Geothermal Surface manifestation mapping in South- Western Tanzania

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ABSTRACT

Geothermal exploration by mapping surface manifestations, which includes geological mapping, structural mapping and hydrothermal mapping was carried out in the four geothermal prospects of South-western Tanzania namely Songwe, Mapulo-Kasimulo, Rungwe and Lake Ngozi area. The major objective was to produce a hydrothermal map including phenomena like hot and warm grounds, hot and warm springs, steam vents, mud pits, geothermal altered rocks and any kind of surface thermal manifestation. For practical purposes hot springs, faults, major fractures and young volcanic features like volcanic craters, eruptive fissures and hot grounds were mapped as a link is often found to exist between tectonic features and the distribution of geothermal manifestations.

During mapping surface temperatures of the hot ground, hot springs, lakes, rivers and stream were measured. The highest surface temperature of 98^{o}C was registered at the Rungwe, 85^{o}C at Songwe, 65^{o}C at Mampulo-Kasimulo and around 65 ^{o}C at Lake Ngozi prospects respectively. The lake is a crater lake and the satellite imagery indicated some promising sources of heat. The water encountered is of HCO_3 type and the underground temperature were estimated using Giggenbach ternary diagram; it showed a tkn temperature of 180^{o}C at Mampulo, 210^{o}C at Songwe, 220^{o}C at Rungwe and Malonde. The estimation of heat stored in rocks, fluid, vapor and condensate was done. The potential usable heat was calculated and the result was used to estimate the Power Potential for Songwe which is 107MWe.These preliminary results are an indication that Tanzania has a potential for geothermal exploitation.

Key words: *surface manifestation, surface temperature, volcanic features and hosprings.*

1.0 INTRODUCTION

Tanzania is one of the several countries that are truncated by the East African Rift. The rift system has a high geothermal gradient and a number of hot spots that are suitable for development of power generation. In this study, the potential for geothermal exploration in Tanzania has been overviewed and evaluated with field studies by surface mapping of geothermal manifestation features.

Tanzania have more than 15 locations with hot springs of temperatures greater than 40^oC. Some of these springs are found over and near the active rift segments with quaternary volcanism, but others lie over the Tanzanian (Archean) craton and its Precambrian surroundings. In southern western Tanzania, in the northern extension of the Malawi Rift, about three prospects of high-intermediate temperature at Songwe, Kyela (Mampulo and Kasimulo) and Rungwe are indicated by the occurrence of hot springs. Tanzanian geothermal potential is estimated to be 650 MW (McNitt, 1982).

A strong possibility of resumption of geothermal exploration programme in Tanzania in the near future is foreseen. The need to update major inferences drawn since the publication of a phase one reconnaissance survey (SWECO-VIRKIR, 1978; Mnzava *et al*, 2004, 2005, 2006a, 2006b and 2008) have acted as sources of inspiration for presenting this case-study of the most promising active hydrothermal system of South-western Tanzania along the African Eastern Rift Valley..

2.0 MATERIALS AND METHODS

2.1 Location and geology of the study area

The study area is in the Mbeya region, Southwestern Tanzania, known as the Mbeya prospect. The prospect has three main areas of geothermal interest:

(a) The Songwe valley area, which is situated about 27km west of Mbeya town and located between Latitude 8^o 50' S-8^o 56' S and Longitude 33^o 10' E-33^o 15' E (Fig.1).

(b) The Kyela (Mampulo and Kasumulo) area is situated about 10 km west of Kyela town and is located between Latitude 9^o 31' S-9^o 54' S and Longitude 33^o 44' E-33^o 51' E (Fig. 1).

(c) The Rungwe-Kalambo area is situated about 15 km South of Sarabwe along the Mbaka fault and is located between Latitude 9^{o} 22' S-9^{o} 27' S and Longitude 33^{o} 39' E-33^{o} 59’ E (Fig.1)

(d) The Lake ngozi prospect is located a few kilometers North of Mbeya town.

