SOUTHERN RHODESIA.

GEOLOGICAL SURVEY BULLETIN
No. **23.**

A Preliminary Report on the Mineral Springs of Southern Rhodesia.

By H. B. Maufe, M A., F.G.S.

Issued by Authority.

CONTENTS.

ILLUSTRATIONS.

A Preliminary Report on the Mineral Springs of Southern Rhodesia.

INTRODUCTION.

Not much interest has been taken up to the present in the mineral springs of Southern Rhodesia, and certainly very little use has been made of them. Exceptions to the latter statement are the use of "The Hot Springs," Mutambara, and to some extent the Rupisi hot spring in the same district, for health purposes; the experiments to extract commercial salt from the Nichenge brine springs; and the use of the dilute Sunga springs to form an important part of the Wankie water supply. Apart from the above the natives extract a salt from some of the spring waters or from the vleis into which they flow, and perhaps use some for medicinal purposes.

PREVIOUS INVESTIGATIONS.

The first account of an exact nature of any Rhodesian springs was given in a paper by D. Ferguson (1) in 1902. A. J. C. Molyneux (2) and F. P. Mennell (3) made contributions soon afterwards.

Since the inception of the Geological Survey information about the springs has been collected as opportunity offered, and B. Lightfoot (4) recorded observations in Bulletin No. 4 on "The Geology of the North-Western Part of the Wankie Coalfield."

The general information gathered was collated in 1916 and sent to Professor M. M. Rindl (5), Grey University College, Bloemfontein, who made use of it in his paper on "The Medicinal Springs of South Africa."

Thermal springs, the location of which was known, were marked on the Provisional Geological Maps of Southern Rhodesia (6) published in 1921 and 1928 respectively.

A further systematic collation of the information on the Geological Survey files was made by Mr. S. C. Morgan in 1928, and this information was sent to Professor Rindl (7), who made use of some of it in one of his supplementary papers on the medicinal springs of South Africa. Mr. Morgan's compilation has been thoroughly revised and brought up to date.

In this work the writer has had the assistance of Mr. E. Golding, Chemist to the Geological Survey, who, apart from contributing the original analyses, has re-calculated the older analyses to those of the International Standard Measurements.

A LIST OF MINERAL SPRINGS IN SOUTHERN RHODESIA AND CLOSE TO ITS BORDERS.

No.	Name.	Solids. Parts per million.	Chief ions.	Temp. °C.	Height above sea level.	Formation and deposits.
	LOMAGUNDI DISTRICT.					
2601	Chipiso thermal spring	1321	SO_4, Na	hot	—	Gneiss near down-faulted Karroo beds. Calcareous sinter and salt deposited
2602	Mendayatswa ooze	1583	SO_4, Na	circ. 50°	1270	Karroo beds ? faulted
2603	Kalishe swamp	2234	SO_4, Na	cold	1350	Karroo beds
2604	Thermal spring	—	—	—	—	—
	MELSETTER DISTRICT.					
3101	Mwengezi thermal spring	354	HCO_3, Na, some H_2S	53°	2050	Near fault in Archaean granite
3102	"The Hot Springs," Mutambara	368	HCO_3, Na, some H_2S	36° to 56°	2000	Fault between Umkondo beds and Archaean
3103	Rupisi hot spring	389	HCO_3, Na, some H_2S	62°	1680	Gneiss perhaps near fault
3104	Sulphurous spring	—	Some H_2S	cold	—	? Archaean
3105	Dunstan spring	273	SO_4, Na, Ca	tepid	—	Umkondo beds
3106	Chimanimani geyser	—	—	? hot	—	? Frontier system
3107	Chiwichuhagwe thermal spring	—	—	? hot	—	Intrusive contact of granite with Karroo basalts
	SEBUNGWE DISTRICT.					
3701	Kabira (or Zongala) gushers	622	Cl, K, some H_2S	52° to 97°	2019	Karroo beds
3702	Lubimbi thermal spring	1290	Cl, CO_3, SO_4, Na, some H_2S	hot	below 3000	Karroo beds

3703	Sampakaluma thermal spring	—	Probably Cl	boiling	1551	Karroo beds
3704	Thermal spring	—	—	—	—	Karroo beds
3705	Sibila thermal spring	—	Some H_2S	warm	—	Madumabisa Shales of the Karroo system
3706	Sinesitonko thermal spring	—	Some H_2S	hot	—	Madumabisa Shales of the Karroo system
	Umtali District.					
3901	Spring	—	? CO_3, Na	cold	about 2000	—
	Victoria District.					
4101	Thermal spring	—	Some H_2S	? warm	—	Granite
	Wankie District.					
4201	Gobo springs	2960	Cl, Na, some H_2S	cold	about 2500	Fault in Karroo beds
4202	Sulphur spring	—	Some H_2S	cold	about 2600	Batoka Basalts
4203	Chawato springs	4367	Cl, Na, H_2S	13.3°	about 2600	Karroo beds near faults
4204	Nichenge brine springs	6621	Cl, Na	one warm	3050	Archaean granite
4205	Sidenda thermal spring	—	? Cl, ? Na	? very hot	about 2000	? Batoka Basalts
4206	Bidida thermal spring	—	? Cl, ? Na	? warm	—	Karroo beds
4207	Shumba thermal springs	—	—	warm	—	Karroo beds
4208	Sunga thermal springs	576	CO_3, Na	warm	1990	Fault between Karroo sandstones and basalts
4209	Sigobomo or Elephant spring	3771	SO_4, Ca	cold	2440	Kalahari sand overlying Karroo beds

No.	Name.	Solids. Parts per million.	Chief ions.	Temp. °C.	Height above sea level.	Formation and deposits.
4210	Sigobonya thermal spring	—	—	? hot	—	? Basalt
4211	No. 9 bore-hole water	732	SO_4, Na	cold	2295	Karroo beds
4212	Chigwadada thermal spring	—	—	tepid	—	Karroo beds
4213	Sakabika thermal spring	—	—	warm	—	Archaean granite
	BECHUANALAND PROTECTORATE near the Southern Rhodesia border.					
4301	Nungwe thermal spring	10802	Cl, SO_4, Na	warm	—	? Batoka Basalts
	NORTHERN RHODESIA near the Zambezi river.					
4401	Thermal spring	—	? Cl, Na	hot	—	Batoka Basalts
4402	Chilundu springs	—	—	31°	—	? Karroo beds. Some sinter
4403	Chilambwa thermal springs	—	? Cl, Na	90°	—	? Basalt. Some sinter and salt
4404	Manzaia thermal spring	—	—	66°	—	? Karroo beds
4405	Kapesa (or Chatenta) thermal spring	—	S, ? Cl, Na	73°	—	Karroo beds. Some sinter
4406	Spring	—	—	—	—	Sandstone
4407	Spring (? gusher)	—	—	? tepid	—	Some travertine deposited
4408	Nakuyu springs	—	? Cl, Na	32°	—	Karroo beds
4409	Kabwili ooze	—	? Cl, Na	21°	—	? Karroo beds
	PORTUGUESE EAST AFRICA near the Southern Rhodesia border.					
4501	Thermal spring	—	—	—	—	? Frontier system
4502	Thermal spring	—	—	—	—	? Karroo beds
4503	Shaiva thermal spring	—	—	—	—	Karroo beds

DISTRIBUTION OF THE MINERAL SPRINGS.

In all, thirty-two localities have been recorded in Southern Rhodesia, but as the issue of mineral springs knows no political boundaries and as a number issue just without the boundaries of Southern Rhodesia, particularly on the left bank of the Zambezi river, such information as has been obtainable about another thirteen springs closely related to those issuing in Southern Rhodesia has been included in the foregoing list.

The localities of all these springs have been plotted on the map at the end of the volume. It shows their distribution in a striking way: namely, a group aligned south-west to north-east down the Zambezi valley and another one aligned north to south down the eastern border. There is some evidence for an east to west line of springs on the right flank of the Limpopo valley in the northern Transvaal, but there appears to be only one of this group recorded as issuing within the area of the map: namely, the Stindal spring east of Rhodes' Drift (Rindl, 5) about which no further information is available. The only recorded exception to this remarkable distribution is the small thermal spring, 4101, on the right bank of the Mtilikwe river south of Fort Victoria.

THEIR RELATION TO THE GEOLOGICAL STRUCTURE.

It may be said at once that the two groups issue in those two areas in which faulting and the displacement of blocks and strips of the earth's crust have taken place in times later than the outpouring of basaltic lavas at the end of the Karroo period. It is in the same two areas that slight earthquake shocks are felt more often than in other parts of the Colony. Before the age of the lavas was established, and they were thought to be of Tertiary age or even younger, the hot springs were believed to represent the closing phase of that period of volcanic activity. It now appears that there is no connexion between the extrusion of the Karroo lavas and the present day hot springs, and the origin of the latter must be sought in other directions.

The chief known faults of post-Karroo age are shown on the map, and it is very evident that there is a close correspondence between the distribution of the mineral springs and that of the faults. This is well shown in the country around Wankie, which has been mapped in detail (4, 8).

Here the Sunga thermal spring may actually be seen to issue from the fault fissure. "The Hot Springs" in the Mutambara Reserve also issue on or close to the line of a powerful fault.

The effect of the faults in the Zambezi valley has been to throw down strips or blocks of Karroo beds to lower levels. Frequently a suite of more or less parallel faults throws down the beds in a succession of steps, but in places a strip of country is let down into a trough between opposing faults. In the list of springs it will be noticed that a large majority of those belonging to the Zambezi group issue from the sediments and lavas of the Karroo system. The exceptions which issue from Archaean rocks appear in or in the vicinity of down-faulted blocks or strips of Karroo rocks.

The thickness of the Karroo sediments in the Wankie District is less than 1,700 feet (8), and this thickness is not likely to be greatly increased down the Zambezi valley. It will be shown later that many of the thermal springs must arise from much greater depths than 1,700 feet. They must therefore arise in the underlying Archaean complex. The fact that in the foregoing list so many springs are noted as issuing from Karroo beds is not to be taken as indicating a direct association of the mineral springs with the Karroo system. The connexion is between the mineral springs and the belts of faulted country, that is, with the geological structure, not the geological formation. A case in which the influence of the Karroo formation has determined the character of a mineral spring water is that of the Sigobomo spring, 4209, discussed in the final section of this bulletin.

The Melsetter District is stepped down towards the west by two powerful faults trending north and south. Two of the better known springs issue from, or in close proximity to, the more westerly fault. The line of the eastern fault and the position of the springs in its vicinity is too little known to make any definite statement on the relationship. Both faults affect the dolerite sills which are intruded not only into the Umkondo beds but into the Karroo rocks situated to the west of the Sabi valley. These faults are therefore, so far as we can tell, of about the same age as those of the Zambezi valley. Both series are apparently an extension of the more intensive movements which took place at intervals throughout several geological periods in central and east central Africa, and culminated in the formation of the well-known Rift Valleys of that region. The volcanic activity associated with those movements, which probably commenced in Upper Cretaceous times, has extended throughout the Tertiary period and is not yet at an end as is evidenced by the recently active volcanoes of Teleki and Donyo Ngai.

It is more reasonable, therefore, to connect the earth movements and thermal springs of the Zambezi valley and of the eastern border with the earth movements, volcanoes, fumaroles, etc., of east central Africa than with the much older period of volcanic activity in late Karroo times.

THE ORIGIN OF THE THERMAL SPRINGS.

Two distinct hypotheses have been put forward to account for the origin of thermal springs. In the one it is thought that in these step-faulted and trough-faulted regions which are therefore subject to tensional stresses, there are fissures, whether fault fissures or not, penetrating sufficiently deeply into the earth's crust and sufficiently open to permit the percolation of waters from the surface. The water is thereby raised to the required temperature and may be brought to the surface again largely by hydrostatic pressure, but partly by convection. On this hypothesis thermal springs may be expected to issue generally on relatively low ground, and this certainly appears to be the case in this country. Of the springs whose altitude has been ascertained, only one issues above the 3,000 foot contour, whilst it is estimated that two thirds of the country lies above this altitude. A majority issue either somewhat above or a little below the 2,000 foot contour, and in this connexion it is to be remembered that very little land in Southern Rhodesia lies below the 1,000 foot contour.

Underground water acts chemically upon the rocks through which it moves, and dissolves some of its constituents. Hot water is naturally more active chemically, can dissolve more constituents and generally much larger quantities of them. The mineral content of thermal springs is, on the hypothesis under discussion, obtained from the rocks through which the water moves on its downward course, but more especially on its ascent to the surface in a heated condition.

The Depth of Origin. It is well known by reason of the temperature attained by the rocks in deep mines and boreholes that the temperature of the earth's crust rises at a fairly uniform rate as one descends into it. The water which percolates deep into the crust must reach almost exactly the temperature of the rock in which it moves before beginning its ascent. If we know the rate of increase of temperature (thermal gradient), it is easy to calculate the approximate depth from which a hot spring rises.

$$\text{Temp. of spring} = \text{mean ann. temp.} + \frac{\text{depth of origin}}{\text{depth for diff. of 1 deg.}}$$

Therefore, depth of origin = temp. of spring − mean ann. temp. × depth for diff. of 1 deg.

The thermal gradient in this country is known from observations made in the Globe and Phœnix Mine to be one degree Fahrenheit for 119 feet in granite country (9); that is, for every 119 feet of depth below the surface the temperature of the rocks rises one degree Fahrenheit.

The mean annual temperature at the spring must be calculated by allowing a rise of three degrees Fahrenheit for every 1,000 feet decrease of altitude below the nearest meteorological station.

In the case of "The Hot Springs," Mutambara, 3102, which lie 3,500 feet below Melsetter with a mean annual temperature of 62.9 degs. F., the mean annual temperature may be taken as 62.9 + 10.5 = 73.4 degs. F. As the temperature of the hot eye is 133 degs. F., the depth from which the water rises is:—

133 − 73.4 × 119 = 59.6 × 119 = 7,092 feet.

For the Rupisi hot springs, 3103, and for the Kabira gusher, 3701, the depths of origin appear to be approximately 8,300 and 15,300 feet respectively.

It is very difficult to imagine conditions in which fissures would remain so persistently open as to allow surface waters to percolate to these great depths continuously.

The second hypothesis on the origin of the water of thermal springs is based on the fact that all igneous rocks, including granite and other deep seated rocks that only appear at the surface through erosion of the rocks overlying them, contain water in appreciable amounts. Further, water mainly in the form of steam is given off copiously during volcanic eruptions and escapes in clouds from molten lava as it solidifies. It is not necessary to assume that the water of thermal springs is meteoric (surface) water which has descended into the crust and been returned to the surface. It may have been a constituent of the molten magmas of the interior. Such waters which are thought to have reached the earth's surface for the first time are known as juvenile waters, in contrast with meteoric waters which have penetrated from the surface and are known as vadose.

The distribution of the mineral springs in Southern Rhodesia in the faulted regions, which appear to be a prolongation of the more intensely faulted regions situated to the north in which volcanic activity has been rife and is not yet extinct, is quite in accord with this hypothesis.

If the temperature of the rocks forming the walls of the faults is raised by friction due to fault movements or by an underlying body of molten magma which has moved up from greater depths, then the thermal gradient is increased, and the depth of origin of the springs will be less than that calculated by the formula given above.

THE NATURE OF THE MINERAL SPRING WATERS.

