Rafin Rewa Warm Spring, A New Geothermal Discovery

M.L.Garba
Department of Geology
Ahmadu University
Zaria, Nigeria.

E. Kurowska
Department of Fundamental Geology
University Silesia, Katowice
Poland

K. Schoeneich
Department of Geology
Ahmadu University
Zaria, Nigeria.

I. Abdullahi
Department of Plant Science
Ahmadu University
Zaria, Nigeria.

Abstract

Rafin Rewa warm Spring is an ascending perennial spring that yields up to 0.1 l/s, flows from an unconfined aquifer, made up of saprolite, mostly gritty clays and clayey sands derived from the Weathering of migmatite on the Precambrian crystalline rocks of Northern Nigeria. The water is fresh and alkaline, with a mineralization of 318 mg/l. The predominant cation is sodium, with 88.51 mg/l, while the predominant anion, bicarbonate is 207.0 mg/l. A gas with the smell of hydrogen sulphide bubbles and emanates from the spring as its water ascend to the surface. The water and gas are of endogenic origin, flowing from depth not less than 700 metres below ground level, thus making the spring the only known occurrence of juvenile water in Nigeria.

Introduction

The term "warm water" relates to all kinds of groundwater that are heated by the normal terrestrial heat gradient Mazor, (2004b). In Nigeria, there are many known thermal springs such as the Wikki warm spring, but with a single exception, all of them are located in the Benue trough, a regional synclinorium that was in filled with Cretaceous to Recent marine and continental sediments, of about 5,000 metres thick. Although this synclinorium was affected by the Tertiary – Recent magmatic volcanism, none of these warm springs has its temperature related to this volcanic activity, It can only be correlated with geothermal gradient. The single exception among these warm springs mentioned above, is Igokosi warm spring situated in south-western Nigeria that flows from a fracture in Precambrian crystalline rocks, Oladipo, et al (2005). Which until recently, is the only known thermal spring in Nigeria that is located outside the Cretaceous Benue trough.

Rafin Rewa warm spring, presented for the first time in this paper is now the second known thermal spring in Nigeria which also flows from Precambrian rocks (migmatite – gneiss).

Geological Setting and Geomorphology

The area is located at the fringes of the Jos Plateau, to the SW (fig. 1), the centre of the Nigerian An Orogenic Younger Granite province of Jurassic age, and directly east of the near by Rishiwa ring complex. The area is well drained by a good network of rivers most of which take their source from the nearby ring complexes of the Jos plateau (Fig.1). The Geology It is composed of migmatite gneiss as the oldest rocks, Pan African granites and bauchites. The bauchite is an unusual rock of acid to intermediate composition, containing, in addition to fayalite, extremely iron rich pyroxenes (ferrohedenbergite and orthoferrosilite), Oyawoye and Makanjuola(1972). The topography of the area is more or less flat laying with the migmatites occurring as low lying exposures, while the granitic rocks stands out conspicuously thereby dotting the landscape.

Figure 1: Sketched Geological Map of Nigeria Showing the Study Area.

