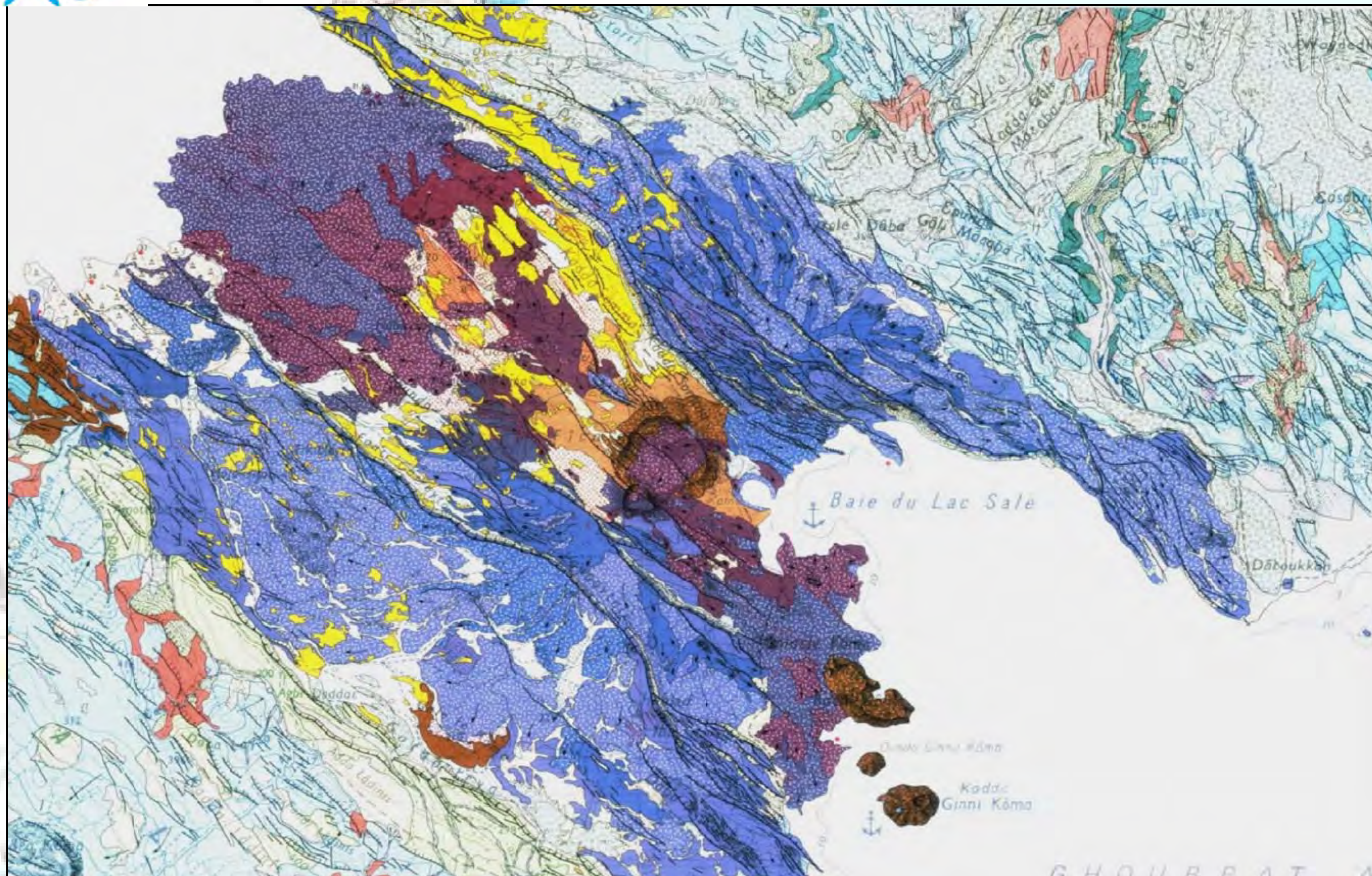
- Use of Deviated Drilling Techniques to:
  - Cut through Permeable Vertical Faults to Maximize Geothermal Fluid Production
  - Reduce Impact to Lava Lake Environmental Anomaly
- Aerated Drilling Technique to:
  - Improve Drill Penetration Rate
  - Reduce Formation Damage
- Well Tests Certified to be in Accordance with Approved Well Test Protocol to Assure IPP Bidder Confidence in Results
- Tests Include Temperature, Chemistry and 90 Day Flow Testing
- Intermediate Reservoir Testing at ~ 600 Meters before Drilling First Well to Depth (Possible Lower Temperature Binary Application)

Geological study

The active nature of the Asal volcanic and tectonic range, displaying a continuous basaltic activity .

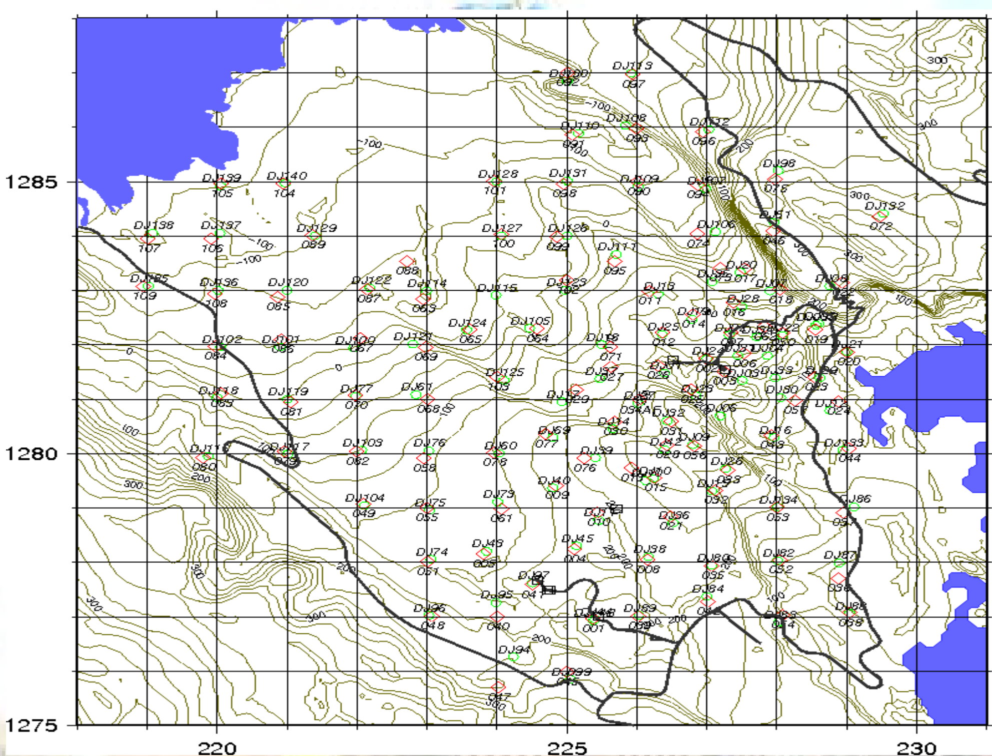
Heat source at shallow depth, the last expression of which was found in the lava lake at Fiale

