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CARBON DIOXIDE-BEARING ALKALINE HYDROTHERMS AND STRONTIUM-BEARING TRAVERTINES IN THE SONGWE RIVER VALLEY (*Tanzania*)

B. I. Pisarskii, A. A. Konev, K. G. Levi, and D. Delvaux*

Institute of the Earth's Crust, Siberian Branch of the RAS, ul. Lermontova, 128, Irkutsk, 664033, Russia
**Royal Museum for Central Africa, PB 3080, Tervuren, Belgium*

The paper presents an original description of thermal waters of a group of hot springs in the valley of the Songwe River (7–10 km downstream from the Panda Hill carbonatite massif) and the derived calcareous tuffs. It is suggested that Th hydrotherms are related to the latest, Quaternary, alkaline magmatism that acted throughout the East-African rift system, including the Rukwa graben, along which the Songwe River flows. The thermal waters contain carbon dioxide, alkalis, silicon, carbonates, and hydrocarbonates, mineralization being 3.3–3.4 g/l. They differ from thermal waters of other continental rift systems, in particular from those of the Baikal Rift, in some chemical ratios (Li/Rb, Sr/Li, Sr/Rb, *r*Na/*r*Cl). Major (calcite and aragonite) and secondary (dolomite and strontianite) carbonate minerals of the tuffs were taken through microprobe analysis. The calcites show extremely high contents of Sr (up to 5.6 wt.% SrO) and Mg (up to 5 wt.% MgO). The aragonites are likewise high in Sr (11.5–36.8 wt.% SrO) but low in Mg (0.05–0.17 wt.% MgO) and form a complete isomorphic series with Ca-strontianite (46.8–54.2 wt.% SrO). The tuffs occasionally contain grains of terrigenous quartz and feldspar and admixtures of trona, halite, and hydromicaceous minerals.

Hydrotherms, alkaline magmatism, travertines, Tanzania

In the course of the 1993 field trip to the valley of the Songwe River (Rukwa graben) we studied a voluminous hydrothermal vent, which occurs in a vast travertine field extending for 7 km along the left riverside (Fig. 1). Three water samples and sixteen samples of travertines were taken, which were analyzed in detail in laboratories of the Institute of the Earth's Crust (Irkutsk).

HYDROTHERMS IN THE SONGWE RIVER VALLEY

Hot springs in the travertine fields in the Songwe River basin were described by James in 1959 [1] as "the Rambo group" (Figs. 1 and 2). In the course of our research the Songwe group was revealed to be approximately 7–8 km upstream from the Rambo one. It involves hydrotherms discharging from 1.5–3.0 m wide cone-shaped pits in travertines over an area of 7.0 km^2 and is associated with a northwesterly striking fault hidden by travertine fields. The downflowing thermal waters merge into larger brooks with a total discharge over 500 l/s, which then flow into the Songwe River. One major hydrotherm with a temperature of 65 °C (Fig. 1, vent 1) discharges from a conic bulge with a cone-shaped fractured pit located on the bench of a travertine ridge along the left bank of the Songwe River. The riverbed is incised into the travertines to a depth of 30 m. The discharge of hot water is about 20 l/s. Gas is intensely released as small bubbles for 5 to 50 s at intervals of 60–70 s, creating an impression of boiling water. The vent is surrounded by a number of small low-discharge colder springs. Travertine precipitates from the water immediately within the pit.

Another site of hydrotherms (Fig. 1, vent 2) found upstream at some distance from the former one is attributed to a flat round travertine body 15–20 m in diameter and 1.5–2 m in height. Thermal waters there form underground flows although water purling is heard at the surface. The flows spring out in shallow pits from which ascending streams flow out and down in several hot brooks with a total discharge of about 25 l/s.

