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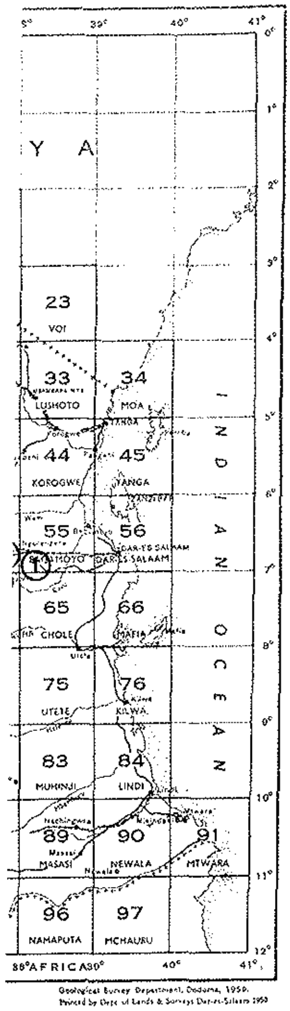

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17. HELIUM AND HOT SPRING INVESTIGATION—PROGRESS REPORT

By T. C. James, *Geologist*

A detailed survey was made of the helium-bearing springs of Musoma and North Mara Districts for the United Kingdom Atomic Energy Authority who are investigating the occurrences as sources of helium. The natural rate of emission of helium from Maji Moto hot spring is about 25 litres per hour and from Nyamosi and the Mananka group about [illegible] and 4 litres per hour respectively. Drilling at the spring vents is in progress with the object of increasing the yield.

During the year a number of helium-bearing springs were discovered in the area between Dodoma and Singida. Some of these springs have considerable natural rates of emission of helium; that of Manyeghi springs in the Mponde River valley is estimated to be of the order of 50 litres per hour while that of Mponde spring is about 20 litres per hour. Other helium-bearing springs occur at Takwa, Singida District, Gonga, Kondoa District and Saranda, Manyoni District, but the natural rates of emission of helium from these is less than 20 litres per hour. The spring waters at all of these occurrences are saline and contain between 3[illegible] and 3,060 p.p.m. total solids. The low concentration of the brines together with their unsuitable chemical composition renders them useless as sources of salts.

There is little doubt that most, if not all, of the hot springs in Tanganyika are volcanic in origin and it is possible that geothermal steam exists in depth beneath them. It is debatable if the steam could be tapped by boreholes within a reasonable depth, but on theoretical grounds the most promising occurrence is the hot springs in the Songwe River valley, Mbeya District.

19. OCCURRENCES OF HELIUM-BEARING GASES IN MUSOMA AND NORTH MARA DISTRICTS, LAKE PROVINCE

By T. C. JAMES, *Geologist*

ABSTRACT

Gas containing an exceptionally high proportion of helium is emitted from the hot springs at Maji Moto, Musoma District and Nyamosi, North Mara District. Analyses have been made of the gases which are found to consist almost entirely of helium and nitrogen. The yield of gas through the springs is at present low but might be improved by drilling at or near the spring vent.

The springs are thought to be volcanic in origin and fumarolic in nature.

I. INTRODUCTION

During an investigation of hot springs and surface salt deposits in the territory, visits were made to Maji Moto, Musoma District and Nyamosi, North Mara District in October, 1954. Hot springs have been known at these localities for many years. Samples of gas emitted from the springs were taken at both places and subsequently analysed by the Government Chemist, London.

II. SITUATION AND COMMUNICATIONS

Maji Moto hot spring is situated on the south side of the Mara River, 39 miles east of the town of Musoma, at Latitude 1°37′ and Longitude 34°20′. There is a motorable track to within a short distance of the hot springs; Maji Moto rest-house is about half a mile to the east.

Nyamosi hot spring is situated a few miles north-west of the town of Tarime, the district headquarters of North Mara District. From Tarime, the road to Kenya is followed northwards for a distance of about 3 miles. A cattle-track branches off to the west and this is followed for a distance of about 2 miles. The hot spring appears through a rock platform in the bed of the Rekirato River, a left bank tributary of the River Murare.

III. GEOLOGICAL SETTING

The area in which the springs occur has been geologically surveyed by G. M. Stockley and his findings are recorded on Map. G.S. 159, Eastern Musoma Goldfield (Stockley, 1935). Much of the area is granite which has intruded members of the Musoma Series, Kuria Volcanics and North Mara Series (Muva-Ankolean*). The regional trend of these Precambrian rocks is east-west. Relics of the Katanga System (Bukoban) overlie the earlier formations at some points. To the south of Tarime phonolitic lavas of probable Tertiary age are displaced by a fault scarp, the Utimbaru Scarp, which has a minimum throw of approximately 1,000 feet.

Maji Moto hot spring appears through a wide valley-bottom infilled with alluvium which is set in acid and basic volcanic rocks of the Musoma Series. There is no apparent relationship between the structure of the Precambrian rocks and the location of the spring. Stockley records no recent faults in the immediate vicinity.

*The Muva-Ankolean System is now known as the Karagwe-Ankolean System. Quennell, A. M., 1957, *Lexique Stratigraphique Inter.*, Vol. IV, Fasc. 8c, p. 76.

Nyamosi hot spring is located approximately on the boundary of basic volcanics of the Musoma Series and granite but again there is no obvious relationship with the structure of the Precambrian rocks.

A hot spring occurs at Mananka at the foot of the Utimbaru Scarp to the south of Tarime and, although this was not visited personally, a sample of the water was collected by a local inhabitant.

IV. Description of the Deposit

(a) Maji Moto Hot Spring

To the west of Maji Moto rest-house a river valley runs northwards between hills composed of rocks of the Musoma Series. North of the road to Musoma, in a flat valley-bottom, is a marshy area, about 250 by 300 yards, covered by a thick growth of coarse, round-stemmed reeds. A number of hot springs rise to the surface in this area. One large spring forms an open pool, about 15 feet in diameter, in the reeds. Much green weed and a little salt incrustation can be seen on the soft surrounding sand and in the bottom of the pool. The whole vicinity is marshy and soft under foot and care must be taken when approaching the edge of the pool.