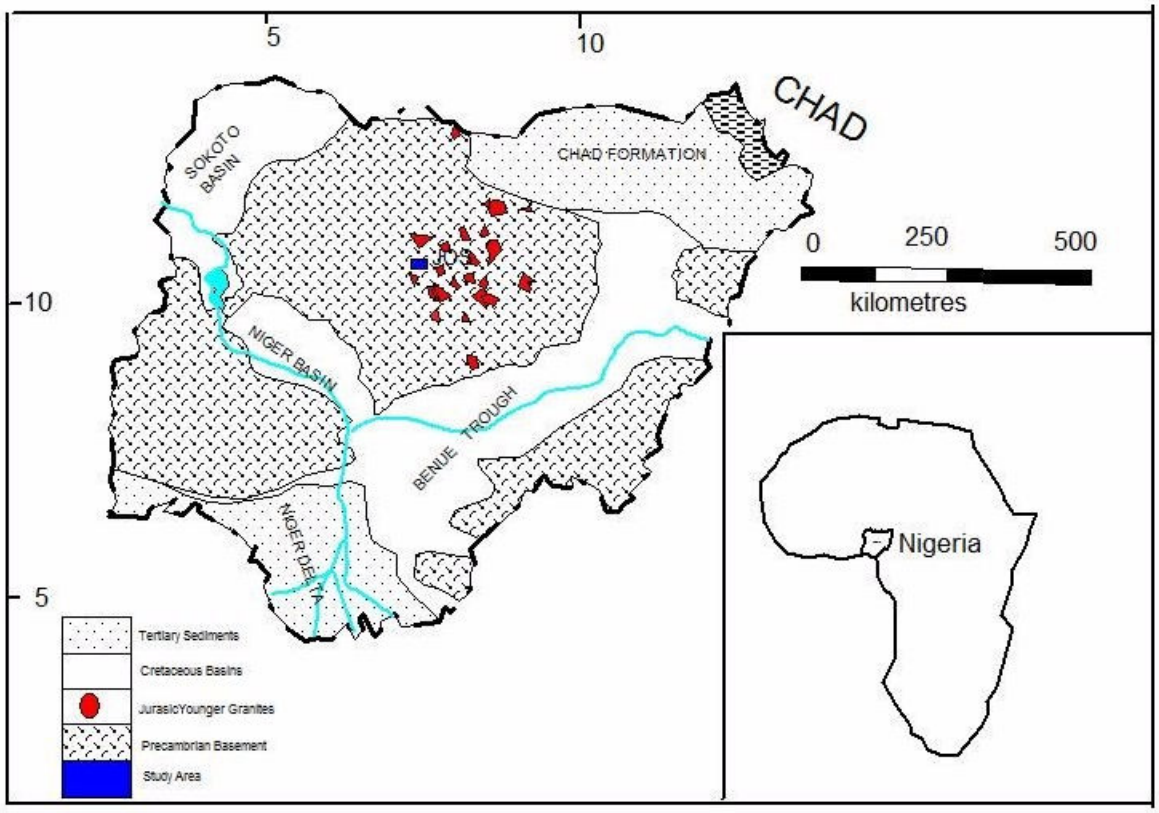

Figure 2: Geological Map of the Study Area

Material and Method

Field work was carried out during which a samples were collected. At the time of sample collection, temperature of the water was measured using a maximum thermometer, while pH, and electrical conductivity (EC) of the sample were measured in situ using field portable Ph and conductivity meters. Samples were then collected using cleaned polythene containers. Containers were well rinsed with the spring water before sample collection. Samples were collected and sealed with the container fully immersed into the water at least for the purpose of entrapping the gas content.

Analysis of collected samples were under taken at the Water laboratory of the Główny Instytut Górnictwa, Katowice Poland using ICP – OES method.

Origin of the Water in Rafin Rewa Warm Spring

Two chemical parameters observed to be in excessively high concentrations, makes the water from Rafin Rewa warm Spring unique among the known springs occurring in the Crystalline Hydrogeological Province of Nigeria:

These are sodium and bicarbonate. Sodium, according to Schoeneich, (2001), is released by weathering of plagioclase from the host rocks, since it do not exist in the atmosphere except as particulate matter. Thus, with the only source of sodium being the products of weathering of the crystalline rocks, sodium is the second cation after calcium in meteoric water of the Crystalline Hydrogeological Province, within the range of concentrations of 0.8 to 20.0 mg/l and 5.0 mg/l as an average concentrations (table 1). However, water from the Rafin Rewa warm spring has 88.51 mg/l of sodium, 17 times higher than the average concentrations in meteoric water. This sodium could not have been leached from the thin (maximum 30 metres) weathered mantle on the site of the spring. This then suggest that It can only come from the earth interior through fractures in the fresh crystalline rocks.

