Geochemistry of Aluto-Langano and Corbetti Geothermal Systems

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General Geology and Geochemistry the Rift

Afar
- Basaltic volcanism
- Sodium chloride

MER
- Acid volcanics
- Sodium bicarbonate waters

Adopted from Mackenzie et al, 2005
Scope of the presentation

- Fluid chemistry - (surface manifestations and deep exploratory wells)
- Water-rock interaction processes
- Physical conditions / processes
Outstanding Phenomenon in the MER Waters

- **Water Type:** NaHCO3

- **High bicarbonate**
  - High CO₂ underground: 30 bars at 2500m at reservoir conditions at Aluto-Langano Geothermal Field

- **Very low Ca and Mg:** < 2 mg/L
  - Boiling removes Ca and Mg from the fluids - fixed with calcite, epidote, etc

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Water Chemistry

- **High fluoride (about 30 mg/L)**
  - Groundwaters
    - Acidic rocks: Chem weath/dissolution
    - High T underground: over 340°C at 2500m at Aluto-Lanagno
    - High HCO₃
    - Low Ca
  - Lakes
    - Subsequent evaporation in the Lakes
    - It seems that fluoride is a mobile in the MER waters!

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Chemical Characteristics of Deep Fluids

- TDS: ~ 3.2 g/L
- Ionic strength: < 0.06
- Fluids < 0.2% by wt of either NaCl or HCO3
## Gas Chemistry – Total Discharge

<table>
<thead>
<tr>
<th>Well</th>
<th>H₂</th>
<th>O₂</th>
<th>N₂</th>
<th>CO₂</th>
<th>H₂S</th>
<th>NH₃</th>
<th>CH₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA-6</td>
<td>0.04</td>
<td>1x10⁻²⁹</td>
<td>0.25</td>
<td>32</td>
<td>0.2</td>
<td>3.6x10⁻³</td>
<td>0.13</td>
</tr>
<tr>
<td>LA-8</td>
<td>0.02</td>
<td>1.6x10⁻³⁴</td>
<td>0.47</td>
<td>40</td>
<td>0.03</td>
<td>1.5x10⁻³</td>
<td>0.45</td>
</tr>
</tbody>
</table>

## CO₂ in the Steam Phase

<table>
<thead>
<tr>
<th>Well</th>
<th>mM/100M</th>
<th>xᵢ</th>
<th>Mol%</th>
<th>Wt%</th>
<th>SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA-6</td>
<td>2606</td>
<td>0.026</td>
<td>2.6</td>
<td>6.3</td>
<td>7.4</td>
</tr>
</tbody>
</table>
PCO2 Vs Temperature

Numbers correspond to LAC.

\[ R^2 = 0.84 \quad \text{PCO2} = 0.28T + 126.49 \]

\[ \text{CO}_2 \text{(bar)} \]

\[ \text{Temperature (°C)} \]
Upflow Zone of the Field

Fig. 10. Na/K distribution map of the Aluto-Langano deep wells (Gizaw, 1989).
Physical processes

Mixing processes

B - Cl
\[ B = -0.19639 + 5.7278e^{-3}Cl; \ R^2 = 0.968 \]

SO4 - Cl

SiO2 - Cl
\[ SiO_2 = 30.312 + 0.40737Cl; \ R^2 = 0.972 \]

O-18 - Cl

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Physical processes

Mixing models

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Boiling Processes

- Temperature decreases by > 100°C within 200m in LA-6
- 2.6°C temperature drop for each % of water vaporized in LA-6

Fig 2.6 Overall temperature profiles of the Wells
Geothermometry

Na Vs K - Aluto-Langano Area, etc - Calibrated
Na Vs K - Aluto-Langano Area

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\[ \text{Shallow mixed waters} \quad (T < 180^\circ C) \]

\[ \text{Deep wells} \quad (T > 200^\circ C) \]

- \( \text{CO}_2 + \text{H}_2\text{O} + \text{Na,K-sil} \)
- \( \text{HCO}_3^- + \text{Na, K + H-sil} \)
- \( \text{K-sil + Na} \rightarrow \text{Na-sil + K} \)
The State of Fluorite Saturation

Saturation with respect to Anhydrite and Pyrite

Unsaturated

Anhydrite

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Mineral distribution in deep Aluto-Langano wells
Photomicrographs showing primary and secondary minerals

LA-4: 1250m 40x

LA-6: 1505m 85x

LA-8: 2500m 85x
Isotope Indications
Isotope Indications

Recharge: Escarpment

- Relief difference
- Rainfall
- Isotopic evidence
Environmental aspect

LA-3 water pond used by local people for domestic purposes:

- Not appropriate due to its high – TDS, Cl, Etc.

- RInjection the fluid back into the system is to be encouraged.
Conclusions

- The Aluto-Langano geothermal system is matured one
- Neither potential scaling nor corrosion is anticipated
- The fluid is suitable for commercial utilization
- The anticipated recharge mechanism is assumed to be sufficient to support sustainable development of the field
Recommendations

- Full scale exploration and development
- GSE and EEPCo need to work closely in a sustainable manner
Corbetti Geothermal Prospect

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Silicic volcanic system

A classic resurgent cauldron with post-caldera volcanism during the Pleistocene having produced four major volcanic edifices: Urji, Chebi, and volcanoes.

Surface hydrothermal alteration - mixed layered clays (montmorillonite), kaolin, and amorphous silica (sinters), while the study of hydrothermal alteration minerals on the cuttings recovered from TG - high temperature mineral assemblages such as chlorite, kaolin, calcite and quartz.
Geochemistry

- Thermal manifestations – restricted to steaming grounds and fumaroles
- Three out of the six drilled TG wells (93-178m) reached the shallow groundwater level
Geochemistry

Water type

- The chemistry of shallow gradient wells - sodium bicarbonate type.

- The waters encountered in these wells – affected by evaporation (TG-3) and steam heating (TG-2)

- Relatively high H2S (Koka fumaroles)
Geochemistry

Subsurface temperatures predicted - in excess of 300ºC

• Gas equilibrium temperatures,
• Helium and neon measurements from two steam vents,
• Isotope geothermometers

Isotopic investigations

• The 18O enrichment of some temperature gradient wells is probably due to evaporation.
• The isotopic composition of the steam from fumaroles lies on the meteoric line.
• Isotopic and chemical data suggest that the system is recharged from the eastern escarpment.
Shallow groundwater flow direction:

- Dominantly from south to north

Zeal Bessemer, 2003

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Conclusion and recommendations

Conclusion

✓ Corbetti is one of the most promising geothermal field in the Lakes District

Recommendations

• Detailed structural and hydrothermal alteration studies - to help in locating the more permeable zones of the deep reservoir area.
• Detailed geochemical work – especially soil geochemical investigation (CO₂, Rn, Hg) - to aid in identifying zones of leakage and map the up-flow zone
• Shallow (slim?) well drilling – to understand the top-most part of the geothermal system and to contribute to the better planning of the deep investigation-drilling program should be drilled to reach at least the hot water surface that should be expected to be at about the 1600-1620m asl.
Thank you!