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NATIONAL ENERGY AUTHORITY
GEOTHERMAL DIVISION

Halldór Ármannsson
Gestur Gíslason

GEOTHERMAL RESOURCES OF BURUNDI

Report on a reconnaissance mission 1982.08.30-09.13

OS-83025/JHD-06
Reykjavík, Apríl 1983

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GRENSÁSVEGUR 9,
108 REYKJAVÍK ICELAND

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ABSTRACT

During a geothermal reconnaisance mission in Burundi in the autumn of 1982, two scientists from the National Energy Authority, Iceland, and one from the Ministry of Public Works, Energy and Mines, Burundi, visited 14 geothermal locations. Fifteen samples of geothermal water, three of cold groundwater and one of gas were collected.

Eight of the locations are outside the western branch of the East African rift valley, but six inside it. All the springs outside it rise through Precambrian rock. The springs at one location inside the rift valley also rise through Precambrian rock, but at the other five through sediments. Using chemical geothermometers the highest probable source temperatures were found at three of these, all situated in the Rusizi valley. It is unlikely that exploitable geothermal reservoirs can be found in the Precambrian rock, but the porosity of the sediments in the Rusizi valley should be adequate for potential exploitation there.

Reservoirs with source temperatures above 100°C probably underlie parts of the Tshibinde volcanic zone south of Lake Kivu. The geothermal manifestations in the Rusizi valley are likely to be a part of this, but other parts of the volcanic zone lie in Zaire and Rwanda. It is recommended that further geological and geophysical studies should cover the whole of this potential geothermal area in co-operation between Burundi, Rwanda and Zaire.

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Geothermal Division

Our date 1983.05.04 | Our ref. GP/sv
Your date | Your ref.

Mr. Thor Gudmundsson
The Icelandic International Development Agency
Raudarárstígur 25
101 Reykjavík

The Geothermal Division of the Icelandic National Energy Authority herewith transmits to the Icelandic International Development Agency its report on a geothermal energy reconnaissance mission to the Republic of Burundi, which was carried out on 30 Aug. - 13 Sept. 1982.

The mission was undertaken in response to a request dated 18 August 1981 from the Minister of Public Works, Energy and Mines in Burundi to the Icelandic Minister of Industry. A proposal was drawn up by the Geothermal Division as to the feasibility and scope of the mission, whereupon a decision was taken to carry out the mission under the auspices of the Icelandic International Development Agency. The cost was borne jointly by the IIDA and the INEA.

Two INEA geothermal scientists, Messrs. Gestur Gíslason geologist and Halldór Ármannsson chemist, undertook the reconnaissance mission, which was carried out with the co-operation of Mr. Liboire Muhagaze, a counterpart from the government of Burundi. Fourteen geothermal sites were visited. Samples of water and gas were drawn and analysed for volatile constituents in Burundi, and samples for complete chemical analysis were sent to the INEA laboratories in Iceland.

The main conclusion emerging from the mission is that only under the Rusizi valley in northwestern Burundi is it likely that an exploitable reservoir with a source temperature of over 100°C will be found. This area is the southeastern part of the Tshibinde volcanic zone, most of which lies in Rwanda and Zaire.

It is recommended that further geological and geophysical studies be carried out in the Rusizi valley in order to better define the boundaries of potential reservoirs. In view of the geographical extension of the Tshibinde volcanic zone within Burundi, Zaire and Rwanda, it would be advantageous if such a study could be carried out in co-operation between these three countries.

Respectfully yours

Gudm. Pálmason

Gudmundur Pálmason
Director, Geothermal Division, INEA

Mailing address: Grensásv. 9, 108 Reykjavík Iceland | Id number: 6901-3058 | Telephone: 8 36 00 | Cable address: Orkustofnun | Telex: 2339 Orkust Is | Bank: L.Í., Laugav. 77 | Account nr.: 4669

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1 INTRODUCTION

In a letter dated 1981.08.18 from the Minister of Public Works Energy and Mines, Burundi, to the Icelandic Minister of Energy and Industry, assistance was requested in estimating the possibilities of utilization of geothermal resources in Burundi. A report by Edeline **et al** (1981) which included a description of geothermal manifestations in Burundi and analyses of some geothermal waters accompanied the letter.

The Icelandic Minstry requested that Orkustofnun (The National Energy Authority of Iceland) performed the necessary studies. A short preliminary report (Ármannsson & Kristmannsdóttir 1981) was handed to the Ministry shortly afterwards. Its recommendation was that further data be obtained so that a fuller assessment could be given. All available data were gathered and a report recommending a reconnaisance mission was published as a result (Gíslason & Ármannsson 1982). Furthermore the NEA received a request for technical aid to Burundi in the geothermal field from the Icelandic Foreign Ministry 1982.01.07. The letters to the Icelandic ministries of Industry and Foreign Affairs are printed in Appendix 1.

The recommended reconnaisance mission was undertaken by the authors of this report from 30th August to 13th September 1982.

The results obtained during and after the mission together with the data gathered previous to it form the basis of this report.

In Burundi the research was carried out in cooperation with Mr. Liboire Muhagaze, a counterpart from the government of Burundi which also provided a vehicle, a driver and access to a chemical laboratory.

2 EXECUTION OF THE STUDY

2.1 Data collection

Data on previous geological and geothermal research were obtained from the available literature (McNitt 1969, Deelstra et al 1972, Edeline et al. 1981) and geological and other maps (Ministere des Colonies 1956, Lepersonne & Waleffe 1975, Lepersonne 1977, Waleffe 1979, Waleffe 1981, Radulescu 1981). Data on the chemical composition of cold water in Burundi were supplied by Burundian Water Board, Regideso. Two meetings were held with the directors of geology and general energy and Mr. Muhagaze and one with the Minister of Public Works, Energy and Mines, where information on the country's energy situation and needs were made available. Further details were filled in and inconsistencies corroborated by consulting a report from the World Bank and UNDP (Hughart et al. 1982).

2.2 Reconnaisance

The field study was organized in such a way that for most of the time the participants spent their nights in Bujumbura, but their days driving to and stopping at field sites. During the study of the northern part of the country the participants spent one night in a catholic mission house. All known geothermal localities were visited by the authors of this report and Mr L. Muhagaze. The guidance of local people proved very helpful indeed. In fact, the only locality not previously described, i.e. Gasenyi, would not have been found without such local assistance. All localities visited and those for which cold water analyses were obtained are shown in Fig. 1.

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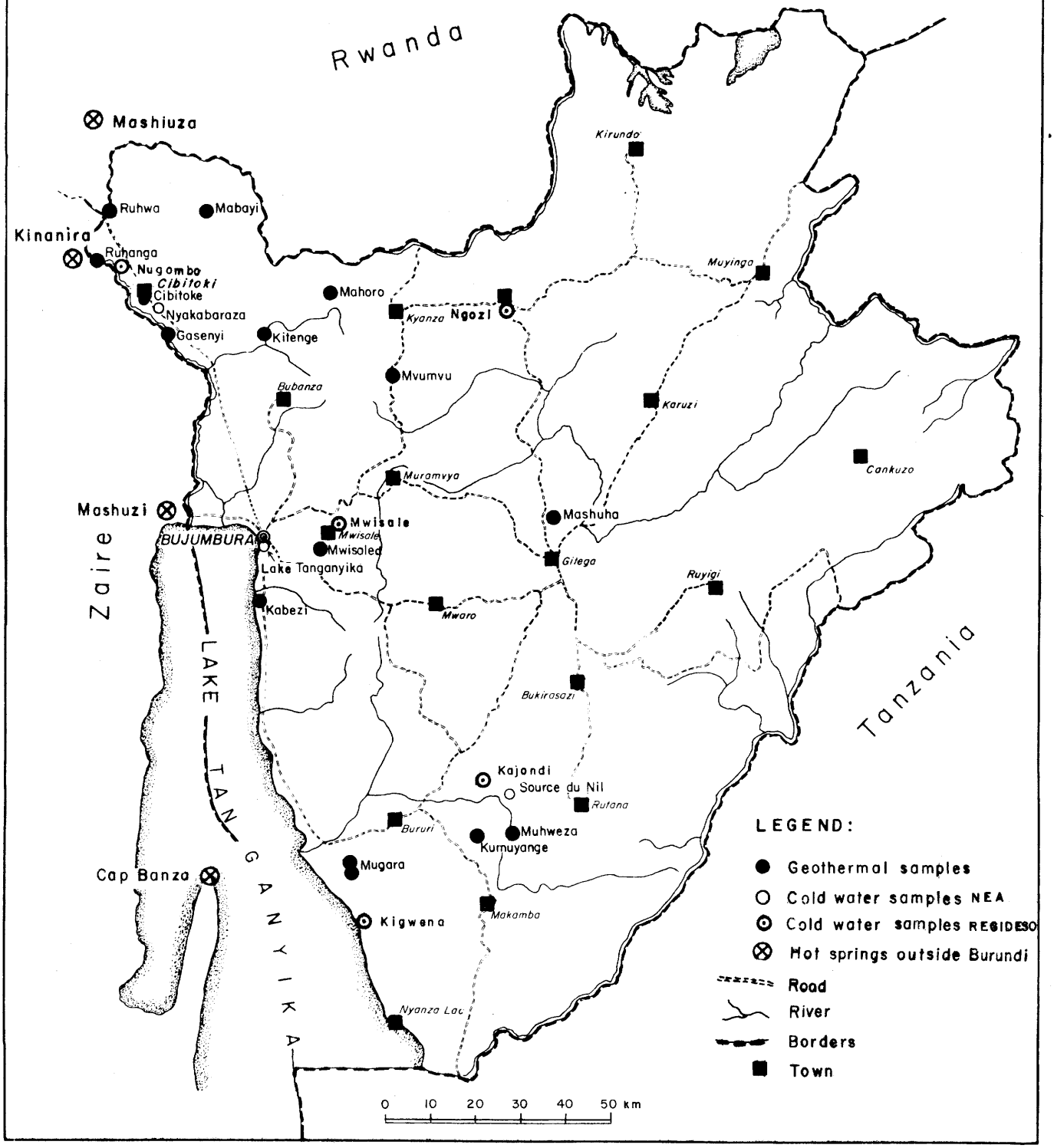
Fig. I. Burundi Sampling locations



2.3 Methods of surveying, sampling and chemical analysis

At the geothermal sites the main geological features were studied, i.e. rock types, possible faults, the distribution of hot springs and the possibility of mixing between thermal and cold surface water. The flow rate was measured or estimated. The temperature was measured in all springs with a digital thermometer, NEA designed and made, connected to a two-terminal integrated circuit temperature transducer probe on a one metre long bar. At each sampling location three water samples were drawn.

1) Raw untreated sample (Ru) into an air-tight 250 ml glass-tube for the analysis of pH, CO_2 and H_2S.
2) Filtered untreated sample (Fu) was filtered through a 0,45 Millipore membrane filter and collected into a one litre plastic bottle for the analysis of SiO_2, SO_4, Cl, F and total dissolved solids (TDS).
3) Filtered acidified sample (Fa) was filtered as above, acidified with 2 ml 6 N HCl and collected into a one litre plasic bottle for the analysis of Na, K, Ca, Mg and Li.

All the samples were cooled to ca 20°C by passing them through a cooling spiral immersed in ice-water to prevent the formation of gas bubbles in the Ru samples. The analysis for pH, CO_2 and H_2S was performed daily by the authors at the chemical laboratory of the Department of Geology, Ministry of Public Works, Energy and Mines, Bujumbura. At one location a gas sample was drawn into an air-tight 250 ml glass tube by first filling it with cooled sample water which was subsequently driven out by the gas stream. The analytical methods used in water analysis, their precision and source references are listed in Table 1. The precision of the pH determination is that cited by the producers (Schott-Geräte 1977), that for SiO_2, Na, K, Ca, Mg, CO_2, SO_4, H_2S and Cl is obtained from the results of the determination of several duplicates of different concentrations in the NEA laboratory, but the one for F and TDS from the results of the multiple determinations of two reference samples of different chemical compositions.

TABLE 1 BURUNDI 1982. Methods of chemical analysis

Constituent	Sample Fraction	Method	Precision	References
pH	Ru	Combined glass electrode Schott type N-62 Meter type CG 718	±0.01 pH	Schott-Geräte 1977
SiO_2	Fu	Spectrophotometric on yellow ammonium molybdate β-complex after treatment with I_2 and $Na_2S_2O_3$	1.6%	Strickland 1952 Govett 1961 Elísson 1969
Na	Fa	Atomic absorption spectrometry on solution containing 100 ppm Li	1.4%	Perkin-Elmer 1976 Ármannsson & Hauksson 1978
K	Fa	Atomic absorption spectrometry	1.4%	Perkin-Elmer 1976
Li		Atomic absorption spectrometry		Perkin-Elmer 1976
Ca	Fa	Atomic absorption spectrometry on solution containing 2% La	4.3%	Willis 1961 Perkin-Elmer 1976
Mg	Fa	Atomic absorption spectrometry on solution containing 2% La	13.8%	Willis 1961 Perkin-Elmer 1976
CO_2	Ru	pH adjusted to 8.20 titration with 0.1N HCl to pH 3.80	3.8%	Ellis & Mahon 1977
SO_4^{-2}	Fu	Titration with $BaCl_4$ using thorin as indicator	2.6%	Henriksen & Bergmann-Paulssen 1974 Gunnlaugsson 1978
H_2S	Ru	Titration with $HgAc_2$ using dithizone as indicator	13.7%	Archer 1956 Arnórsson 1969
Cl^-	Fu	Titration with $AgNO_3$ using $KCrO_4$ as indicator (Mohr titration)	2.3%	ASTM 1966
F^-	Fu	Determination with selective electrodes (ORION 94-09 and 90-01 as reference) after addition of TISAB buffer	3.9%	Orion 1977
Total dissolved solids	Fu	Evaporation	3.2%	

The standard deviation for the duplicates is obtained from the relation

$$\% S = \sqrt{\frac{\sum_{1}^{N} \left(\frac{2ti}{ti_1 + ti_2}\right)^2 - \sum_{1}^{N} \left(\frac{2ti}{ti_1 + ti_2}\right)^2 / N}{N - 1}} \qquad (1)$$

where %S=Precision (standard deviation on per cent basis).
ti: Result of a singular determination
ti_1, ti_2: Results of duplicate determinations of each sample.
N: Number of determinations.

For multiple determinations relation (2) was used

$$\% S = \sqrt{\frac{\sum_{1}^{N} ti^2 - \left(\sum_{1}^{N} ti\right)^2}{N - 1}} \qquad (2)$$

The precision value obtained for magnesium (Table 1) is probably an overestimate in relation to the present samples, since several high temperature samples with very low magnesium concentrations were included.

The gas sample was analyzed with a Carle AGC 111 H,S gas chromatograph using a Poropak column to retain and separate H_2O, CO_2 and H_2S from the rest of the gas, and a Molecular Sieve 13X column at 75°C to separate H_2, O_2 + Ar, N_2 and CH_4. Nitrogen was used as a carrier gas for hydrogen detection, but helium for the detection of the others. Detection is by a thermal conductivity detector (Hauksson 1981).

The analyses for deuterium and oxygen-18 were carried out mass-spectrometrically by Dr. George Darling, Institute of Geological Sciences, Hydrological Division, Crowmarsh Gifford, Wallingford, Oxfordshire, England, and his assistance is fully acknowledged.

3 GEOTHERMAL RESOURCES

3.1 General features

The temperature of the earth's crust increases with depth. Heat flows from the interior of the earth to the surface by means of conduction or mass transfer. Observations from various geological settings demonstrate a difference in heat flow, generally decreasing with age (Pollack 1982). The heat flow from Cenozoic volcanic areas can be, on average, twice as high as from Precambrian shields. Geothermal fields are areas where the geothermal gradient is abnormally high and a large amount of heat is transferred to the earth's surface usually by means of water circulation. Abnormally high heat flow to the surface is most obvious in regions of volcanic activity in the form of volcanic eruptions where molten lava extrudes and fumaroles and hot springs are numerous. Volcanic activity and associated geothermal fields are found in many parts of the world usually closely related to plate boundaries. Geothermal fields are found in areas where plates are being formed, such as in Iceland as well as in areas of plate subduction (New Zealand, Japan, Philippines). The anomalous geothermal gradient in such areas is usually caused by the intrusion of magma into the upper layers of the crust. The magma body cooling at a shallow depth causes a local high geothermal gradient, the ground water becomes heated and moves due to a reduction in density towards the surface where the heat is released into the atmosphere.

Besides the very high geothermal gradient around cooling intrusions at high crustal level, the regional gradient in certain areas can be sufficient for geothermal systems to form, provided that permeable strata or fractures allow deep circulation of groundwater, under a hydrostatic head. Upflow of warm groundwater and geothermal surface manifestations would in this case preferably be found along faults at topographically low levels. This type of geothermal system usually leads to lower temperatures than the former and is referred to as a low temperature area as opposed to a high temperature area.

3.2 Terminology

Surveys of geothermal energy utilization have been carried out at the request of the Technical Panel on Geothermal Energy of the Preparatory Committee for the United Nations Conference on New an Renewable Sources of Energy, Nairobi 10th - 21st August 1981 (Guðmundsson & Pálmason 1981, Bolton 1981). For the purpose of these surveys it was decided convenient by the Panel to use 180°C as the temperature limit dividing high and low temperature geothermal fields. This terminology will be adhered to in this report. High temperature areas are characterized by fumaroles, solfataras, mud pools and alteration of the surrounding rocks. They are usually connected with active volcanism. Low temperature areas are characterized by hot water springs and little alteration of the rocks. Of course, 180°C is no absolute limit and there exists a number of borderline cases.