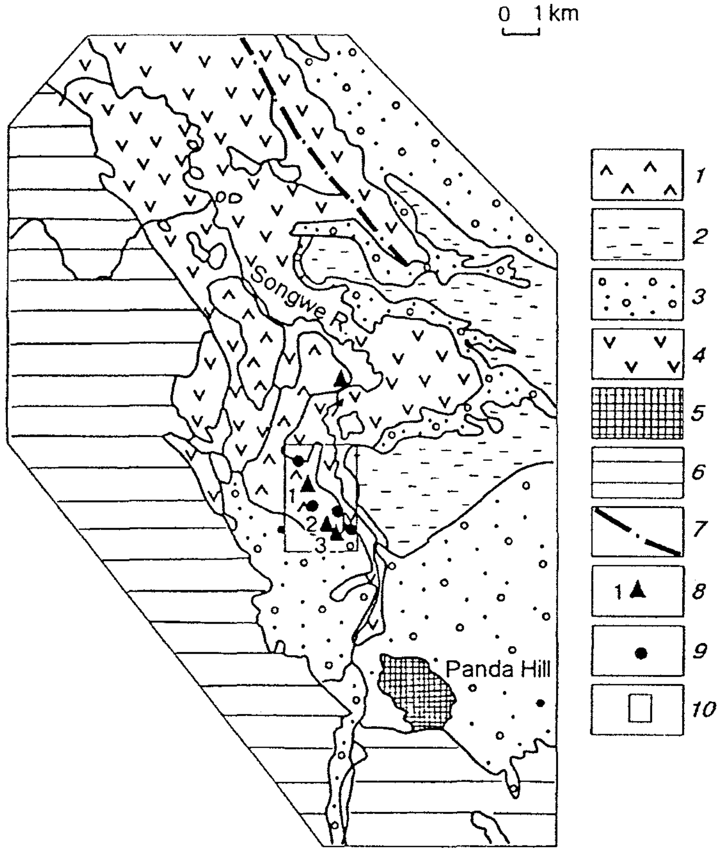

Fig. 1. Geologic setting, hot springs, and travertines in the region of the Panda Hill carbonatite massif (Tanzania), modified from [9]. Deposits (*1–6*): *1* — travertines (calcareous tuffs); *2* — volcanics; *3* — alluvial deposits; *4* — sandstones (white and red), clays, and ashes; *5* — carbonatites; *6* — garnet-bearing gneisses; *7* — faults; *8* — hot springs (digits stand for vent numbers in Table 1); *9* — travertine sampling localities; *10* — area of study.

The highest temperature of the largest vent is 75 °C. At the base of the travertine body, cold waters (T = 18 °C) ooze weakly out of fractures 3–5 m above the Songwe bench (Fig. 1, vent 3). These are low-discharge waters which, flowing down, accumulate in a shallow ditch.

A similar weak flow is observed downstream at the foot of the travertine bench. The waters there damp only the grass-covered topsoil and the grass is coated with a snow-white loose trona crust.

The composition of the studied thermal waters in the Songwe valley is given in Table 1. The average composition may be expressed as follows:

$$\mathrm{M}\,3.38 - 3.41\frac{(\mathrm{HCO_3} + \mathrm{CO_3})75 - 77\,\mathrm{Cl}\,14 - 15\,\mathrm{SO_4}\,8}{\mathrm{Na}\,87 - 88\,\mathrm{K}\,6 - 7}\,\mathrm{pH}\,7.8 - 8.25 \cdot \mathrm{H_2SiO_4}\,76 - 100\ \mathrm{mg/l}.$$

For comparison, the composition of the Rambo spring water is [1]:

$$\mathrm{M}\,3.3\frac{(\mathrm{HCO_3} + \mathrm{CO_3})\,76\,\mathrm{Cl}\,16}{(\mathrm{Na} + \mathrm{K})\,96}\,\mathrm{pH}\,8.4\,\mathrm{H_4SiO_4}\,143\ \mathrm{mg/l}.$$

Carbon dioxide is a predominant gas in the hydrotherms (97.2 vol.%). The other gases are N_2 (2.6 vol.%) and He (0.1 vol.%).

Thus, we have revealed a series of high-discharge carbon dioxide- and silicon-bearing sodium carbonate-hydrocarbonate vents in the Songwe travertine field. The water's mineralization is 3.3–3.4 g/l (Table 1), which suggests their low salinity. They have extremely low concentrations of calcium and magnesium

Table 1

Chemical Composition of Carbon Dioxide-Bearing Thermal Waters in the Songwe River Valley