Bubbles of gas rise continuously from an elongated area of sand about 5 feet by 1 foot in the centre of the pool which at this point is about 18 inches deep. Bubbles also rise periodically over the whole area of the pool. An analysis by the Government Chemist, London, of a sample of gas from the centre of the pool gave the following composition:

	% by vol.
Carbon dioxide	0·4
Hydrogen sulphide	Less than 0·1
Carbon monoxide	Less than 0·1
Oxygen	0·1
Hydrogen	Less than 0·1
Hydrocarbons	Less than 0·1
Helium	13·2
Nitrogen and other inert gases	86·3
(J. 3623)	

The helium content of the gas was checked by mass spectroscopy methods at the Atomic Energy Research Establishment, Harwell, U.K., and found to be 13·5 per cent. by volume.

The quantity of gas liberated from this spring was found during a subsequent investigation to be about 200 litres per hour. Other gas-bearing springs in the immediate vicinity were not examined.

The pool of water supplied by the spring appears to be about 18 inches above the general level of water in the swamp and is held up by a surrounding rim of coarse, round-stemmed reeds mixed with sand. The overflow follows a channel to the south-east and is estimated to be about 1,800 gallons per hour.

The temperature of the water in the middle of the pool is 130°F. and around the edge, [illegible]5°F. The temperature of the sand in the bottom of the pool appears to be 135°F.

Samples of water were taken from the pool and also from a river-bed situated about [illegible] miles to the south-west of the springs; it is thought that the river-water is probably typical of ground-water in the area. These were analysed by the Geological Laboratory Services and the results are given below.

	Maji Moto Hot Spring	Ground-water
pH approx.	9·5	7·0
Total solids (dried at 180°C.)	5,170 ppm	180 ppm
Cl	1,170 ppm	6 ppm
SO_4	430 ppm	Nil
F	23 ppm	1·4 ppm
CO_3	530 ppm	n.d.
HCO_3	1,720 ppm	140 ppm
SiO_2	100 ppm	40 ppm
Ca	approx. 1 ppm	15 ppm
Mg	less than 1 ppm	4 ppm
K	approx. 10 ppm	approx. 3 ppm

Corresponding to the following approximate composition:—

	Maji Moto Hot Spring	Ground-water
NaCl	1,920 ppm	10 ppm
Na_2SO_4	640 ppm	—
Na_2CO_3	940 ppm	—
$NaHCO_3$	2,370 ppm	104 ppm
NaF	50 ppm	3 ppm
$Ca(HCO_3)_2$	—	61 ppm
$Mg(HCO_3)_2$	—	24 ppm
SiO_2	100 ppm	40 ppm

(G.S. File X/4158. Analyst: R. A. Sutton).

(b) Nyamosi Hot Spring

At the point where the cattle-track crosses the Rekirato River, there is a wide rocky platform composed of well-jointed micro-amphibolite; most of the surrounding countryside appears to be formed of migmatitic gneisses and granite. Several small hot springs rise in the joints in the amphibolite where they have dissolved out shallow depressions about a foot in diameter and three inches in depth. The rock is warm under-foot and there appear to be 30 to 50 small vents in an area of about 30 by 100 yards. The water delivered from the springs is immediately mixed with the river-water but it is estimated that the total flow is of the order of 100 gallons per hour. The flow of water from individual vents is sufficient to lift quartz grains 0·3 mm. in diameter in the vent. The highest temperature of spring water recorded in the group was 100°F.; the temperature of the river-water was 68°F. The sand in the bottom of one of the vents had a temperature of 105°F.

A sample of gas was collected from one of the larger vents and subsequently analysed by the Government Chemist, London, who obtained the following composition:

	% by vol.
Carbon dioxide	0·2
Hydrogen sulphide	Less than 0·1
Carbon monoxide	Less than 0·1
Oxygen	0·2
Hydrogen	Less than 0·1
Hydrocarbons (as methane)	*0·5
Helium	17·9
Nitrogen and other inert gases	81·2

(J. 3675)

*Presence doubtful, within limits of experimental error.

The helium content of the gas was checked by mass spectroscopy methods at the Atomic Energy Research Establishment, Harwell, U.K., and found to be 18·2 per cent. by volume.

The quantity of gas emitted from the springs could not be estimated but during a subsequent investigation the flow was found to be 55 litres per hour.

A sample of the water was obtained from the same spring-vent as that of the gas. The sample was poured directly into a bottle and was completely filled with the ground-glass stopper in place. It was then noticed that minute bubbles of gas were separating out from the water and gathering beneath the stopper; the sample at this time had a temperature of approximately 35°C. On return to the laboratory the volume of gas was measured (by difference), corrected to 35°C., and found to be 6 c.c. The volume of the sample bottle was 1,035 c.c. Thus the sample of water from the spring contained about 0·006 per cent. gas either dissolved in the water or contained therein as minute bubbles. Since the gas-sample was taken in a similar manner over spring-water displaced from an inverted bottle, this gas should have approximately the same composition as that quoted above.

A sample of what is believed to be typical ground-water was obtained from a seepage about 100 yards to the east of the springs. The analyses (by the Geological Laboratory Services) of this and the spring water are quoted below.

	Nyamosi Hot Spring	Ground-water
pH approx.	9·5	7·0
Total solids (dried at 180°C.)	3,480 ppm	105 ppm
Cl	440 ppm approx.	1 ppm
SO_4	200 ppm	Nil
F	23 ppm	0·6 ppm
CO_3	480 ppm	—
HCO_3	1,680 ppm	90 ppm
SiO_2	90 ppm	30 ppm
Ca	approx. 2 ppm	10 ppm
Mg	less than 1 ppm	4 ppm
K	approx 13 ppm	trace
Nitrite	...	—
Nitrate	...	—

Corresponding to the following approximate composition:

	Nyamosi Hot Spring	Ground-water
NaCl	725 ppm	approx. 2 ppm
Na_2SO_4	290 ppm	—
Na_2CO_3	850 ppm	—
$NaHCO_3$	2,310 ppm	55 ppm
NaF	50 ppm	1·3 ppm
$Ca(HCO_3)_2$	—	40 ppm
$Mg(HCO_3)_2$	—	24 ppm
SiO_2	90 ppm	30 ppm

(G.S. File X/4158. Analyst: R. A. Sutton)

Herds of cattle visit the hot springs to drink the saline water and the small quantities of nitrite and nitrate shown in the analysis are probably caused by contamination from their excreta.

