SURFACE HYDROTHERMAL ALTERATION IN THE TULU MOYE AREA, LAKES DISTRICT RIFT, ETHIOPIA

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ABSTRACT

Tulu Moye Geothermal Prospect is located in the Ethiopian Rift Valley, which is part of the Great African Rift system. Tulu Moye area is characterized by silicic centers and basalt lava flows ranging in age from Pleistocene to Historic times. It is affected by NNE-SSW trending faults, which is intersected by transverse NNW-SSE faults. The surface hydrothermal manifestations are mainly warm and hot steaming grounds with an extensive area of altered ground. The XRD analyses suggest the mineral assemblages of kaolinite, tridimyte which correspond temperature less than 100°C in an acidic environment; smectite and albite in alkaline (near neutral pH) environment.

1. INTRODUCTION

Tulu Moye Geothermal Prospect is located in the Main Ethiopian Rift (MER) which is part of the Ethiopian Rift Valley (Fig. 1). This area was first studied in 1969 (UNDP, 1973). Later on a coordinated study was carried out as a project by Electroconsult (ELC, 1987) in association with Geothermica Italiana and the Ethiopian Institute of Geological Surveys in the years 1985 – 1987. The project mainly concentrated on a reconnaissance study of the geothermal sites in most parts of the Ethiopian Rift Valley.

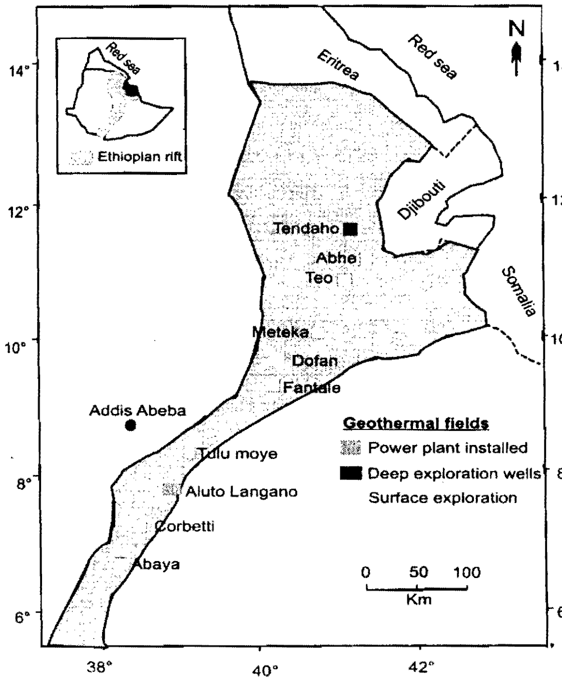

Figure 1: Location map of Tulu Moye

Based on the results of the survey, Tulu Moye Prospect area was given priority for further geoscientific investigations. Recently a detailed surface hydrothermal alteration geological mapping (1:20,000) and geophysical investigations has been carried out in the Tulu Moye area. Five shallow temperature gradient holes have been drilled having temperature around 90°C.

The purpose of the present study is to understand the hydrothermal alteration process in Tulu Moye area. 20 altered rock samples were analyzed by XRD, 5 representative rock samples by XRF and petrographyic study were conducted on few selected samples. This report briefly summarizes the surface hydrothermal alteration process which took place in the Tulu Moye area.