Component	Vent 1		Vent 2		Vent 3	
	mg/l	% equiv.	mg/l	% equiv.	mg/l	% equiv.
Ca^{2+}	20.04	2.32	24.05	2.86	20.04	2.34
Mg^{2+}	14.55	2.80	14.59	2.86	19.46	3.76
Na^{+}	870.4	88.3	842.6	87.3	851.9	87.0
K^{+}	108.8	6.48	108.8	6.62	112.8	6.77
NH_4^{+}	0.70	0.09	3.00	0.40	0.70	0.09
HCO_3^{2}	1916	75.3	1885.5	71.86	1953	77.28
CO_3^{2-}	N.f.		6.0	0.48	N.f.	
SO_4^{2-}	165.4	8.24	163.8	8.26	162.9	8.19
Cl^{-}	226.9	15.3	223.4	15.26	198.6	13.52
F^{-}	8.80	1.10	8.80	1.12	8.00	1.01
Br^{-}	0.40	0.02	0.40	0.02	0.27	0.01
H_4SiO_4	76.0		100.0		80.0	
H_3BO_3	0.65		0.65		0.70	
Li	0.85		0.83		0.80	
Rb	0.96		0.74		0.88	
Cs	0.18		0.20		0.20	
Sr	5.34		8.75		7.60	
Mineralization	3408		3380		3407	
Physical and chemical parameters						
pH*	7.95		8.25		7.80	
T_{wat}, °C	65.0		75.0		18.0	

Note. Analyzed by L. A. Durban. N.f. — Not found. *pH was determined in the laboratory 20 days after sampling.

Table 2

Geochemical Ratios of Carbon Dioxide-Bearing Thermal Waters in the Songwe River Valley and in the Baikal Rift Zone (BRZ)

Ratios	Vent 1	Vent 2	Vent 3	Zhemchug, BRZ
Li/Rb	0.89	1.12	0.91	21.78
Sr/Rb	5.56	11.82	8.64	26.67
Na/Cl	5.90	5.82	6.61	14.85
Rb/Cs	5.33	3.70	4.40	–
Sr/Li	6.28	10.54	9.50	1.22

and elevated contents of chlorine and sulfate although the travertines deposited from these waters are dominated by calcium and magnesium.

The specific composition of the waters is corroborated by geochemical ratios that, most likely, reflect the relation of hydrothermalism with carbonatite volcanism (Table 2). For comparison, we present the same ratios for the carbon dioxide-bearing magnesium-sodium hydrocarbonate hydrotherms of the Tunka basin (western segment of the Baikal Rift) penetrated by a 1 km deep borehole (Zhemchug Village). In the Late Cenozoic, the basin was involved in active basaltic volcanism. As seen from the table, the waters differ greatly in chemistry,

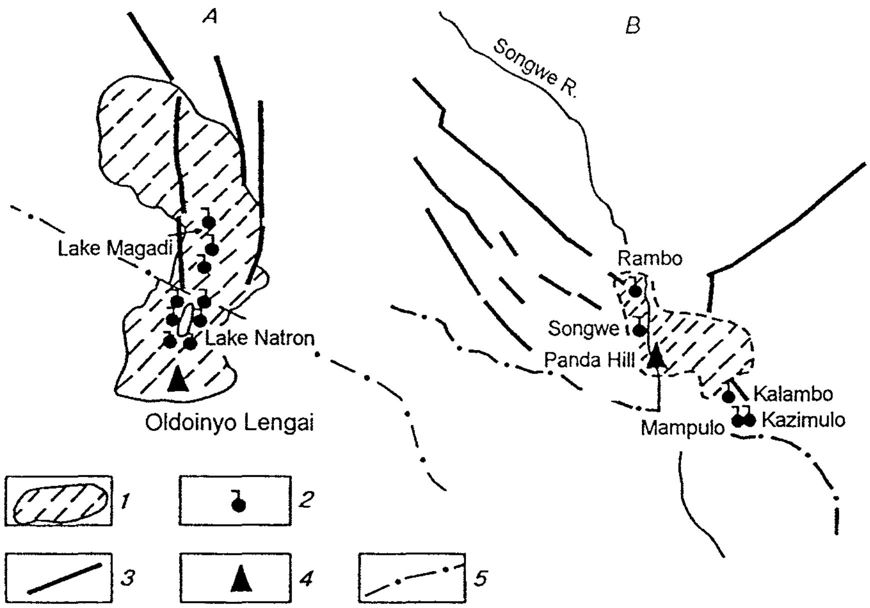

Fig. 2. Location map of volcanic deposits (carbonatites, travertines, trona, ashes) and hydrotherms in the areas adjacent to active Oldoinyo Lengai Volcano (*A*) and the Mesozoic Panda Hill carbonatite massif (*B*). *1* — **sodium carbonate-hydrocarbonate vents;** *2* — **hot springs;** *3* — **faults;** *4* — **Oldoinyo Lengai Volcano and Panda Hill Massif;** *5* — **frontiers of Tanzania.**

