TRAINING ON SURFACE EXPLORATION STUDIES FOR GEOTHERMAL RESOURCES AND DEVELOPMENT OF CONCEPTUAL MODELS

UNDER THE AUSPICES OF INTERIM PROJECT COORDINATION UNIT OF THE AFRICA GEOTHERMAL CENTER OF EXCELLENCE

SEISMIC MONITORING – LESSONS LEARNED IN KENYA
Antony Wamalwa, Geothermal Development Company – Kenya
Email: - awamalwa@gdc.co.ke
Seismic monitoring can be conducted before the geothermal drilling and after:

- Used for geohazard monitoring
- Used as geophysical exploration method
- Used for geothermal resource development (production well drilling)
How do earthquakes occur?
Is this a normal fault or a reverse fault?
GEOTHERMAL SYSTEM
Seismic Monitoring in Menengai
Seismic Monitoring in Menengai

Seismic Raypaths across the Menengai Caldera
Seismic Monitoring in Menengai

Figure 5.1. Average Vp/Vs ratio variations in the Menengai study area showing proposed test drill sites [Stars], interpreted upflow zones and fluid recharge for the system.

A map of Vp/Vs across the Menengai Caldera
Seismic Monitoring in Menengai

Micro seismic event distribution with depth within the Menengai prospect
Lessons from Seismic Monitoring in Menengai

✓ Micro-seismic Monitoring can be used as an exploration geophysical technique even before drilling is done.
✓ Identify targets not only for production wells but also exploration wells by mapping the shallow seismic intensity areas.
✓ Can help in determining the fluid flow pathways i.e. the recharge and the upflow zones.
✓ By the analysis of the ray-paths the data can help map the location of the heat source.
Seismic Monitoring in Olkaria

[b] Depth [km]

-8 -7 -6 -5 -4 -3 -2 -1 0

OWF OCF NEF-DOMES

Horizontal error

0 2000 4000 M

Vertical error

Grid Northings [m]

0 2000 4000 M
Seismic monitoring - Olkaria

- Micro-seismic event distribution with depth at the Olkaria Geothermal Field
- Show that most events are shallow than 5km depth within the reservoir area
- The brittle–ductile transition zone is at the depth below 5km
- The ductile zone is below 7km depth
Shear wave attenuation; Raypath section across Olkaria

More than one shear wave attenuating bodies are inferred in Olkaria

The shear wave attenuating bodies/magma sits about 7km below
Seismic monitoring-Olkaria

Events with clear P and S wave arrivals, have two clear phases with similar frequency.
They are much deeper.
This could be related to volcano tectonic faults.
Seismic monitoring-Olkaria

Event with no clear P and S wave arrivals.
The signal has two phases, with different frequencies.
They are hard to infer the origin but could be related to the noise in the reservoir.
Seismic monitoring - Olkaria

- Event lacks clear phases after 1st arrival
- Have higher frequency
- Events are relatively shallow and occur in clusters
- Event related to the breaking of rocks within the reservoir.
- Could occur due to pressure changes in the reservoir.
Seismic monitoring in Olkaria

- Monitoring of seismicity during well discharge
- Events show a unique pattern and happen along fluid flow pathways.
- Events are located only along fluid filled fractures.
- The monitoring shows that only wells drilled along the fluid filled fractures were productive.
- Wells drilled off the fluid filled fractures were not productive.
Lessons from Seismic Monitoring - Olkaria

- Micro-earthquake monitoring can improve the understanding of the heat source of the geothermal field during development phase
- It can help understand the fluid flow paths in order to clearly define the recharge and the upflow zones
- It will help improve the targeting if production wells during field expansion
- Micro-earthquake monitoring is useful in mapping of the fluid pathways within the system and the behavior of the reservoir
- Can be used as a geohazard monitoring tool during development of the field
Seismic Monitoring in Baringo-Silali
Seismic Monitoring in Baringo Silali

- Ten micro earthquake recording station installed in Paka and Korosi geothermal prospect
- The purpose of this network is to conduct a geohazard monitoring
- Data retrieval done monthly from the station and processed
- Real time data transmission system will be installed as drilling progresses
Seismic Monitoring in Baringo-Silali

A team installing the seismic stations for geohazard monitoring

Things to consider

- ✓ Noise level at station to be away from surface water runway
- ✓ Stations to be installed on hard ground
- ✓ Security of the system
Seismic Monitoring in Baringo-Silali
Seismic Monitoring in Baringo-Silali

Evaluate the number of events over time
Seismic Monitoring in Baringo-Silali

Evaluate the number of events and magnitude over time
Seismic Monitoring in Baringo-Silali

NUMBER OF EVENTS PER YEAR

<table>
<thead>
<tr>
<th>Year</th>
<th>NO OF EVENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>18</td>
</tr>
<tr>
<td>2016</td>
<td>82</td>
</tr>
<tr>
<td>2017</td>
<td>53</td>
</tr>
<tr>
<td>2018</td>
<td>19</td>
</tr>
<tr>
<td>2019</td>
<td>16</td>
</tr>
</tbody>
</table>
Lessons from Seismic Monitoring in Baringo- Silali

- The fields are active seismically apart from Silali
- The Paka volcano is fairly and constantly active with activity concentrating in the southern edge. But why?
- The majority of events recorded are less than magnitude 3
- Potential geothermal fluid movement in the area as seen from the micro earthquakes
- There is a number of deep tectonic events recorded in the prospect area. This indicate that the area is still tectonically active
- There is a slight increase in events recorded soon after drilling started.
Seismic Monitoring for Conceptual Model Development

Mapping of Heat Source
✓ Help identify magma body related to volcanic activity thru
✓ S-Wave Attenuation
✓ Seismicity shadow zone (brittle-ductile transition zone)

Reservoir Characterization
✓ Fluid availability and recharge
✓ Pathways/Conduit for fluid circulation
✓ Status of the Reservoir (liquid/vapour)