3.3 Utilization

Geothermal water has been used by man for centuries for bathing, cooking and heating, but any further utilization has been minimal until quite recently. Geothermal power can now be used at a wide range of temperatures. Fig. 2 shows the approximate temperatures for various geothermal uses (Edwards et al. 1982). The utilization can be divided into two categories, direct and indirect. The former includes space heating and cooling, agriculture and agricultural production, and industrial processes. A recent study of the world's direct geothermal energy utilization shows that about 8000 MW thermal are installed in 11 countries (Guðmundsson & Pálmason 1981). The production of electricity is by far the most important indirect utilization of geothermal energy, and in 1980 the installed capacity for geothermally generated electricity was 2462 MW electric (Bolton 1981).

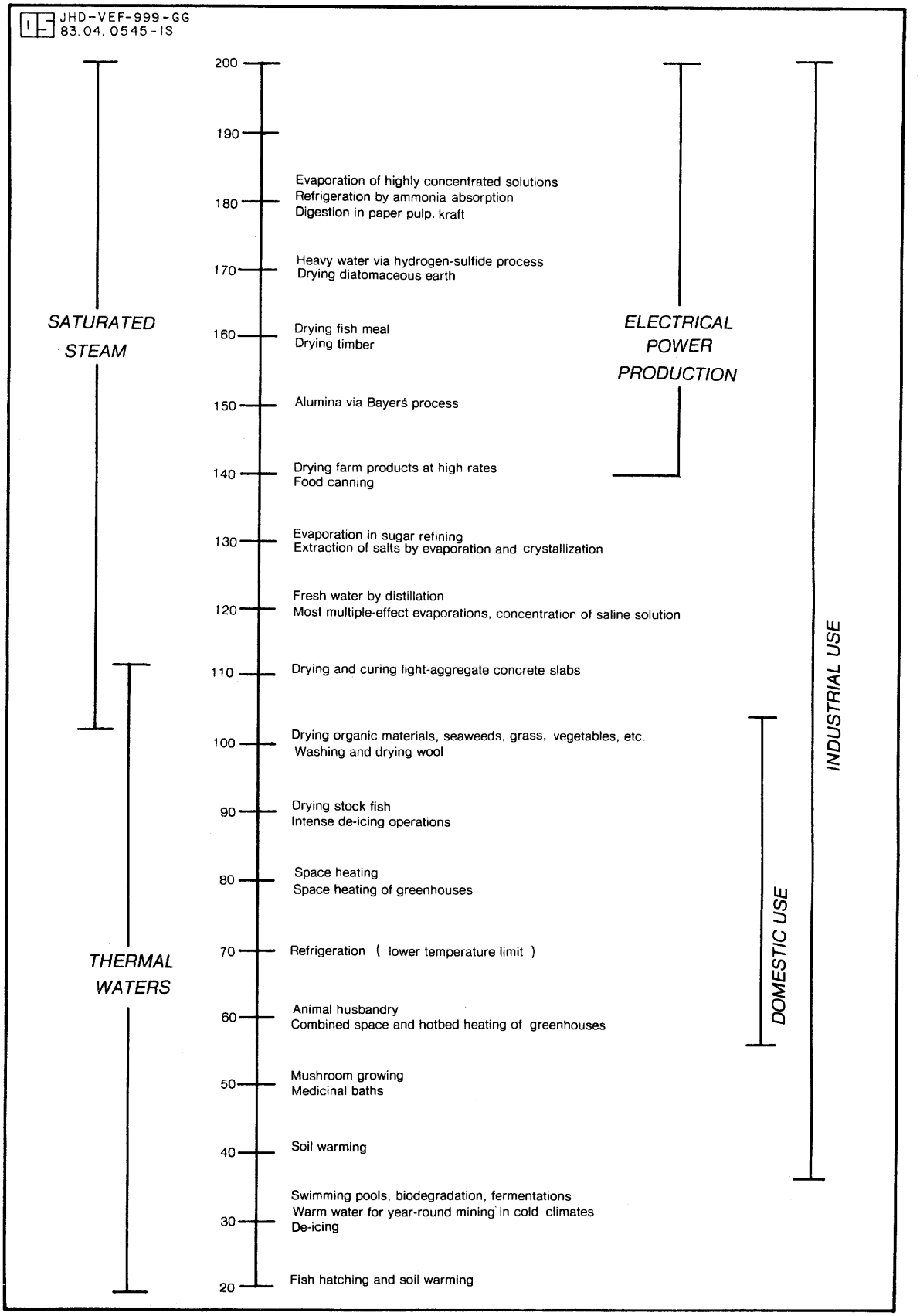


Fig. 2 Approximate temperatures for various geothermal uses

4 THE ENERGY SITUATION IN BURUNDI. PRESENT STATE AND FUTURE NEEDS

Burundi is a landlocked country in central Africa. It has borders with Zaïre in the west, Rwanda in the north and Tanzania in the east and south. Its area is 27820 km^2 and its population 4.2 millions. The biggest city is the capital Bujumbura, with ca 150000 inhabitants. The main industry is agriculture and the major products are cotton, rice, tea and coffee. The income from coffee constitutes about 90% of that of the total export, so that Burundi's economy is very much dependent on the world coffee price. Industry is not extensive and mostly connected with agriculture, such as in textiles, tea and coffee.

The bulk of the information below was obtained at meetings with the people responsible for Burundi's energy sector, but it has been supplemented after consultation with the UNDP/World Bank report by Hughart **et al.** (1982) who surveyed the energy situation in Burundi. Details of energy sources and uses are listed in Table 2 and locations of energy plants and power transmission lines are shown in Fig. 3.

The major problems in Burundi's energy sector are the very extensive use of fuelwood, which is causing a very rapid dwindling in its supply, and the very high cost of petroleum products caused partly by last decade's rise in oil prices but also the high cost of transport. The most pressing needs are thus the reduction in the use of these two fuel types. Both high and low temperature geothermal areas could be useful in this respect. It is in the industrial use in the tea factories, the brewery and the textile factory, where at first glance it seems most promising to replace fuelwood or fuel oil by geothermal water or steam. Some household uses are feasible even though space heating is not in great demand. Hot water might be piped into homes, missions or farms for various uses. Several of the geothermal sources in Burundi have traditionally been used for bathing and some are renowned for their curative properties. These are generally large flow sources, where construction and running of pools would not present great problems. With the advent of tourism warm pools and health spas might be a valuable asset. Some of the thermal waters are carbon-dioxide rich.

TABLE 2 Burundi 1982. Energy sources (present and planned) and their uses

Energy source	Location	Stage	Production	Chief uses	Notes
Agricultural and forestry resource base (Forests, savannah, fuelwood agricultural residues)	All over		Reputed to be ca 90% of all energy consumption	Rural and urban households (Cooking, heating, lightning) Tea factories, Missions	Includes charcoal production, chiefly for urban households
Peat	Akanyaru Basin Nyamuswaga Highland (Kishubi, Kitanga, Nyacijima, Kashiro, Kurunyange	Early development	10.000 tns/year estimated for 1982. (1981: 6.000 tons)	Tea factories Missions	Estimates range from 100-1500 million ton resources
Hydro-electricity	Rusizi I.	Complete	Total 28 MW Burundi 9 MW	Urban households. Urban industrial/ commercial (lighting, electrial appliances etc.)	Imported from Zaire
	Mugere	- " -	8 MW		
	Rwegura	Under construction Expected to be completed in 1986	18 MW (planned)		Imports from Zaire will discontinue, when completed
	Rusizi II	Planned. Construction expected to start 1983	Total 40 MW planned. Burundi's share uncertain		EGL project with Rwanda and Zaire
	Rusumo Falls Rwanda	Under study	Total 60MW planned, Burundi's share uncertain. Could be 20-70 MW according to design.		Cooperation project with Uganda, Rwanda and Tanzania. Tanzania's interest deciding factor
	Gitega	Just completed	1.2 MW		Germany supervised construction REGIDESO about to take over

TABLE 2 (cont.)

Energy source	Location	Stage	Production	Chief uses	Notes
Hydro-electricity	Muramvya		0.85 MW		REGIDESO
	Taza		0.2 MW		Tea estate, privately owned
	Cibitoha		0.08 MW		Mission, privately owned
	Mugera		0.06 MW		Mission, privately owned
	Mwaro		0.08 MW		Sanatorium, privately owned
	Burasira		0.02 MW		Mission privately owned
	Muyinga	Under construction Completion expected 1983	0.85 MW		KfW financed
	Kirundo	Under construction	0.24 MW		KfW financed
	Miscellaneous	Under construction	6 plants 0.03-0.08 MW Probably ca 0.3 MW		Government "Villagization" process
	Miscellaneous	Under study	5 locations Probably ca 0.2 MW		Government "Villagization" process
Diesel-driven electricity	Bujumbura		2 MW		Rated capacity >5 MW Rehabilitation under way. Mostly operated on standby basis
	Gitega		0.5 MW		REGIDESO
	Bururi		0.3 MW		REGIDESO
	Taza		0.6 MW		Tea estate Privately owned
	Rwegura		0.2 MW		Tea estate privatly owned
	Imbo		0.2 MW		Farm, privatly owned

TABLE 2 (cont.)

Energy source	Location	Stage	Production	Chief uses	Notes
Diesel-driven electricity	Kihonga		0.06 MW		Mission privately owned
	Ngozi		0.12 MW		Mission 0.8MW School 0.4 MW Privately owned
	Miscella-neous		0.36 MW		Missions privately owned
	Miscella-neous		0.04 MW		Provincial headquarters
	Miscella-neous		0.1 MW		5 Hospitals, privately owned
	Miscella-neous		0.1 MW		17 Post & Telephone offices
	Miscella-neous		0.1 MW		Various private owners
	Miscella-neous	In preparation	54, range 0.017-0.1 MW Probably 3 MW		Provided by the Japanese government to isolated hospitals and missions
Petroleum products			45 mn liters/year Gasoline 53% Gas-oil 37% Fuel-oil 7% Kerosene 3%	Tea factories Missions Urban industrial ~~commercial~~ (lighting, electrical appliances process heat, engines) Transport-ation and construction	Largest industrial user brewery (2.4 mn liters) Textile plant 0.46 mn liters 1980, but designed to use 7.2 mn liters. Both use primarily fuel oil

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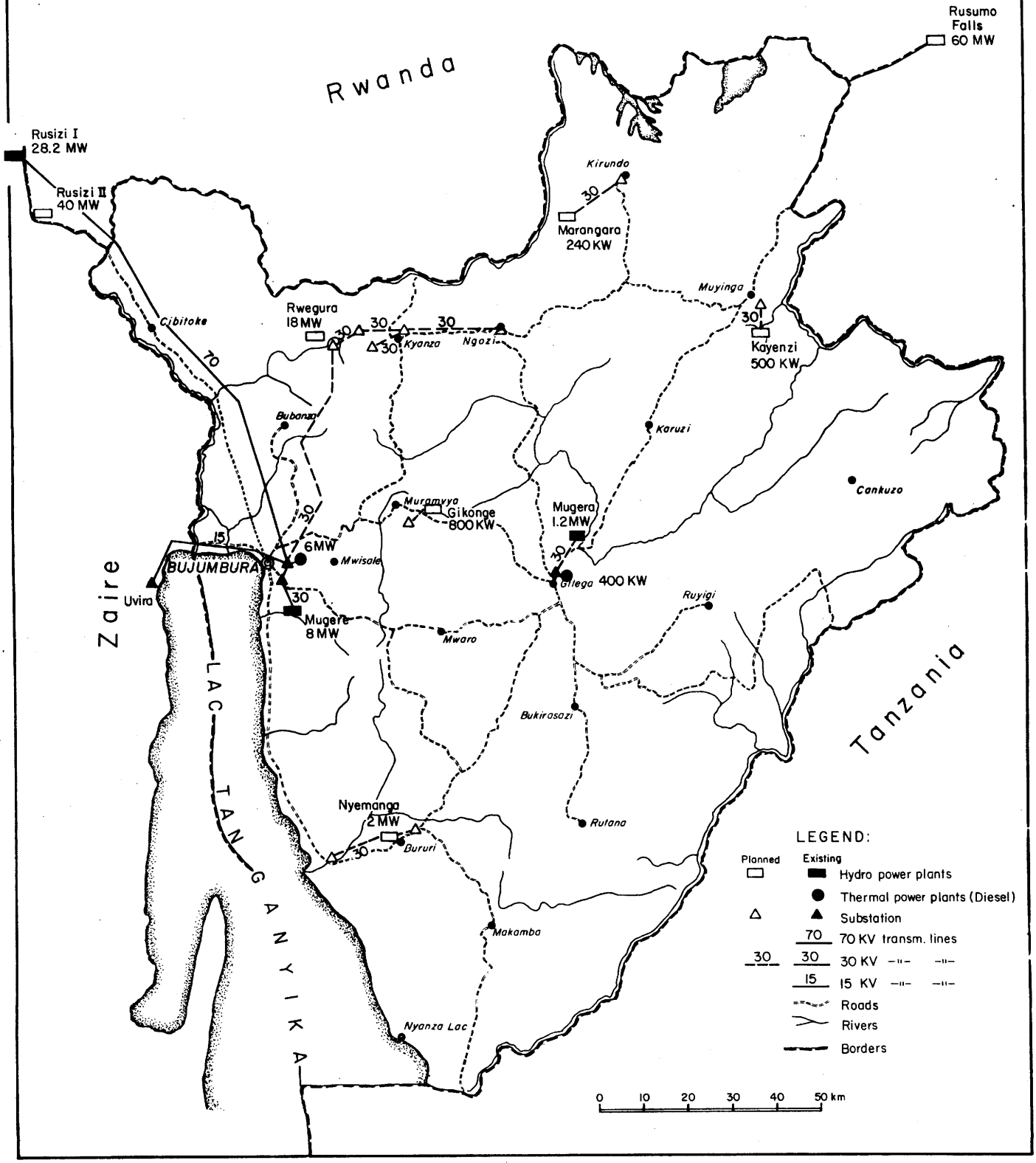
FIG. 3. BURUNDI: POWER PLANTS AND TRANSMISSION LINES



Such natural mineral water is by many regarded as a health drink, and its bottling could become a minor source of income.

An overview of the electricity situation in Burundi is presented in Table 2 and it is summarized in Table 3 making the following assumptions:

- That Burundi's share of the production from the Rusizi II plant will be one third.
- That a 60 MW plant will be constructed at the Rusumo Falls in Rwanda, and that Burundi's share of its production will be a quarter.
- That the diesel-driven generators in Bujumbura will be rehabilitated.
- That Burundi will cease to buy electricity from the Rusizi I plant, when the Rwegura plant starts producing.

In their report Hughart et al. (1982) assume that the growth in demand for electrical power will remain at 10-11% per annum during the 1980s. This is considerably lower than the government's estimate, but even at that rate all planned electricity plants and those under study would only just manage to satisfy this demand in 10-11 years time, if successfully completed by then. The future energy situation thus needs serious consideration. Electricity would, however, not be produced from geothermal resources unless high temperature areas were found.