especially in Li/Rb ratios, which are close to unity for the Songwe hydrotherms and greater than 20 for those of the Zhemchug group; the Sr/Li ratio is 6 to 10 and 1, respectively. The Sr/Rb and *r*Na/*r*Cl (genetic index) ratios also show great difference. The Li/Rb ratio in hydrotherms usually averages 8–10, sometimes decreasing to 5. Thermal waters with Li/Rb close to unity are very scarce [2].

According to Walker [3], in the Songwe valley there are three more groups of hot springs (T = 55–76 °C) besides the Rambo group. These are high-discharge waters with intense CO_2 bubbling. No other information is available.

Approximately 130–150 km southeastward from the Panda Hill carbonatite massif, in the southern part of the volcanic Rungwe Massif, there are three groups of hot springs, Kalambo, Kazimulo, and Mampulo with water temperatures in a range of 60 to 75 °C (Fig. 2). According to Walker, the former two are similar in chemical composition and mineralization to the above-described Songwe vents, slightly differing from these only in relative concentrations of chlorine and sulfates. All these low-salinity waters are controlled by the master fault of the Rukwa rift and attributed to the Mesozoic Panda Hill carbonatite massif.

A special case is sodium-bearing waters. The grass and soil of the Songwe floodplain are coated with trona deposited from cold Na-bearing waters. Although, owing to scarcity of facts, Na accumulation cannot be interpreted unambiguously, its direct relationship to volcanism is clear near active Oldoinyo Lengai Volcano in northern Tanzania (Fig. 2), which erupted alkaline carbonatite lavas and ash in 1960, 1961, and 1969 [4]. Sixteen kilometers north of the volcano (around Lake Natron) and farther northward (on the shore of Lake Magadi in Kenya), high-discharge carbon dioxide- and fluorine-bearing sodium chloride-carbonate hydrotherms with mineralization as high as 65.7 g/l were found [5]. The lakes are rich in soda (trona), halite (Fig. 2), and concentrated brines of similar compositions with mineralization exceeding 300 g/l.

The mechanism of deposition of magnesium-calcium travertines from water solutions is of paramount importance for elucidating the conditions of hydrotherm formation in the Songwe basin. The hydrotherms discharge at the surface as Mg- and Ca-low Na carbonate-hydrocarbonate solutions where CO_2 bubbles in the alkaline medium (pH > 7.8) and CO_3^{2-} arises among anions, which is theoretically inconsistent with the presence of dissolved CO_2. Carbon dioxide-bearing waters are known to have pH = 6.3–6.9, less frequently, 7.1 (Karlovy Vary) [6, 7]. As was emphasized by Tkachenko [8], CO_2-bearing alkaline waters in the areas of carbonatite volcanism are rather unusual.

CHEMICAL AND MINERAL COMPOSITION OF TRAVERTINES

According to Logachev [9], travertine fields are widespread on the left side of the Songwe River. They cover Cretaceous terrigenous sediments of flat divides at the bottom of the Rukwa graben, often reaching the Songwe riverbed. The measured thickness of travertines attains 80 m, i.e., their total volume is enormous. Travertine deposits are produced by hydrothermal activity associated with Neogene-Quaternary volcanism in the conditions of a completed drainage network. The travertines are composed mainly of carbonates, and their composition is most evident from bulk chemistry. Table 3 presents results of 16 analyses on travertines from the Songwe River. Carbon dioxide content in them varies from 27 to 43%, which confirms their carbonate composition. Their mineralogy is dominated by calcite, and aragonite and dolomite are present in minor amounts. CaO varies from 33 to 55%. Mg is as low as 0.2 to 3.3%.

An interesting feature of some travertines is a high content of SrO varying from 0.03 to 7.35% and exceeding 2% in half the samples. This is higher than in other carbonatites, in particular those of the neighboring Panda Hill Massif [10]. As far as we know, such Sr-rich travertines have no match elsewhere in the world. The Pushchino travertines (Kamchatka Peninsula), described by Naboko [11] contain 0.1–3% Sr but these are preliminary data that need reliable quantitative substantiation.

