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# GEOTHERMAL RESOURCES OF MALAWI - AN OVERVIEW

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## ABSTRACT

Malawi lies in south-eastern Africa between latitudes $9^o$ S and $17^o$ S and longitudes $32^o$ E and $36^o$ E. The country lies at the southern end of the Western branch of the East African Rift System.
The geology of the country is mainly comprised of metamorphics of Precambrian to Lower Palaeozoic age. Volcanism associated with the rifting is well developed to the south of the country.
Malawi almost entirely relies on hydroelectricity for its power generation. However, due to serious environmental degradation, the power generation capacity has since 2003 been seriously affected sometimes by as low as 75%. These problems have negatively affected the industrial sector. This has forced the government to consider alternative sources of power such as coal, gas and geothermal energy.
The paper highlights the major hotsprings centres in the country, their physico-chemical characteristics and recommends geothermal energy as an alternative source of power.

**Key Words:** Malawi, Rifting, Hydro-Electricity, Siltation, Hotsprings, Physico-chemical.

## 1. INTRODUCTION

Malawi lies in south-eastern Africa (fig.1) between latitudes $9^o$ S and $17^o$ S and longitudes $32^o$ E and $36^o$ E. It is bounded by Tanzania to the north and north-east; Zambia to the west and north west; Mozambique to the east, south and south west.

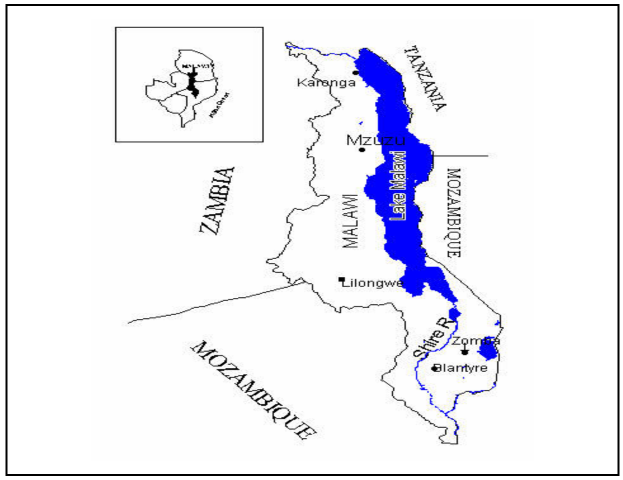



*Fig. 1 Relationship of Malawi with its neighbours.*

The country lies at the southern end of the western branch of the East African rift system. The major geological units are Precambrian to lower Palaeozoic high metamorphic rocks with shaly and semi-shaly affinities. Intercalated within these are calc-silicate units and marbles. Orthogneissic rocks include calc-alkaline and (ultra-)basic rocks. These are found in both concordant and discordant relationships to the country rocks. Sedimentary rocks were deposited in a number of basins to the northern and southern parts of the country since Permian. In general Karoo and Cretaceous to recent sedimentary rocks are distinguished. Karoo volcanicity manifests itself in form of basaltic and diabasic lava flows. Upper Jurassic to lower Cretaceous magmatic activity is ascribed to the Chilwa Alkaline Province. This is a suite of alkaline igneous rocks including carbonatites and related rocks, syenites and granites. This province is well developed to the south of the country and is related to the rift system.

The thermal springs of the Malawi were known as early as the dawn of the last century (1890's). Due to the serious power fluctuations the country has been facing since 2003, it recently became important to review this information and re-assess the role of these in the generation of thermal power. Since October, 2003, the Geological Survey Department is trying to review the hotspring resources of the country in order to assess their suitability as sources of geothermal power. A Global Positioning System (GPS) has been used to acquire the positional information for the various hotsprings. Results were downloaded on a computer and plotted on a base map after projection to a UTM projection (Arc 1950, Zone 36 S) and superimposed on a geological base map.