The waters of all springs and of the underground reservoirs from which they issue contain some mineral matter and some gases in solution. The waters of mineral springs are characterized by a notable amount of these substances in solution. The dividing line between mineral springs and ordinary springs is thus purely arbitrary. It is often taken for convenience at a tenor of one gram of dissolved solids per litre (equals 70.15 grains per gallon). In terms of the units recommended for use by the International Committee on Standard Measurements in 1929 (10) and used throughout this report, one gram per litre is, of course, represented by 1,000 parts of solids per million. On this basis it will be noticed that a number of the springs, for example, the Sunga springs, from which the water supply of Wankie is drawn in part, is strictly speaking not a mineral spring, but it is convenient to class this and other thermal springs as mineral springs.

It will be seen that all the waters are weak solutions, this being particularly noticeable in those in the Melsetter District. The three strongest solutions here recorded are the Nungwe spring just within the Bechuanaland Protectorate, No. 9 bore-hole water at Wankie and the water from the warm eye at the Nichenge brine springs. The last mentioned, with 6621.0 parts of dissolved solids per million, has only about one eighth the strength of the same brine collected from the development shaft in the vlei below the spring and containing 54,880 parts per million. This brine has, no doubt, been concentrated by evaporation, and it is likely that the same process has acted on No. 9 bore-hole water, for at times it reaches to a foot below the surface.

It is usual to classify a mineral water according to the dominant non-metallic constituent, acid radicle or anion dissolved in it. The mineral springs of Southern Rhodesia thus fall into three main classes, namely: chloride waters, sulphate waters and carbonate waters. A fourth class contains the mixed or indifferent waters, that is, those without one predominant anion. Any of these waters may also contain sulphuretted hydrogen (H_2S), easily recognizable by its smell of rotten eggs. This gas is recorded from twelve out of the thirty two mineral springs, as follows: 3101, Mwengezi; 3102, "The Hot Springs," Mutambara; 3103, Rupisi hot spring; 3104, spring; 3701, Kabira; 3702, Lubimbi; 3705, Sibila; 3706, Sinesitonko; 4101, Thermal spring; 4201, Gobo; 4202, Sulphur spring and 4203, Chawato. The presence of the gas sometimes forms the criterion for a class of "sulphuretted waters," but the quantity in Rhodesian waters is always small and the above group manifestly comprises waters of different types.

Chalybeate waters rich in iron compounds undoubtedly occur in Southern Rhodesia, but there is not sufficient known about any of them to bring them into this account.

Another class is that of the silicated waters containing silica which is deposited in the form of siliceous sinter. Apparently the Kabira gusher (3701) is the only Southern Rhodesian spring which deposits any appreciable amount of siliceous sinter. The three thermal bicarbonate waters, 3101/3, from the Melsetter District are comparatively rich in silica, doubtless owing to their relatively high content of alkaline bicarbonate.

No estimation of the radio-activity of any of the mineral spring waters appears to have been made.

SOUTHERN RHODESIAN MINERAL WATERS CLASSIFIED BY COMPOSITION.

Parts per million or milligrams per litre.

		Nitrate	Chloride	Sulphate	Bicarbonate	Carbonate	Potassium	Sodium	Calcium	Magnesium	Alumina and iron oxide	Silica	Totals
CHLORIDE WATERS.													
Kabira	3701	—	274.2	—	—	12.6	215.9	50.9	8.4	—	—	60.0	622.0
Gobo	4201	trace	1285.1	229.3	—	282.7	33.5	978.7	91.5	29.6	6.2	24.0	2960.6
Chawato	4203	trace	1963.2	288.5	—	391.7	35.1	1537.4	84.1	30.2	4.0	32.8	4367.0
Nichenge ...	4204	nil	3195.0	520.5	389.7	23.8	2264.9 (Potassium and Sodium)		140.4	28.7	14.4	44.0	6621.0
SULPHATO-CHLORIDE WATER.													
Nungwe, B.P.	4301	nil	3510.5	3368.5	—	28.0	trace	3395.7	425.9	28.3	8.0	37.6	10802.5
SULPHATE WATERS.													
Chipiso	2601	nil	78.1	613.1	—	87.3	30.2	326.5	50.0	5.0	11.0	120.0	1321.2
Mendayatswa	2602	nil	200.2	748.2	—	42.0	7.2	425.3	72.0	4.2	4.0	80.0	1583.1
Kalishe	2603	1.5	319.1	1005.1	—	83.9	—	667.1	75.1	trace	trace	82.0	2233.8
Dunstan	3105	trace	14.2	113.2	—	49.1	2.4	49.4	31.4	8.6	4.4	trace	272.7
Sigobomo ...	4209	trace	53.3	2544.2	—	29.2	241.5 (Potassium and Sodium)		610.0	166.7	Fe 5.0 Al 17.0	98.4	*3771.2
No. 9 bore-hole, Wankie	4211	—	73.5	6631.1	—	511.7	—	2540.9	328.2	368.8	—	7.1	10461.3

Parts per million or milligrams per litre.

		Nitrate	Chloride	Sulphate	Bicarbonate	Carbonate	Potassium	Sodium	Calcium	Magnesium	Alumina and iron oxide	Silica	Totals
CARBONATE WATERS.													
Mwengezi ...	3101	n.d.	33.2	32.2	127.8	8.8	n.d.	85.1	3.4	1.4	7.8	53.6	353.3
"The Hot Springs"	3102	nil	35.5	50.7	97.8	5.7	3.1	82.5	1.4	1.5	6.0	83.6	367.9
Rupisi	3103	n.d.	48.9	21.6	127.8	6.6	—	90.3	3.2	0.7	2.1	87.4	388.6
Sunga	4208	n.d.	74.0	62.4	—	198.6	—	126.7	54.1	18.2	6.4	36.0	576.4
TRIPLE WATER.													
Lubimbi	3702	—	330.1	161.0	—	234.0	n.d.	420.7	34.0	5.5	7.0	98.0	1290.3
													*Mn 5.9

Only fifteen out of the thirty-two recorded mineral springs of Southern Rhodesia have been analysed and one from the Bechuanaland Protectorate near the Southern Rhodesia border. These are classified in the foregoing table in a form which allows easy comparison.

The three chloride waters from the Wankie District comprise a uniform group of weak brines. The high potassium content of the Kabira gusher, 3701, is noteworthy.

Amongst the six sulphate waters the three from the Lomagundi District are closely comparable. The Sigobomo spring, 4209, has calcium predominant over sodium. This spring and the Kabira gusher, 3701, are the only exceptions to the rule that sodium is the predominant metallic radicle or kation amongst the Southern Rhodesian mineral waters. In describing this spring it is pointed out that the mineral content of the water is probably derived from the underlying rocks at no great depth. It is probably a vadose water, and the same explanation may apply to the Dunstan spring, 3105.

The three bicarbonate waters (3101/3) from the line of the Sabi fault are also closely comparable, and noteworthy for their high content of silica. These three springs have the characters assigned to juvenile waters. The table is not free from the slight ambiguity due to the different ways of stating the analysis of a carbonate water. The carbon dioxide may be reported in terms of the bicarbonate ion (HCO_3) in the presence of which larger quantities of calcium, magnesium, iron and silica may remain in solution, or it may be reported as the carbonate ion (CO_3). In the latter case the statement of the analysis is considered from the point of view of the anhydrous residue obtained from the evaporation of the water. In such a residue no bicarbonate would exist, with the possible exception of sodium bicarbonate in certain circumstances. It has been thought best to quote the analysis in the form given originally.

The Lubimbi thermal spring, 3702, seems best classified as a triple water.

In the following table some analyses of well-known European and South African mineral springs are quoted for comparison. The data for the European springs have been taken from de Launay's "Recherche, captage et aménagement des sources thermo-minérales" (Paris, 1899); those for the South African springs from Professor Rindl's papers (5, 7), and converted, where necessary, to the standard units used in this report.

ANALYSES OF SOME EUROPEAN AND SOUTH AFRICAN MINERAL WATERS.

Parts per million or milligrams per litre.

	Chloride	Sulphate	Bicarbonate	Carbonate	Potassium	Sodium	Calcium	Magnesium	Alumina	Iron oxide	Silica		Totals
CHLORIDE WATERS.													
Kissengen, Bavaria	96050.4	20.7	—	—	—	63286.8	—	—	—	—	—		159357.9
Wiesbaden, Prussia	4670.0	60.4	—	260.4	70.1	2695.7	370.8	53.3	—	—	60.4	Br, I, Mn, Li traces	8241.1
Warmbad, S.W.A.	7077.0	5452.0	426.8	—	95.7	5489.2	1632.2	55.0	9.1	12.0	831.5	NO_3 trace	21080.5
SULPHATE WATER.													
Bath, England ...	167.1	1264.0	—	—	—	108.7	432.7	58.5	—	—	—		2031.0
CARBONATE WATERS.													
Vichy (Hôpital), France	340.3	176.3	2140.0	1020.0	170.0	1854.0	160.0	12.0	—	—	60.0	Li = 1.0	5953.6
Warmbaths, Transvaal	850.0	110.0	—	950.0	90.0	1210.0	110.0	trace	—	—	—	As_2O_5 = trace P_2O_5 = 20.0 Li trace	3320.0
CHALYBEATE WATER.													
Caledon, C.P. ...	397.6	139.2	225.7	—	210.6	98.9	67.1	32.4	86.4	134.4	—		1392.3

* Parts per million or milligrams per litre.

	Chloride	Sulphate	Bicarbonate	Carbonate	Potassium	Sodium	Calcium	Magnesium	Alumina	Iron oxide	Silica		Totals
SULPHURETTED WATERS.													
Aix les Bains, France	18.1	145.4	—	120.0	—	22.6	101.3	16.3	—	4.8	40.1	I trace P_2O_5 = 6.0 S_2O_3 = 2.1 H_2S = 4.2 Li trace	480.9
Cauterets, France	36.0	23.6	—	—	2.7	59.9	—	—	—	—	58.8	Br, I, B, P traces; SO_3 = 6.4 S = 8.0	195.4
Malmesbury, C.P.	5611.0	522.0	797.1	—	trace	3620.6	515.7	37.8	15.4	7.7	—	Br = 9.1 free H_2S = 74.4 free CO_2 = 66.0	11276.8
MIXED WATERS.													
Karlsbad, Czecho-Slovakia	630.0	1749.0	—	860.2	713.0	1246.0	122.5	51.0	—	1.7	75.0	Sr = 0.6 Mn = 0.4	5449.4
Montagu, C.P. ...	132.6	161.6	181.4	—	35.1	86.8	62.0	26.6	51.9	2.7	115.8	Li = 0.16	856.7

TABLE OF DISTRIBUTION OF CLASSES OF MINERAL WATERS.

	B.P. border	N.R. border	Wankie	Sebungwe	Lomagundi	Umtali	Victoria	Melsetter	P.E.A. border	Total for S. Rhodesia	Totals
Chloride waters	...	...	3	1	...	...	...	...	...	4	4
Sulphate waters	...	...	2	...	3	...	...	1	...	6	6
Carbonate waters	...	..	1	...	...	...	...	3	...	4	4
Waters of mixed type	1	...	...	1	...	...	...	...	...	1	2
Unclassified, probably chloride	...	5	2	1	...	...	...	...	...	3	8
Unclassified, probably carbonate	...	...	...	...	...	1	...	..	...	1	1
Unclassified	...	4	5	3	1	...	1	3	3	13	20
Number of springs	1	9	13	6	4	1	1	7	3	32	45
Reported to contain sulphuretted hydrogen	...	...	3	2	...	...	1	4	...	10	10

The table above shows the distribution of the classes of mineral waters and the number in each class, but in the absence of definite knowledge about so many of the springs it is difficult to make any useful generalizations. The table suggests that chloride waters predominate in the Wankie District and immediately north of the Zambezi. These chloride waters, except the Kabira gusher, are brines, but in describing the Nichenge springs (4204) it has been pointed out that there are no reasons for thinking that they indicate the presence of bodies of rock salt amongst the beds of the Karroo system. Sulphate waters appear to predominate in the Lomagundi District and bicarbonate waters in the Sabi valley.

TEMPERATURE OF THE THERMAL SPRINGS.

Twenty-three out of the thirty-two recorded mineral springs in Southern Rhodesia may be described as thermal springs, though in a number of cases the temperature has not been accurately determined. It is difficult to be accurate about the temperature without the use of a thermometer, but it may be remarked here that a water that is only just bearable by the hand would have a temperature near 50 degs. C., though it is possible to drink a water up to about 55 degs. C. Waters above this temperature are, in the absence of a thermometer, best reported as very hot or scalding. The presence of bubbles of gas frequently leads to these waters being wrongly reported as boiling.

Just as in composition the difference between a mineral spring and an ordinary spring has to be taken at some arbitrary point, so in temperature a thermal spring is usually defined arbitrarily as one having a temperature of over 20 degs. C. (68 degs. F.).

The hottest recorded water is the potassium chloride water of the Kabira gusher at 97 degs. C., which is very near the boiling point of water at the altitude of the gusher. The alkaline bicarbonate water of the Rupisi hot springs appears to be boiling owing to the evolution of gas, but its temperature is only 62 degs. C. Three of the group issuing just across the northern Rhodesia border in the region of the Kabira gusher have temperatures higher than the latter.

The relation of temperature to depth of origin of the spring has already been discussed.

RATE OF FLOW.

The rate of flow has been measured in only a very few cases, namely:—

"The Hot Springs," Mutambara (3102), about 3,300 gallons per hour;

Shumba thermal spring (4207), estimated 5,000 to 10,000 gallons per hour;

Sunga spring (4208), not less than 25,000 gallons per hour;

Kabira gusher (3701), 3,600 gallons per hour;

Lubimbi thermal spring (3702), estimated 2 to 4 cusecs, say 45,500 to 91,000 gallons per hour.

The above includes some of the larger springs. Their rate of flow compares well with that of some of the well-known European mineral springs.

DEPOSITS FROM THE MINERAL SPRINGS.

The substances deposited by mineral waters on reaching the surface fall naturally into two classes: (1) the sinters, generally deposited round the eye of a spring and consisting of substances like silica or calcium carbonate not readily soluble in cold water; (2) salts, soluble in water and deposited generally as efflorescences in the dry season on the edges of pools or sluggish streams rising from the springs.

In no case are any extensive deposits found around any of the mineral springs in Southern Rhodesia. To some extent this is accounted for by the dilute character of the waters, but the nature of the waters is such as to lead us to expect soluble salt deposits in most cases, and these, if deposited in the dry season, are always likely to be re-dissolved in the following rains.

Siliceous and some calcareous sinter are reported from the Kabira gusher, 3701, and calcareous sinter with very small incrustations of sulphur and of sodium sulphate (Glauber's salt) from the Chipiso thermal springs, 2601.

Around the eye of the Lubimbi thermal spring, 3702, a salt consisting of nearly equal parts of sodium sulphate and chloride, with a little sodium carbonate, is deposited, whilst as an efflorescence around the spring is a salt consisting largely of sodium sulphate. Sodium sulphate efflorescences come from the Mendayatswa ooze, 2602, and the Kalishe swamp, 2603.

Common salt of a pleasantly "sweet" taste may be obtained at times around the Nichenge brine springs, 4204, and the natives are reported to obtain common salt for their own use from the deposits around some of the other brine springs, notably Sampakaluma, 3703. The spring 3901 in the Umtali District is said to deposit sodium carbonate (washing soda), but it has not been possible to confirm this by its examination.

