40th Anniversary

δD and $\delta^{18}O$ systematics of the Olkaria geothermal system: Tracing water sources and secondary processes

Kennedy M. Kamunya

MSc Student
UNU-GTP

UNITED NATIONS UNIVERSITY
UNU-GTP
Geothermal Training Programme

UNU-GTP

Outline

- Purpose
- The Olkaria Geothermal system
- Sampling, analysis and isotope geochemical modeling
- δD and $\delta^{18}O$ systematics: sources and processes
- Conclusion

Introduction

- Among the first important contribution of stable isotope geochemistry to understand geothermal systems was the demonstration of Harmon Craig that water in these systems was meteoric and seawater, not magmatic.
- For geothermal system, the reservoir δD is similar to the local precipitation, groundwater or seawater whereas $\delta^{18}O$ shifts towards higher values due rock leaching.
- Boiling from the reservaoir to surface may further fractionate the δD and $\delta^{18}O$ between the vapor and liquid phase.

Purpose

- The δD and $\delta^{18}O$ in geothermal water depends on sources and processes
- The sources can be multiple, variable water bodies and precipitation from different locations
- The two main processes,water-rock interaction and boiling change δD and $\delta^{18}O$
- The purpose of this study was to assess the source(s) and quantify the effects of boiling on δD and $\delta^{18}O$ systematics for the Olkaria geothermal system

Olkaria Geothermal Area

- Located 120 km NW of Nairobi, in southern sector of the East African Rift System in Kenya
- High temperature geothermal system hosted by a multi centre erruption volcanic complex of Quartenary Age
- The volcanic complex covers 240 km^2
- >300 wells, 900-3500 m, Max 365°C, 950-2650 kJ/kg
- Installed capacity 674 MW$_e$ (Dec 2017)
    - KenGen 530 MW$_e$
    - Orpower 4 Inc: 140 MW$_e$
    - Oserian: 4 MW$_e$
- Direct use: Spa and Green house heating

Sampling and analysis

- 17 samples of two phase well fluids were collected in Nov. 2017
- Analyzed for major solutes and gases in the liquid and vapor phases (electrode, titrations, IC, ICP-OES, GC)
- Analyzed for δD and $\delta^{18}O$ of H_2O in the liquid and vapor phases (IRMS)

Modeling

- The reservoir fluid compostion was calculated from the vapor and liquid samples of two-phase well discharges using WATCH (Bjarnason, 2010)
- The phase relations were calculated using conservation of enthalpy

$$h^{fluid} = x^{vapor}h^{vapor}+(1-x^{vapor})h^{liquid}$$

- Two models were applied
  - $h^{fluid} = h^{discharge}$
  - $h^{fluid} = h^{liquid}$ at $T^{reservoir}$
  - $T^{reservoir}$ was calculated from quartz geothermometry

Modeling

- The isotope modeling was calculated using IsoGEM (Stefánsson, Gunnarsson-Robin, Kleine, 2018) and WATCH
- The isotope system is defined by