(c) Mananka Hot Spring*

This hot spring is situated at the foot of the Utimbaru Scarp, about two and a half hours' walking time to the south of Tarime. The spring was not visited personally but a local

*A subsequent investigation of this spring showed it to be one of a group of springs which in total are about the size of Maji Moto hot spring, and which emit a similar nitrogen-type gas containing 5 to 9 per cent. helium. In addition two small areas of spring vents of similar type were found at Nyarukamu and Ukiruruma to the west of Mananka.

inhabitant kindly collected a sample of water. From his description of the occurrence the spring appears to be bigger than that at Nyamosi, but it is thought to be not so hot; the temperature is inferred to be about 80°F. The water sample, on receipt, was cloudy (sulphur?) and smelt strongly of hydrogen sulphide. It is not improbable that gas is also emitted from this spring.

The analysis of the water, by the Geological Laboratory Services, is as follows.

pH approx.		9·5
Total solids (dried at 180°C.)		1,730 ppm
Cl		355 ppm
SO_4		130 ppm
F		11 ppm
CO_3		130 ppm
HCO_3		730 ppm
SiO_2		50 ppm
Ca	approx.	2 ppm
Mg	less than	1 ppm
K	approx.	10 ppm

Corresponding to the following approximate composition:

NaCl	585 ppm
Na_2SO_4	190 ppm
Na_2CO_3	230 ppm
$NaHCO_3$	1,000 ppm
NaF	24 ppm
SiO_2	50 ppm

(G.S. File X/4158. Analyst: R. A. Sutton)

V. ORIGIN OF THE HOT SPRINGS

An examination has recently been made of the analyses of gas and brines from all known hot and cold springs and also of some ground-waters in the territory. Springs with similar composition of gas and brine to those at Nyamosi and Maji Moto are known from nine other localities, although at these the gases contain a lesser proportion of helium. From the location and distribution of these other occurrences it is inferred that the gas-bearing springs are of volcanic origin and that they are probably fumarolic in nature.

Day and Allen (1925), quote analyses of gases from hot springs and geysers in the Yellowstone National Park, U.S.A. Here a similar range in composition is found and the analyses of what are considered to be two end members of a series are quoted below. Two gases from Tanganyika showing the same range are placed alongside.

	I	II*	III	IV*
Carbon dioxide	1·32	0·2	98·68	89·9
Hydrogen sulphide	0	L.t. 0·1	0·46	N.d.
Carbon monoxide		L.t. 0·1		N.d.
Oxygen	3·50	0·8	0·06	0·9
Hydrogen	0·10	0·2	0·17	N.d.
Hydrocarbons (expressed as methane)	0	L.t. 0·1	0	N.d.
Helium		5·7		0·06
Nitrogen and other inert gases	95·08	93·1	0·63	9·8

L.t. 0·1=Less than 0·1

N.d.=Not determined

I. Artemesia Geyser, Upper Geyser Basin, Yellowstone National Park, U.S.A.

II. Hot Spring on the east shore of Lake Eyasi, Mbulu District, Northern Province, Tanganyika.

*Analyses by Government Chemist, London.

III Mammoth Hot Springs, Yellowstone National Park, U.S.A.

IV. Maji ya Yeta hot spring, Morogoro District, Eastern Province, Tanganyika.

In the examples quoted above of the gases from the Yellowstone National Park the helium content is not given and it is possible that it was not determined. If this is so it will have been included in the figure for nitrogen.

There seems little doubt that the gas from the Tanganyika springs is of volcanic origin.

VI. Helium Content of the Gases

The gases at Nyamosi and Maji Moto contain the highest content of helium found so far in occurrences in Tanganyika. Examples at Ivuna, Lake Balangida and Uvinza contain 1·1, 1·7 and 2·5 per cent. respectively, but at these places the quantity emitted is small. The only up-to-date reference, available in Dodoma, of helium occurrences in other parts of the world is contained in Geochemistry (University of Chicago Press) by Rankama and Sahama (1955) who state, "the gases from some mineral waters in France contain 10·31 per cent. helium)". "Very notable helium contents may be found in petroligenic natural gas, the maximum being 16 per cent. He by volume in natural gas from the eastern slope of the Rocky Mountains in the United States. However, noteworthy helium contents have been found only in the nitrogen-rich gases, and, even among these, gases containing more than 1 per cent. He are relatively uncommon. Total helium reserves in the United States are estimated at over $200 \cdot 10^6 m^3$".

VII. Uses of Helium

No up-to-date information is available but it is believed that helium is used in the metallurgy of titanium. The only available information on price is given in the text-book, "Industrial Minerals and Rocks" (1949) which quotes approximately $10·00 per 1,000 cu. ft. in 1941.

VIII. Further Investigation of the Deposits

It seems unlikely that the present quantity of gas emitted from the Maji Moto occurrence would warrant exploitation, and it is suggested that the deposit might be drilled with a view to increasing the yield. A drill-hole for water at Esegeri, Kenya, was sited in volcanic rocks. Gas was first encountered at a depth of 450 feet. The hole was abandoned at 530 feet because the drilling tools would not drop down the hole. The hole was capped and pressures between 40 and 80 lb. per square inch were reported during subsequent tests. The composition of the gas was found to be 97·8 per cent. carbon dioxide and 2·2 per cent oxygen.

The experience at Esegeri is the only information on which an estimate can be based. The siting of a drill-hole cannot be suggested on geological grounds and must be determined by the practical possibility of drilling through a hot spring.

IX. Conclusions and Recommendations

The occurrence of helium in the gas-bearing springs at Maji Moto and Nyamosi cannot be regarded as anything but a scientific curiosity at present. However, if the yield could be increased, the occurrences might become economic sources of helium and nitrogen. The simple composition of the spring gases would seem to indicate that relatively-pure products could be obtained.

