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GEOTHERMAL RESOURCES OF TANZANIA

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ABSTRACT

At least 15 thermal areas with hot (T > 40ºC) spring activity occur in Tanzania. Ten of these occur over and near to active rift segments with Quaternary volcanism; the others lie over the Tanzanian (Archean) craton and its Precambrian surrounds. In N Tanzania, at the S end of the Gregory Rift, a few advective, low temperature systems can be found which have little development potential, despite the large heat output (at least 50 MW) of one, the Lake Natron system. In S Tanzania, over the northern extension of the Malawi Rift, up to three high (intermediate) temperature reservoirs are indicated by the occurrence of hot springs at the foot of long, concealed outflows discharging neutral pH bicarbonate water depositing travertine. The largest prospect is that at the Songwe River, transferring c. 10 MW of heat. Thermal springs over the craton and its surrounds are supplied by small, low temperature fracture zone reservoirs; they have small natural outputs and little development potential. The known geothermal resources of Tanzania are therefore limited in terms of present technology.

1. INTRODUCTION

At least 15 thermal spring areas with temperatures > 40ºC occur in Tanzania. Most are associated with areas of Quaternary volcanism in two regions, namely in N Tanzania, at the southern end of the eastern branch of the African Rift system (Gregory Rift), and in S Tanzania near the Rungwe volcanic field which infils the northern Malawi rift segment and which belongs to the western branch of the African Rift system (Fig.1). Almost all the thermal springs in Tanzania have already been described (Walker, 1969); a summary of their gas compositions has been given by James (1967). Most of the thermal areas were visited during a Swedish aid project (SWECO, 1976). A short summary based on these data has been given by Makundi and Kifua (1985).
By 1995 it was still not known whether there were any major hydrothermal reservoirs which warranted development. Sponsorship by the State Electricity Co. (TANESCO, Dar Es Salaam) allowed the authors to make a reconnaissance study of major geothermal prospects in Tanzania in January - February 1995. During the study hot spring areas discharging thermal water at T > 40ºC were visited and their potential and natural heat output assessed.

As shown in Fig.1, the eastern branch of the African Rift extends into N Tanzania where the separation movement is taken up by smaller faults in a fan- shaped area marking the southern end of the rift. Rifting stops where the fan faults are in contact with the thick, cold crust of the Archean craton (c. 3000 Mill. yr old) outcropping in the western half of Tanzania (UNESCO, 1976). However, volcanic activity at the southern end of the rift is still significant as shown by the presence of two active volcanoes (Lengai and Mt Meru, 5.2 and 5.3 in Fig.1). A third one, Mt Kilimanjaro (5.4 in Fig.1), is dormant. Rifting is displaced towards the western edge of the Tanzanian craton, c. 800 km to the west, where it continues in early Proterozoic rocks (age c. 2000 Mill. yr). Volcanism along the western branch of the rift is sparse and only occurs in Uganda and in S Tanzania. Rifting of the western branch started c. 10 Mill yr ago (Ebinger et al., 1989); present day rifting rates are small, of the order of 1 mm/yr. Nevertheless this has caused the development of the largest rift lakes on earth, namely the c. 650 km long (up to 1.4 km deep) Lake Tanganyika and the c. 550 km long (up to 0.7 km deep) Lake Malawi. All segments of the western branch exhibit significant earthquake activity (Iranga, 1992).
Rifting appears to be associated with some crustal heat generation as indicated by the occurrence of numerous hot springs with temperatures >70ºC along the western shores of Lake Tanganyika in Zaire and Zambia. However, high temperature springs have not been found along the eastern (Tanzanian) shore. En-echelon propagation of rifting continues in older Precambrian rocks in S Tanzania (Rukwa Basin) which links up with the rift in Malawi. There are several hot springs along both sides of Lake Malawi although none along its NE (Tanzanian) shore. High heat transfer at the bottom of the lakes is indicated by local hot spots with above normal heat flux values (Degens et al., 1971).