$$\delta^{fluid} = x^{vapor}\delta^{vapor} + (1 - x^{vapor})\delta^{liquid}$$

$$\alpha = \frac{1000+\delta^{vapor}}{1000+\delta^{liquid}}$$

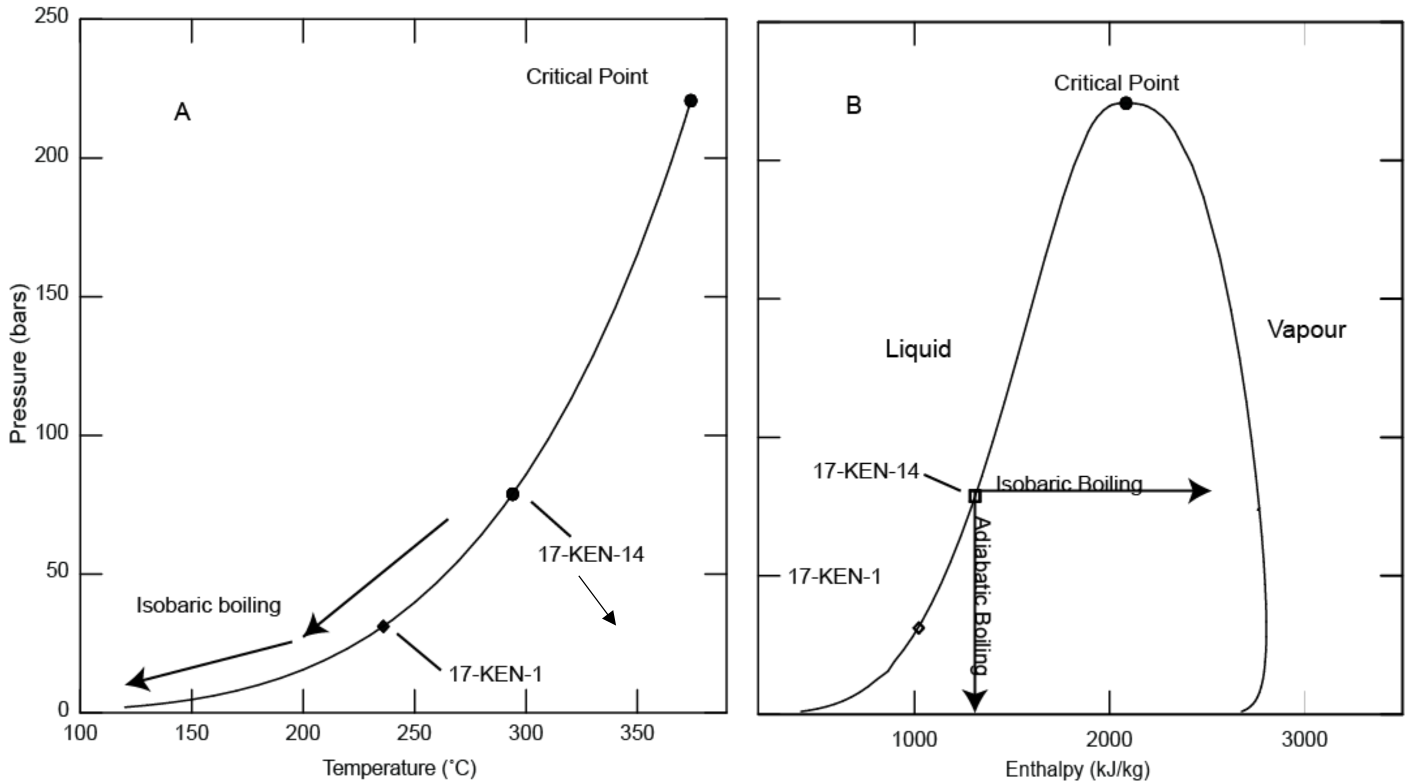
$$10^3 ln\alpha_{l-v}(^{18}O) = -7.685 + 6.7123\frac{10^3}{T} - 1.6664\frac{10^6}{T^2} + 0.35041\frac{10^9}{T^3}$$

$$10^3 ln\alpha_{l-v}(D) = 1158.8\frac{T^3}{10^9} - 1620.1\frac{T^2}{10^6} + 794.84\frac{T}{10^3} - 1620.1 + 2.9992\frac{10^9}{T^3}$$