It would appear that the best method of increasing the yield is by sinking a drill hole either on or close to the spring-vents in the hope that more gas would be liberated and also that the flow of gas could be controlled.

X. References

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Rankama, K. and Th. G. Sahama. 1955. Geochemistry. The University of Chicago Press.

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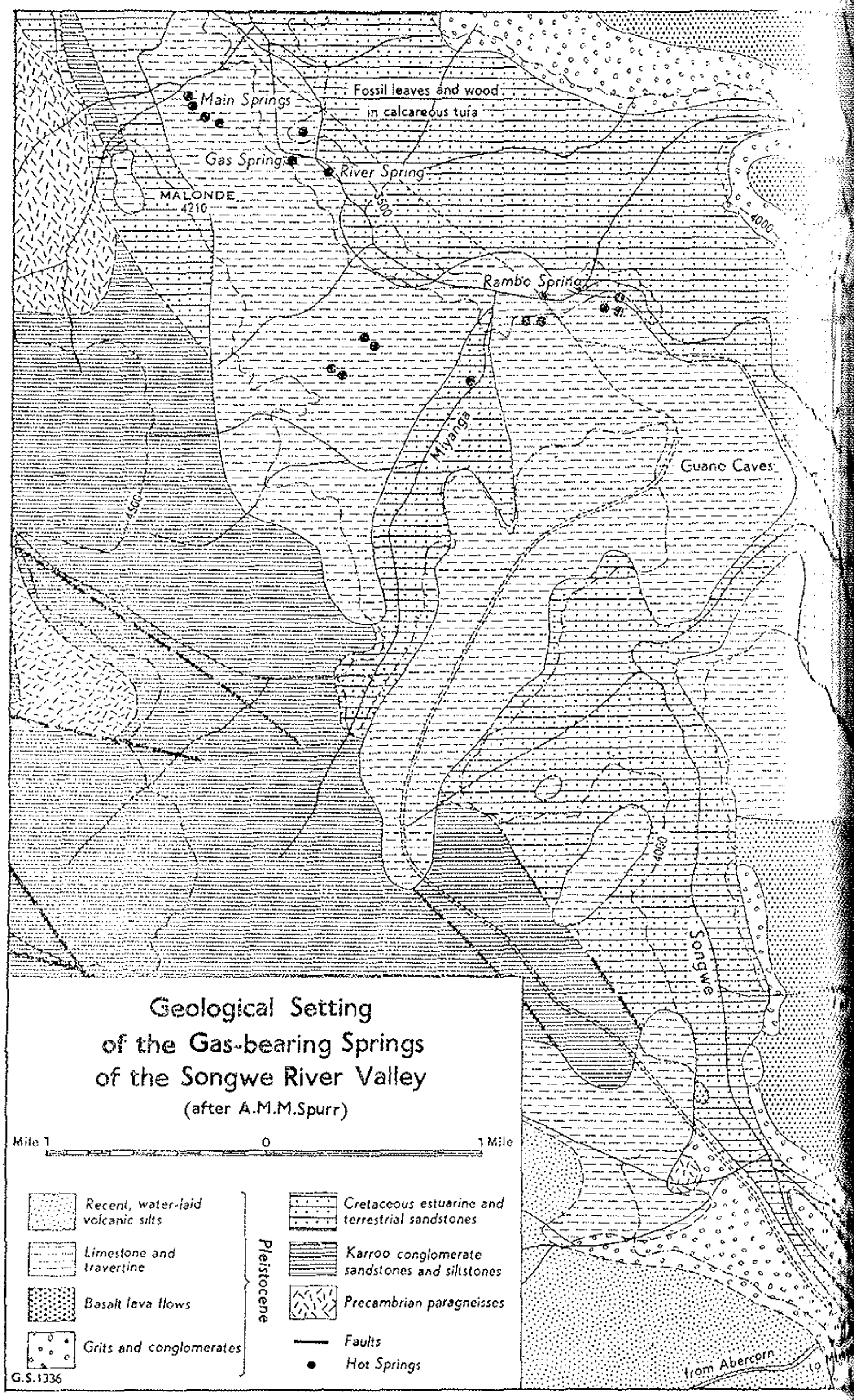
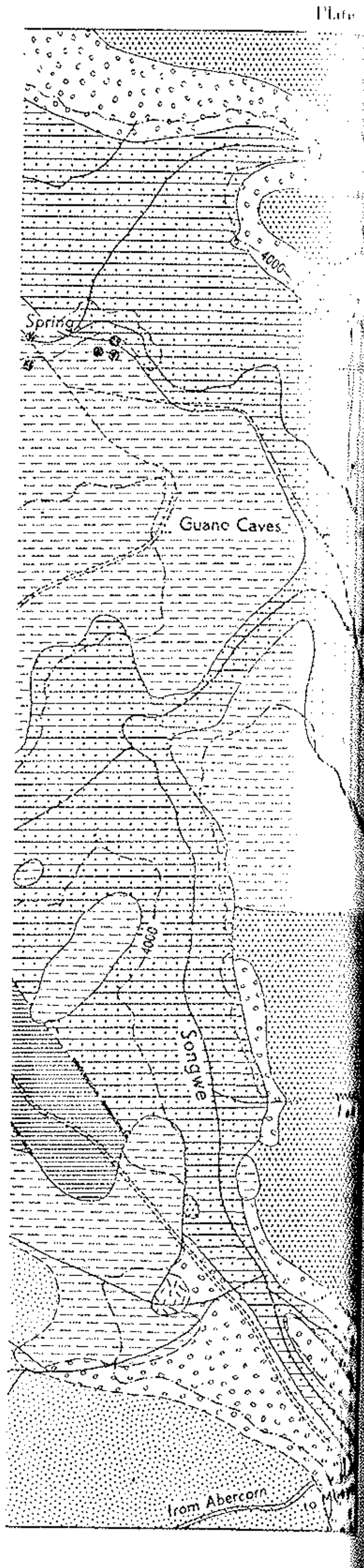


Geological Setting of the Gas-bearing Springs of the Songwe River Valley (after A.M.M.Spurr)



CARBON DIOXIDE-BEARING HOT SPRINGS IN THE SONGWE RIVER VALLEY, MBEYA DISTRICT

By T. C. James, *Geologist*

Abstract

Gas, containing 99·2 per cent. carbon dioxide is emitted from a hot spring vent in the Songwe River Valley. The yield of gas is very roughly estimated to be of the order of 1 cubic foot per minute. Other hot springs in the vicinity also emit gas and at one other occurrence the gas is mainly carbon dioxide. It is concluded that if a market for liquid and solid carbon dioxide exists in the Territory, these occurrences would possibly be worth further attention with a view to ascertaining the maximum yield, possibly by drilling.

