GEOCHEMISTRY OF RWENZORI THERMAL SPRING WATERS

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1. Introduction

Rwenzori springs refer to thermal springs around R nzori Mountains, in western Uganda. A chemical and isotopic sampling programme was undertaken by the authors as part of the GEOTHERM programme, a technical cooperation project between the Government of Uganda and Germany. The programme was part of the field investigations, which included gravity survey, Transient Electromagnetic (TEM) survey and Schrumberger Sounding. Geophysical work was mainly focused around Buranga hot springs, on the western side of Rwenzori. Later on a network of seismic stations were installed around Mt Rwenzori. Geochemical and isotopic sampling was regional in scope, to understand the relationship of the neighboring thermal manifestations to Buranga hot spring system. It involved sampling thermal water and tufa deposits, measuring of surface temperature, conductivity and pH. Thermal springs sampled included L. Kitagata, Muhokya, Kibenge, Bugoye, Rwimi, Rwagimba, Nyansimbe, Kagoro, Mumbuga and Kibuku. This report is a result of integrated field and laboratory studies carried out on Rwenzori thermal springs.

2. General geology

Rwenzori region is a zone of crustal uplift and volcanism as evidenced by quaternary alkaline volcanic centers around Fort Portal (Ndale, Kasekere, Fortpotal). Lithologically, it is made up of banded gneiss, granite and schist. Peaks are made up of amphibolites, hornblende gabbros and metasediments, which make up Stanley series. Schistose trends nearly dipping vertical and these must have had controlling influence on later structural development. Near vertical fractures are more likely to play a principal role in water migration. The western boundary is made up of banded biotite gneiss. Rwenzori axis runs about N30°E and the area is seismically active. The thermal springs appear to be structurally controlled by faults and most of them are associated with tufa. Tufa deposits are reported in some of the explosion craters around Fort Portal (Saka, Kasekere and Nyabusozi) on the eastern side of Rwenzori and on the northern end of Rwenzori nose, around Kibuku area and are regarded as field-wide characteristics of Rwenzori thermal springs. Almost all springs are associated with tufa deposits with the exception of Kibenge, Nyakalenjijo (Mubuku River) and Muhokya.

3. Field activities.

The fieldwork included chemical sampling of thermal water, gases and tufa deposits, measurement of temperature, pH-field and conductivity. Thermal springs with flow over 0.5 L/s were preferentially sampled since these were less likely to have been affected by dilution and evaporation. Water samples were collected in a jug (on a rod, at Nyansimbe pool) so that they could be obtained from the center of the spring. Each spring was sampled at its hottest part, which was presumed to be the point where hot water enters the pool. The waters were transferred to a rinsed 100-ml plastic bottle.

The untreated water samples were analysed for pH-lab, SO_4, and bicarbonate. pH was also measured at the time of field collection. Another set of water samples were treated at the time of collection (filtered through 0.4µm filters and acidified with a measured amount of Nitric acid, 1ml of acid per 100ml of water sample). This was to ensure that the analyses represent the chemistry of the thermal waters as closely as possible. This was collected into a rinsed 50-ml polythene bottles and were analysed for chloride, silica and major cations. By bottling the samples at the sampling temperature, errors arising from evaporation were minimised (Mahon, 1961).

Model of Ruwenzori. After British surveys.

Figure 1: Rwenzori Mountain

4. Results of chemical analysis

Laboratory analysis was carried out at BGR, Germany and the results are summarized in table 1. All samples are near neutral to slightly alkaline.

5. Ion balance

Ion balance was carried out to assess the quality of chemical analysis. This involved comparing the sum of the molal concentration of the major positively charged species times their valence (charge) against the sum of the molal concentration of the major negatively charged species. Prior to carrying out ion balance, data was converted from ppm (mg/kg) to molal units. Again for convenience in determining the ion balance, molal units were converted to millimolal units (1 mole = 1000 millimoles).