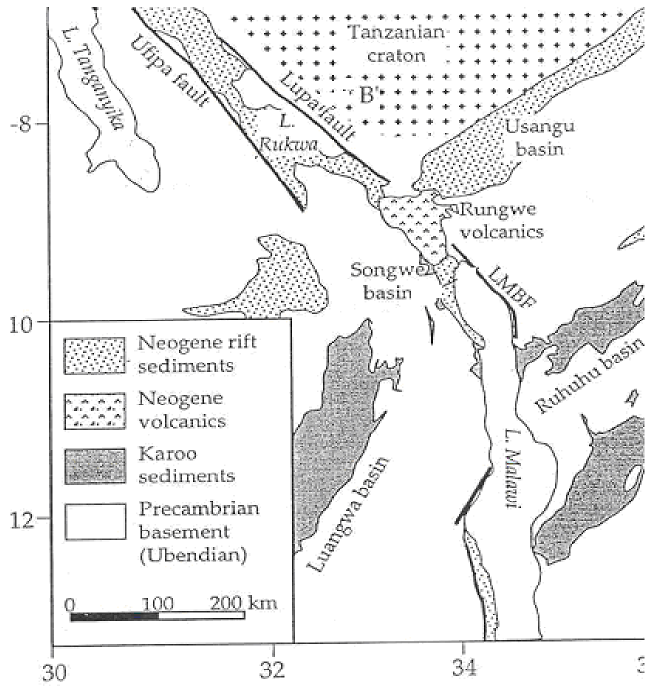

Fig 1: Simplified geological map showing the triple junction, location of the study area, Rungwe volcanics and Songwe basin in relation to the Western and Eastern Rift valley (Van Der Beck *et al.,* 1998)

3. Field Work

3.1 Mapping of Surface Manifestations

The surface manifestations of geothermal activity were studied using thermal method. Springs in the three different prospects were mapped and different parameters such temperature, flow rate, altered rock, mud pools, sulphur, artesian springs and structure setting of the springs were observed and recorded.Water samples were collected (Fig.3.1, 3.2 and 3.3)

At Songwe (Fig. 3.1), the hot springs have deposited almost 15 million tones of travertine as a hanging cliff in the valley wall and the deposition of calcium carbonate is going on at a rate of 5gms/sec (Hoechstain, 2000). A big boiling fracture spring with steam was encountered.