I. Introduction

During an investigation of hot springs and surface salt deposits in the Territory, a visit was made to the Songwe River valley, Mbeya District, in December, 1955. Hot springs have been known in the area for many years and were first described by Bornhardt (1900). Samples of the gas emitted from the springs were taken and subsequently analysed by the Government Chemist, London.

II. Situations and Communications

The springs are situated in the bottom of the wide gorge formed by the Songwe River at a distance of 17 miles due west of the town of Mbeya. They are reached by following the main road to Rhodesia from Mbeya for a distance of 21 miles to the bridge over the Songwe River where a minor track branches off to the north and can be followed for 5½ miles to a point overlooking the gorge at the bat-guano caves. From here a descent is made on foot into the gorge and hot springs are found along the bed of the river and in the vicinity of the left bank for a distance of 2½ miles. The springs are recorded on map Africa 1 : 125,000 Sheet South C36/D111. A track could probably be constructed from the guano caves to the vicinity of the springs.

Four spring vents are described in this report and their location is given on Plate XI.

III. Geological Setting

The geology of the Songwe River area is described by Spurr (1954). The Songwe River at this point flows in the floor of the south-east segment of the Rukwa Trough (Rift Valley) and has cut a steep-sided gorge in soft, red sandstones of probable Cretaceous age overlain by thin deposits of travertine limestones of Pleistocene to Recent age. Basalt lava flows overlie the red sandstones to the east of the gorge. To the west, Karroo conglomerates and sandstones are found along the "rift" escarpment and are thought to lie unconformably on the Basement paragneisses which form the escarpment. The carbonatite at Panda Hill is situated some 7½ miles to the south-east of the area in which the springs occur.

All of the hot springs rise through vents in the Pleistocene travertine limestone in the bottom of the gorge. The four springs described are situated along a line followed by the river, running in a west-north-west direction. Rambo Spring is situated in the flat valley-bottom close to the river and about ½ mile north-north-west of the bat-guano caves. The next spring, named River Spring, is situated in the river bank about 1½ miles downstream to the north-west. The Gas Spring is about 200 yards to the west-north-west of this point and the Main Springs are a further 300-400 yards in this direction. It is possible that these springs are located on a fault buried beneath the travertine. Photographs of the occurrences are to be found in Plates XII and XIII.

It is believed that the springs are volcanic in origin and fumarolic in nature and that they may belong either to the volcanism at Rungwe or to a dying phase of the volcanicity attached to the carbonatite intrusion at Panda Hill.

IV. Description of the Deposit

(a) Rambo Hot Spring

This spring is situated in the flat bottom of the valley of the Songwe River and appears in a soft, marshy area about 100 yards in diameter on what is probably an old river terrace. A number of small spring vents giving rise to pools 5 to 10 feet in diameter are found in the marshy area. The immediate vicinity of the pools is covered by a short, round-stemmed reed which is characteristic of hot salt springs of this type and close at hand are Phoenix palms, considered by Bornhardt to be always found around such springs, e.g., Maji ya Weta, Tagalalla See. These features can be observed in the photograph, Plate XII, Fig. 1.

The flow of water from the numerous small vents is canalized into a stream and it is estimated that the total flow is of the order of ½ to 1 cusec. The temperature of the water from the largest vent in the group is estimated to be about 150°F. The water can be seen to be bubbling up forcibly in the vents and sandy material and calcareous concretions formed at the bottom of the pool are lifted about 3 inches by the flow. An analysis of this spring water by the Government Chemist, London, gives the following composition:—

	Parts per million
Total dissolved solids dried at 180°C.	2,340
Total Hardness, as $CaCO_3$	82
Calcium, as $CaCO_3$	62
Magnesium, as $MgCO_3$	20
Total Alkalinity, as $CaCO_3$ (including that due to silicate)	1,570
Sulphate, as SO_4	163
Chloride, as Cl	223
Nitrate, as N	0·3
Fluoride, as F	8·2
Phosphate, as P_2O_5	0·2
Silicate, as SiO_2	90
Sodium, as Na...	835
Potassium, as K	114
pH Value	(8·4)

Corresponding to the following approximate composition:—

	Parts per million
NaCl	196
Na_2SO_4	241
$NaHCO_3$	2,337
NaF	18
KCl	218
$Ca(HCO_3)_2$	100
$Mg(HCO_3)_2$	35
SiO_2	90

(J.4059)

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	Parts per million
... ...	2,340
... ...	82
... ...	62
... ...	20
ɔ silicate)	1,570
... ...	163
... ...	223
... ...	0·3
... ...	8·2
... ...	0·2
... ...	90
.. ...	835
.. ...	114
.. ...	(8·4)

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	Parts per million
... ...	196
... ...	241
... ...	2,337
... ...	18
... ...	218
... ...	100
... ...	35
... ...	90