TABLE 3. Burundi 1982. Electricity production, present and planned (MW)

Plant Types	Present		Planned		Total, when all projects finished	Need in 10-11 years, assuming 10-11% growth per year.
	Imported	Internal production	Under construction	Under study		
Hydro-electricity	9	10,5	33	15	58,5	
Diesel-driven		4,7	6		10,7	
Total	9	15,2	39	15	69,2	69

5 BURUNDI: GEOLOGY AND GEOTHERMAL FEATURES.

5.1 Geological information

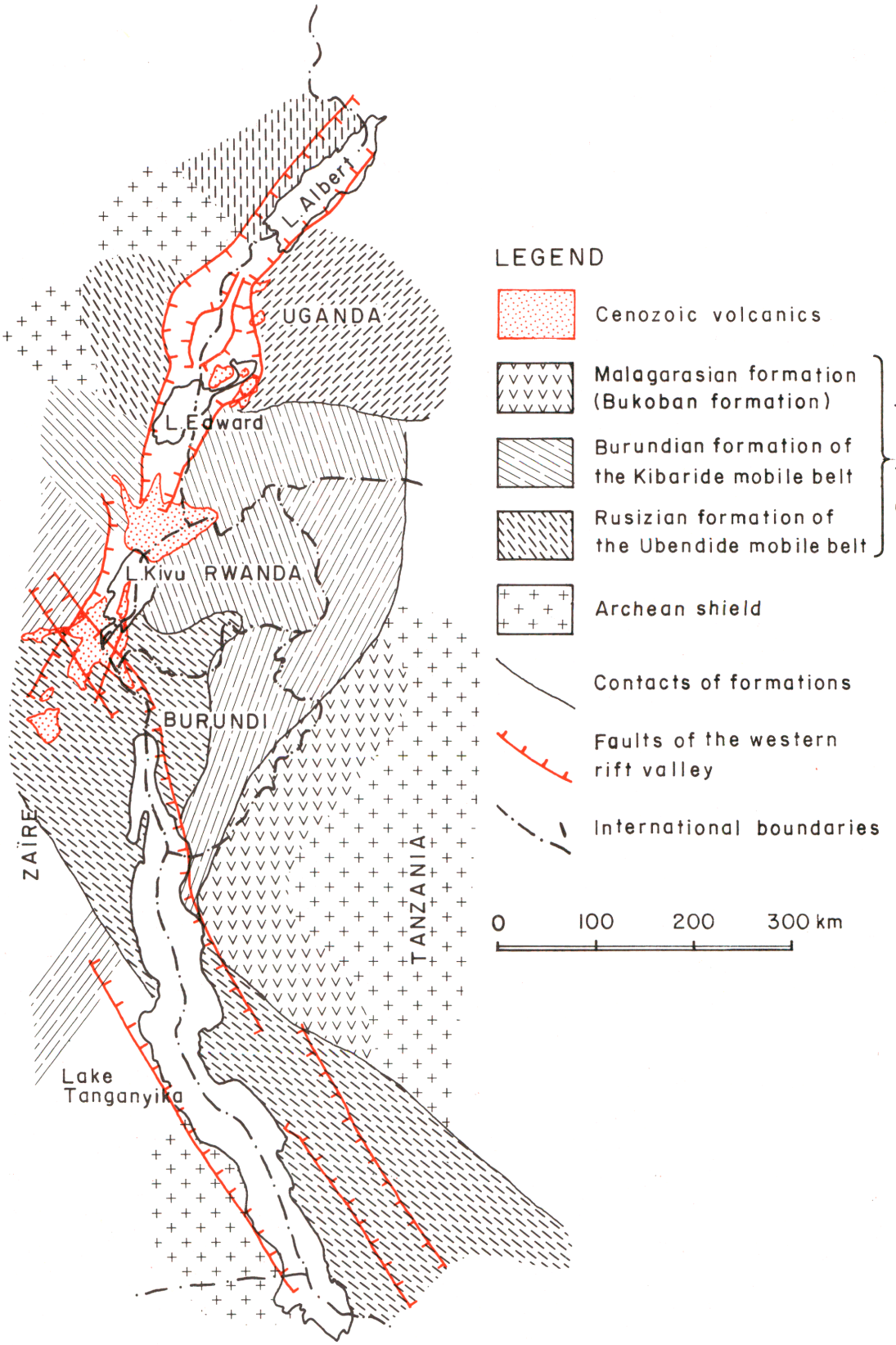
The structure of East-Africa away from the rift zone is typical of stable shield areas. The base rock is of Precambrian age and can be described as granitoid shields of Archean age flanked by metamorphic rocks of Proterozoic orogenic belts (McConnell 1972). One of the shields is the Tanganyika shield of Tanzania which has a minimum age of 3000 m.y. The shield is flanked in the west and south by the Ubendide, Kibaride and Bukoban orogenic belts (Fig 4). Burundi is west of the Tanganyika shield and its oldest rock formation is the Rusizian of the Ubendide belt, whose age is in the 2000 to 1600 m.y. range. The Burundian belt of the Kibaride formation overlies unconformably the Rusizian. Its age is in the 1300-1000 m.y. range. The Malagarasian lies unconformably on the Burundian. This formation which is a continuation of the Bukoban formation of Tanzania seems to be formed outside the orogenic belts and is therefore less folded than the older formations. The age of this formation is 900-500 m.y. Many types of rocks are found within these formations, such as quartzite, which seems to be the most common, schist, dolomite, sandstone, conglomerate, phyllite and intrusive rocks such as gabbro, dunite, serpentinite and granite.

The rift system is a much younger structure in the geology of East-Africa than the formations described above. It extends over 6500 km from Turkey to Mozambique and includes the Dead Sea, the Red Sea, the Gulf of Aden, and the East African rift which is divided into two branches, the eastern and western rifts, separated by the Tanzanian shield. The rifts frequently run parallel to the Precambrian mobile belts. The western rift runs for instance parallel to the Ubendian and Rusizian fold belts. Some authors believe that the rifts originated in the Precambrian era and that they have been reactivated several times (McConnel 1972).

Seismic and gravimetric studies suggest that a significant

Fig. 4

The principal geological structures of central Africa



thinning of the crust occurs in the rift zones (Long et al. 1972, Darracott et al. 1972, Baker et al. 1972). The nature of the zones indicates a magmatic mechanism similar to those underlying the mid-oceanic ridges, although no new oceanic crust has been formed in the intracontinental rift of East Africa.

The East African rift system is of Cenozoic age (McConnel 1972) and is still active as numerous active volcanoes and seismic activity show (Fairhead & Stuart 1982, Williams 1982, Barberi et al. 1982). The floor of the western rift valley is usually covered with young sediments. In the Lake Albert region the thickness of the sediments is 2.5 km and close to 1 km in the Albert Nile sector(Williams 1982). The sediments can form a good geothermal reservoir, whereas the Precambrian rocks are considered very poor in this respect.

Heat flow in the rift is anomalously high although not as high as in the oceanic ridges. Anomalous heat flow is not found on a regional scale in the western rift but is limited to areas or nodes where strikes cross or change direction (McConnel 1972). Heat flow studies suggest relatively low values for Lakes Malawi and Tanganyika although high local values can be found there. In Lake Kivu a wide range of heat flow has been found (Degens et al. 1973, Morgan 1982). An intense volcanism is known in the eastern rift. In the western rift volcanism occurs at fewer localities near rift culminations at rift arms junctions (McConnel 1972, Barberi et al. 1982). The volcanic zones are Rungwe, South Lake Kivu, Virunga and Toro-Ankole (Fig. 4 & 5). The alcalic composition of the rocks indicates great depth of magma generation below both rifts.

Burundi lies east and north of Lake Tanganyika. It is situated astride the eastern margin of the western rift. The Burundian coast of Lake Tanganyika and the Rusizi valley belong to the rift. This part of the country is considered to have the highest heat flow and is therefore the most probable area of potential geothermal resources. There are no active volcanic areas in Burundi, but the South Lake Kivu volcanic area is just north of the borders in Zaire and Rwanda (Fig. 4). It is located on the intersection of the NW-SE trending part of the rift (Lake Tanganyika) and the NE-SW trending part (Lake Kivu to Lake

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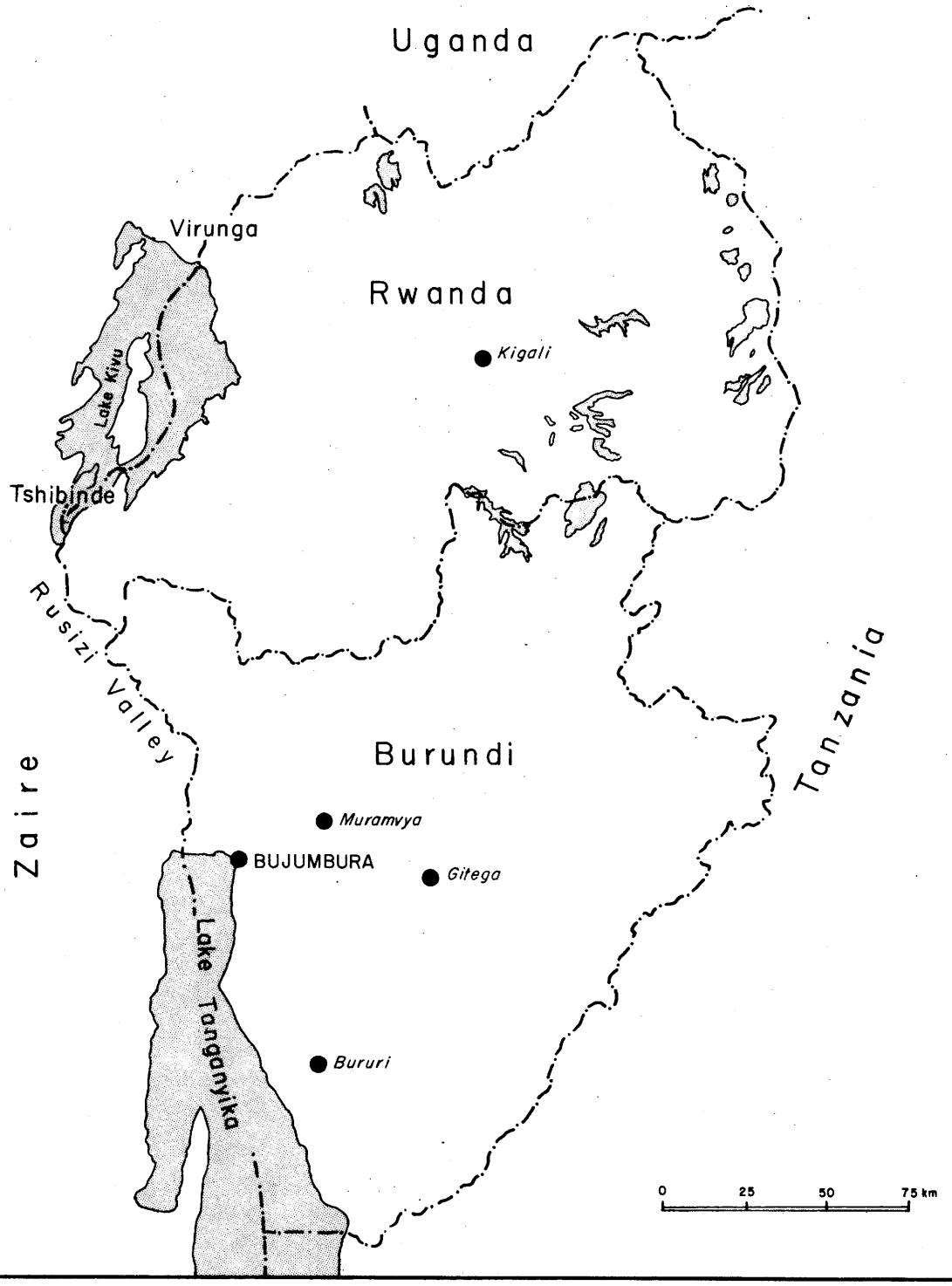
Fig. 5. Burundi and neighbouring countries



Albert). The volcanic activity is clearly related to the fissure system. The area is divided into two separate fields, the Mwenga-Kamitunga, which lies outside the intersection, and the Tshibinde zone just south of Lake Kivu (Guibert 1977 a, b, Barberi et al. 1982). The lavas are basanites, alkalibasalts, and transitional quarts and olivine-tholeites, tholeites being very rare elsewhere in the East African rift system (Williams 1982). The age of the volcanic activity is uncertain but seems to range from late Cretaceous (70-90 m.y.) to present. The youngest reported eruption occurred during the last century (Guibert 1977 a,b).

5.2 Summary of previous geothermal research in Burundi

The first description of geothermal manifestations in Burundi was given by Stanley (1878), but the first specific investigation of geothermal activity in the country was carried out in 1968 by the UNDP following a request from the Burundian government (McNitt 1969). This study covered eight geothermal locations. The geology of their surroundings was described, and a geochemical examination of the discharges recommended. Deelstra et al. (1972) described 15 hot springs in Burundi, 1 in Rwanda and 3 in Zaïre. Results of chemical analyses of 9 Burundian , one Rwandan two Zaïrian geothermal water samples were reported. Edeline et al. (1981) described 14 geothermal locations and reported chemical analysis of samples from 13 of them.

All these reports concentrate on descriptions of the thermal sources and their immediate surroundings. The geothermal activity is mostly connected with faults in Precambrian rock or sediments. There is no record of a connection between recent volcanism and geothermal activity even though one of the geothermal locations is in an area of basaltic formations according to the geological map edited by Radulescu (1981). Little attempt is made to relate the existence of geothermal heat to the general geology of the country. It is, however, clear that all the sources are situated in the western or central parts of the country and none in the eastern part where intrusions are absent and which lies farthest away from the active

rift zone.

All reported geothermal sources in Burundi are water pools. There is no record of surface steam (fumaroles) or mud pools. Therefore it seems unlikely that high temperature geothermal areas will be found there. The highest recorded geothermal spring temperature is 68°C at Ruhwa (Fig.1)(McNitt 1969, Deelestra et al. 1972, Edeline et al. 1981). Application of the quartz geothermometer of Fournier & Rowe (1966) to the results of Deelstra et al. (1972) and Edeline et al. (1981) suggests underground source temperatures as high as 110-120°C in at least two places in the Rusizi Valley.

6 THE RESULTS OF THE NEA RECONNAISANCE MISSION 1982.08.30 - 09.13

6.1 Descriptions of geothermal manifestations

This chapter contains short descriptions of all the geothermal locations visited during the present study. It is not possible to make an in depth geological study while on a short field trip and detailed geological maps were only available of two of the sites (Lepersonne 1977). Geological descriptions are therefore rather meagre.

Kabezi: The area is about 20 km south of Bujumbura, on the eastern bank of Lake Tanganyika. The thermal water rises through uncemented lake sediments in 4 pools each less than 1 m in diameter. The pool sites are obviously controlled by a linear structure, perhaps one of the faults which form the eastern escarpment of the rift valley. The slope to the east of the valley starts rising a few hundred metres to the east of the springs and the trend of the escarpment is similar to that of the structure controlling the direction of the observed spring sites. The hot water flow is difficult to estimate because no run-off stream is formed, but the water seeps through the surface soil towards the lake. The maximum temperature is 38.0°C in the main spring but values ranging from 34.0 to 37.7°C were recorded in the other three. No gas flow was observed nor were there any signs of deposits.

Mwisale: The village Mwisale is situated in the mountain range which forms the eastern escarpment of the western rift about an hour's drive from Bujumbura. The village lies in a deep valley and a noticable feature was a considerable water flow through all gullies running into the valley even though the field trip was made late in the dry season. This indicates that the rainwater is able to penetrate into the Precambrian rock. This permeability is higher than expected and could be caused by Tertiary and Quaternary faults related to the formation of the rift. The geothermal source is found high up on a slope to the south of an E-W trending valley close to a contact between schist and

quartzite. Three springs were found and the estimated total flow is 10-20 l/s. The temperature of the main spring is 37.0° C, but 31.6 and 36.2°C were redorded in the other two which are slightly to the west of it. All the springs lie in a NNE-SSW trending gully which apparently is controlled by a fault. No gas flow was observed but deposits of iron compounds are found on stones in the springs.

Mashuha: The Mashuha spring is situated at the foot of a low quartzite hill of Precambrian age. The water flows from a small pool in which a considerable gas flow is observed. Its temperature is 37.7°C and the flow was estimated at 10 l/s. The pool is used by local people for laundering and bathing. No obvious connection with fractures or faults was to be seen, and this manifestation is the one in Burundi which is farthest away from the western rift.

Mvumvu: The Mvumvu spring is situated close to the main road from Bujumbura to Kigali via Muramvya. The thermal water flows into a small pond in a valley covered with sediments. The area is covered with vegetation, but the water probably rises through syenite. The temperature is 28.5°C and the flow close to 5 l/s. Very little gas flow was observed. The spring is used for laundering. No linear structures to which geothermal manifestations could be related were observed. The distance to the rift valley is 20-30 km so a connection with young tectonic structures must be considered unlikely.

Mahoro: The Mahoro spring lies in a small valley which is covered with vegetation. The hot springs form a pond about 10 m in diameter. The upflow is clearly controlled by a linear structure because small outflows of water accompanied by considerable gas flows were observed forming a line on the bottom of the pond. A steeply dipping quartzite outcrop whose strike is parallel to the line of the springs is situated close to the pond. Joints in the dipping rock formation are more likely to control the upflow of warm water than young tectonic structures. The temperature is 45.0°C and the flow estimated at 8 l/s. This warm water is believed to have healing effects on those who bathe in it and is to a considerable extent used for this purpose.

Kitenge: The geothermal manifestations are found in the

deep valley of the river Kitenge. The area is very mountainous and it is a part of the uplifted eastern margin of the rift valley. The water flows from cracks in the quartzite which seems to be the dominant rock type. Warm water is also found in the alluvium. This is also a gold panning site. Many shallow holes have been dug in the sediment for this purpose and some of those are now full of warm water. At least 3 springs were found discharging from the quartzite. The temperature of the warmest one was 47.1°C, and its flow 4 l/s. The area lies in the uplifted mountain range bordering the rift. Thus relatively young faults could exist there. The terrain, however, is difficult and it proved impossible in the short time available to investigate in detail the possibility of a connection between the hot springs and young faults.

Mabayi: The hot water flows from the river Nyamagana alluvium. The rock formation cannot be seen because of the vegetation covering it. The manifestations are situated in a sugar cane field and form a little pool on the river bank. Some gas flow was observed. The flow was estimated at 7 l/s, and the temperature recorded was 37.7°C. Springs were observed on the bottom of the river, where a temperature of 37.9°C was recorded and gas bubbles were seen rising. Another spring is reported to be situated on the other side of the river, but this was not visited. The manifestations lie on a line trending N6°E and are controlled by a fault or a syncline.

The Rusizi valley: The part of the western rift valley which lies between Lake Tanganyika and Lake Kivu is called the Rusizi valley taking its name from the river flowing through it. The floor of the valley is filled with young sediments, although low hills made of older rocks are found within the rift. At least four geothermal locations are known in the Burundi part of the Rusizi valley all of which were visited during this study: the Ruhwa, Ruhanga, Gasenyi and Cibitoke sites.

Ruhwa: The hot spring is located on the bank of the river Lua about 100 m upstream from where it meets the Rusizi. The Lua serves as the border between Burundi and Rwanda and the Rusizi as the border between Burundi and Zaire. The water rises from the top of a small travertine elevation, about 20 m in diameter and 4-5 m high. The thermal spring

is in a pool which has a 2-2.5 m diameter, and through which there is a violent gas release. Its temperature is 63°C and its flow 1 l/s. The area is covered with vegetation but the site is shown within a Tertiary basalt formation on the geological map edited by Radulescu (1981). Furthermore basalt has been reported in a nearby drillhole (Deelstra et al. 1972).