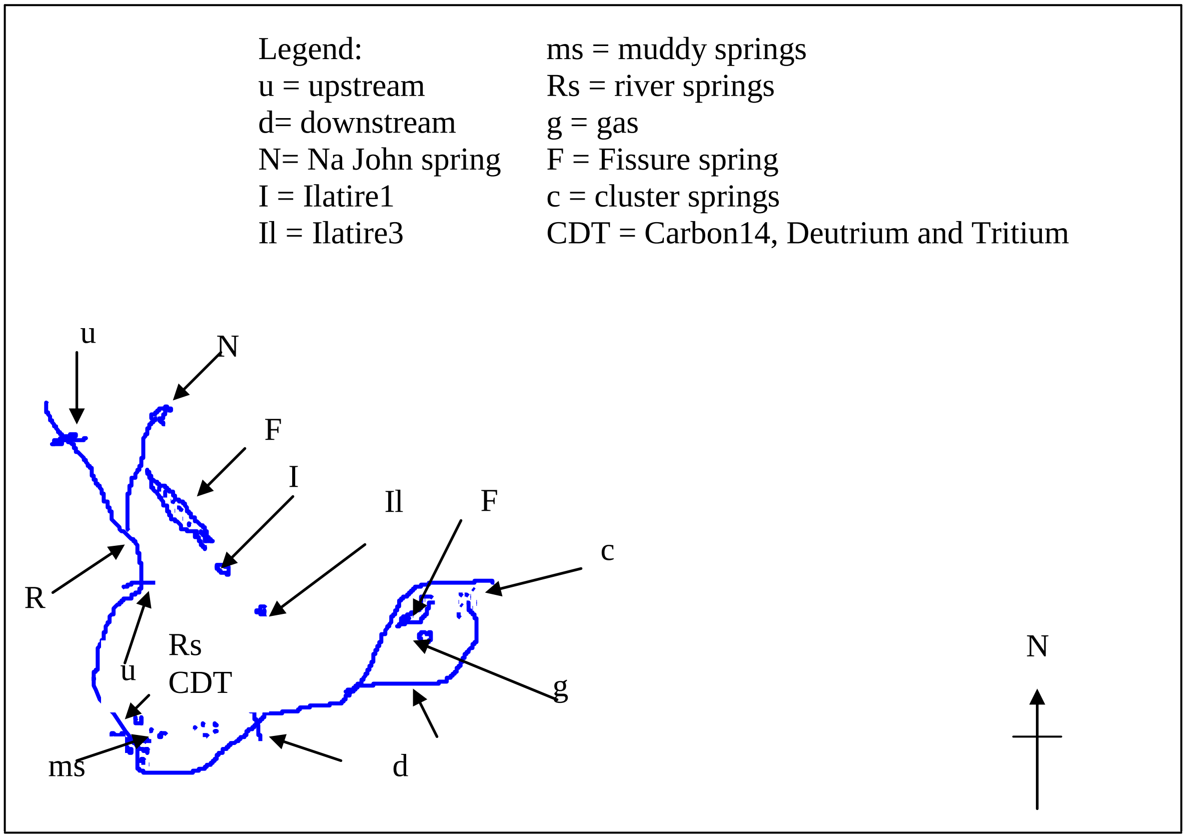

Fig.3.1: Sketch map of Songwe prospect surface manifestation mapping locations

The Kyela prospect (Fig. 3.2), has three separate prospects, Mampulo, Mwakalinga; and Kasimulo close to the border of Tanzania and Malawi. The springs are located at probably an old alluvial fun. The Mampulo prospect has a hallo of vegetation zonation and it is situated between two hills where the southern hill separates the prospect of Mampulo from that of Mwakalinga.

The Rungwe prospect (Fig. 3.3) is situated at the Valley of Ngungwisi river with a myriads of hot spring along and in the river discharging CO_2 and at Makwehe stream where a geyser is discharging boiling water and steam. Lake Ngozi is a crater lake in the Rungwe volcanics. The temperature at the lake were not as high as that at the valley.