Table 1: Chemical composition of Rwenzori thermal springs in ppm (mg/kg)

Location	**Temp**	**Ph**	**Cond**	**SiO_2**	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**Li^+**	**B**	**Al**	**Fe**
Mumbuga	94	8.7	17900	70	2850	3133	3222	4716	166	6.24	1.94	1.2	14.8	0.015	0.02
Nyansimbe	75.4	8.4	22400	77.4	3630	4019	4186	5991	218	6.55	1.97	1.51	18.1	0.02	0.02
Kagoro	88	8.6	21000	76.6	3360	3735	3842	5561	199	7.01	1.97	1.41	17.2	0.71	0.91
Well-1	62	8.3	21500	73.5	3440	3839	4001	5738	209	7.11	1.77	1.45	17.5	0.031	0.16
L. Kitagata	64	8.7	31300	81.7	4160	2447	12959	9237	634	2.41	0.86	0.048	3.22	0.02	0.02
Kibenge	42.5	8.2	3580	44.5	98	585	894	550	24.3	226	6.4	0.221	1.89	0.163	0.3
Muhokya	41	8.2	8460	50.9	143	460	1075	586	18.8	206	13.1	0.062	1.42	0.039	1.05
Rwagimba	69	8.1	6390	62.5	800	838	1468	1480	41.6	74.1	5.38	0.452	2.77	0.01	0.48
Rwimi-1	25.9	7.2	3880	92.7	2100	232	693	424	60.7	380	198	0.071	0.94	0.154	6.42
Rwimi-2	24.6	7.1	3640	84.8	2020	189	523	356	56.8	361	181	0.056	0.73	0.031	6.25

Table 2: Chemical analysis in millimolal units

Location	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**Δ charge %**
Mumbuga	46.7	88.3	33.56	205	4.2	0.16	0.07	+1.83
Nyansimbe	59.5	113.2	43.6	260	5.6	0.16	0.08	+1.17
Kagoro	55.1	105.2	40.02	241	5.1	0.17	0.08	+1.29
Well-1	56.4	108.1	41.7	249.5	5.3	0.18	0.07	+1.47
L. Kitagata	68.2	68.9	134.9	402	16.2	0.06	0.04	+1.39
Kibenge	1.61	16.5	9.3	24	0.6	5.65	0.26	-0.39
Muhokya	2.34	12.9	11.2	25.5	0.5	5.15	0.54	-0.34
Rwagimba	13.1	23.6	15.3	64	1.06	1.85	0.22	+1.39
Rwimi-1	34.4	6.54	7.2	18	1.5	9.5	8.15	-0.49
Rwimi-2	33.1	5.32	5.4	15.5	1.5	9.03	7.44	+0.72

According to table 2 analysis fall within the acceptable range, that is below 5%. Hence, the analysis was generally good and of adequate quality and compares reasonably with earlier analysis (Sharma, 1971, Armannsson, 1994).

6. Classification of waters using relative Cl^-, SO_4^{2-} & HCO_3^-

The Cl and SO_4 contents of Rwimi, Rwagimba, Mumbuga, Nyansimbe, Kagoro, Kibenge and Muhokya exhibit a high degree of co-variance ($R^2 = 0.9935$). Lake Kitagata is excluded in this compositional range and possibly belongs to a different geothermal reservoir. The highest concentration of Cl and SO_4 (Mumbuga, Nyansimbe, well-1 and Kagoro) are possibly influenced by magmatic HCl and SO_2 input. The lowest values at Rwagimba, Rwimi, Kibenge and Muhokya are reflecting little input from magmatic sources for these species. Mumbuga, Nyansimbe, Well-1 and Kagoro waters are chemically similar implying they are emanating from the same source and possibly along the same migratory path. Partial equilibration and mixing among the different water may have given rise to the formation of intermediate / hybrid waters as represented by Buranga thermal water samples.

