Geochemistry of Aluto-Langano and Corbetti Geothermal Systems

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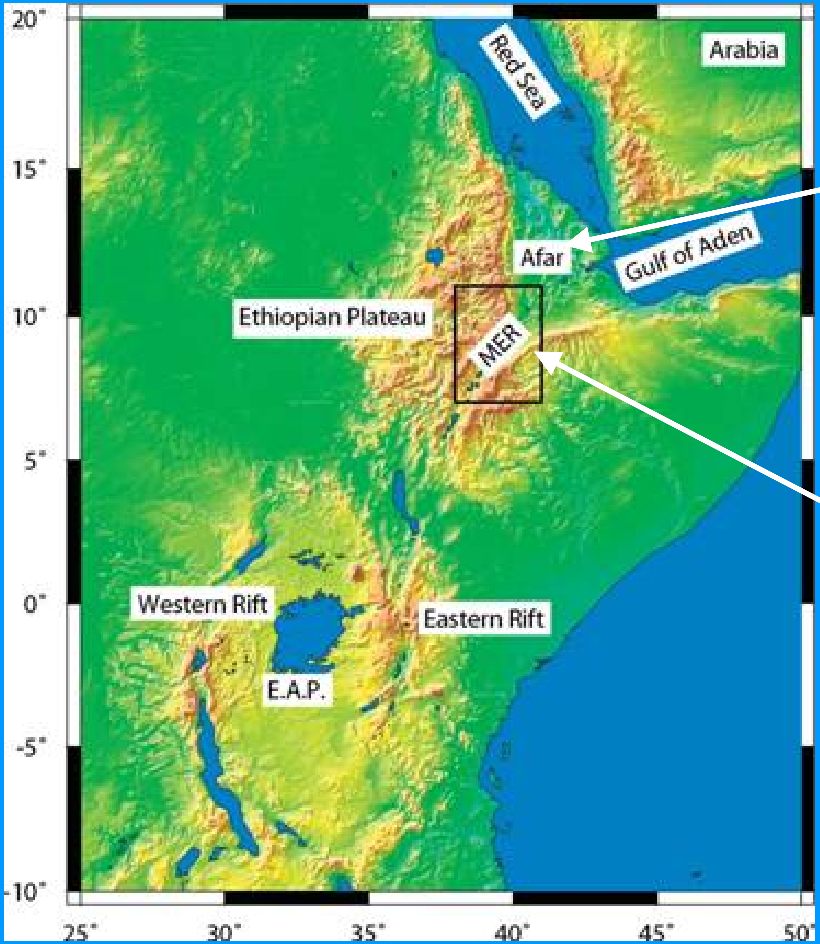
General Geology and Geochemistry the Rift



Afar
- **Basaltic volcanism**
- **Sodium chloride**

MER
- **Acid volcanics**
- **Sodium bicarbonate waters**

Adopted from Mackenzie et al, 2005

Scope of the presentation

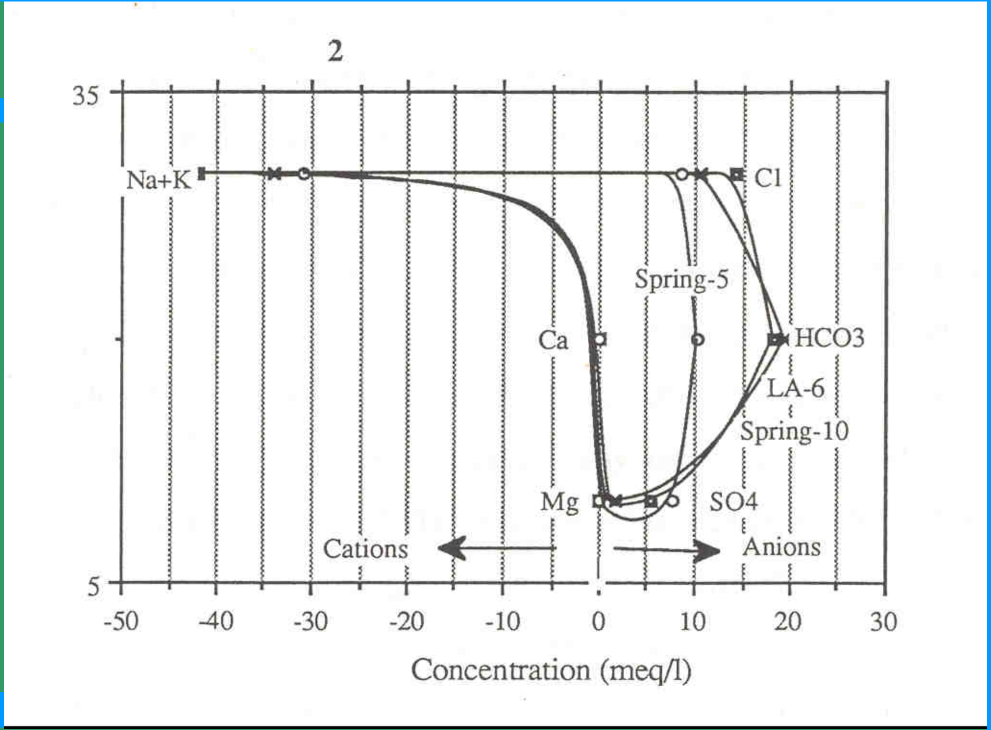
- ☞ Fluid chemistry - (surface manifestations and deep exploratory wells)
- ☞ Water-rock interaction processes
- ☞ Physical conditions / processes

Outstanding Phenomenon in the MER Waters

- **Water Type: NaHCO3**

- **High bicarbonate**

  High CO_2 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

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 HCO_3
    - ✓Low Ca
  - Lakes
    - ✓Subsequent evaporation in the Lakes
    - ✓It seems that fluoride is a mobile in the MER waters!

Chemical Characteristics of Deep Fluids

- ☞ **TDS: ~ 3.2 g/L**
- ☞ **Ionic strength: < 0.06**
- ☞ **Fluids < 0.2% by wt of either NaCl or HCO3**