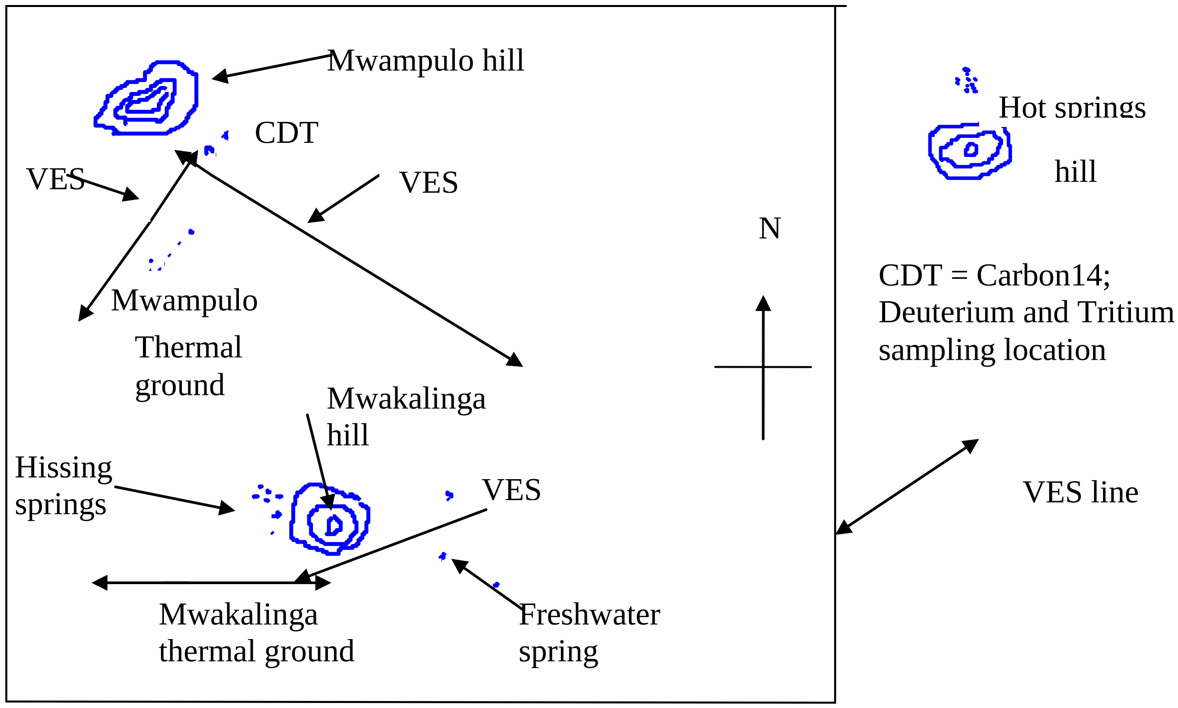

Fig. 3.2: Kyela showing the Mampulo and Mwakalinga thermal grounds

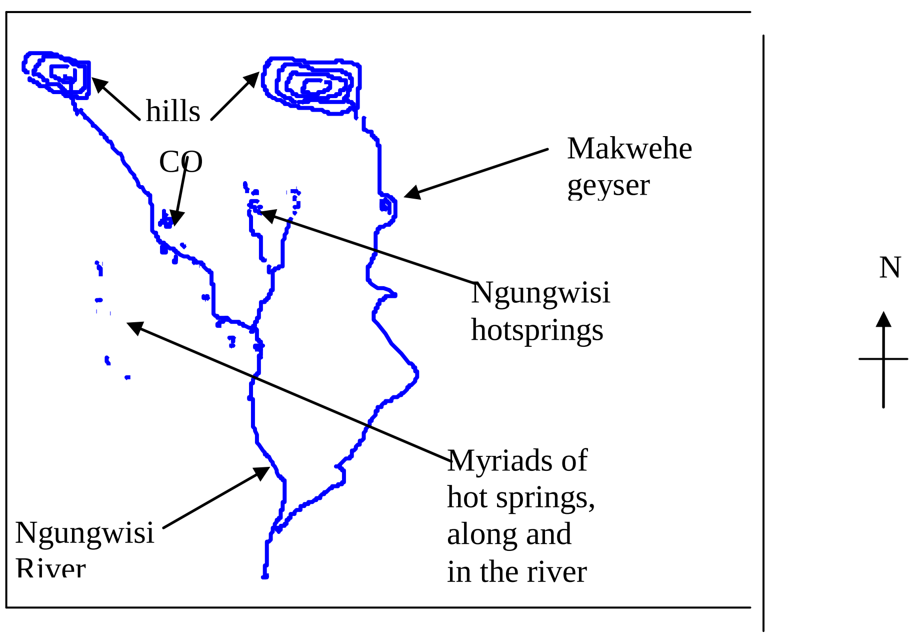

Fig. 3.3: Rungwe hot springs

3.3 Geochemical Sampling procedure

(iv) Sampling of both hot water from the hot springs and cold water within the study areas (Figs. 3.1, 3.2 and 3.3) was done using methods outlined by Arnorsson and Gunlaugsson (1975), Olafsson (1988) and Giggenbach and Goguel (1988).

Samples were collected from all sources within the study area. While on the follow up fieldworks only some specific sources (high temperature with high chloride concentration and less magnesium concentration) from the results were sampled.

In Songwe, sampling was possible in some springs, but impossible in deep fracture controlled springs and those springs that were very high up in the travertine limestone cliff (Fig.3.1).At Kyela sampling was done at Mampulo, Mwakalinga and Kasimulo (Fig. 3.2). In Rungwe, sampling was done at Kindandali, Ngungwisi and Makwehe (3.3).

3.3.1 Analysis of samples

The analyses were done in accordance with Standard Methods (APHA *et al.,* 1992) and the species analysed are as shown in Table 3.1. Total alkalinity, total hardness and Silica (SiO_2) analyses were done on the same day of sampling.

The type of water was identified by using CL-SO_4- HCO_3 ternary diagrams and the underground temperature was estimated by the Giggenbach ternary diagram.

3.4 Simple Reservoir Assessment

Simple reservoir assessment for the Songwe prospect was done to assess the anomalous heat stored in rocks, fluid, vapor and condensate, stored usable heat and the power potential of the prospect.