2. METHODS

For the 1995 reconnaissance survey we visited almost all thermal springs with temperatures > 40ºC listed in the inventory of Walker (1969). Locations were checked with a small GPS unit with reference to positions in existing geological maps (1 : 125,000). Temperatures were measured with calibrated thermistors, pH data were collected using a portable pH meter. Mass flowrates of thermal water were assessed where natural channels existed and from up- and downstream measurements of smaller streams.
Since all our water samples were lost in transit, we had to use for this study chemical analyses from the SWECO report (1976), those cited by Makundi and Kifua (1985), and older analyses summarized by Walker (1969). Comparison of repeat analyses showed an acceptable agreement between older and more recent data (<15 % difference for most major constituents) although for a few older analyses the K and HCO3 data are poor. Deeper fluid equilibrium temperatures were inferred from SiO2, Na/K and K/Mg geothermometers summarized in Hochstein (1988). For SiO2 equilibria the chalcedony geothermometer T (CH) was used throughout since it gives more realistic values for low temperature systems (Hochstein, 1988).

3. THERMAL SYSTEMS IN NORTHERN TANZANIA

The volcanic rocks in the Rift exhibit a mixture of basaltic trachydolerites, trachytes, phonolites and carbonatites. Thermal springs of advective systems discharge alkaline water in the Rift Valley, but also near the margin of the volcanic cover, which can attain brine concentration (dissolved salts > 30 g/kg) where saline sediments are leached. Such systems are common in the E African Rift, both in Kenya and further north in Ethiopia (Hochstein, 1999).

3.1 Kibo Crater (Mt Kilimanjaro)

Continous fumarolic activity has been observed in Kibo Crater (5.4 in Fig.1) on Mt Kilimanjaro ever since observations started c. 100 yr ago; up to 10 fumaroles and a few solfataras discharge steam in the crater at local boiling point (Downie and Wilkinson, 1972). No volcanic eruptions have occurred here during the last 2000 yr. This setting points to the existence of a volcanic-hydrothermal system somewhere beneath the summit area of Mt. Kilimanjaro. Volcanic-hydrothermal systems were only recognised about a decade ago (Giggenbach, 1997).

Nearby Mt Meru (5.3 in Fig.1) has minor fumarolic activity near its summit; however, two significant eruptions with lava flows have occurred here during the last 150 yr. Mt Meru is probably a volcanic system. There is also no evidence for any hydrothermal output at Lengai (5.2 in Fig.1), the most active volcano in the rift with more than 12 documented eruptions during this century (Simkin and Siebert, 1994).

3.2 Thermal springs around Lake Natron

At least 20 warm, saline springs with temperatures between 32 and 52ºC and discharge rates between c.30 and up to c. 300 kg/s occur along the shore of Lake Natron (5.1 in Fig.1), a large, shallow (< 1 m deep), hypersaline lake whose brine (c.300 g/kg dissolved salts) has been concentrated by evaporation. The lake covers an area between c.100 to 250 km^2 discharging into the lake. It constitutes a regional hydrological sink for the southern part of the Rift Valley which reaches here its lowest elevation (c. 600 m asl). The lake is surrounded by a crust of mainly crystalline sodium carbonates (trona); older lake sediments containing evaporites occur around the entire lake, up to 200 m above lake level.

The thermal springs around Lake Natron discharge alkaline Na-HCO3 brines with a salinity of 3 to 40 g/kg (median 14 g/kg) and a pH value between 9 and 10 (Guest and Stevens, 1951; JICA, 1976). The only complete analysis of an albeit diluted saline spring is listed in the SWECO report (1976), see Table 1. The SiO2 content is moderate, between 30 and 65 mg/kg in most samples, pointing to deeper equilibrium temperatures of T(CH) between c. 48 and 85ºC. There is no correlation between spring temperature and mineralisation of the springs but there is close similarity between the Lake Natron springs and those at Lake Magadi, another hypersaline lake across the border in Kenya (Clarke et al., 1990). The composition of a saline spring at Lake Magadi is shown for comparison in Table 1.

Thermal springs at Lake Natron discharge from scree slopes adjacent to the salt pans as small seeps, small springs and clusters of larger seeps and gushing springs. The total discharge rate of springs (with flow rates >30 kg/s) is of the order of 1000 kg/s. A significant discharge is also associated with the smaller seeps and springs (discharging usually between 1 and 30 kg/s) which in the SW and S sector outnumber the larger springs by 3 to 1. These smaller springs are not listed in the inventory of Guest and Stevens, but might also contribute up to 1000 kg/s of thermal brine discharged along the whole circumference of the c. 40 km long lake. With a mean annual temperature of 28ºC and a median temperature of 40ºC for all thermal springs, this indicates a heat transfer between 50 and 100 MW. The total heat discharged is probably greater since thermal brine might also enter the bottom of the lake.