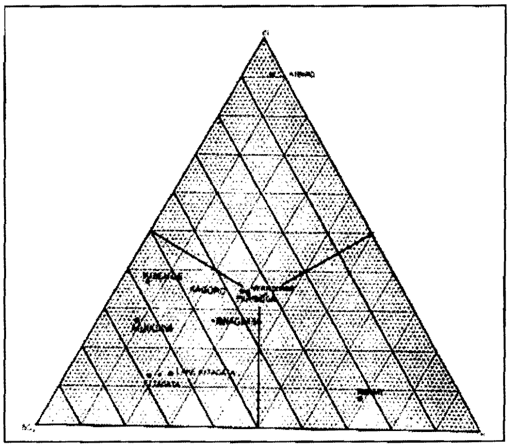

Figure 2: Relative contents of Cl, HCO and SO4 in ppm

L. Kitagata, slightly alkaline, is characterized by high SO_4 content possibly attributed to magmatic SO_2 input. The sample has the highest sulphate to Cl ratio possibly attributed to magmatic vapor input. Since it is plotting in the corners or along the axis, it must have been affected by mixing of SO_4 waters with some meteoric waters. SO_4 waters normally contain appreciable contents of Cl (>1000ppm Cl) as in case of L. Kitagata (2447ppm). The presence of high Cl contents, distinguish magmatic or volcanic SO_4 sources from SO_4 waters of steam-heated origin, which have very little Cl content. The source of Cl like SO_4 in L. Kitagata hot water sample is possibly due to absorption of HCl bearing volcanic gas into meteoric water. Kibenge thermal waters are slightly alkaline with appreciable SO_4 contents relative to other major anions. These can be described as Cl- SO_4 waters, plotting almost on the axis. It appears to be of steam-heated origin rather than volcanic origin. The high Mg contents might be attributed to mixing with meteoric ground-waters. Muhokya thermal waters are slightly alkaline and can be classified as Cl-SO_4 waters. High Mg contents might indicate mixing with meteoric waters. It appears to be of steam-heated origin rather than volcanic origin. Rwagimba thermal waters are slightly alkaline and have more SO_4 than Cl and HCO_3. These Cl-SO_4 waters are possibly steam-heated waters rather than volcanic in origin. Rwimi samples are HCO_3 **waters** (CO_2-rich waters) with appreciable amounts of HCO_3. They have low Cl content and variable SO_4^{2-} contents. HCO_3 waters typically form in the marginal / peripheral zone and shallow subsurface region where CO_2 gas is absorbed and steam is condensed into cool ground waters.

7. Relative Na, K and Mg contents.

Rwimi samples plot close to the Mg corner reflecting their high immaturity. Rwimi samples exhibit higher than equilibration Mg contents (181-198ppm). These are typical of low temperature environments created by the underground absorption of CO_2-rich vapours into meteoric groundwater. It is not justifiable to apply geothermometry on such non-equilibrated waters. Rwimi waters represent solutions affected largely by rock dissolution rather than fluid equilibration.

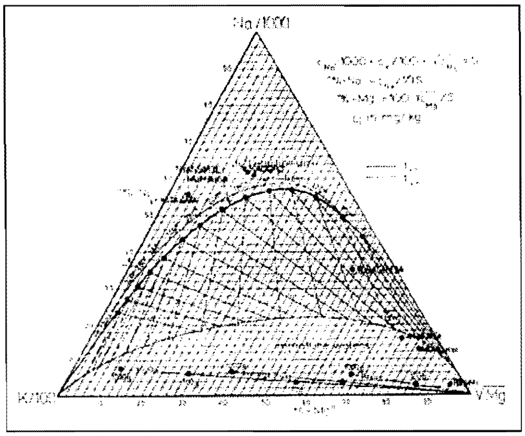

Figure 3: Relative contents of Na, K and Mg, showing dilution / mixing trend towards mg rich waters

