Preliminary Microgravity Measurement Of Paka Geothermal Prospect

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Introduction

• Microgravity is a geophysical method that measures minute changes in the force of the earth’s gravity.

• It entails gravity measurements at a network of stations with respect to a permanent base.

• Microgravity surveys are carried out from the surface using portable equipment (CG5 Autograv)

• Microgravity surveys seek to detect areas of contrasting or anomalous density.
Introduction

- Paka is a magmatic active zone

- Hence, need for regular monitoring campaigns with the scope to determine inherent geological changes

- Paka volcano is targeted for accelerated geothermal development by Kenya Government through GDC.

- Information from monitoring campaigns will enhance donor confidence in partnering with GDC
Introduction

GDC has set up a deformation monitoring system in Paka that includes microgravity survey and differential GPS measurements.

Motives for establishment of a monitoring system
• To acquire information on surface deformations related to magmatic movement

• To assess ground deformation as part of the wider scope of determining the inherent geological changes
Synchronized gravity and GPS measurements are a powerful blend for detecting subsurface mass changes.

Repeated deformation and gravity surveys can provide information on how the gravity and height relationship evolves.

Associated to spatial and temporal changes of mass and magma chamber volume within the medium (Charco M. A., 2009).

Basic relations between microgravimetry and deformation (Rymer, N, 1996), Scarpa and Tilling, 1996)
Previous Microgravity Projects

Olkaria Geothermal Field. (Monitor gravity changes from 1988 - 1996 due to geothermal fluid withdrawal, Mariita, 2000)

- Detected relative changes of a few tens of mGals per year in the area under exploitation.
- Observations from wells showed a steep decline of average yearly mass discharge from 1988/96.
- Explained as a sudden subsidence occurring around 1988 when the level of recharge fluid inflow could not keep up with extraction level.
Previous Microgravity Projects

Krafla Volcano. (Rymer and Tryggvason, 1993; de Zeeuw-Van Dalfsen et al., 2005).
• Used an integrated approach,(microgravity and geodetic precise leveling, GPS, and InSAR studies).
• Objective was to attain perception of the deeper processes controlling volcanic activity in Krafla geothermal field, Iceland

Askja Volcano : Studies showed deflation in the period of 1988–2003 to a maximum of 0.46 m in the center of the caldera relative to a station outside.

Aso Volcano, Japan: Monitoring Geothermal Activity: Looking at hydrothermal dynamics beneath Aso volcano using repeat microgravity measurements.
(Yayan SOFYAN, Jun NISHIJIMA, Yasuhiro FUJIMITSU et al)

Usu Volcano in Japan : Shown the power of microgravity monitoring to detect and interpret subsurface mass changes associated with volcanic activity.

Mt Etna in Italy : (1990-1991) microgravity and deformation measurements recorded the intrusion of magma into the summit feeder system and flank fractures Rymer et al., 1995
Objectives

• Preliminary microgravity data acquisition procedure

• Technique used for data processing to set baseline information for geo-hazard monitoring.
Projects Area

- Paka geothermal prospect is situated in the Kenya Rift 20 km NNE of L. Baringo
- The summit elevation is about 1697 masl and rises about 700 m above rift floor.
- The volcano is dominated by a caldera with a diameter of 1.5 km.
- The volcanic complex is dotted with a number of smaller satellite volcanic centers
- Geothermal activity manifestations are present at the summit caldera and northern flank and include widespread fumarolic activity, hot grounds and hydrothermally altered rocks.
Network has a relative gravity base station and several field stations.

First station occupied is the station to close.

Each field gravity station readings consisted of three 60-second measurements.
Field Procedure:
Meter is placed precisely on a predetermined station.

Gravity measurements done repeatedly to produce an average value and standard deviation.

