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RECONNAISSANCE OF GEOTHERMAL RESOURCES IN TANZANIA

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ABSTRACT

On the basis of their geology and fluid chemistry, the thermal activity in Tanzania can be grouped into four regional systems: the Mbeya Region (south), the Ngorongoro Region including Musoma area (north), the Dodoma/Singida/Kondoa Region (central) and the Kisaki/Rufiji River Region (east). Considerable volcanism associated with rifting exists in the Mbeya and Ngorongoro Regions whereas the latter two regions are associated with tectonic fractures in crystalline rocks of the Rift System.

The fumarolic activity in the craters of Ol Doinyo Lengai and Mount Meru indicates that high deep temperatures and even high-temperature reservoirs may exist in the vicinity of the volcanoes although there is presently no conclusive evidence from the chemical geothermometers. On the other hand, geothermometers indicate that high-temperature geothermal activity may exist in the Mbeya Region but low temperature activity in the Dodoma/Singida/Kindoa and Kisaki/Rufiji River area.

INTRODUCTION

After the oil crisis of 1973 and the subsequent ever increasing oil prices, the government of Tanzania decided to look into the prospects for geothermal power in the country. Earlier investigation for helium has shown that a number of thermal springs do exist in various parts of the country.

The first reconnaissance survey to evaluate geothermal potential was undertaken in 1976/77 jointly by the Swedish and Icelandic Consulting Groups (SWECO and VIRKIR). During the survey all known major thermal features including craters, calderas, volcanoes and hot springs were visited and assessed; water samples were also collected and analysed.

Rift System and Volcanism

The African Rift system covers a large area of Tanzania, the eastern arm of the Rift enters Tanzania from the north through Arusha Region into the Dodoma and Singida Regions where it fades away, but is evident again towards Lake Nyasa. The western arm runs through Lake Tanganyika and Mbeya Region to Lake Nyasa where it intersects the eastern arm. Tectonic movements still occur in these regions as evidenced by recent craters cut by tectonic fissures.

The Ol Doinyo Lengai and Meru volcanoes in the Northern Volcanic Province, and Kiejo in the Rungwe Volcanic Complex in the south have been active in recent historical times. Mount Kilimanjaro has been erupted a number of times in the last 15 million years but has shown only fumarolic and solfataric activity in the recent past. Ol Doinyo Lengai seems to have been active since the Upper Pleistocene, and its latest eruption occurred in 1966 accompanied by minor ash discharge with fumarolic activity continuing until the present day. Mount Meru erupted in 1877, 1886 and since the last eruption in 1910, the volcano seems to be in a solfataric stage. A great many craters around Meru indicate extensive and intensive volcanic activity in the past.

The last volcanic eruption in the Rungwe Volcanic Complex occurred some 150 years ago when Kiejo erupted. Several volcanic centres are located within the Complex; the Rungwe volcano itself being the most impressive with a large caldera containing younger craters. There are many calderas and craters in the region and some are occupied by lakes.

Geology of Geothermal Areas

Volcanic rocks in the Northern Volcanic Province include older and younger extrusives belonging to the basalt-trachyte-phonolite association. North of Lake Manyara Tertiary basaltic rocks dominate but further north and south crystalline metamorphic basement rocks outcrop. North and north-east of Lake Eyasi several volcanic cones and lava flows are present but metamorphic rocks outcrop on its eastern shore. The area east of Lake Natron is dominated by volcanic rocks of the Gelai Complex but the southern shores are covered by soda rich carbonate lavas and ashes from the Ol Doinyo Lengai volcano. The most spectacular geologic feature in the region is the Ngorongoro Caldera, 15 kilometers in diameter and with its rim about 200 meters above the caldera floor. There are a number of cones and craters within this caldera.

