GEOCHEMISTRY IN GEOTHERMAL EXPLORATION

Argeo-C2 Conference

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Entebbe, Uganda

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Role of Geochemistry in Geothermal Exploration

KenGen

- 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

KenGen

- 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

Boiling steam jets

- Steam jets at L. Bogoria which sprout like geysers
- Found at the western edge of the lake
- They are at local boiling temp (98 ^{o}C)
- Famous tourist attraction

Fumarole occurrences

Discharging fumaroles

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

Altered grounds

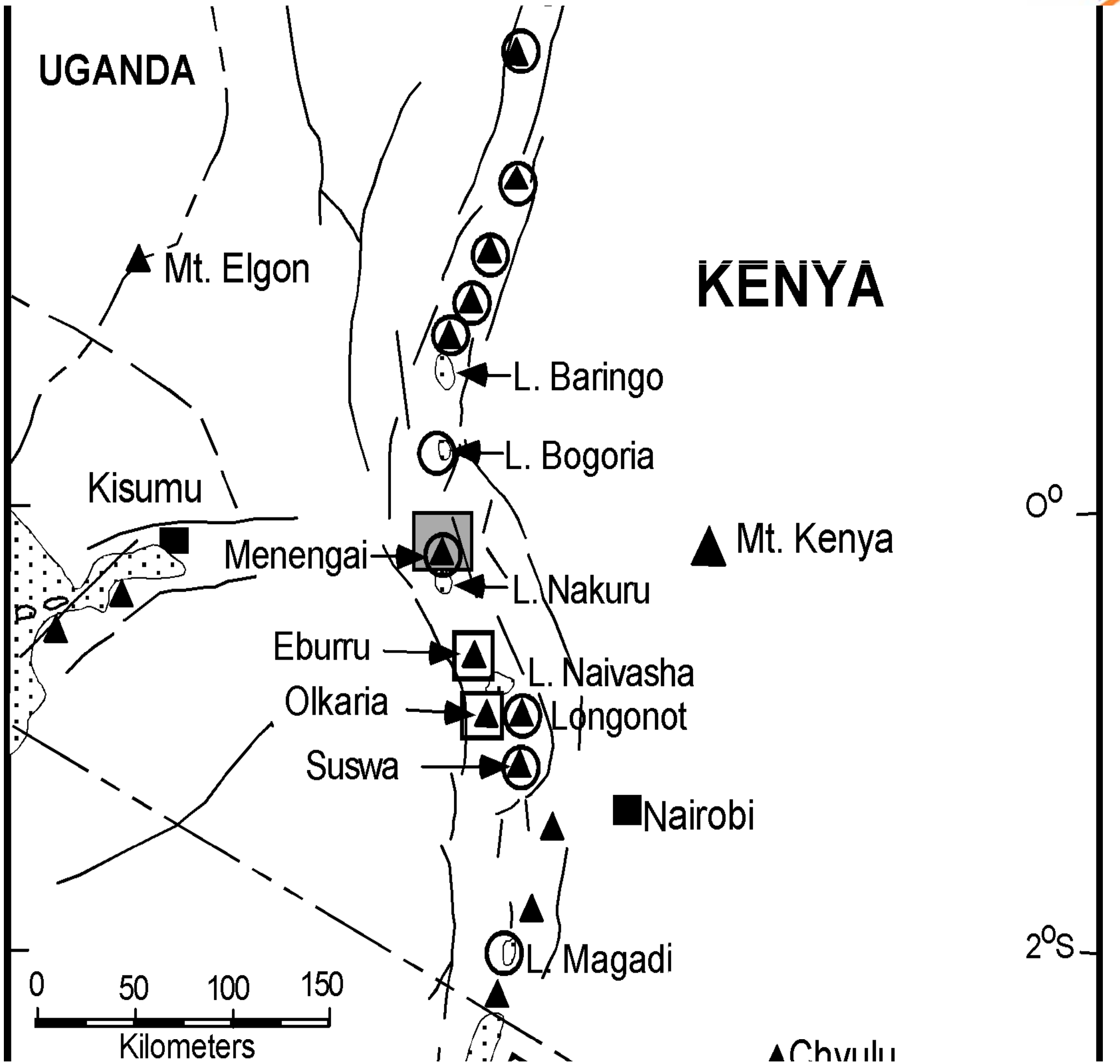
Altered grounds

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

Case example

KenGen

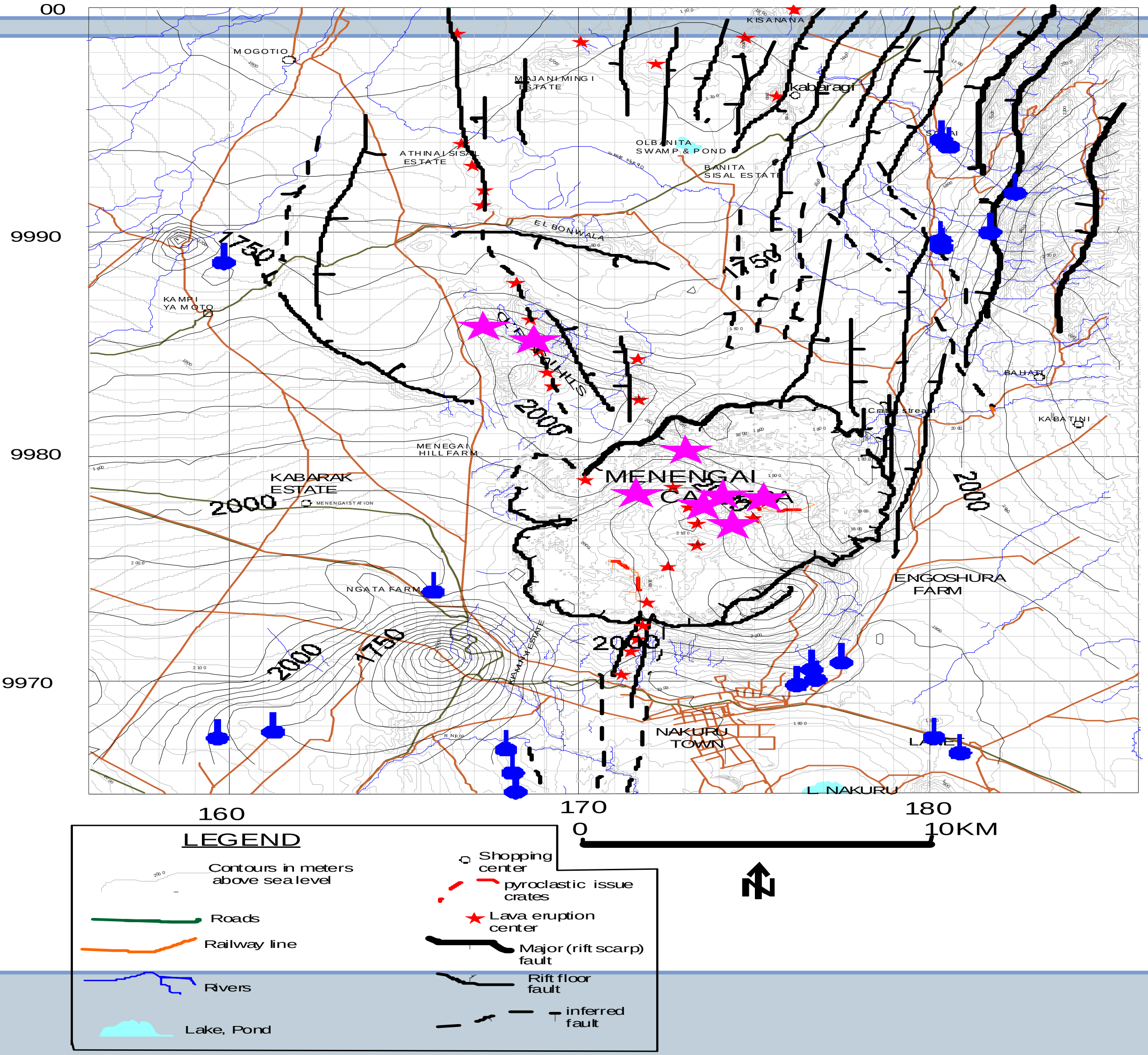
- Surface exploration in Menengai Area in Nakuru District – Kenya.
- Area characterised by very few surface geothermal manifestations- only a few fumaroles inside the main Menengai crater and to the NW close to caldera rim
- Few boreholes produce warm water located to the NW and SW of crater
- Cold water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