## 2. CURRENT OUTLOOK OF MALAWI'S HYDRO-ELECTRICITY

Hydroelectricity is the single largest source of power in the country contributing to almost 99% of the country's electricity. This is generated on the Shire River, Lake Malawi's outlet and the largest river in the country. Due to the growing population, the need for more land for agricultural use is paramount. Coupled with this is the fact that the majority of Malawians cannot afford to pay for the electricity and resort to the use of cheaper energy fuels like wood energy. These factors have led to serious deforestation along the Shire River catchment basin. These factors have resulted into siltation which in turn have hampered the generation of electricity on the Shire River. In addition, there has been an influx of a water weeds called water hyacinth, which not only clog the turbines, but also pose a threat to the river's existence in the medium to long term.
As a result of the foregoing, the country has been forced the to look for alternative energy sources because Malawi continues to experience so many blackouts which are adversely affecting the industrial sector. In 2003, for instance, the generating capacity was reduced by 75 % from 240 Megawatts to about 60 Megawatts (The Weekend Nation, 18 April, 2003). Electricity Supply Comission of Malawi (ESCOM), the country's sole power supplier, has in the past opted to installing other hydroelectric plants in the north and importation of power from neighbouring countries such as Mozambique, efforts which have yielded little positive results.
With such a bleak outlook, the only hope to revive this sector lies in coal-fired power plants, geothermal energy and gas operated turbines. These options however, have not been fully explored.
Malawi has thirteen coal fields with resouces amounting to about 800 million tonnes in the northern and southern parts of the country. In this report however, geothermal energy is recommended because it offers considerable advantages over conventional fossil fuelled electricity through greatly reduced gaseous emissions. In the Malawian set-up, the geographical distribution of the country's hotspring centres may not pose a big challenge for geothermal electricity development and distribution to the major consumer centres when compared to the coal resources once exploited.

## 3. THERMAL ENERGY POTENTIAL AND OVERVIEW OF SOME HOTSPRING CENTRES

Geothermal systems derive their heat from the high heat fluxes from the crustal rocks due to conduction or due to magmatic bodies at deeper levels due to convection. The former systems mainly occur in rift settings with high heat flow and geothermal gradients. Due to Malawi's geological setting within the rift valley, the opportunities for the conductive systems are therefore enormous.
Almost all the known geothermal energy sources of the country are of the convective type. These are found in a number of places across the country (fig.2-4) from north to south. Only the prominent ones are highlighted in this report. Temperatures variations are from luke warm to boiling. Some other chemical compositons are listed in the appendices. The hotsprings are generally considered to be related to the waning phases of volcanicity associated with the East African Rifts System (Harrison and Chapusa, 1975).

### 3.1 THE NORTHERN REGION HOTSPRINGS

Five hotsprings are reported in the Chitipa-Karonga area. These include Chinuka, two at Mwankenja, Vungu, Mpata, Chiwondo and Ngala. One hotspring is found in the Rumphi area (Chiweta). Only Vungu, Mwankenja, Mbande, Chiwondo and Ngala were visited in the Chitipa-Karonga area in the present work.

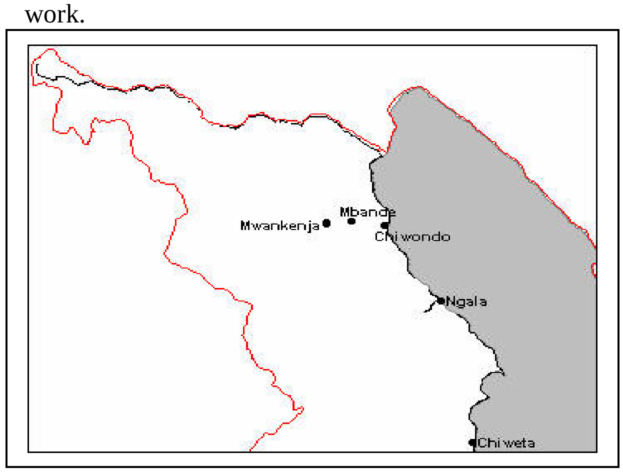



*Fig.2 Hotsprings in the Northern Region*

**Chinuka** - this is found in Chitipa district. This spring has a 'strong sulphurous smell and has been polluted by human and animal usage' (Ray, 1975). The spring is situated on a minor fault and rocks nearby contain breccias and quartz veins
**Mwankenja** – Universal Transverse Mercator (UTM) coordinates (0584952, 8900779). The hotspring is found in banded biotite gneisses on a major north-south trending fault. Another hotspring is found in the same area at UTM coordinates

(0584965, 8899941). This hotspring is found on the banks of Vungu stream. The water flows from a rock and is less warmer than that of the first locality. Both springs have sulphurous smell.