The Rungwe Volcanic Complex consists of extensive younger phonolitic trachytes, pumice, ash and lavas, and basaltic lavas. The oldest include trachytes and phonolite tuffs. The Songwe River, south-west of Mbeya town, has cut a canyon through strata of travertine at least 200 meters thick. The Lake Rukwa area is characterized by Pleistocene to

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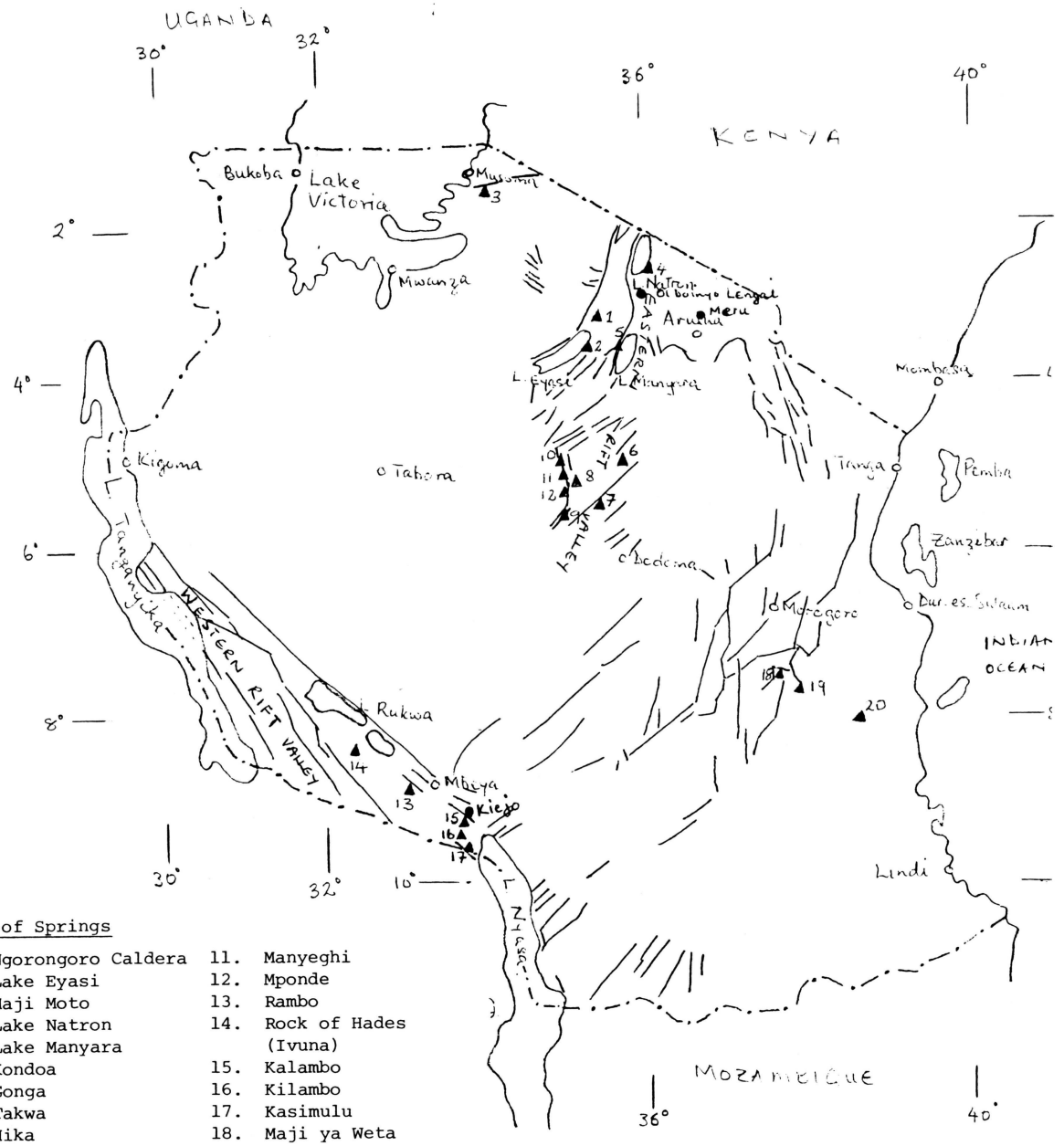
TANZANIA STRUCTURAL MAP SHOWING LOCATION OF SPRINGS



Name of Springs

1. Ngorongoro Caldera
2. Lake Eyasi
3. Maji Moto
4. Lake Natron
5. Lake Manyara
6. Kondoa
7. Gonga
8. Takwa
9. Hika
10. Isanja
11. Manyeghi
12. Mponde
13. Rambo
14. Rock of Hades (Ivuna)
15. Kalambo
16. Kilambo
17. Kasimulu
18. Maji ya Weta
19. Tagallala
20. Utete

Scale 1: 6,400,000

to Miocene sandstones, limestones, and mudstones underlying recent alluvium. On the slopes of Keijo younger phonolitic trachyte lava overlies thick black tephra whereas the volcano is surrounded by older silicic tephra. The Rungwe Caldera is mostly filled with lavas and pyroclastics from the younger craters located in the caldera itself.