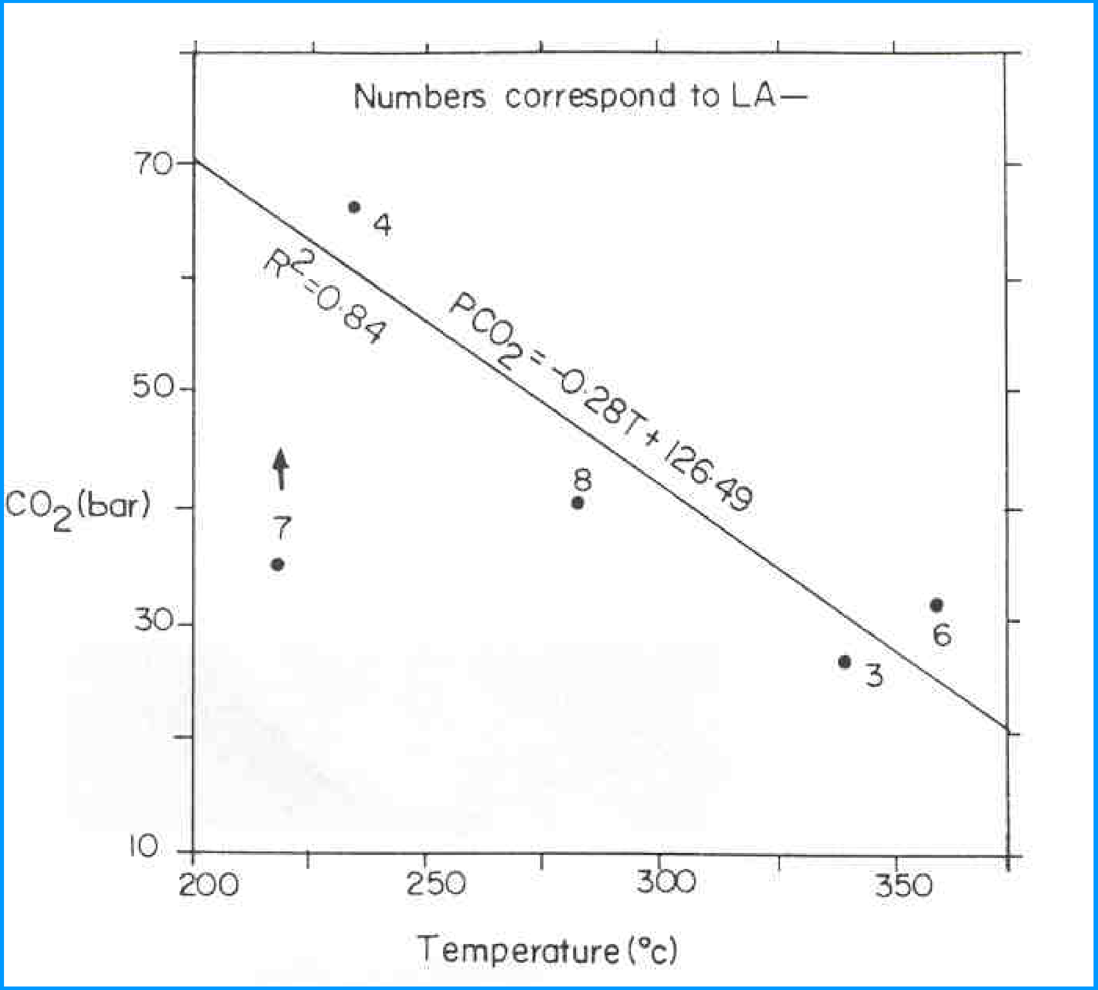
Gas Chemistry – Total Discharge

Well	H_2	O_2	N_2	CO_2	H_2S	NH_3	CH_4
LA-6	0.04	$1x10^{-29}$	0.25	32	0.2	$3.6x10^{-3}$	0.13
LA-8	0.02	$1.6x10^{-34}$	0.47	40	0.03	$1.5x10^{-3}$	0.45

CO_2 in the Steam Phase

Well	mM/100M	xi	Mol%	Wt%	SP
LA-6	2606	0.026	2.6	6.3	7.4

PCO2 Vs Temperature



Upflow Zone of the Field

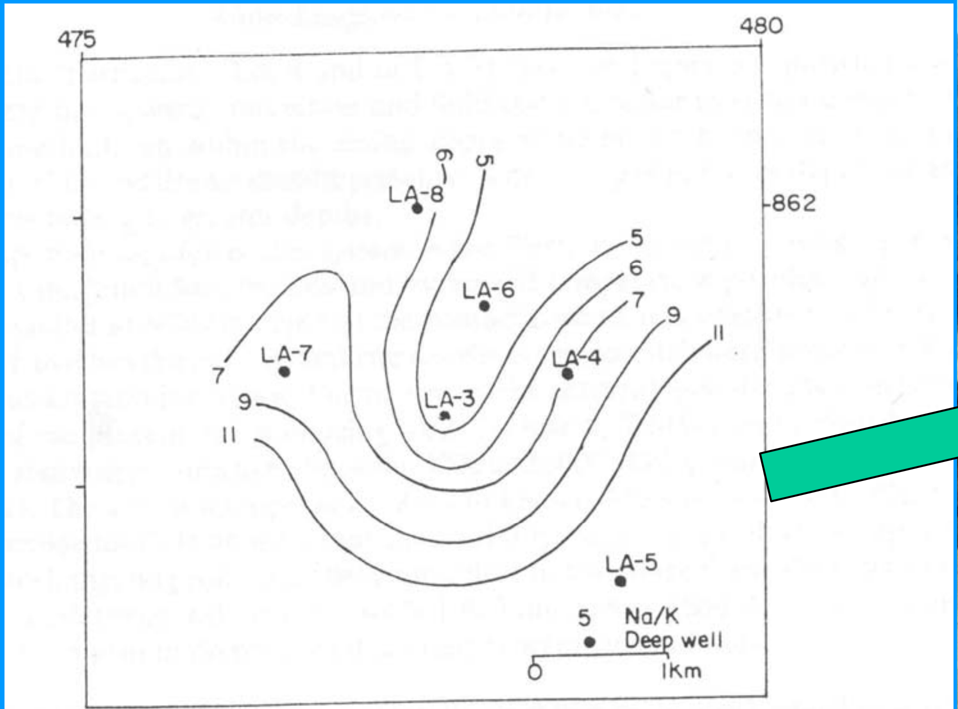
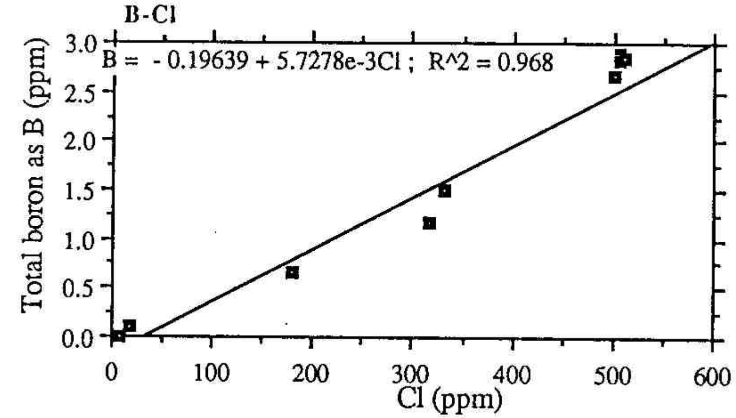
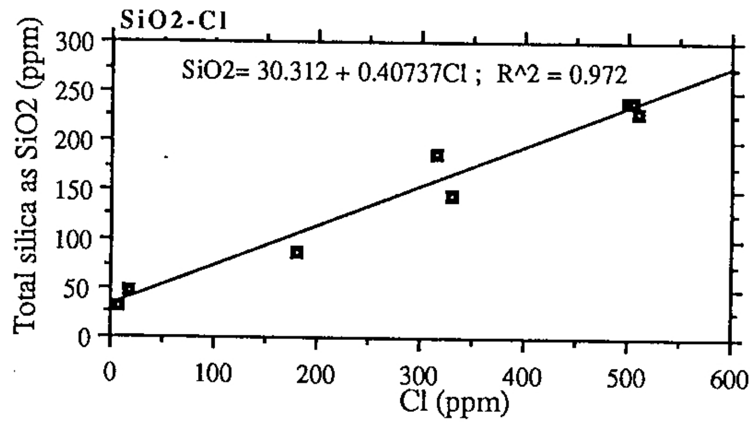


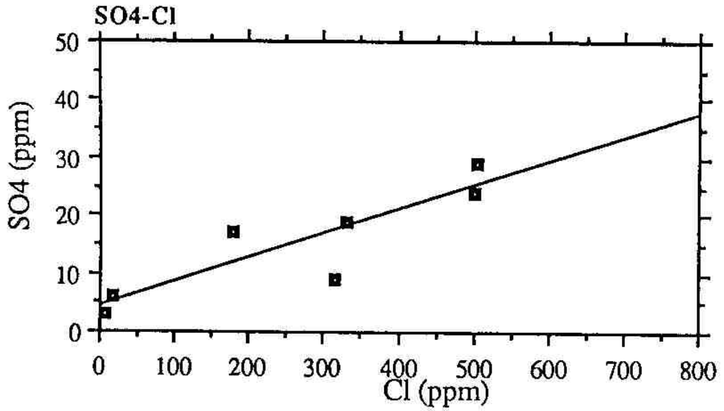
Fig. 10. Na/K distribution map of the Aluto-Langano deep wells (Gizaw, 1989).