Buranga samples plot above the full equilibrium line, possibly indicating boiling / steam loss which might have led to increase in the absolute solute contents. Rwagimba sample occupy intermediate position reflecting partial attainment of equilibrium with rock at generally low temperatures. Indicated temperatures is between $T_{K\text{-}Na}$ 140-160°C and that of $T_{K\text{-}Mg}$ of 100-120°C, having acquired Mg during their rise to lower temperatures without readjustment of K/Na ratios. L. Kitagata waters plot above the equilibrium line possibly due to steam loss / boiling. Kibenge thermal waters plot on boundary between immature waters and partially equilibrated water. Muhokya waters are plotting in the immature zone. All assumed steam-heated waters (Muhokya, Rwimi, Kibenge, Rwagimba) occupy positions close to the Mg corner, reflecting their highly immature state. In their case, application of solute geothermometers, based on assumption of attainment even of only partial equilibrium is not justified. These form end-members water-type. Thermal waters from Kagoro, Mumbuga, Nyansimbe, Well-1, Rwimi, Muhokya, Kibenge and Rwagimba are highly correlated (R^2=0.9978). This high correlation might be attributed to genetic relationship and might point to single source of these thermal waters and the same migratory path-way, possibly reflect mixing between "dissolved rock" and fully equilibrated waters, obvious from the ternary diagram above.

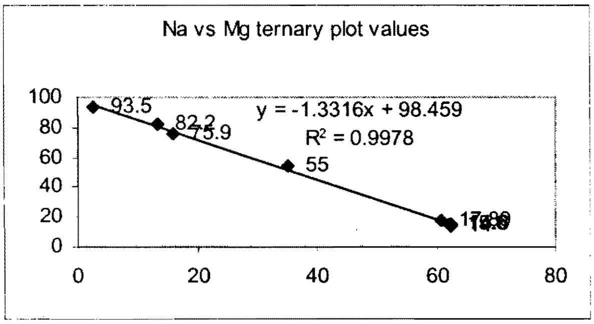

Figure 4: Graph showing sodium values plotted against magnesium values.

8. Relative Cl-Li-B contents

All thermal water samples plot close to the Cl corner. Since Li tends to remain in solution, it is the relative Cl and B contents which are likely to change the B/Cl ratio. Low B/Cl ratio in steam is likely be brought about by addition of more Cl from a magmatic source not from simple rock leaching or from progressive boiling over time, which might have resulted in a low B/Cl ratio in a mature system. This might indicate that all Cl are supplied after rock dissolution possibly absorption of low B/Cl magmatic vapors. A magma chamber is the most reasonable source of huge quantities of CO_2, B and Li.

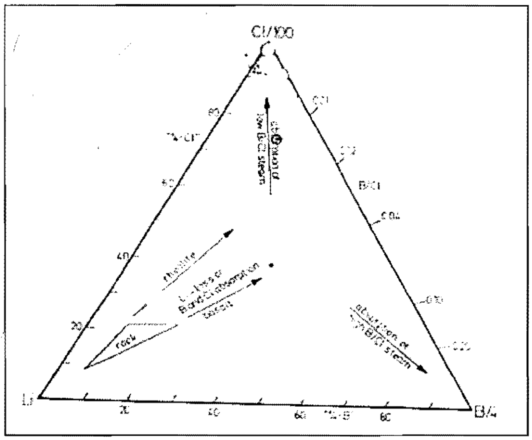

Figure 5 Relative contents of Li, B and Cl

9. Chemical geothermometry

The results indicated by Na-K geothermometers are not reliable for Rwimi waters, since they contain appreciable quantities of Ca (361-380ppm) and deposit travertine. Such geothermometer are not ideal for cool, CO_2-rich springs like Rwimi and hence results should be used with caution. Kibenge, Muhokya, Rwagimba and Rwimi do not contain reasonable contents of chloride; hence K/Na temperatures are not representative of those of the deeper neutral Cl water. Otherwise they are likely to reflect the lower temperatures (~150°c) typical of environments created by the underground absorption of CO_2-rich vapors into groundwater at the periphery or margins of a system.