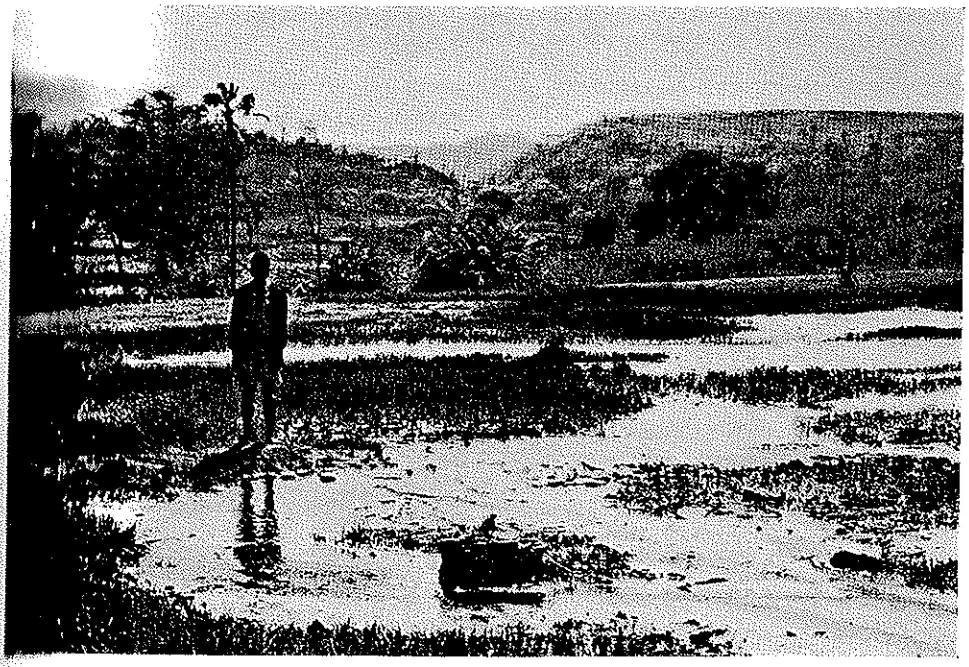


Figure 1. A general view of the Rambo Hot Spring looking south-eastwards up the Songwe River Valley. The vent from which the water and gas samples were taken is immediately at the feet of the man. Note the round-stemmed reeds and Phoenix palm.

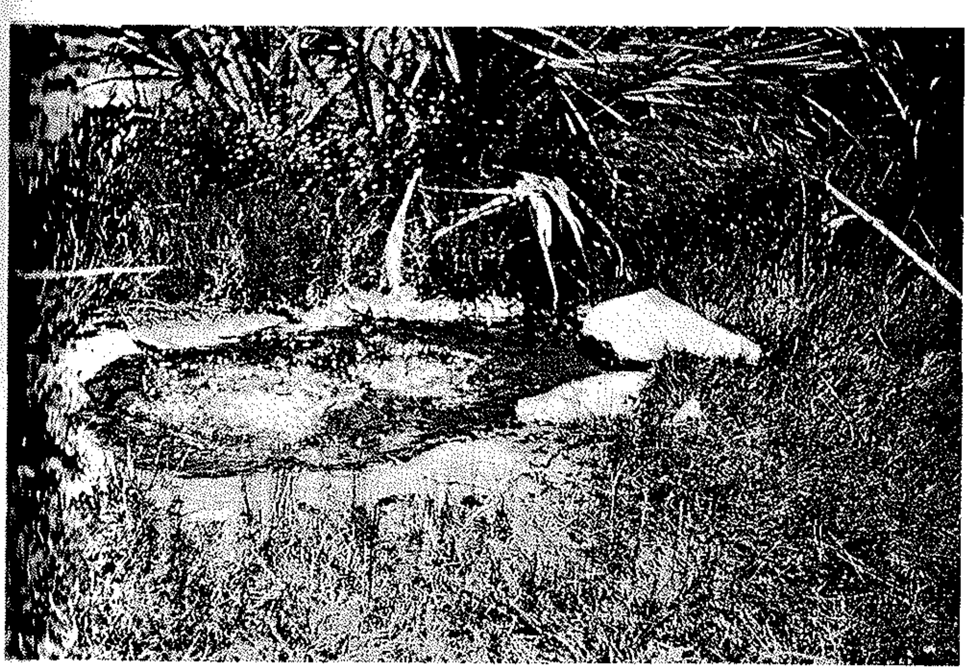


Figure 2. Gas Hot Spring. The pool is about 3 feet in diameter. Two areas of bubbles caused by gas rising to the surface can be clearly seen in the centre of the pool. The edge of the pool is composed of travertine limestone.

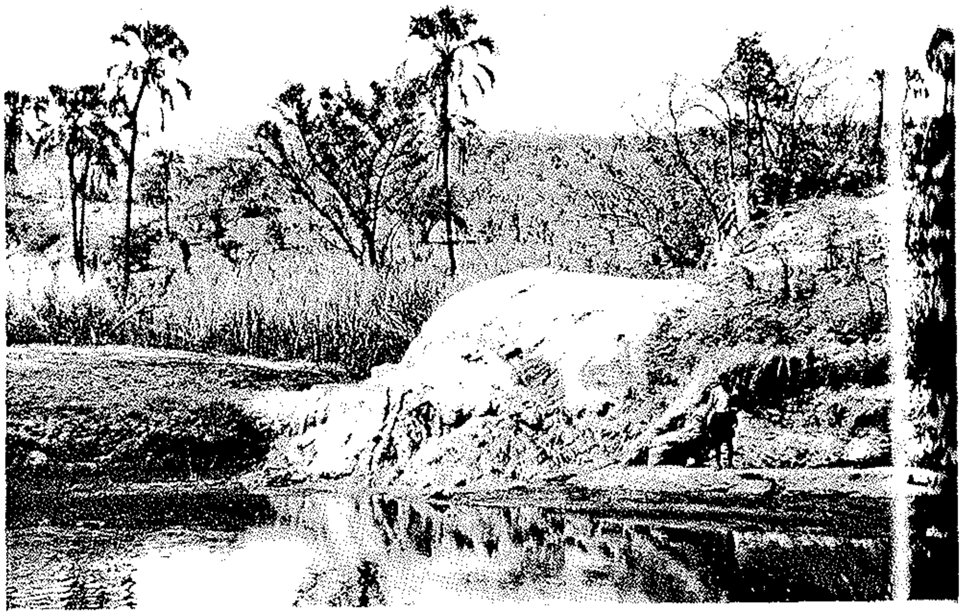


Figure 1. River Hot Spring. The cone is composed of calcareous tuffa covered with green weed and red algae. It is set against the south-east end of a travertine limestone ridge. The top of the water spout is just visible at the base of the Phoenix palm in the centre of the picture. The Songwe River is in the foreground.

