GEOCHEMISTRY IN GEOTHERMAL EXPLORATION

Argeo-C2 Conference
24th-28th November 2008
Entebbe, Uganda

James Wambugu – KenGen
Role of Geochemistry in Geothermal Exploration

- Mapping, sampling & chemical analysis of surface discharges
- Chemical data interpretation
- Discharges include: water (hot/cold), fumarole steam
- Non-manifestation areas – Soil gas survey
- Soil gas survey include measuring chemical components associated with geothermal activity (CO\(_2\) gas, Hg, Rn-222 radioactivity)
Objectives of Geochemical Work

- To gather enough geochemical data which would be adequate to address the following questions:
  - Availability and extent of a geothermal resource
  - Locate possible drilling targets
  - Characterize geothermal fluids using the chemistry
  - Predict prevailing deep fluid temp.
Geothermal Manifestations

- Geothermal indicators occur in form of the following:
  - Fumaroles
  - Hot (boiling) springs
  - Mudpools
  - Hot altered grounds
  - Geysers
Steam jets at L. Bogoria which sprout like geysers

- Found at the western edge of the lake
- They are at local boiling temp (98 °C)
- Famous tourist attraction

Boiling steam jets
Fumarole occurrences

- Sometimes fumaroles occur in extremely difficult terrain
- Strong fumaroles are associated with mineral alteration products
Altered grounds

- Some areas are characterized by hot altered grounds with no visible discharges.
- Such areas could be having buried fumarolic activity.
Case example

- Surface exploration in Menengai Area in Nakuru District – Kenya.
- Area characterised by very few surface geothermal manifestations- only a few fumaroles inside the main Menengai crater and to the NW close to caldera rim
- Few boreholes produce warm water located to the NW and SW of crater
- Cold water producing boreholes in the eastern side
Geochemical Data Collection

- Field work started on 25\textsuperscript{th} January 2004
- Work divided into three parts:
  - Water sampling (B/holes, springs etc)
  - Fumarole steam and condensate sampling
  - Soil gas survey (for Rn-222, CO\textsubscript{2}, temp)
Fumarole /borehole location
Soil gas survey sample points
Fumarole sampling

- Gases collected in special gas sampling flasks after evacuation and charged with NaOH solution to absorb acidic gases

Evacuated gas sampling flask
Fumarole discharges

- Some manifestations are too weak and pumping is necessary.
- Samples analysed for gases and condensate analysed for volatile components in the lab.
Why work in three Parts?

1. **Fumaroles:** results help in computing reservoir temp at depth where the steam is being formed

2. **Water analysis:** results used to evaluate origin of the fluids (use of isotopes), temp estimations at depth, predict scaling and corrosion problems

3. **Soil gas survey:** Rn-222 and CO\(_2\) in the soil gas are indicators of permeability and possible location of a reservoir. CO\(_2\) may also be used in locating buried fumarolic activities where other evidence is lacking
Soil gas survey

- CO$_2$ gas sampled from the soil gas in the field using an Orsat apparatus
- CO$_2$ absorbed in vessels containing KOH solution and measured in %

Gas absorption vessels
Chemical Analysis

- Equipments used for chemical analysis include:
  - AAS, ICP
  - GC, IC
  - UV-VIS
  - Titrproprocessors
  - etc
Chemical analysis

- Collected samples are analyzed in the lab
- Water samples analyzed for all the major & minor components
- Steam condensate analyzed for volatile components
Gas analysis

- Fumarole gases analyzed using a Gas chromatograph
- Gases analyzed by GC: \( \text{N}_2, \text{H}_2, \text{O}_2, \text{CH}_4 \)
- \( \text{CO}_2 \) and \( \text{H}_2\text{S} \) analyzed by titration
# Fumarole gas analysis (mmol/kg steam)