Ruhanga: The manifestation is right on the Rusizi bank in the alluvium. It is probably flooded during the rainy season. The floor of the valley is covered with sediments consisting mainly of quartzite cemented with carbonate. The river has eroded a channel, about 20 m deep, into the sediments, and the alluvium is composed of pebbles of quartzite and basalt. The source is a small pool with a very small flow, whose temperature is 48.3°C. Few signs of deposits were observed.

Gasenyi: This location is very similar to that of Ruhanga, but here the outflow of warm water is in the river itself. It proved impossible to measure the flow but some gas flow was observed. Gas bubbles were seen in the river as far as 3 m from the bank. The highest recorded temperature 59.5°C was on the river bottom, but highest on shore was 49.6°C in a small pool from which the sample for chemical analysis was drawn (See section 6.2).

Cibitoke: This hot spring is the only one in the valley which is not situated on the Rusizi river bank. It is on the flat floor of the valley, hidden in a field of very tall grass. The surface manifestation is a pool about 1 m in diameter and at least 2 m deep. It is difficult to estimate the flow, but it could be 4-5 l/s, and the temperature is 30.6°C. The water in the pool was muddy and violently agitated by the rapid escape of gas.

The four locations of surface geothermal activity in the Burundi part of the Rusizi valley are all found within the sedimentary formation. It is difficult to see whether their locations are related to young faults or other structures, but their occurrence within the still active rift zone and the relatively short distances between the manifestations could indicate a high geothermal gradient in the Rusizi valley.

Mugara: The Mugara springs are all within the rift valley even though the water rises through Precambrian quartzites. Mugara I and II are separated by a few hundred metres and are situated in a small hollow. The water rises from fractures in the rock and temperatures and flows were recorded as 46.8°C and 20 l/s; and 44.8°C and 10 l/s for Mugara I and II respectively. Mugara III is located about 1 km north of the above springs. Here the hot water rises in several springs in a relatively flat landscape, where there is dense vegatation. Its temperature was recorded as 46.0°C and flow estimated at 20 l/s. Iron oxide deposits were observed at all three locations, but no gas flow was observed. Vegetation made it difficult to determine whether the geothermal activity is controlled by faults or other structures but the geological map available (Lepersonne 1977) shows the main fault of the eastern escarpment of the rift only 1-2 km east of the springs, and a fault possibly runs through the Mugara sites.

Kumuyange: Two springs, separated by 2-300 m rise from Precambrian quartzite. Walls have been built around the main springs and the water is used by local people for bathing. The temperature of the more southern (western) spring was recorded as 38.4°C and its flow as 3-4 l/s. Some gas flow was noticed. There is no knowledge of structural control of the springs but the site is clearly outside the rift valley.

Muhweza: This manifestation is rather similar to Kumuyange. The water rises from fractures in quartzite in two springs, separated by some 50 m. Both are used for bathing. The temperature was recorded as 37.3°C but the flow is not known. Gas flow is minimal. The Muhweza springs lie about 8 km east of Kumuyange and a connection with the rift zone is not likely.

Cold water sample sites: Three samples of cold water were collected for reference during the study. The first spring sampled rises through the Rusizi valley sediments at Nyakabaraza close to Cibitoke. Its temperature was 22,7°C. The second cold water sample was drawn from Source du Nil, east of the rift valley in Precambrian rock. Its temperature was 16.8°C. The last cold water sample was collected from Lake Tanganyika from the shore in the southern part of Bujumbura. Its temperature was 28.0°C.

6.2 Results of chemical analysis

Results of the chemical analysis of the water samples are reported in Table 4, of the gas sample from Ruhwa in Table 5 and the isotope analysis in Table 6. Speciation, mineral composition, and deep water composition at the quartz temperature were calculated using the WATCH 3 computer programme (Arnórsson et al. 1982, Svavarsson 1981). The resulting printouts are in Appendix 2. As a first approximation it may be noted that the samples from the rift valley have a higher pH, are more mineralised and have greater carbon dioxide concentrations than those which originate from the Precambrian rock. These results will be looked at in more detail in the following sections.

6.3 Chemical geothermometers

These are generally of two types, i.e. those based on the solubility of species e.g. silica, and those based on concentrations of constituents resulting from exchange reactions, e.g. alkali and alkaline earth metals. The solubility of silica is controlled by the mineralogy. At high temperatures (>150°C) it is generally quartz which controls the solubility but in some cases, especially in young formations, minerals such as chalcedony or even cristobalite may become effective at lower temperatures. Thus the chalcedony thermometer has proved quite useful in Iceland (Arnórsson et al. 1983). In Burundi, however, the situation is quite different. Rock formations are relatively old and the chief silica mineral observed is quartz. It seems reasonable to assume that the quartz geothermometer is the one that should give the results for underground temperatures which most closely approach the true ones, even at temperatures well below 150°C. At temperatures below 80°C the increase in silica concentration with increasing temperature is relatively small and it may be difficult to use this chemical geothermometer to obtain an accurate source temperature. At 100°C, this increase has become very significant (Fig. 6).

TABLE 4 Burundi 1982. Results of chemical analysis of water samples

Location	Date	Sample No	T°C	pH/°C	SiO_2 mg/kg	Na mg/kg	K mg/kg	Li mg/kg	Ca mg/kg	Mg mg/kg	SO_4 mg/kg	Cl mg/kg	F mg/kg	TDS[1] mg/kg	CO_2 mg/kg	H_2S mg/kg
Kabezi	820831	2001	38.0	7.90/27	31.7	938.9	10.5	<0.02	3.3	4.70	1.1	135.0	2.08	2279	1734	<0.1
Mwisale	820901	2002	37.0	5.81/26	20.4	1.6	1.0	<0.02	2.1	1.63	2.2	0.6	0.08	41	31.1	<0.1
Mashuha	820903	2003	37.7	6.08/27	24.2	3.0	0.7	<0.02	1.9	0.81	2.4	1.1	0.11	44	25.3	<0.1
Mvumvu	820906	2004	28.5	7.34/26	45.9	18.9	6.3	<0.02	58.4	2.79	10.9	4.1	0.46	241	189	<0.1
Mahoro	820906	2005	45.0	6.40/26	33.5	15.6	2.5	<0.02	8.1	3.07	12.8	1.8	0.40	80	93.4	<0.1
Kitenge	820907	2006	47.1	6.10/26	28.5	14.8	1.7	0.02	8.4	3.41	41.4	3.0	0.11	97	56.5	<0.1
Mabayi	820907	2007	37.7	7.60/27	18.7	5.6	1.0	0.03	29.5	17.19	9.8	3.2	0.18	143	134	<0.1
Ruhwa	820907	2008	63.1	7.00/27	59.2	389.1	68.5	0.82	63.6	54.87	8.5	82.8	2.69	1314	1228	<0.1
Ruhanga	820908	2009	48.3	6.88/26	73.4	833.2	161.6	3.08	96.8	118.54	21.5	552.5	2.00	2816	2145	<0.1
Gasenyi	820910	2017	59.5	7.08/28	79.2	568.9	33.8	0.78	20.0	8.04	121.0	125.0	5.03	1549	1099	<0.1
Cibitoke	820908	2010	30.6	5.98/26	29.0	47.2	20.7	0.24	97.0	57.94	316.8	6.7	1.00	768	810	<0.1
Nyakabaraza	820908	2011	22.7	7.94/26	34.5	35.2	1.8	<0.02	39.2	60.16	25.8	0.2	1.85	407	35.7	<0.1
Mugara I	820909	2012	46.8	6.12/32	38.8	10.6	4.2	0.02	5.8	1.78	9.9	2.0	0.29	n.d.[2]	82.4	<0.1
Mugara III	820909	2013	46.0	6.10/30	42.7	11.7	3.0	0.02	4.6	1.41	11.6	3.3	0.36	77	71.8	<0.1
Kumuyange	820909	2014	40.1	5.85/30	24.7	0.8	1.1	<0.02	1.6	0.94	1.1	<0.2	0.04	34	47.3	<0.1
Muhweza	820909	2015	37.3	6.29/30	23.0	0.8	1.4	<0.02	5.1	3.53	6.3	0.4	0.05	42	34.1	<0.1
Source du Nil	820909	2016	16.8	6.80/30	7.2	0.6	0.5	<0.02	2.0	1.34	1.2	0.2	0.03	18	17.6	<0.1
Lac Tanganyika	820910	2018	28.0	8.80/27	5.8	65.6	33.3	<0.02	14.4	41.65	6.6	29.3	0.75	374	292	<0.1

1) TDS = total dissolved solids

2) n.d. = not determined

TABLE 5. Burundi 1982. Ruhwa. Chemical composition of gas sample

Constituent	CO_2	H_2S	H_2	O_2+Ar	CH_4	N_2
Volume %	99.60	0.02	0.00	0.11	0.00	0.27

TABLE 6. Burundi 1982: Results of D and ^{18}O determinations

Location	$\delta^{18}O‰$	$\delta D‰$	Measured temperature °C	High or low altitude
Mwisale	-3.3	-19	37.0	High
Ruhwa	-3.2	-17	63.1	Low
Gasenyi	-3.0	-22	59.5	Low
Nyakabaraza	-1.7	-11	22.7	Low
Kumuyange	-3.4	-18	40.1	High
Source du Nil	-3.2	-21	16.8	High

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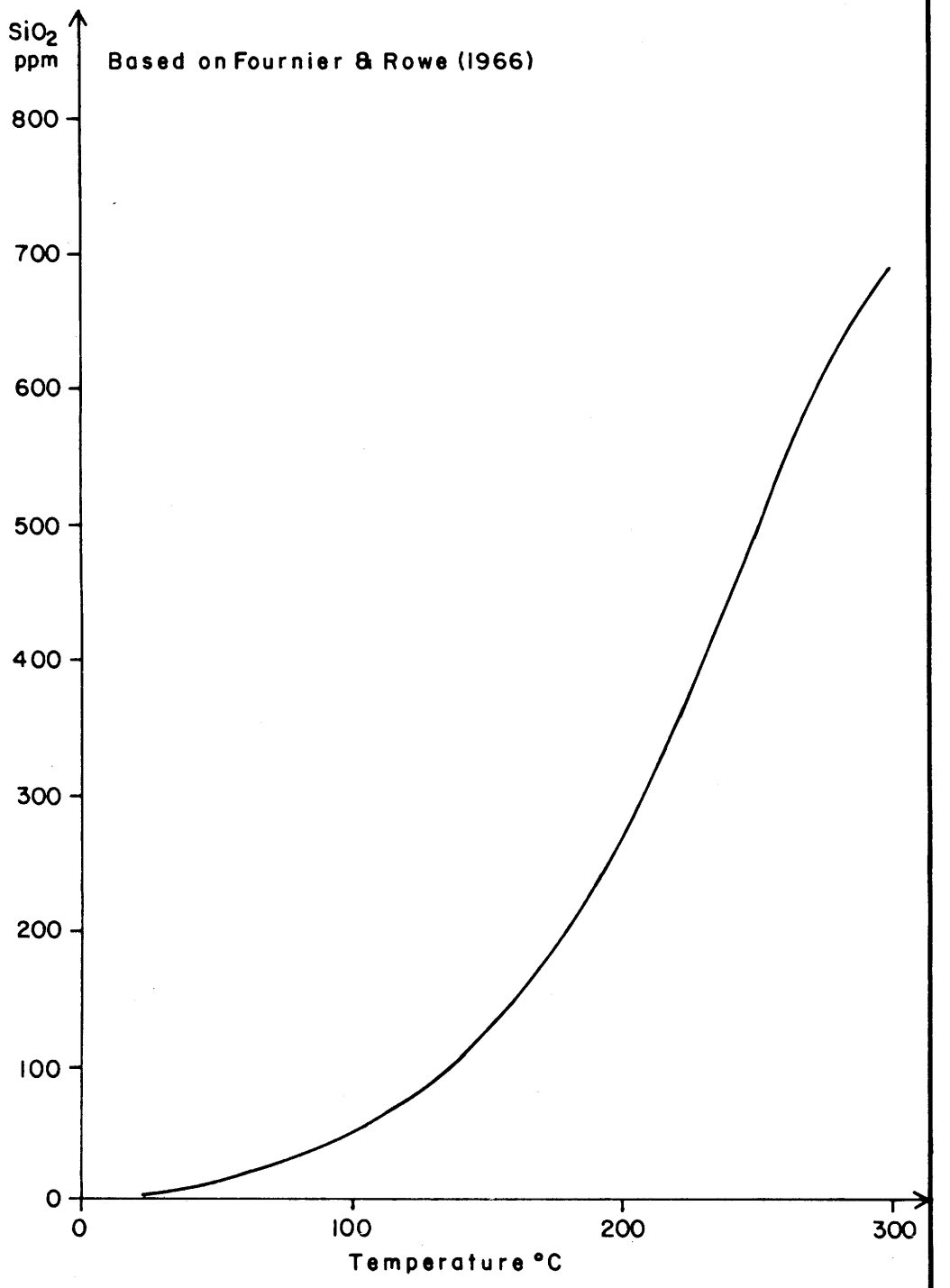
Fig. 6

The solubility of quartz in the temperature range 25-300°C as a 3 phase curve

Quartz-water-steam



The most commonly used exchange thermometers are based on the sodium/potassium ratio. The Na-K-Ca geothermometer (Fournier & Truesdell 1973) takes exchange reactions involving calcium into account and the Na-K-Ca-Mg geothermometer (Fournier & Potter 1979) adds a correction for magnesium concentrations. As a result of a survey of geothermometers it was decided to calculate and base the estimation of underground temperatures on the following chemical geothermometers:

1) Quartz. The equation due to Fournier & Rowe 1966:

$$t°C = \frac{1309}{5,19 - \log C_{SiO_2}} - 273,15 \qquad (1)$$

where C_{SiO_2} = SiO_2 concentration in mg/kg water has been modified to

$$t°C = \frac{1309}{0,41 - \log [SiO_2]} - 273,15 \qquad (2)$$

where $[SiO_2]$ = mole SiO_2/kg water is calculated as free SiO_2 present in H_4SiO_4, i.e. available SiO_2

2) Chalcedony (Arnórsson et al. 1983)

$$t°C = \frac{1101}{0,11 - \log [SiO_2]} - 273,15 \qquad (3)$$

where $[SiO_2]$ = concentration of available SiO_2 in moles/kg water (computed activity of H_4SiO_4).

3) Na-K-Ca-Mg (Fournier & Potter 1979)
The Na-K-Ca temperature is calculated

$$t°C = \frac{1647}{\log([Na]/[K]) + \beta\log(\sqrt{[Ca]}/[Na]) + 2,24} - 273,15 \qquad (4)$$

where [ ] = concentration of metal in moles/kg
β = 1/3 for temperatures > 100°C
β = 4/3 for temperatures < 100°C.

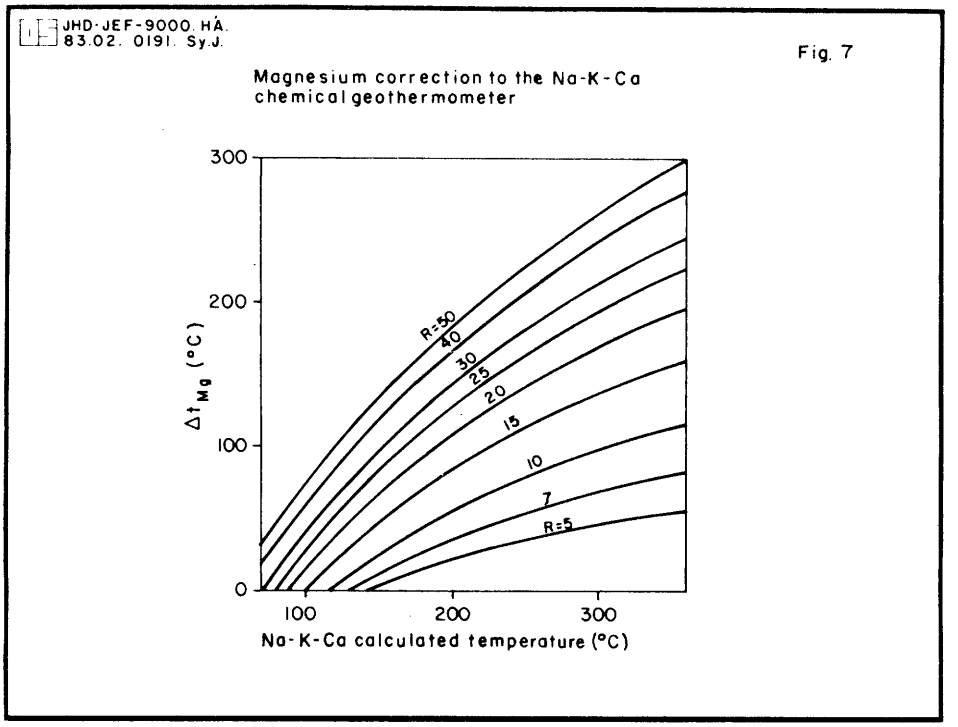
The magnesium factor ,R, is calculated as

$$R = \{[Mg]/[Mg] + [Ca] + [K]\} \cdot 100 \qquad (5)$$

where [ ] = concentration in moles/kg. If R>50, the water is assumed to come from a relatively cool underground environment at a temperature approximately equal to the measured water temperature, irrespective of high calculated Na-K-Ca temperature. If $t_{Na-K-Ca}$ >70°C and R<50, use Fig. 7 to estimate the magnesium temperature correction, Δt_{Mg} , to be subtracted from $t_{Na-K-Ca}$ drawn from the following equation

$$\Delta t_{Mg} = 10,66 - 4,7415R + 325,87(\log R)^2 - 1,032\cdot10^5(\log R)^2/T$$

$$- 1,968\cdot10^7(\log R)^2/T^2 + 1,605\cdot10^7(\log R)^3/T^2 \qquad (6)$$



The results of the application of the above three geothermometers to the Burundi samples are listed in Table 7 along with measured temperatures and likely source temperatures which are estimated from the geothermometer results after taking the following considerations into account.