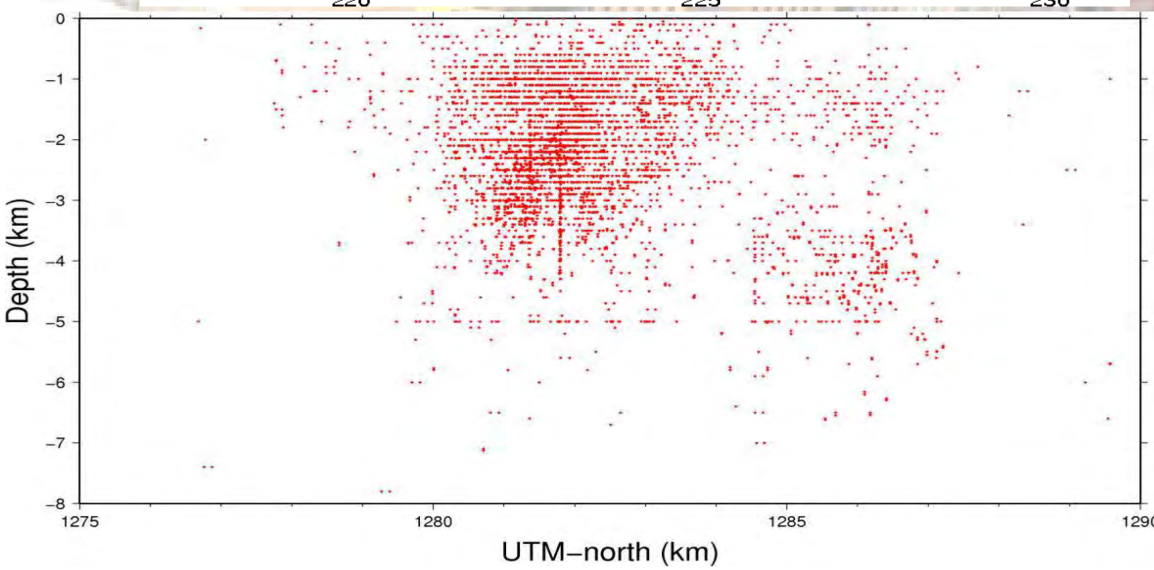


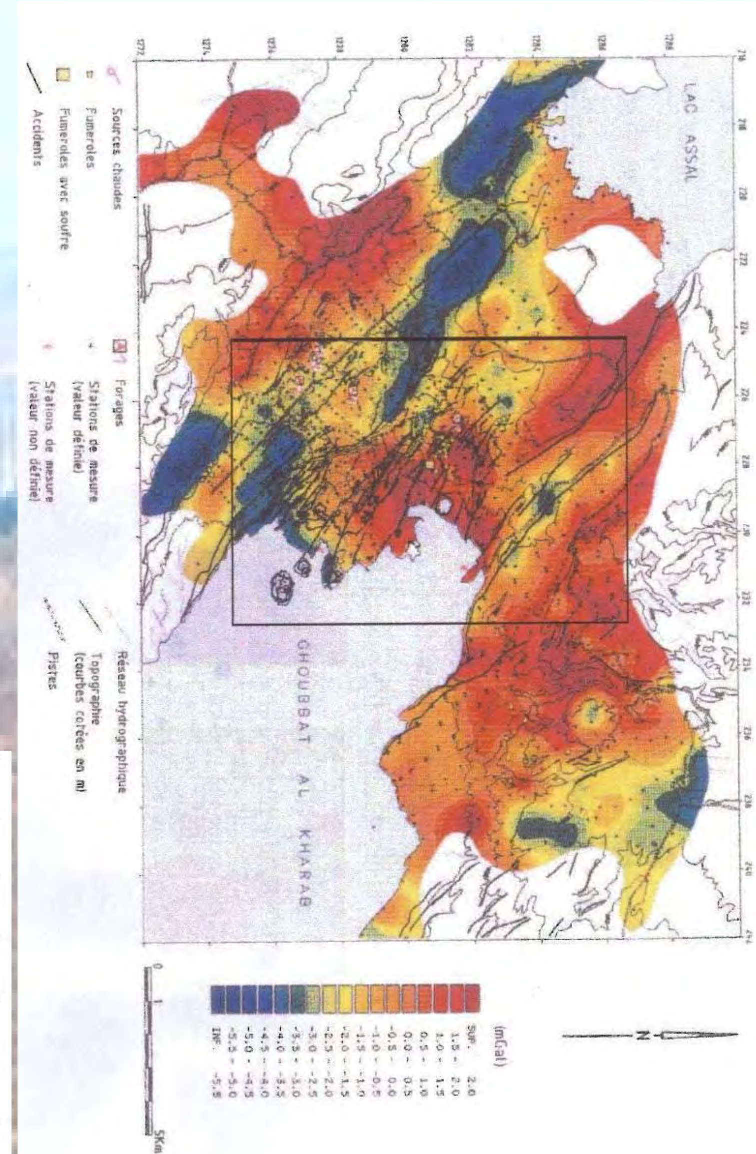


Geological map of the Asal rift
hyaloclastites in orange, recent basalts in deep blue and violet; early rift basalts (300.000 – 100.000 y.) in pale blue ; stratoid series (3 to 1 My) in very pale blue. Lacustrine deposits (diatomite) in yellow

