Geothermal potential in Eastern D.R. Congo

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Abstract

Thermal water samples were collected in North and South Kivu provinces of D.R. Congo, along the western branch of the East African Rift System (EARS). Surface temperatures range from 30ºC to 100ºC and the springs are neutral to alkaline. Chemical analysis of all samples show strikingly high bicarbonate content relative to the common major anions in hot springs, i.e., chloride and sulphate. Due the unusually high CO_2 content in high temperature volcanic gases of the nearby Nyiragongo volcano, and due to the huge amount of dissolved magmatic CO_2 in Lake Kivu, it is suggested that the high bicarbonate content in the springs stems from a constant supply of magmatic carbon dioxide to the geothermal system.
Na-K geothermometers suggest underground temperature of 163 to 177 ºC for Mayi-ya-Moto site in North Kivu, which is promising for geothermal development. The entire eastern DRC along the western branch of EARS has geothermal potential and can therefore offer environmentally friendly alternative sources of electricity and heating. Detailed surface exploration is recommended.

Introduction

The Democratic Republic of Congo is known to be endowed with natural resources, especially minerals, fresh water and timber. As far as power generation is concerned, the potentialities for hydroelectricity are high. The current installed capacity at Inga dam on Congo River is 1740 MW, though only 10% of the country population benefit from it. There are plans for expanding Inga hydro plant to its full potential; if this is implemented the country will undoubtedly become the first electric power exporter in Africa. However, due to the country's large size, it is not evident that remote areas like the Kivu provinces will soon benefit from the main hydroelectric power which is generated from Inga power plant, two thousand kilometers away in the west. The government is therefore planning to develop local power sources for the countryside including eastern Congo, where most towns and all villages do not have power, but the focus is always exclusively on hydroelectric potential.

The entire eastern border of D.R Congo stretches along the western branch of the East African Rift System (EARS); neighboring from North to South respectively Uganda, Rwanda, Burundi and Tanzania (Fig.1). In the eastern branch of EARS, especially in Kenya and Ethiopia, geothermal power has already been developed. Closer to Congo in the western branch of EARS, Uganda is in an advanced stage of geothermal power generation.
It is therefore not surprising that there are several hot springs in eastern Congo too. Their study might lead to finding alternatives power sources and therefore give the government an opportunity to select the best available energy resources around, considering not only the cost but also other advantages, including the long term environmental benefits.
The present paper aims to present a preliminary inventory of hot springs in the provinces of North and South Kivu with emphasis on geothermal potential, from the geochemical point of view.

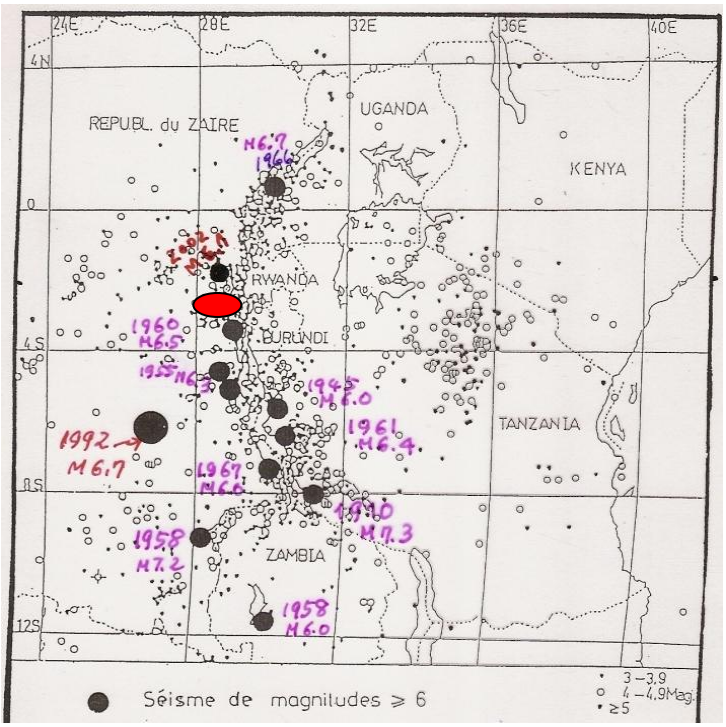
Samples and locations.