2. GENERAL GEOLOGY

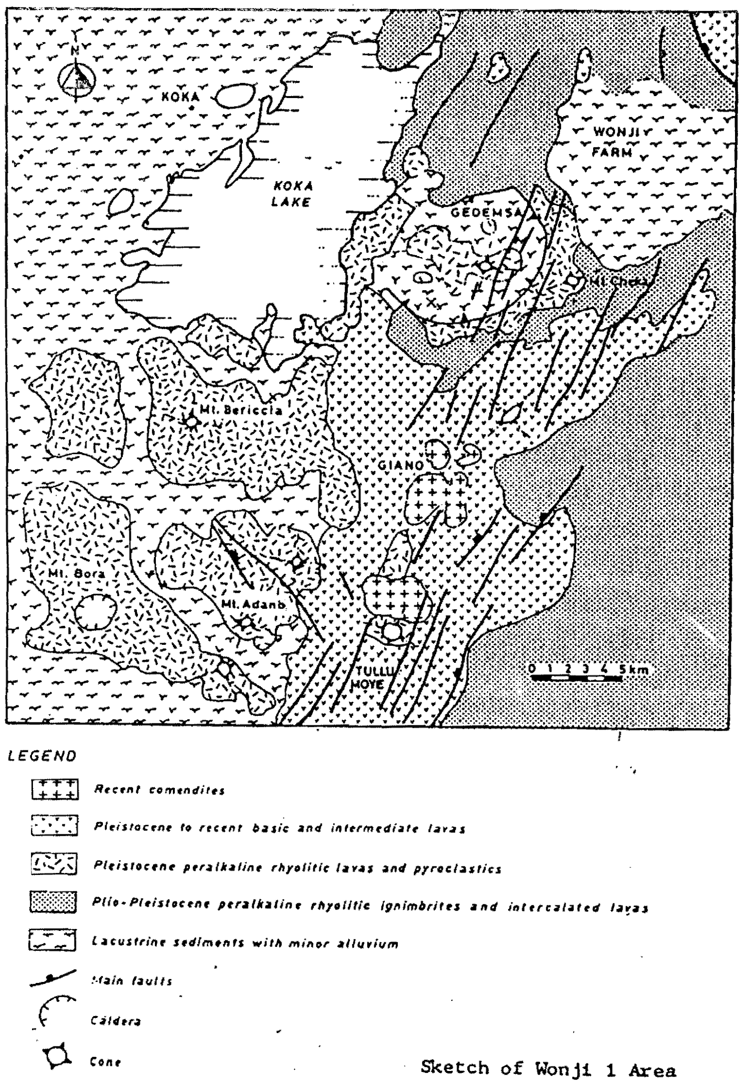

Figure 2: The Wonji fault belt at Tulu Moye and its surrounding

The prospect area situated on the northe sector of MER runni generally in NNE-SS direction. The MI extends from Lake Chan in the south and Dof volcano to the north. It bounded on both sides, the plateau (2500 m.a.s. where the lowest part is th rift floor (Fig. 2). This are is highly affected by th Wonji Fault Belt (WFB (Mohr, 1967). The WF results in forming sever segments of Quaternar volcano-tectonic activities.

The physiography of th region is mainly dominate by numerous sub-centra volcanic edifices risin above a gently sloping bas with an elevation of 1,750 - 1,800) m.a.s.l. Th volcanoes of Tulu Moye reach to an elevation o 2,349 m; and Bericha, 2,285; Bora 2,293 and Others like Jima (2,075 m), Dima (1950), Adano (2000) and Werdi (2,120 m) rising from the surrounding plains.

The lithologies are generally obsidians, rhyolites, trachytes, basalts, pyroclastics and ignimbrites (ELC, 1987; Abebe, 1987; Mamo, 2001 and Di Paola, 1970 and others).

The eastern part of Tulu Moye is affected by NNE – SSW trending closely spaced normal fault swarms and open tensional fissures. This is presently active axis of the Rift structures (ELC, 1987). Mt. Bora and Berricha are characterized by NW - SE transverse normal faults. These transverse faults intersect the NNE – SSW major fault systems.

3. HYDROTHERMAL ACTIVITY

The Tulu Moye area is strongly affected by hydrothermal activity. The main hydrothermal manifestations in the area are weak fumaroles, active steaming grounds and altered grounds. These manifestations are mainly wide spread in the western and central parts of the mapped area. They are aligned in a NNW direction along the transverse faults. The manifestations extend from east of Tulu Moye to the south and north of Berricha volcanic complex. Most of the steaming grounds are associated with weak fumarolic activity. There is a wide area of altered ground and steaming ground in the west central part of the mapped area having temperature ranging from 70 - 80°C. The pyroclastic deposits are highly altered and changed to clay. The altered grounds are characterized by weak fumaroles.

There are chalcedony deposits along the foots, sides of the central hills covering an area of 30 meters radius. Chalcedony veins are also observed in the pumice breccia, running 320° NW, dipping 65° (50° NE). The pyroclastics and ignimbrites are fractured and filled with silica.