Tokol St. located outside the main zone of deformation used as control point.
RESULTS (Microgravity)

Gravity differences between Benchmarks

<table>
<thead>
<tr>
<th>Traverses</th>
<th>G-Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kokocha - Lokales</td>
<td>2.299</td>
</tr>
<tr>
<td>Kokocha - Nakidoka</td>
<td>59.586</td>
</tr>
<tr>
<td>Lokales - Nakidoka</td>
<td>57.287</td>
</tr>
<tr>
<td>Tuwot - Kokocha</td>
<td>4.203</td>
</tr>
<tr>
<td>Tuwot - Chelopo</td>
<td>79.585</td>
</tr>
<tr>
<td>Kokocha - Chelopo</td>
<td>75.382</td>
</tr>
<tr>
<td>Tuwot - Kakogh</td>
<td>69.841</td>
</tr>
<tr>
<td>Tuwot - Riongo S</td>
<td>9.817</td>
</tr>
<tr>
<td>Riongo S - Chemukutan</td>
<td>46.667</td>
</tr>
<tr>
<td>Chemukutan - Kakogh</td>
<td>34.091</td>
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<tr>
<td>Kakogh - Chelopo</td>
<td>9.792</td>
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<tr>
<td>Nakidoka - Chelopo</td>
<td>15.906</td>
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<tr>
<td>Riongo S - Naudo</td>
<td>3.143</td>
</tr>
<tr>
<td>Naudo - Chemukutan</td>
<td>43.526</td>
</tr>
</tbody>
</table>
Gravity changes over benchmarks in with respect to Tokol ground control point
DGPS

#. Differential GPS Components (dGPS)

- Satellites.
- Receiver hardware.
- Field procedures.
- Software
Why DGPS?

- Ionosphere.
- Troposphere
- Ephemeris data
- Satellite clock drift
- Multipath
- Measurement noise

Differential correction reduces the effects of some GPS errors.

Paka Terrain
METHODOLOGY (DGPS)

Satellite Geometry

- Mask Angles
- Recording interval
- Threshold for 3D coordinates recording

The duration of data collection depends on

- precision
- Visible satellites
- Satellite geometry (DOP). HDOP, VDOP, T
  DOP
- Distance between receivers
METHODOLOGY (DGPS)

PDOP - Horizontal (HDOP) and Vertical (VDOP) measurements (latitude, longitude and altitude)

PDOP values
<=4 excellent
5-8 acceptable
>=9 poor

The vertical component of a GPS measurement is typically two to five times less accurate than the horizontal component. Why is this?
It's strictly a matter of geometry: it's a function of where the satellites are with respect to your position.
Ephemeris data

Configurations
- Base receiver
- Rover receivers
- Static Survey style
- Occupation time

- A list of the satellite’s positions as a function of time
- Each satellite broadcasts its individual ephemeris
- Almanac vs. ephemeris
  - Almanac = predicted orbit data for all satellites
  - Ephemeris = precise orbit data for an individual satellite

- IGS file (precise, Broadcast) (18 days after observation)

DGPS baseline Vectors
Vertical dilution of Position

The vertical component of a GPS measurement is typically two to five times less accurate than the horizontal component. Why is this?

It's strictly a matter of geometry: it's a function of where the satellites are with respect to your position.

\[ PDOP^2 = HDOP^2 + VDOP^2 \]
Software (Static data post Processing)

Data Post Processing

- Trimble Business Centre
- Leica Geo office
- Project Settings
- Ephemeris files (IGS)
- Select Baseline Matrix
- Assign known controls
- Initiate Post process interface

Output of Easting, Northing and Elevation
Micro-gravity monitoring is a technique that can be used to detect and interpret subsurface mass changes associated with volcanic activity.

Microgravity and GPS data can provide enough information on monitoring of volcanic systems.

GPS survey data processing, statistical and congruency testing, show insignificant displacement in the baselines tested for the considered time period with displacement magnitude within the accuracy limits of the GPS survey.

The Controls used are therefore firmly stable in terms of (E,N&Z).

Results of gravity measurements will be treated as a baseline for the next survey.
CONCLUSION AND RECOMMENDATIONS

This can be enhanced if combined with other techniques running concurrently such as microseismics, InSAR and precise leveling.

The current network of ground control benchmarks needs to be expanded to include control stations far away from Paka geothermal prospect.
THANK YOU