The western branch of the EARS spreads on more than 1500 km from the North to the South. On the geophysical point of view, it consists of 3 seismic active zones: (1) the Ruwenzori region from Lake Albert (sometimes also called Lake Mobutu) to Lake Edward (also called Lake Idi Amin); (2) the Kivu lake basin and (3) the Tanganyika region from the south of the Lake Kivu to Lake Tanganyika. Fig.1 shows the entire eastern border of Congo with the epicentres of the recent earthquakes of magnitude higher than 6. The most recent earthquake occurred in Bukavu area and western Rwanda on 3rd February 2008, destroying several buildings and houses.
Besides seismicity, eastern Congo, especially the Virunga area north of Lake Kivu, is famous for active volcanism. There are several dormant volcanoes and two active volcanoes, the Nyamulagira and Nyiragongo whose last eruption in 2002 swallowed up 13% of Goma town (and 80% of its economical activities) with a thick basaltic lava flow. Following that eruption, the Goma Volcanological Observatory was established with the main aim of close monitoring of the two active volcanoes and the seismicity of the western branch of EARS. Mount Nyirangongo in particular has a permanent lava lake in its crater. The Lake Kivu itself, at the shore of which are the town of Goma in Congo and Gisenyi in Rwanda, has got large amounts of dissolved carbon dioxide and methane gases (Tietze et al, 1980).

Sites for water samples collection are listed in Table 1, some with precise geographical positions. There are 6 sites in South Kivu province and 11 sites in North Kivu. The numbers in bold in Table 1 are the same as on Fig. 3, which shows the locations of some of the sites on the map. Fig. 2 shows particularly the sites in the vicinity of Lake Kivu, i.e. parts of the districts of Masisi, Rutshuru and Kabare, as well as the active volcanoes (Nyiragongo and Nyamulagira), the rift limits and the regional faults.
Sites 10 and 11 on Fig 3, respectively *Mbau* and *Kikingi*, have just been identified but there are yet to be sampled.

Sampling and analysis

The dates of sampling respective to the sites are given in Table 2. In most cases the pH and temperature were measured in situ.
Chemical analysis for the first sample in Table 2 (Mayi ya Moto) was done at Kusatsu-Shirane Volcanological Observatory in Japan. Analyses for samples 2 to 15 and for all complete analyses for samples between 19 and 27 were carried out at Universities of Naples and Florence in Italy. Samples 16, 17 and 18 were analysed at Goma Volcanological Observatory (OVG) where facilities for geochemical measurements are limited to the determination of fluoride, nitrate, sulphate and chloride anions only, using a DR 2500 spectrophotometer.
As for the remaining samples, (No 20, 24, 28, 29 and 30, only in situ temperature measurement was done.



Bukavu felt earthquake on February 3, 2008

Fig. 1: The eastern border of D.R. Congo: the western branch of EARS. The most recently recorded seisms of magnitude >6 are also indicated, with the year of occurrence.

Table 1: Sample site information

No	Site name	District	Province	Type	Longitude	Latitude	Altitude
1	Uvira	Uvira	South Kivu	HS	29.07.72E	03.24.33S	855
2	Nyangezi	Walungu	"	HS			
3	Mahyuza	Kabare	"	HS	28.50.45E	02.14.62S	1582
4	Kankule	Kabare	"	HS	28.50.12E	02.14.94S	1595
5	Maziba	Kabare	"	HS			
12	Muganzo	Kabare	"	HS			
6	Mayi ya Moto	Rutshuru	North Kivu	HS			
7	Kambo/Kasindi	Beni	"	HS	29.40.17E	00.03.77N	1014
8	Masambo	Beni	"	HS	29.41.75E	00.10.85N	1006
9	Mutsora	Beni	"	HS	29.44.49E	00.18.35N	1094
13	Tingi/Sake	Masisi	"	HS			
14	Tingi/Sake	Masisi	"	CS			
15	Kisuma	Masisi	"	HS			
16	Kisuma spring	Masisi	"	CS			
17	Kalieri /Katale	Rutshuru	"	CS			
18	Nyabugezi	Rutshuru	"	CS			
19	Bukomo	Masisi	"	CS			