THE INDIVIDUAL SPRINGS.

In this section the information about each spring has been collected under its own name and arranged in alphabetical order for convenient reference. In the numbers assigned to the springs the first two numerals refer to the district or country, namely Lomagundi 26; Melsetter 31; Sebungwe 37; Umtali 39; Victoria 41; Wankie 42; Bechuanaland Protectorate 43; Northern Rhodesia 44 and Portuguese East Africa 45. The two latter numerals represent the number assigned to the spring in the district or country. The springs will be found tabulated according to districts in the list on pages 8-10 and their location is indicated on the map at the end of the bulletin.

The recommendations of the International Society of Medical Hydrology in regard to international standard measurements of waters published in 1929 (10) have been followed in this report. Thus it is recommended that an "analysis, whether expressed in ions or salines, shall be in terms of parts per million; either as milligrams per litre or milligrams per kilogram." This column is headed "I.S.M.," an abbreviation for International Standard Measurement. The analysis is also to be expressed in terms of milli-normality or milli-mols. "This is defined as the number of times the molecular weight of the ion in milligrams is contained in a litre of water; it is the concentration of the ion in terms of the well-known chemical symbol N/1000." This will be found in the fourth column headed N/1000. The percentage composition of the solute, that is, of the solids dissolved in the water, has been calculated, and added in a fifth column. The first set of figures has been used in the table classifying the waters according to composition (pages 17-18).

A further recommendation is that "the analysis may also be expressed in salines, if these are computed by an arbitrary method of calculation which the Society approve for international adoption." This recommendation has been followed in each table headed "Hypothetical Composition of Salines." It is, of course, well known that the salts actually deposited on evaporation of a mineral water may vary in composition and in relative quantity according to the conditions under which the evaporation is carried out. It is quite unlikely that the salts obtained by successive fractional evaporations of a water would agree with the "hypothetical composition" except in the total amounts.

If an analysis was originally expressed in units differing from the above, such as in grains per gallon, the original analysis has, when possible, been quoted in full and then re-calculated in the above units.

If it be desired to convert the figures into grains per gallon, the figures given under parts per million should be divided by 14.25.

BIDIDA THERMAL SPRINGS, 4206.

A thermal brine spring is said to issue on a small stream very close to the path from Wankie to Kariangwe via the Lukosi valley, and nine to ten miles east of the Gwai river, Wankie District.

The formation in the neighbourhood is the Karroo sedimentary system.

Authority: native information per Mr. F. W. T. Posselt.

CHATENTA SPRINGS. *See Kapesa gushers* 4405.

CHAWATO SPRINGS, 4203.

The springs are situated about twenty miles south-west of Wankie railway station. They occur at the foot of a scarp facing north-east, within one mile of the source of the Mambani river, which flows north-east to join the Umkwisisi, a tributary of the Deka river, Wankie District. The position is shown on the map accompanying Geological Survey Bulletin No. 4, and lies about 2,600 feet above sea level.

The water is slightly turbid, is yellowish in colour, and has an offensive odour, which it appears is due in part to sulphuretted hydrogen.

The springs issue from a fire-clay bed underlying the Upper Wankie Sandstone of the Karroo system. The locality is much disturbed by faults, but the springs are not apparently associated with any fault seen on the surface.

Analysis by E. Golding (1928) of a sample collected by B. Lightfoot.

Lab. No. W.A.3		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	trace	...	...
Chloride	Cl	1963.2	55.30	44.97
Sulphate	SO_4	288.5	6.01	6.60
Carbonate	CO_3	391.7	13.05	8.97
Potassium	K	35.1	0.90	0.80
Sodium	Na	1537.4	66.84	35.20
Calcium	Ca	84.1	4.21	1.93
Magnesium	Mg	30.2	2.49	0.69
Alumina and iron oxide	Al_2O_3, Fe_2O_3	4.0	...	0.09
Silica	SiO_2	32.8	...	0.75
Total		4367.0		100.00

Hypothetical Composition of Salines

		Parts per million.
Potassium chloride	KCl	66.9
Sodium chloride	NaCl	3184.1
Sodium sulphate	Na_2SO_4	426.6
Sodium carbonate	Na_2CO_3	337.8
Calcium carbonate	$CaCO_3$	210.0
Magnesium carbonate	$MgCO_3$	104.8
Alumina and iron oxide	Al_2O_3, Fe_2O_3	4.0
Silica	SiO_2	32.8
Total		4367.0

The water is a weak brine with small amounts of carbonate and sulphate, sodium being the dominant kation.

Reference. Lightfoot, B. The Geology of the North-Western Part of the Wankie Coalfield. *Southern Rhodesia Geological Survey Bulletin No.* 4, pages 20 and 44. Bulawayo, 1914.

CHIGWADADA THERMAL SPRINGS, 4212.

The spring is situated near the right bank of the Lubu (? Sebungwe) river, about three miles above its confluence with the Zambezi river, Wankie District.

The spring issues at the head of a small glen eroded in the Karroo formation. The water is not very warm, and gives rise to a tiny rivulet.

Reference. Ferguson, D. The Geysers or Hot Springs of the Zambesi and Kafue Valleys. *Proceedings of the Rhodesia Scientific Association.* Vol. III, p. 10, 1902.

CHILAMBWA THERMAL SPRINGS, 4403.

The group is located in Northern Rhodesia, about 130 miles north-east of Wankie township. The springs are situated near the Chezia river at the foot of Chilambwa hill, and are about five miles from the Zambezi river. (See Plate II, A.)

Temperatures up to 90 degs. C. (194 degs. F.) have been registered. The water in some springs is stated to be boiling, and to gush from the rocks or from the stream bed in bubbling, steaming streams. A deposit, from which the natives extract salt, is associated with the cooler oozes belonging to the group. Siliceous sinter is deposited by the hottest springs.

The springs and oozes occur at intervals of a few feet for a distance of over 500 yards. The outflow from the springs forms a stream 18 inches wide and 6 inches deep. The formation from which they issue is believed to be basalt (Upper Karroo lavas).

Reference. Information from Mr. C. F. Molyneux dated 16th May, 1919.

CHIWICHUHAGWE THERMAL SPRINGS, 3107.

A spring having the above name is marked on the 1 : 250,000 map (sheet 18) of the Colony close to the Sabi river and in latitude 21 degs. 4 min. south. Other information indicates that it issues from the sand on the Melsetter side of the river and that it is hot, but nothing is known about its volume or the composition of its water. The above location plotted on to the Victoria Prospecting Company's geological map appears on the edge of an acid igneous complex of granite, syenite and more basic differentiates, which is intrusive into the Karroo basalt lavas. Across the Sabi river about 1½ miles west or north-west are the Loupangwan claims, on which copper and tungsten ores were located many years ago. These claims are in the Ndanga East Native Reserve.

Chilundu springs, 4402.

The group is situated at Chilundu, a mile from the confluence of the Zongwe and Zambezi rivers, draining towards the former and fifty feet above the latter. The confluence is about 110 miles north-east of Wankie township. The group is in Northern Rhodesia.

The highest temperature recorded is 31 degs. C. (88 degs. F.), the mean temperature of the Zambezi river water on the same date being 72 degs. F. A small amount of siliceous deposit is associated with the waters.

The group consists of three main springs with crater-like outlets and of oozes which extend at intervals of 80 to 100 yards in an east to west direction for a distance of about half a mile along the foot of a flat-topped range of hills rising 250 feet above the plain.

The rock formation in the area is believed to be Karroo.

Reference. Information from Mr. C. F. Molyneux dated 16th May, 1919.

Chimanimani geyser, 3106.

A true geyser, that is, a gusher with intermittent action, has been reported to issue on the plateau of the highest range of the Chimanimani mountains which trend north and south along the Portuguese East Africa border. Natives say that on occasions the water spurts forth to a height of several feet and then subsides.

Mr. J. L. Martin, M.P., states that he had heard a report of hot water spouting 12 to 15 inches out of the ground in the Chimanimani range, probably somewhere in the unalienated ground south of Chamois farm.

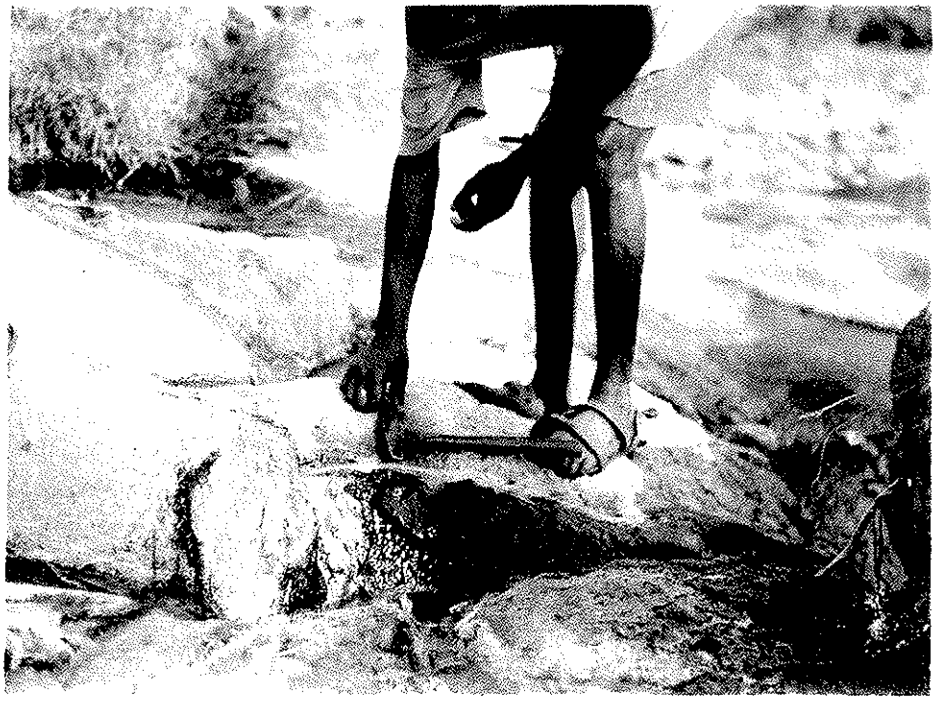
The Chimanimani range consists of intensely folded white quartzites older than the Umkondo quartzites from which they are separated by a powerful north and south fault.

Reference. "The Rhodesia Herald," dated 20th January, 1928.

PLATE I.

A. PHOTO. C. F. MOLYNEUX

The main jet at the Kabira or Zongala Gushers, No. 3701. Sebungwe District.



B. PHOTO. B.L.

The main jet at the Chipiso Thermal Springs, No. 2601. Lomagundi District.

ZINCO COLLOTYPE CO., EDINBURGH.

CHIPISO THERMAL SPRINGS, 2601.

Mr. Lightfoot writes: "These springs are situated beyond the north-west corner of the Urungwe Native Reserve, Lomagundi District. They can be reached by a Native Department road, which leaves the Sinoia-Miami road 4.9 miles before reaching Miami. At the Salvation Army Mission (24.1 miles) the road forks, and the turn to the right is taken. At 32 miles from the Mission Nematambo's kraal on the Gachegache river is reached, at which point the road ends.

A native footpath leads over a big range of hills, named Magumbura and composed of gneiss with foliation planes dipping steeply north. About 1½ hour's walk (say 4½ miles) brings one to the summit of the range, and three quarter of an hour's walk (say 2¼ miles) to the foot of the steep, scarp-like northern slope. On the descent the native guides pointed out the confluence of the Sundi and Gachegache rivers, towards which the path seemed to be heading. On reaching the foot of the range the path was left, and a northerly direction kept for 15 minutes (say ¾ mile) on heavy, sandy soil to the Sundi river. The dry bed of the meandering Sundi river was followed till some reedy pools were reached. In a few, low cliff sections here were exposures of flat-bedded sandstone and shale containing ill-assorted boulders of local types of gneiss. These beds resemble those described by Wagner (A Traverse through the Northern Portion of the Mazoe District, of Southern Rhodesia, into Portuguese Territory. *Trans. Geol. Soc. S.A.* Vol. XV, p. 135, 1912.) in the Mkumvura basin, and are most probably of Karroo age.

At the head of the pools a runnel of warm water comes in on the left bank. Following this south for about 170 yards the springs were reached. It is difficult to estimate the length of this part of the journey, but it cannot be much more than two miles. A communication from Mr. F. Hulley, dated 20th December, 1916, states that the spring is about 3 miles east of the confluence of the Sundi and Gachegache rivers.

The springs emerge at the foot of a steep scarp facing north, which rises up nearly 1,000 feet, and the rock from which they emerge is a muscovite-gneiss (probably a para-gneiss) with the planes of foliation dipping steeply north. The Karroo rocks mentioned above are probably faulted against this gneiss, and the point of emergence of the spring must be very close to the fault plane.

Above the main spring are two pools, the water flowing from which is lukewarm and has a strong saline taste. The floors of the pools are covered with white sediment looking like milk of sulphur.

There are two eyes to the main spring, the water of which is nearly boiling. The one is a jet about 16 inches long issuing almost horizontally (Plate I, B), whilst the other about 9 feet away, issues from a hole about 11 inches long and ·2 inches high at the level of the stream. From time to time the jet emits gurgling noises apparently due to steam bubbles. A smell of sulphuretted hydrogen (rotten eggs) is noticeable. Round the mouth of this jet was a deposit of white calcareous sinter (analysis below), whilst the rock is unpleasantly warm.

Below these two main eyes are two more pools into which springs also issue, as bubbles are seen to rise from their floor at intervals. The final flow of water is about 1 foot wide and 6 inches deep, and runs down into the Sundi river. The channel is full of algæ, which are apparently depositing lime.

In the river bed for about half a mile are pools with an abundant growth of reeds. The water is unpalatable, except that of the final pool, but it seems quite acceptable to elephant and rhinoceros which frequent the spot."

The three analyses given below show that the Chipiso spring water may be classed as a weak sulphate water in which the chief metallic base or positive ion is sodium.

Analyses by G. N. Blackshaw (1915 and 1920) and E. Golding (1929).

		I.S.M. Parts per million.			Milli-normality N/1000.			Solute per cent.		
		Agricultural Lab. No. 1280	Agricultural Lab. No. 140 G.	Geological Survey Lab. No. G.W. 10	Agricultural Lab. No. 1280	Agricultural Lab. No. 140 G.	Geological Survey Lab. No. G.W. 10	Agricultural Lab. No. 1280	Agricultural Lab. No. 140 G.	Geological Survey Lab. No. G.W. 10
		1915	1920	1929	1915	1920	1929	1915	1920	1929
Nitrate	NO_3	...	...	nil	...	...	...	...	...	...
Chloride	Cl	64.3	65.5	78.1	1.81	1.85	2.20	6.52	5.10	5.91
Sulphate	SO_4	563.9	604.0	613.1	11.75	12.58	12.77	57.19	47.04	46.41
Carbonate	CO_3	...	79.2	87.3	...	2.64	2.91	...	6.17	6.61
Potassium	K	...	35.0	30.2	...	0.90	0.77	...	2.73	2.29
Sodium	Na	224.3	328.0	326.5	9.75	14.26	14.17	22.75	25.55	24.71
Calcium	Ca	64.2	42.1	50.0	3.21	2.11	2.50	6.51	3.27	3.78
Magnesium	Mg	7.3	2.1	5.0	0.60	0.17	0.41	0.74	0.16	0.38
Alumina and iron oxide	Al_2O_3 Fe_2O_3	26.0	6.6	11.0				2.64	0.52	0.83
Silica	SiO_2	36.0	121.4	120.0				3.65	9.46	9.08
Totals		986.0	1283.9	1321.2				100.00	100.00	100.00
Sulphuretted hydrogen	H_2S	3.8								

Hypothetical Composition of Salines.