Geophysical studies







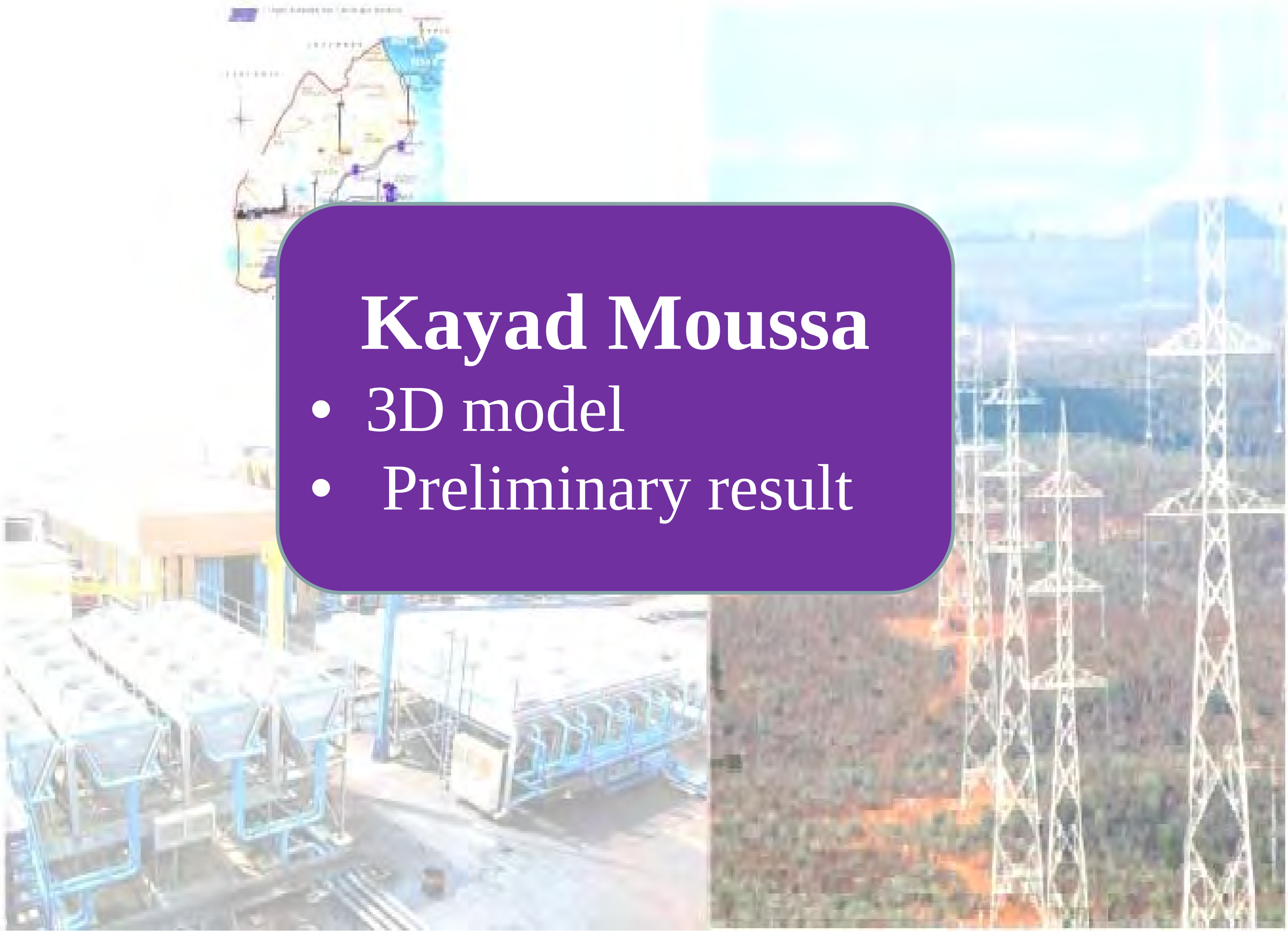
Geochemical study

- The wells produces a high-salinity fluid with 1692 moll of Na, 2977 moll of Cl and a pH of 5,1 (Aquater report). The origin of this fluid is referred to a marine water.
- By using a steam fraction at the weir-box of 0.27 and a fluid density of 1.1 g/cm we have calculated the composition of the deep fluid (ppm):

Chemical composition of the fluid	PPM	Chemical composition of the fluid	PPM
$N_a{}^{+}$	24,865	NH^{+}	5,1
K^{+}	4,826	Fe^{2+}	4,47
$C_a{}^{2+}$	15,879	SO^{2-}	19,1
$M_g{}^{2+}$	24,6	F^{4-}	2,3
SiO_2	500	Cl^{-}	70,058
PH	5,1		

Assal Lake drilling well's characteristics

N°	Drilled wells	Date: Beginning Of drilling	Date: End of drilling	Final depth (m)	Temperature at bottom (°C)	Total mass flow (t/h)	Salinity g/l	Drilling duration (days)
1	Asal 1	8-03-75	12-06-75	1146	260	135	120	97
2	Asal 2	1-07-75	10-09-75	1554	233 (926m)	-	-	72
3	Asal 3	11-06-87	11-09-87	1316	264	350 (WHP = 12,5Bars)	130	93
4	Asal 4	15-09-87	21-12-87	2013	359	-	180	97
5	Asal 5	7-01-88	7-03-88	2105	359	-	-	61
6	Asal 6	8-04-88	10-07-88	1761	265	150	130	94
Total								524



Kayad Moussa

- 3D model
- Preliminary result

Field data for the 3D Model

Wellbore data :

Log (dip meter), core
Gravimetric analysis
Borehole televiewer (BHTV)

Field scale data :

Reservoir structure
Seismic data
Lithology index

Fracture class properties :

Fracture orientation: dip, azimuth
Fracture length, fracture aperture

Common parameters : friction angle, cohesion, stress field

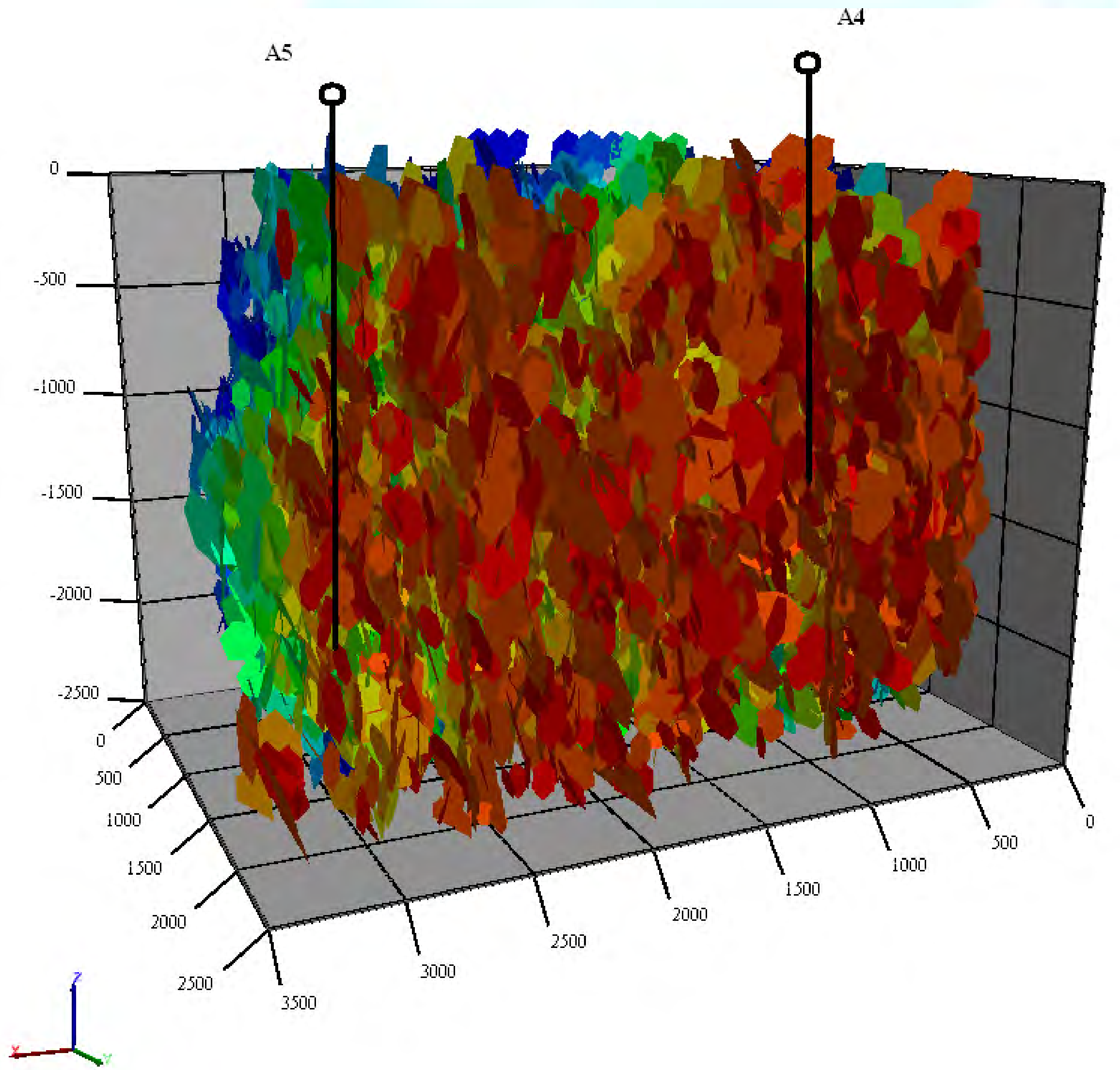
Group	Direction	Density	Perméability
1	N130	$4x10^{-7}$	$2.x10^{-14}$
2	N130	$5x10^{-7}$	$4x10^{-14}$
3	N130	$5x10^{-7}$	$12x10^{-14}$
4	N130	$5x10^{-7}$	$2.6x10^{-14}$
5	N100	$2x10^{-7}$	$2.6x10^{-14}$