Thermal activity in Central Tanzania is associated with faults in crystalline metamorphic rocks. Granite outcrops at some spring locations but mostly the springs are confined to depressions covered by recent alluvium. However east of Lake

Balangida there is an extensive volcanic area dominated by the Hanang volcano of probable Late Tertiary age.

The thermal activity in Eastern Tanzania is related to block faulting in metamorphic rocks and the Karroo sedimentary rocks. The Karroo here consists of Upper Carboniferons to Lower Turassic sandstones, limestones, shales, mudstones and overlies the metamorphic basement.

Thermal Manifestations

The locations of springs are shown on figure 1. On the western shore of Lake Manyara two springs emerge from metamorphic rock talus at the foot of a fault. Their temperatures are 41° and 63°C and discharges of 0.2 L/sec. and 2 - 3 L/sec respectively. At least 10 springs emerge on a salt covered sandy flat on the south-eastern shore of Lake Eyasi. Their highest temperature is 42°C and they have considerable discharge. Several warm springs are situated around Lake Natron; the largest group on the eastern shore has a discharge rate of at least 60 L/sec. at temperatures from 38 to 40°C. The springs issue from agglomerate between lava flows. In the Ngorongoro Caldera there are cold springs discharging into the bottom of a small lake and another small warm spring (32°C) is located in the eastern part of the caldera. The Maji Ya Moto springs, in Musoma area, have temperatures of 59.5°C and an estimated total discharge of 6-7 L/Sec. A temperature of 98°C was recorded in a drill hole at a depth of 35 meters and a relatively high amount of helium was encountered, (James 1967).

The Rambo Springs, the most impressive and extensive in the country, emerge on the western slope of the Songwe River Valley Canyon, at the valley floor and in the river itself. A maximum temperature of 86°C has been recorded and gas emission is considerable. The Kilambo, Kasimulu and Kiwira River Springs in Tukuyu-Kyela area range in temperature from 58° to 64°C. The Kasimulu and Kiwira spring are close to a fault and issue from fissures in mica schist bedrock. The Kalambo springs in southern Rungwe Volcanic Complex have a temperature of 58°C (1977) and issue from basaltic lava in and along the banks of a stream; in places a thin layer of travertine has deposited. Considerable amount of gas is being emitted by the springs. Walker (1969) recorded a temperature of 75°C

In Central Tanzania the springs are unimpressive: the Kondoa spring issues from conglomerate overlying metamorphic basement and has a large flow but a temperature of only 35°C. The Gonga springs, ranging in temperature from 45° to 47°C, emerge from granites along the Bubu Fault in the Bubu River. All the springs are to be submerged by high river flows. The Takwa, Isanja, Manyeghi, Mponde and Hika springs form small swamps in local depressions located close to major faults. The temperatures of these springs range from 32° to 41°C.

The Maji ya Weta springs in Eastern Tanzania have a highest temperature of 70°C and deposit calcium carbonate. The Utete Spring has a temperature of 55°C and an estimated discharge rate of 8 L/sec; No salt deposits around the spring have Kifua
been observed.

Water Chemistry

Springs in Northern Tanzania have a fairly similar chemistry of sodium bicarbonate type. (table 1). The springs on shores of Lakes Natron and Eyasi are saline - the reason being that they are located in basins where a hydrological balance is maintained through evaporation. The Maji ya Moto, Lake Natron and Lake Eyasi springs have high pH (8.9 - 9.4) compared to other high bicarbonate springs (6.7 - 7.6). Nzaro (1970) suggests that nitrogen and helium in these springs may cause their high pH. The chemical geothermometry for springs in the region indicate deep temperatures below 100°C with the exception of the Ngorongoro Caldera spring which indicate temperature above 200°C, (table 2).

In Southern Tanzania, the Rambo, Kilambo, Kasimulu and Kalambo springs have fairly homogeneous waters of neutral sodium bicarbonate type. The Rambo and Kilambo springs are associated with carbonate bearing sediments in the Rift. The high carbonates (HCO_3^- + CO_2) may result from high deep temperatures and strong conductive cooling due to relatively low rock permeability. The chemical geothermometers in this region indicate deep temperatures between 140-200°C but locally as high as 220°C, (table 2).