HS: hot spring; CS: cold water spring. Latitude and longitude are given in degrees, minutes and seconds.
Numbers in bold are the same as on Fig. 2

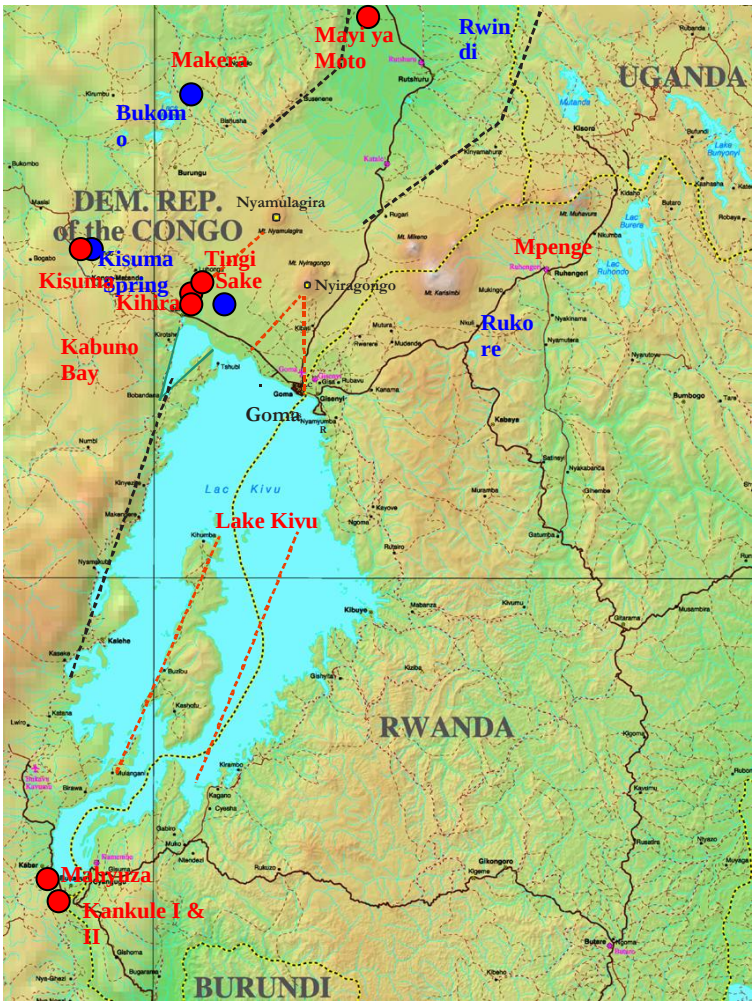


Fig.2: Some water sampling sites

Thermal water

Cold water

Legend

Rift limits

Main regional faults

Kabuno Bay

Active volcanic centres

Results and discussion

Analytical results are given in Table 2. It appears that hydrogeno-carbonate content is much higher than the content of the other major anions commonly occurring in hot springs, i.e., chloride and sulphate. This applies to all samples, i.e., to both hot and cold springs and it is confirmed by a quick comparison with data of Ugandan hot springs (Bazaale-Dolo, 1971). The anion ratio Cl/HCO_3 calculated from Table 2 is 0.007 to 0.3 whereas the ratio for Ugandan hot springs is 0.2 to 3.5 for most samples.

High temperature volcanic gases are known to contain over 60 mol % of water vapour followed by variable amount of SO_2 and CO_2 (Matsuo, 1961; Gerlach, 1983). Usually SO_2 comes second after water. Mount Nyiragongo however, is an exception to that trend. Gases collected from its lava lake show nearly 50 mol % of carbon dioxide which is sometimes more abundant than water. In addition, Lake Kivu, with a volume of 580 km^3, contains large amounts of dissolved gases: (1) carbon dioxide estimated at 300 x 10^9 m^3 and (2) methane estimated at 63 x 10^9 m^3 (Tietze et al., 1980). The dissolved CO_2 is believed to be constantly supplied by volcanic emanations at the bottom of the lake, whereas methane was formed by bacteria from abiogenetic carbon dioxide and hydrogen. (Deuser et al., 1973; Degens and Kulbicki, 1973; Schoell et al., 1988).

In view of the above, it is suggested that the relative high bicarbonate content of hot springs in the western branch of EARS in eastern Congo is due mainly to the constant supply of magmatic carbon dioxide to the geothermal system.