		Parts per million. Agricultural Lab. No. 1280. 1915	Agricultural Lab. No. 140 G. 1920	Geological Survey Lab. No. G W 10. 1929
Potassium chloride	KCl	...	66.7	57.6
Sodium chloride	$NaCl$	106.0	55.7	83.6
Sodium sulphate	Na_2SO_4	564.0	893.4	906.7
Sodium carbonate	Na_2CO_3	...	38.5	...
Calcium sulphate	$CaSO_4$	218.0	...	...
Calcium carbonate	$CaCO_3$	...	87.0	125.0
Magnesium sulphate	$MgSO_4$	36.0	...	...
Magnesium carbonate	$MgCO_3$	...	7.3	17.3
Calcium unaccounted	Ca	...	7.3	...
Alumina and iron oxide	Al_2O_3, Fe_2O_3	26.0	6.6	11.0
Silica	SiO_2	36.0	121.4	120.0
Totals		986.0	1283.9	1321.2

The sample for the 1920 analysis was sent in to the Agricultural Laboratory by Mr. F. Hulley, and was collected from the main eye. In his report (Agric. Lab. No. 140G) Mr. Blackshaw remarked that "the water was colourless, clear and contained only a small amount of suspended matter. No odour was perceptible from it, and it gave no reaction with lead acetate paper. It gave a faintly alkaline reaction with litmus." The temporary hardness is given as eleven degrees, the permanent hardness nil.

The sample for the 1929 analysis was collected from the main jet by Mr. Lightfoot, and agrees essentially with the 1920 analysis.

The first-quoted analysis, made by Mr. Blackshaw in 1915 on a sample of water submitted by the Chief Native Commissioner, is thought to have been taken from the main eye. Mr. Blackshaw remarked that the water smelt strongly of sulphuretted hydrogen, and he found that it contained 3.8 parts per million in solution.

In his report on the 1920 analysis he commented on the difference in the samples, notably shown by the fact that the 1915 sample possessed 26 degrees of permanent hardness. As no other sulphur spring is known in the neighbourhood, it is difficult to account for the differences. That the spring had changed in composition between 1915 and 1920 is a possibility for which there is no other evidence. If it did so, the change is not a continuous one, as is shown by the similarity in the 1920 and 1929 analyses.

Accompanying the 1915 sample were specimens of three deposits: (1) from the main eye consisted chiefly of sulphur; (2) "scrapings from rocks opposite the main spring" consisted chiefly of calcium carbonate and organic matter, and (3) described as "chemical left by steam condensing on rocks perpendicular to main exit," was found to be composed chiefly of sodium sulphate.

A sample collected by Mr. Lightfoot in 1929 of a deposit surrounding the jet was analysed in the Geological Survey Laboratory and found to consist of 92.80 per cent of calcium carbonate. The sulphur proved by analysis was seen under the microscope in a powdered portion of the incrustation to be free sulphur.

Analysis by E. Golding (1929) of incrustation from the main jet, Chipiso thermal spring, 2601.

Lab No. W.A. 11.

Sample dried at 150 degs. C.		Per cent.	
Silica and insoluble silicates	SiO_2	4.34	
Alumina	Al_2O_3	0.39	
Iron oxide	Fe_2O_3	0.49	
Magnesium oxide	MgO	0.75	
Calcium oxide	CaO	52.00	equivalent to 92.80% $CaCO_3$
Sodium oxide	Na_2O	0.35	
Potassium oxide	K_2O	trace	
Sulphur (free)	S	0.54	
Chlorine	Cl	nil	
Manganous oxide	MnO	0.15	
Loss on ignition	H_2O, CO_2 & organic matter.	41.54	
Total		100.55	

Carbon dioxide (determined) CO_2 41.01

References. Unpublished reports by G. N. Blackshaw, Chief Agricultural Chemist, dated 29th May, 1915 and 31st March, 1920.

Information from B. Lightfoot, 1929.

DUNSTAN SPRING, 3105.

A small lukewarm spring issues in a cold swamp in the centre of the southern part of Dunstan farm and on the road from Rocklands to Tilbury farm, Melsetter District.

An analysis of a sample sent in by Mr. J. L. Martin, M.P., to whom the above information is due, shows it to be a sulphate water, sodium not being greatly in excess of calcium.

Analysis by E. Golding (1929).

Lab. No. G.W. 9.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	trace	...	...
Chloride	Cl	14.2	0.400	5.21
Sulphate	SO_4	113.2	2.358	41.51
Carbonate	CO_3	49.1	1.636	18.01
Potassium	K	2.4	0.061	0.89
Sodium	Na	49.4	2.147	18.11
Calcium	Ca	31.4	1.570	11.52
Magnesium	Mg	8.6	0.910	3.14
Alumina and iron oxide	Al_2O_3,Fe_2O_3	4.4	...	1.61
Silica	SiO_2	trace	...	...
Totals		272.7		100.00

Hypothetical Composition of Salines.

		Parts per million.
Potassium chloride	KCl	4.6
Sodium chloride	NaCl	19.8
Sodium sulphate	Na_2SO_4	128.4
Calcium carbonate	$CaCO_3$	78.4
Magnesium carbonate	$MgCO_3$	4.0
Magnesium sulphate	$MgSO_4$	33.0
Alumina and iron oxide	Al_2O_3,Fe_2O_3	4.4
Silica	SiO_2	trace
Total		272.6

ELEPHANT SPRING. *See Sigobomo spring*, 4209.

GOBO SPRINGS, 4201.

The position of this group is plotted on the geological map accompanying the Southern Rhodesia Geological Survey Bulletin No. 4. It is situated about eight miles south-west of Deka siding on the Bulawayo-Victoria Falls railway line, Wankie District, and the altitude is about 2,500 feet.

The water is brackish to the taste, smells slightly of sulphuretted hydrogen and has a somewhat milky appearance. The natives do not consider the waters potable, and claim that they act as a purgative. Animals, however, drink the water.

Analysis by E. Golding (1928), of a sample collected by B. Lightfoot.

Lab No. W.A. 4.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	slight trace	...	...
Chloride	Cl	1285.1	36.200	43.41
Sulphate	SO_4	229.3	4.777	7.74
Carbonate	CO_3	282.7	9.423	9.55
Potassium	K	33.5	0.859	1.13
Sodium	Na	978.7	42.552	33.06
Calcium	Ca	91.5	4.575	3.09
Magnesium	Mg	29.6	2.446	1.00
Alumina and iron oxide	Al_2O_3, Fe_2O_3	6.2	...	0.21
Silica	SiO_2	24.0	...	0.81
Totals		2960.6		100.00

Hypothetical Composition of Salines.

		Parts per million.
Potassium chloride	KCl	64.0
Sodium chloride	NaCl	2067.6
Sodium sulphate	Na_2SO_4	339.1
Sodium carbonate	Na_2CO_3	128.8
Calcium carbonate	$CaCO_3$	228.4
Magnesium carbonate	$MgCO_3$	102.5
Alumina and iron oxide	Al_2O_3, Fe_2O_3	6.2
Silica	SiO_2	24.0
Total		2960.6

The water is a weak brine with small amounts of carbonate and sulphate, sodium being the dominant kation.

The group consists of a number of springs located along the line of the Gobo river fault which trends in a north-east to south-west direction through the Escarpment Grits of the Karroo system.

Reference. Lightfoot, B. The Geology of the North-Western Part of the Wankie Coalfield. *Southern Rhodesia Geological Survey Bulletin No.* 4, pp. 27 and 44, Bulawayo, 1914.

Kabira or Zongala gushers, 3701.

Mr. F. W. T. Posselt states that the native name is Kabira, meaning boiling water, though Mr. D. Ferguson in his published account uses the name Zongala, the origin of which is not given. The group is situated about one and three quarter miles from the south bank of the Zambezi river, four miles below Mosanga Island, near Fulunka's kraal, and about twelve miles from Chief Binga's kraal, Sebungwe District. Ferguson gives the longitude as 27 deg. 28 min. east, the latitude as 17 deg. 31 min. south and the altitude as 2,019 feet, the height above the Zambezi river being 345 feet.

The springs, eight in number, are of the gusher type. The largest is the so-called geyser, but it may more properly be called a jet. Water accompanied by steam is ejected from an orifice 1½ inches in diameter with a hissing sound. There is some evidence suggesting that the jet is weakening. In 1901 it was estimated to be eight to nine feet high, whilst in 1928 it was reported to have diminished to two feet. In Plate I, A, the photograph for which was taken at an intermediate period, the jet appears to have an intermediate height. It has been noted by observers that when the jet was plugged with a stick or a stone placed over the orifice, the flow of the adjacent springs increased. The water has a disagreeable taste.

The temperature of the various springs of the group ranges from 52 degs. C. (126 degs. F.) to 97 degs. C. (206 degs. F.). The last mentioned figure is close to the boiling point of water at the altitude of these springs. Ferguson gives the rate of flow as 3,600 gallons per hour, but Posselt places it at less than half the amount. It is possible that the supposed diminution in height is accompanied by a lessening of the volume.

Analysis by D. Ferguson (1902).

		Per cent.
Calcium carbonate	$CaCO_3$	0.00210
Potassium chloride	KCl	0.04117
Sodium chloride	NaCl	0.01293
Silica	SiO_2	0.00600
Total		0.06220

The table below shows the analysis re-calculated in ions. The composition of the water is shown in parts per million, and is followed by the milli-normality and by the percentage composition of the solute.

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	274.2	7.72	44.08
Carbonate	CO_3	12.6	0.42	2.03
Potassium	K	215.9	5.53	34.70
Sodium	Na	50.9	2.21	8.20
Calcium	Ca	8.4	0.42	1.35
Silica	SiO_2	60.0	...	9.64
Totals		622.0		100.00

Sulphuretted hydrogen is given off by the waters, and around the springs are deposits of siliceous and some calcareous sinter.

The springs are situated along the foot of a range of hills formed of sandstones, grits and conglomerates of the Karroo system, no volcanic rocks being seen anywhere near them. The rocks are stated to be tilted up in long step-like ridges.

References. Ferguson, D. The Geysers or Hot Springs of the Zambesi and Kafue Valleys. *Proceedings Rhodesia Scientific Association*, Vol III, pp. 11-13, 1902.

Unpublished communications from Mr. F. W. T. Posselt received 10th November, 1916, and from Lt. Col. Carbutt dated 3rd February, 1930.

Rindl, Professor M. M. The Medicinal Springs of South Africa. *South African Journal of Science*, Vol. XIII, p. 538, 1917.

KABWILI OOZE, 4409.

The ooze is located in Northern Rhodesia, about 18 miles south-west of the confluence of the Kafue river and about 10 miles west of the left bank of the Zambezi river.

The waters contain salt. The temperature when recorded was 21 degs. C. (70 degs. F.).

The waters are believed to come to the surface through rocks of Karroo age.

Reference. Information from Mr. C. F. Molyneux dated 16th May, 1919, and 11th April, 1929.

KALISHE SWAMP, 2603 (KARUSHU SALT PAN).

A reedy green swamp with patches of open water lies about three hundred yards east of the Miami-Chirundu aerodrome road three and a half miles before reaching the banks of the Zambezi river. This spot is 19½ miles beyond the road drift on the Nyamasanga river and at the south-eastern corner of the spurs from Chirundu hill, Lomagundi District. The 1932 survey for the Sinoia-Kafue railway route passes just to the east of it.

It is sometimes known as the Kirushu or Karusha salt pan, but it appears to be a permanent swamp into which a sulphate water oozes without visible flow. It measures about 125 yards across from north to south. From west to east it is somewhat longer, and seepage from it takes place to the east, in which direction there are said to be other oozes or springs. Kalishe is the name the natives give to the local efflorescences of salt, and it suggests a Portuguese origin. A slight efflorescence of a white, bitter salt is noticeable on the lumps of black soil in the swamp.

Kalishe swamp is about 100 feet above the Zambezi river, that is, it lies at an altitude of about 1,350 feet above sea level. A gravel containing well-rolled pebbles up to two inches long appears through the soil between it and the road, and it may represent an old terrace of the Zambezi river. A number of the pebbles have been broken and fashioned into implements by middle stone age man. The underlying formation, as seen by outcrops in the neighbourhood, consists of Chirundu sandstones and grits which probably belong to the Escarpment Grits (Upper Karroo).

The following figures are re-calculated from those of an analysis made by Geo. A. Pingstone, The Bulawayo Assay Office and Public Laboratory, Report No. 1903, 20th December, 1930.

Labelled water sample No. 35 from Karushu salt pan.

		Parts per million.	Milli-normality N/1000.	Percentage composition of solute.
Nitrate	NO_3	1.5	0.02	0.06
Chloride	Cl	319.1	8.99	14.29
Sulphate	SO_4	1005.1	20.94	45.00
Carbonate	CO_3	83.9	2.80	3.76
Sodium	Na	667.1	29.00	29.86
Calcium	Ca	75.1	3.76	3.36
Magnesium	Mg	trace	...	...
Alumina and iron oxide	Al_2O_3,Fe_2O_3	trace	...	...
Silica	SiO_2	82.0	...	3.67
Suspended matter		trace	...	...
Total		2233.8		100.00

Hypothetical Composition of Salines.

		Parts per million.
Sodium nitrate	$NaNO_3$	2.0
Sodium chloride	NaCl	526.1
Sodium sulphate	Na_2SO_4	1220.4
Sodium carbonate	Na_2CO_3	148.3
Calcium sulphate	$CaSO_4$	255.0
Magnesium sulphate	$MgSO_4$	trace
Silica	SiO_2	82.0
Total		2233.8

Organic Analysis.

	Parts per million.
Free ammonia	0.90
Albuminoid ammonia	0.40
Nitrogen as nitrates	0.38
Chlorine	319.50

The water forming the above sample was reported as slightly opalescent with a yellow tint, slight sediment, no smell, alkaline reaction. It was also pointed out that the water was organically impure. At the time of the author's visit the water had not recently been disturbed by animals. It was bright and clear, and not unpleasant to the taste.

A native stated that there were several salt crusts "fanika lo Epsom-salt" in the neighbouring country. The probability is that they are really Glauber's salt like the efflorescence from the Mendayatswa ooze and the one quoted below.

Analysis by E. Golding of surface salt deposit from Kalishe swamp.

Specimen received from J. E. S. Jeffares, Esq., Sinoia-Kafue Railway Survey: November, 1931.

Analysis of the salt gave the following results:—

		Per cent.
Nitrate	NO_3	nil
Chloride	Cl	2.84
Sulphate	SO_4	61.65
Carbonate	CO_3	0.27
Bicarbonate	HCO_3	1.38
Sodium	Na	31.36
Potassium	K	nil
Calcium	Ca	0.50
Magnesium	Mg	0.07
Alumina and iron oxide	Al_2O_3,Fe_2O_3	trace
Silica	SiO_2	0.67
Moisture at 110 degrees C.	H_2O	1.14
Total		99.88

Probable Composition of Salines.