The setting of the thermal springs indicates an advective flow system where heat is swept from hot upper crustal rocks by meteoric waters infiltrating the higher rift shoulders, attaining in part their mineral content by leaching of the surrounding sediments containing evaporites. A regional crustal (?) CO2 flux enhances the development of the bicarbonate brine which is typical for advective systems in the southern part of the Gregory Rift with young carbonatite volcanism. The thermal springs have little development potential using present technology.

3.3 Lake Manyara thermal springs

Along the W margin of the wider rift lies the small Lake Manyara National Park where a number of small, alkaline (pH up to 9.5) hot springs (T max = 72ºC) occur over a distance of c. 150 m at the bottom of the W rift escarpment. The springs (5.5 in Fig.1) discharge sodium-bicarbonate water (Harris, 1951). The moderate SiO2 concentration of 98 mg/kg points to moderate subsurface temperatures of c. 107^oC. Cation geothermometers cannot be used because of uncertainties in the potassium concentration (see Table 1).

The total visible discharge of thermal water at the foot of the escarpment was about 28 kg/s as measured in five separate channels, pointing to a natural discharge of at least 3.3 MW. The springs discharge into a large swampy area which drains into the nearby Lake Manyara, an ephemeral saline lake, surrounded by a thin salt crust. The thermal system appears to be associated with some advective flow coming from beneath the higher volcanic terrain to the west; its geothermal potential is small.

3.4 Minor thermal springs

About 80 km WSW from Lake Manyara occurs another small, advective brine system along the SE shore of the ephemeral Lake Eyasi (5.7 in Fig.1). Here alkaline (pH=9.4), NaCl-HCO3 water (TDS = 15 g/kg) is discharged by several small seepages (T max = 42ºC) which together transfer < 1 MW. Chemical analysis (Table 1) indicates that its composition is similar to that of the springs feeding the larger advective brine systems in the rift; however, the gas discharged (mainly N2 and minor CH4) contains almost no CO2 (SWECO, 1976).

About 35 km to the NW lies the huge Ngorongoro Caldera (c.15 to 20 km diameter) whose floor is 600 m below the crater rim (5.6 in Fig.1). It has been inferred that it could host a hydrothermal system if hot rocks still occur beneath the caldera floor (Makundi and Kifua, 1985). An analysis (SWECO,1976) of a tepid spring (32ºC) showed a rather high content (c.110 mg/kg) of dissolved SiO2 although the water contained no signature of deeper thermal fluids. In January 1995, five springs were found inside the caldera but their temperature was only 7 to 12ºC above mean annual temperature (c. 15ºC); the tepid spring could not be re-located. No signs of thermal alteration were found so it was concluded that the Ngorongoro Caldera does not now host a hydrothermal system.

4. THERMAL SYSTEMS IN SOUTHERN TANZANIA

Moderate hydrothermal activity occurs over and adjacent to the Rungwe volcanic field which consists of mainly basaltic and trachytic rocks of Miocene to Quaternary age which infill the northern section of the Malawi Rift Valley. The field has been described by Harkin (1960) and more recently by Ebinger et al. (1989, 1993). Mt Kiejo (5.12 in Fig.1) is an active volcano which errupted last time 200 yr ago; c. 20 km to the north lies the larger, dormant Rungwe Volcano. No visible thermal activity is associated with either volcano.

4.1 Mt Kiejo

Anomalous heat is not discharged at the surface around this volcano although there are signs of degassing as indicated by a patch of moffettas, c. 4 km SW from the summit. Here also cold CO2 gas is abstracted by three shallow bores and used commercially. Harkin (1960) reported some sinter coating along the Suma River, near the Mbaka fault scarp (c. 10 km WSW of Kiejo), indicative of some hot spring activity in the past.