Location	Qtz no steam loss	Qtz max steam loss	Na-K (Fournier)	Na-K (Giggenbach)
Mumbuga	118.3	116	140.9	161.4
Nyansimbe	123.4	121.1	143.7	162.7
Kagoro	122.9	120.7	142.3	162.7
Well-1	120.8	118.8	143.8	162.7
L.Kitagata	126.3	123.6	186.2	204.7
Kibenge	96.6	98	155.5	175.4
Muhokya	102.8	103.4	135.9	156.0
Rwagimba	112.6	119.2	128.6	148.2
Rwimi-1	132.2	128.6	249.3	262.0
Rwimi-2	128.5	125.4	260.7	272.1

10. Relative proportions of B, Cl and Na

There is an indicated high correlation (R^2=0.9966) between Na and Cl of thermal waters at Buranga, Rwimi, Muhokya, Kibenge and Rwagimba (Figure 6). This points to a possible genetic relationship between these waters possibly influenced by mixing process.

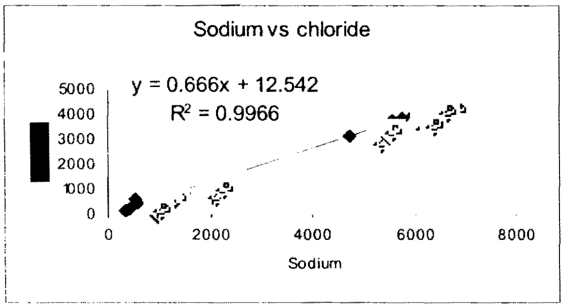

Figure 6: Graph showing Cl conc. (ppm) versus Na conc. (ppm). Note the near linear relationship

There is a highly correlated linear trend (R^2=0.9976) between Cl and B values of Nyansime, Kagoro, Mumbuga, Rwimi, Muhokya, Kibenge and Rwagimba. Again this might point to a genetic relationship between these waters. A high correlation (R^2 = 0.9997) is observed between K and Cl, for springs Nyansimbe, Kagoro, Mumbuga, Rwagimba, Muhokya and Kibenge. Rwimi and L. Kitagata hot springs plot in different compositional field. This correlation possibly points to the different environment. There is a systematic change of K with respect to chloride. K increases in a linear fashion with chloride in the sediment-starved systems, while sediment-hosted systems show high K with no systematic trend relative to Cl. The high K/Cl at L. Kitagata and Rwimi possibly reflect the much greater concentrations of K relative to Cl in sediments relative to sediment-starved systems. The increase in cationic charge from Ca exactly compensates the decrease in charge due to loss of Na, which is especially evident at high chloride concentrations. This can be demonstrated by plotting Na plus two times Ca (**Na+2Ca**) versus Cl, which gives a highly correlated trend (R^2=0.9988) for springs at Mumbuga, Nyansimbe, Kagoro, Rwagimba, Muhokya and Kibenge. Rwimi and Lake Kitagata are *out of the compositional range again due to anomalous Ca and K contents respectively.*

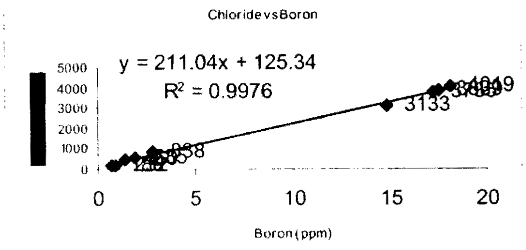

Figure 7. Graph showing Cl conc. (ppm) versus B conc. (ppm)

11. Salinity analysis

A plot of Br versus Cl for waters of Nyansimbe, Mumbuga, Kagoro, Rwagimba, Rwimi, Muhokya and Kibenge reveal a high correlation (R^2=0.9976). This highly correlated linear trend points a possible genetic relationship possibly influenced by mixing and partial equilibration. The Br/Cl ratios fall in a range 0.00451 to 0.01120. This is somewhat higher than seawater (typically 0.00347). Br/Cl increased ratios might be due to increased Br or reduced Cl contents. The latter seems more probable. This may suggest that Cl salinity may be *largely* derived from silicate rock-water interaction / fluid inclusion leaching, rather than from modified seawater or from evaporates at depth. It points to a non-marine, non-evaporitic source of Br and Cl (Andreasen & Fleck, 1997).