Geothermometry

The data of cation content given in Table 2 can be used to make a preliminary estimation of underground temperatures for the respective geothermal areas. As geoindicators involving Ca may not be suitable for our carbonate-rich springs, and due to lack of silica data, only Na-K (Truesdell, 1975; Fournier, 1979 and Giggenbach 1988) is applied. Calculations for K-Mg temperatures (Giggenbach, 1988) were also done but the values are unrealistically so low (between 0 and 30ºC) that there are not presented.

The results of the geothermometer calculation are presented in Table 3. Data for cold springs are not used so they are not part of Table 3. In total there are seven investigated geothermal areas including three sites in North Kivu and four sites in South Kivu. The temperatures are designated T_{NaK}^{a}, T_{NaK}^{b} and T_{NaK}^{c} following the use of the formula Na-K formulas respectively by Giggenbach (1988), Fournier (1979) and Truesdell (1975)

In North Kivu, *Mayi ya Moto* has T_{NaK}^{a} of 163 to 177 ºC whereas T_{NaK}^{b} and T_{NaK}^{c} are 90 to 128ºC which is almost the temperature range for the surface temperature of 94.5 to 100ºC. T_{NaK}^{b} and T_{NaK}^{c} are therefore not applicable to this site.
Tingi/Sake presents rather consistent data for T_{NaK}^{a} , T_{NaK}^{b} and T_{NaK}^{c}., between 255 et 290ºC. However, due to low surface temperatures (>75ºC), accurate equilibrium underground temperature can not be obtained from cation data. Other geothermometry methods should be used such as isotope and gas geothermometry.

For *Kisuma/Masisi*, there is a wide discrepancy in the calculated temperatures. It is therefore too early to make a reasonable suggestion before other geothemometry methods can also be applied.

In South Kivu sites all the three T_{NaK}^{b} , T_{NaK}^{b} and T_{NaK}^{c} give reasonably consistent data as follows:
Muganzo: 339 – 364ºC
Kankule: 337 – 369ºC
Mahyuza: 345 – 374ºC
Maziba: 275 – 294ºC
Again other geothermometry methods should be used here because of low surface temperature.

Conclusion

The present study gives preliminary results showing that geothermal potential do exist in Eastern D. R. Congo. Based of cation geothermometry, the most promising site is the Mayi-ya-moto in North Kivu, with equilibrium temperature estimated at 163 to 177ºC. As for the other sites, other methods such as isotope and gas geothermometers would be more applicable. It is therefore recommended that in-situ measurements of CO_2 and H_2S gas be carried out in future. In addition, further investigations are required for a comprehensive surface exploration; including

- in-situ measurement of Rn, discharge rates, and heat flow
- Geological and geophysical surveys
- Isotope Hydrology