- As the Na-K-Ca-Mg geothermometer does in several cases yield values which are lower than measured temperatures it is assumed that its application generally leads to slight underestimates.
- Quartz is the major silica mineral, but it is the most soluble of the ones which could possibly be present. Hence the quartz geothermometer is likely to give maximum values if it is assumed that no boiling or mixing with cold groundwater has occurred in the upflow zone or the reservoir.
- On the same grounds application of the chalcedony geothermometer is likely to lead to values below the actual underground source temperatures.
- Quartz temperatures below 80°C are inaccurate.
- Some individual cases are discussed below.
- The results for Mabayi are obviously too low, being below the measured temperature. However, these low results suggest strongly that the underground source is not much warmer than the surface outflow.
- The Na-K-Ca-Mg temperatures for Ruhwa (34°C) and Ruhanga (37°C) are obviously much too low, measured temperatures (63°C and 48°C respectively) being considerably higher. The quartz temperatures (109°C and 120°C) seem likely to be closest to the truth in these cases.

The highest estimated underground source temperatures are for Gasenyi, probably >100°C, and Ruhanga and Ruhwa, probably similar. Furthermore the Gasenyi sample source is right on the Rusizi river bank, virtually in the river, and its temperature was 49.6°C, even though a temperature of 59.5°C was recorded on the river bottom only a couple of metres away. Therefore it is almost certain that this sample source was mixed with cold water. The Gasenyi, Ruhwa and Ruhanga springs are all found in uncemented recent sediments which makes mixing with local cold groundwater in upflow zones likely.

No samples were actually taken from the rivers Lua and

TABLE 7 Burundi 1982. Measured temperatures, chemical geothermometer temperatures and probable source temperatures.

Location	Measured temperature °C	Chalcedony temperature °C	Quartz temperature °C	Na-K-Ca-Mg temperature °C	Probable source temperature °C
Kabezi	38.0	49	79	50	65
Mwisale	37.0	34	64	34	45
Mashuha	37.7	41	71	32	55
Mvumvu	28.5	67	97	45	60
Mahoro	45.0	54	84	54	70
Kitenge	47.1	47	77	43	65
Mabayi	37.7	31	60	4	45
Ruhwa	63.1	80	109	34	100
Ruhanga	48.3	90	120	37	105
Gasenyi	59.5	93	123	93	110
Cibitoke	30.6	48	78	45	60
Nyakabaraza	22.7	54	84	23	23
Mugara I	46.8	60	90	73	85
Mugara III	46.0	65	95	68	85
Kumuyange	40.1	42	72	35	60
Muhweza	37.3	39	69	22	55
Source du Nil	16.8	0	29	11	17
Lac Tanganyika	28.0	-8	20	28	28

Rusizi, but the water from Nyakabaraza is assumed to be representative of the cold water of the region. Using Fournier's (1977) mixing models the results reported in Table 8 were obtained for possible temperatures of unmixed underground geothermal fluids for the cases of cooling without boiling and boiling with maximum steam loss. Boiling is likely to have occurred, although not necessarily with maximum steam loss. The lower values are therefore probably closer to the true ones than the higher values.

TABLE 8 Burundi 1982. Gasenyi, Ruhanga, Ruhwa. Results of mixing models. Cold water source: Nyakabaraza

Location	Underground source temperature assuming no boiling, °C	Underground source temperature assuming maximum steam loss, °C
Gasenyi	240	160
Ruhanga	220	150
Ruhwa	140	130

The results of the geothermometer study indicate that the reservoir temperatures are not high enough at most of the locations for them to be of commercial interest. The only exception are the springs in the Rusizi valley below which a reservoir with a temperature in excess of 100°C. may exist.

6.4 Carbon dioxide rich discharges

Barnes et al. (1978) have defined a CO_2-rich discharge as that of a gas containing more than 90 per cent CO_2 by volume by chemical analysis or water with pH less than 8.3 containing > 1000 mg/l bicarbonate. Arnórsson & Benjamínsson (1980) consider these limits as high and suggest that waters containing more than 300 mg/l CO_2 should be considered CO_2-rich. By all definitions the waters from Kabezi, Ruhwa, Ruhanga and Gasenyi can be considered as CO_2-rich, with the water from Cibitoke being close to it also. The gas from Ruhwa also qualifies (Table 5). Barnes et al. (1978) point out that CO_2-rich discharges and seismic epicenters are concentrated mainly along or near the boundaries of major crustal plates, and probably result from the interaction of the plates. It is along these active plate margins that the resistance to plate motion is expressed as seismic energy and anomalous temperatures. Here, conditions are appropriate for the release of CO_2 from marine carbonate bearing rocks through processes of subduction and igneous intrusion. In addition fractures extending to sufficient depth may also yield CO_2 from the mantle. Attempts at distinguishing between these two source types are mainly made by studying the ^{13}C concentration in the CO_2, as marine carbonate derived CO_2 is considered to have a ^{13}C concentration of ca 0 0/00 (SMOW), but mantle derived CO_2 -4 to -8 0/00. There is a possible overlap, but some useful information might be obtained by studying this parameter. Degens et al. (1971) found $\delta^{13}C = 0$ in CO_2 from Lake Tanganyika. The presence of these CO_2-rich discharges enhances the possibility of finding high-temperature sources, as it suggests proximity with active magma sources.

6.5 Calcite saturation

Areas with high carbon dioxide concentrations are the most likely to be troubled with calcite deposition in fissures. In the dilute waters undersaturation with respect to calcite is to be expected, but saturation or slight supersaturation in the more mineralized CO_2-rich

waters. Severe supersaturation is not expected, unless the water has recently boiled and has not yet reequilibrated.

The ionic product $[Ca^{++}]$ $[CO_3^{--}]$ at the quartz temperature has been calculated for all the geothermal samples and the results are compared with the saturation curve (Helgeson 1969) in Fig.8. As expected most of the dilute waters are undersaturated. The Cibitoke and Mabayi waters are close to saturation, the Kabezi water slightly supersaturated, but the Mvumvu, Ruhanga, Ruhwa and Gasenyi waters are considerably supersaturated. When mixing models were considered, it was indicated that the latter three waters may have undergone boiling (see chapter 6.3), and the present result seems to support this. Boiling was not suggested in the other CO_2-rich waters, i.e. from Kabezi and Cibitoke, and the small supersaturation in Kabezi probably results from a relatively fast supply of CO_2.

6.6 Chloride concentrations and their distribution

Chloride in geothermal systems may originate from several types of sources, i.e. leaching of rocks or deposits, from rainwater, or percolating sea water. But once its concentration is established, it is relatively unaffected by changes in temperature and pressure as it does not participate in the formation of secondary minerals, and its contents in the water are controlled by the available supply. It is thus often a useful parameter in tracing geothermal water masses, whose chemical composition is otherwise affected by physical conditions, especially in conjunction with other constituents, similarly unaffected.

High chloride concentrations are often indicative of high temperature hot-water systems (White 1970). Such concentrations are then generally much above the chloride concentrations of nearby surface and ground waters. The area including Ruhanga, Gasenyi and Ruhwa (and possibly Kabezi) (Fig.9) shows the characteristics of such a system the effect being clear when the chloride concentrations of samples from these spots are compared with that of the sample from Nyakabaraza, which is regarded as a typical cold groundwater sample from the area. The variation of

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Fig. 8

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Calcium carbonate ionic products and saturation curve

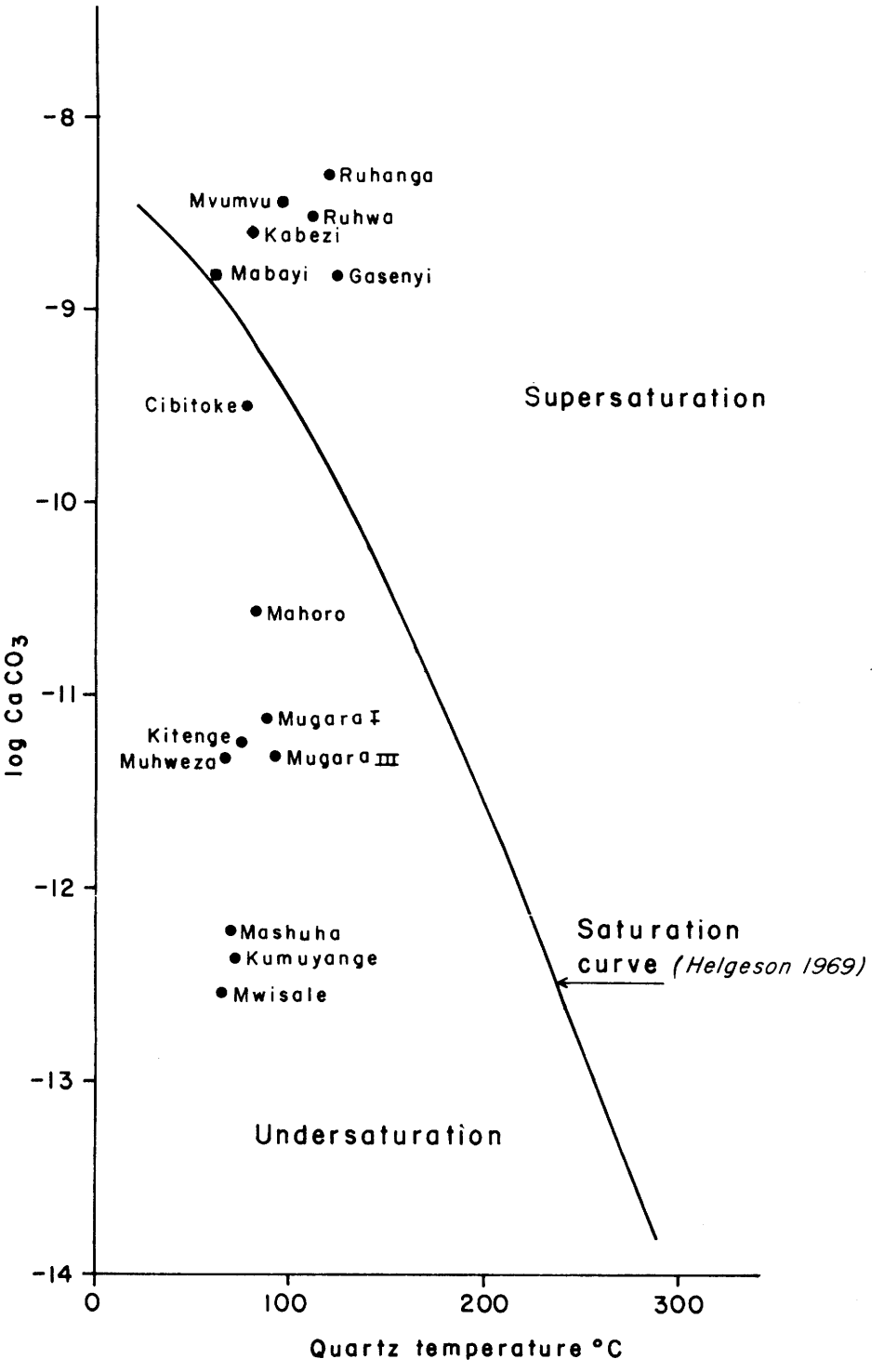

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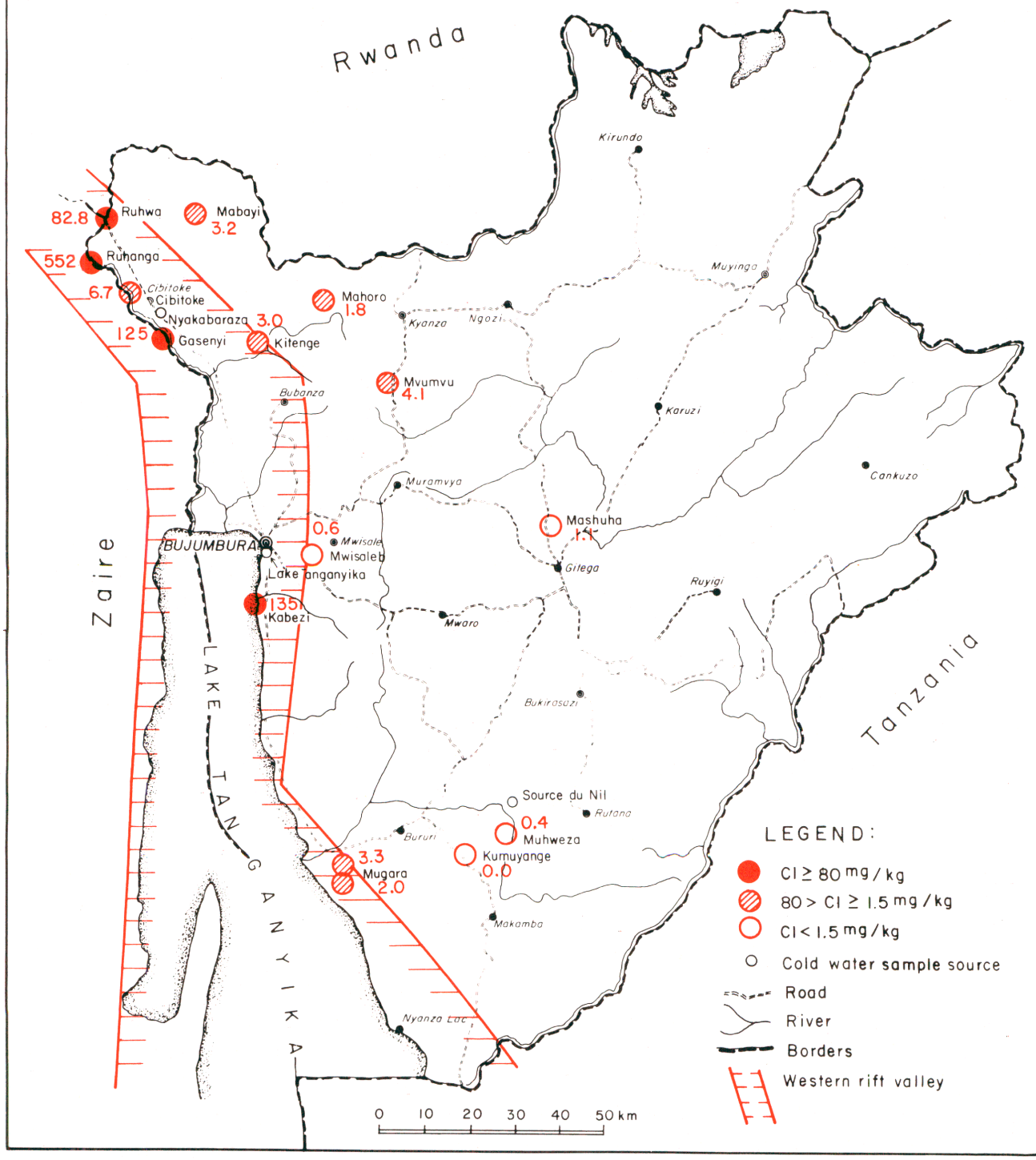
Fig. 9. Burundi 1982 Cl distribution



chloride concentrations within an already established hydrothermal system can also give valuable information. Thus relatively high chloride concentrations indicate a permeable zone with flow from deep levels to the surface.

It may be argued that in some sedimentary environments chloride will be leached, and that this could account for the high concentrations of chloride in the Rusizi area. The low chloride concentrations in the Cibitoke and Nyakabaraza samples would seem to refute this.

Even allowing for differential dilution with cold water, the highest chloride concentration is at Ruhanga, and thus it would seem that there is the most direct connection with the deep reservoir (see Mahon 1970) The origin of the chloride may, however, be different in which case the last statement is not valid. Na/Cl ratio has sometimes been used to get an idea about whether water has a geothermal origin. High ratios usually indicate geothermicity. It is probably not very valid here, both because sea water effects in the rainwater are probably minimal, and some of the waters are CO_2-rich, and this may modify their cationic composition.

Looking at Table 9 and Fig.10, however, relatively high Na/Cl-ratios are found in most of those places where the highest temperatures are indicated by the geothermometers described above, with the notable exception of Ruhanga.

Highest $Cl/(HCO_3^- + CO_3^{--})$ (here reported as Cl/CO_2) in related waters should indicate highest subsurface temperatures (Fournier & Truesdell 1970). Inspection of Table 9 and Fig.11 suggests highest subsurface temperature in the Rusizi area at Ruhanga on these grounds.