Alkali contents are usually low: Na_2O varies from 0.03 to 0.68%, except for two samples where it is 3.05 and 35.37% owing to the presence of trona; K_2O content varies from traces to 1.6%.

Silica content varies from 0.55 to 25.15%. In most samples it is under 1.5% thus approaching perfectly carbonate compositions. High Si abundances are due to admixture of quartz and feldspar evident in thin sections as terrigenous clasts. Quartz is shown up on heating curves as a typical endothermic peak. Low contents of silica are due to admixture of hydromicas, muscovite, and montmorillonite, also revealed from heating curves (thermography carried out by N. Nartova, Institute of the Earth's Crust). Alumina exists in micaceous minerals, not free and in small amounts of under 0.4%. In five samples alumina content is higher (1 to 4.8%) due to terrigenous alkali feldspar present in clasts together with quartz.

Ferric oxide and manganese contents are extremely low. Note the presence of sulfur: SO_3 content varies from 0.01 to 4.42%, the latter value attesting to the existence of a sulfate. The same trona-bearing rock (Table 3, sample 3) was found to contain 1.2% Cl and 0.1% B.

The specific chemistry of travertines is a reflection of their mineralogy. Three main mineral phases can be recognized among tuffs: calcites, aragonites, and trona, as well as intermediate varieties. Trona deposits are of limited occurrence and form thin extremely brittle snow-white porous crusts. Calcite and aragonite are visually indistinguishable and diversified: Sometimes they exist as white and yellowish-gray, occasionally, pinkish and orange porous deposits; locally they are dense and solid, with laminated shell-like structure, covered with brown crusts.

Six samples of travertines with the highest Sr enrichment were taken through microprobe analysis, and the results are used in description of the minerals below.

Calcite is naturally the major component of travertines, but, as seen from Table 4, this is an unusual calcite. It contains 0.7 to 6.6% SrO and 0.8 to 5% MgO. Admixtures of barium and iron are negligible. Note that these data are only for high-Sr travertines. Highest Sr in calcites is found in the samples where the total content of SrO is above 7%. Hitherto, high-Sr calcites have been known only in high-temperature carbonatites (Murun Massif), since the strontium ions have a notably larger radius than the calcium ones (1.23 against 0.99 Å, respectively, according to L. Pauling). Its incorporation into the low-temperature calcite of travertines was, probably, facilitated by the presence of magnesium with a smaller ionic radius in the calcite structure. Otherwise the high magnesium content in calcites is difficult to explain. Calcite has a standard optical constant, N_0 = 1.660–1.665; its powder pattern is similar to the standard one.

Aragonite is inferior in abundance to calcite, but sometimes it makes up travertines throughout. More often it occurs as an admixture. In high-Sr travertines aragonite is a Sr concentrator. The content of SrO in it varies from 11.5 to 36.8% (Table 4). It also concentrates Ba (0.11–0.56% BaO) but, in contrast to calcite, does not contain Mg and Fe. The presence of Ca-strontianite was established by microprobing (Table 4). It occurs either as independent crystal assemblages or as fine exsolution features in calcite. Together with Sr-aragonites, Ca-strontianites form a continuous isomorphic series with 11.5 to 70 mol.% Sr. This is the range of Sr contents, which has never been observed in natural minerals before although the complete series was reproduced in experiments. Until these new results were obtained, the series had remained incomplete even with the 50–60 mol.% Sr natural minerals recently found in the Murun Massif.

Trona is a white acicular mineral either forming crusts on or making part of some travertines. It is a