4.2 Kilambo

Close to a NW trending, major fault zone (Mbaka Fault), where Precambrian gneisses have been uplifted in the centre of the rift, c. 15 km to the SSE of Kiejo volcano, lies the Kilambo thermal area, also called 'Kalambo' by Harkin (1960). Here about 20 to 40 kg/s of hot (up to 70ºC) bicarbonate waters discharge with significant artesian flow (spouting springs), transferring probably between 3.5 and 7 MW. Travertine deposits are widespread, especially along creeks which drain the area. Only c. 1 km to the SW, at the foot of the fault zone, are aligned, water filled phreato-magmatic eruption craters of Holocene age (maars) which, however, are now cold.

The thermal water of the Kilambo springs (Table 1) contains 151 mg/kg of SiO2, pointing to a T(CH) of 138ºC. Significant mixing with shallow water and non-equilibration of constituents is indicated by the K/Mg geothermometer, since T (K/Mg) is < T (CH); T (Na/K) is c. 180ºC. This indicates that the Kilambo springs are likely an outflow of thermal water derived from a concealed reservoir further upstream. Since the minor sinter deposits along the Suma River occur c. 17 km upstream along the same fault, an inferred hydrothermal reservoir might occur there.

4.3 Mampulo and Kasimolo

Both thermal areas (5.14 in Fig.1) occur in flat lying lacustrine sediments of Neogene age near the W margin of the rift; Mampulo lies c. 21 km and Kasimolo c. 24 km south of the Kilambo springs. In both areas neutral pH, sodium-bicarbonate waters discharge with low yields.

At Mampulo, thermal water is discharged in two separate swampy areas covered by travertine over an area of c. 30,000 m^2. We estimated that the total discharge was c. 5 to 10 kg/s with T max = 63ºC, transferring c. 1 MW of heat. Only an incomplete, older chemical analysis is available (see Table 1) which indicates that the fluid has a composition similar to that at Kasimolo.

The thermal springs at Kasimolo also occur in a swamp, close to old gneissic rocks. The discharge rate is less (< 5 kg/s with T max = 56ºC) than that at Mampulo and travertine deposits are also less extensive. A chemical analysis (Table 1) shows that the thermal water at Kasimolo contains more SiO2 than at Kilambo. Since the cation ratios are also similar, similar equilibrium temperatures are indicated for the deeper fluids upstream, except that the indicated T (Na/K) at Kasimolo is slightly higher, namely c. 190ºC.

Because of the similarity in discharge and fluid characteristics, it is inferred that the Mampulo and Kasimolo springs are located at the foot of concealed, thermal outflows which emerge from beneath the Rungwe volcanic field. The two thermal areas probably derive their fluids from a separate reservoir, somewhere upstream but close to the western rift valley margin.

4.4 Songwe River thermal area

About 90 km to the NW of the Kilambo hot springs lies the most impressive geothermal area in Tanzania, the Songwe prospect (5.11 in Fig.1). It has been described by James (1959); a stratigraphic column for the Songwe Basin is given by Ebinger et al. (1989).

Close to the Songwe River numerous small and large thermal springs discharge hot Na-bicarbonate water between 50 to 80ºC, often together with CO2 gas vents. The springs show NNW alignment and occur in clusters over a distance of c. 3 km on top of extensive travertine, between 5 to 70 m thick, covering an area of c. 13 km^2. The travertine layer is draped upon sandstones. At the southeastern end older travertine is overlain by a young (Upper Pleistocene), up to 5 m thick flow of olivine basalt. Travertine is now being deposited by all thermal springs.

The largest discharge of thermal water occurs at the northern end where several spouting jets discharge water at a rate of c.25 kg/s (T = 70ºC, pH = 6.5) from the bottom of a travertine cliff, c. 35 m above river level. The discharge rates of springs in the southern part are smaller, rarely exceeding 1 kg/s. In one of the southern springs, the maximum temperature of 80ºC (pH = 6.9) was measured; most of the southern springs also stand c. 30 to 50 m above river level. Some degassed thermal water discharges at river level. The total discharge rate was estimated to be between 50 and 75 kg/s; with a median temperature of 60ºC this points to a total heat transfer of the order of 10 MW.

The chemical composition of the thermal water (Table 1), the CO2 discharge of the higher springs, and the travertine, all indicate that the Songwe hot springs mark the terminus of a concealed outflow of hot water, channelled by a confined aquifer. We infer that some boiling, and hence partial escape of CO2, occurs in the aquifer close to the hot springs. This inference is confirmed by the chemical compositions since temperatures of c. 100ºC and 122ºC are indicated by the chalcedony and K/Mg geothermometers respectively. The rather high T (Na/K) value of c. 255ºC indicates that the thermal water might derive from a reservoir located far away from the springs.