Sodium chloride	NaCl	4.66
Sodium carbonate	Na_2CO_3	0.48
Sodium bicarbonate	$NaHCO_3$	1.90
Sodium sulphate	Na_2SO_4	88.97
Calcium sulphate	$CaSO_4$	1.70
Magnesium sulphate	$MgSO_4$	0.36

It is stated that a small spring bubbles up on the eastern flank of Chirundu hill about half way between Kalishe swamp and the Zambezi river bank. The stream from it forms some pools, but does not reach the road. An efflorescence of white salt occurs below the eye, but whether it is also mainly sodium sulphate (Glauber's salt) or not is not known.

Kapesa (or Chatenta) thermal springs, 4405.

The group is located in Northern Rhodesia about 1½ miles north from the Zambezi river, and 4½ miles upstream from the Sanyati river confluence close to a proposed route of the Sinoia-Kafue railway. The altitude is about 1,450 feet.

A number of salt oozes, from which the natives extract salt, occur in a valley two miles across. At the head of the valley between basalt hills are a number of hot springs issuing over a length of fifty yards.

The temperature of the water when recorded was 73 degs. C. (172 degs. F.), and it is said to be constant. The water is stated to smell of sulphur, and a siliceous deposit is associated with the springs. The rate of flow does not vary, and it is estimated that the overflow would fill a three inch pipe.

As sediments of Karroo age are known to occur both north and south of this locality, the basalt referred to above is no doubt a lava of the Upper Karroo (Stormberg age) overlying the sediments.

References. Information from Mr. G. R. Holgate dated 2nd October, 1916, and from Mr. C. F. Molyneux dated 16th May, 1919.

Rindl, Professor M. M. The Medicinal Springs of South Africa. *South African Journal of Science*, Vol. XIII, p. 543, 1917.

LUBIMBI THERMAL SPRING, 3702.

The Lubimbi thermal spring is located in the Lubimbi salt swamp which extends from the north bank of the Shangani river to the foot of some sandstone kopjes about three miles from the river. The swamp is situated about six miles east of Shangani drift on the Walker's Drift road, and in the south-western corner of the Sebungwe District. The altitude is probably between 2,500 and 3,000 feet.

The rock formation in the area is a sedimentary series of the Karroo system.

The spring is stated to be very hot. The flow is considerable, being estimated at 2 to 4 cusecs by Dr. E. A. Nobbs, who collected the sample, the analysis of which is quoted below.

The water smells of sulphuretted hydrogen and is slightly turbid. Titration of a portion of a sample (Lab. No. 147 G) received at the Agricultural Chemical Laboratory in a quart bottle with a cork stopper in July, 1920, with centinormal iodine solution gave the sulphuretted hydrogen content of the water as 24.0 parts per million. After suction through a Berkefeld filter, the sulphuretted hydrogen was removed, but the water gave an alkaline reaction with litmus.

Analysis by A. W. Facer (1920) of filtered water for salines.

Agric. Lab. No. 147 G.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	330.1	9.30	25.58
Sulphate	SO_4	161.0	3.35	12.48
Carbonate	CO_3	234.0	7.80	18.14
Potassium	K	not detd		
Sodium	Na	420.7	18.29	32.61
Calcium	Ca	34.0	1.70	2.64
Magnesium	Mg	5.5	0.45	0.42
Alumina and iron oxide	Al_2O_3, Fe_2O_3	7.0	...	0.54
Silica	SiO_2	98.0	...	7.59
Totals		1290.3		100.00

Total dissolved solids dried at 180 degs. C. (direct) 1420.0 parts per million.

Hypothetical Composition of Salines.

		Parts per million.
Sodium chloride	NaCl	544.1
Sodium sulphate	Na_2SO_4	238.1
Sodium carbonate	Na_2CO_3	298.8
Calcium carbonate	$CaCO_3$	85.0
Magnesium carbonate	$MgCO_3$	19.3
Alumina and iron oxide	Al_2O_3, Fe_2O_3	7.0
Silica	SiO_2	98.0
Total		1290.3

The water is one of mixed type and might be classed as an indifferent water. Sodium is again the dominant positive ion.

The following information relating to incrustations collected by Dr. Nobbs is quoted verbatim from a report by Mr. A. W. Facer dated 20th July, 1920.

Lab. No. 148G: *Salt incrustation from surface of soil.*

The sample was a whitish grey powder. It effervesced with acid showing the presence of a certain amount of carbonate. The aqueous extract from the substance was found to be slightly alkaline in reaction. It gave pronounced reactions for chloride and sulphate, but contained no nitrate. It was found to contain a trace of lime and magnesia. The flame test showed sodium very prominent, with a trace of potassium.

From this it is evident that the carbonate, chloride and sulphate are almost entirely combined with sodium.

The water soluble constituents of the substance were quantitatively determined as follows:—

50 gms. of the sample which has been passed through a 1 mm. sieve were shaken for two days with about 800 c.c. of water, then filtered and made up to 1,000 c.c.

Determinations of total solid and saline constituents were then made upon this extract, yielding results as follow:—

Portion of substance soluble in water—13.74 per cent (dried at 180 degs. C.).

The composition of the water-soluble portion was found to be as follows:—

(Amount of sodium salts found by combining the amounts of acid radicles determined by analysis with the quantities of sodium found by calculation to satisfy them.)

Percentage Composition: Water-soluble solids, dried at 180 *degs. C.* (13.74 *per cent of original substance*).

		Per cent.
Loss on ignition		1.05
Sodium carbonate	Na_2CO_3	1.83
Sodium chloride	$NaCl$	9.02
Sodium sulphate	Na_2SO_4	81.74
Total		93.64

Portion unaccounted for (Ca, Mg and K salts) 6.36

Lab. No. 149G: *Salt from eye of spring.*

This consisted of whitish grey thick flakes. It effervesced with acid showing the presence of carbonate. The aqueous extract was found to be decidedly alkaline in reaction. Qualitative analysis showed it to contain chloride and sulphate but no nitrate. Examination for metals gave only very slight traces of calcium and magnesium, and it was therefore presumed that the acid radicles were nearly entirely combined with sodium; which was predominant in the flame test (by which no potassium could be observed).

Estimation of the water soluble solids by the same method as for 148 G gave:—

Portion of substance soluble in water—66.29 per cent (dried at 180 degs. C.).

The composition of the water soluble portion (determined as in the case of 148 G) was found to be as follows:—

Percentage Composition: Water-soluble solids, dried at 180 *degs. C.* (66.29 *per cent of original substance*).

		Per cent.
Loss on ignition		0.5
Sodium carbonate	Na_2CO_3	2.59
Sodium chloride	NaCl	41.37
Sodium sulphate	Na_2SO_4	54.7
Total solids accounted for		99.16

MANZAIA THERMAL SPRING, 4404.

The spring is located in Northern Rhodesia, 1½ miles from the left bank of the Zambezi river, about 50 miles west-south-west of the Sanyati confluence, and about 10 miles downstream from the confluence of the Sengwa river.

The temperature recorded was 66 degs. C. (150 degs. F.). No vegetation grows in the immediate vicinity of the spring, and there is no salt deposit.

The geological formation of the area in which the spring is located is believed to be a sedimentary series of sandstones, grits and shales of Karroo age, but basalt is reported to occur a mile away.

Reference. Information from Mr. C. F. Molyneux dated 16th May, 1919, and 11th April, 1929.

MENDAYATSWA OOZE, 2602.

This ooze is situated about five feet below the normal flood terrace of the Zambezi river and on its right bank at the western foot of Chirundu hill, Lomagundi District. It is reached by a rough track (1.8 miles long) leaving the Miami-Chirundu aerodrome road to the left (south-west) 0.6 mile before reaching the terminus of the road on the river bank. The altitude is probably about 1,270 feet above sea level.

The ooze consists of a sixteen yard length of hot, black mud under a layer of sand on the edge of a pool in a branch of the Zambezi river only in use when the river is in flood. The mud is uncomfortably hot (about 50 degs. C.) five inches below the surface, but the water of the pool is only tepid to warm. There is no visible flow from it, bubbles are scarce, but a slight smell of sulphur is noticeable at times. The sand around the pool is speckled with a light efflorescence of white salt, which consists essentially of sodium sulphate (Glauber's salt) as the analysis below shows.. A similar salt comes from the Kalishe swamp 2603 on the other side of Chirundu hill.

Analysis by E. Golding (1933) of efflorescence at the Mendayatswa ooze collected by H. B. Maufe, 22nd August, 1932.

Lab. No. G.W. 20.

	Per cent.		Per cent.	Recalculated to pure salts. Per cent.
NO_3	trace	KCl	0.88	1.09
Cl	1.16	NaCl	1.22	1.51
CO_3	1.15	Na_2SO_4	73.28	90.92
SO_4	52.06	$CaSO_4$	1.32	1.64
Na	24.21	$CaCO_3$	1.92	2.38
K	0.46	$MgSO_4$	1.98	2.46
Ca	1.16	Al_2O_3, Fe_2O_3	1.20	...
Mg	0.40	SiO_2	18.08	...
Al_2O_3, Fe_2O_3	1.20			
SiO_2	18.08			
	99.88		99.88	100.00

Two Winchester quart bottles of the water were received from Mr. L. McAdams, Native Commissioner, in 1931. Mr. Golding reports that the water was turbid and contained a sandy sediment. No smell of sulphur could be detected on arrival at the laboratory.

Analysis by E. Golding (1931).

Lab. No. G.W. 18.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	nil	...	...
Chloride	Cl	200.2	5.64	12.65
Sulphate	SO_4	748.2	15.57	47.26
Carbonate	CO_3	42.0	1.40	2.65
Potassium	K	7.2	0.18	0.45
Sodium	Na	425.3	18.49	26.87
Calcium	Ca	72.0	3.60	4.55
Magnesium	Mg	4.2	0.35	0.27
Alumina and iron oxide	Al_2O_3,Fe_2O_3	4.0	...	0.25
Silica	SiO_2	80.0	...	5.05
Totals		1583.1		100.00

Hypothetical Composition of Salines.

		Parts per million.
Potassium chloride	KCl	13.8
Sodium chloride	NaCl	319.2
Sodium sulphate	Na_2SO_4	925.6
Calcium carbonate	$CaCO_3$	53.0
Calcium sulphate	$CaSO_4$	173.3
Magnesium carbonate	$MgCO_3$	14.2
Alumina and iron oxide	Al_2O_3,Fe_2O_3	4.0
Silica	SiO_2	80.0
Total		1583.1

A weak chloride-sulphate water with sodium as the dominant kation.

Chirundu hill consists of buff and red mottled sandstones and grits, the latter containing scattered white quartz pebbles in places, thus resembling the Escarpment Grits of the Karroo system. The outcrops at the foot of the hill near the Mendayatswa ooze are quartzites, evidently the sandstones silicified. They appear to be dipping at an angle of 30 degrees to the west, that is, towards the ooze and the Zambezi river. This unusually high dip suggests the presence of a fault, which may be trending in a south-easterly direction parallel to the extension of the ooze.

Reference. Information and specimen of water from Mr. L. McAdams, Assistant Native Commissioner, 1930.

Observations by the author, 1932.

MUTAMBARA. *See "The Hot Springs,"* 3102.

MWENGEZI (WENGESI) THERMAL SPRING, 3101.

The spring is located on crown-land north of the Umvumvuvu river, which was transferred in 1929 from the Umtali District to the Melsetter District. The eye is 200 yards from the left bank of the Odzi river and 70 feet above it. It is approached by means of a track half a mile long leaving the old Umtali-Chipinga road one mile north of the lowest drift through the Umvumvuvu river. Mumundega's kraal is close by. The altitude is 2,050 feet above sea level.

The spring issues into a pool four feet by two feet, through which a gas smelling slightly of sulphuretted hydrogen bubbles spasmodically. A very small stream runs from the pool to the Odzi river. The temperature of the water at the eye is 53 degrees centigrade and is just bearable by the hand.

Analysis by A. G. Holborrow, Government Chemist (1916).

Agric. Lab. No. 1702.		Parts per million.
Sodium chloride	$NaCl$	54.7
Sodium bicarbonate	$NaHCO_3$	176.0
Sodium sulphate	Na_2SO_4	47.6
Calcium carbonate	$CaCO_3$	8.6
Magnesium carbonate	$MgCO_3$	5.0
Alumina and iron oxide	Al_2O_3, Fe_2O_3	7.8
Silica	SiO_2	53.6
Total		353.3

Potash salts and organic matter not determined.

Total solids at 105 degs. C.	364
Loss on ignition	58

The table below shows the analysis re-calculated in ions. The composition of the water is shown in parts per million, and is followed by the milli-normality and percentage composition of the solute.

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	33.2	0.93	9.40
Sulphate	SO_4	32.2	0.67	9.11
Bicarbonate	HCO_3	127.8	2.09	36.17
Carbonate	CO_3	8.8	0.29	2.49
Sodium	Na	85.1	3.70	24.09
Calcium	Ca	3.4	0.17	0.96
Magnesium	Mg	1.4	0.11	0.40
Alumina and iron oxide	Al_2O_3, Fe_2O_3	7.8	...	2.21
Silica	SiO_2	53.6	...	15.17
Totals		353.3		100.00

The water is a weak carbonate one having sodium for the principal metallic base or positive ion. It is of course also a weak alkaline water.

Although grey granite crops out along the line of the main road a red, highly felspathic granite takes its place a short distance west of the road, and crops out again on the banks of the Odzi river immediately west of the spring. The red granite is here much shattered and is traversed by veinlets of quartz. It is probably close to the line of the Sabi fault or a branch of it. The Mutambara (3102) and Rupisi thermal springs (3103) are also weak carbonate waters, and the former is very definitely associated with the Sabi fault.

Reference. Observations by the author.

NAKUYU SPRINGS, 4408.

The group is located in Northern Rhodesia on the left bank of the Zambezi river about 58 miles south-west of the Sanyati confluence.

The waters contain salt. The temperature of the hottest spring at the time the observations were made was 32 degs. C. (90 degs. F.). The springs drain into the Zambezi river.

The geological formation of the area in which the group occurs is a sedimentary series of sandstones, grits and shales of Karroo age.

Reference. Information from Mr. C. F. Molyneux, 16th May, 1919, and 11th April, 1929.

NICHENGE BRINE SPRINGS, 4204.

The group is situated about 18 miles west-south-west of Lukosi siding on the Bulawayo-Victoria Falls railway line, Wankie District. The altitude by aneroid barometer checked against the Bulawayo standard barometer is 3,050 feet.

The springs issue slowly in three groups from the flanks of low kopjes, and most of the waters drain into a vlei.

Analyses I, II and III by Geo. A. Pingstone (1916) of samples collected by the author.

I.

		Parts per million.
Chloride,	Cl as sodium chloride	16,400
Sulphate,	SO_4 as sodium sulphate	2,170
Calcium,	Ca as carbonate	trace
Magnesium,	Mg as carbonate	100
		18,670

Each analysis has been re-calculated to the standard form adopted in this work.

		I.S.M. Parts per million.	Milli-normality N/100.	Solute Per cent.
Chloride	Cl	9,948.2	280.20	53.29
Sulphate	SO_4	1,467.4	30.57	7.86
Carbonate	CO_3	71.2	2.37	0.38
Sodium	Na	7,154.4	311.06	38.32
Calcium	Ca	trace	...	...
Magnesium	Mg	28.8	2.38	0.15
		18,670.0		100.00

II.