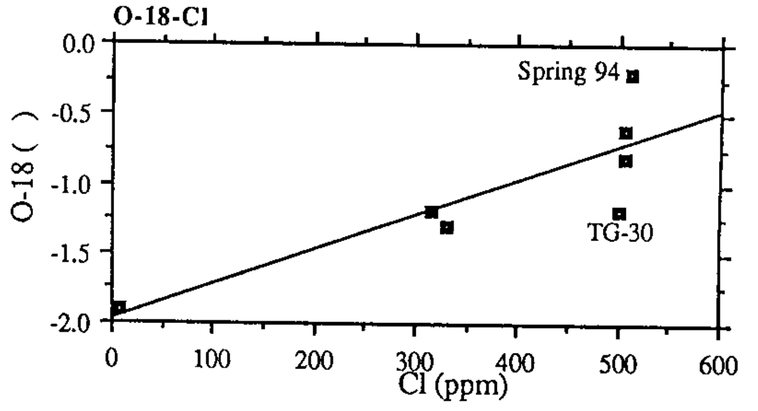
Physical processes

Mixing processes



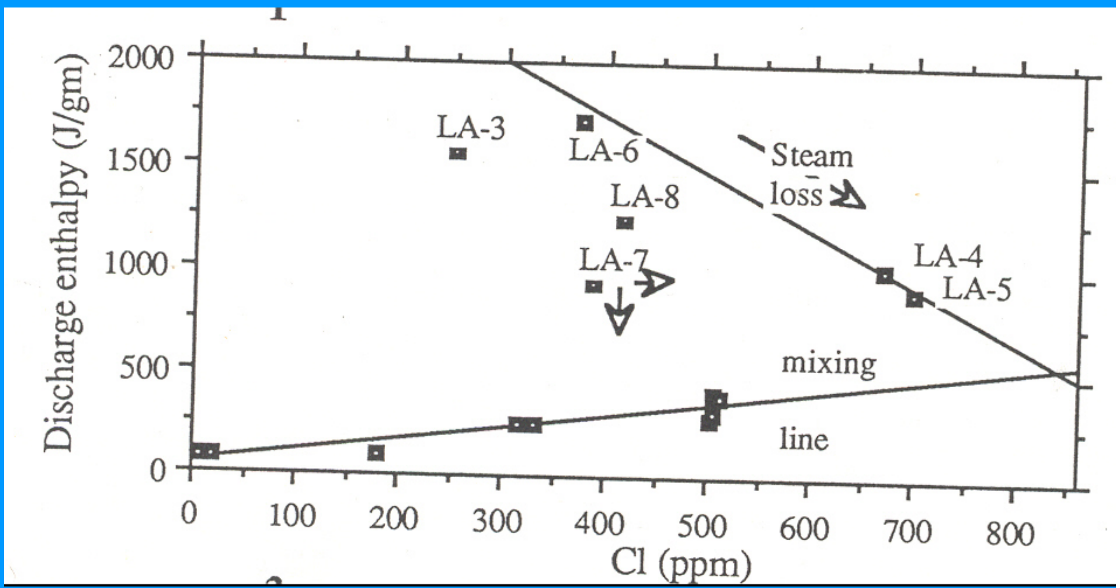


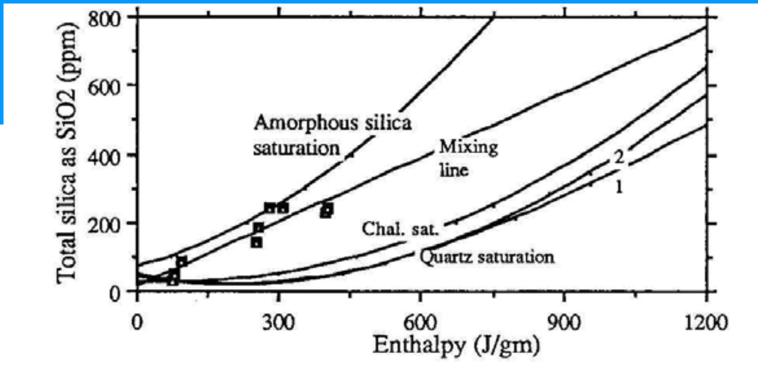


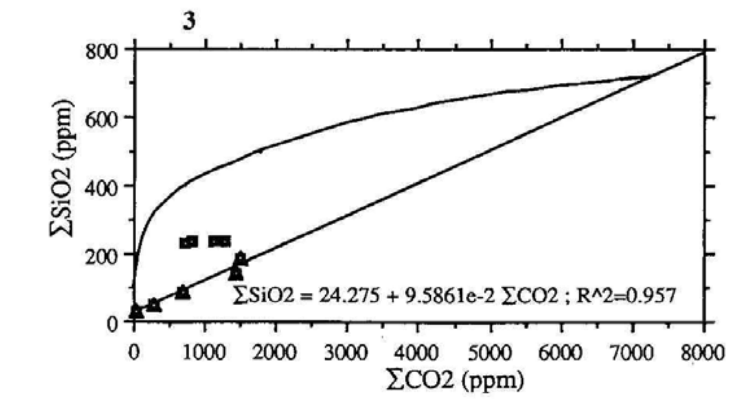


Physical processes

Mixing models



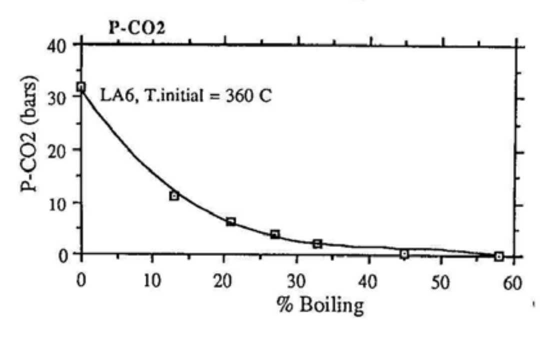


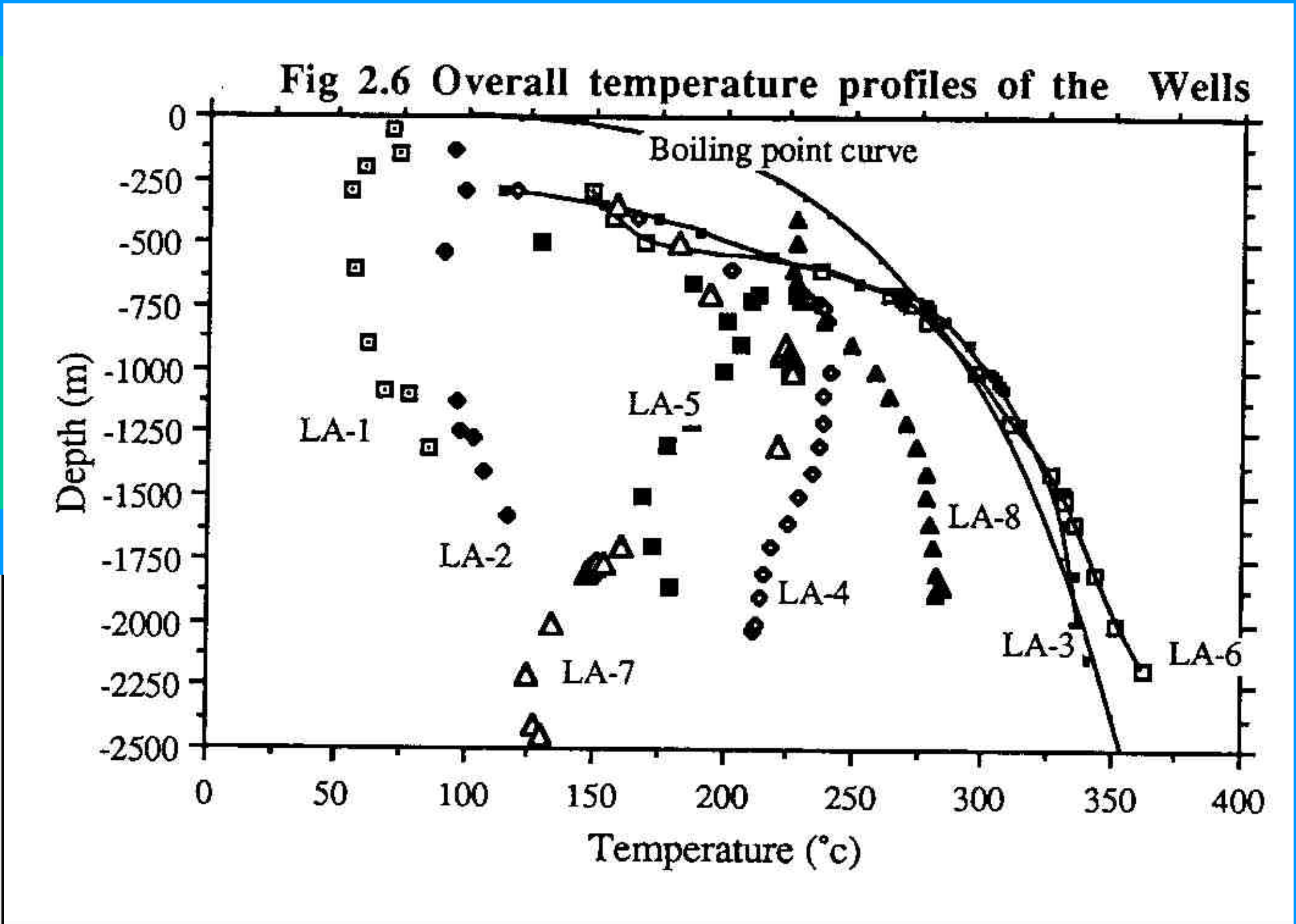


Boiling Processes

☞ T. decreases by > 100°C within 200m in LA-6

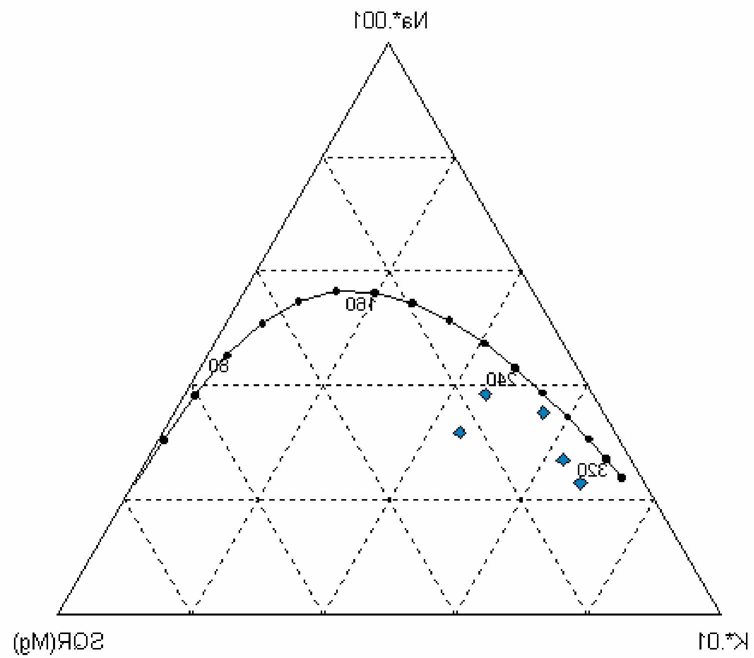
☞ 2.6°C Temp. drop for each % of water vaporized in LA-6