The large volume (> 150 Mill. m^3) of travertine points to a long depositional history (c. 2 Mill. yr) if the present day CaCO3 deposition (rate of c. 5g/s) has prevailed during that period. If the thermal water derives from a single hydrothermal reservoir, a large parent system is indicated. It is also possible that the outflow channel has served several systems throughout the Quaternary. The Songwe prospect constitutes a significant geothermal resource.

4.5 Ivuna

A few small thermal springs occur near Lake Rukwa, the Ivuna springs, c. 85 km NW from the Songwe springs (5.10 in Fig.1). These springs discharge c. 2.5 kg/s of NaCl water at T = 60ºC (pH = 8.0) associated with c. 0.3 MW heat discharge. The springs have been diverted into evaporation ponds which sustain a small, local salt industry. Minor gas is discharged which, according to James (1967), contains almost no CO2 but consists mainly of N2.

The chemical data (Table 1) allow the following interpretation: The fast equilibrating constituents in the water point to underground temperatures of c. 110ºC, as given by T(CH). However, it is not likely that the thermal water derives from a deeper, high temperature reservoir because of the absence of CO2. Since saline deposits do not occur in the Rukwa sediments, the cause of the salinity of the water remains unclear.

4.6 Thermal springs in the SW Usangu Basin

To the NE of the Rungwe volcanic field lies another, young sedimentary basin, the Usunga Basin, which has been created by rifting (Ebinger et al., 1989). A few minor thermal springs, labelled GR I to GR IV in Walker's inventory (1969), occur at its margins. They discharge sulfate-bicarbonate waters with low mineral contents (< 1g/kg TDS). One of these springs (GR I of Walker) was visited in 1995; it lies c. 2 km E of the Usaya escarpment and discharges < 0.5 kg/s of hot water at T = 66ºC (pH = 7.3). From the description of the other springs and the appearance of the GR I spring, we infer that these springs have no geothermal potential at present.

5 THERMAL SPRINGS OVER THE CRATON AND PRECAMBRIAN TERRANE

A few other thermal spring areas are listed in the list of Walker (1969) which lie outside the active rift segments and which derive their heat from the crustal rocks of the Tanzanian Craton and its surrounding Precambrian rocks. These exhibit an anomalously low crustal heat flow of between 20 to 45 mW/m^2 (Nyblade and Pollack, 1993).
The Mtagate hot springs occur in the NW corner of Tanzania, near Rwanda (5.9 in Fig.1). They discharge c. 5 kg/s of hot water at T = 53ºC. The springs are surrounded by Proterozoic rocks. The chemical composition (Table 1) indicates that the thermal water at Mtagate derives from deeply penetrating local groundwater.
An interesting geothermal prospect, the Musoma Hot Springs, occurs near Maji Moto (5.8 in Fig.1). Results of earlier studies (Walker 1969, James 1967; SWECO 1976) show that c. 7 kg/s of hot, alkaline (pH=9.4) sodium-bicarbonate water (TDS = 5.7 g/kg) is discharged here at T = 60ºC, transferring heat at a rate of c. 1 MW; its chemical composition is similar to that of advective (brine) systems in the Gregory Rift (see Table 1). The Musoma springs discharge from a depression in Archean rocks and produce a large amount of helium (c. 13 % of the gas volume) with little CO2. The T (CH) geothermometer points to an underground feed temperature of c. 107ºC; cation geo-thermometers indicate equilibrium temperatures of up to 135ºC (T K/Mg). An advective system is indicated as source, presumably sweeping also helium from deep granites. The geothermal potential of the prospect appears to be small.
A group of widely scattered thermal springs with no thermal potential occurs in Archean gneisses c. 150 km SSW from Lake Manyara (5.16 in Fig.1), the Takwa-Sambaru group. Here, small (< 1 to 2 kg/s) discharges of thermal Na-chloride-sulfate water with moderate mineralisation (up to 2 g/kg TDS) and T of up to 40ºC occur. The surface is flat throughout; the mere existence of these springs points to freely convecting fluids within deep reaching, presumably young fracture zones which, in turn, are probably the result of the present-day, active tectonic deformation. Assuming a crustal temperature gradient of c. 15ºC / km for the craton, circulation depths of at least 3 km are indicated by the chalcedony geothermometer (T = 72ºC) of the Hika spring (Walker, 1969), the only spring in the Takwa-Sambaru group whose SiO2 concentration is known. Another half a dozen of thermal springs (not shown in Fig.1) with T < 40ºC can also be found over the craton; they all discharge little heat (< 1MW) with almost no potential for development.