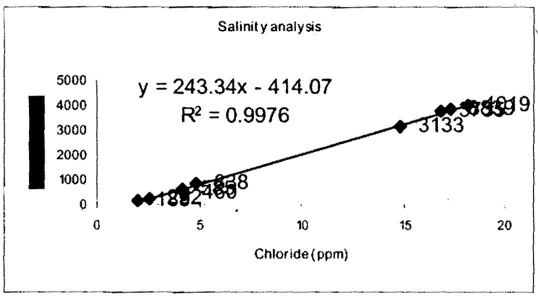

Figure 8: Br (ppm) versus Cl (ppm)

12. Isotopic geochemistry

$\delta^{13}C$ and $\delta^{18}O$ of tufa and limestone samples were analysed at the Institute of Geological and Nuclear Sciences, in New Zealand. Buranga tufa plot in carbonatite magma field (See figure 3), hence are a hydrothermal equivalent of carbonatite, i.e. the isotopic range of samples indicates magma-derived C as the probable origin of the CO_2 that dissolved into the fluid from which travertine precipitated.

(All measurements ± 0.1‰)

No.	Locality	$\delta^{13}C_{PDB}(CO_2)$	$\delta^{18}O_{PDB}(CO_2)$
1	Buranga	-3.78	-17.10
2	Buranga	-2.67	-16.04
3	Buranga	-2.54	-15.95
4	Buranga	-3.68	-15.21
5	Katwe	1.41	5.16
6	Katwe	2.87	7.36
7	Muhokya	0.89	-3.27
8	Lincoln carbonate	2.11	-6.55
9	GNS Marble	2.11	-6.55

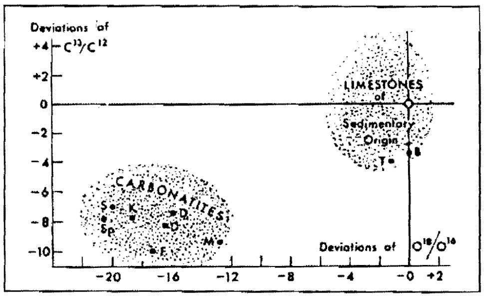

Figure 9: Buranga travertine plot in the carbonatite fields together with samples from Katwe, Mbuga crater, Fort Portal and Sukulu. Bunyrauguru and Muhokya limestone samples plot in the sedimentary field.

The points represent deviations of $^{18}O/^{16}O$ from arbitrary standard limestone (marked 0), plotted against the corresponding deviations of $^{13}C/^{12}C$, and fall into well-separated fields (shaded) for magmatic carbon and thermally derived sedimentary carbon respectively (Holmes, 1964). According to Allard et al, 1977; Allard, 1979; Rollinson, 1993, evidence for significant magmatic carbon input to a system should have a value of –4 to 8‰. Isotopic evidence favors meteoric recharge from Mt Rwenzori (Armannsson, 1994; Kato, 2000; IAEA TC-PROJECT UGA/8/003) possibly from melt water. The hot springs are nearly identical in deuterium content to the water from River Mubuku (Nyakalenjijo). This points to recharge zone around Mubuku River. Kibenge δD values (-20.2) compares reasonably with Kagoro values (-19.4) according to IAEA TC-PROJECT UGA/8/003 (2003). The springs are nearly identical in δD content and indicate no appreciable oxygen shift that is observed in some high-temperature hot-springs. According to isotope geochemistry, Kibenge and Buranga thermal waters have no detectable T contents (IAEA TC-PROJECT UGA/8/003, 2003). These springs do not prove entry of meteoric water of high T content and very short subsurface travel time since they escape isotopic detection. Possibly, the greatly dominant component of these thermal waters is concluded to be of meteoric origin (Armannsson, 1994; Kato, 2000; IAEA TC-PROJECT UGA/8/003, 2003) with an age of at least more than 54 years since isolation from direct contact with the atmosphere.