		Parts per million.
Chloride,	Cl as sodium chloride	48,700
Sulphate,	SO_4 as sodium sulphate	6,000
Calcium,	Ca as carbonate	80
Magnesium,	Mg as carbonate	100
		54,880

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	29,541.4	832.15	53.83
Sulphate	SO_4	4,057.2	84.52	7.39
Carbonate	CO_3	119.2	3.97	0.22
Sodium	Na	21,101.4	917.45	38.45
Calcium	Ca	32.0	1.60	0.06
Magnesium	Mg	28.8	2.38	0.05
		54,880.0		100.00

III.

		Parts per million.
Chloride,	Cl as sodium chloride	23,000
Sulphate,	SO_4 as sodium sulphate	4,600
Calcium,	Ca as carbonate	190
Magnesium,	Mg as carbonate	trace
		27,790

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	13,951.8	393.01	50.21
Sulphate	SO_4	3,110.5	64.80	11.19
Carbonate	CO_3	113.9	3.79	0.41
Sodium	Na	10,537.7	458.16	37.92
Calcium	Ca	76.1	3.81	0.27
Magnesium	Mg	trace	—	—
		27,790.0		100.00

I. Sample from shaft sunk in vlei, brine standing about 10 feet below surface.

II. Sample from small excavation below the most easterly of the south-westerly group of springs.

III. Sample from shaft below the most westerly of the northern group of springs.

The water is a weak brine with some sulphate, sodium being the dominant kation. It is, however, a noticeably stronger brine than the water taken direct from the thermal spring, and doubtless indicates that the solution has been strengthened by natural evaporation.

These springs are the only ones at which an attempt has been made to extract the salt on a commercial scale. They were first pegged in 1907 as the Usanga claims under Pt. V of the mining law by A. Wirth and F. A. Norvall. Some shallow shafts were sunk and a stone-lined evaporating pan constructed. The analyses were made on samples taken from these shafts. They were re-pegged in 1921 by Mr. J. Hepker as the Lukosi claims, and some more shallow shafts sunk, but the claims went to forfeiture in the following year.

In 1932 the site of the springs was again pegged, this time by Mr. H. R. Cumming as the Sinementala claims, and experiments are being conducted both by solar evaporation in different kinds of pans and by fire heating with the object of producing a commercial salt.

Analysis by E. Golding (1932) of salt obtained by evaporating a composite sample of brine.

Lab. No G.W. 6A.		Per cent.
Nitrate	NO_3	nil
Chloride	Cl	52.83
Sulphate	SO_4	8.24
Carbonate	CO_3	trace
Sodium	Na	35.31
Potassium	K	1.85
Calcium	Ca	0.96
Magnesium	Mg	0.37
Alumina and iron oxide	Al_2O_3, Fe_2O_3	0.16
Silica	SiO_2	0.28
Total		100.00

Composition of the Salt.

		Per cent.
Potassium chloride	KCl	3.53
Sodium chloride	NaCl	84.32
Sodium sulphate	Na_2SO_4	6.62
Calcium sulphate	$CaSO_4$	3.26
Magnesium sulphate	$MgSO_4$	1.83
Alumina and iron oxide	Al_2O_3, Fe_2O_3	0.16
Silica	SiO_2	0.28
Total		100.00

Mr. Golding remarks: "It will be seen that the total chlorides amount to 87.85 per cent of the salt obtained, the remaining 12.15 per cent being impurities. The impurities in the salt are represented by sulphate, oxides of iron and aluminium, and silica. These impurities are not serious and could be eliminated in practice, if the evaporation is not allowed to proceed too far."

This salt was obtained from a sample of brine from the Sinementala claims sent in by Mr. H. R. Cumming. The brine was analysed in the Geological Survey Laboratory and the result quoted below confirms the figures of the previous analyses by Mr. G. A. Pingstone.

Analysis by E. Golding (1932) of a sample sent in by H. R. Cumming.

Lab. No. G.W. 6.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	nil	nil	nil
Chloride	Cl	12,452.0	350.76	52.51
Sulphate	SO_4	1,833.0	38.19	7.73
Carbonate	CO_3	nil	—	—
Bicarbonate	HCO_3	269.5	4.42	1.14
Sodium	Na	8,757.0	380.74	36.93
Potassium	K	88.0	2.26	0.37
Calcium	Ca	177.0	8.85	0.74
Magnesium	Mg	77.0	6.36	0.32
Alumina and iron oxide	Al_2O_3, Fe_2O_3	24.0	—	0.10
Silica	SiO_2	35.2	—	0.16
Totals		23,712.7		100.00

Total solids in solution are 23,736 parts per million dried at 100 degs. centigrade or 0.237lb per gallon.

The sample when received had a distinct odour of sulphuretted hydrogen, which was found to be present to the extent of 7.5 parts per million.

Hypothetical Composition of Salines.

		I.S.M. Parts per million.	Grains per gallon.
Potassium chloride	KCl	168.0	11.76
Sodium chloride	$NaCl$	20,397.0	1,427.79
Sodium sulphate	Na_2SO_4	2,261.0	158.27
Magnesium sulphate	$MgSO_4$	381.0	26.67
Calcium bicarbonate	$Ca(HCO_3)_2$	446.5	31.26
Alumina and iron oxide	Al_2O_3, Fe_2O_3	24.0	1.68
Silica	SiO_2	35.2	2.46
Totals		23,712.7	1,659.89

Mr. H. R. Cumming states that the water of one of this group of springs is pleasantly warm on a cold morning. This thermal eye is not a very strong one, but its presence is of considerable interest, as it indicates that the group is not essentially different from other mineral springs in the district. There is an idea that the brine in these springs comes from water belonging to the ordinary underground circulation percolating through a bed of rock salt and dissolving some of it. There is, however, no evidence in the local Karroo rocks to lead one to think that a deposit of rock salt might be included in them. That these springs are really normal thermal springs is also indicated by the character of the water from the thermal eye. A sample of this was sent in by Mr. Cumming and analysed in the Geological Survey Laboratory. The figures quoted below show that the water is a weak brine with a little sulphate and bicarbonate, and that it does not differ in any essential respect from the neighbouring Gobo 4201 and Chawato 4203 springs.

Analysis by E. Golding (1932) of water from the thermal spring at Nichenge (Sinementala claims) sent in by Mr. H. R. Cumming.

Lab. No. G.W. 9.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	nil	—	—
Chloride	Cl	3,195.0	90.00	48.26
Sulphate	SO_4	520.5	10.84	7.86
Carbonate	CO_3	23.8	0.79	0.36
Bicarbonate	HCO_3	389.7	6.39	5.89
Sodium / Potassium	Na / K	2,264.9	98.47	34.21
Calcium	Ca	140.0	7.00	2.11
Magnesium	Mg	28.7	2.37	0.43
Alumina and iron oxide	Al_2O_3, Fe_2O_3	14.4	—	0.22
Silica	SiO_2	44.0	—	0.66
Totals		6,621.0		100.00

The springs are located in an area between two important faults. The lowest beds of the Karroo system, comprising the Lower Wankie Sandstone, the Black Shales with coal and the Fireclay, rest unconformably on a somewhat irregular surface of the ancient granitic gneiss. The springs issue or appear to issue from the ancient rocks, and in no case can penetrate far through the Karroo rocks. This is further evidence for regarding them as having an origin similar to that of the other mineral springs of the district.

References. Observation by the author and information from Mr. H. R. Cumming.

No. 9 BORE-HOLE WATER, WANKIE, 4211.

A mineral water was struck in bore-hole No. 9, Wankie Coalfield, situated about four miles north-west of Wankie railway station. The top of the bore-hole is 2,295.5 feet above sea level.

During the rainy season and for a short period afterwards water issues from points near the bore-hole. When the spring was visited during June (nearly the middle of the dry season) the water stood in the bore-hole to a depth of one foot below the surface.

Analysis by Geo. A. Pingstone (1920) made for the Wankie Colliery Company and published by permission of the General Manager.

Incrusting Solids.

	Grains per gallon.
Calcium carbonate	57.37
Calcium sulphate	nil
Calcium chloride	nil
Magnesium carbonate	1.55
Magnesium sulphate	125.58
Magnesium chloride	nil
Iron and alumina	traces
Silica	0.50
Total	185.00

Non-incrusting Solids.

	Grains per gallon.
Sodium sulphate	538.25
Sodium chloride	8.48
Sodium carbonate	0.57
Sodium nitrate	nil
Total	547.30

Pounds of incrusting solids in one thousands gallons	26.40
Alkalinity	58.8
Carbonic acid	12.93

"The foregoing figures of analysis prove this water to be unsuitable for irrigation purposes, but as a medicinal water of an aperient character it may be of value. The above figures have been fitted up into their combination as salts as far as ordinary analysis shows. If used for medicinal purposes and it is proposed to advertise same, it would be worth a more complete investigation.

(Signed) Geo. Pingstone."

The above analysis is re-calculated in the table below in ions. The composition of the water is shown as parts per million, and is followed by the milli-normality and by the percentage composition of the solute.

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	73.5	2.07	0.70
Sulphate	SO_4	6,631.1	138.14	63.39
Carbonate	CO_3	511.7	17.05	4.89
Sodium	Na	2,540.9	110.47	24.29
Calcium	Ca	328.2	16.41	3.14
Magnesium	Mg	368.8	30.47	3.52
Silica	SiO_2	7.1	...	0.07
Totals		10,461.3		100.00

Hypothetical Composition of Salines.

		Parts per million.
Sodium chloride	NaCl	121.1
Sodium sulphate	Na_2SO_4	7,689.3
Sodium carbonate	Na_2CO_3	8.1
Calcium carbonate	$CaCO_3$	819.6
Magnesium sulphate	$MgSO_4$	1,794.0
Magnesium carbonate	$MgCO_3$	22.1
Silica	SiO_2	7.1
Total		10,461.3

The bore-hole was put down in the Madumabisa Shales belonging to the middle division of the sedimentary rocks of the Karroo system.

References. Information from the Wankie Colliery Company, Limited, and from Mr. B. Lightfoot. See also Geological Survey Bulletin No. 15.

NUNGWE THERMAL SPRING, 4301.

This spring is situated in low-lying country about 200 yards from the right bank of the Chobe river about four miles upstream from the confluence with the Zambezi river at Kasangula. This spring is thus within the Bechuanaland Protectorate. The altitude above sea level is about 3,040 feet.

The locality is said to be subject to inundation by the Chobe river. The water issues from two eyes and is stated to become at times quite warm.

The underlying formation is probably the amygdaloidal basalts of the Karroo system.

Analysis by E. Golding (1931) of a specimen collected on 27th December and received from Mr. J. A. Legge.

On arrival at the laboratory the sample was found to be slightly turbid and colourless.

Lab. No. G.W. 17.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	nil	...	...
Chloride	Cl	3,510.5	98.89	32.50
Sulphate	SO_4	3,368.5	70.18	31.18
Carbonate	CO_3	28.0	0.93	0.26
Potassium	K	trace	...	...
Sodium	Na	3,395.7	147.64	31.44
Calcium	Ca	425.9	21.30	3.94
Magnesium	Mg	28.3	2.34	0.26
Alumina and iron oxide	Al_2O_3, Fe_2O_3	8.0	...	0.07
Silica	SiO_2	37.6	...	0.35
Total		10,802.5		100.00

Hypothetical Composition of Salines.

		Parts per million.
Sodium chloride	NaCl	5,787.5
Sodium sulphate	Na_2SO_4	3,455.1
Calcium carbonate	$CaCO_3$	70.0
Calcium sulphate	$CaSO_4$	1,304.2
Magnesium sulphate	$MgSO_4$	140.1
Alumina and iron oxide	Al_2O_3, Fe_2O_3	8.0
Silica	SiO_2	37.6
Total		10,802.5

It is classified as a sulphato-chloride water having sodium as the dominant kation.

Information from Mr. J. A. Legge, Kasane, and from Mr. A. Giese, Lukosi.

Rupisi hot spring, 3103.

This well-known spring is the source of the Rupisi river, and is situated about two miles north of the Musikiwanu Native Reserve in the Melsetter District, one and a half miles south of the Chipungu river drift on the Sabi valley road, and nearly seven miles east of the Sabi river. The altitude was found by corrected aneroid barometer observation to be 1,680 feet.

It is a large spring having apparently about the same flow at the main eye of "The Hot Springs," 3102, in the Mutamabara Reserve. It issues at the western foot of a low ridge of decomposed grey gneissic granite, the eastern scarp of the Umkondo beds commencing to rise up apparently about half a mile to the east.

The Victoria Prospecting Company's geological map shows the hot spring situated on the ancient granite at the eastern edge of a tract of alluvium some fourteen miles broad, through the middle of which the Sabi river flows. Messrs. Teale and Wilson (11) considered that a powerful fault throws down the Umkondo beds on its western side and that the hot spring marks the line of the fault. This view is certainly consistent with the evidence for faulting quoted above in connexion with the springs of similar type (3101 and 3102) situated farther north in the Odzi valley.

Bubbles of gas come up, generally in bursts, with the water, and give it an appearance of boiling. The temperature, however, is 62 degs. C. (144 degs. F., nearly), being thus only slightly scalding and not hot enough for cooking. No smell was noticed at the spring, but the cooled water has a faint taste of sulphuretted hydrogen.

The main eye is surrounded by an ooze of warm water in which a temperature of 56 degs. C. was obtained at thirteen paces to the north. At thirty three paces on the edge of the ooze there is a small cold spring, the water of which was at 29 degs. C. or 9 degs. below the air temperature at the moment of observation.

A bathing pool has been dug out near the cattle dip about 200 yards downstream. The temperature of the water has here fallen to 42.5 degs. C. (108.5 degs. F.).

Analysis by A. G. Holborrow (1916).

Agric. Lab. No. 1899.		Parts per million.
Sodium chloride	$NaCl$	80.7
Sodium bicarbonate	$NaHCO_3$	176.0
Sodium sulphate	Na_2SO_4	31.9
Calcium carbonate	$CaCO_3$	8.0
Magnesium carbonate	$MgCO_3$	2.5
Alumina and iron oxide	Al_2O_3,Fe_2O_3	2.1
Silica	SiO_2	87.4
		388.6

Potassium and organic matter not determined.

The analysis is re-calculated below in ions. The composition of the water is shown in parts per million, and is followed by the milli-normality and by the percentage composition of the solute.

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	48.9	1.37	12.59
Sulphate	SO_4	21.6	0.45	5.56
Bicarbonate	HCO_3	127.8	2.09	32.88
Carbonate	CO_3	6.6	0.22	1.70
Sodium	Na	90.3	3.92	23.23
Calcium	Ca	3.2	0.16	0.83
Magnesium	Mg	0.7	0.06	0.18
Alumina and iron oxide	Al_2O_3, Fe_2O_3	2.1	...	0.54
Silica	SiO_2	87.4	...	22.49
Totals		388.6		100.00

The water is a weak carbonate one with sodium as the chief metallic base or positive ion. It is, of course, a weak alkaline water, and closely comparable with the Mutambara, 3102, and Mwengezi thermal springs, 3101, which arise near the line of the "Sabi fault" some 55 and 69 miles respectively to the north.

Reference. Observations by the author.

Sakabika thermal spring, 4213.

