

Temperature Estimation for Olkaria geothermal field using fluid inclusion studies. Case study of Olkaria East and Domes.

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Keywords: Fluid inclusions, Temperature, Estimation

ABSTRACT

Fluid inclusions are small droplets of fluid trapped within crystals during growth or subsequent recrystallization. They serve as a fossil record of the fluids involved in the formation and evolution of rocks and minerals providing valuable data on the temperatures, pressures and physicochemical conditions at the time of trapping. The study of the inclusions is the only direct evidence of the paleo fluids that have circulated at different times through the reservoir rocks. This study shows results of the fluid inclusion of OW 53C located in the Olkaria East geothermal field. The study was carried out at the University of Iceland. The results attempt to reconstruct the paleo history of the Olkaria East geothermal field. Further interrogation and review of the existing studied wells OW 916,912B,911,914,901,902.903 was also done to make informed judgement of the temperature and hydrothermal conditions of the well by comparing the formation temperatures and the homogenization temperatures of the fluid inclusions using quartz crystals. The combination of these fluid inclusion studies with other geological and reservoir studies have been used to make judgement of the east and domes geothermal field in Olkaria. The study involved structural interrogation of the field, binocular and petrographic analysis of the drill cutting and micro thermometric analysis of the fluid inclusions. The results of which are accurately compared with the formation temperatures, alteration temperatures and the boiling curve temperatures. The Olkaria East geothermal field from the analysis well 53C, showed possible cooling of the geothermal system, which may also be structurally controlled while the domes area showed that the system has maintained steady state equilibrium or showed past cooling conditions and evolutions. It will be imperative to note that most of the Olkaria field has not been studied conclusively for fluid inclusions and together with other methods, this study will be handy in the hydrothermal characterization of the Olkaria geothermal field, the experience of which can be vital for the development of the Eburru geothermal field.

2. INTRODUCTION

The Olkaria geothermal field is in the Kenya Rift valley with several geoscientific studies having been carried out since the 1950s. Kenya Electricity Generating Company has spearheaded the development of geothermal in Kenya in collaboration with other independent power developers. Fluid inclusions have to some extent been studied in this field but its imperative to note that there is need to constantly do more on the scientific studies and update the conceptual model. Fluid inclusions will give the ancient conditions of the geothermal system, and while the results can be compared and used together with other scientific studies of various geothermal fields,

2. STUDY AREA

2.1 Location of Olkaria East Geothermal field

The Olkaria geothermal field has been extensively studied. It is a high temperature geothermal field with enthalpy values above 200°C at depth of approximately 1000m. It is subdivided into several subfields which includes Olkaria East, Olkaria Central, Olkaria Northeast, Domes, southeast and Olkaria East Southwest fields (Figure 1). The development of these fields has been going on since 1950s, with over 300 wells having been drilled.

2.2 Local Geological Setting

Within the central sector of the Kenyan Rift valley lies the Olkaria Volcanic complex, the volcanic system is associated with the region of quaternary volcanism. The thickness of the crust is given as 30-35km. Riaroh & Okoth, 1994, Ring 2014 There was intense faulting that affected the Miocene volcanics, this later formed the Mau and Kananga tuffs (Clarke et al., 1990). The faulting resulted in the in the development of the graben structures and fissure eruptions mostly of trachyte, basalts, basaltic trachyandesites and trachyandesites.

2.3 Structural setting

Structures are the pathways through which geothermal fluids flow. They play vital role as the conduits for the movement of the fluids. The permeability in the structures are therefore the flow providers. Structures may also act as barriers to flow in the geothermal system. (Calasis et al., 2008). Structures in Olkaria follow the fault trends, among them the Ol-Njorowa gorge N-S, NW-SE, NNW-SSE, ENE-WSW Olkaria Olkaria fault and the ring structure (Lagat, 2005).