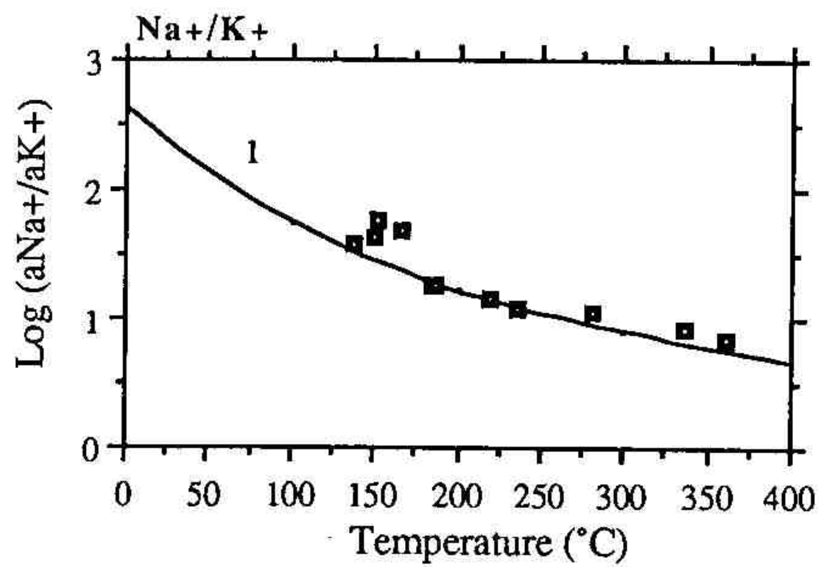


Geothermometry

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

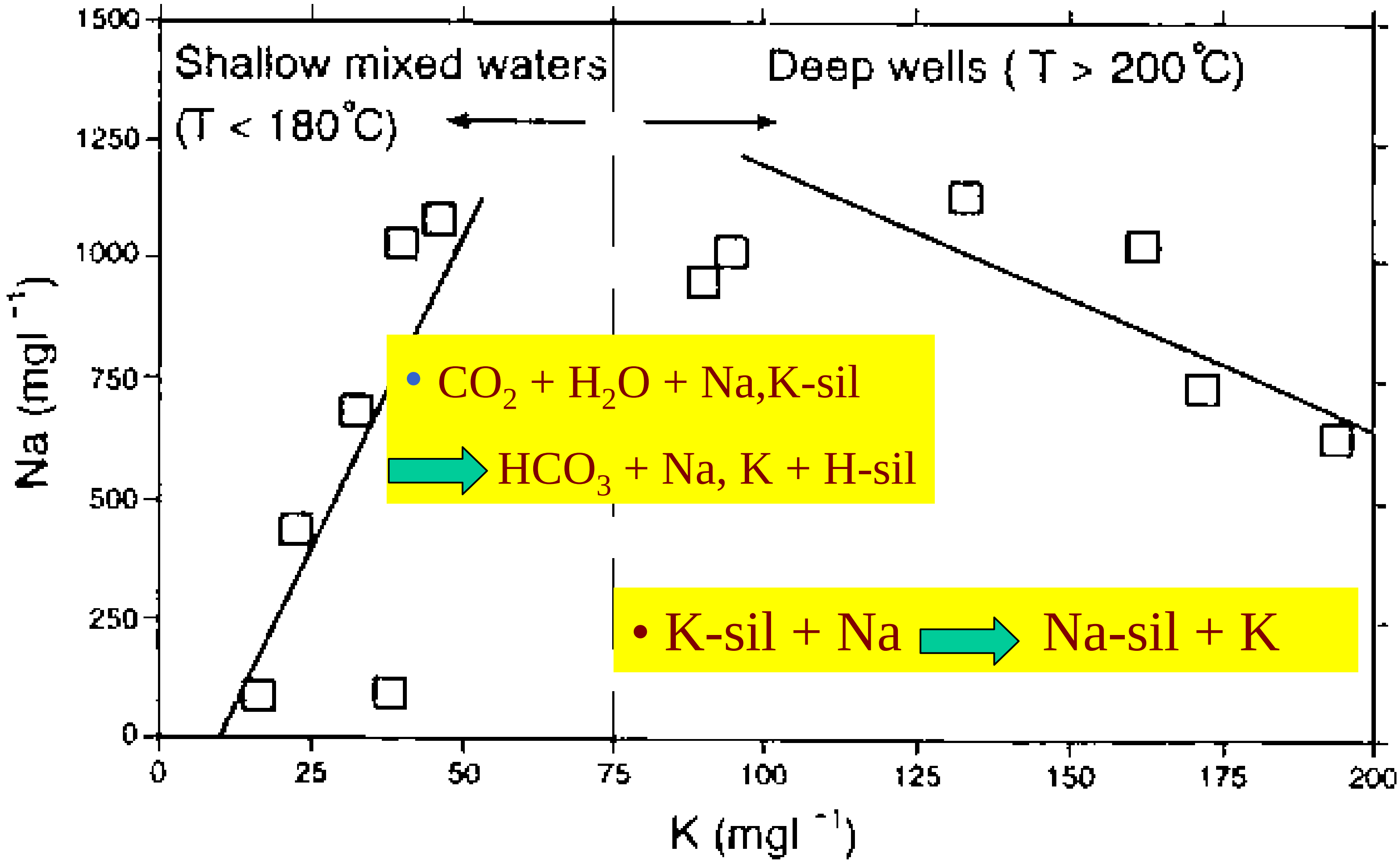


Geothermal Division, 2002

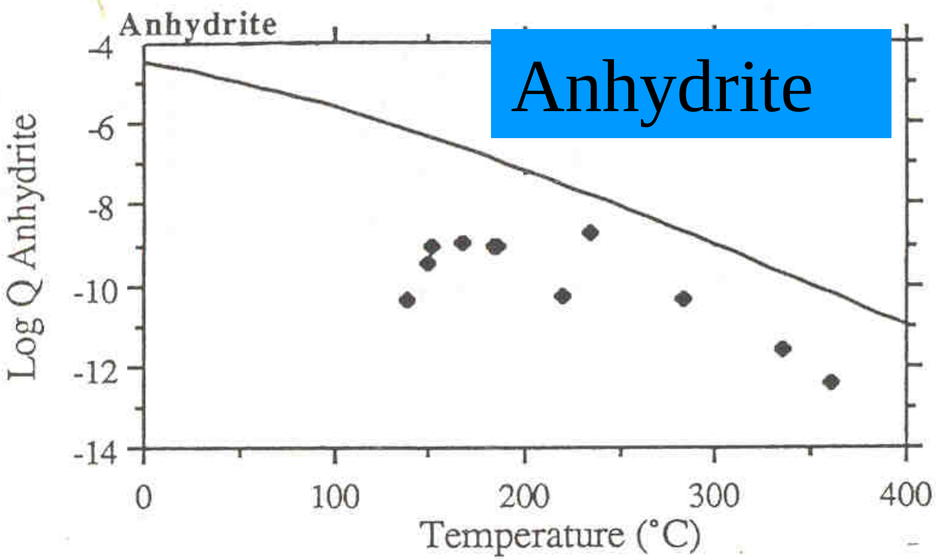


	Geothermometer	Temperature functions, (°C). Range 200-360°C	Units	R^2
1	FeH	$\log \sqrt{Fe^{+2}} / H^{+} = 9.0514 - 2.5646 \times 10^{-2}\, t^{-2} - 2.0079 \times 10\text{-}5\, t^{2}$	a	0.986
2	CaK	$\log \sqrt{Ca^{+2}} / H^{+} = 2.3182 - 1.7627 \times 10^{-2}\, t + 4.1260 \times 10^{-5}\, t^{2} - 4.4095 \times 10\text{-}8\, t^{3}$	a	0.930
3	HF	$\log HF^{0} = -8.3977 - 1.8387 \times 10^{-2}\, t + 2.7340 \times 10^{-4}\, t^{2} -5.1643 \times 10^{-7}\, t^{3}$	m	0.945
4	AlOH	$\log Al(OH)_4^{-} / OH^{-} = -4.6604 + 3.3892 \times 10^{-2}\, t -1.0430 \times 10\text{-}4\, t^{2}$	a	0.986
5	KH	$\log K^{+} / H^{+} = 11.205 -5.9411 \times 10^{-2}\, t + 1.4268 \times 10\text{-}4\, t^{2} -7.8559 \times 10\text{-}8\, t^{3}$	a	0.715
6	NaH	$\log Na^{+} / H^{+} = 15.628 - 8.9698 \times 10^{-2}\, t -2.3539 \times 104\, t^{2} - 1.7908 \times 10\text{-}7\, t^{3}$	a	0.840
7	NaK	$Na^{+} / K+ = 25.309 - 0.10113\, t + 1.1370 \times 10\text{-}4\, t^{2}$	ppm	0.981
8	Na	$Na^{+} = 1904.9 - 1.9081\, t - 4.3453 \times 10\text{-}3\, t^{2}$	ppm	0.994
9	K	$K^{+} = -639.27 + 7.6580\, t -2.5245 \times 10^{-2}\, t^{2} + 2.8869 \times 10^{-5}\, t^{3}$	ppm	0.995
10	Na/Li	$Na^{+} / Li^{+} = 1.7814 \times 10^{4} - 124.13\, t + 0.18868\, t^{2} + 1.2840 \times 10^{-4}\, t^{3}$	ppm	0.923
11	SO4/H2S	$SO4^{-2} / H2S^{0} = 658.54 - 5.9038\, t + 1.7664 \times 10^{-2}\, t^{2} - 1.7623 \times 10^{-5}\, t^{3}$	ppm	1.000
12	CO2/H2S	$CO2^{0} / H2S^{0} = 7043.6 - 37.98\, t + 5.1664 \times 10^{-2}\, t^{2}$	mM/100M	1.000
13	TDS	$TDS = 7712.5 - 12.676\, t$	ppm	0.992
14	I	$I = 0.11950 - 2.6956 \times 10^{-4}\, t$	m	0.980
15	Eh	$Eh = 0.77083 - 6.8811 \times 10^{-3} + 7.0364 \times 10^{-6}\, t^{2}$	volt	0.999