A group of nine springs issues two miles slightly south of east of the most south-westerly beacon (No. 18) of the Wankie Coal Concession. This beacon lies eight miles south-south-west of Lukosi siding on the Bulawayo-Victoria Falls line, and over eleven miles west-south-west of Tshontanda siding. One spring on the northern edge of this group has water which always feels warm, and is described as bubbling up to an inch or two. The volume is said to be no stronger than that of the Nichenge springs.

Weak brine is to be found in the water-course below the springs, especially where it is joined by the Lagombe water-course. The latter is reported to rise in some minor brine springs a few miles to the south and situated on higher ground.

The spring issues from the ancient granite at some little distance south-west of the main southern-eastern boundary fault of the Wankie coalfield, by which the Karroo rocks are thrown down to the north-west against the Archaean granite.

Reference. Information from Mr. A. Giese, Lukosi.

SAMPAKALUMA THERMAL SPRINGS, 3703.

The springs are located in the north-eastern corner of the Sebungwe District on the south bank of the Zambezi river about four miles upstream from the confluence of the Sanyati river. The altitude is about 1,550 feet above sea level.

The water, where it issues from the several orifices, is described as boiling. The overflow into a swamp forms a deposit from which the local natives obtain their salt. The rate of flow is stated to be constant.

The springs issue from numerous crater-like openings in soft, boggy ground, forming together a pool about thirty feet in length and about ten feet wide.

The rock formation in that area is a series of sedimentary rocks belonging to the Karroo system. The Kapesa springs 4405, situated on the opposite bank of the Zambezi river, issue from basaltic lava.

Reference. Information from Trooper W. A. Hills, British South Africa Police, dated 30th June, 1924.

SHAIVA THERMAL SPRING, 4503.

A thermal spring issues near the road from Spungabera to Massangena, eight miles south of the Mossurize (Umzelezwe) river and west of the Zinhumbo hills in the Mossurize province of Portuguese East Africa. This is apparently the Shaiva spring referred to by Messrs. Teale and Wilson as being less powerful than 4502. It is also mentioned by C. F. de Andrade, who states that the waters issue from sandstone dipping beneath basalt sheets.

These rocks are doubtless of Karroo age.

Authorities. O. E. Teale and R. C. Wilson (11). C. F. de Andrade (12).

SHUMBA THERMAL SPRINGS, 4207.

The springs are situated on the east bank of the Shumba river and about three miles from Tshabi's old kraal on the Mlibizi river, Wankie District. The road from Walker's Drift on the Zambezi river, at about eighteen miles south from the river, passes close to the springs.

The group consists of four powerful springs rising within a few yards of one another, and estimated to have a total flow of five to ten thousand gallons an hour. The water is warm, and described as somewhat bitter but potable.

The Shumba river, a few miles below the springs, passes over a tract of level ground, where a white deposit of salt has been formed. The local natives obtain their salt from this source and it is a favourite "salt-lick" for game.

The rock formation in the area is a series of sedimentary rocks belonging to the Karroo system.

Reference. Unpublished communication from Mr. F. W. T. Posselt, received 10th November, 1916.

Sibila thermal spring, 3705.

The spring is situated at the foot of a kopje on the north side of the Matobolo flats in the Sebungwe District. It was one of the watering places on the old road from Bulawayo to Lubu camp in the Sibaba Native Reserve, and it is estimated to be about 22 miles south-east of the old camp Kariyangwe.

The water is said to issue slowly in small but constant volume through mud and to form a wet vlei about twenty yards long. It has a slight smell of sulphuretted hydrogen. The name indicates boiling water, but it is described as appreciably warm. Apparently it has no noticeable taste and was constantly used for cooking and drinking without ill effects, the surrounding area being waterless, at any rate in winter.

The Matobolo flats south of the locality are described as mud flats scattered over by round nodules of limestone, which indicates that the flats are underlain by the Madumabisa Shales of the Karroo system.

Reference. Information from Lt.-Col. Carbutt, Chief Native Commissioner, 1933.

Sidenda thermal spring, 4205.

The spring is located on the right (south) bank of the Zambezi river about three miles upstream from the confluence of the Matetsi river at an altitude of about 2,000 feet above sea level. The confluence is situated in the Wankie District about 25 miles east-north-east of Wankie township.

The spring is reported by natives to be very hot and to contain much salt.

The Zambezi river in that locality flows over basaltic lavas of Karroo age.

Reference. Information from Mr. F. W. T. Posselt, Native Commissioner.

SIGOBOMO OR ELEPHANT SPRING, 4209.

The spring is located in a vlei near the Dett river, about twelve miles south-east of Dett railway station on the Victoria Falls line. It is close to the Bulawayo-Victoria Falls road which traverses the Dett valley, and its altitude is 2,440 feet above sea level.

The water is slightly turbid, pale yellowish in colour and odourless.

Analysis by E. Golding (1928) of a sample collected by B. Lightfoot.

Lab. No. W.A. 5.		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Nitrate	NO_3	trace	...	...
Chloride	Cl	53.3	1.501	1.41
Sulphate	SO_4	2,544.2	53.004	67.47
Carbonate	CO_3	29.2	0.973	0.77
Potassium / Sodium	K / Na	241.5	10.500	6.40
Calcium	Ca	610.0	30.500	16.18
Magnesium	Mg	166.7	13.776	4.42
Aluminium	Al	17.0	1.888	0.45
Iron	Fe	5.0	0.179	0.13
Manganese	Mn	5.9	0.214	0.16
Silica	SiO_2	98.4	...	2.61
Totals		3,771.2		100.00

Hypothetical Composition of Salines.

		Parts per million.
Sodium chloride	NaCl	87.8
Sodium sulphate	Na_2SO_4	639.3
Calcium sulphate	$CaSO_4$	2,045.2
Calcium carbonate	$CaCO_3$	20.0
Magnesium sulphate	$MgSO_4$	825.1
Manganese sulphate	$MnSO_4$	16.2
Alumina	Al_2O_3	32.0
Iron oxide	Fe_2O_3	7.2
Silica	SiO_2	98.4
Total		3,771.2

This is a sulphate water differing from the other sulphate waters in having calcium in place of sodium as the dominant metallic base or kation.

The spring issues in superficial deposits in a valley eroded in the Kalahari sand. The geology is obscure, but it is probable that the formation underlying the sand is the Madumabisa Shale group belonging to the Karroo system. The beds of this group contain disseminated pyrites and included in it are beds and nodules of limestone more or less magnesian in character. The acid produced by waters penetrating from the surface and oxidizing the pyrites would act on the limestones, giving calcium and magnesium sulphates in solution. As this is a cold spring there is no reason for thinking that the waters come from a great depth, and the above explanation may easily account for its mineral contents.

Reedy pools in the Dett vlei have been seen by the author to give off marsh gas which ignites spontaneously, doubtless owing to the small admixture of phosgene gas (PH_3). The phenomenon, visible at night, is of course that of the well-known will o' the wisp, and is sufficient to account for the alleged spontaneous burning of the vlei in the dry season. After the burning the ground around the pools becomes coated with a snow-like efflorescence which was found to consist mainly of magnesium sulphate (Epsom-salt).

Reference. Observations by B. Lightfoot and the author.

Sigobonya thermal spring, 4210.

The spring is located near the confluence of the Gwai river with the Zambezi, Wankie District, and the water is reported by the natives as hot, but good for drinking.

The rock from which the spring issues is probably basalt belonging to the Upper Karroo system.

References. Ferguson, D. The Geysers or Hot Springs of the Zambesi and Kafue Valleys. *Proceedings Rhodesia Scientific Association*, Vol III, p. 10, 1902. Also communication from Mr. A. H. Johnstone, Native Commissioner.

Sinementala. *See Nichenge brine springs*, 4204.

Sinesitonko thermal spring, 3706.

This spring issues in the Matobolo flats of the Sebungwe District at a spot roughly half way between the Sibila spring

3705 and Gololo hill where Nkaka's kraal once stood. The locality is not well defined, but is probably between three and five miles north-north-east of Sibila vlei. The spring derives its name from the chief who lived near it until the natives were moved off the flats on account of sleeping sickness.

The spring has a considerable volume, the water flowing off in a well-defined channel through black soil towards the left bank of the Busi river. At the eye the water is distinctly hot, and there is a smell of sulphuretted hydrogen, especially when the mud is stirred up.

The formation from which it issues is probably, like that of the Sibila spring, the Madumabisa Shales of the Karroo system.

Reference. Information from Lt.-Col. Carbutt, Chief Native Commissioner.

Spring, 3901.

A cold spring issues beside the old road from Odzi to the Umkondo copper mine half a mile north of the drift through the Sabi river and in the Umtali District. The drift is about three miles upstream from the confluence with the Odzi river. The spring water deposits a white salt said to be sodium carbonate.

Authority. Mr. J. L. Martin, M.P.

Spring, 4406.

The spring is situated near the road from Walker's Drift to Monze (Northern Rhodesia), about 4 miles north of the Zambezi river.

This small spring issues high up in hills of "crumpled sandstone."

Reference. Ferguson, D. The Geysers or Hot Springs of the Zambesi and Kafue Valleys. *Proc. Rhod. Sci. Assoc.* Vol. III, p. 10, 1902.

Spring, 4407.

The spring is situated near the road from Walker's Drift to Monze (Northern Rhodesia), at the foot of the Batokaland plateau. It is about 27 miles north of the Zambezi river.

The description suggests that this spring is a gusher of low temperature. Travertine deposits are associated with the overflow water.

The formation from which the spring issues is not known.

Reference. Ferguson, D. The Geysers and Hot Springs of the Zambesi and Kafue Valleys. *Proc. Rhod. Sci. Assoc.* Vol. III, p. 10, 1902.

SULPHUR SPRING, 4202.

The position of this spring is plotted on the geological map accompanying Southern Rhodesia Geological Survey Bulletin No. 4. It is located on the right bank of the Deka river, about twenty miles south-west of the Deka bridge on the Bulawayo-Victoria Falls railway line, Wankie District, and the altitude is about 2,600 feet.

The spring comes to the surface through the Batoka Basalts of Karroo age.

Reference. Information from Mr. B. Lightfoot.

SULPHUROUS SPRING, 3104.

A very small spring trickles out of rock on the eastern face of a hill called Tambatsura on sheet 18 of the 1: 250,000 map of the Colony, and situated about two miles north of the Nyautsa river and about five miles west of Redwood farm, Melsetter District. North and east of it are old copper claims pegged at first as the Mafouni and later as the Chi-impi claims.

The water is cold and smells of rotten eggs (sulphuretted hydrogen), but can be used for cooking and drinking.

Authority. Mr. J. L. Martin, M.P.

SUNGA THERMAL SPRINGS, 4208.

This group issues in the Deka river nine miles below the Deka railway bridge on the Bulawayo-Victoria Falls line, Wankie District. The position is shown on the maps accompanying Geological Survey Bulletins 4 and 15, and the altitude is 1,900 feet above sea level.

The main eye emerges right on the line of the important Deka fault, which extends in both north-east and south-west directions for upwards of forty miles. The Batoka Basalts to the north-west of the fault have been let down against the Escarpment Grits on the south-east. At the point of emergence a subsidiary fault has caused a slight kink in the main fault. This spring is an important contributor to the Wankie water supply. Its flow has never been known to fall below 25,000 gallons per hour in the dry season. The water is warm to the hand.

The water of the main spring was analysed by Mr. Geo. Pingstone for the Wankie Colliery Company, Limited, and is published below by permission of the General Manager.

Analysis by Geo. Pingstone (1920).

Incrusting Solids.	Grains per gallon.	Non-incrusting Solids.	Grains per gallon.
Calcium carbonate	9.45	Sodium sulphate	6.46
Calcium sulphate	nil	Sodium chloride	8.54
Calcium chloride	nil	Sodium carbonate	8.52
Magnesium carbonate	4.41	Sodium nitrate	traces
Magnesium sulphate	nil		
Magnesium chloride	nil		
Alumina and iron oxide	0.45		
Silica	2.52		
Totals	16.83		23.52

Pounds of incrusting solids in one thousand gallons	2.40
Alkalinity	22.75
Hardness	6.65
Carbonic acid	10.01

"The foregoing figures of analysis shows this to be an alkaline spring water. It is scarcely to be classed as a medicinal water although it contains some sodium carbonate and sodium sulphate, the amounts being very small.

"For boiler purposes this would not be so bad, as owing to the presence of sodium carbonate the bulk of the lime and magnesia salts would be thrown down as a sludge on heating and could be blown off from time to time.

(Signed) Geo. Pingstone."

PLATE II.

A. PHOTO. C. F. MOLYNEUX

Chilambwa Thermal Springs, No. 4403. About 5 miles from the left bank of the Zambezi river, Makabuka District, Northern Rhodesia.

B. PHOTO. H.B.M.

The main eye at "The Hot Springs," No. 3102, in the Sabi Valley. Mutambara Native Reserve, Melsetter District.

ZINCO COLLOTYPE CO., EDINBURGH.

The table below shows the analysis re-calculated in ions. The composition of the water is shown as parts per million, and is followed by the milli-normality and by the percentage composition of the solute.

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	74.0	2.08	12.83
Sulphate	SO_4	62.4	1.30	10.83
Carbonate	CO_3	198.6	6.62	34.46
Sodium	Na	126.7	5.51	21.98
Calcium	Ca	54.1	2.71	9.38
Magnesium	Mg	18.2	1.50	3.16
Alumina and iron oxide	Al_2O_3, Fe_2O_3	6.4	—	1.11
Silica	SiO_2	36.0	—	6.25
Totals		576.4		100.00

The water may thus be classed as a very weak carbonate water with sodium as the principal metallic base or positive ion.

Mr. P. B. Mack, Industrial Chemist to the Wankie Colliery Company, Limited, states that two minor springs issue about 20 to 30 yards from the main spring, one having a temperature of 38 degs. C., the other a temperature of 37 degs. C. An analysis of the former follows. In the last column the original figures in grains per gallon have been re-calculated in parts per million for the sake of comparison with other figures.

Analysis by P. B. Mack (1933).

	Grains per gallon.	Parts per million.
Calcium carbonate	9.01	128.7
Magnesium carbonate	3.68	52.6
Iron and alumina	0.11	1.6
Silica	2.81	40.1
Sodium sulphate	6.92	99.0
Sodium chloride	8.73	124.7
Sodium carbonate	8.87	126.7
Total	40.13	573.4

Alkalinity in terms of sodium carbonate 23.1

The above analysis was re-calculated into the standard units used throughout this work as follows:—

		I.S.M. Parts per million.	Milli-normality N/1000.	Solute per cent.
Chloride	Cl	75.6	2.13	13.19
Sulphate	SO_4	67.0	1.40	11.69
Carbonate	CO_3	186.3	6.21	32.49
Sodium	Na	136.1	5.91	23.73
Calcium	Ca	51.3	2.58	8.98
Magnesium	Mg	15.2	1.25	2.65
Alumina and iron oxide	Al_2O_3, Fe_2O_3	1.6	—	0.28
Silica	SiO_2	40.1	—	6.99
Totals		573.4		100.00

Small mineral veins are associated with the faulting in the hillsides near the Sunga pump, and are composed of comby quartz with a deposit of mammillated psilomelane (manganese dioxide) in the centre of the vein.

Reference. Lightfoot, B. The Geology of the Central Part of the Wankie Coalfield. *Southern Rhodesia Geological Survey Bulletin No.* 15, p. 59. Salisbury, 1929.

"THE HOT SPRINGS," MUTAMBARA NATIVE RESERVE, 3102.