6.7 Fluoride concentrations

Fluoride is usually present in thermal waters at much higher concentration levels (commonly in the range 1-10 mg/kg (Ellis & Mahon 1977)) than are common in cold waters. Concentrations of this magnitude are found in samples from Kabezi, Ruhwa, Ruhanga, Cibitoke and Gasenyi (Fig.12), but also from Nyakabaraza, so that this is not an infallible

TABLE 9. Burundi 1982. Ratios between some chemical constituents (mg/mg)

Location	SiO_2/TDS x10^2	Na/K	Na/Ca	F/Cl x10^2	Na/Cl	Na/CO_2 x10^2	Ca/SO_4	Cl/CO_2 x10^3
Kabezi	1,39	89,5	286	1,54	6,95	54,1	3,09	77,8
Mwisale	49,6	1,61	0,76	12,8	2,51	5,24	1,00	19,3
Mashua	55,5	3,95	1,57	10,4	2,69	11,7	0,78	43,5
Mvumvu	19,1	3,01	0,32	11,2	4,63	10,0	5,33	21,7
Mahoro	41,6	6,32	1,92	21,7	8,53	16,7	0,64	19,3
Kitenge	29,3	8,53	1,77	3,80	4,92	26,1	0,20	53,0
Mabayi	13,1	5,69	0,19	5,65	1,77	4,16	3,03	23,9
Ruhwa	4,50	5,68	6,12	3,25	4,70	31,7	7,52	67,4
Ruhanga	2,61	5,16	8,60	0,36	1,51	38,8	4,51	258
Gasenyi	5,11	16,8	27,3	4,02	4,55	51,8	0,17	114
Cibitoke	3,77	2,28	0,49	15,0	7,10	5,83	0,31	8,3
Nyakabaraza	8,49	20,1	0,90	∞ [2]	∞ [2]	98,5	1,52	0 [2]
Mugara I	n.d. [1]	2,51	1,85	14,4	5,32	12,9	0,58	24,3
Mugara III	55,1	3,90	2,54	10,8	3,49	16,3	0,40	46,0
Kumuyange	72,9	0,77	0,52	∞ [2]	∞ [2]	1,75	1,39	0 [2]
Muhweza	54,9	0,58	0,16	11,1	1,80	2,38	0,81	11,7
Source du Nil	39,6	1,25	0,31	∞ [2]	∞ [2]	3,64	1,67	0 [2]
Lac Tanganyika	1,55	1,97	4,55	2,55	2,24	22,5	2,18	100

1) n.d. not determined

2) Cl $\leq$ 0,2 mg/kg

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Fig. 10. Burundi 1982 Na/Cl distribution

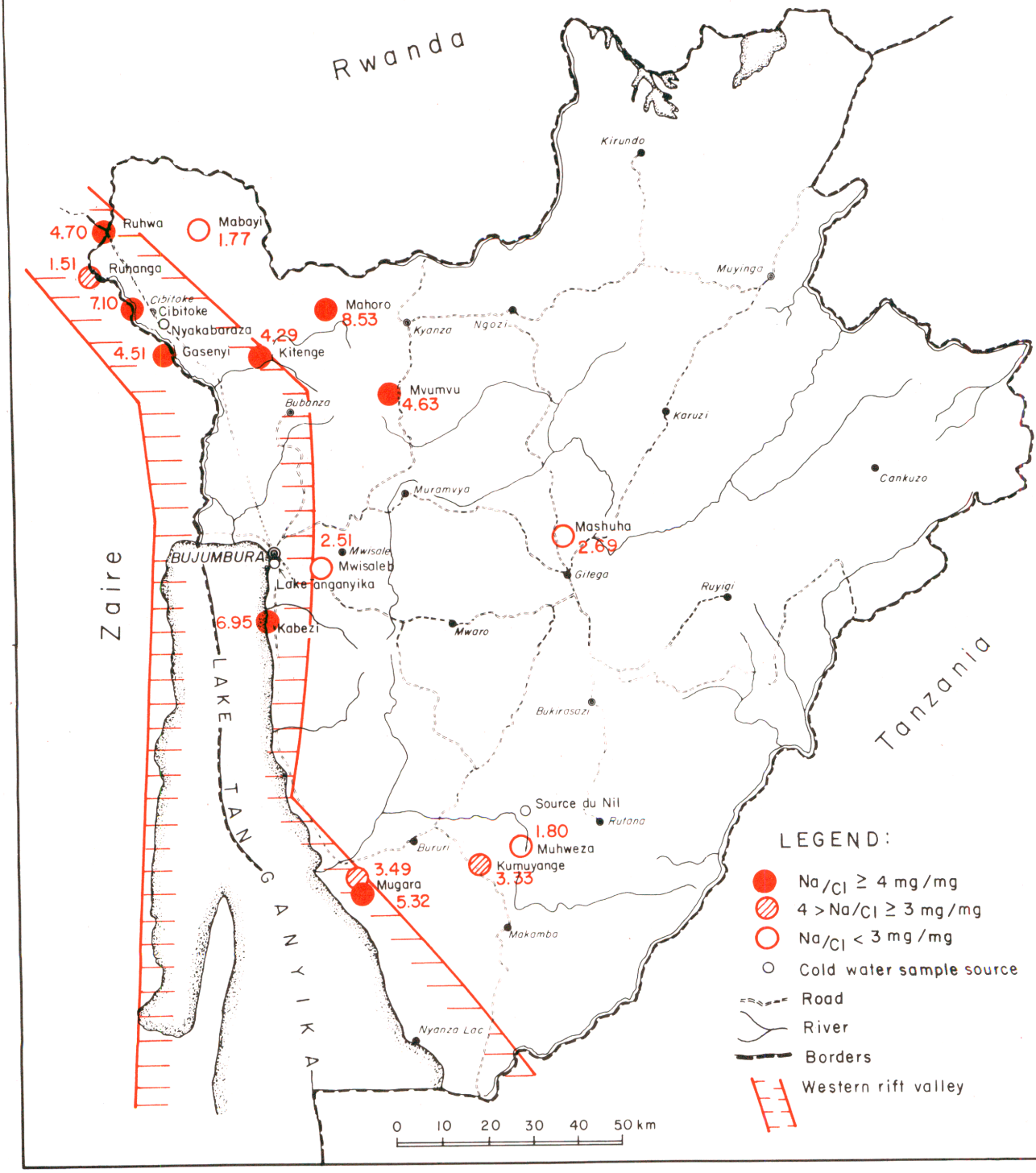

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Fig. 11. Burundi 1982 Cl/CO_2 distribution

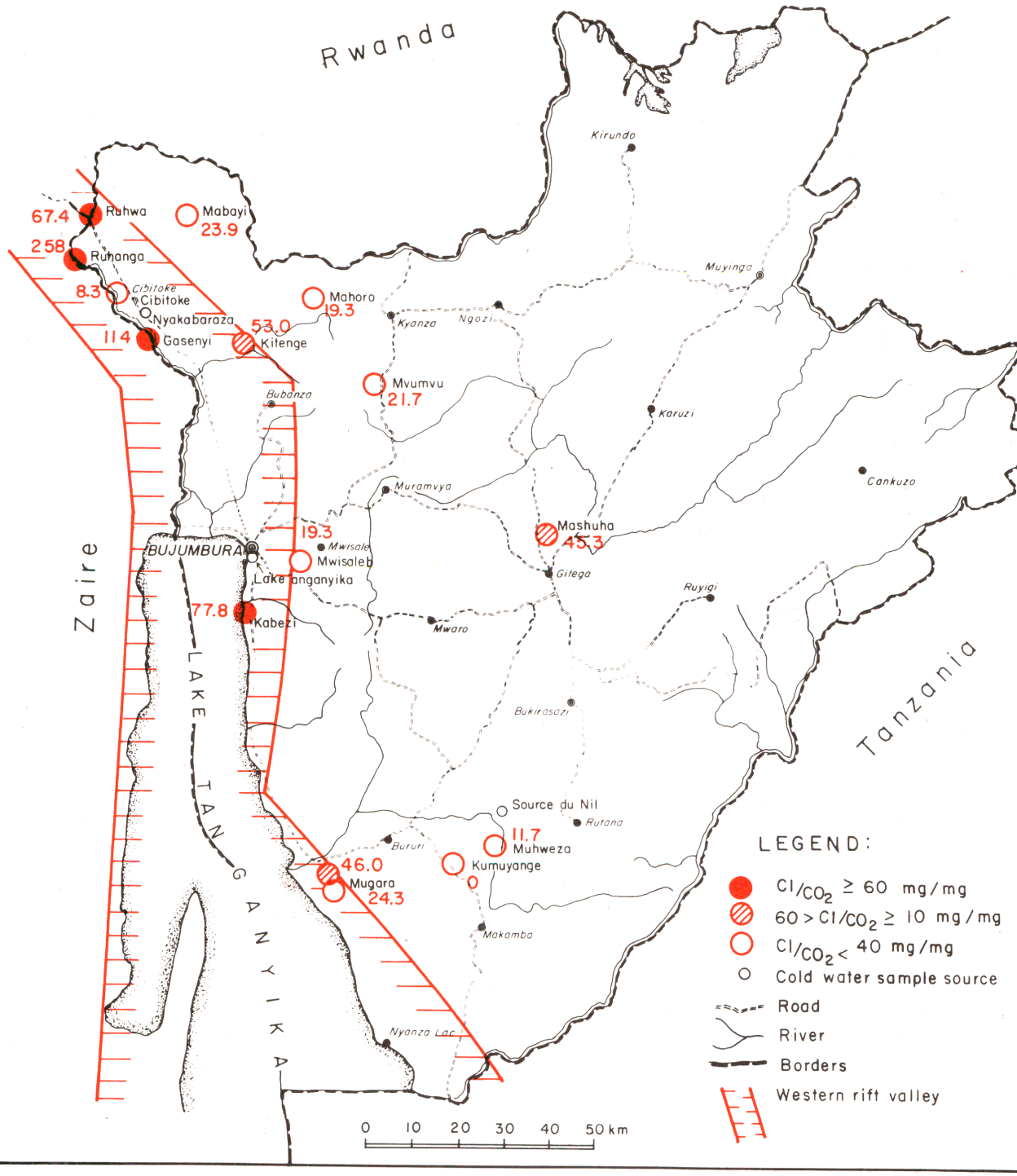

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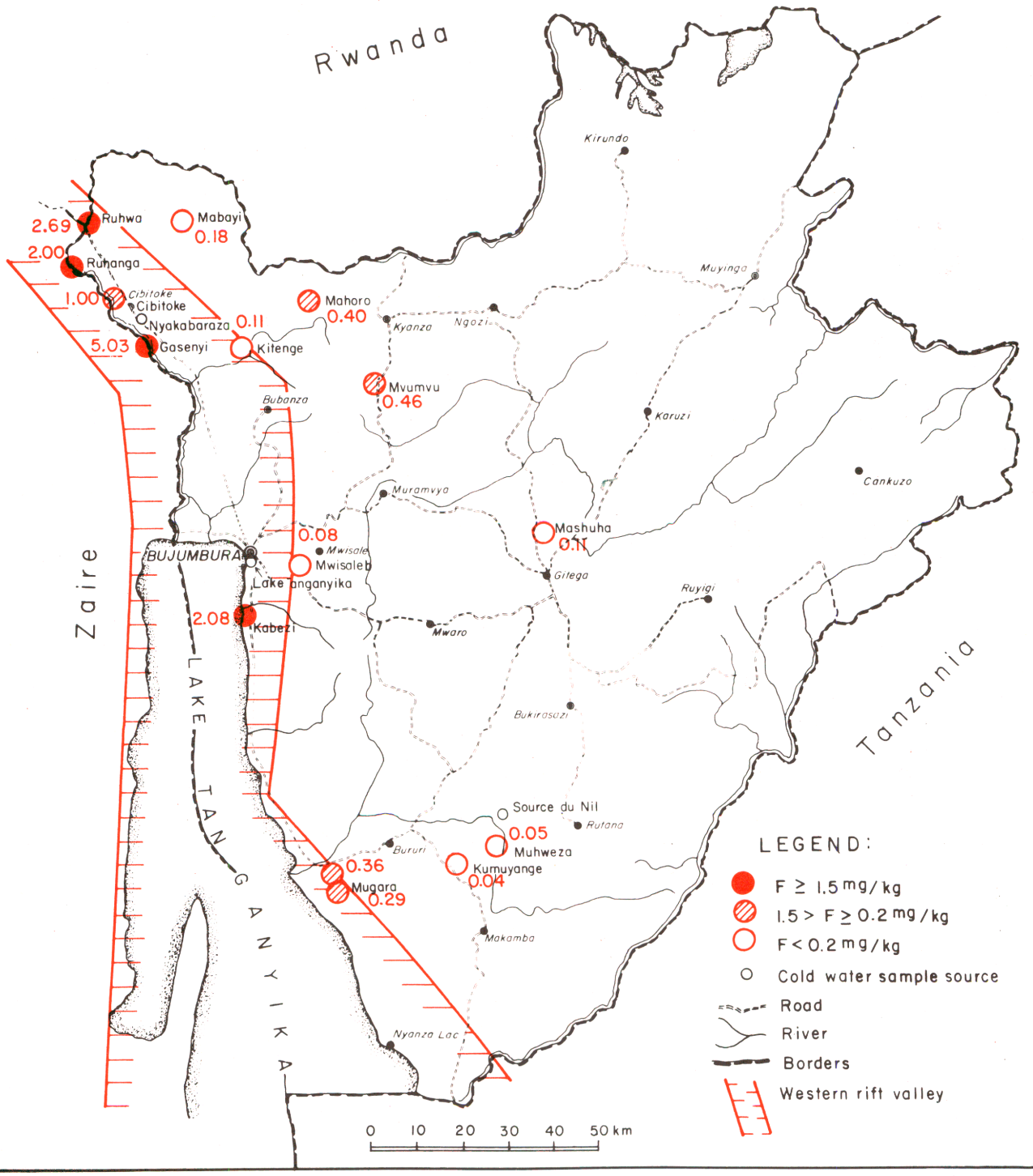
Fig. 12. Burundi 1982 F distribution



guide. Some of the other waters are very dilute, so a low absolute concentration of fluoride need not indicate cold water. Ratios which have been considered are: $[F^-]/[OH^-]$ on the grounds that an exchange reaction between these ions controls their concentrations, when the solution is undersaturated with respect to fluorite (Nordström & Jenne 1977, Pálmason et al. 1978); F/Cl whose quantitative application as a geothermometer is prevented by the Ca content (as controlled by the pH and CO_3^{--} contents) (White 1970). It has been suggested (Pálmason et al. 1978) that at temperatures below 100°C one mineral controls the $[F^-]/[OH^-]$ ratio in such a way that there is an increase with increasing source temperature but at temperatures above 100 °C another mineral is in control and this ratio is relatively constant. In Fig.13 this ratio is drawn against the estimated source temperature (see Chapter 6.3), and it appears that a relationship exists between the two. In fact this relationship is in agreement with the idea, described above, that this ratio increases up to a certain temperature, but becomes constant above this value. The threshold value, however, appears to lie closer to 80°C in this case than the predicted 100°C.

Although the F/Cl ratio cannot be applied quantitatively as a geothermometer it has often proved to be a useful qualitative guide (Mahon 1970). Fig.14 suggests a slightly different pattern than indicated by the geothermometers compared in Table 7.

6.8 Isotopic composition.

The results of deuterium (δD) and oxygen-18 ($\delta^{18}O$) analyses for 6 of the samples are reported in Table 6, and these results ar plotted in Fig.15 along with the meteoric line for δD - $\delta^{18}O$ (Craig 1961), a line obtained for East-African lakes (Craig 1961), and a line drawn through three average results for rain at continental African stations (Dansgaard 1964). The rainwater station which lies closest to Burundi is Entebbe. The present results are of the same magnitude, and, as expected, similar to those for continental African rain. There may, however, be a slight oxygen shift, which could result from water-rock