4.0 RESULTS AND DISCUSSION

4.1. Surface discharge features

4.2. The different surface discharge features of geothermal systems encountered are divided into; Diffuse discharge; thermal ground and steaming ground features, which were encountered in Songwe (Plates 4.1) and Mampulo (Plates 4.2), respectively.

Plate 4.1: Songwe-Bwana Hutu hot ground(40^{o}C)

Steaming ground was encountered in the Songwe valley that is in the rift, which forms part of the East-African rift Valley like Olkaria in Kenya. At the hot/steaming ground characterized by absence of vegetation, the surface temperature ranges between 30-40^{o}C. As one moves out of the hot ground the vegetation is dwarfed and in the periphery of the hot/steaming ground the temperature are optimal for tall vegetation hence the term "vegetation zonation".

Plate 4.2: Mampulo hot ground showing vegetation zonation

The plant zonation due to thermal ground was much pronounced at Kyela prospect-Mampulo (Plate 4.2) than in Songwe (Plate 4.1). It is divided into two thermal grounds (Figure 1.3), namely Mampulo (Plate 4.2) and Kasimulo prospect.

(2) Direct discharge; warm and hot springs, steam vents, fumaroles. These were encountered in all the study areas localized. At the end of the rain season, the discharges of some of the hotsprings were approximately 2.5-10 litres per second. In the Songwe valley the hot springs are rising through the fractures on the draping wall of Pleistocene travertine limestone forming the wall of the Songwe valley gorge. At the travertine limestone cliff a fracture controlled spring was encountered in which the water was boiling within and the steam was coming out of the fracture as shown in Plate 4.3. Muddy springs were encountered down in the valley at the river bank where the mud ebullition

rises up to a height of about 6 cm with a temperature of 84^{o}C and a pungent smell of hydrogen sulphide gas (H_2S). About three meters above the river bank a dry spring has formed a steam vent with a temperature of 85^{o}C at the mouth of the vent.

Plate 4.3: A fracture controlled spring, steam rising along the fracture from the boiling water within

The surface manifestation at Malonde is extensively of rock alteration by hot water and the old famous geysers about 71^{o}Cwere dying away while a rumbling noise of probably boiling water within the travertine limestone cliffcould be head at a distance.

At Kyela, the spring are flowing out from an old alluvial fun with unsorted sediments and the maximum temperature at Mampulo was about 68^{o}C and at Kasimulo 65^{o}C.

(3) Concealed discharge; seepage, concealed outflows.

These features were observed at the bend of the Songwe river where fishes die during dry season when the river water decreases. Although it was at the end of the rain season and still water was overflowing the river banks, there was a difference of 0.1^{o} C between the upstream and downstream samples. During the dry season the temperature difference was about 4^{o}C. This indicated that there are concealed features that discharge hot fluid into the river.

(4) Intermittent discharge; geysers

The later features were encountered at Malonde in Mbozi and at Makwehe in Rungwe. At Malonde the geyser are dying, flow rate is about 2.5 l/s intermittent (not continuous) and the artesian height is very low 0.3 m compared to the flow rate of Makwehe 30 l/s with an artesian height of 1.5 m (geyser).

(5) Catastrophic discharge; hydrothermal eruptions.

This feature occurred in July 2000 close to Ngubwisi stream (Plate 4.4). This can be explained by the pressure built-up in the reservoir. Newly forming springs and steam vents were observed at Songwe and at Ngunbwisi in Rungwe.

Plate 4.4: Makwehe-Rungwe geysers with steam rising at the top left corner of the photograph

Songwe prospect might be of high to medium temperature as indicated by the hot thermal ground at Bwana Hutu with a spring surface temperature of up to 81^{o}C and Ilatire spring up to 83^{o}C. The deposition of huge amount of travertine and the ongoing precipitation of calcium carbonate suggests the presence of either a very big reservoir or multi-reservoirs system that can account for this. However, the location of the reservoir is suspected to be close to lake Ngozi and Near Rwanga in Rungwe volcanic mountains.

Kyela might be a high temperature prospect, which is indicated by hot thermal ground, with clearly marked vegetation zonations. High surface temperatures of up to 98^oC at Makwehe hotsprings indicate that Rungwe prospect is of higher temperature.