These springs are known as "The Hot Springs" and are the only ones in the country at which an establishment has been set up to aid in the use of the waters for health purposes, though a bathing pool has been dug in the outflow of the Rupisi springs, 3103. The natives call all thermal springs in the Melsetter District "rupisi," but the name is attached by Europeans to one particular spring (3103). Mr. J. L. Martin, M.P., points out as probably more than a coincidence that the chiefs in whose lands these "rupisi" springs are situated are each named Chibuwe.

These springs are situated in the Mutambara Reserve in the Melsetter District about 850 yards east of the Odzi river, on the very edge of the Umtali-Chipinga road, 10½ miles south of the Umvumvuvu river and 9 miles north of the Nyanyadzi river. The altitude was found by corrected aneroid barometer observations to be just under 2,000 feet.

The springs issue in two groups, the southerly one being hotter, greater in volume and the one on which bathing pools are established at The Hot Springs Hotel (Mr. H. W. Keynes).

In Plate II, B the whitened stones mark the edge of the Umtali-Chipinga road. The main eye is just below the hammer with a subsidiary eye close to it. A third eye, obviously of lesser volume than the other two combined, issues into the dark pool on the left of the photograph. The combined flow was estimated by means of a notch to be about 3,300 gallons per hour.

The temperature of the water observed morning and evening for a few days was found to be 56 degs. C. (133 degs. F.), falling once or twice to 55½ degs. The temperature of the water at the third eye was also 56 degs. C. The water is too hot to hold in a metal cup, but is just not too hot to drink. The water from the main eye gushes up about eight inches, and carries up small stones with it. Bubbles of gas come up every now and then. The water tastes of sulphuretted hydrogen, but not so strongly as the Mwengezi water (3101). This taste passes away completely when the water is allowed to stand and cool down.

The second group of springs lies 400 yards to the north and just on the west of the road. "B" spring, 30 yards from the road, issues from below an outcrop of reddened granite into a quiet pool at a point where the sand appears to boil. The highest temperature obtained here was 45 degs. C. (113 degs. F.). Bubbles of gas rise up every ten or twelve seconds through the water which feels warm and tastes of rotten eggs.

"C" spring, fourteen paces to the north, is a similar small spring with a temperature of 44 degs. C. (111 degs. F.).

"D" spring is situated about 40 paces to the north-west and at a lower level. Four eyelets four to eight inches apart discharge from a horizontal crack in a dark greenish igneous rock, which seems to be an altered dolerite. The temperature in the main eyelet was 36 degs. C. (90 degs. F.). The water feels just warm and tastes only slightly of sulphuretted hydrogen.

The sample from which the 1921 analysis was made was submitted by the Assistant Director of Land Settlement to the Chemical Laboratory of the Department of Agriculture. Two bottles were sent in and it was not stated from which eye the water was taken, or whether the sample was a mixed one taken from different springs. In any case the analysis was made on a sample obtained by mixing equal portions of the contents of both bottles and filtering.

The sample from which the 1929 analysis was made was collected by the author from the pool as near the main eye as possible in two Winchester quart stoppered bottles.

Analyses by A. W. Facer (1921) and E. Golding (1929).

		I.S.M. Parts per million.		Milli-normality N/1000		Solute Per cent.	
		Agric. Lab. No. 514 G.	Geol. Surv. Lab. No. W.A.9	Agric. Lab. No. 514 G.	Geol. Surv. Lab. No. W.A.9	Agric. Lab. No. 514 G.	Geol. Surv. Lab. No. W.A.9
		1921	1929	1921	1929	1921	1929
Nitrate	NO_3	nil	nil	...	...	...	...
Chloride	Cl	31.60	35.5	0.89	1.00	9.75	9.65
Sulphate	SO_4	45.6	50.7	0.95	1.56	14.07	13.78
Bicarbonate	HCO_3	...	97.9	...	1.60	...	26.61
Carbonate	CO_3	64.2	5.7	2.14	0.19	19.82	1.55
Potassium	K	not detd	3.1	...	0.08	...	0.84
Sodium	Na	82.1*	82.5	3.57	3.58	25.34	22.43
Calcium	Ca	6.5	1.4	0.33	0.07	2.01	0.38
Magnesium	Mg	1.0	1.5	0.08	0.12	0.31	0.41
Alumina and iron oxide	Al_2O_3, Fe_2O_3	5.0	6.0	...	...	1.54	1.63
Silica	SiO_2	88.0	83.6	...	...	27.16	22.72
Total solids		324.0	367.9			100.00	100.00
Total solids dried at 180 degs. C. (direct)		341.0					

*Calculated.

Hypothetical Composition of Salines.

		Parts per million. 1921.	1929.
Potassium chloride	KCl	...	5.8
Sodium chloride	NaCl	52.1	54.1
Sodium sulphate	Na_2SO_4	67.4	75.0
Sodium bicarbonate	$NaHCO_3$	...	134.8
Sodium carbonate	Na_2CO_3	91.8	...
Calcium carbonate	$CaCO_3$	16.2	3.6
Magnesium carbonate	$MgCO_3$	3.5	5.0
Alumina and iron oxide	Al_2O_3, Fe_2O_3	5.0	6.0
Silica	SiO_2	88.0	83.6
Totals		324.0	367.9

To the west of both groups of springs the country down to and across the Odzi river is underlain by the quartzites of the Umkondo system. Whilst these quartzites usually lie horizontally or nearly so, they are here greatly disturbed and dip at angles varying from 25 to 45 degrees to the west. East of the springs the country is underlain by granite, which about a mile and a half east of the road rises up into the precipitous hill called Dokotok. The base of the Umkondo beds, which form the higher hills of the scarp still farther east must lie at a considerably higher altitude than "The Hot Springs." It is in fact quite clear that these springs issue very close to, if not actually on, the line of a large fault throwing down to the west, and that it is the one described by Mr. F. P. Mennell (3) as the Sabi fault.

One hundred and fifty yards to the north of the northerly group of springs a donga exposes red and grey granite with a dolerite dyke about 80 yards broad. The dolerite is shattered, altered and in places veined by quartz. It is no doubt a continuation of the still more altered rock from which the "D" spring issues.

The water may be classed as a weak alkaline carbonate water containing 134.8 parts of sodium bicarbonate per million. Apollinaris waters contain 1352 parts of sodium bicarbonate per million.

There appears to be no record of the therapeutic value of the water.

Reference. Observations by the author.

Thermal spring, 2604.

Situated on the right bank of the Charara river and west of Nyagatonoro hill on the left bank. The locality is stated to be upstream from the confluence of the Mwembusa river near a foot-path coming from the east.

Reported by Mr. John Banks, Mem. Sth. Afr. Inst. Civ. Eng.

Thermal spring, 3704.

The spring is situated in the Sebungwe District about three miles from the confluence of the Masumo river with the Zambezi. The confluence is about 90 miles north-east of Wankie township.

The rock formation of the area around the confluence is a sedimentary series of sandstones, grits and shales of Karroo age.

Thermal spring, 4401.

The spring is located on the left (Northern Rhodesia) bank of the Zambezi river about one mile below the confluence of the Matetsi river. The confluence is about 25 miles east-north-east of Wankie township, and very roughly about 2,000 feet above sea-level.

It is stated that the temperature is high, the flow considerable, and that the water contains salt.

The spring rises a few yards from the waters of the Zambezi, issuing from the Batoka Basalt formation of Karroo age.

Reference. Information from Mr. F. W. T. Posselt, N.C., dated 21st November, 1916.

Thermal spring, 4501.

A thermal spring issues near the south-western corner of the Sitatonga range and perhaps three quarters of a mile south of the Lusitu river in the north-western corner of the Mossurize province of Portuguese East Africa.

Authority. Mr. J. L. Martin, M.P.

Thermal spring, 4502.

A thermal spring issues at the south end of the Sitatonga range and within a mile of the Busi river, Mossurize province of Portuguese East Africa.

Authority. Mr. J. L. Martin, M.P.

Also mentioned by Messrs. Teale and Wilson (11) and C. F. de Andrade (12).

USANGA. *See Nichenge brine spring*, 4204.

WENGESI. *See Mwengezi thermal spring*, 3101.

ZOMBA THERMAL SPRING, 4101.

A thermal spring of very small volume issues in a depression on the right bank of the Mtilikwe river in the south-east corner of the Nyajena Native Reserve half a mile to a mile north of Zomba mountain, which bears the corner beacon of the reserve. There is a slight smell of sulphuretted hydrogen. The country is underlain by granite.

Information from Lt.-Col. Carbutt, Chief Native Commissioner.

ZONGALA. *See Kabira gusher*, 3701.

LIST OF REFERENCES.

(1) Ferguson, D. The Geysers or Hot Springs of the Zambesi and Kafue Valleys. *Proceedings of the Rhodesia Scientific Association.* Vol. III, pp. 9-20. 1902

(2) Molyneux, A. J. C. The Sedimentary Deposits of Southern Rhodesia. *Quarterly Journal of the Geological Society.* Vol. LIX, p. 282. 1903.

(3) Mennell, F. P. The Geology of Southern Rhodesia. *Rhodesia Museum, Bulawayo. Special Report No.* 2. 1904.

(4) Lightfoot, B. *Southern Rhodesia Geological Survey Bulletin No.* 4. Salisbury, 1914.

(5) Rindl, M. M. The Medicinal Springs of South Africa. *South African Journal of Science.* Vol. XIII, No. 10, 1917.

(6) Geological Survey. Provisional Geological Map of Southern Rhodesia, 1921. Second edition, 1928. Salisbury, Southern Rhodesia.

(7) Rindl, M. M. The Medicinal Springs of South Africa. Supplement II. *South African Journal of Science.* Vol. XXV, pp. 116-126. 1928.

(8) Lightfoot, B. The Geology of the Central Part of the Wankie Coalfield. *Southern Rhodesia Geological Survey Bulletin No.* 15. Salisbury, 1929.

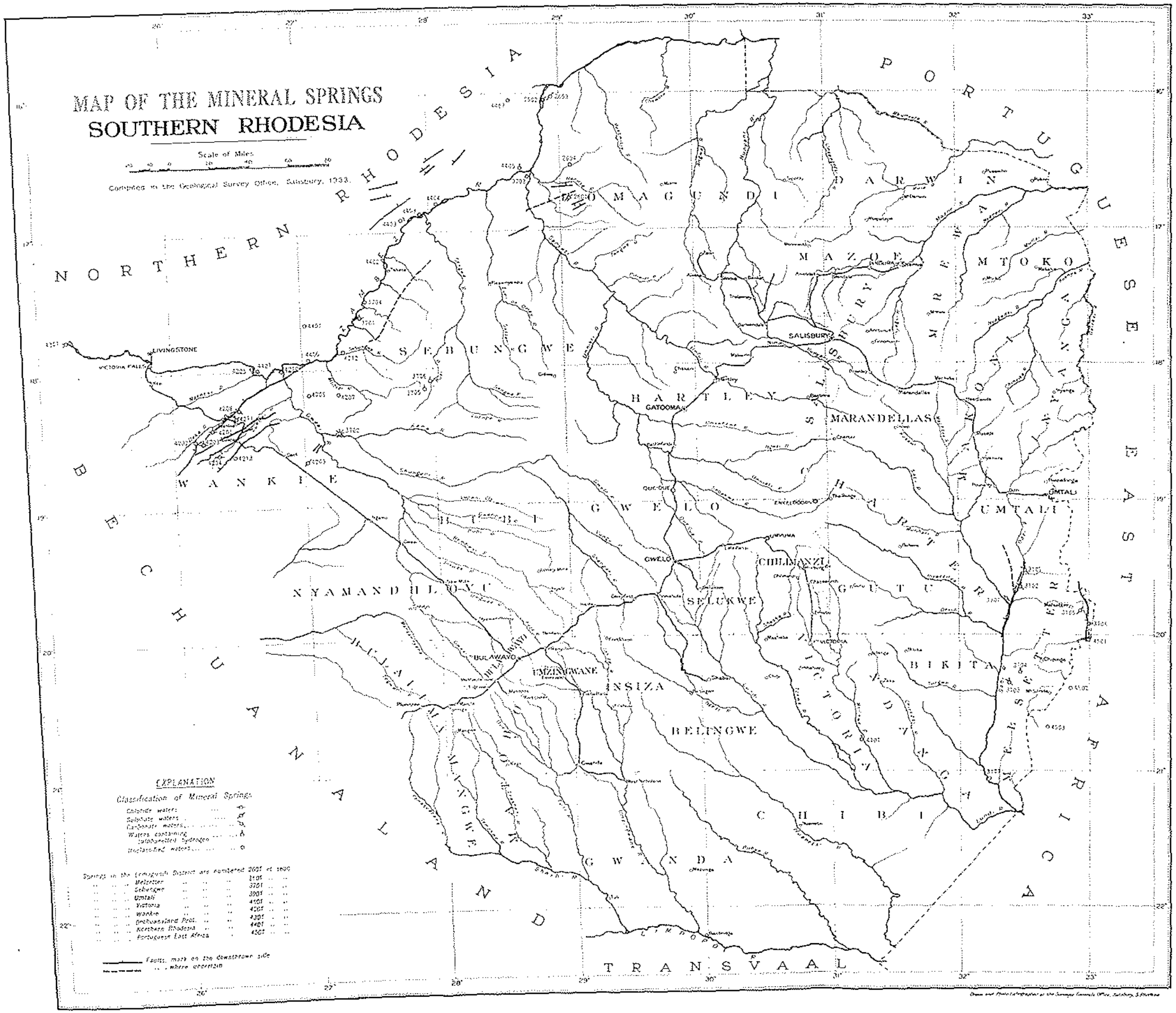
(9) MacGregor, A. M. The Geology of the Country around Que Que, Gwelo District. *Southern Rhodesia Geological Survey Bulletin No.* 20, p. 66. Salisbury, 1932.

(10) Report of Council of the International Society of Medical Hydrology. *Archives of Medical Hydrology.* Anno. VII, No. 1, pp. 153-156. London. January, 1929.

(11) Teale, E. O. and Wilson, R. C. Portuguese East Africa between the Zambezi river and the Sabi river: a consideration of the relation of its tectonic and physiographical features. *The Geographical Journal.* Vol. XLV, p. 36. January, 1915.

(12) De Andrade, C. F. Esbôço geológico da Provincia de Moçambique, pp. 198-201. Lisboa, 1929.

INDEX.



MAP OF THE MINERAL SPRINGS
SOUTHERN RHODESIA
Scale of Miles
Compiled in the Geological Survey Office, Salisbury, 1933.
NORTHERN RHODESIA
PORTUGUESE EAST AFRICA
BECHUANALAND
TRANSVAAL
LIVINGSTONE
VICTORIA FALLS
SALISBURY
GATOOMA
GWELO
BULAWAYO
UMTALI
LOMAGUNDI
DARWIN
MAZOE
MTOKO
SEBUNGWE
HARTLEY
MARANDELLAS
WANKIE
GWELO
CHILIMANZI
SELUKWE
NYAMANDHLOVU
BUBI
UMZINGWANE
INSIZA
BELINGWE
BIKITA
NDANGA
VICTORIA
CHIBI
GWANDA
CHARTER
UMTALI
EXPLANATION
Classification of Mineral Springs
Chloride waters
Sulphate waters
Carbonate waters
Waters containing sulphuretted hydrogen
Unclassified waters
Faults, mark on the downthrown side
" where uncertain