UGANDA
KENYA
Mt. Elgon
L. Baringo
L. Bogoria
Kisumu
0°
Mt. Kenya
Menengai
L. Nakuru
Eburru
L. Naivasha
Olkaria
Longonot
Suswa
Nairobi
2°S
L. Magadi
0
50
100
150
Kilometers

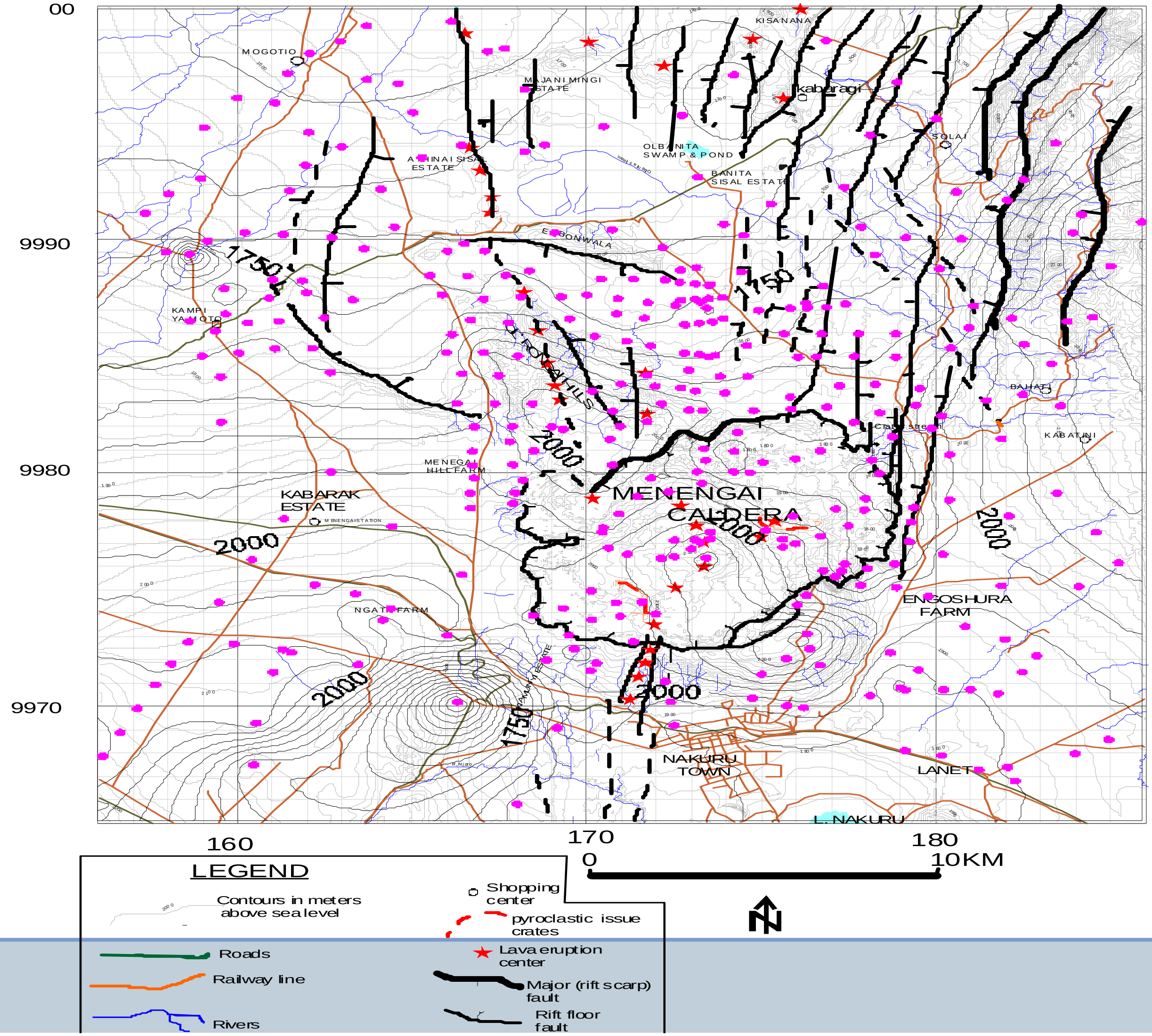
Geochemical Data Collection

- Field work started on 25th 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_2, temp)

Fumarole /borehore location



Soil gas survey sample points



Fumarole sampling

Evacuated gas sampling flask

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

Fumarole discharges

Sampling pump

- 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

Gas absorption vessels

- 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 %

Chemical Analysis

- Equipments used for chemical analysis include:
  - AAS, ICP
  - GC, IC
  - UV-VIS
  - Titrpoprocessors