3D Stochastic model for Assal reservoir

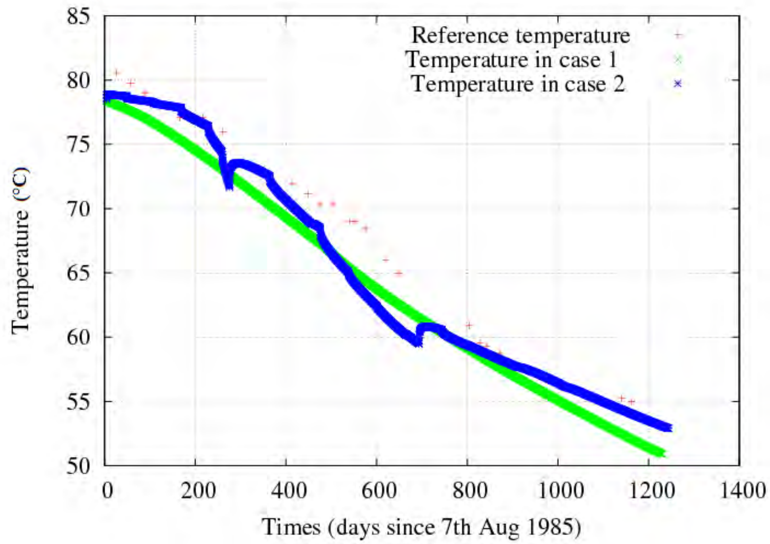
➢ These data can be used to generate stochastic model.

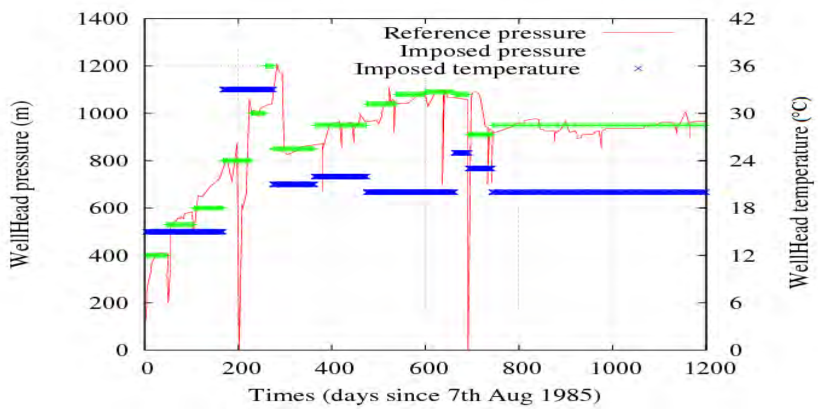
➢ This model :

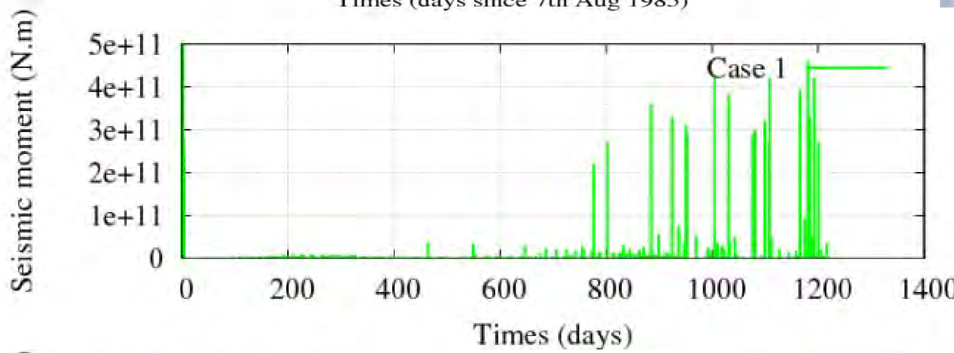
- o will be eventually achieve hydraulic stimulation in order to feed the deep reservoir.
- o can simulate the requisite pressure and flow rate for that in order to mitigate the induced seismicity.
- o can estimate the flow of fluids within the reservoir, over its production lifetime.