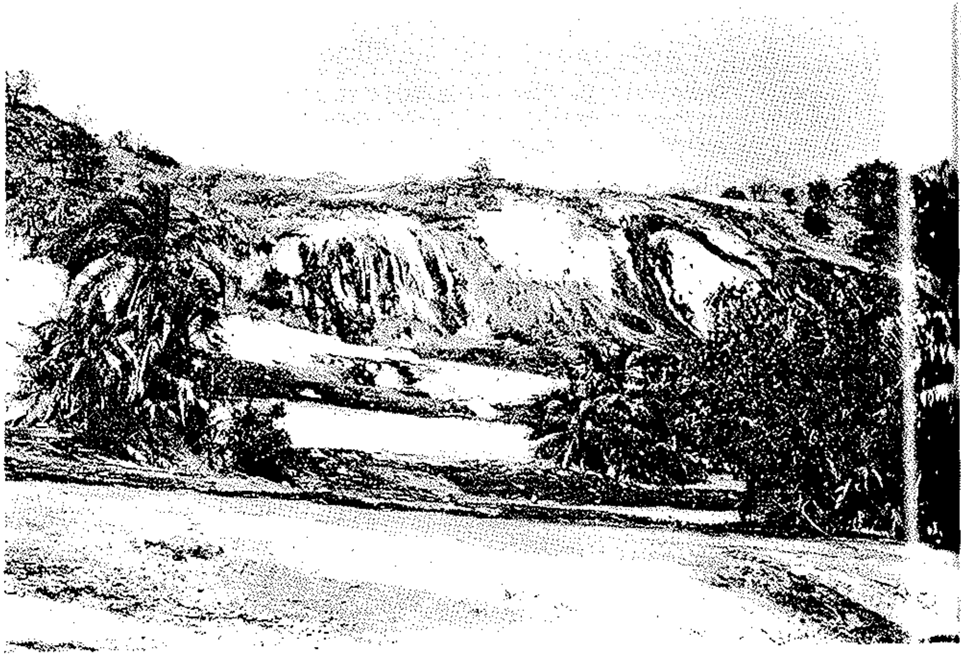
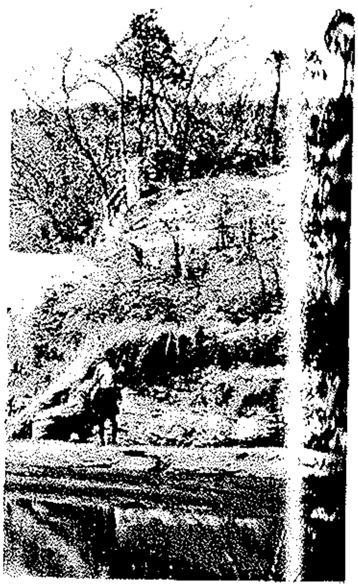


Figure 2. The Main Hot Springs. The three spring vents are situated on the top of the scarp and overflow down its face depositing tuffa and causing the growth of green weed and algae in vertical streaks. The scarp is 30 to 40 feet in height.

Plate XIII



ous tuffa covered with green ... of a travertine limestone ridge. The Phoenix palm in the centre ... the foreground.

situated on the top of the scarp and the growth of green weed and algae to 40 feet in height.

Bubbles of gas are emitted intermittently from various points in the pools. In the centre of the largest pool gas is emitted fairly constantly and a sample was collected over brine from this point. The rate of delivery of the gas cannot be estimated but can be seen to be small. An analysis by the Government Chemist, London gave the following composition:—

		% by vol.
Carbon dioxide		97·2
Hydrogen sulphide		not detected
Carbon monoxide	less than	0·1
Oxygen		0·7
Hydrogen	less than	0·1
Hydrocarbons (as methane) ...	less than	0·1
Helium	less than	0·1
Nitrogen and other inert gases (by difference)...		2·1

(J. 4058)

(b) River Hot Spring

This is the most spectacular of the springs in the area. The spring waters have built up a small cone of calcareous tuffa about 9 feet high and 15 feet in diameter, situated at the end of a long ridge of travertine in which numerous active and also old vents are to be found. In 1952, hot water with an estimated temperature of 170°F. and containing bubbles of gas flowed out from the top of the cone and a small spurt of water was emitted from a point about half-way down the side of the cone. Visitors to the occurrence placed stones and various debris in the main vent and this was completely sealed when the occurrence was revisited in 1956. The whole outflow from the spring is now from the subsidiary vent about half-way down the side of the cone. At this point a mixture of gas and hot water spurts upwards to a height of about three feet. A photograph of the cone is shown in Plate XIII, Fig. 1. No analyses of either gas or water are available.

(c) Gas Hot Spring

The spring vent is situated on the crest of the rocky ridge of travertine limestone and is about 100 feet above, and 300 feet from, the Songwe River to the north. On the south side of the ridge at about 10 feet below its crest the ground is flat for a considerable distance and is strewn with fragments of travertine limestone. The gas bubbling in the spring vent is audible for a distance of a hundred yards or so.

A photograph of the spring is shown in Plate XII, Fig. 2. The pool is about 3 feet in diameter and set in travertine limestone. The water level appears to be static and the temperature of the water is that of a hot bath, i.e., about 130°F. A sample of gas over water was taken from the pool and subsequently analysed by the Government Chemist, London, who obtained the following composition:—

		% by vol.
Carbon dioxide		99·2
Hydrogen sulphide		not detected
Carbon monoxide	less than	0·1
Oxygen		0·2
Hydrogen	less than	0·1
Hydrocarbons (as methane) ...	less than	0·1
Helium	less than	0·01
Nitrogen and other inert gases (by difference) ...		0·6

(J. 4060)

Using an ordinary 670 cc. brandy bottle inverted over the gas bubbles in the water it is estimated that 500 ccs. of gas were collected in about three minutes. The gas bubbles cover two areas in the pool continuously and these are estimated to be about one foot and nine inches in diameter respectively. Probably fifty per cent. of these areas are covered at any moment by gas. The chances of collecting gas bubbles was probably increased by two by moving the sample bottle about in the pool. The quantity of gas emitted from this pool is thus estimated to be of the order of 20 to 30 litres per minute or about 1 cubic foot per minute. This is an unsatisfactory method of calculating the yield and a more exact measurement could be easily obtained by capping the pool and measuring the amount of water displaced in a large receptacle.