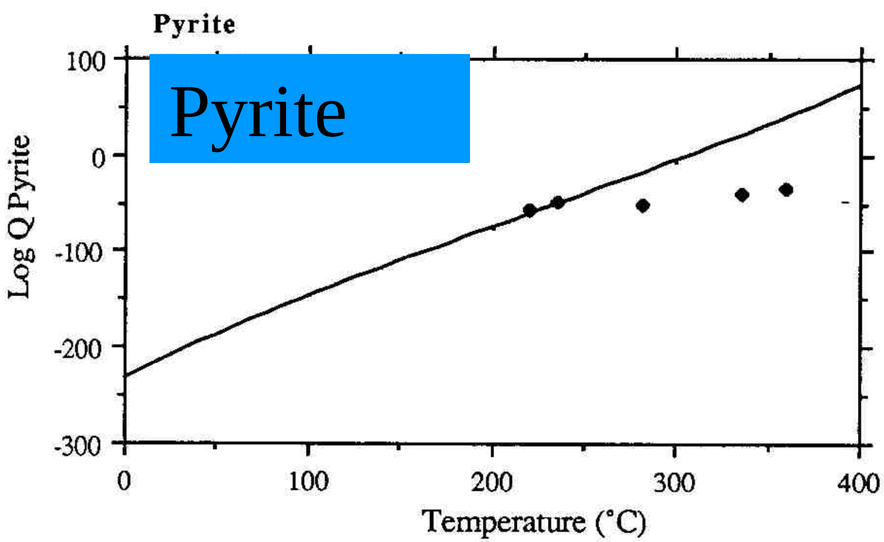
Na Vs K - Aluto-Langano Area



The State of Fluorite Saturation

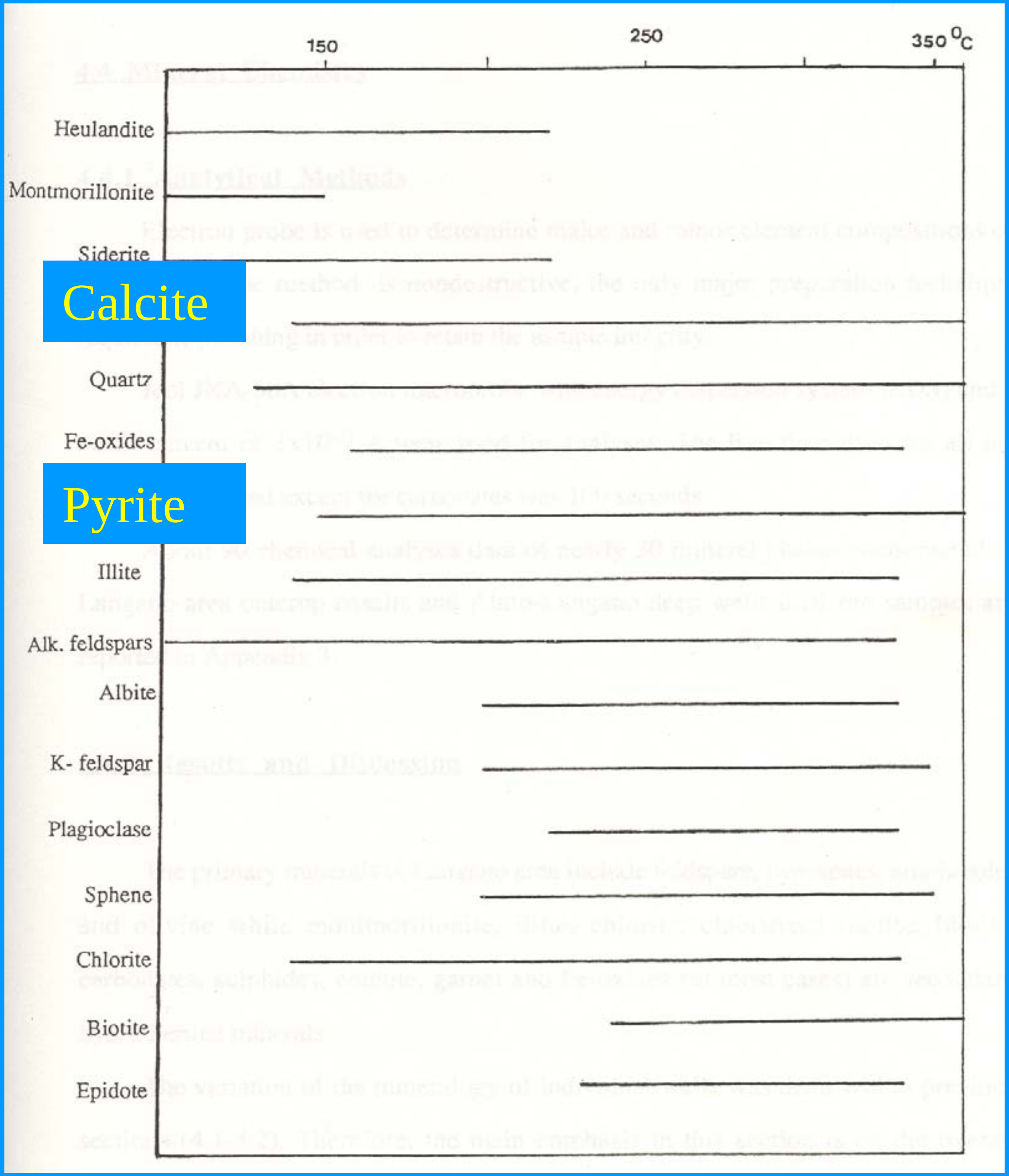


Saturation with respect to Anhydrite and Pyrite

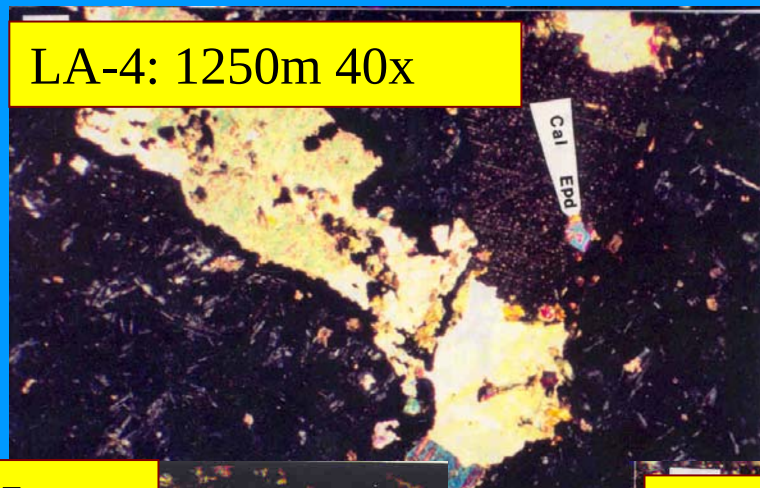


Unsaturated

Mineral distribution in deep Aluto-Langano wells

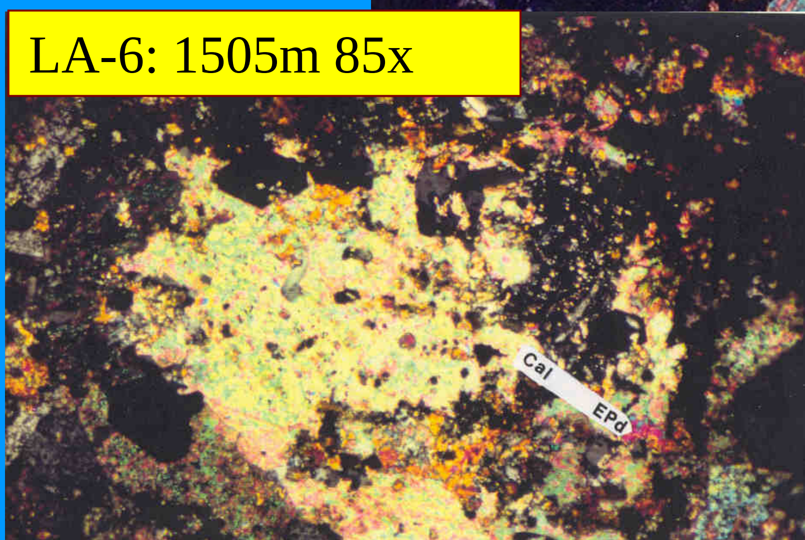


Photomicrographs showing primary and secondary minerals

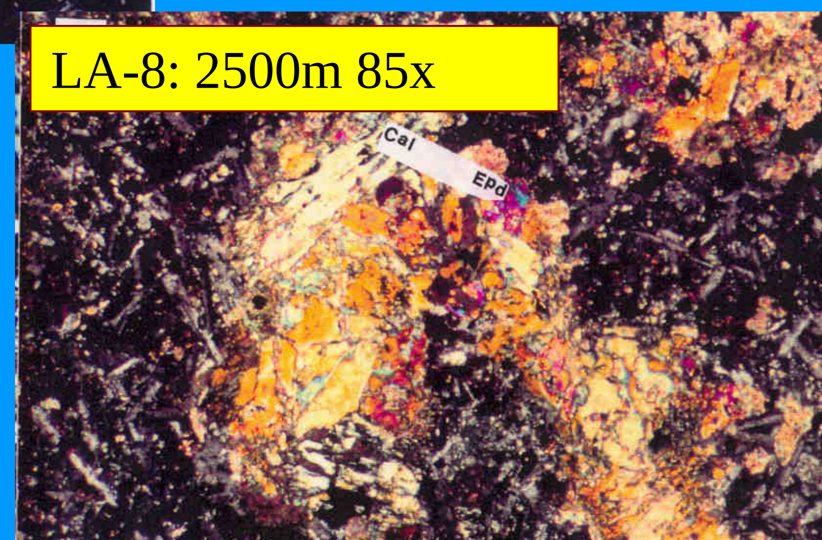