The Isanja, Manyeghi, Mponde, and other thermal springs in Central Tanzania have low temperatures but are still well above the mean annual temperature, (Nzaro 1970). The CL/SO_4 ratios are nearly the same (table 1) suggesting a similar chemistry and the variation in salinity may be due mostly to evaporation. The waters are low in carbonates (HCO_3^- + CO_2) which suggest low deep temperatures and the geothermometers indicate these are in the region of 50-75°C but locally as high as 105°C.

DISCUSSION

In Northern Tanzania the occurrence of several young volcanic craters north-east of Lake Eyasi suggests that thermal activity is not solely a result of faulting but is also a consequence of young volcanism. The many craters on the slopes of Ol Doinyo Lengai on the southern shore of Lake Natron indicate tremendous volcanic activity in the past. The cones and craters in the Ngorongoro Caldera also suggest concealed thermal activity as experience from other parts of the world has shown that calderas seem favourable for geothermal reservoirs.

The extensive volcanic rocks and many craters and calderas, added by active volcanism (Kiejo) in recent times reflect favourable geological condition for a geothermal reservoir in southern Tanzania. The chemical geothermometers have also indicated high deep temperatures in the region.

Apart from the Balangida springs which are located near Hanang Volcano, the spring in Central Tanzania are associated with young faults in crystalline rocks. This may indicate that only low-temperature activity exists in the region and this conclusion has been confirmed by chemical geothermometry.

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Table 1. WATER CHEMISTRY OF SOME OF THE TANZANIA SPRINGS

Spring	Temp °C	Flow L/S	pH	SiO_2	CL	SO_4	F	Ca	Mg	CO_3	HCO_3	CO_2	Na	K	CL/SO_4	Na/K
Rambo 1	86	3	6.6	68	215	170	9	23	8	0	1920	110	840	93	3.42	15.03
Rambo 2	83	2	7.0	61	220	165	9.1	23	8.2	0	1940	222	860	90	3.61	15.90
Kalambo 1	58	-	6.8	120	410	230	3.2	73	34	0	2610	472	1170	65	4.82	29.95
Ngorongoro Caldera	32	0.2	7.6	110	12	2	1.4	4.5	11	0	268	12	61	12	16.22	8.46
Maji Moto Musoma	59.5	6-7	9.4	98	1140	445	20	1	1	441	1832	0	1980	33	6.93	97.31
Lake Natron	38-50	60	8.9	30	940	145	24	2	1	316	3781	0	2280	56	17.53	67.74
Isanja	33	-	8.1	33	380	150	6.8	8.9	2.6	0	293	5	420	5	6.85	139.76
Manyeghi	37	-	8.3	29	770	360	9.5	5.5	2.0	0	590	5	915	8	5.78	190.30
Mponde	41	-	8.95	34	720	350	8.3	2.3	0.05	13	214	<1	730	6	5.56	202.43
Maji ya Weta	70	-	7.6*	39	175	460	7.2	44	23	0	1630	74	825	52	1.03	26.40
Utete	55	7-8	7.3*	38	155	260	4.3	19	5.5	0	756	69	465	21	1.61	36.84

Table 2. TEMPERATURES OF THE CHEMICAL GEOTHERMOMETERS

Geothermal Area	Name of Spring	Flow L/S	t°C measured	t°C qtz	t°C Na-K	t°C Na-K-Ca	t°C Chalc.
Songwe River Valley (Southern Tanzania)	Rambo 1	~ 3	86	117	196	216	86
	Rambo 2	~ 2	83	111	189	213	81
Ringwe. Volc. Complex Kiejo (Southern Tanzania)	Kalambo 1		58	148	124	172	121
Northern Volc. Complex	Ngorongoro Caldera	~ 0.2	32	143	279	215	115
	Lake Natron	60	38-50	80	-	172	46
Musoma Area	Maji Moto	6-7	60	123	-	156	95
Dodoma/Singida Area (Central Tanzania)	Isanja	-	33	84	-	104	50
	Manyeghi	-	37	78	-	105	45
	Mponde	-	41	81	-	106	48
Kisaki/Utete Area (Eastern Tanzania)	Maji ya Weta	-	70	91	136	177	58
	Utete	7-8	55	90	-	157	57

Since the Kisaki and Rufiji River Springs in eastern Tanzania are not associated with the major tectonic structures of the Rift Valley, geologically the area does not seem to have a high potential for geothermal reservoirs.

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