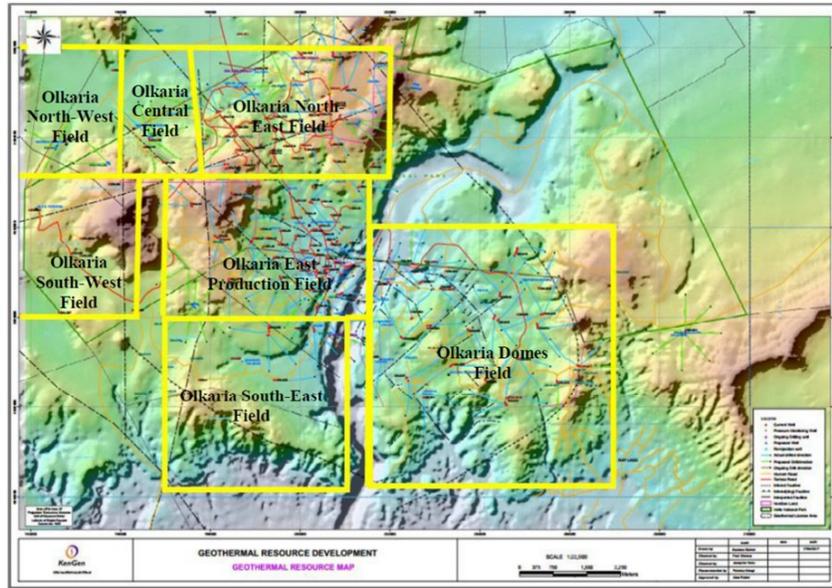


Figure 1. Map showing the Sub-fields of the Olkaria geothermal field (modified from KenGen 2017)

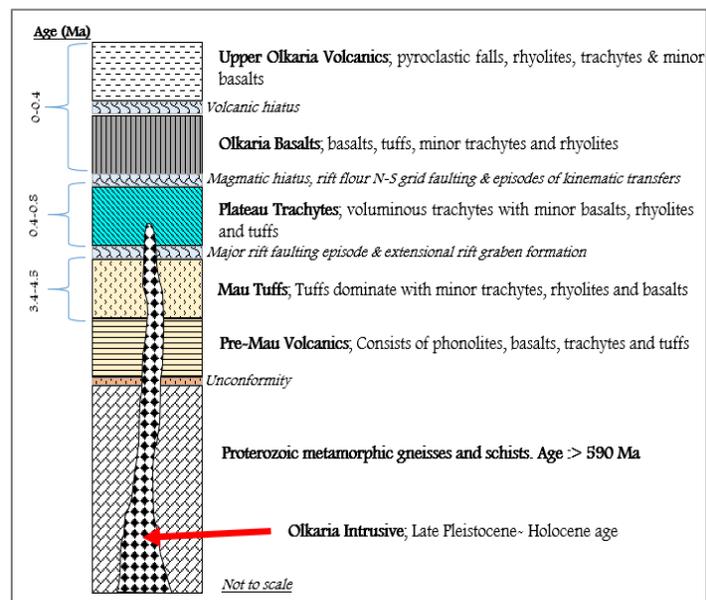


Figure 2. Stratigraphy of Olkaria Volcanic complex. (Updated from Omenda,1998 and with inputs from logs of drilled wells)

are expected. The samples are cooled to recover the phase changes and the process repeated, observed phase transformations noted and the dissolution of the homogenization temperatures noted. The freezing process will require the samples to be cooled to negative 80°C and heated at a rate of 20°C to 0.1°C per minute, the phase transition temperatures recorded and the temperatures of the final ice melting to estimate the CO₂ contents by the phase diagram (Diamond 2003)

5.0 RESULTS

Two samples of fluid inclusions of Olkaria well OW 53C were analyzed at the Institute of Earth Sciences, University of Iceland using the Linklam TMS94. The hydrothermal quartz crystals were used for the fluid inclusion studies of this well. The log plot of the well was first developed, and samples carefully chosen from the depths with veins, feed zones and intrusions.

