ISOTOPIC DETERMINATIONS OF BURANGA AND KATWE TRAVERTINE DEPOSITS, UGANDA

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INTRODUCTION.

The report is a result of preliminary interpretation made on isotopic data as part of the GEOTHERM programme between BGR and DGSM. Isotopic determination was carried out on travertine samples from Buranga and Katwe to determine the likely source of heat being mined by Buranga and Katwe geothermal systems. The exercise was to determine whether there is any magmatic carbon input in the fluids or it was lacustrine carbonates / organic sedimentary rocks. Limestone (lacustrine origin) from Muhokya was also sampled for comparison purposes. Trace element analysis was also carried out on these samples to supplement the isotopic determination. Isotopic determination of $\delta^{18}O$ and $\delta^{13}C$ was carried out at the Institute of Geological and Nuclear Sciences Limited in New Zealand (Stable Isotope Laboratory) while trace analysis was carried out at Act lab Ultrace in Canada.

CARBONATITE AROUND BURANGA.

Since there is volcanic activity within the area (Fort Portal and Rusekere Volcanic fields, a magma body inferred north of the hot spring), the heat source might be a buried hot magma body related to young igneous rocks in the area. Toro-Ankole explosive eruptions began in Upper Pleistocene and stopped about 4,000 years ago. The volcanic field is small covering about 50 square miles and contains 49 undoubted volcanoes which are, however, much smaller than those of other fields (Nixon, 1969). The diameter of the crater rims is usually between 45m and 183m. The volcanoes lie along linear N.W. trending zones with steeper inner slope (mean angle of 33°) than the outer slope (Nixon, 1969). The tuffs are very recent and notably at Kalyango crater near Nyakasura, there are lavas with a high carbonate content with very little SiO_2 and alkalis.

Nixon describes volcanics at Fort Portal as highly carbonate rich ultra basic lavas formed by reactions of sialic rocks with carbonate magma. A magma chamber is the most reasonable source for large quantities of CO_2 observed at Buranga. Reaction between carbonatite magma and crustal rocks not only liberate vast quantities of carbon dioxide but would also produce highly basic and ultrabasic rocks like pyroxenites and peridotites as well as the alkaline rocks. Some of the later would become molten and being highly charged with gases would be readily erupted as a spray of lapili or vesicular lavas. The lavas in Fort Portal and Rusekere are carbonitic (Holmes, 1964, Dixon and Morton, 1967). Reaction between carbonatite magma and crustal rocks would only liberate vast quantities of CO_2 but would also produce highly basic and ultra basic rocks as well as alkaline rocks observed around Fort Portal and Rusekere volcanic fields.

PREVIOUS STUDIES

According to Holmes (1964) Lava flows are rare except from the isolated volcano of Katunga in the south and from the clustered volcanoes of Fort Portal in the north.

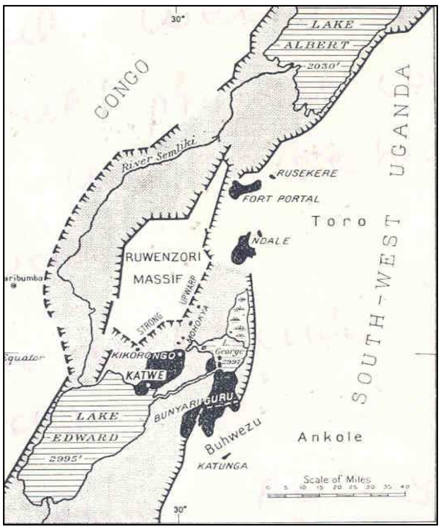

Figure 1: Map of part of the western Rift valley, showing the massif of Rwenzori and adjoining volcanic areas (black) after Holmes (1964).

Isotopic determinations made for Holmes by P. Baertschi show that travertine recently deposited from Hot springs around Lake Katwe is a hydrothermal equivalent of carbonatite magma. As shown by the data in figure below, ordinary limestone contain appreciably higher proportions of the isotopes ^{18}O and ^{13}C than carbonatites. Doubtful cases, such as Katwe Travertine (derived from Carbonatite) and some of the ejected blocks from craters in the Bunyaruguru field (sedimentary origin) were settled by isotopic analysis (Holmes, 1964).