  - 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

GC

- Fumarole gases analyzed using a Gas chromatograph
- Gases analyzed by GC: N_2, H_2, O_2, CH_4
- CO_2 and H_2S analyzed by titration

Fumarole gas analysis (mmol/kg steam)

Fum No.	loc	date	Temp ºC	CO_2	H_2S	H_2	CH_4	N_2	O_2
MF1	E1724 N9975	29.1.04	60	28.28	0.1	0.3	-	1.97	0.722
MF2	E1753 N9977	6.2.04	91.2	3590	0.42	0	0.34	4.69	1.39

Steam condensate chemistry

Fum	T °C	pH/20 °C	CO_2	H_2S	Cl	SO_4	B	F	TDS	Cond
MF1	60	6.0	33	0.17	19.5	3.45	0.17	0.19	11	20
MF2	94	6.0	38	0.17	24.1	5.1	0.07	0.96	20	50
MF3	77	7.5	88	0.03	31.4	6.7	0.12	0.13	6	10
MF4	81	5.8	143	0.17	15.6	7.0	0.14	<0.1	4	10
MF5	88	6.7	77	0.17	16	5.43	0.05	0.214	6	10
MF6	84	6.7	33	0.7	16.3	6.74	0.2	<0.1	5.6	10
MF7	73	6.9	88	0.07	33	29	0.38	0.26	12	25
MF8	90	6.9	220	0.03	34.1	8.6	0.14	1.64	8	15