LA-4: 1250m 40x

Photomicrographs showing primary and secondary minerals



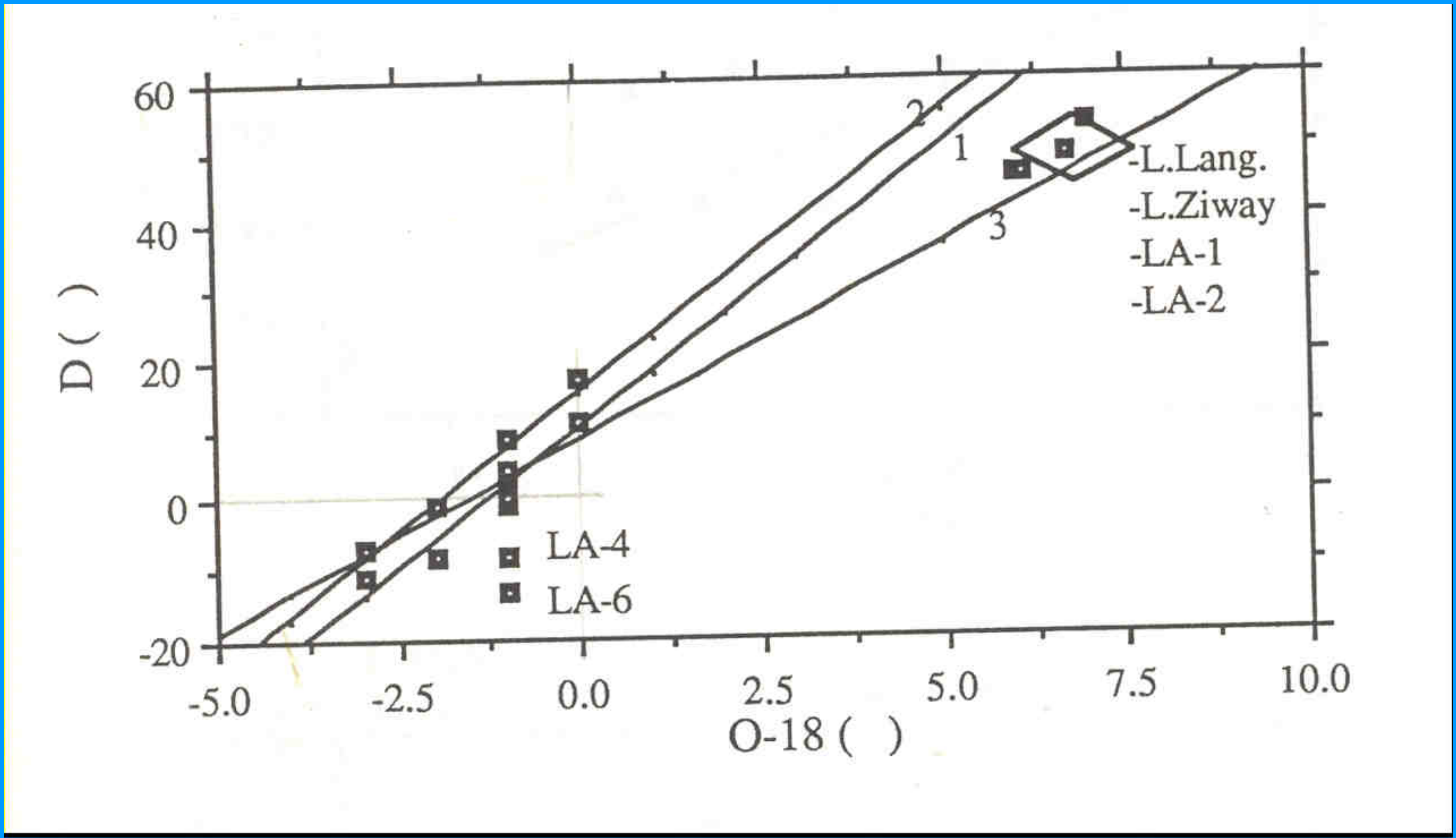
LA-6: 1505m 85x



LA-8: 2500m 85x

Aluto-Langano and Corbetti Geothermal Systems

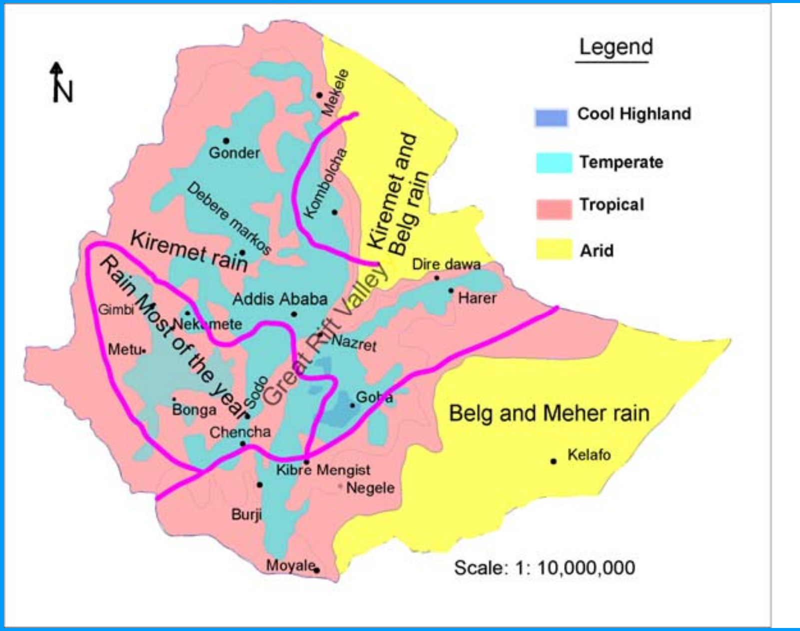
Isotope Indications

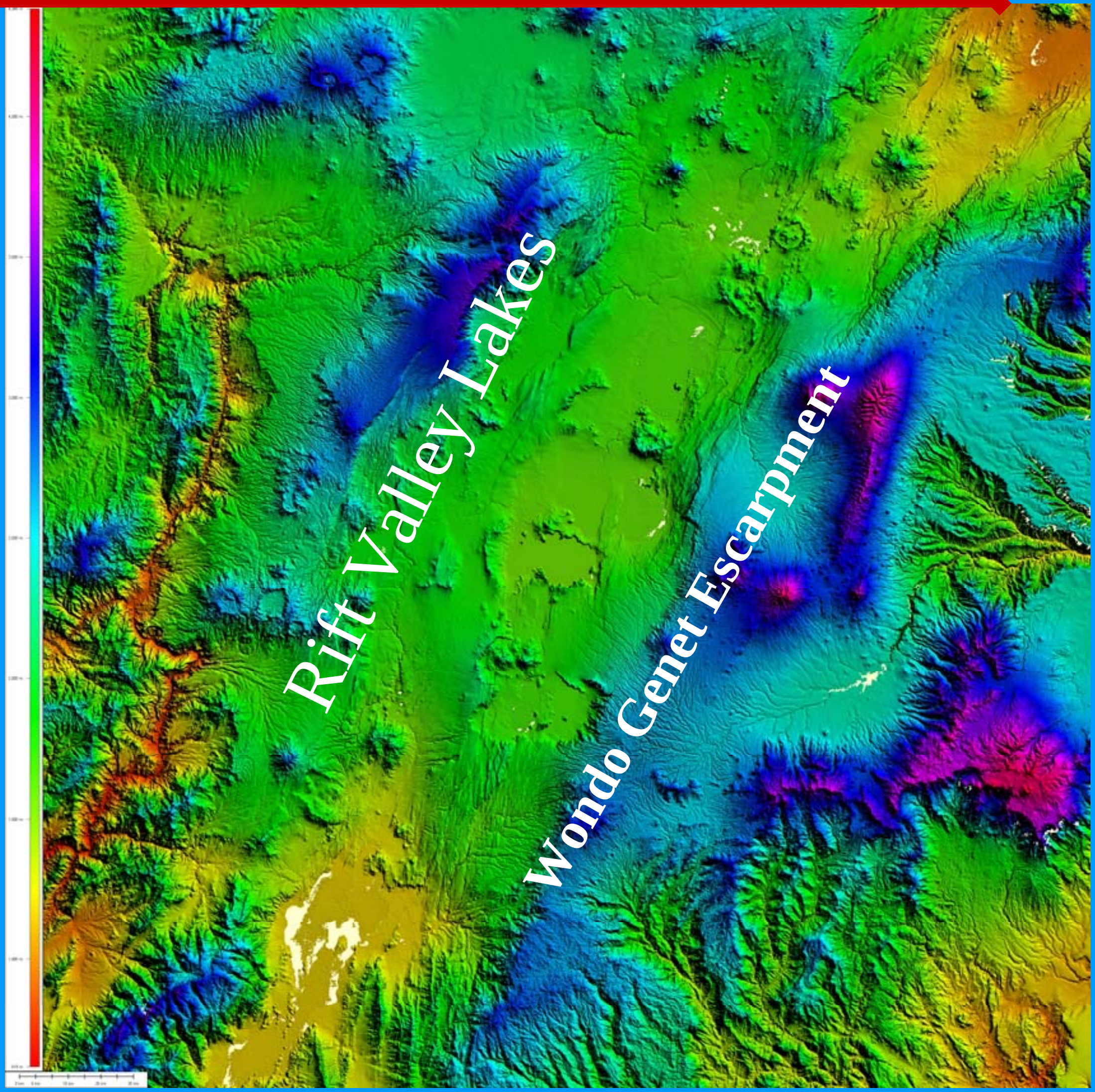


Isotope Indications

Recharge: Escarpment

- ☞ Relief difference
- ☞ Rainfall
- ☞ Isotopic evidence

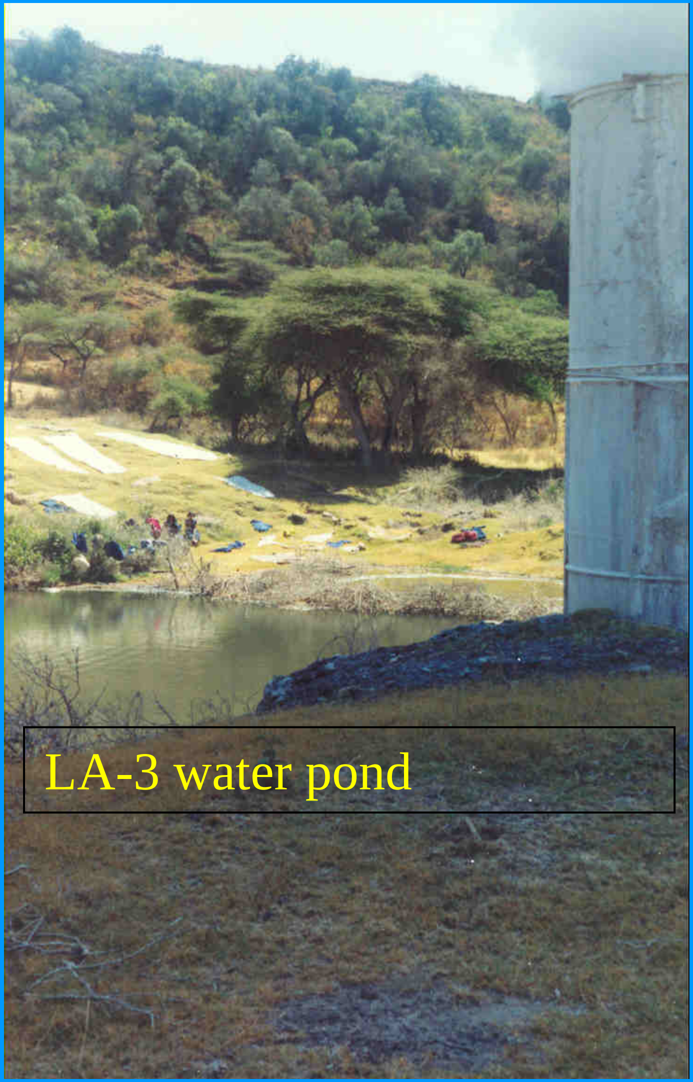