Table 3

Chemical Composition of Travertines from the Songwe Valley, wt.%

Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	1a	2	2a	3	3a	4	4-1	4a	4-3	4-3-1	4-3-2	4-4-1	4-4-2	5	5-1	6
SiO_2	13.89	1.25	0.55	5.97	1.72	4.02	0.86	1.06	11.00	15.65	25.15	1.35	1.15	0.61	3.95	0.96
TiO_2	0.36	0.03	Tr.	Tr.	0.03	0.07	0.07	0.03	0.36	0.32	Tr.	Tr.	0.03	0.13	0.07	0.10
Al_2O_3	4.80	0.40	0.40	0.40	0.40	1.20	0.40	0.40	3.50	2.75	3.80	0.40	0.40	0.40	1.10	0.40
Fe_2O_3	1.27	0.07	0.08	0.08	0.07	0.66	0.25	0.31	1.06	0.56	0.61	1.32	0.49	0.85	0.37	0.11
FeO	0.04	–	–	–	–	–	–	–	0.07	–	–	0.29	–	–	–	–
MnO	0.38	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.18	0.05	0.05	0.05	0.05
MgO	0.50	1.85	3.10	1.20	2.30	1.60	3.20	3.30	1.00	1.05	0.90	0.20	0.20	2.00	0.85	2.90
CaO	41.50	43.65	45.60	4.00	49.50	46.20	51.50	46.50	45.80	43.85	37.30	55.10	50.60	50.60	51.85	50.00
SrO	0.27	7.35	7.20	3.83	2.40	5.60	1.33	5.50	0.54	0.14	0.13	0.07	0.03	2.66	0.11	6.40
Na_2O	0.68	3.05	0.07	35.37	0.18	0.04	0.06	0.19	0.25	0.29	0.68	0.06	0.03	0.06	0.04	0.05
K_2O	0.49	0.13	0.01	1.60	0.03	0.14	0.01	0.01	0.49	0.49	0.78	0.03	Tr.	0.01	0.01	0.01
P_2O_5	0.19	0.11	0.03	Tr.	–	0.01	–	0.09	0.01	–	–	–	–	0.03	–	–
SO_3	0.04	0.35	0.06	4.42	0.08	0.08	0.25	0.08	0.04	0.17	0.08	0.04	0.02	0.16	0.01	0.05
LOI	35.22	41.91	43.22	37.72	43.60	40.63	40.63	44.46	36.13	33.94	30.14	42.10	43.45	43.22	41.25	40.04
Total	99.63	99.75	99.92	94.19	99.91	100.25	101.06	101.03	100.25	99.21	99.57	100.74	100.50	100.33	99.61	100.63
CO_2	34.10	41.80	42.45	32.45	41.25	40.15	43.45	41.25	31.35	30.35	26.95	41.25	42.15	43.45	40.15	40.15
Cl	–	–	–	1.20	–	–	–	–	–	–	–	–	–	–	–	–
HBO_2	–	–	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–

Note. 1 — opal-bearing calcites; 2 — pinkish light-gray aragonites with thin coatings of white trona on the surface; 3 — white porous fine-grained calcite-aragonites with obscure bedding; 4 — porous fine-grained brittle crusts of white trona; 5 — yellowish-gray fine-grained massive rock; 6 — yellowish-gray porous fine-grained massive calcites; 7 — pink solid and dense finely laminated calcites; 8 — white weakly porous fine-grained laminated flowstones with a brown crust; 9 — gray dense fine-grained massive calcites; 10 — light-gray weakly porous calcite crusts; 11 — light-gray weakly porous rocks with pink thin coatings; 12 — calcites; 13 — yellow-orange fine-grained massive calcites; 14 — pink dense radiolitic calcite crusts; 15 — calcites; 16 — light-pink solid fine-grained massive calcites. Analyzed by V. A. Pisarskaya and L. N. Gomonova.

Table 4

Chemical Composition of Carbonates from Sr-Rich Travertines from the Songwe Valley, wt.%

No.	Sample no.	CaO	SrO	BaO	MgO	FeO	MnO	CO_2	Total	n
1	4	54.92	0.70	0.01	0.84	0.02	0.04	44.30	100.83	4
2	6	54.05	1.35	0.01	1.63	0.06	0.00	44.79	101.89	4
3	2	50.21	1.68	0.22	3.70	0.00	0.00	44.21	100.02	1
4	2	46.30	5.21	0.35	5.06	0.00	0.02	44.17	101.11	1
5	2a	47.38	5.62	0.18	3.27	0.02	0.00	43.19	99.66	4
6	4a	43.59	11.53	0.11	0.13	0.01	0.00	39.27	94.64	1
7	2	43.15	14.92	0.64	0.05	0.02	0.05	40.47	99.30	1
8	2a	43.21	16.12	0.35	0.12	0.01	0.01	40.98	100.79	1
9	2a	40.88	17.38	0.48	0.17	0.15	0.06	39.91	98.96	1
10	2a	26.17	36.83	0.56	0.04	0.00	0.00	36.38	99.98	1
11	4	12.05	46.85	0.39	0.07	0.00	0.00	29.53	88.89	1
12	6	12.12	54.20	0.38	0.03	0.03	0.01	32.69	99.46	1

Note. 1–5 — calcites; 6–10 — Sr-aragonites; 11–12 — Ca-strontianites. Analyses were carried out by L. F. Suvorova on a Superprobe-733 at the Institute of Geochemistry. CO_2 content was calculated by cations; n is number of analyses.

low-temperature diagenetic hydrothermal mineral with N_g = 1.540 and extremely high birefraction, with a powder pattern similar to the standard one.