(d) Main Hot Springs

The Main Springs occur on what is possibly a small fault scarp about 30 feet in height overlooking the Songwe River at a distance of about 300 yards to the east. The escarpment is about 150 yards long and strikes to the north-west, see Plate XIII, Fig. 2. There are three large spring-vents situated at or near the top of the scarp and from each of these, deposits of calcareous tuffa have been laid down over the travertine limestone through which the springs rise. Some older deposits of tuffa have been laid down from vents now extinct.

The temperature of the water issuing from the springs is estimated to be 130° to 150°F. A few bubbles of gas were observed to issue from two of the vents. The other vent is located in a horizontal joint and the point of issue cannot be observed. The total flow of water from all vents is estimated to be of the order of 2 cusecs.

V. Origin of the Hot Springs

An examination has recently been made of the analyses of gas and brines from all known hot and cold springs and also some ground-waters in the Territory. Springs with similar composition of gas and brine to those in the Songwe River valley are known from ten other localities, although at most of these the gases contain a higher proportion of nitrogen and other inert gases. From the location and distribution of these other occurrences it is inferred that the gas-bearing springs are of volcanic origin and that they are probably fumarolic in nature.

Analyses of similar gases from hot springs in Tanganyika are quoted below. The gas from the Kondoa cold spring is included to illustrate the nitrogen-rich type; that from the Yellowstone National Park is an example from a well-established volcanic area.

	I*	II*	III*	IV
Carbon dioxide	89·9	12·4	3·9	98·67
Hydrogen sulphide	n.d.	2·5		0
Carbon monoxide	n.d.		n.d.	
Oxygen	0·9	0·2	2·7	0·66
Hydrogen	n.d.		n.d.	0
Hydrocarbons (expressed as methane)	n.d.	0·8	n.d.	0
Helium	0·06	0·25	0·3	
Argon, (Krypton, Neon, Xenon)			1·0	
Nitrogen and other inert gases (by difference)	9·8	83·9	91·5	0·67

n.d. = not detected.

I. Maji ya Weta hot spring, Morogoro District, Eastern Province, Tanganyika.
II. Utete hot spring, Rufiji District, Eastern Province, Tanganyika.
III. Kondoa cold spring, Kondoa District, Central Province, Tanganyika.
IV. Sulphur Spring, Mammoth Hot Springs, Yellowstone National Park, U.S.A. (see Day and Allen, 1925).

Gases of similar composition are known from various parts of the U.S.A. and New Zealand and in every case the hot springs are ascribed to fumarolic activity closely connected with nearby volcanism. The usual type of gas emitted at these occurrences is composed principally of carbon dioxide.

*Analysis by Government Chemist, London.

The volcano, Rungwe, active in historic times, is 32 miles to the south-east of the Songwe River springs; several groups of hot springs are known in its vicinity. The carbonatite at Panda Hill represents an eroded volcano of considerable antiquity, but the hot springs may be a dying phase of this volcanism.

VI. Uses of Carbon Dioxide

Carbon dioxide has a wide variety of uses and the reader is referred to suitable text books on the subject. A good summary is contained in the text book, "Non-metallic Minerals" by Ladoo and Myers, 1951, and the section on Utilization is quoted in full.

"New uses are continually being found. The most important are the carbonation of beverages and refrigeration of perishable products. Liquid carbon dioxide is commonly used in the preparation of soft drinks. This is transported in steel containers to the bottling plants for conversion to gas and introduction in the bottle. Solid material is extensively employed in the protection of ice-cream and in the refrigeration of trucks and cars used to transport perishable commodities. It is employed as a chilling agent in many industrial operations, as an inflator of life rafts, fire extinguisher, agent for the manufacture of cellular mixtures, raw material for the preparation of soda ash and other carbonates, explosive in coal mining, and as an aid to cause precipitation and induce rainfall. Direct application of the gas to the soil to accelerate plant growth has been studied for years. In 1948 consumption of liquified gas was reported at 244,184,000 lb. while use of the solid amounted to 494,926,000 lb. Liquified gas in cylinders sells for about 6 cents per pound" (about 40 cents per pound East African currency).

Additional uses quoted from other sources are, in the preparation of blood plasma, the manufacture of penicillin and of synthetic rubber. It is also used in the manufacture of varnish and sundry chemicals, to stop the flow of water in pipes, shafts, etc., and to kill rats and vermin.

VII. Further Investigation of the Deposits

Similar natural gas wells are being used extensively in other parts of the world for the production of solid and liquid carbon dioxide and are considered to be good local sources. The economic future of the Songwe gas wells will depend firstly on the internal demand in the Territory for such a product and secondly on the yield of gas from the wells.

The "Gas" Hot Spring is evidently the best occurrence and an attempt should be made to cap the pool and make accurate measurements over a period of time of the flow of gas. It is not anticipated that any difficulty will be experienced in capping the pool. The yield of gas might be increased by enlarging the vent, but this should be done with extreme caution since the spring channel is almost certainly sealed with secondary tuffa. If this seal is broken the flow of water and gas may be diverted and dissipated underground.

Other springs in the area, such as Rambo Spring, might profitably be drilled since the yield of gas is at present small.

VIII. Conclusions and Recommendations

If a demand for solid and liquid carbon dioxide can be found within the Territory, the "Gas" Hot Spring in the Songwe River Valley is possibly a suitable source. The spring liberates gas containing 99·2 per cent. carbon dioxide, 0·2 per cent. oxygen and 0·6 per cent. nitrogen at an estimated rate of 1 cubic foot per minute. The vent should be capped and accurate measurements made of the yield.

Drilling at Rambo and River Springs might increase the quantity of gas delivered to the surface.

IX. References

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