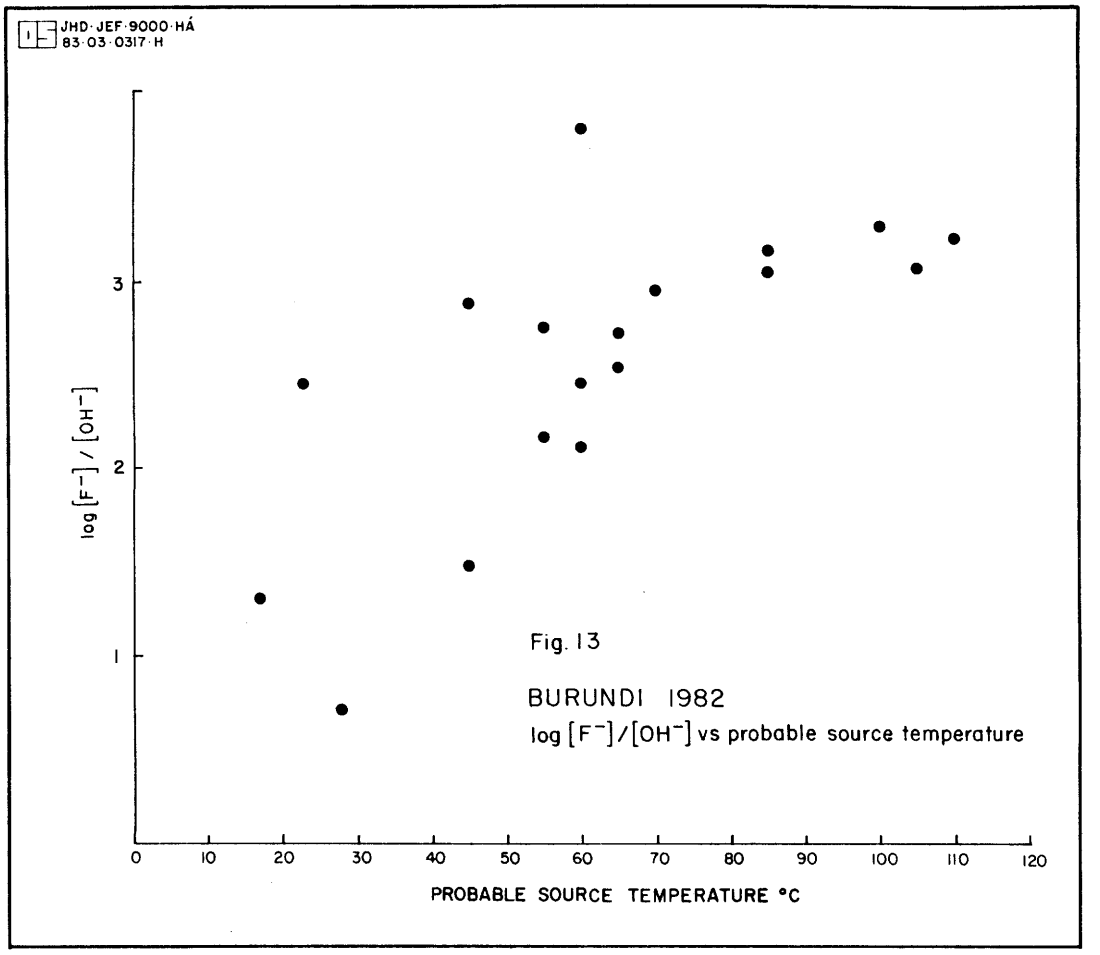


Fig. 13

BURUNDI 1982

log $[F^-]/[OH^-]$ vs probable source temperature

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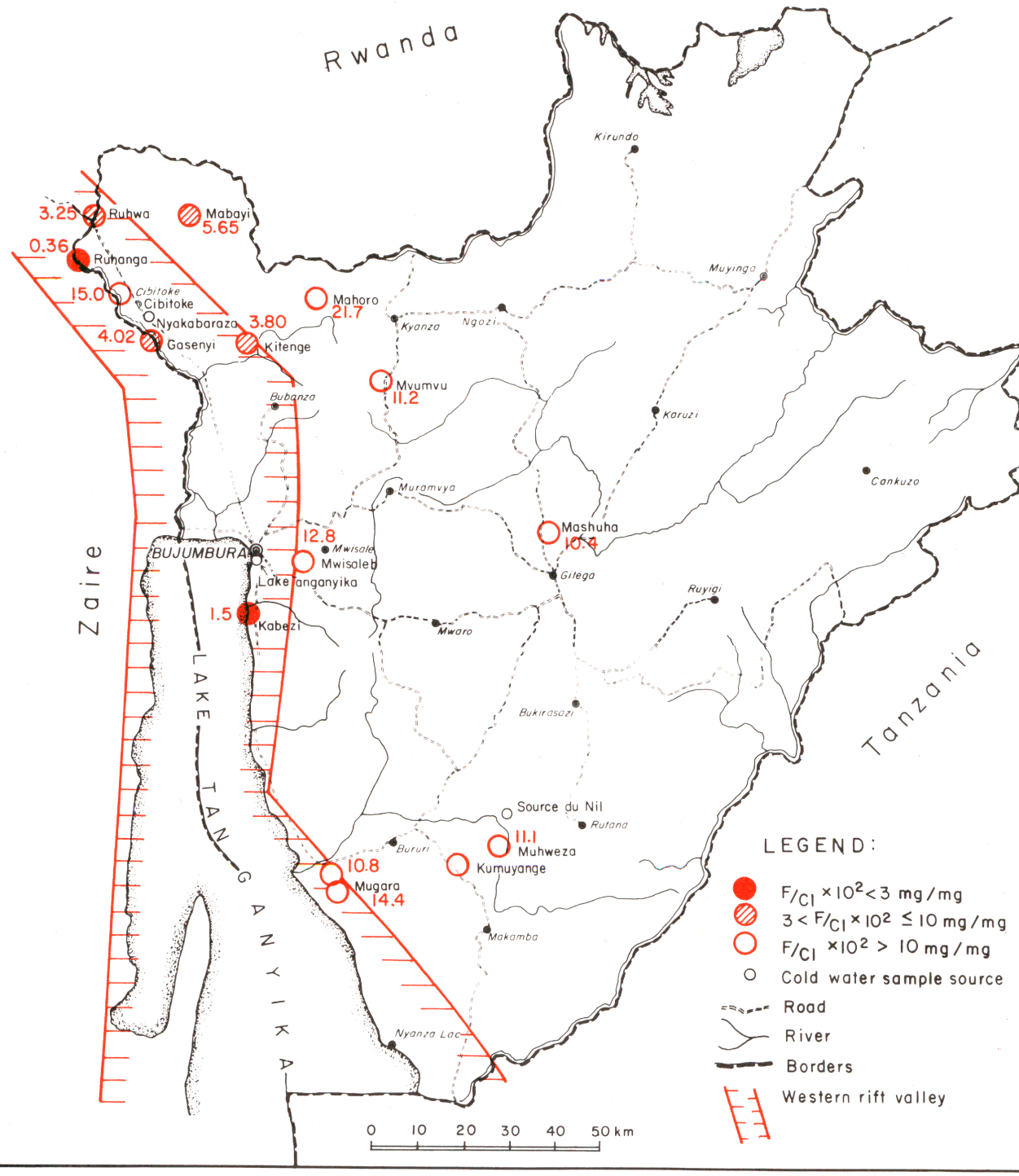
Fig.14. Burundi 1982 F/Cl ($\times 10^2$) distribution



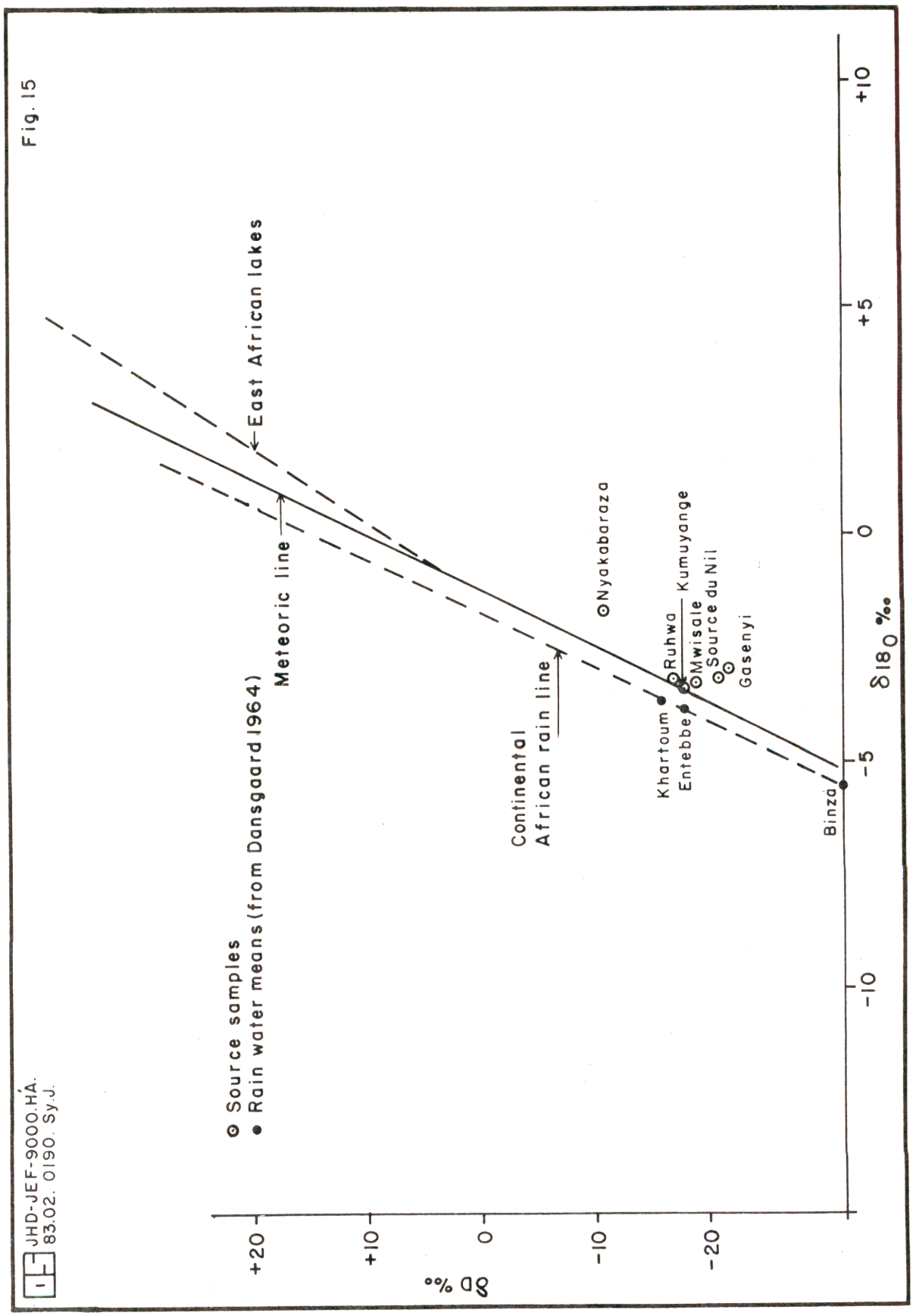


Fig. 15
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Source samples
Rain water means (from Dansgaard 1964)
Meteoric line
East African lakes
Continental
African rain line
Nyakabaraza
Ruhwa
Kumuyange
Mwisale
Source du Nil
Gasenyi
Khartoum
Entebbe
Binza
δD ‰
δ18O ‰
+20
+10
0
-10
-20
+10
+5
0
-5
-10

interaction after the rainfall. There is little variation between the Burundi samples, although the Nyakabaraza sample is a little richer in the heavier isotopes than the rest. As there is a variation in isotopes in rainwater with altitude a difference of this magnitude might result from different origins, i.e. that the water which is more enriched in the heavier isotopes might have fallen as rain in the rift valley at an altitude of 5-700 m.y.s., whereas the rest might have fallen as rain in the mountains at 1500-2000 m.y.s. This explanation invokes a model where the water sampled at Ruhwa and Gasenyi would be assumed to have fallen as rain in the mountains, seeped deep down into the ground, come into contact with a heat source, and emerged again as geothermal water down in the valley after some underground residence time. The Nyakabaraza water on the other hand would be considered to have fallen as rain in the valley. Another possible explanation is that, as before, the high level samples (Source du Nil, Mwisale, Kumuyange) are lighter due to the altitude, and the low level waters all have their origin from rain in the lowland, but that the water from Ruhwa and Gasenyi has had longer residence time underground than the Nyakabaraza water, since there tends to be an annual variation in the isotopic content of the precipitation. The Nyakabaraza water would thus reflect the relatively dry season rain composition which is more enriched in heavy isotopes, due to evaporation effects (Dansgaard 1964), but the Ruhwa and Gasenyi waters would reflect the mean annual composition. Thus the high level samples would also be reflecting the dry season composition. This explanation seems more unlikely, since there is very little rain during the dry season and it is unlikely that it could feed these springs, the apparent oxygen shift in the Nyakabaraza water and its considerable mineralization would be unlikely if it originated in very recent precipitation, and the similarity between the Ruhwa and Gasenyi samples on the one hand, and the high altitude samples on the other would have to be fortuitous. It is tentatively suggested that the Ruhwa and Gasenyi waters originate in the mountains and emerge after considerable underground circulation. The Mwisale and Kumuyange waters probably have much shorter underground residence times, but come into contact with localised relatively powerful heat sources.

Only much more extensive sampling of rainwater and hot and

cold groundwater springs can confirm or refute this conclusion.

6.9 Cold groundwater

Results of cold water analyses were obtained from REGIDESO (App. 3). As it was its suitability as drinking water that was being tested, the constituents determined were to a large extent different from those in the present study. However the ones that were comparable are reported in Table 10 along with the results for the cold groundwater samples and the geothermal samples from the present study that were the closest geographically to the REGIDESO samples.

As expected the geothermal waters are generally quite different from their neighbouring cold groundwaters. The differences are, however, not in all cases the ones expected, f.inst. at Mwisale, the cold water is more mineralized than the hot water. Considering the conductivity values, the cold water from Ngozi is apparently more mineralized than both the Mvumvu and Mahoro waters, even though the CO_2 concentrations and the hardness values are higher for the latter ones. In fact, some of the REGIDEO hardness values seem very low, and there may be a question of comparability of values, regarding this parameter. Again going by the conductivity the Kigwena water is more mineralized than the two Mugara waters, although the results for individual constituents are not entirely dissimilar. The Kajondi water is more mineralized than the Muhweza and Kumuyange waters, but the latter have compositions similar to the Source du Nil water. These results support the idea that the hot water sources in the old formations in the mountains such as Mwisale, Mahoro, Mugara, Kumuyange and Muhweza may result from powerful localised heat sources, with which relatively recent rainwater comes into contact, and the residence time of such waters is therefore short. Some of the cold groundwaters apparently have a relatively long underground circulation time.

TABLE 10 Burundi 1982. Cold water sources and neighbouring hot water sources. Comparison of some chemical properties.

Area No	Location	Date	Sampled by	Temp. °C Hot or cold source	pH	CO_2 mg/kg	Cl mg/kg	SO_4 mg/kg	Hardness mg$CaCO_3$/l	Conductivity µs
1	Mwisale a)	810729	REGIDESO	(C)	7.2	2.8	15	20.8	5.8	600
	Mwisale b)	820901	NEA	37.0(H)	5.8	31.1	0.65	2.15	11.9	35
2	Ngozi[1]	810415	REGIDESO	19.5(C)	8.3	33			0.7	720
	Mvumvu	820906	NEA	28.5(H)	7.3	189	4.08	11.5	157	360
	Mahoro	820906	NEA	45.0(H)	6.4	93.4	1.83	12.8	32.6	140
3a	Rugombo[2]	810723	REGIDESO	(C)	7.0	2.1	25.7	15	6	390
	Ruhanga	820908	NEA	48.3(H)	6.9	2145	552	21.5	730	4000
	Ruhwa	820907	NEA	63.1(H)	7.0	1228	82.8	8.46	384	1350
3b	Nyakabaraza	820908	NEA	22.7(C)	7.9	35.7	0	25.8	346	640
	Cibitoke	820908	NEA	30.6 (H)	6.0	810	6.65	317	481	950
	Gasenyi	820910	NEA	59.5 (H)	7.1	1099	125	121	85	2200
4	Lac Tanganyika	820910	NEA	28.0 (C)	8.8	292	29.3	6.6	207	650
	Kabezi	820831	NEA	38.0 (H)	7.9	1734	135	1.06	27.5	3200
5	Kigwena	820305	REGIDESO	(C)	7.2	18.5	5.3	12	1	850
	Mugara I	820909	NEA	46.8 (H)	6.1	82.4	2.0	9.89	21.8	95
6	Kajondi	820408	REGIDESO	20 (C)	6.8	1.4	117	17	14	1400
	Source de Nil	820909	NEA	16.8 (C)	6.8	17.6	0	1.2	10.5	23
	Muhweza	820909	NEA	37.3 (H)	6.3	34.1	0.45	6.29	27.3	62
	Kumuyange	820909	NEA	40.1 (H)	5.8	47.3	0	1.15	7.9	22

1) Mean of 4 sources

2) Mean of 2 sources

The situation is quite different in the rift valley where a hot water source such as Ruhanga is much more mineralized than the near-by cold water sources of Nyakabaraza and Rugombo. This suggests a relatively long underground circulation time for the Ruhanga water. The water from Cibitoke is, however, mineralized to a similar extent as these neighbouring cold waters, but this was not considered to be a very hot source. The Ruhwa and Gasenyi waters are similar to the Ruhanga water and the same argument should apply to them, although they lie further away from the cold water sources sampled.

The waters sources of cold springs vary considerably in chemistry. Generally they are neutral or slightly basic. All, except the Source du Nil water, are relatively mineralized.

7 RELATIONS BETWEEN GEOTHERMAL MANIFESTATIONS IN THE RUSIZI VALLEY AND THE TSIBINDE VOLCANIC ZONE

The geological and geochemical evidence presented in Chapter 6 indicates that the most promising area for finding potential geothermal systems is in the rift valley in the north-western part of Burundi.

Geological evidence suggests that the area, which includes the Ruhwa, Ruhanga, Gasenyi and Cibitoke springs, is a part of the Tshibinde volcanic zone south of Lake Kivu (Fig.4), indicating that an anomalously high geothermal gradient could be expected in this region. This has in fact been confirmed for Lake Kivu by Degens **et al.** (1973). Furthermore several geothermal manifestations have been reported in the area by some authors (Degens **et al.** 1973, Deelstra **et al.** 1972). Some of these are shown in Fig. 1. Chemical analysis of samples from five localities in Rwanda and N-E Zaire were reported. Some of the results are presented in Table 11 and much similarity is suggested between all samples from the Rusizi valley, from Lake Tanganyika in the south to Lake Kivu in the north. Cap Banza by Lake Tanganyika is a hotter source but totally different in character. The source at Kinanira has not been investigated but information on it could be valuable in view of its closeness to the Ruhanga source. This evidence strongly suggests that geothermal areas within the Tshibinde zone should be regarded as a connected geothermal prospect. Even though they are divided between three countries the best way to investigate the possibilites of discovering economically exploitable sources would be to include the whole of the Tshibinde region in all surveys.

TABLE 11 Information on locations outside Burundi.