4. ANALYTICAL RESULTS

Petrographic, XRD and XRF techniques were used to understand the hydrothermal alteration process and are described below:

4.1 Petrographic Analysis

The obsidians have aphyric and porphyritic textures. The porphyritic variety has spherulitic (vitro-porphyritic) texture with phenocrysts of plagioclase (sanidine) and pyroxene (partially altered to clay) groundmass is totally glass.

There are numerous rhyolitic centers in the area and in most cases they are fractured. Predominantly they are concentrated in the center. Texturally, there are varieties of phenocrtsts if sanidine and microphenocrysts of pyroxene (aegerine and augite), quartz and amphiboles (hornblende). Groundmass is mainly glass and sometimes opaque minerals, leucoxene and iron-oxides.

The basalts are scoriaceous and associated with scoria cones. Texurally they are finegraind, sparcely porphyritic and porphyritic varieties. The major constituents are plagioclase feldspars (labradorite-bytowanite), olivine (partially idingsitized) and pyroxene. The groundmass is mainly glass and plagioclase lath.

The ignimbrites are poorly welded, top weathered but more or less fresh with different lithic fragments (pumice, rhyolite and basalt). The major phenocrysts are sanidine, amphibole (honblende) and microphenocrysts of hornblende, feldspar, quartz and iron-oxide.

4.2 XRD Analysis

The XRD analysis of the surface and temperature gradient holes rock samples are shown on Table 2. They are predominantly kaolinite, smectite and sometimes halloysite and tridymite and rare time's calcite. The mineral associations observed by kaolinite, halloysite and tridimyte indicate argillic type of alteration. This mineral association corresponds to alteration temperature less than 100°C (Izawa, 200[illegible] lecture notes). Since Tulu Moye has lots of rising centers and it has uplifted the area and resulted in [illegible] higher topograhy. Steam at depth mainly containing acidic gas (CO_2 and H_2S) will react with water a[illegible] the surface or near surface and result in acid formation and leach the surrounding formations and wher[illegible] the original plagioclase feldspar is altered to clay. The formation of smectite, albite and amorphous silic[illegible] (transforming to tridymite) indicates alteration process taking place in alkaline or near neutral (pH[illegible] environment where calcium is leached from the plagioclase and albite will precipitate and also amorphou[illegible] silica.

Presently very active and extensive areas of thermal activity exist in the Tulu Moye area. It is observed o[illegible] the eastern side of the mapped area at relatively higher elevation and where precipitation of rain is higher; therefore, smectite could have resulted. Smectite could also have also resulted from weathering.

Presence of pyrite at depth and alunite on the surface suggest the presence of sulphur (which could be from H_2S)

Table 1: Lithologies analyzed by XRD

No.	Field No.	Description
1	T-21a	Reddish-brown, silicified and altered pumicious pyroclastics.
2	AD-13	Reddish-brown, silicified and altered pumicious pyroclastics.
3	T-27	Various color (white, brown and grey) highly altered pumicious pyroclastics.
4	T-29a	Various colors (white, brown and grey) silicified and highly altered pumicious pyroclastics.
5	AD-8	Light-brown, highly altered pumicious pyroclastics.
6	T-5b	Greenish-grey, partially altered rhyolite.
7	T-11c	Various color (white, brown and pink), silicified and highly altered pumicious pyroclastics.
8	T-21b	Whitish highly altered pumiceous pyroclsatics.
9	T-8	Whitish, yellowish-green altered pumicious pyroclastics.
10	AD-6	White and light pink altered pumicious pyroclastics.
11	AD-15	White and light pink altered pumicious pyroclastics.
12	T-1	Light-pink and greenish altered pumiceous pyroclastics.
13	T-19b	Light-brownish, grayish-green pyroclastics (pumice and rhyolite breccias).
14	T-4	Whitish, pinkish altered pumicious pyroclastics.
15	TG 1-133	Grayish-green fractured and partially altered fine-grained rhyolite.
16	TG 2- 129.2	Grayish, fractured, partially altered basalt where the fractures are filled by secondary mineral (silica).
17	TG 3-72	Partially altered rhyolite.
18	TG 4-123	Hard, fractured and altered welded tuff (ignimbrite).
19	TG 5-45	Vesicular, porphyritic fractured basalt where the fractures are filled with white secondary minerals (silica and/or carbonate).
20	TG 5-114	Vesicular, fractured basalt where the fractures are filled by secondary carbonate (calcite).