The second parameter making Rafin Rewa water so different is its high content of bicarbonates, 207 mg/l, six times higher than the average concentration in meteoric water. Bicarbonate in meteoric water has two sources: one is atmospheric carbon dioxide dissolved by rain water, and the second is carbon dioxide present in the humus soil, which is absorbed by water during infiltration (Schoeneich 2001). Both sources provide on average 35 mg/l, maximum 100 mg/l, as shown in table 1. This is not enough to justify the high content of bicarbonates in Rafin Rewa warm spring. It then means that the bubbling warm water from the spring is not only a meteoric water, It must have an another origin, most likely the volcanoes that are located within the Younger granite province.

With the average geothermal gradient in Crystalline Hydrogeological Province of Nigeria at only 1.8 ^{o}C/100m (Schoeneich and Askira 1990), and with allowance for cooling on its passage upwards, the depth from which the water is coming from must be more than 1 kilometre, since the temperature of water, 42.5 ^{0}C, suggests that the water comes from a great depth.

The sodium rich juvenile water probably carries also juvenile fluoride, which as Table 1 shows, is at a level, six times (7. 54 mg/l) above meteoric water background (average 1.20 mg/l).

Also the presence of organic nitrogen in form of nitrite and nitrate, as well as sulphate suggests that the juvenile water on its way upwards, through the soft overburden aquifer, absorbed some meteoric water. Sulphate, which is slightly above the level characteristic for meteoric water, has been produced by oxidation of juvenile sulphides by oxygen from meteoric water.

Discussion and Conclusion

From the data presented above, it is apparent that Rafin Rewa warm water is a clear manifestation of volcanic activity, because of the nature of the water type ($NaHCO_3$) which have been classified by some authors as of volcanic origin, (Donald 1957), and also because of its high Fl content above the natural background concentration typical of the basement complex aquifers of Nigeria. Based on some criteria which include, chemical composition, relative quantity, and depth of penetration of mixing meteoric water and water of other origin Donald (1957) classified warm waters of volcanic origin as either having dominantly NaCl type and $NaHCO_3$ and or acid sulphate chloride. This also correlates with Selin et al., (2008) findings on the geothermal springs located along the North Anatolian Fault Zone in Turkey which are mostly Na-HCO_3 in character with the exceptions of Na-SO_4 type waters (at Yalova) and Ca-HCO_3 type waters (at Bolu and Mudurnu). But in their case the dominant HCO_3 character in the hot and the cold waters was attributed to the dissolution of reservoir rocks that which are dominated by Mesozoic limestones through ion exchange with the overlying sediments which is probably responsible for the dominance of Na cation in the hot waters. But this is not the case as for the Rewa spring which is flows through crystalline Metamorphic rocks (noncarbonate rocks).

Based on Donald's (1957) Classification, it can be concluded that the water of Rafin Rewa warm spring may have originated from the Quaternary to Recent magmatic activity that affected the Jos Plateau area of Nigeria, and which possibly after mixing with meteoric water flows out as an ascending spring through regional lineaments that transcends the area. These lineaments which have a regional extent have also been been mapped by previous workers, Eric and Ca by, (2007).

Table 1. Results of laboratory analysis of Rafin Rewa warm Spring. Column three shows the Non-polluted hydrochemical background (Schoeneich 2001). * indicates insitu measurements.