The waters encountered in the study area are peripheral waters of HCO_3 type (Fig.4.10)

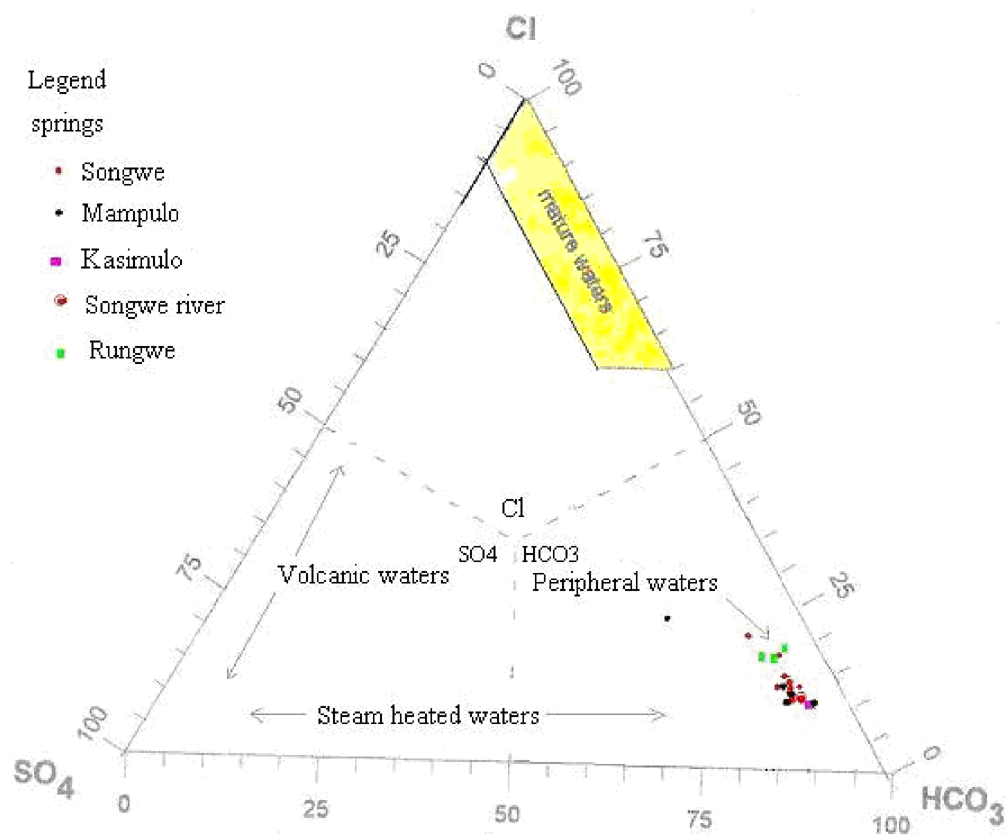

Fig.4.1 Classification of water type by Cl-HCO_3-SO_4 ternary diagram

The fluid mineral equilibria and subsurface temperatures were estimated using Giggenbach ternary diagram (Fig 4.2) The waters have not reached full equilibrium, most of the springs data plotted in the intermediate zone and were used for temperature estimation. The temperature given by tkn in the diagram were around 220°C Rungwe; 210°C Songwe; 209°C Mampulo and 180°C Kasumulo