Figure 2: Katwe travertine in background

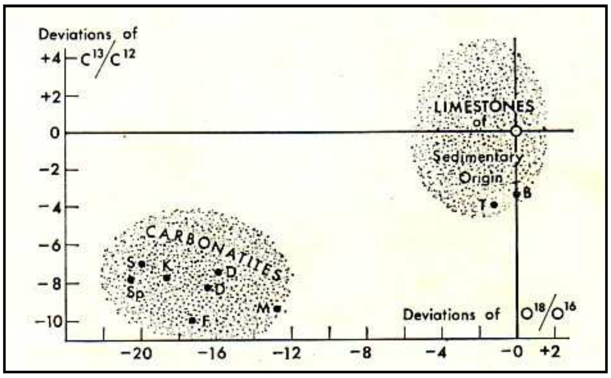

Figure 3: Isotopic determinations by P. Baertschi, abstracted from (Holmes, 1964)

The points representing deviations of $^{18}O/^{16}O$ from arbitrary standard limestone (marked 0), plotted against the corresponding deviations of $^{13}C/^{12}C$, fall into well-separated fields (shaded) for carbonatites and sedimentary carbonate rocks respectively (Holmes, 1964).

The travertine K from Lake Katwe falls within the carbonatite field, while an ejected block, B, from one of the Bunyaruguru craters falls within the sedimentary field. Similarly, Sp from the Spitzkop alkaline complex in the Bushveld South Africa can clearly be distinguished as a carbonatite from the sedimentary limestone, T, from the Transvaal System, with which it was formerly identified. The other carbonatites are D, dykes from the Pretoria Diamond Mine, South Africa, F, lava from the Fort Portal volcanic area, M, carbonatite lava from Mbuga crater, Katwe-Kikorongo volcanic area and S, carbonatite core from Sukulu volcano, eastern Uganda (Homes, 1964).

It is reported that hot waters from Buranga have trace values of tritium (IAEA TC-PROJECT UGA/8/003), which escape isotopic detection. This may indicate that the waters are older than 60 years (prebomb tritium values) or there was mixing of meteoric waters with higher tritium values and old connate waters with low tritium values to produce a hybrid, which could reasonably escape isotopic detection (diluted beyond isotopic recognition).

Isotopic evidence favors recharge of meteoric waters. The hot spring waters have different deuterium content from the spring waters in the area which might indicate the cold spring waters are not the source of recharge, but isotopically lighter meteoric waters possibly from the towering Rwenzori mountains (Kato, 2000). However, they plot on meteoric line with hardly any major oxygen shift commonly observed in high temperature hot spring systems. This might imply there was no exchange of oxygen between circulating meteoric cold waters and silicate minerals that are being hydrothermally altered or possibly it might be related to high meteoric water flow and good permeable structures. Another possible explanation might be direct near surface dilution of the deep thermal chloride water by huge quantities of surface meteoric waters.

RECENT STUDY

The results in table 1 were analysed at the Institute of Geological and Nuclear Sciences, in New Zealand under the **GEOTHERM** programme. According to figure 3, Buranga travertine deposits plot in a zone of carbonatite magma, hence are a hydrothermal equivalent of carbonatite, i.e. the isotopic range of samples indicates a magmatic origin of the carbon dioxide that dissolved into the fluid from which travertine precipitated.

Table 1: Stable isotope results

(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

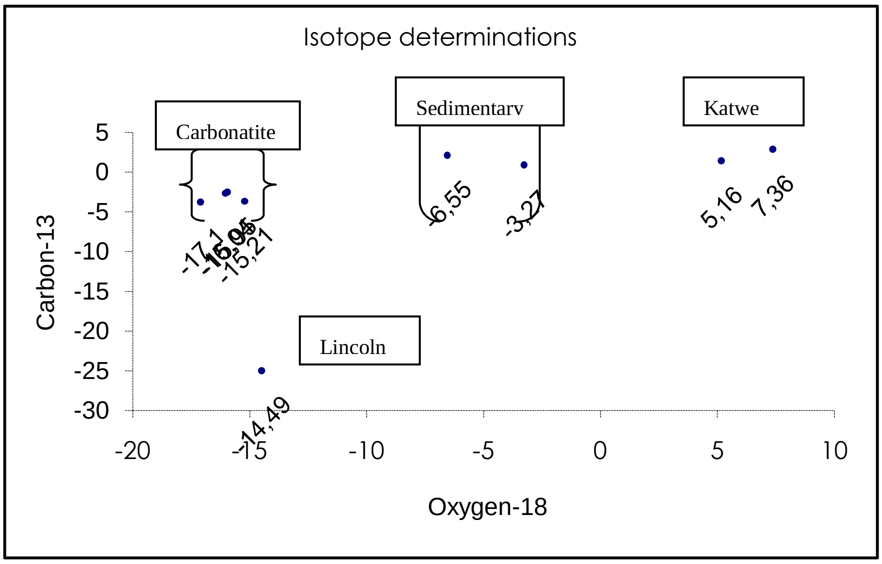

Figure 4: Samples from Buranga plot in the carbonatite field, while those from Muhokya plot in a sedimentary field. Samples from Katwe exhibit appreciably higher proportions of the isotopes oxygen-18 and carbon-13.