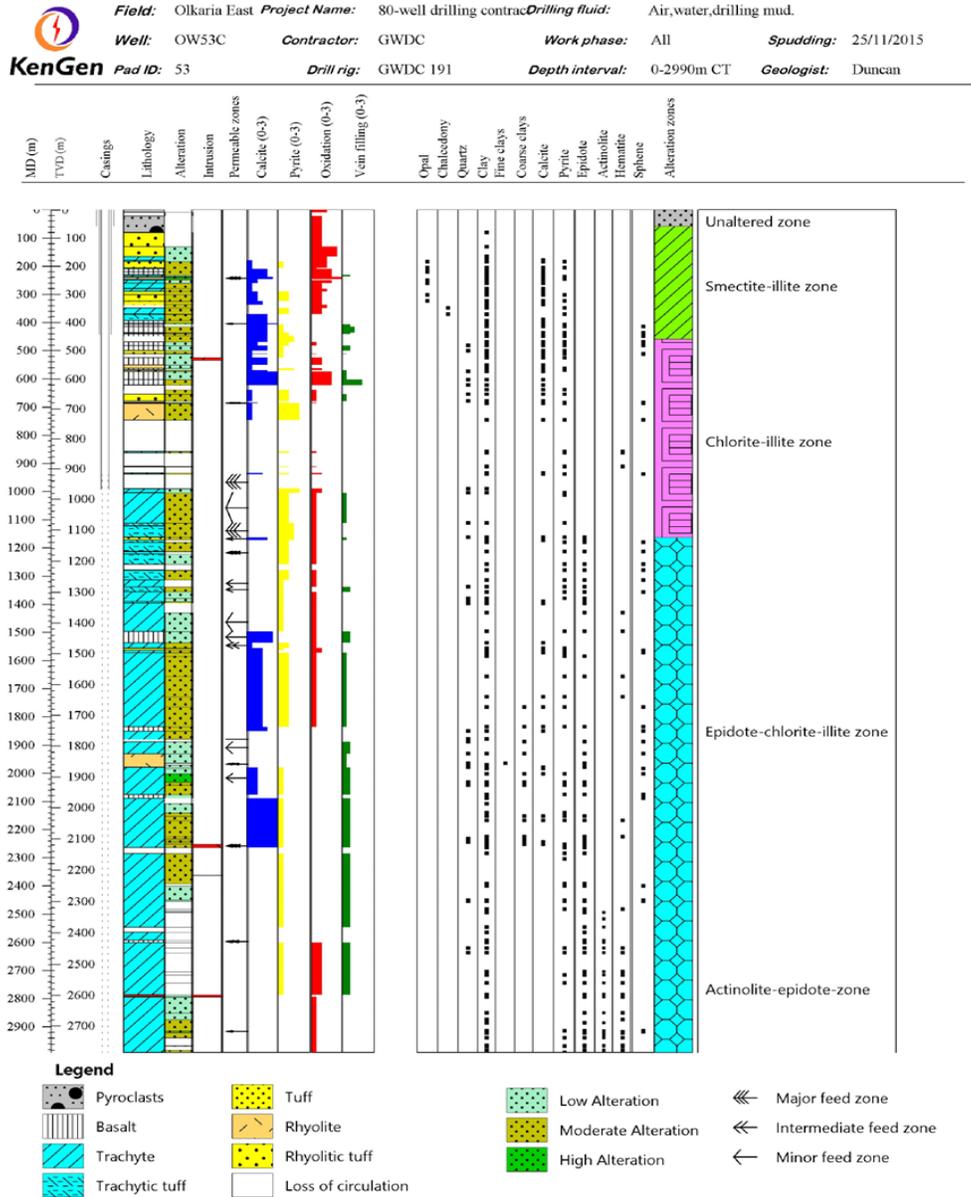


Figure 4: Log plot of OW 53C

From the depth of 700m, the quartz minerals were analyzed for fluid inclusions with the results shown in the tables below

Table 1 below shows homogenization temperatures for quartz inclusions samples analyzed at depths of 700m of OW 53C. The formation temperature is 208°C

Table 1: Homogenization temperature for quartz at depth of 700 m for OW 53C

Vein	Th °C
Quartz	280
Quartz	285
Quartz	280
Quartz	279
Quartz	280
AVERAGE	282

Table 2: Homogenization temperature results for quartz inclusions analyzed, Sampled depth 518m

Vein	Th°C
Quartz	187
Quartz	195
Quartz	216
Quartz	185
Quartz	196
AVERAGE	195

From the fluid inclusion data presented above there is possible cooling in the geothermal system which might also be structurally informed. The gorge farm fault is believed to be a conduit in the geothermal system.

Table 3. Homogenization temperature results for ow 901,902,903 modified from (lagat 2004)

Well, OW 901 204masl. Measured temp 314°C		Well 902 671masl Measured temp 247°C		Well 903,517masl Measured temp 256°C	
Vein	Th°C	Vein	Th°C	Vein	Th
Quartz	258	Quartz	246	Quartz	187
Quartz	258	Quartz	253	Quartz	216
Quartz	238	Quartz	221	Quartz	220
Quartz	240	Quartz	248	Quartz	242
Quartz	260	Quartz	256	Quartz	222
Quartz	238	Quartz	240	Quartz	220
Quartz	269	Quartz	238	Quartz	240
Quartz	271	Quartz	217	Quartz	240
Quarz	247	Quartz	215	Quarz	195

Quartz	320	Quarz	220	Quartz	185
Quartz	304	Quartz	252	Quartz	200
Quartz	280	Quartz	235	Quartz	240
Quartz	298			Quartz	224
Quartz	298			Quartz	178
				Quartz	220
				Quartz	191
				Quartz	275
				Quarz	228
Average Th°C °C 256		Average Th°C 232		Average Th°C 230.	
Interpretation, past cooling conditions		Past cooling conditions		System more or less in equilibrium	

Table 4: Modified from (Otieno 2017)

Name of well	OW 916 domes area
Depth of analysis	1600m
No of inclusions	13 inclusions
Homogenization temp range Th°C	275-305°C
Average homogenization temp Th°C	282°C
Estimated formation Temperature (Mwangi 2012)	276°C

The comparison of the alteration temperature curve, fluid inclusion temperature plot indicates that the system is around OW 916 has maintained a steady state of equilibrium.