Environmental aspect

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.**



LA-3 water pond

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

Geology

- 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.

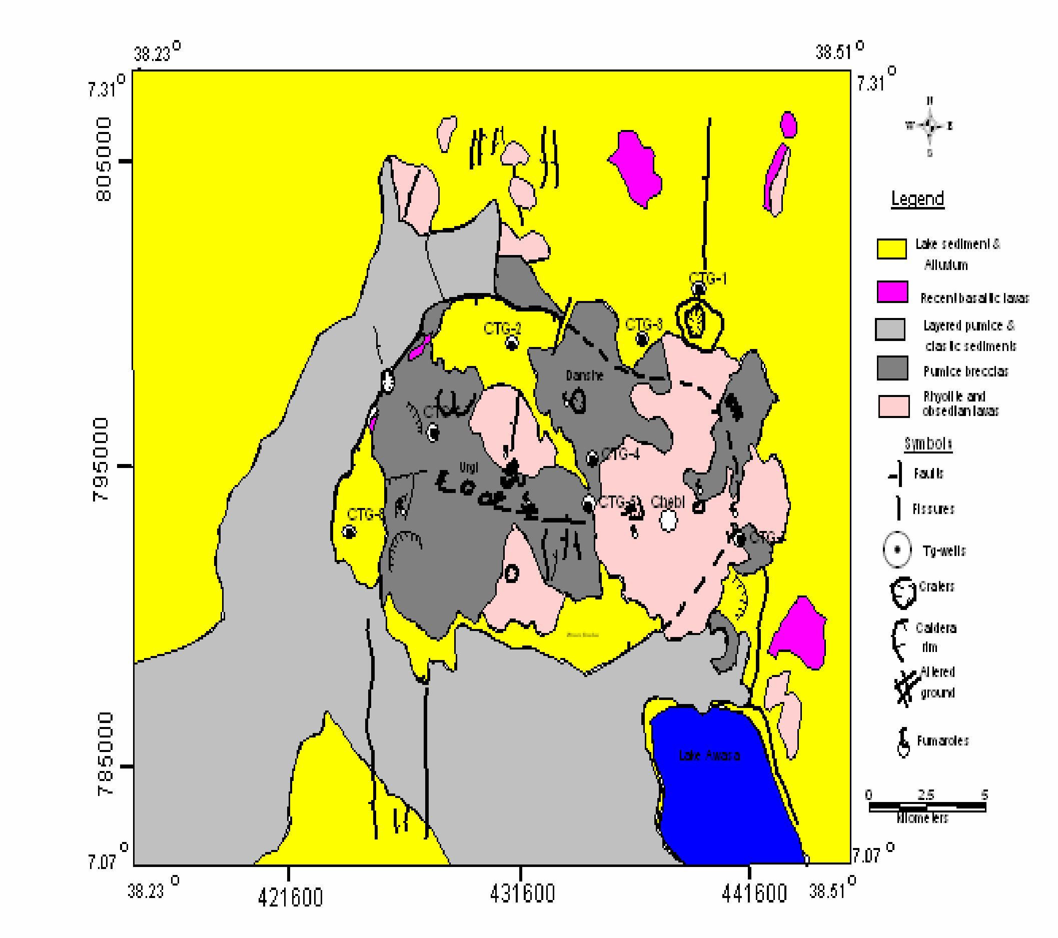


Figure 11, Geological map of Corbetti geothermal prospect (GSE, 1987)

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 H_2S (Koka fumaroles)

Geochemistry