Muhokya limestone, a known fresh water lacustrine limestone deposits (figure 5) plots in a sedimentary limestone deposit (figure 4).

Figure 5: Muhokya fresh water lacustrine limestone deposit

Previous studies by Holmes (1964) indicated that travertine deposit from Lake Katwe falls within the carbonatite field. However, the recent analysis showed that Lake Katwe travertine was highly enriched in $\delta^{18}O$ and $\delta^{13}C$. It is ordinary limestone that contains appreciably higher proportions of the isotopes ^{18}O and ^{13}C than those derived from carbonatite (Holmes, 1964). This becomes an anomalous case, which needs further detailed study.

This study also reveals a marked difference between isotopic constitution of the Sr in Buranga travertine and that in limestone of sedimentary origin (Muhokya limestone). Once again Katwe sample had appreciably higher proportions of Sr, possibly being a reworked sample, which was found in cross-bedded tuffs of Katwe crater. Baertschi's results (1964) confirmed the marked difference between the isotopic constitution of the Sr in carbonatites and that in limestone of sedimentary origin.

CONCLUSION

Buranga travertine is derived from carbonatite according to isotopic range of samples. This points to a magmatic carbon dioxide (CO_2) input and infers a more recent intrusion as a likely source of heat that is being mined by Buranga geothermal field. This can be confirmed or disapproved by examining $^3He/^4He$ ratios in the Buranga geothermal fluids. Also $\delta^{34}S$ in H_2S can be applied to prove an igneous source of sulphur in Buranga geothermal field.

Muhokya limestone turned out, as expected, to be of sedimentary origin. Lake Katwe samples contained appreciably higher proportions of the isotopes ^{18}O and ^{13}O higher than the carbonatite varieties. This is contrary to what Holmes (1964) had found out. Isotopic determination made for Holmes by P. Baertsch showed that Lake Katwe travertine is a hydrothermal equivalent of a carbonatite magma falling within the carbonatite field (Holmes, 1964, pp1072). This needs further investigations. It is also likely that Holmes (1964) sampled moulds and pinnacles of travertine recently deposited from hot springs around Lake Katwe. The sample collected during GEOTHERM programme was probably from reworked seams of tufa interbedded with *cross-bedded* volcanic tuffs.

Isotopic evidence favors recharge of meteoric waters to Buranga geothermal system instead of connate or metamorphic waters. It is reported that hot waters from Buranga have trace values of tritium, which escape isotopic detection. This may indicate that the waters are older than 60 years (prebomb tritium values) or there was mixing of meteoric waters with higher tritium values and old waters with low tritium values to produce a hybrid, which could reasonably escape isotopic detection (diluted beyond isotopic recognition).

REFERENCES CITED.

Baertschi, P., 1964. Isotopic determinations of limestone.

Holmes, A., 1964. Principals of physical geology, University of Edinburgh, pp1069-1074, T. Nelson and Sons, London.

IAEA TC-PROJECT UGA/8/003, 2003. Terminal Report "Isotope hydrology for exploring geothermal resources", UGA/8/003.

Logatchev et al. 1972. East African Rift development, Tectonophysics, Elsevier Publishing Company, Amsterdam, The Netherlands.

Nixon, P. H., 1968. Notes on volcanicity in the western rift in Uganda, unpublished report, Geological Survey and Mines Department, Entebbe, Uganda.

Nixon, P. H., 1969. The carbonatites lavas and tuffs near Fort Portal, western Uganda, unpublished report, Geological Survey and Mines Department, Entebbe, Uganda.

Nixon, P. H., 1967. The geology of the Fort Portal and Kasekere volcanic fields, unpublished report, Geological Survey and Mines Department, Entebbe, Uganda.

Von Knorring, O., and DU Bois, C. G. B., 1961.Carbonatite lava from Fort Portal area in Western Uganda, Nature, vol. 192, pp1064-5.