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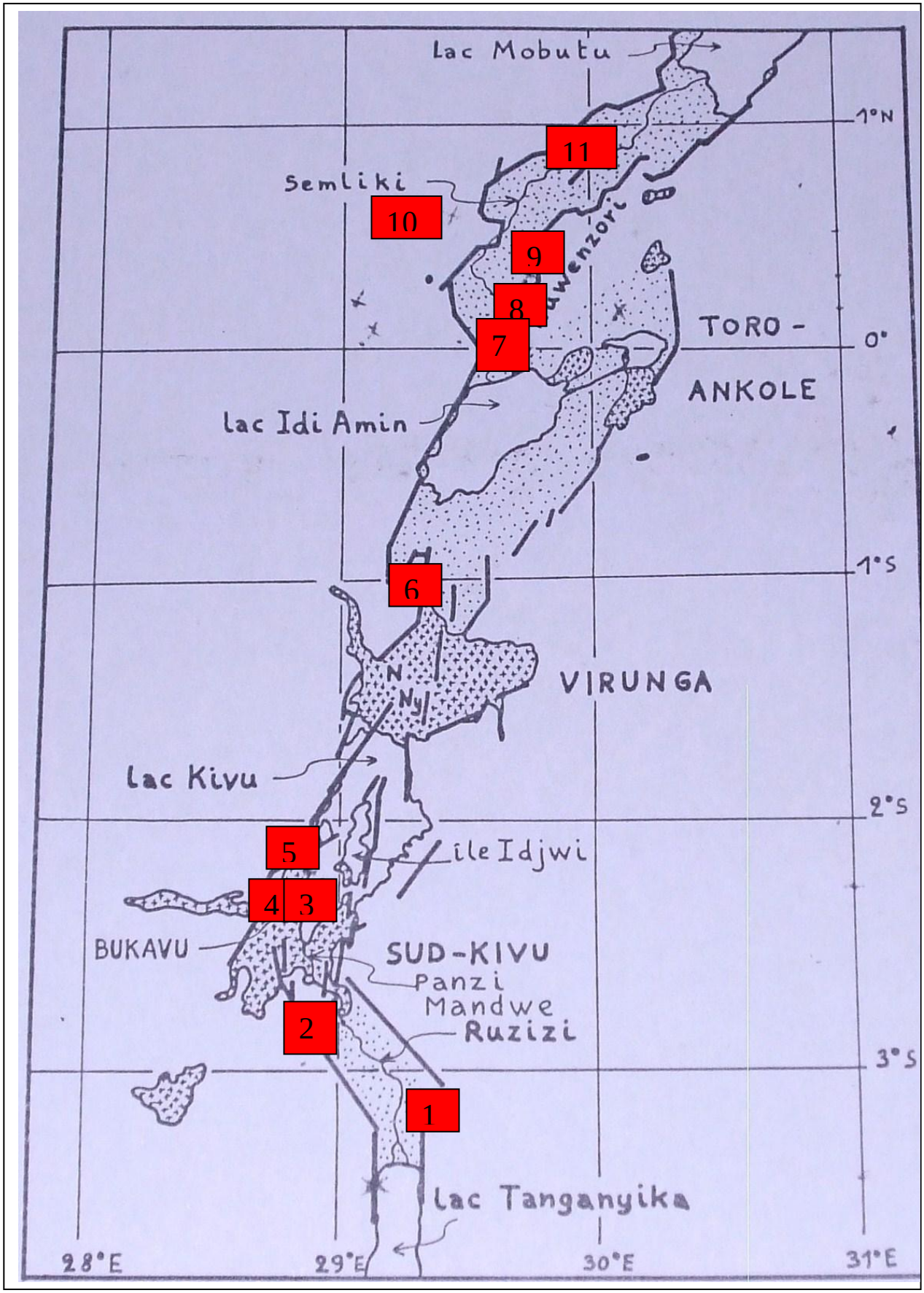

Fig. 3: Water sampling sites: the numbers are the same as the bold numbers of Table 1.
1. Uvira 2. Nyangezi 3. Mahyuza 4. Kankule 5. Maziba 6. Mayi ya Moto
7. Kambo (Kasindi) 8. Masambo 9.Mutsora 10. Mbau 11. Kikingi

Table 2: Chemical Composition of thermal springs in North and South Kivu, D.R. Congo *(in mg/l)*