**Mbande** - (UTM coordinates 0592357, 8900937). This spring is found on a small tributary of North Rukuru river to the east of Mwankenja hotsprings. The spring has strong sulphurous smell with some white sulphur powder noted in the vicinity.

**Chiwondo** - (UTM coordinates 0609313, 8900937). This lies within the swamps near the western shore of Lake Malawi. The water is luke warm with some sulphur smell and is polluted by human and animal usage.

**Ngala** – Two hotsprings with UTM cordinates 0619840, 8871444 and 0619802, 8871498 are found on the lake shore. Though temperatures were estimated by hands, the former hotspring is probably the hottest in Karonga district. Both these springs have sulphur smell. Yellowish sulphur compounds can be observed in the springs.

**Chiweta** - (UTM coordinates 0629682, 8818910). These springs are within Mphizi stream which is found some 100 m to the north of North Rumphi River. The springs have gas bubbles and very strong sulphurous smell with steaming waters. This is probably the hottest spring in the country at the moment.

## 3.2 THE CENTRAL REGION HOTSPRINGS

Eleven hotsprings are known in this area and some are being tapped for water supply in townships of the region.

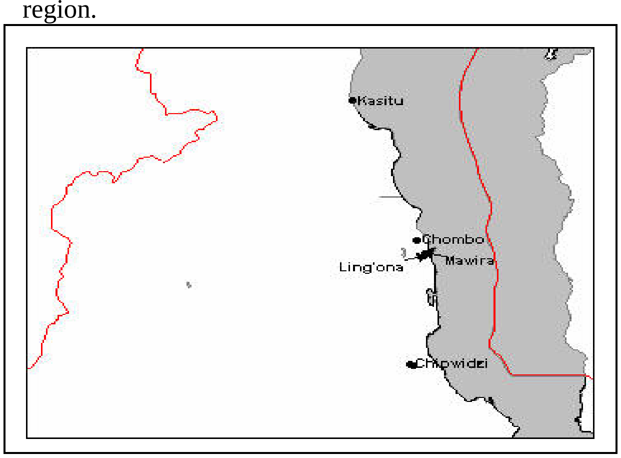



*Fig.3 Hotsprings in the Central Region*

Important centres are as follows:

**Kasitu** – this is found to the north of Nkhota-kota (UTM coordinates 0612182, 8642482). The springs are found near the shores of the Lake and have sulphur compounds. The country rocks are migmatized biotite gneisses.

**Chombo** – this spring lies to the north of Nkhota-kota (UTM coordinates 0636515, 8575051) in a swampy area. The spring has sulphur smell and the temperatures are luke warm.

**Mawira** – three hotsprings are found near Nkhota-kota district headquarters with the following UTM coordinates (0640101, 8568713; 640103, 8568653; 640074, 8568839). All these springs have sulphur smell. The second spring has steaming waters.

**Ling'ona** - UTM coordinates (0639080, 8567454). These are found near Nkhota-kota district headquarters about one and a half kilometer west of the radio transmitter. The spring water has sulphur compounds.

**Chipwidzi** – two hotsprings are found in Traditional Authority (T.A.) Mwadzama's area to the south of Nkhota-kota (Salima district). The first one lies at UTM coordinates (0634251, 8514862). The spring water steams and flows out forcefully and has sulphur smell. A second spring is found on the streambed of Chipwidzi (UTM coordinates 0635230, 8514475) to the east of the first point. This has luke warm water and some sulphur smell.