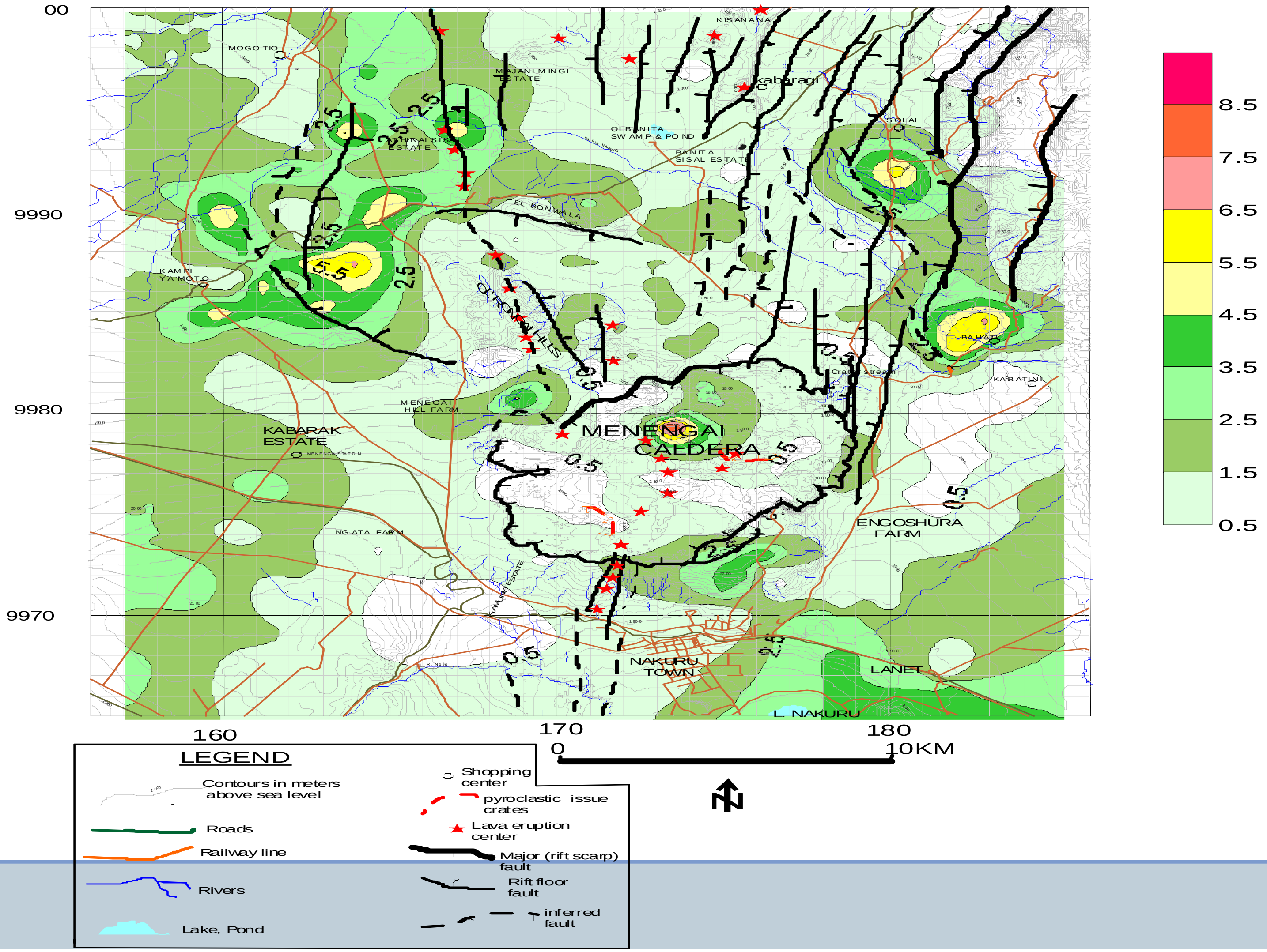
Gas ratios

Fuma	CO_2/H_2S	CO_2/H_2	H_2/H_2S	H_2/CO_2	CO_2/N_2