Parameter	Samples from Rafin Rewa Analysed by Glowny Instytut Gornictwa, Katowice	Non Polluted Hydrochemical Background – Meteoric Water from the Crystalline Hydrogeological Province of Nigeria
PH	8.10(8.3*)	5.0 to 7.4, av. 6.4
Electro – conductivity	350 µS/cm	10 75, av. 35 µS/cm
Hardness,permanent	0.0mg/l $CaCO_3$	0.0 mg/l $CaCO_3$
Alkalinity "m"	3.40 meq/l	10 t0 40, av. 20 mg/l $CaCO_3$
Metabolic acid	0.093 mg/l	No data exist
Metasilic acid	90.2 mg/l	No data exist
Total Dissolved Solids	214 (240*) mg/l	14 to 250, av. 60.0 mg/l
Calcium	1.50mg/l	0.3 to 33.0, av.10.0 mg/l
Magnesium	0.06mg/l	0.1 to 5.8,av. 1.0 mg/l
Sodium	88.51 mg/l	0.8 to 20.0,av.5.0 mg/l
Potassium	1.64 mg/l	0.3 to 6.0, av. 3.0 mg/l
Iron	0.03 mg/l	0.01 to 1.50,av. 0.30 mg/l
Manganese	0.001 mg/l	0.003 to 0.100, av. 0.02 mg/l
Ammonia	<0.05mg/l	0.04 to 10.50, av. 2.40 mg/l
Barium	<0.005 mg/l	No data exist
Strontium	<0.05 mg/l	0.00 t0 0.02, av. 0.006 mg/l
Chloride	6.17 mg/l	0.00 to 6.00, av. 1.28 mg/l
Sulphate	3.66 mg/l	0.00 to 2.70, av, 0.60 mg/l
Sulphides	<0.01 mg/l	No data exist
Carbonate	<0.00 mg/l	0.02 to 0.04 mg/l
Bicarbonate	207.0 mg/l	8.00 to 100.00, av. 35 mg/l
Nitrate	1.73 mg/l	0.00 to 19.0, av. 3.0 mg/l
Nitrite	<0.02 mg/l	0.00 t0 0.006,av. 0.01 mg/l
Bromine	<0.05 mg/l	<0.005 mg/l
Iodine	<0.1	
Fluoride	7.54mg/l	0.000 to 1.20, av. 0.30 mg/l
Arsenic	<0.005 mg/l	0.006 – 0.010 mg/l
Chromium	<0.001 mg/l	0.000 – 0.040, av. 0.017 mg/l
Zinc	0.003 mg/l	0.002 – 0.007,av.0.004 mg/l
Cadmium	<0.001	0.0001 – 0.0021,av. 0.0004 mg/l

Table 2: Comparison of the Physico Chemical Parameters of the Rafin Rewa in North Western Nigerian Basement with other occurrence of Warm Waters in Nigeria and the World.

Parameter	Ikogosi Warm Spring Nigeria (Oladipo, et al., 2005)	Shuirebaozha,China. `(Guoping et al.,2007)	**Borehole At Kilauea Volcano, Hawaii(Robert et al., 1996)	Rafin Rewa Spring
		Ca-Na-HCO_3	$NaHCO_3$	$NaHCO_3$
Tempt. ^0C	35.8	41.6	36	42.2
pH	6.1	8.1	6.5	8.1
TDS (mg/l)	170		N.D	214
SiO_2		188	87	N.A
Fe(mg/l)	0.17			0.03
Ca (mg/l)	2.67	8.04	66	1.5
Mg (mg/l)	4.41	0.45	86	0.06
Cu(mg/l)				<0.003
Li (mg/l)				0.03
Na (mg/l)	0.71	144	71	88.51
K (mg/l)	0.84	53	7.9	1.64
Mn (mg/l)				0
Sr (mg/l)				<0.03
B (mg/l)				<0.005
CO_3 (mg/l)		N.D.	N.D.	0
HCO_3 (mg/l)		622	799	207
SO_4 (mg/l)	50.1	41.4	154	3.66
Cl (mg/l)	10.9	313	4.1	6.17
Fl (mg/l)		14.9	N.D.	7.54
Br (mg/l)				<0.05
I (mg/l)				<0.1
B (mg/l)			0.07	
Ni (mg/l)				<0.001
Pb (mg/l)	0.02			<0.002
Zn (mg/l)	0.05			
NO_3 (mg/l)		33.1		1.73

N.D.; no data

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