## 3.3 THE SOUTHERN REGION HOTSPRINGS

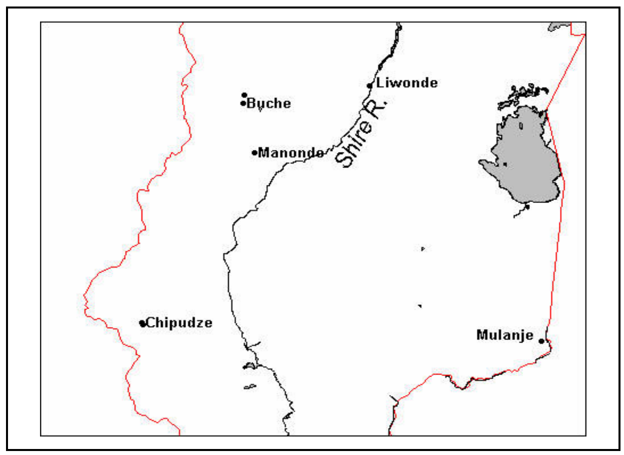



*Fig.4 Hotsprings in the Southern region*

**Buche** – two springs are documented in a report by Bloomfield and Garson (1965). They are some 1.5 km to the SE of Buche ridge on the banks of the Lisungwe river (Ntcheu district). According to the existing information, these springs lie approximately at UTM Coordinates 0691240, 8325270 and 691421, 8328352. Current efforts to locate these springs proved futile.

**Manondo** – two springs are found in the vicinity of Manondo village in the banks of Madziphisa stream while the other is at the head of a small gully, between Lisungwe River and Manondo village. The springs are about 400 m apart and appear to be situated on an ENE-trending fault. The Madziphisa spring lies at UTM Coordinates (0695396, 8305526).

**Chipudze** – two springs are located at UTM Coordinates 0654565, 8238068; 0655305, 8237290 in T.A. Chapananga's area along the NW-striking Mwanza fault south of Miyowe hill near Lengwe Game Reserve. The two springs have surface temperatures of 45$^{o}$ C and 42$^{o}$ C respectively.

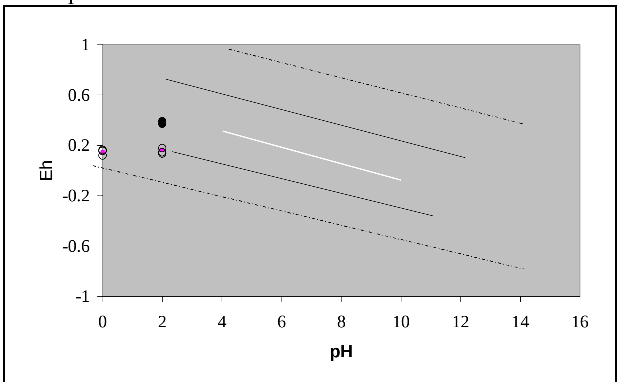
## 3.4 OTHER HOTSPRINGS

One hotspring is found near Mulanje about 100 km to the south-east of Zomba. Some two hotsprings are found at Liwonde some 60 km to the north-west of Zomba.

## 4. PHYSICO-CHEMICAL CHARACTERISTICS OF THE MALAWI HOTSPRINGS

The thermal springs have variable temperatures from mild to boiling. The Chiweta springs were found to be the hottest of all the springs. The water ranges from being relatively soft to hard and neutral to basic in pH with very low conductivity (see appendix for details).

Almost all the hotsprings have associated sulphur compounds although chemical analyses (see appendix) indicate insignificant amounts of these compounds.




Open Circles - Mwankenja, Mpata, Vungu and Chinuka: Solid circles - Liwonde. Dashed line Upper-lower limit of water stability; White line Transitional Environments: Continuous Black line - (lower) environments isolated from atmosphere (upper) - environments in contact with atmosphere. Most natural conditions have pH between 4 and 9.

*Fig. 5: Eh/pH Diagrams for some of the country's hotsprings*

The Eh/pH diagram for some of the country's hotsprings is shown in fig. 5. Only the Liwonde springs plot close to the transitional environments between ground (bog) waters and water in contact with the atmosphere. In general however, the springs are within the range of bog waters. This probably indicates that the chemical composition of the water from these springs is partly affected by surficial (atmospheric) conditions and is not immune from human and other organic activities.

## 5. CONCLUSION

Malawi's hydro-powered electricity remains unreliable due to environmental degradation along the Shire River catchment area. With changing global climate seriously affecting the weather and the impact of other fossil fuels on the climate, it is hoped that geothermal energy will be a major and an important source of power globally in general and in Malawi in particular.