Thermal waters are on both sides of Rwenzori block and since Rwenzori is made of crystalline basement rocks (granite / granitic gneiss, schist, amphibolite gneiss). These rocks are not sufficiently permeable to form a natural hydrothermal reservoir; hence the only plausible permeable structures indicated are faults or fractures (cracks and fissures). The geothermal reservoir is most likely to be fracture controlled not porosity controlled. Most of the Rwenzori rocks are not highly porous and thus thermal water is likely to be located primarily in fractures. It is important to locate the orientation of the most important hot-water bearing fractures, to be consistent with the regional extension trend. Isotopic studies $^{87}Sr/^{86}Sr$ (IAEA TC-PROJECT UGA/8/003) point to water-rock interaction with granitic gneiss for Buranga thermal waters. Felsic type of igneous rocks (gneiss, granitic gneiss) tend to have high mean florine contents. This is also evidenced in the thermal waters of Buranga, possibly suggesting a fracture-controlled geothermal reservoir in the crystalline basement rocks.

13. Gas geochemistry

The negative very high correlation (R^2 =0.9868) of the N_2 and CO_2 sampled from thermal springs in different areas of Rwenzori, probably indicates the existence of a common geothermal reservoir from which gases originate. In general, N_2 concentrations correlated negatively with CO_2 pointing to a possible genetic relationship of Rwenzori hot springs. Buranga and Rwimi springs are characterized by relatively high CO_2 and CH_4, and negligible H_2. Such chemical characteristics imply a strong component of fluid from hot temperature reservoir (Walters et al 1992). These two springs score better than Kibenge with very little CO_2 and CH_4 Fluids with a strong meteoric signature come from the southern part (Kibenge) as evidenced by high N_2 contents. This supported by also high Mg contents. Kibenge sample has high N_2 contents consistent with higher contribution of atmospheric or air-saturated water. There is a clear trend from an air-saturated meteoric water end member (Kibenge) to CH4 rich source (13.19 vol %) at Buranga. There is a trend towards gas rich (CH_4 & CO_2) composition at Buranga, possibly attributed to proximity to geothermal reservoir. The much flushing of southern hot springs is possibly due to higher meteoric recharge to the southern thermal springs. This trend is chemically evidenced in chloride contents, discharge rates and heat flow increasing northwards. Values of $\delta^{13}C$ from Buranga and Rwimi are consistent with magmatic values (-8 to -4‰). There was no obvious correlation between CH_4 and N_2 ruling out the possibility of thermal break down of organic matter. The major difference between northern thermal springs (Buranga) and southern springs (Kibenge) is the higher surface temperature, considerable contribution of carbon-rich gases and the lower $\delta^{13}C$ of CO_2 in the former.

14. Noble gas geochemistry

Magmatic fluids are characterized by He isotopic values ranging from *1.5 to 2.8Ra*. The elevated He concentrations in the thermal waters of Mumbuga, Kagoro and Rwimi are most likely separating from a magma body at depth, perhaps as a vapor phase at high temperature and pressure. A magma chamber is the most reasonable source for the elevated He values in the Rwenzori thermal springs. All springs indicated a component of mantle-derived He with a possible crustal contamination. The constancy of ratios R/Ra for Buranga springs (*Mumbuga & Kagoro*) possibly indicates same influence of mantle helium while the reduced R/Ra value at Rwimi bubbling pool indicates reduced influence of mantle He or dilution by radiogenic He (crustal He). Different values of He reflect **different degrees of interaction** between fluids of deep and shallow origin. Buranga hot springs are more to the up-flow zone compared to Rwimi due to elevated mantle He concentrations. This is supported by less heat loss by conduction, less fluid mixing and high surface temperatures (95° near boiling water) and high discharge rates (17 l/sec).