N.B 1-14 Surface Samples, 15-20, Core samples from temperature gradient holes

: Results of XRD Analysis

Sample No.	Cr	Td	Qz	Ab	Feld	Sm	Hal	Kao	St	Cc	Py	Al	Hm	Ho
					(sand)									
T-21a			~ ~ ~		~ ~			~ ~						
AD-13		~~						~ ~ ~					~	
T-27			~ ~					~ ~ ~		~ ~				
T-29a			~ ~					~ ~ ~		~				
AD-8				~~	~	~ ~	~~	~						
T-5b				~~	~ ~	~ ~			~					
T-11c		~~	~			~ ~	~~	~ ~ ~						
T-21b			~ ~			~ ~		~ ~ ~				~		
T-8			~ ~	~	~ ~	~ ~		~ ~ ~						
AD-6			~ ~					~ ~ ~				~		
AD-15			~ ~					~ ~ ~						
T-1			~ ~	~~	~	~ ~	~~	~ ~	~					
T-19b			~ ~	~~~	~	~ ~								~
T-4			~					~ ~ ~				~ ~		
TG 1-133			~ ~		~ ~									~ ~
TG 2-129.2	~~		~ ~					~			~			
TG 3-72			~ ~		~ ~									
TG 4-123			~ ~		~ ~	~								
TG 5-45	~~~				~ ~					~	~		~	
TG 5-114			~							~ ~ ~				

=smectite, Kao=kaolinite, Al=alunite, Qz=quartz, Cc=calcite, Py=pyrite, Feld=sanidine,
=hematite,
stilbite, Ho=hornblende, Hal=halloysite, Cr=cristobalite, TR=tridymite, Ab=albite.
undance
rare ~ ~ common ~ ~ ~ abundant

3 XRF Analysis

When observing the XRF analysis there is a relatively high content of $Fe2O3$ which could be due to hydrothermal alteration. In general from the XRF analysis show the lithologies are more or less fresh.

Table 3: Results of XRF Analysis

	T-21a	AD-13	TG1-133	TG4-79.6	TG5-114
SiO2 (wt %)	74.38	75.48	72.08	67.85	45.09
TiO2 (wt %)	0.276	0.277	0.322	0.384	3.713
Al2O3 (wt %)	8.79	8.78	11.64	11.49	13.45
Fe2O3 (wt %)	8.19	7.18	5.51	6.45	14.9
MnO (wt %)	0.061	0.054	0.146	0.17	0.208
MgO (wt %)	0.501	0.501	0.015	0.036	6.818
CaO (wt %)	0.53	0.5	0.34	0.29	8.75
Na2O (wt %)	1.77	1.81	4.62	2.9	2.91
K2O (wt %)	2.71	2.81	4.73	6.22	1.53
P2O5 (wt %)	0.03	0.028	0.014	0.006	0.543
H2O-(wt %)	1.8	1.8	0.03	2.52	1.38
H2O+ (wt %)	2.38	2.21	.036	3.95	1.81

S(ppm)	18	17	3	16	4
Cl(ppm)	98	101	5	8	25
Cr(ppm)	8	7	11	7	15
Ni(ppm)	4	5	5	4	6
V(ppm)	44	45	42	49	831
Zn(ppm)	337	335	215	230	131
As(ppm)	22	21	11	10	3
Zr(ppm)	1450	1452	810	856	246
Pb(ppm)	64	62	26	32	8
Ga(ppm)	34	33	36	38	21
Rb(ppm)	122	125	151	159	32
Y(ppm)	245	249	160	170	45
Cu(ppm)	6	4	3	2	87
Sr(ppm)	25	23	1	0	376
Ba(ppm)	60	44	62	53	658
Co(ppm)	10	11	8	9	30
Nb(ppm)	1227	1237	680	798	206

ONCLUSION

Moye area is mainly characterized by Pleistocene to Recent volcano-tectonic activity. An extensive of warm and hot ground indicates heat source at depth. The alteration mineral assemblages of nite, tridymite and smectite indicate temperature of alteration less than 100°C. The intersection of -SSW and NNW-SSE fault systems helps in fracturing the underlying formations (which is observed red sections of the TG wells) resulting in increasing the permeability.

refore, the present study favors the presence of a geothermal resource and in conjunction with other iplines encourages future deep exploration well drilling.

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