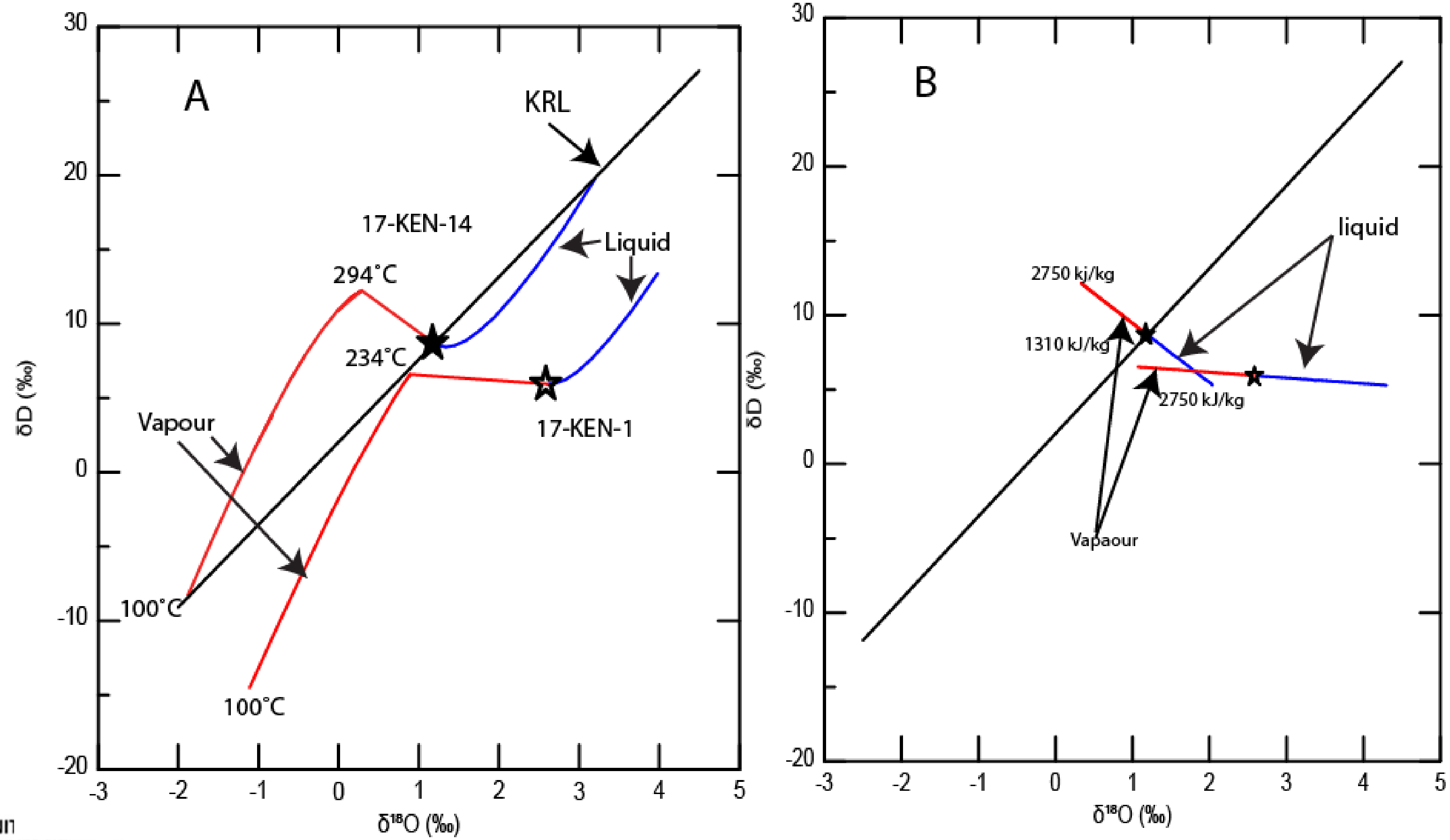
(Horita and Wesolowski, 1994)

Boiling

- The effects of boiling simulated in two ways
- Adiabatic boiling (constant enthalpy)
- Isobaric boiling (variable enthalpy, constant pressure and temperature)