15. Discussion

According to isotopic evidence, Buranga geothermal system has a magmatic heat source (He ratio 1.5- 2.8Ra). Since the chemistry of Rwenzori springs (Buranga, Rwimi, Kibenge, Muhokya, and Rwagimba) is highly correlated, it implies that there are genetically related and possibly influenced by partial equilibration and mixing. L. Kitagata seems to belong to another geothermal system other than the Rwenzori spring system. The high correlation of chemistry of waters sampled around Rwenzori probably indicates the existence of a common reservoir from which gases originate. The magma chamber is the most reasonable source of huge quantities of CO_2 discharged at Mulyambuzi (Fort Portal), Buranga and Rwimi. As Beall and Box (1993), noted, an increase in contents of CO_2, might be attributed to change in geothermal reservoir pressure, causing open-system flow of CO_2-rich gases into the Rwimi area, from below the geothermal reservoir.

Qualitatively high HCO_3 contents can be taken as an indication for comparatively low temperature system. Since most thermal springs (Buranga, Rwimi, Bugoye, Rwagimba, Kibuku, and Fort Portal craters) are depositing travertine, these appear to be outflows of a system possibly in the Rwenzori Mountain. This might be explained by an interaction of CO_2-rich waters with rock at shallow-peripheral levels. Such CO_2-charged waters are formed by underground absorption of vapors separated from deeper Cl water into cooler groundwater (Hedenquist, 1990; Lonker et al., 1990). Isenthalpic expansion of steam, separated from a deeper liquid phase, to close to atmospheric pressures, is accompanied by a drop in temperature to about 160°C. The temperatures of secondary HCO_3 waters formed in this way are therefore in the vicinity range of 150-160°C (Giggenbach, 1978; Cioni et al., 1984; Hedenquist, 1990). According to geothermometry, Buranga, Kibenge, Muhokya and Rwagimba fall in the range 150-160°C (Armannsson, 1994), possibly indicating that these are outflow of a huge geothermal system of Rwenzori. Considering the geographical variation of HCO_3, silica, flow rate, heat loss by conduction, surface temperature and Cl contents in Rwenzori hot springs, Buranga hot springs are nearer to the up flow zone than

Rwimi, Muhokya, Rwagimba, Nyakalenjijo and Kibenge. More work should be concentrated around Buranga hot springs focused on Rwenzori. This system is likely to be fracture controlled (*crystalline basement complex*) in a steep terrain of Rwenzori.

14. Conclusion

The high correlation of the chemistry may indicate that Rwenzori thermal springs have a single geothermal reservoir. Buranga thermal waters cluster an evidence of single source system. Evidence for recharge of meteoric waters points at Rwenzori Mountain (around River Mubuku) while a fracture controlled crystalline basement reservoir is envisaged. Buranga (Nyansimbe, Kagoro and Mumbuga) thermal prospect has impressive surface manifestations, occurring in steep mountain terrain hence could easily be mistaken for up flows of a reservoir system. The up flow system surface manifestation is still elusive. This is very common with high temperature systems in steep mountain terrain often associated with concealed outflow structures. The springs indicate a low temperature system, possibly an outflow as indicated by low SiO_2 contents and high HCO_3. The high salinity at Buranga could be explained by magmatic input not simple leaching of rocks. Contribution of magma-derived carbon to Buranga geothermal system has been indicated by δC^{13} vs δO^{18} analyses from Buranga, tufa between –2.54 to –3.78‰ and from noble gas geochemistry evidence. Surface manifestation at Rwimi (high CO_2 contents) could be explained by magmatic gas contribution in a low-pressure zone. Geochemically, there are a number of chemical trends that differentiate Lake Kitagata from the Rwenzori thermal springs. Rwenzori thermal springs are as a result of different degrees of mixing and partial equilibration of the same thermal waters.

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