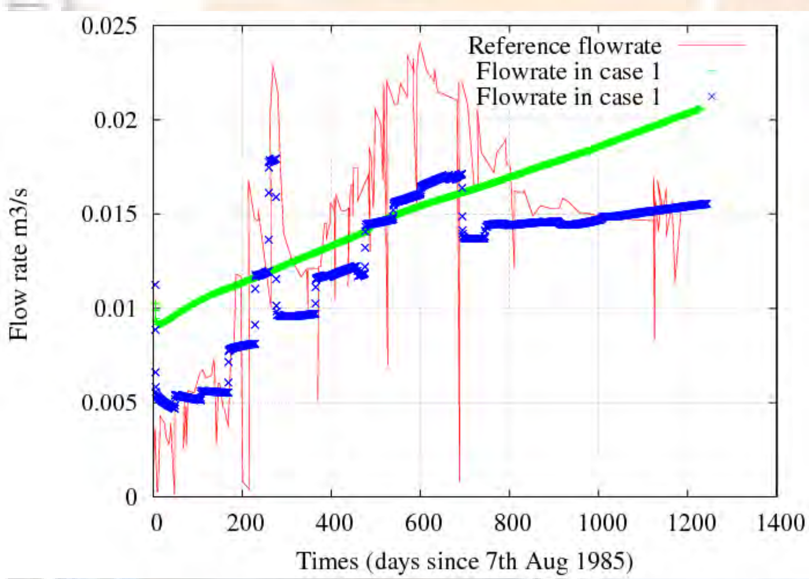


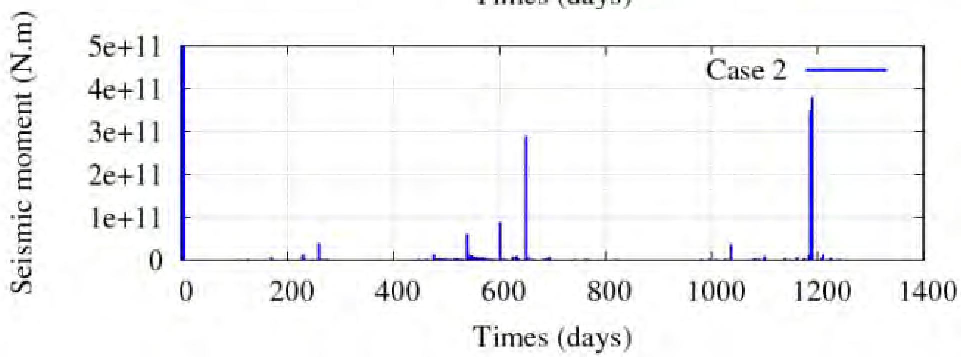
Hydraulic and thermal results

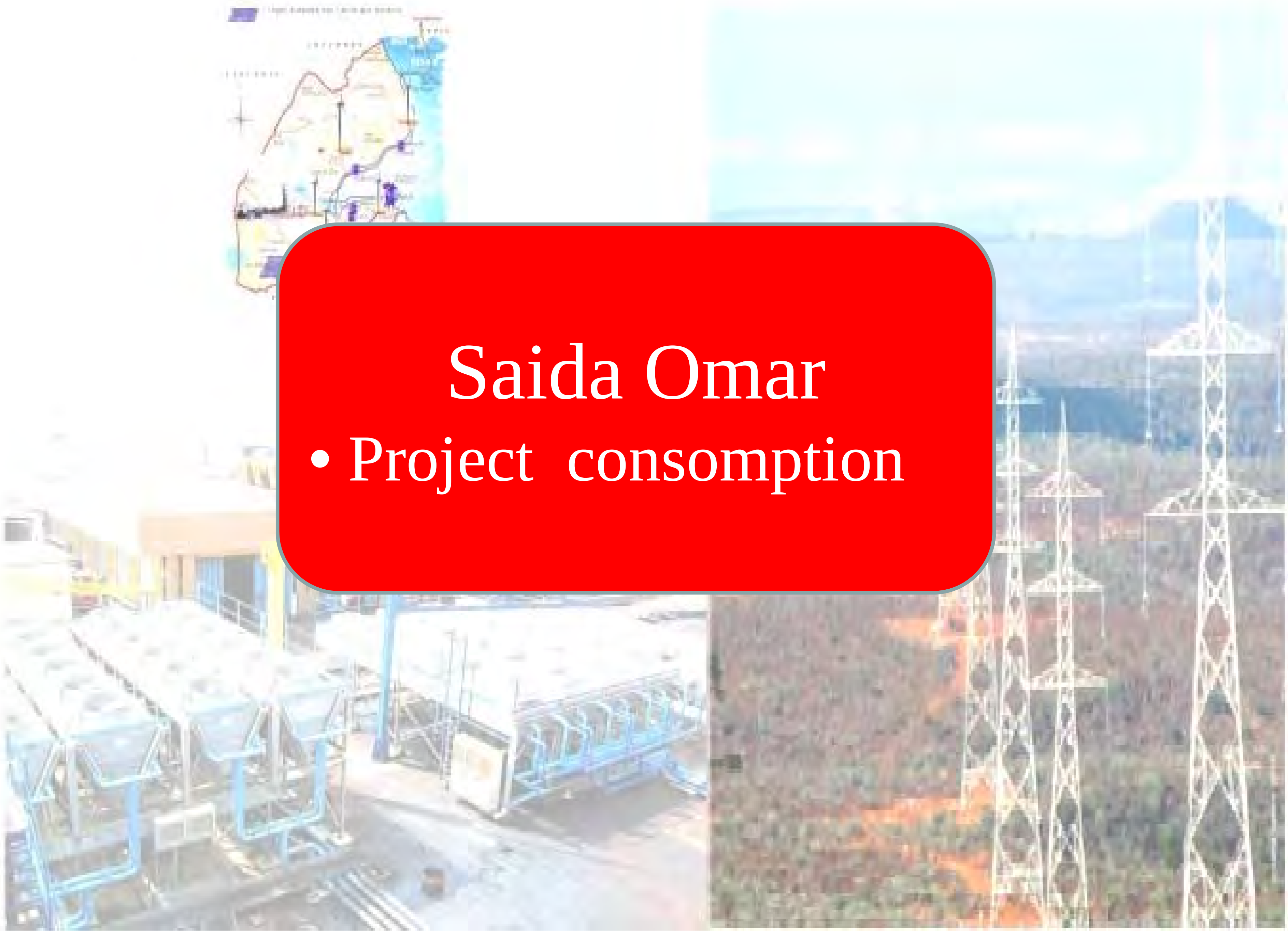












Saida Omar

- Project consomption

The project will be carried out in 2 phases in the form of a PPP

The development of geothermal capacity would be done in two phases

- **Phase 1 – Geothermal exploratory drilling**
  - financed by GoDj (using grants and soft loans from AFD, AfDB, ESMAP, GEF, IDA, OFID and SEFA)
  - aims at assessing the commercial viability of the geothermal resource in Fiale Caldera, located in the Lake Assal region of Djibouti.
- **Phase 2 – Geothermal Power Plant Development**
  - If the geothermal resources is adequate for large scale power generation, the development of the power plant will be competitively tendered to an IPP

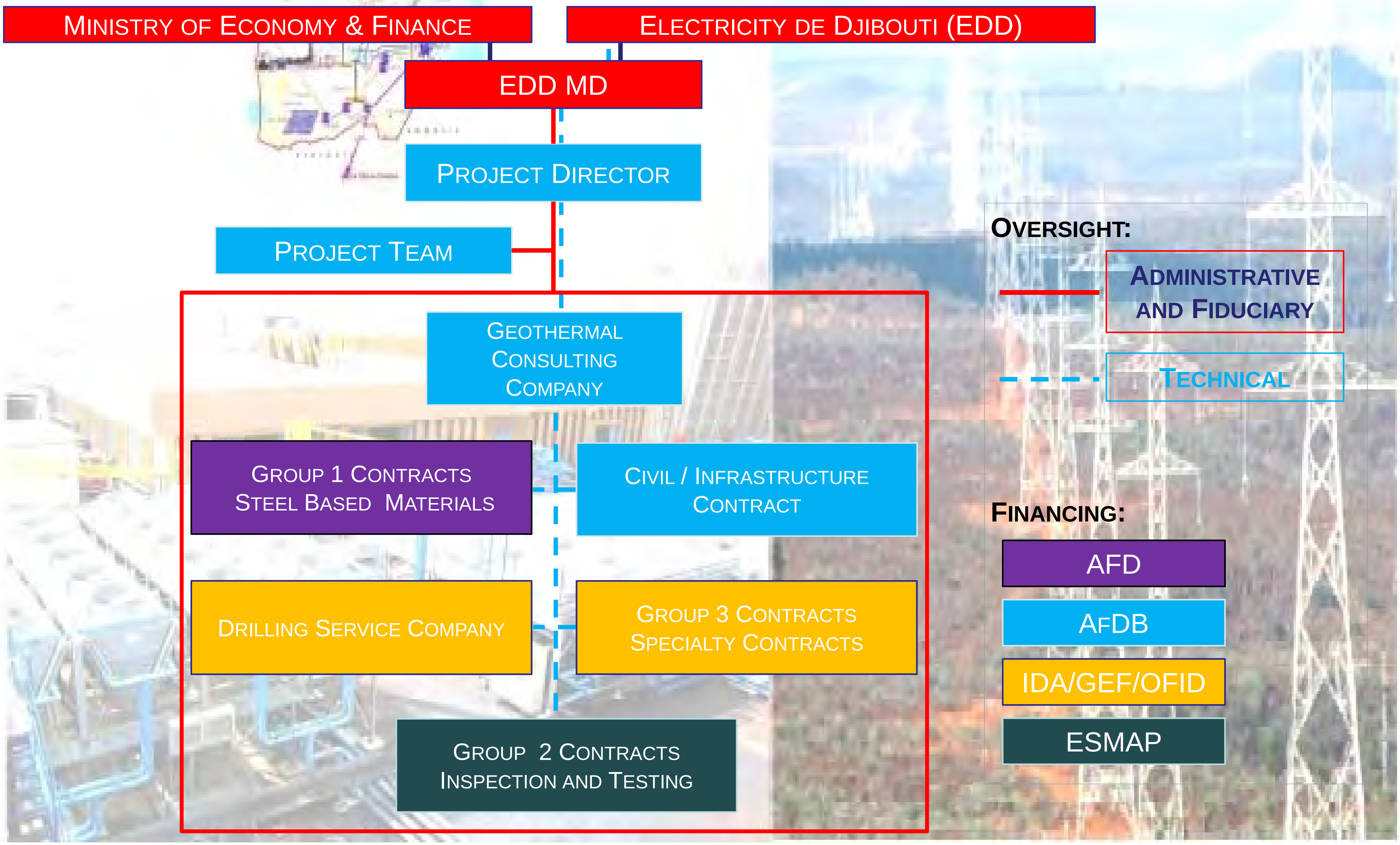
Djibouti’s geothermal potential can be developed