MF1	282.8	94.3	3	0.011	14.4
MF2	8547.6	-	-	-	764.8

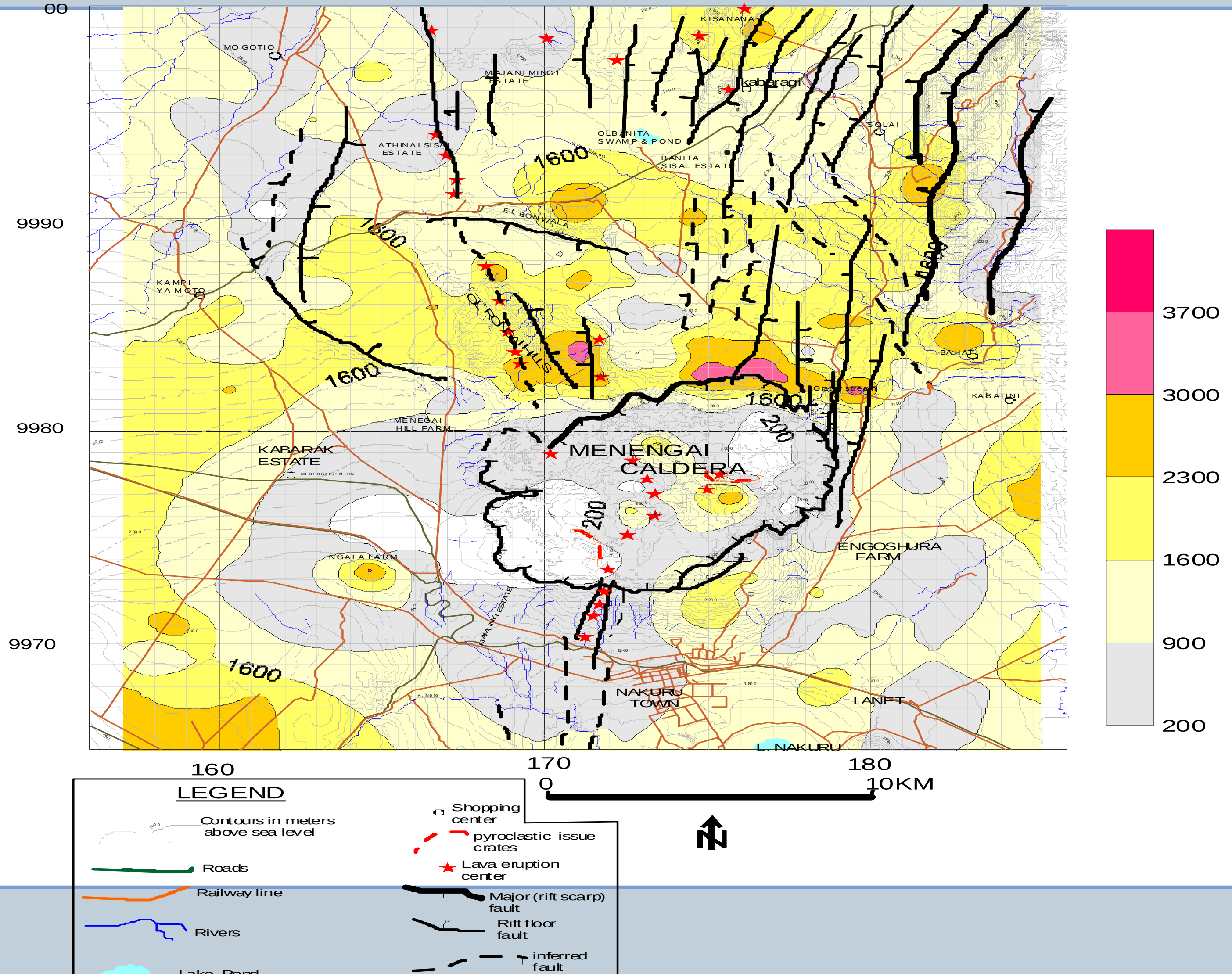
Gas geo temp (^oC)