The country's possesses potential for geothermal energy due to its geological setting within the rift valley. A number of hotspring resources exist in the country from north to south which currently are only utilised for domestic purposes and tourism. If properly explored, these could become important for the country's development for power generation.

The Eh/pH diagram of some of Malawi hotsprings indicates that the chemical compositions of most hotsprings are partly influenced by surface conditions. Only the Liwonde springs plot in the transition zone between the ground water and surface water conditions.

These results imply that the chemical conditions of these springs may be very different at greater depth and this should be the subject for further research. Temperatures for these springs range from mild to boiling and most of the water is soft, neutral to basic.

## 6. REFERENCES


Bloomfield, K. (1965). The Geology of the Zomba Area. Bull. Geol. Surv. Mw. 16.

Bloomfield, K.; Garson, M.S. (1965). The Geology of the Kirk Range – Lisungwe Valley Area. Bull. Geol. Surv. Mw, 17.

Harrison, D. R.; Chapusa, F.W.P. (1975). The Geology of the Nkhota-kota – Benga Area. Bull. Geol. Surv. Mw. 32

Ray, G.E. (1975). The Geology of the Chitipa-Karonga Area. Bull. Geol. Surv. Mw. 42.


## 7. APPENDIX

**Table: Physico-chemical Characteristics of some of theCountry's Thermal Springs**

| SPRING | TEMP ($^oC$) | TOTAL SOLIDS (mg/l) | TOTAL HARD. (mg $CaCO_3$/l) |
|---|---|---|---|
| CHINUKA | 29 | 410 | 48 |
| CHINUKA | - | 360 | 63 |
| MWANKENJA | - | 440 | 21 |
| MWANKENJA | 53.4 | 482 | 43 |
| MWANKENJA | 50.1 | - | - |
| VUNGU | 38.2 | 474 | 28 |
| MPATA | 46 | 392 | 8 |
| MPATA | 50.1 | - | - |
| NKHOTAKOTA | 65 | 388 | 14 |
| CHIPWIDZI | 52.4 | 376 | 8 |
| LIWONDE | - | - | 4 |
| LIWONDE | - | - | 8 |
| MANONDO | 38 | - | 6 |

Source: Bloomfield and Garson (1965); Bloomfield (1975); Ray (1975); Harrison and Chapusa (1975)

| **SPRING** | **Ca** | **Mg** | **Na** | **K** |
|---|---|---|---|---|
| CHINUKA | 16 | 1.9 | 132 | 6.6 |
| CHINUKA | 18 | 3.5 | 134 | 10.5 |
| MWANKENJA | 5 | 12 | 108 | 3.1 |
| MWANKENJA | 6.8 | 6.2 | 324 | 4 |
| MWANKENJA | <1 | 7 | 150 | 3.1 |
| VUNGU | 3.2 | 4.8 | 327 | 3.1 |
| MPATA | 1.6 | 1 | 312 | 2.7 |
| MPATA | <1 | 2 | 145 | 2.2 |
| NKHOTAKOTA | 4.4 | 0.7 | 282 | 3 |
| CHIPWIDZI | 2.4 | 0.5 | 270 | 2.2 |
| LIWONDE | - | - | - | nd |
| LIWONDE | - | - | - | 2.7 |
| MANONDO | 12 | 6.7 | 110.5 | 5.5 |

Source: Bloomfield and Garson (1965); Bloomfield (1975); Ray (1975); Harrison and Chapusa (1975)

| **SPRING** | **K** | **Fe** | **Mn** | **Cu** |
|---|---|---|---|---|
| CHINUKA | 6.6 | - | - | - |
| CHINUKA | 10.5 | - | - | - |
| MWANKENJA | 3.1 | - | - | - |
| MWANKENJA | 4 | nd | nd | nd |
| MWANKENJA | 3.1 | <0.2 | - | - |
| VUNGU | 3.1 | nd | nd | nd |
| MPATA | 2.7 | nd | nd | nd |
| MPATA | 2.2 | <0.2 | - | - |
| NKHOTAKOTA | 3 | nd | nd | nd |
| CHIPWIDZI | 2.2 | nd | nd | nd |
| LIWONDE | nd | nd | - | - |
| LIWONDE | 2.7 | 0 | - | - |
| MANONDO | 5.5 | - | - | - |