<table>
<thead>
<tr>
<th>Fum No.</th>
<th>loc</th>
<th>date</th>
<th>Temp °C</th>
<th>CO₂</th>
<th>H₂S</th>
<th>H₂</th>
<th>CH₄</th>
<th>N₂</th>
<th>O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF1</td>
<td>E1724 N9975</td>
<td>29.1.04</td>
<td>60</td>
<td>28.28</td>
<td>0.1</td>
<td>0.3</td>
<td>-</td>
<td>1.97</td>
<td>0.722</td>
</tr>
<tr>
<td>MF2</td>
<td>E1753 N9977</td>
<td>6.2.04</td>
<td>91.2</td>
<td>3590</td>
<td>0.42</td>
<td>0</td>
<td>0.34</td>
<td>4.69</td>
<td>1.39</td>
</tr>
</tbody>
</table>
## Steam condensate chemistry

<table>
<thead>
<tr>
<th>Fum</th>
<th>T °C</th>
<th>pH/20 °C</th>
<th>CO₂</th>
<th>H₂S</th>
<th>Cl</th>
<th>SO₄</th>
<th>B</th>
<th>F</th>
<th>TDS</th>
<th>Cond</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF1</td>
<td>60</td>
<td>6.0</td>
<td>33</td>
<td>0.17</td>
<td>19.5</td>
<td>3.45</td>
<td>0.17</td>
<td>0.19</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>MF2</td>
<td>94</td>
<td>6.0</td>
<td>38</td>
<td>0.17</td>
<td>24.1</td>
<td>5.1</td>
<td>0.07</td>
<td>0.96</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>MF3</td>
<td>77</td>
<td>7.5</td>
<td>88</td>
<td>0.03</td>
<td>31.4</td>
<td>6.7</td>
<td>0.12</td>
<td>0.13</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>MF4</td>
<td>81</td>
<td>5.8</td>
<td>143</td>
<td>0.17</td>
<td>15.6</td>
<td>7.0</td>
<td>0.14</td>
<td>&lt;0.1</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>MF5</td>
<td>88</td>
<td>6.7</td>
<td>77</td>
<td>0.17</td>
<td>16</td>
<td>5.43</td>
<td>0.05</td>
<td>0.214</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>MF6</td>
<td>84</td>
<td>6.7</td>
<td>33</td>
<td>0.7</td>
<td>16.3</td>
<td>6.74</td>
<td>0.2</td>
<td>&lt;0.1</td>
<td>5.6</td>
<td>10</td>
</tr>
<tr>
<td>MF7</td>
<td>73</td>
<td>6.9</td>
<td>88</td>
<td>0.07</td>
<td>33</td>
<td>29</td>
<td>0.38</td>
<td>0.26</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>MF8</td>
<td>90</td>
<td>6.9</td>
<td>220</td>
<td>0.03</td>
<td>34.1</td>
<td>8.6</td>
<td>0.14</td>
<td>1.64</td>
<td>8</td>
<td>15</td>
</tr>
</tbody>
</table>
## Gas ratios

<table>
<thead>
<tr>
<th>Fuma</th>
<th>CO$_2$/H$_2$S</th>
<th>CO$_2$/H$_2$</th>
<th>H$_2$/H$_2$S</th>
<th>H$_2$/CO$_2$</th>
<th>CO$_2$/N$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF1</td>
<td>282.8</td>
<td>94.3</td>
<td>3</td>
<td>0.011</td>
<td>14.4</td>
</tr>
<tr>
<td>MF2</td>
<td>8547.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>764.8</td>
</tr>
</tbody>
</table>
## Gas geo temp (°C)

<table>
<thead>
<tr>
<th></th>
<th>TCO₂/H₂</th>
<th>TH₂</th>
<th>TH₂S</th>
<th>TCO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuma</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF1</td>
<td>285.3</td>
<td>266.2</td>
<td>251.2</td>
<td>298.5</td>
</tr>
<tr>
<td>MF2</td>
<td>-</td>
<td>-</td>
<td>265.5</td>
<td>371.6</td>
</tr>
</tbody>
</table>
Carbon dioxide distribution
Radon-222 distribution
Ground temp (°C)
Conclusions & Recommendations

- A geothermal resource exists in Menengai caldera with reservoir temp in the range of 250°C.
- The high values of CO₂ measured to the NW part of the caldera could suggest a possible resource area.
- From the geochemical data obtained during this study, the area to the south and SE of caldera do not seem to be attractive at all.
- Deep drilling is recommended to proof the resource.
Proposed drill sites
Menegai Caldera floor