At the E margin of a broad, c. 300 km wide strip of Precambrian rocks, folded against the Tanzanian Craton, occur the Maja ya Weta thermal springs (5.17 in Fig. 1). These discharge c. 25 kg/s of Na-bicarbonate-sulfate water at T = 72ºC (see Table 1). Their heat loss of c. 5 MW is the highest of all thermal springs which issue from the Archean-Precambrian rocks in Tanzania. The thermal energy at Maja ya Weta could be exploited by smaller, direct utilization schemes.
Further to the SE, c. 140 km from Maja ya Weta (not shown in Fig.1), one can find the Utete hot springs (T max = 55ºC) which discharge c. 1.5 MW heat with little development potential. These springs occur over a thick wedge of Neogene-Cretaceous sediments which covers the Precambrian rocks in the east.

6 DISCUSSION

The Tanzanian thermal prospects occur in two extreme geological settings, namely those located in areas with active rifting underlain by a hot upper crust and others lying over the old cold Tanzanian Craton and surrounding Precambrian rocks.
There is no evidence pointing to a high temperature hydrothermal system in N Tanzania apart from an inferred volcanic-hydrothermal system beneath Kilimanjaro. Cooling crustal intrusions appear to be absent in this part of the rift despite the vicinity of active volcanoes. A few low temperature, advective systems occur in the region discharging alkaline waters of similar composition. One, at Lake Natron, transfers a large amount of low grade heat (at least 50 MW) although none of the low temperature systems appears to have a commercial potential at present.

The situation is different in S Tanzania where concealed outflows of probably three hydrothermal systems occur within the northern Malawi Rift (part of the W branch of the African Rift system). These systems derive their heat from hot rocks beneath the Rungwe volcanic field. The associated thermal springs are located at the terminus of the outflows; all discharge bicarbonate water and deposit travertine (Songwe River, Kilambo, Mampulo/Kasimolo). Although high temperatures cannot be expected in the close vicinity of these outflows, cation geothermometers point to their origin from intermediate to high temperature reservoirs which probably lie some tens of kilometres upstream from the spring areas. The Songwe River thermal area constitutes a viable low temperature resource as indicated by its natural heat output of c. 10 MW. The output of the other prospects is lower (between 1 to 5 MW) which is marginal for direct utilization schemes. It will be a challenge to locate these inferred parent reservoirs by geophysical surveys.
Minor thermal springs also occur over two subsidiary rift segments, the Rungwe and the SW Usanga Basins. These springs discharge little heat and derive from small, low temperature reservoirs. Their potential for commercial development is practically nil.
Most of the thermal springs which occur over the Tanzanian Craton and surrounding Precambrian rocks have also no commercial potential in the forseeable future. That thermal

spring systems can develop over a flat, cold craton is unexpected, but their existence shows that deep fracture zones can develop even in a rigid craton. The only prospect with some potential for direct utilization in this setting appears to be Maja ja Weta where several hot springs now discharge c. 5 MW heat.

Although being surrounded by active rift segments, and some with volcanic activity, the geothermal resources of Tanzania appear to be rather small. If some development of these resources would occur in future, it should be confined to the few areas with development potential described by this study.