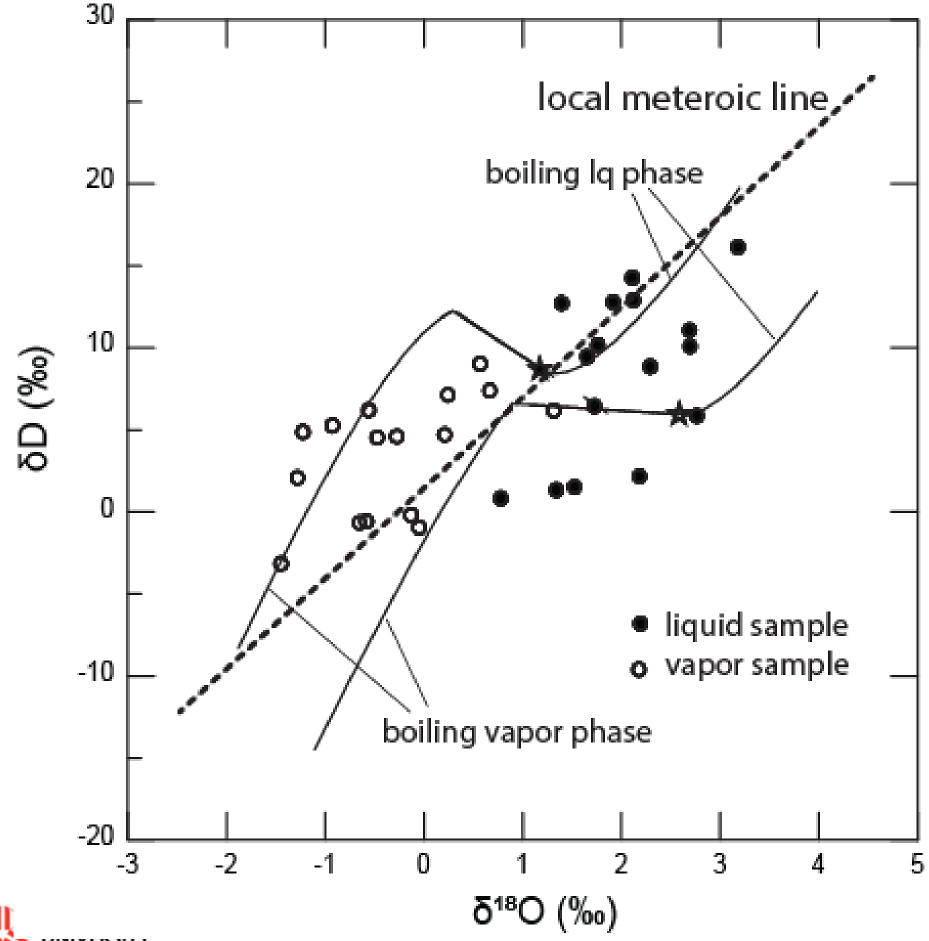


δD and δ^{18}O and boiling



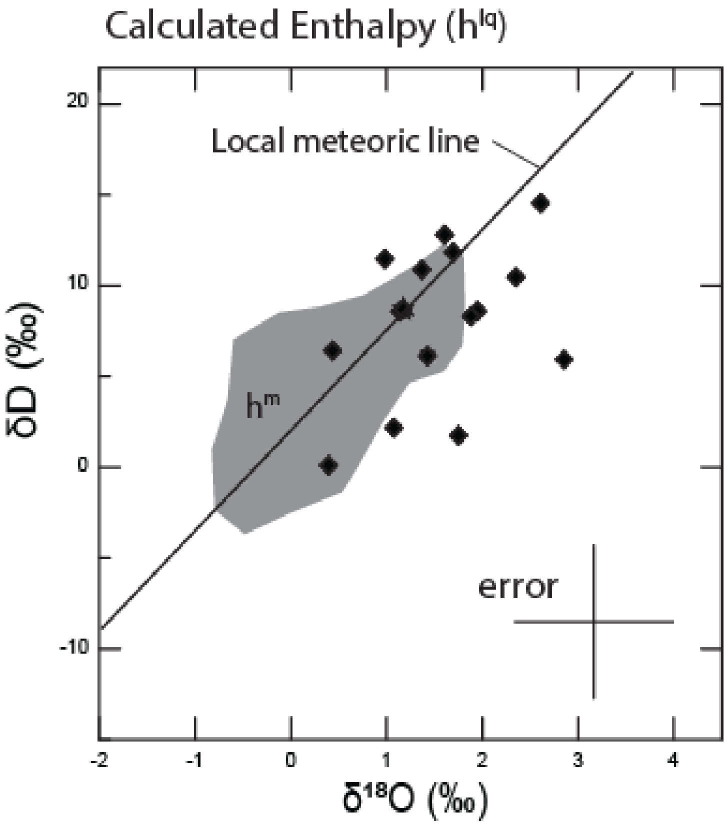
- A: Adiabatic boiling model
- B: Isobaric boiling model
- KRL – Local meteroic line (Allen et al., 1989)