Subsurface temperatures predicted - in excess of 300°C

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

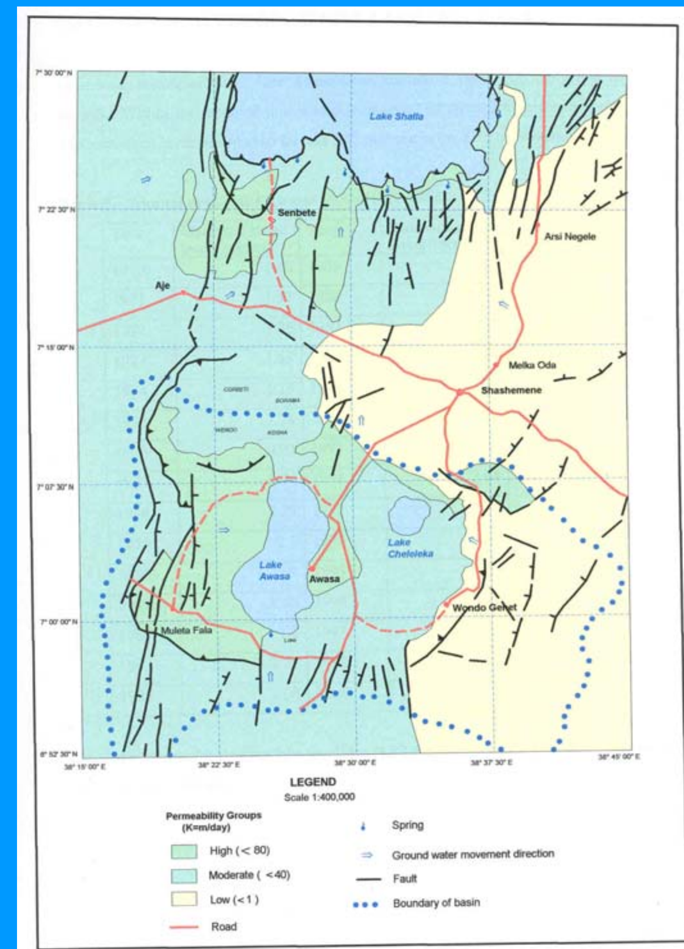
Isotopic investigations

- 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.

Hydrogeology

Shallow groundwater flow direction:

- Dominantly from south to north



Zeal Bessemer, 2003

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 (CO_2,** 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!