- **Technical difficulties can be successful:**
  - Increased geological knowledge: geothermal reservoirs knowledge has markedly improved, targeting of geothermal resources with lower saline and dissolved solids content now possible
  - Technological advances: improvements in geothermal generation technologies (USA, Iceland, Japan) makes it possible to use saline and saturated geothermal fluids for power generation

- **Seven donors are providing financial support to the project**
- **Djibouti government will also contribute**
- **The project design builds on international best practices and the lessons learnt from past geothermal explorations in Djibouti**

Funding Agencies	Funding (USD)	Funding Type
Global Environmental Facility (GEF)	$6,040,000	Conditional Grant
African Development Bank (AfDB)	$5,000,000	Grant
African Development Bank (AfDB) Trust Fund	$2,340,000	Grant (Euros)
Agence Francaise de Developpement (AFD)	$3,250,000	Grant (Euros)
International Development Association (IDA)	$6,000,000	Soft Loan
OPEC Fund for International Development (OFID)	$7,000,000	Soft Loan
Energy Sector Management Assistance Program (ESMAP)	$1,100,000	Conditional Grant
Government of Djibouti (GoDj)	$500,000	Grant
Total Funding:	**$31,230,000**	

Project architecture



Exploratory Drilling – Calculating Financial Return When Using IPP Equity

- Exploratory Drilling Investment has a 100% Risk of Loss
- IPP Developers must Use Equity in Order to take Drilling Risk
- Equity Investment Commands the Highest Annual Rate of Return than Any Other Debt Facility
- It is Anticipated to Take 5 Years from the Initial Equity Investment in Drilling Until the Power Plant Commercial Operations Date (COD)
- Investment Return is Accrued Until the COD after which the Payback Period Starts
- The Accrued Investment + Return is Paid Over the Operating Life of the Plant Starting at the COD

Affect of IPP Accruing $30 M Drilling Cost Through Commercial Operations Date

Drilling Investment Accrued Annually
With 25% Return on Equity

Perform Exploratory Drilling

Commercial Operations Date

Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Payback Period

Year End Accrued Amount

$15,000,000 $33,750,000 $42,187,500 $52,734,375 $65,917,969 $82,397,461

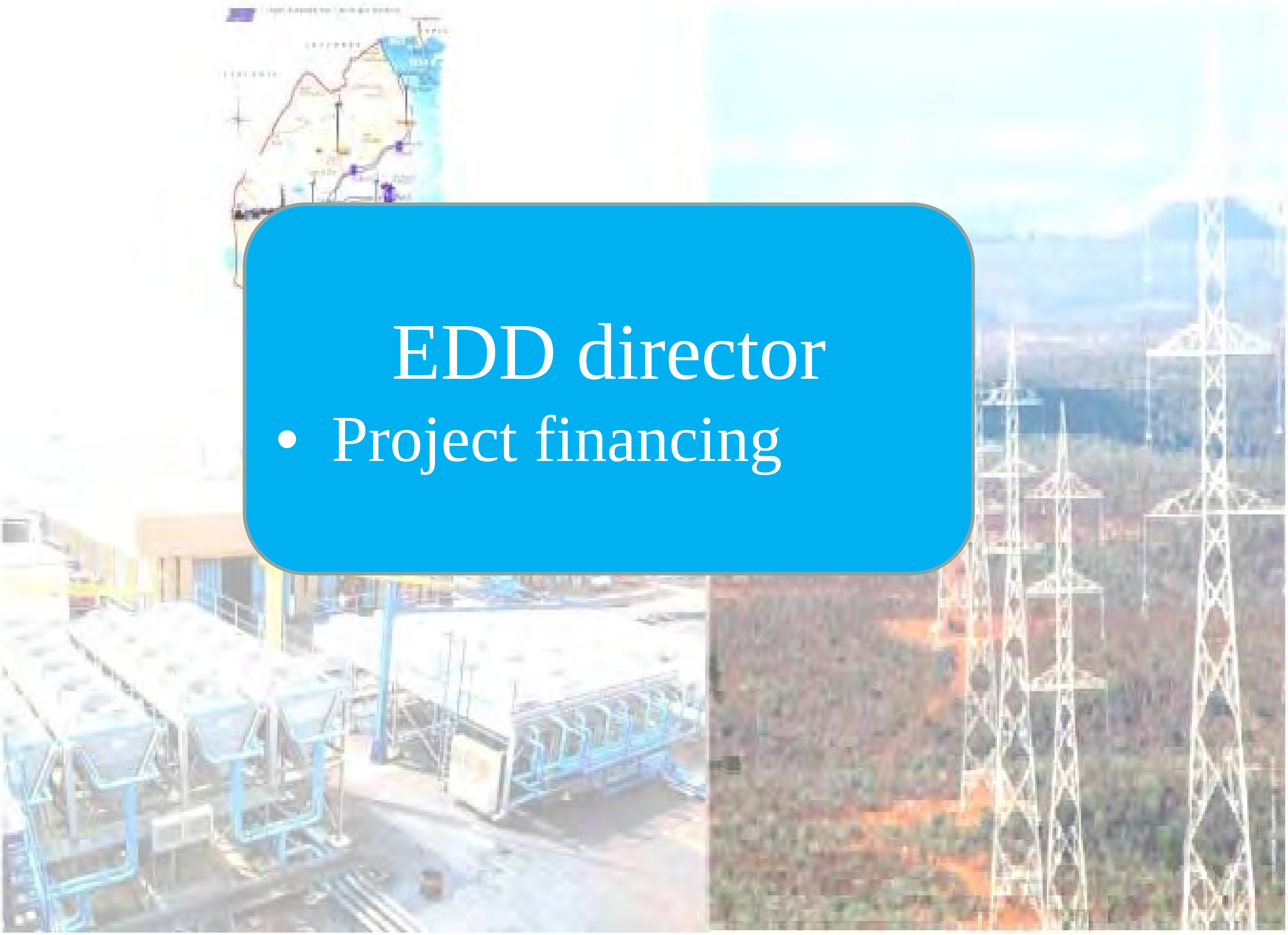
Invested Equity $15 M USD

Invested Equity $15 M USD

Annual Cost to Pay Back $30 Million Equity Investment in Exploratory Drilling Program Over 20 Year Amortization / Payback Period