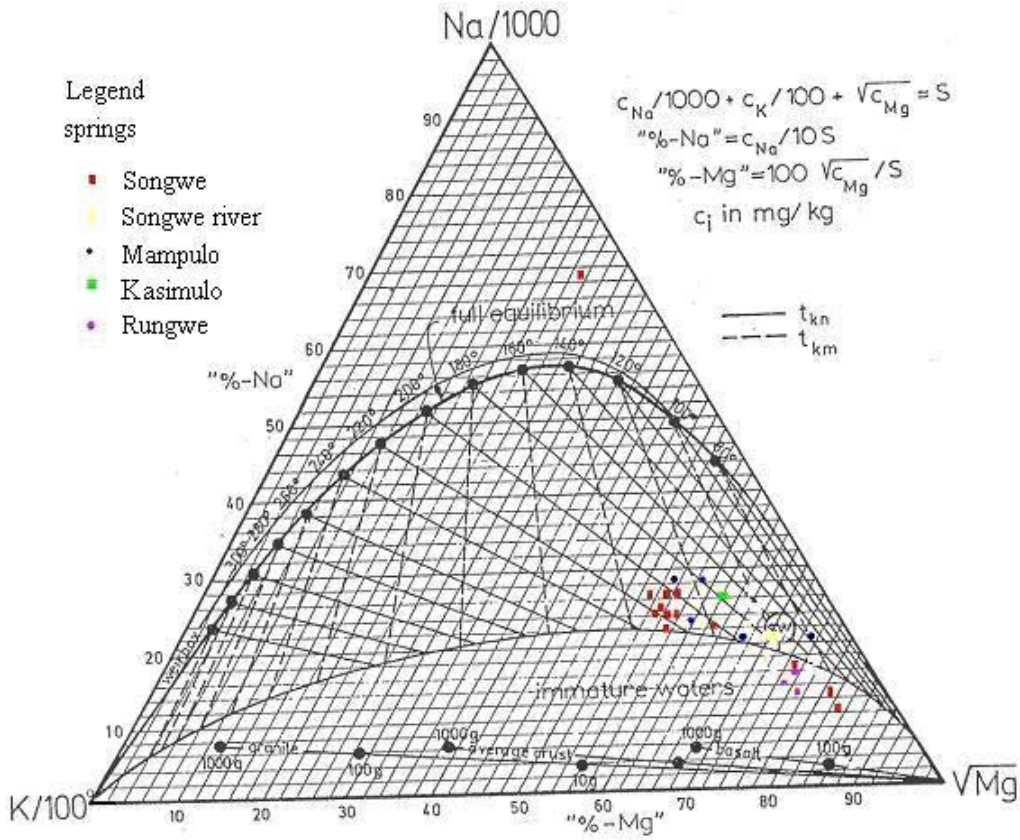

Fig. 4.2: The (Na^+- K^+-$(Mg^{+2})^{1/2}$) ternary diagram for Dec. 2002

4.3 Heat stored, Potential stored heat and the Power potential of the prospect

From the literature it was reported that the prospect have a temperature of 270°C (SWECO-VIRKIR, 1978), therefore this was used to calculate a rough estimate of heat stored in rocks, fluid, vapor and condasate; potential stored heat and power potential of the prospect:

Therefore the Total usable energy potential of Songwe is heat stored in liquid (Q_l), in vapour (Q_v) and in condensate (Q_c) calculated by chain of equations using depth range (km), temperature increase with depth range (T/km), saturation density (kg/m^3), (porosity (ϕ), liquid Saturation(**S_l**) and Storativity (**S_v)** and particle density matrix (σ_p) which was calculated separately for each type of store that is generally the potential usable heat is that heat that can be extracted for use:

Potential usable heat = $Q_l + Q_v + Q_c = 0.27 \times 10^{18}J + 0.014 \times 10^{18}J + 2.24 \times 10^{18} J$

$= \mathbf{2.52 \times 10^{18} J.}$

The assumption was made that the resource have a life sparn of 25 yrs, a recoverable factor of 0.25 and an efficient convertion factor of 0.162.

$$P(MWe) = \left[\frac{Potential\ usable\ heat * recovery\ factor * efficient\ conversion\ factor}{Lifetime(yr) * days(per\ year) * hours(per\ day) * seconds(per\ hour)}\right] \ldots\ldots\ldots\ldots (4.9)$$

$$P(MWe) = \left[\frac{2.52 x 10^{18}\ x 0.25\ x\ 0.162}{25 x 365 x 24 x 3600}\right] = 1.07 x 10^{8}\ (J/s) = 107 \times 10^{6}\ (J/s) = \mathbf{107\ MWe}$$

Conclusion and Reccomandation

From these preliminary studies of surface manifestations it shows that the South-Western Tanzania prospects have a prospective geothermal potential and the estimated power potential of the Songwe prospect is about 107 MWe.

It is recommended that further work for developing the resource should be taken into consideration.

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