Source: Bloomfield and Garson (1965); Bloomfield (1975); Ray (1975); Harrison and Chapusa (1975)

| **SPRING** | **Li** | **Al** | **$CO_3$** | **$HCO_3$** |
|---|---|---|---|---|
| CHINUKA | - | - | 0 | 199 |
| CHINUKA | - | - | 0 | 171 |
| MWANKENJA | - | - | 6 | 226 |
| MWANKENJA | - | - | - | - |
| MWANKENJA | <0.2 | <0.2 | 21 | 271 |
| VUNGU | - | - | - | - |
| MPATA | - | - | - | - |
| MPATA | <0.2 | <0.2 | 22 | 193 |
| NKHOTAKOTA | - | - | - | - |
| CHIPWIDZI | - | - | - | - |
| LIWONDE | - | nd | - | - |
| LIWONDE | - | 0 | - | - |
| MANONDO | - | - | 12 | 97.6 |

Source: Bloomfield and Garson (1965); Bloomfield (1975); Ray (1975); Harrison and Chapusa (1975)

| **SPRING** | **$SO_4$** | **$SiO_2$** | **$P_2O_5$** | **Cl** |
|---|---|---|---|---|
| CHINUKA | 13.4 | - | - | 57 |
| CHINUKA | 27 | - | - | 57 |
| MWANKENJA | 37 | - | - | 32 |
| MWANKENJA | 10 | 70 | 0.02 | 22 |
| MWANKENJA | 75 | 42 | - | 22 |
| VUNGU | 15 | 70 | 0.02 | 22 |
| MPATA | 15 | 70 | 0.02 | 18 |
| MPATA | 93 | 44 | - | 24 |
| NKHOTAKOTA | 20 | 90 | Tr | 18 |
| CHIPWIDZI | 20 | 80 | Tr | 30 |
| LIWONDE | - | nd | - | - |
| LIWONDE | - | 48 | - | - |
| MANONDO | 20.37 | - | - | 71 |

Source: Bloomfield and Garson (1965); Bloomfield (1975); Ray (1975); Harrison and Chapusa (1975)

| **SPRING** | **F** | **Eh (µ mhO/m X $10^2$)** | **pH** | **$Na_2S$** |
|---|---|---|---|---|
| CHINUKA | - | 8.4 | 7.5 | - |
| CHINUKA | - | 6.8 | 8.1 | - |
| MWANKENJA | - | 6.4 | 8.2 | - |
| MWANKENJA | 4 | 6.2 | 7.8 | - |
| MWANKENJA | 3.6 | 7.4 | 8.5 | - |
| VUNGU | 5 | 6.1 | 8.6 | - |
| MPATA | 5 | 5.6 | 8.7 | - |
| MPATA | 5 | 6.9 | 9 | - |
| NKHOTAKOTA | 17 | *505 | 8.7 | - |
| CHIPWIDZI | 8 | *485 | 9.5 | - |
| LIWONDE | 8.3 | 0.39*[1] | 9.1 | 155 |
| LIWONDE | nd | 0.37*[1] | 9.1 | 152 |
| MANONDO | - | - | 7.8 | - |

Source: Bloomfield and Garson (1965); Bloomfield (1975); Ray (1975); Harrison and Chapusa (1975)

| **SPRING** | **$NaCO_3$** | **NaCl** | **NaF** |
|---|---|---|---|
| CHINUKA | - | - | - |
| CHINUKA | - | - | - |
| MWANKENJA | - | - | - |
| MWANKENJA | - | - | - |
| MWANKENJA | - | - | - |
| VUNGU | - | - | - |
| MPATA | - | - | - |
| MPATA | - | - | - |
| NKHOTAKOTA | - | - | - |
| CHIPWIDZI | - | - | - |
| LIWONDE | 202 | 98 | 18 |
| LIWONDE | 200 | 94 | 5 |
| MANONDO | - | - | - |

Source: Bloomfield and Garson (1965); Bloomfield (1975); Ray (1975); Harrison and Chapusa (1975)

NOTE
Chemical values in parts per million (ppm)
* Unit of measurement is RM/$cm^3$ - 20° C
*[1] Millimhoms at 20° C
nd - Not Detected