	A. North Kivu															
N	**Samples**	**Date**	**pH**	**T °C**	**F**	**Br**	**NO_3**	**NH_4**	**Li**	**HCO_3**	**Cl**	**SO_4**	**Na**	**K**	**Ca**	**Mg**
1	**Mayi ya Moto 1**	**27/03/1994**	8,94	94.7						4540	1120	478	2730	126	1	0,9
2	**Mayi ya Moto 2**	**20/02/2003**	8,1	100	21	2,1	<	5,9	2,6	3400	1035	400	2170	117	9,6	1,2
3	**Mayi ya Moto 3**	**30/08/2003**	8,2	96,4	25,5	2,5	0,08	4,5	3	5069	1140	480	2745	100	1,1	2
4	**Mayi ya Moto 4**	**17/02/2004**	7,99	94,5	25	2,4	<	6,2	2,6	4927	1070	590	2660	97	2,4	1,2
5	**Tingi/Sake 1**	**01/03/2003**	8,42	20	2	0,75	4,50	0,77	2,8	2990	275	80	830	165	70	120
6	**Tingi/Sake 2**	**08/08/2003**	6,9	30	1,7	10	3,50	5,96	3,1	2800	276	78	785	149	37	134
7	**Tingi/Sake 3**	**28/08/2003**	6,86	29,2	1,9	0,63	<	2,1	3,3	2795	284	90	787	141	48	137
8	**Tingi/Sake 4**	**04/11/2003**	6,97	30	1,65	0,85	0,35	1,33	3,1	3080	305	90	770	142	170	124
9	**Tingi/Sake 5**	**18/02/2004**	6,68	30,0	1,25	0,87	0,50	1,00	3,03	2654	311	95	812	142	157	126
10	**Kisuma/Masisi 1**	**08/08/2003**	6,2	38,5	1,1	0,02	0,35	0,19	0,1	423	9	24	33	29	57	32
11	**Kisuma/Masisi 2**	**08/08/2003**	6,5	39	0,5	0,05	0,06	0,7	0,11	454	11	29	34	26	59	37
12	**Kisuma spring**	**08/08/2003**	6,8	19,5	1,8	<	0,25	0,22	0,02	259	6	12	18	23	48	15
13	**Kalieri/Katale**	**13/03/2003**	7,63	-	1,5	0,05	0,65	0,04	<0.01	401	35	4	52	61	45	17
14	**Nyabugezi**	**13/03/2003**	6,95	-	1,2	<0.05	0,09	0,77	<0.01	431	3	5	52	72	50	15
15	**Bukomo**	**16/06/2003**	6,85	18,0	2,00	0,01	8,50	0,04	<0.01	203	4	10	14,75	19	35	14
16	**Kambo/Kasindi**	**19/07/2008**	6,97	40,0	3,50		3,10				118	700				
17	**Masambo**	**20/07/2008**	7,63	43,0	6,65		0,44				100	615				
18	**Mutsora**	**20/07/2008**	7,80	57,0	6,65		0,44				132	655				
	B. South Kivu															
N	**Samples**	**Date**	**pH**	**T °C**	**F**	**Br**	**NO_3**	**NH_4**	**Li**	**HCO_3**	**Cl**	**SO_4**	**Na**	**K**	**Ca**	**Mg**
19	**Muganzo**	**05/08/2002**	-	-	1,3	0,12	0,35	nd	0,30	915	49	24	211	63	41	55
20	**Kankule 1**	**20/03/1998**		72												
21	**Kankule 2**	**05/08/2002**	-	-	1,3	0,15	0,14	nd	0,35	1098	54	21	224	62	67	58
22	**Kankule 3**	**05/11/2002**	7,33	70	1,88	0,12	0,65	nd	0,32	976	60	23	222	65	40	60
23	**Kankule 4**	**05/11/2002**	6,77	67	1,82	0,1	0,15	nd	0,35	1098	53	23	231	71	46	62
24	**Kankule 5**	**26/08/2008**		68,4												
25	**Mahyuza 1**	**05/11/2002**	7,24	47	1,55	0,05	0,05	nd	0,27	880	46	16	172	55	86	49
26	**Mahyuza 2**	**27/08/2008**		65,5												
27	**Maziba 1**	**05/11/2002**	6,47	40	0,33	0,05	0,05	nd	0,24	1010	40	17	120	24	117	65
28	**Maziba 2**	**26/08/2008**		40												
29	**Nyangezi**	**08/02/2004**		40												
30	**Uvira**	**08/02/2004**		44												

Table 3: Chemical geothermometer temperatures °C

Province	Site	Date	$T_{NaK}{}^{a}$	$T_{NaK}{}^{b}$	$T_{NaK}{}^{c}$
North Kivu	Mayi ya Moto	27/03/94	177	108	115
		20/02/03	187	121	128,0
		30/08/03	163	90	99,0
		17/02/04	163	90	99
	Tingi/Sake	08/08/03	290	274	268
		28/08/03	283	263	258
		04/11/03	287	270	265
		18/02/04	281	259	255
	Kisuma/Masisi	08/08/03	494	749	658
		08/08/03	470	674	600
South Kivu	Muganzo	05/08/02	339	364	347
	Kankule	05/08/02	329	344	330
		05/11/02	337	359	343
		05/11/02	342	369	352
	Mahyuza	05/11/02	345	374	356
	Maziba	05/11/02	294	281	275

[a]Giggenbach (1988)

[b]Fournier (1979)

[c]Truesdell (1975)

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