$20,839,630 / Year for 20 Years

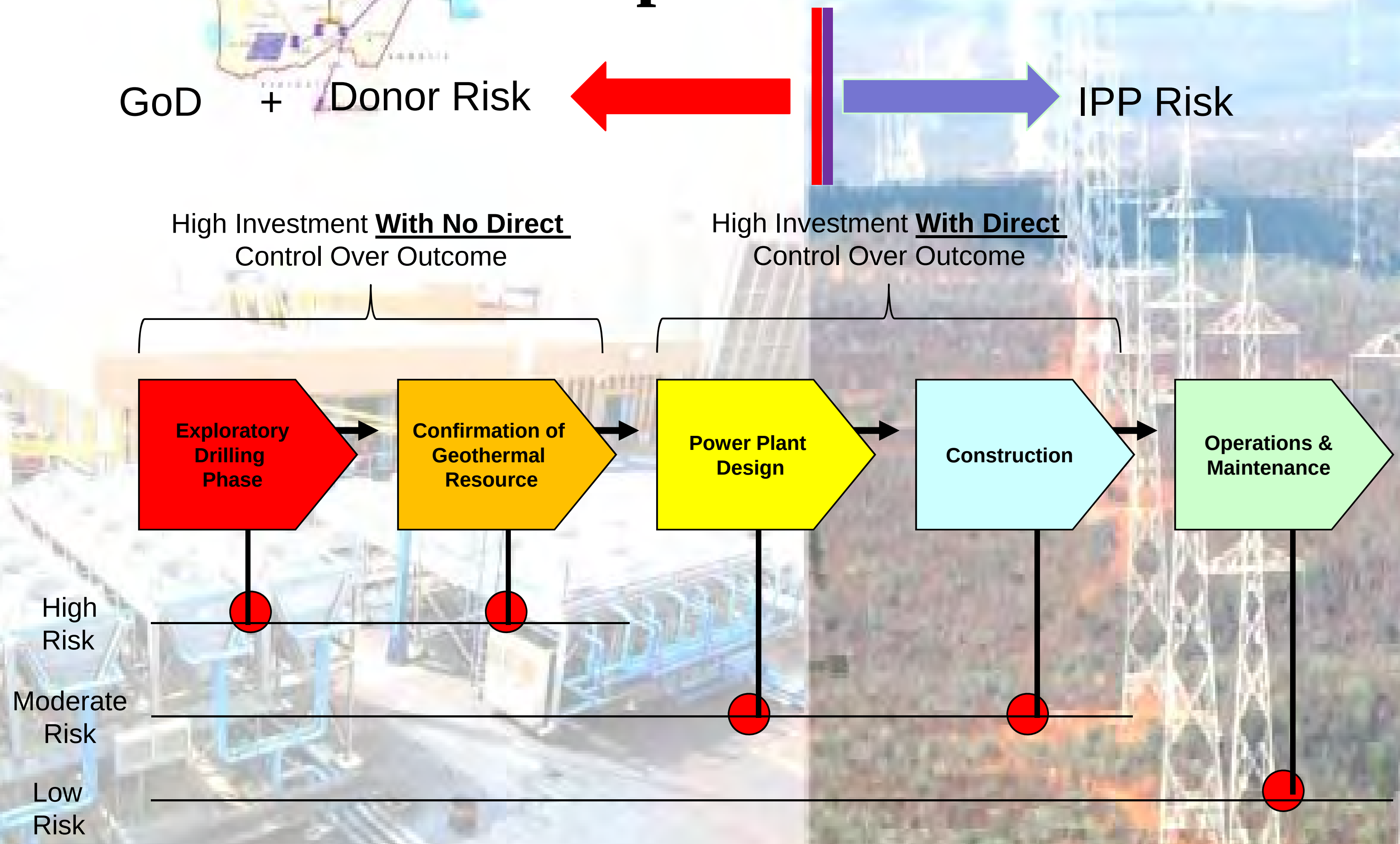
Important Note: Investment will Continue to Accrue During Delays Prior to the Commercial Operations Date



EDD director

- Project financing

Donor Involvement Reduces Development Risk for IPP



Value Derived from Donor Involvement in Exploratory Drilling Phase

- Removes High Cost, High Risk Exploration Phase from Independent Power Producer (IPP) Investment
- Provides for Competitive and Transparent Tendering Process for Public Private Partnership Contracting Arrangements
- Reduced IPP Risk Combined with Transparent, Competitive International Tendering is Anticipated to Reduce IPP Return on Investment

Traditional versus Semi-Integrated Contracting Approach

Under Traditional Approach
Geothermal Developer

- Provides Technical and Fiduciary Management of Total Program Including Drilling Operations
- Performs Feasibility Studies, Designs Drilling Program and Targets Wells
- Contracts and Coordinates Supply of each Specialty Service and Material Provider

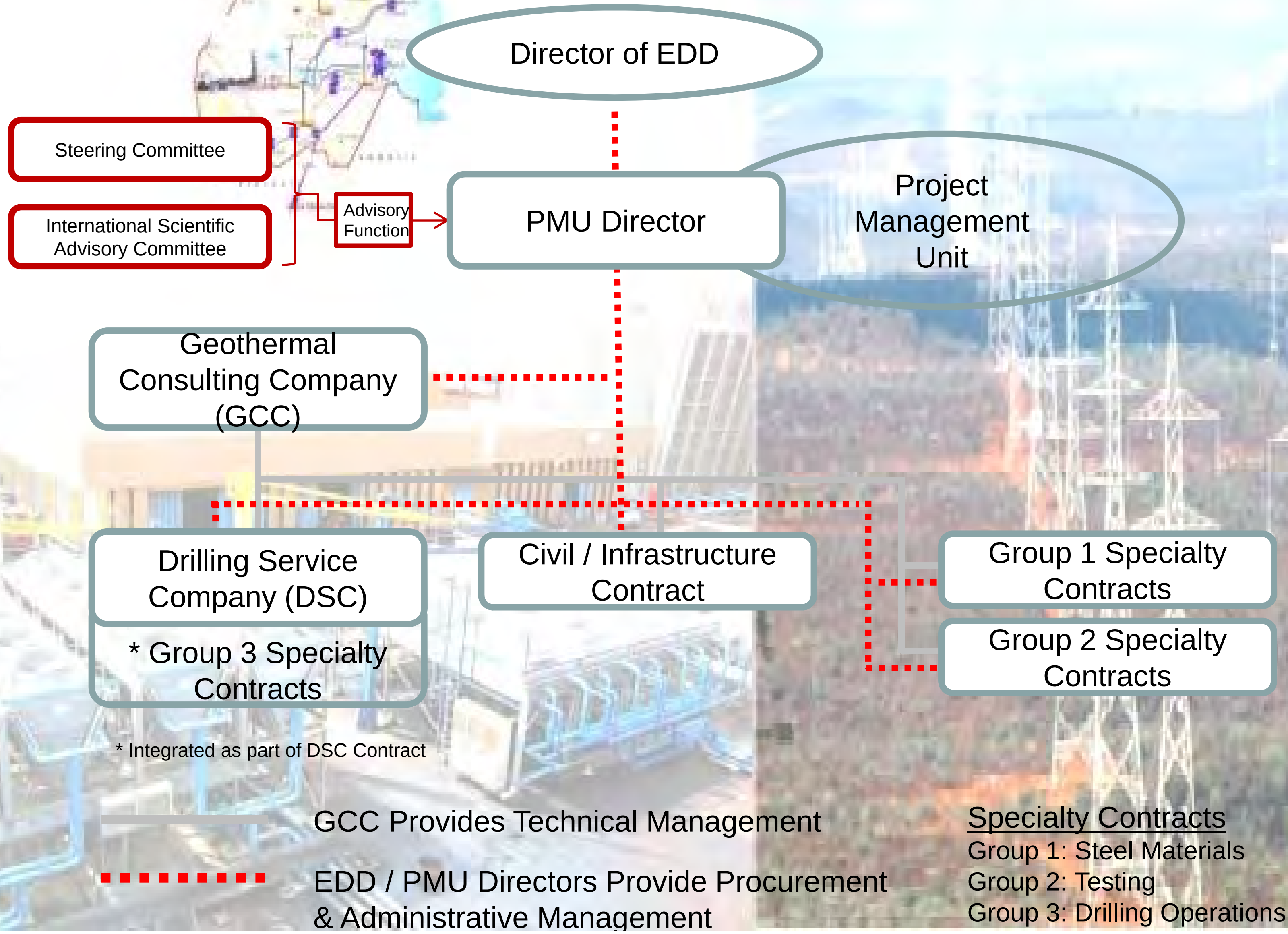
Under Semi-Integrated Approach
Project Management Unit (PMU)