Table 5: Modified from (Otieno 2017)

Name of well	OW 912B
Depth of analysis	756m,1438m
No of inclusions	21,10
Homogenization temperature Th°C	275-305°C
Average homogenization Temp Th°C	276°C

The system has maintained a steady thermal condition as OW 916 above.

Table 5 below, modified from (Otieno 2017)

Name of well	OW 39A
Depth of analysis	810m
Temperature range (Okoo 2013)	210-285°C
Homogenization temp Th°C low	210-215°C
Homogenizations Th°C high	280-285°C

The homogenization temperatures were found to be higher than the prevailing formation temperatures, implying two thermal regimes the higher temperature regime followed by a phase of cooling, the alteration temperatures were higher than the formation temperatures implying a cooling system.

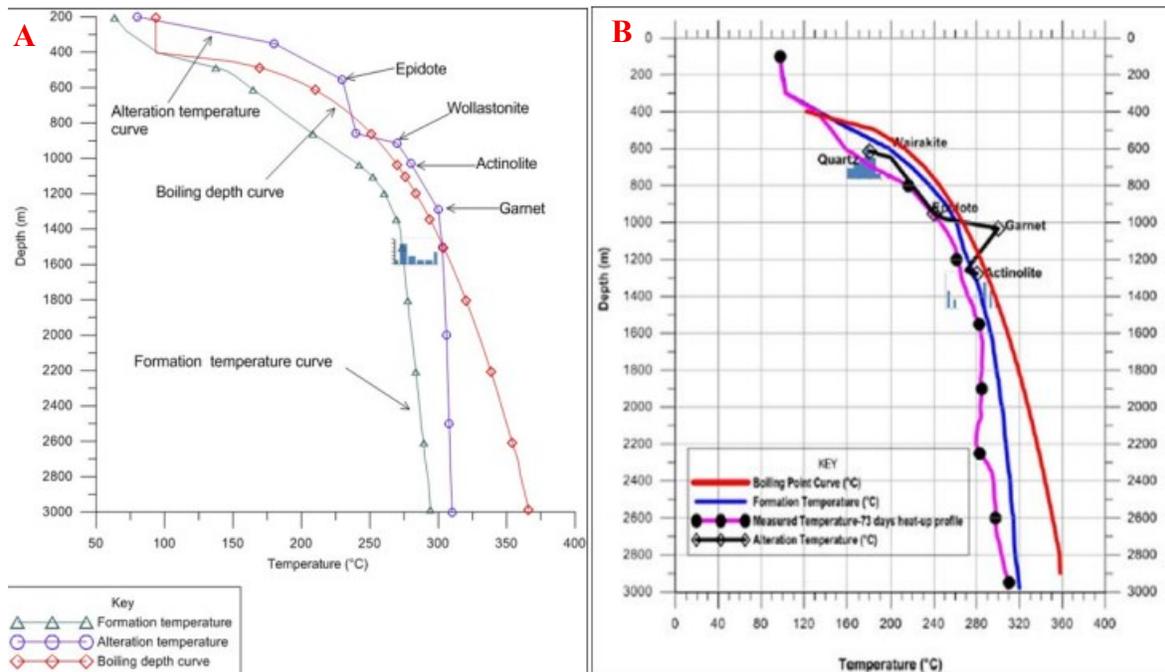


Figure 5: (A) A comparison of fluid Inclusion homogenization temperature, alteration temperature and formation temperature of OW 916 and (B) Comparison of fluid inclusion homogenization temperature, alteration temperature and formation temperature in OW 912 B (Modified from Otieno 2017)

6.0 DISCUSSIONS

Comparing the homogenization temperatures analyzed, measured formation temperatures, and the alteration of temperature from the well that has been studied and reviewing the available data on fluid inclusions from past studies, the temperature variations in the field has been estimated, the homogenization temperature gives the ancient temperature, the measures formation temperature gives the current state of the thermal conditions in the field, it’s possible then to point out that both the east and the domes field in Olkaria has had different temperature regimes, there has been episodes of cooling, episodes of temperature rise and regimes of different temperature phases, these results compared can be used to give temperature estimates in the geothermal field.

7.0 CONCLUSIONS

Fluid inclusions store critical information on the temperature, pressure and composition of geothermal fluids, all of which are important components during mineralization. The paleo temperatures and history of the geothermal field can be reconstructed using the geological, reservoir and fluid inclusion data. Fluid inclusions used and compared together with alteration mineralogy can be used to strengthen the interpretation of geological and geochemical studies of geothermal field.

8.0. RECOMMEDATIONS

Recently there have been field exploration studies in Eburru, the addition of fluid inclusion studies in this field analyzed together with other geological, geochemical, geophysical and reservoir methods would be ideal for the characterization of this field. There is need also to carry out more extensive work in other field sectors in the Olkaria Geothermal field. The measurements of the freezing temperatures should be done to obtain the composition and the gas content of the fluids.

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