Fuma	TCO_2/H_2	TH_2	TH_2S	TCO_2
MF1	285.3	266.2	251.2	298.5
MF2	-	-	265.5	371.6

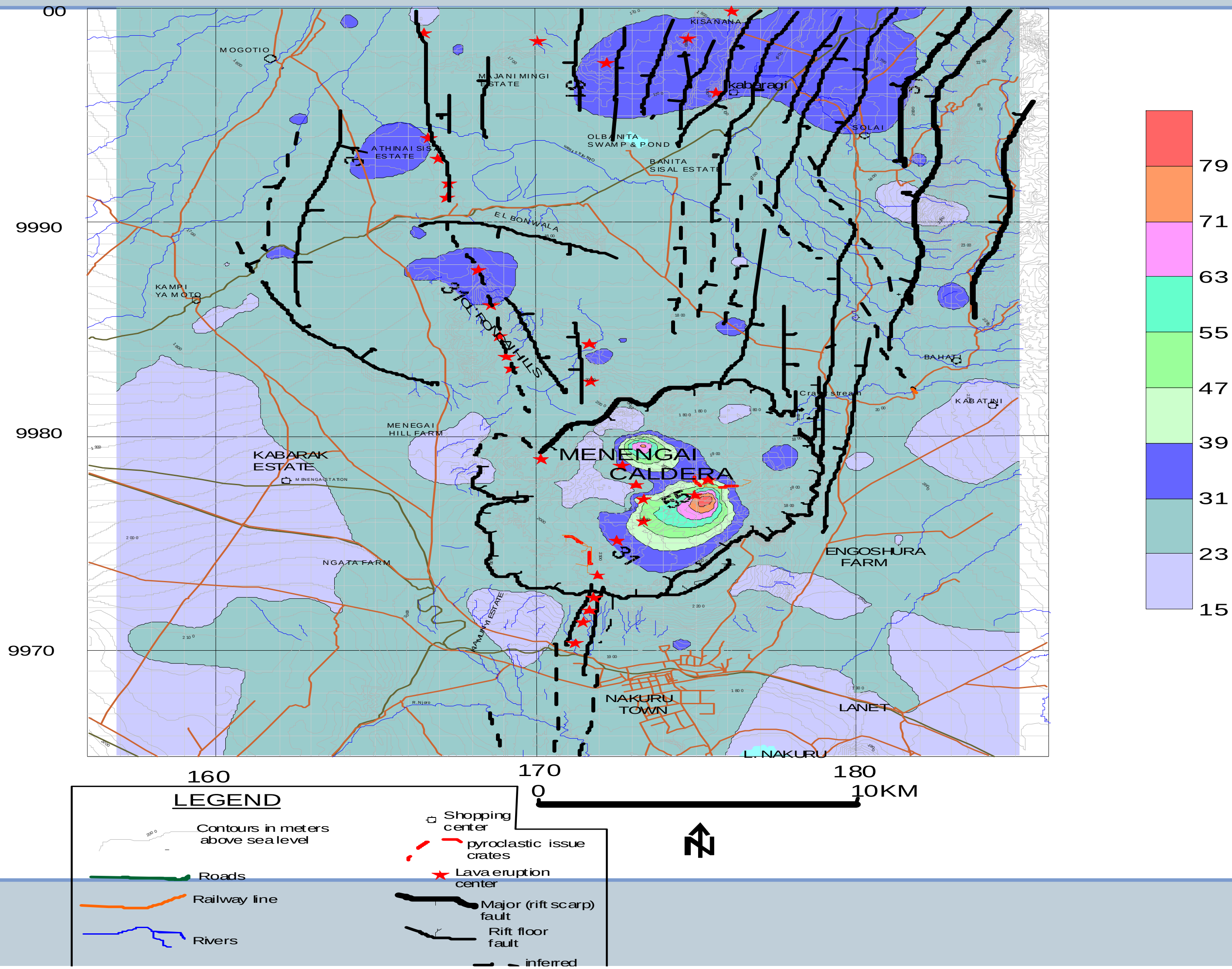
Carbon dioxide distribution



Radon-222 distribution



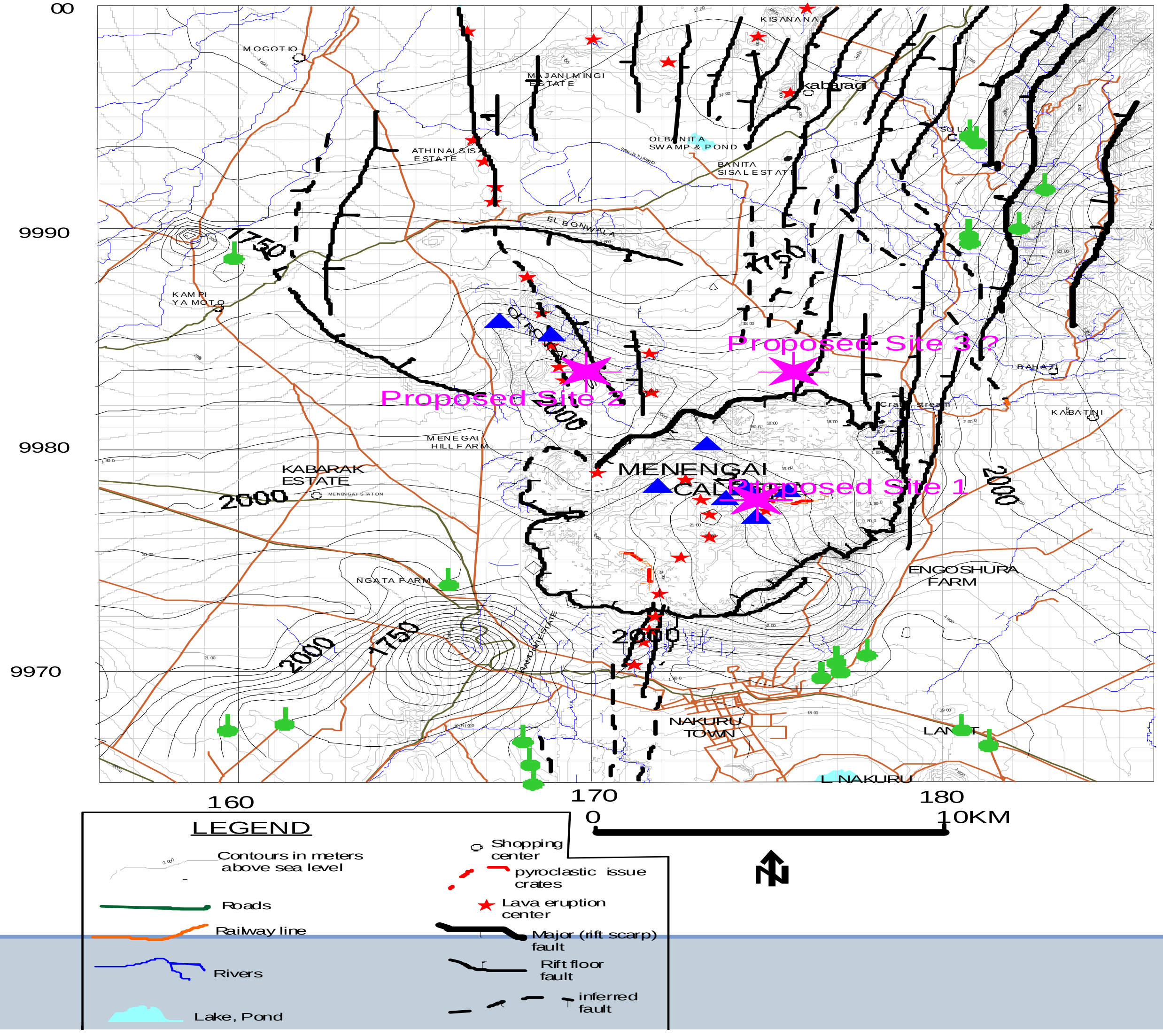
Ground temp (ºC)



Conclusions & Recommendations

- A geothermal resource exists in Menengai caldera with reservoir temp in the range of 250ºC
- The high values of CO_2 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