- Contracts PMU Director to Manage Fiduciary Responsibilities of Program with Direct Line Reporting to EDD Director General
- Contracts Geothermal Consulting Company (GCC) to Perform Feasibility Studies, Design Drilling & Testing Program, Target Wells and Manage Technical Operations and Contract Coordination
- Under GCC Technical Oversight, Contracts and Coordinates Supply of Civil / Infrastructure, Group 1 and Group 2 Specialty Contracts
- Integrates and Engages the Drilling Service Company and Group 3 Drilling Operations Scope of Supply under a Single Contract

Specialty Drilling Contracts

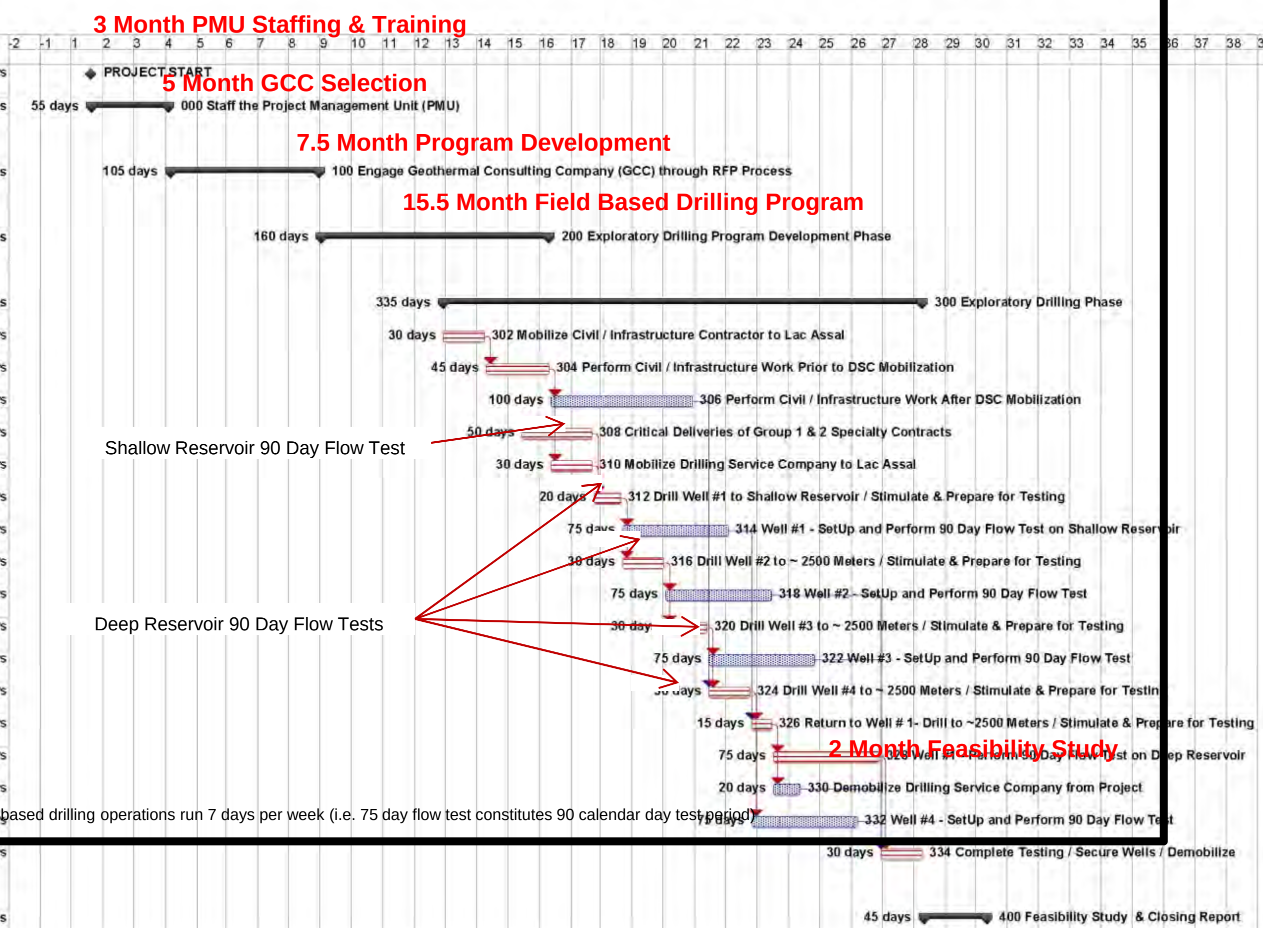
- **Civil / Infrastructure Contract**
  Prepares roads and bridges for mobilization of heavy equipment. Constructs and maintains living quarters and infrastructure to support drilling operations.
- **Drilling Service Company**
  Provides and operates drilling rig
- **Group 1: Steel Based Materials**
  casing
  wellhead
  separators
  drilling bits
  casing accessories
- **Group 2: Inspection & Testing**
  capacity testing
  chemical analysis
  temperature testing
  production testing
  coring & sampling
- **Group 3: Drilling Operations**
  directional drilling,
  cementing,
  general services,
  H2S monitoring provisions,
  mud controlling services,
  mud logging,
  rig
  top drive
  water pumps
  aerated drilling services
  diesel fuel for operations

Project Architecture



Project Schedule

ID	Task Name	Duration
1	PROJECT START	0 days
2	000 Staff the Project Management Unit (PMU)	55 days
6		
7	100 Engage Geothermal Consulting Company (GCC) through RFP Process	105 days
12		
13	200 Exploratory Drilling Program Development Phase	160 days
32		
33	300 Exploratory Drilling Phase	335 days
34	302 Mobilize Civil / Infrastructure Contractor to Lac Assal	30 days
35	304 Perform Civil / Infrastructure Work Prior to DSC Mobilization	45 days
36	306 Perform Civil / Infrastructure Work After DSC Mobilization	100 days
37	308 Critical Deliveries of Group 1 & 2 Specialty Contracts	50 days
38	310 Mobilize Drilling Service Company to Lac Assal	30 days
39	312 Drill Well #1 to Shallow Reservoir / Stimulate & Prepare for Testing	20 days
40	314 Well #1 - SetUp and Perform 90 Day Flow Test on Shallow Reservoir	75 days
41	316 Drill Well #2 to ~ 2500 Meters / Stimulate & Prepare for Testing	30 days
42	318 Well #2 - SetUp and Perform 90 Day Flow Test	75 days
43	320 Drill Well #3 to ~ 2500 Meters / Stimulate & Prepare for Testing	30 days
44	322 Well #3 - SetUp and Perform 90 Day Flow Test	75 days
45	324 Drill Well #4 to ~ 2500 Meters / Stimulate & Prepare for Testing	30 days
46	326 Return to Well # 1- Drill to ~2500 Meters / Stimulate & Prepare for Testing	15 days
47	328 Well #1 - Perform 90 Day Flow Test on Deep Reservoir	75 days
48	330 Demobilize Drilling Service Company from Project	20 days
49	332 Well #4 - SetUp and Perform 90 Day Flow Test	75 days
50	334 Complete Testing / Secure Wells / Demobilize	30 days
51		
52	400 Feasibility Study & Closing Report	45 days



Note: Number of days shown are based on a 5 day work week; however, field based drilling operations run 7 days per week (i.e. 75 day flow test constitutes 90 calendar day test period)

Thank you for your attention