Halite was recognized from its powder pattern (by chlorine). Observed in paragenesis with trona.

SOME PROBLEMS OF ORIGIN OF HYDROTHERMS AND TRAVERTINES

Why are the compositions of the Songwe hydrotherms and travertines so unusual? In our view, they may be controlled by a specific deep-seated magmatic source supplying most of the material dissolved in hydrotherms and then deposited as travertines. The Rukwa graben, on whose southeastern termination the Songwe River flows, is a fragment of the western branch of the East-African rift system where voluminous alkaline magmatism was active from Cretaceous to Quaternary. Note that ashes were also found above the Songwe travertines. There are reasons for associating the unusual hot springs with Neogene-Quaternary magmatism which produced phonolithic trachytes, phonolites, less frequently, melanephelenites and tephrites, and, sometimes, basalts and andesites [9]. In northern Tanzania, 500 km away from the Songwe River, a unique volcano, Oldoinyo Lengai, is erupting K-Na-carbonatite lavas. Na-carbonatite erupted from Oldoinyo Lengai in September 1992 had the following composition (%): CaO – 15.70, Na_2O – 32.10, K_2O – 7.02, SrO – 1.61, BaO – 1.29, CO_2 – 32.00, SO_3 – 2.33, F – 2.83, Cl – 3.2, and H_2O – 1.6 [12]. Obviously, if fluids are released from such a melt and feed hydrotherms, the latter become enriched with Sr. Even the Li and Rb abundances in the erupted lavas were the same as in the Songwe hydrotherms: 234 ppm Li and 245 ppm Rb. Thus, it can be hypothesized that a magma chamber of the Oldoinyo Lengai type has already formed at a certain depth beneath the Songwe valley. If so, the unusual chemistry of the Songwe hydrotherms and travertines become readily explained. Formation of such a chamber is highly probable: Alkali-carbonatitic magmatism acted there as early as the Late Cretaceous (Panda Hill Massif) and alkaline magmatism in the Neogene-Quaternary. Then an alkali-carbonatite chamber may have formed producing a great amount of fluids that mixed with meteoric waters and penetrated along faults into the upper crust to yield a large travertine field.

Strontium isotope data do not contradict this hypothesis. M. N. Maslovskii (Institute of the Earth's Crust) established the following $^{87}Sr/^{86}Sr$ values in the Sr-richest samples of the Songwe travertines: 0.70585 (sample 2a), 0.70557 (sample 4a), and 0.70551 (sample 6), which are almost the same as in the Oldoinyo Lengai carbonatites: 0.7059–0.7061 [13]. In the silicate lavas of the volcano, this coefficient varies from 0.70414 to 0.70512 which points to the mantle origin of Sr. If Sr in the hydrotherms was leached chiefly from the Archean basement, its isotope ratios in the travertines would not be so small. Therefore, Sr, as well as other elements Ca, Mg, Li, and Rb, was transferred to the hydrotherms from a magma chamber.

In our opinion, a detailed study of hydrotherms and travertines in the Songwe River valley and elsewhere in the East-African rift system may give interesting results. Moreover, it should be kept in mind that Sr-rich travertines can be useful as mineral material for extracting Sr.

CONCLUSIONS

1. A group of hot springs of CO_2- and S-bearing alkaline carbonate-hydrocarbonate waters with mineralization of 3.3–3.4 g/l has been revealed in the western segment of the East-African rift system in the basin of the Songwe River.

2. The thermal waters (maximum temperature 75 °C) have been depositing Sr-rich travertines with unusual chemistry. Strontium is a constituent of calcite, aragonite, and strontianite. The latter two form a continuous isomorphous series in the range of Sr contents never observed before in natural minerals.

3. The hydrotherms may have fed from Sr-rich fluids released from an alkali-carbonatite mantle magma chamber.

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