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Table 1: Chemical composition of selected Tanzanian hot springs (all constituents in mg/kg)

Area (see Fig.1)	pH/T C	Na	K	Ca	Mg	Cl	HCO3	SO4	SiO2	F	source
L.Magadi (4.12)	9.9/34	7000	75	0.6	<0.4	3550	13000	52	36	70	a.
L.Natron (5.1)	8.9/38	230?	56	2	1	940	3800	145	30	24	b.
L.Manyara(5.5)	9.9/69	580	?	2	2	235	>1100?	30	98	n.d.	c.
L.Eyasi (5.7)	9.3/42	5450	50	1	1	4800	3400	680	44	60	b.
Musoma (5.8)	9.4/60	1980	33	1	1	1150	2280	445	98	20	b.
Songwe (5.11)	6.9/73	790	102	49	19	185	1990	160	85	7	d.
Kilambo (5.13)	c.7/58	1240	60	54	34	400	2600	255	151	3	d.
Kasimolo(5.14)	c.7/58	1330	74	63	19	220	3010	260	150	2	d.
Mampulo(5.14)	7.2/63	910	n.d.	36	18	135	1425	230	125	-	e.
Mtagate (5.9)	8.1/53	20	3	13	1	14	44	18	50	1	f.
Ivuna (5.10)	8.0/60	1320	76	78	17	2040	200	225	100	7	d.
Takwa (5.16)	8.5/38	815	?	20	4	555	290	400	n.d.	5	f.
M.Ya W. (5.17)	8.5/38	815	?	40	32	160	750	300	65	-	f.

Sources: a. Clarke et al. (1990), #15; b. SWECO (1976); c. Harris (1951); d. Makundi and Kifua(1985); e. Harkin (1960); f.Walker (1969).

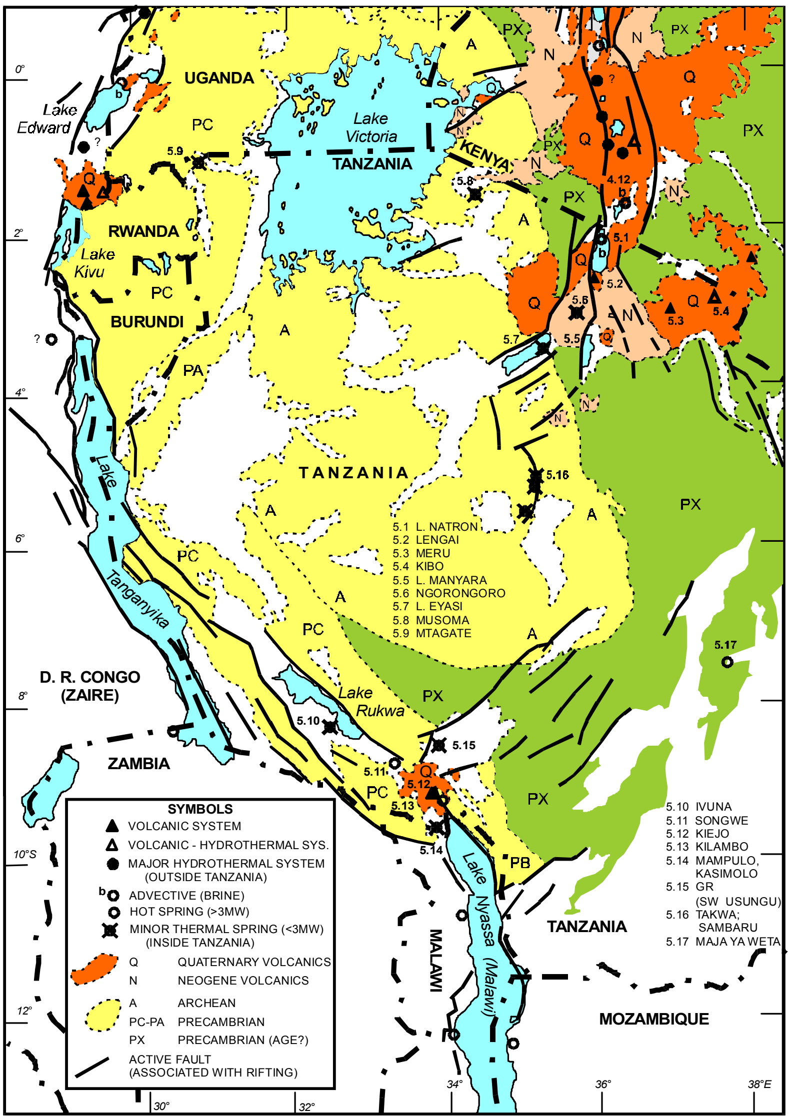

Fig.1: Simplified geological/tectonic map of Tanzania showing location of geothermal systems discussed in the text.