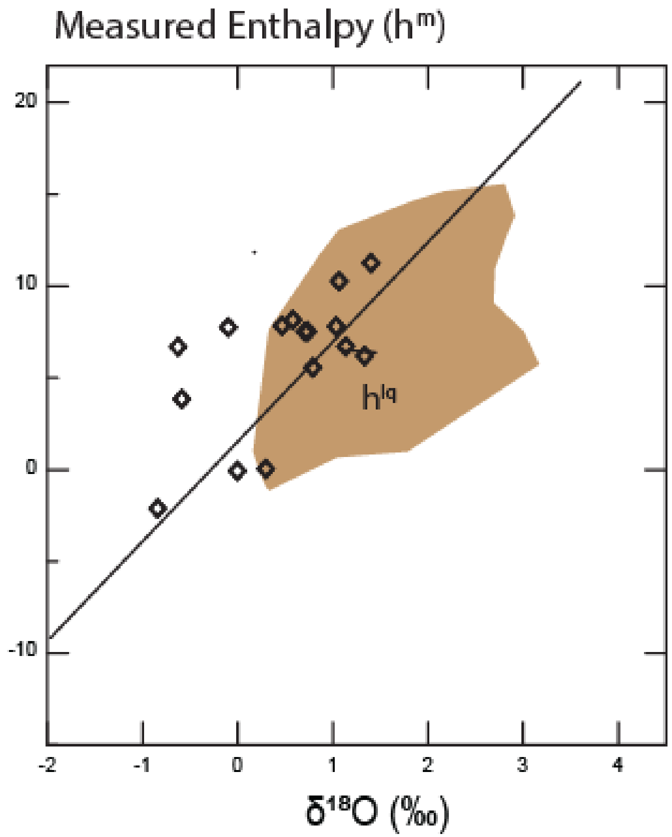
Measured values



- Upon boiling the isotope values changes considerably for the liquid and vapor phase
- Adiabatic boiling results in decrease in δD and $\delta^{18}O$ for the vapor phase
- Adiabatic boiling results in increase in δD and $\delta^{18}O$ for the liquid phase
- Isobaric boiling results in insignificant effects on δD and $\delta^{18}O$ values
- The effects of boiling on δD and $\delta^{18}O$ exceeds the variations of measured values

Reservoir Fluid





The uncertainties related to reconstruction of reservoir water may exceed the range of reservoir water

Makes utilization of δD and δ18O to distinguish source water difficult

Conclusion

- Adiabatic and isobaric boiling can fractionate δD and $\delta^{18}O$ ratios in vapor and liquid phases
- Changes for the vapor phase are upto ~25‰ and ~5‰ for δD and $\delta^{18}O$
- Changes in the liquid phase are upto ~10‰ and ~2‰ for δD and $\delta^{18}O$
- The process of boiling can result in isotope variability exceeding source variability
- The effects of boiling and water-rock interaction needs to be subtracted to assess water sources when applying δD and $\delta^{18}O$ systematics

THANK YOU