Location	Area	t°C	t_{Quartz} °C	$t_{Na-K-Ca-Mg}$ °C	pH	Cl mg/kg	CO_2 mg/kg	Ref.
Kakondo Hot Spring	Near Lake Kivu		89	45		80	1306	Degens et al. 1972
Kaukula Hot Spring	Near Lake Kivu		105	50		63	964	Degens et al. 1972
Mashiuza	SW Rwanda near River Rusizi	60	93	37	7.8	136	858	Deelstra et al. 1972
Mashuzi	Zaïre, NW corner of Lake Tanganyika	67	108	87	7.1	89	519	Deelstra et al. 1972
Cap Banza	Zaïre, Central West coast, Lake Tanganyika	96	169	140	6.5	75	23	Deelstra et al. 1972

8 RECOMMENDATIONS FOR FURTHER RESEARCH

8.1 Reconnaisance

There should be no need for further detailed reconnaisance missions covering the whole of Burundi similar to the one described in this report. However, any previously unknown geothermal locations, especially in the Rusizi valley should be investigated in the manner described here.

To obtain meaningful information about the Rusizi valley geothermal areas a similar reconnaisance mission would have to take place, during which all known geothermal locations in the Rwanda and Zaire parts of it would be visited. Such a mission might be effected under the auspices of the E.G.L. (Organization de la C.E.P.C.L. pour l'Energie des Pays des Grands Lacs).

The following recommendations assume that such a reconnaisance mission will be the next step, and that the investigations listed will cover the whole of the Rusizi valley geothermal areas.

8.2 Further studies in selected geothermal areas

The question whether a geothermal field is suitable for utilization can only be answered by drilling and direct testing of the area. But due to the high cost of drilling the exploration of a geothermal system usually includes preliminary geological, geochemical and geophysical surveys to obtain the maximum possible information about the system and to minimize the risk of selecting wrong drilling sites. Furthermore an extensive surface reconnaisance can show whether a geothermal field is not promising enough for drilling to be recommended.

If the first phase of the reconnaisance leads to the discovery of a suitable target area for further geothermal

studies, it is recommended that the second phase of the exploration be carried out. This involves geological and geophysical methods.

8.3 Geological mapping

A detailed geological map of the prospective area is essential for the study. It should cover the whole of the geothermal field and extend into the surrounding area. Geological formations, folds and faults should be mapped with special emphasis on the younger ones. Furthermore all surface geothermal manifestations should be shown so that possible connections between the structures of the area and geothermal activity can be studied. The aim of the geological mapping is increased understanding of the geothermal system, especially the pointing out of possible heat sources, reservoir rock, cap rock, possible upflow zones and aquifers.

The geologist who carries out the geological work needs to be experienced in geothermal work. One part of the study can be done in the laboratory with the aid of aerial photographs, but a field survey during which the geologist works out a detailed geological map is also necessary. Geoscientific studies in a selected area require maps in the scale 1:50.000 with altitude contours, and also aerial photographs.

8.4 Hydrological survey

The energy from a geothermal system is transferred to the surface by means of water or steam. The knowledge about the hydrological character of a geothermal field is therefore very important for the exploitation of the system. If a potential geothermal field will be discovered it is therefore recommended that a hydrological survey be carried out. This involves the mapping of the field's catchment, rainfall pattern, evapotranspiration and run-off water. Thus values for the available water for

ground water recharge would be obtained. During the first stage of the study all available hydrological data will be gathered and evaluated followed by reconnaisance mapping of the groundwater regime in the geothermal prospect area.

The result of such a study is very useful in evaluating the potential of a geothermal system, especially where the amount of available circulation water is sparse as can be expected in Burundi.

8.5 Geophysical surveys

Many geophysical methods have been used with success in geothermal research, such as measurements of resistivity, magnetism, gravity, geothermal gradient and seismic activity. The most widely used method in the first stage of a geophysical study is resistivity measurements with a Schlumberger dipole-dipole configuration of electrodes. This method has proved very useful in locating low resistivity bodies, like hot reservoirs and permeable zones, in the uppermost 1200-1400 m of the lithosphere. The detection of geological structures such as faults and other boundaries is another possible result. The application of the method requires a skilled geophysicist, a technician and a group of 3 to 4 assistants. It is time consuming.

8.6 Geothermal gradient surveys

The regional geothermal gradient in Burundi is unknown, and if geothermal research is to be continued in the country, an attempt should be made to obtain it by measurements. The first stage would be the measurement of downhole temperatures in some of the already existing narrow research boreholes which have been drilled in Burundi in connection with mineral prospecting (L. Muhagaze, personal communication). Thus the necessary information on the background regional geothermal gradient would be obtained. The drilling of slim 100 m deep drillholes would

be necessary to establish the geothermal gradients in selected geothermal areas of the rift valley.

9 CONCLUSIONS

The geothermal manifestations in Burundi are found mainly in two types of environment, i.e. Precambrian rock, mostly outside the rift valley, and sediments inside the valley. The old age and low porosity of the Precambrian rock make the existence of an exploitable geothermal system within it highly unlikely. The higher porosity of the thick sediment layers, and the recent volcanism in the rift valley constitute conditions which could lead to exploitable geothermal systems. There is considerable volcanism around Lake Kivu in whose vicinity geothermal heat has been reported. The chemical composition of the lake water is affected by geothermal heat. The northwestern part of Burundi is on the edge of the Tshibinde volcanic region of Lake Kivu. Thus from a geological point of view this is the most promising of the geothermal areas in Burundi which were investigated during the present mission.

Six geothermal locations in the rift valley were visited, four in the Rusizi valley, one on the east coast of Lake Tanganyika (Kabezi), and one further south at some distance from the lake (the Mugara springs). In the Rusizi valley and at Kabezi the hot water rises from sediments, but at Mugara from Precambrian rock. Thus the former sources are likely to originate from larger and more open aquifers than the latter.

Chemical geothermometers suggest highest source temperatures in the rift valley and the three highest temperatures were estimated at locations in the Rusizi valley. All discharges rising from sediments were carbon dioxide rich. This could indicate the presence of a powerful heat source. The high carbon dioxide concentrations lead to supersaturation with respect to calcium carbonate in some cases, so that care would have to be exercised in avoiding calcium carbonate deposition in the event of exploitation.

In summary an exploitable geothermal source whose temperature could be in the 100 - 160°C range, may exist in the Rusizi valley and probably extend well into Zaire and Rwanda. This source is thought to be connected to the Tshibinde volcanic area south of Lake Kivu. Therefore an anomalously high geothermal gradient may be expected in

this region.

The base temperature in Burundi is unlikely to be high enough for electricity production, but is suitable for many industrial and domestic uses. Of the existing industries in Burundi, the tea factories, the brewery and the textile factory could benefit from such use, and any new industries especially those in which heating and drying are involved could use such an energy source.

The geothermal water in the Rusizi valley is carbon dioxide rich, and a minor exploitation might involve its cooling and bottling as mineral water. The most chloride rich sources would, however, be unsuitable in this respect.

The water rising from Precambrian rock is unlikely to be exploitable for other than direct uses, such as bathing.

It is recommended that further geological, geochemical and geophysical studies be carried out in the whole of the Tshibinde region, subject, of cource to an agreement between the three governments involved.

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APPENDIX 1.

Request letters for development aid in the geothermal field from the Government of Burundi, received by the Icelandic Industry and Foreign Ministries.

REPUBLIQUE DU BURUNDI

Bujumbura, le 18 Août 1981

Ministère des Travaux Publics,
de l'Energie et des Mines
Cabinet du Ministre

HJORLEIFUR CUTTORMOSSON
Minister of Energy and Industry
Arnarhvoll . Reykjavik . ICELAND

740/516 /CAB/81

Your Excellency,

Let me tell you how happy I was to make your acquaintanance at the Nairobi Conference on new and renewable sources of energy. I was very well impressed by your warm understanding and goodwill towards me and my country, Burundi.

We agreed on your sending us a mission of specialists from Iceland to assist us in the development of geothermal energy.

The planning of the sites for different uses: energy, medical cures, mineral water, thermal bathing for tourism might be additional interests to look into.

We are attaching a copy of a first glance report on 14 thermal sources. Really meaningful further investigations of these sites might bring some good results.

We are relying upon your Government's assistance to assess the possibilities. Your interest in the development of Burundi is certainly greatly appreciate

Yours sincerely.

H.E. Isidore NYABOYA
MINISTER OF PUBLIC WORKS, ENERGY
AND MINES

BB/PP

AMBASSADE DE LA
RÉPUBLIQUE DU BURUNDI

REPRÉSENTATION PERMANENTE
AUPRÈS DE LA COMMUNAUTÉ ÉCONOMIQUE
EUROPÉENNE

BRUXELLES, LE

N° 516.04/1181/A.E/81

L'Ambassade de la République du Burundi à Bruxelles présente ses compliments à l'Ambassade d'Islande à Bruxelles et a l'honneur de lui demander de bien vouloir transmettre au Gouvernement d'Islande la requête que le Gouvernement du Burundi lui adresse et qui consiste en l'envoi d'un expert en énergie géothermique pour une courte durée.

Cette mission aurait notamment pour but de :

- vérifier et éventuellement compléter les données existantes en ce qui concerne les eaux thermales;

- examiner, à la lumière de la qualité physico-chimique de l'eau, l'usage le plus judicieux pour chaque source;

- proposer un programme d'investigation future pour les études de l'énergie géothermique.

L'Ambassade de la République du Burundi à Bruxelles remercie d'ores et déjà l'Ambassade d'Islande de sa diligence et saisit la présente occasion pour lui renouveler les assurances de sa haute considération.

Fait à Bruxelles, le 26 octobre 198

APPENDIX 2.

WATCH 3 computer programme printout

Results of chemical analysis of the water samples and calculated activity coefficients, chemical components, chemical geothermometers, oxidation potentials and solubility products of minerals in deep water.

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820831200 1 KABEZI BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	7.90/27.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	31.68	CO2			
NA	938.86	H2S		SAMPLING PRESSURE BARS ABS.	
K	10.49	H2		DISCHARGE ENTHALPY MJOUL/KG	
CA	3.28	O2		DISCHARGE KG/SEC.	0.5
MG	4.700	CH4			
CO2	1734.00	N2		MEASURED TEMPERATURE DEGREES C	38.0
SO4	1.06			RESISTIVITY/TEMP. OHMM/DEG.C	3.1/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	135.00				
F	2.08	LITERS GAS PER KG			
DISS.SOLIDS	2279.20	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0 0.0	0.0
NH3	0.0000	PH/DEG.C		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0
		NA		0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0

IONIC STRENGTH = 0.04254 IONIC BALANCE : CATIONS (MOL.EQ.)0.04157276
ANIONS (MOL.EQ.)0.04257425
DIFFERENCE (%) -2.38

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	31.68	CO2	1734.00	CO2	0.00	CO2	0.849E-01
NA	938.86	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	10.49	H2	0.00	H2	0.00	H2	0.000E+00
CA	3.28	O2	0.00	O2	0.00	O2	0.000E+00
MG	4.700	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	1.06	N2	0.00	N2	0.00	N2	0.000E+00
CL	134.99	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	2.08					H2O	0.452E+00
DISS.S.	2279.20					TOTAL	0.537E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.844	KSO4-	0.820	FE++	0.468	FECL+	0.807
OH-	0.803	F-	0.803	FE+++	0.226	AL+++	0.226
H3SIO4-	0.807	CL-	0.798	FEOH+	0.816	ALOH++	0.457
H2SIO4--	0.457	NA+	0.807	FE(OH)3-	0.816	AL(OH)2+	0.820
H2BO3-	0.792	K+	0.798	FE(OH)4--	0.450	AL(OH)4-	0.812
HCO3-	0.807	CA++	0.468	FEOH++	0.450	ALSO4+	0.812
CO3--	0.440	MG++	0.500	FE(OH)2+	0.820	AL(SO4)2-	0.812
HS-	0.803	CAHCO3+	0.824	FE(OH)4-	0.820	ALF++	0.457
S--	0.450	MGHCO3+	0.807	FESO4+	0.816	ALF2+	0.820
HSO4-	0.812	CAOH+	0.824	FECL++	0.450	ALF4-	0.812
SO4--	0.431	MGOH+	0.828	FECL2+	0.816	ALF5--	0.440
NASO4-	0.820	NH4+	0.792	FECL4-	0.807	ALF6---	0.159

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-7.787	MG++	3.17	-3.885	FE(OH)3	0.00	0.000
OH-	0.31	-4.744	NACL	0.77	-4.883	FE(OH)4-	0.00	0.000
H4SIO4	47.24	-3.308	KCL	0.00	-7.386	FECL+	0.00	0.000
H3SIO4-	2.54	-4.573	NASO4-	0.07	-6.232	FECL2	0.00	0.000
H2SIO4--	0.00	-7.641	KSO4-	0.00	-7.766	FECL++	0.00	0.000
NAH3SIO4	1.06	-5.046	CASO4	0.00	-7.764	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.03	-6.682	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	1.34	-4.874	FECL4-	0.00	0.000
H2CO3	67.67	-2.962	MGCO3	1.59	-4.726	FESO4	0.00	0.000
HCO3-	2311.36	-1.422	CAHCO3+	3.13	-4.509	FESO4+	0.00	0.000
CO3--	19.43	-3.490	MGHCO3+	3.72	-4.360	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-8.043	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.01	-6.459	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-20.409	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-10.359	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	0.98	-4.991	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-8.204	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	2.08	-3.962	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	134.52	-2.421	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	938.34	-1.389	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	10.49	-3.572	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	1.50	-4.427	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.04250 IONIC BALANCE : CATIONS (MOL.EQ.)0.04149378
ANIONS (MOL.EQ.)0.04249536
DIFFERENCE (%) -2.39

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.84

QUARTZ	78.9
CHALCEDONY	48.9
NAK	41.8

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-18.131	99.999	ALBITE LOW	-17.315	99.999	ANALCIME	-13.821	99.999
ANHYDRITE	-5.319	-10.114	CALCITE	-9.099	-8.603	CHALCEDONY	-3.018	-3.308
MG-CHLORITE	-81.080	99.999	FLUORITE	-10.587	-12.871	GOETHITE	-5.438	99.999
LAUMONTITE	-28.292	99.999	MICROCLINE	-19.666	99.999	MAGNETITE	-31.310	99.999
CA-MONTMOR.	-91.348	99.999	K-MONTMOR.	-44.783	99.999	MG-MONTMOR.	-92.385	99.999
NA-MONTMOR.	-44.718	99.999	MUSCOVITE	-22.561	99.999	PREHNITE	-37.622	99.999
PYRRHOTITE	-110.376	99.999	PYRITE	-162.744	99.999	QUARTZ	-3.308	-3.308
WAIRAKITE	-25.345	99.999	WOLLASTONITE	11.513	7.508	ZOISITE	-36.546	99.999
EPIDOTE	-45.322	99.999	WAIRAKITE	-137.819	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820901200 2 MWISALE BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE				
PH/DEG.C	5.81/26.0	GAS (VOL.%)		REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SIO2	20.35	CO2				
NA	1.63	H2S		SAMPLING PRESSURE	BARS ABS.	
K	1.01	H2		DISCHARGE ENTHALPY	MJOUL/KG	
CA	2.14	O2		DISCHARGE	KG/SEC.	7.5
MG	1.630	CH4				
CO2	31.10	N2		MEASURED TEMPERATURE	DEGREES C	37.0
SO4	2.15			RESISTIVITY/TEMP.	OHMM/DEG.C	285.7/19.0
H2S	0.00			EH/TEMP.	MV/DEG.C	0.000/ 0.0
CL	0.65					
F	0.08	LITERS GAS PER KG				
DISS.SOLIDS	41.00	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
AL	0.0000					
B	0.0000					
FE	0.0000	CONDENSATE (PPM)		0.0	0.0	0.0
NH3	0.0000	PH/DEG.C		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0
		NA		0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0

IONIC STRENGTH = 0.00042 IONIC BALANCE : CATIONS (MOL.EQ.)0.00033673
ANIONS (MOL.EQ.)0.00021794
DIFFERENCE (%) 42.83

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	20.35	CO2	31.10	CO2	0.00	CO2	0.345E-01
NA	1.63	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	1.01	H2	0.00	H2	0.00	H2	0.000E+00
CA	2.14	O2	0.00	O2	0.00	O2	0.000E+00
MG	1.630	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	2.15	N2	0.00	N2	0.00	N2	0.000E+00
CL	0.65	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.08					H2O	0.241E+00
DISS.S.	41.00					TOTAL	0.276E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.976	KSO4-	0.976	FE++	0.906	FECL+	0.975
OH-	0.975	F-	0.975	FE+++	0.805	AL+++	0.805
H3SIO4-	0.975	CL-	0.975	FEOH+	0.975	ALOH++	0.906
H2SIO4--	0.906	NA+	0.975	FE(OH)3-	0.975	AL(OH)2+	0.976
H2BO3-	0.975	K+	0.975	FE(OH)4--	0.906	AL(OH)4-	0.975
HCO3-	0.975	CA++	0.906	FEOH++	0.906	ALSO4+	0.975
CO3--	0.905	MG++	0.907	FE(OH)2+	0.976	AL(SO4)2-	0.975
HS-	0.975	CAHCO3+	0.976	FE(OH)4-	0.976	ALF++	0.906
S--	0.906	MGHCO3+	0.975	FESO4+	0.975	ALF2+	0.976
HSO4-	0.975	CAOH+	0.976	FECL++	0.906	ALF4-	0.975
SO4--	0.905	MGOH+	0.976	FECL2+	0.975	ALF5--	0.905
NASO4-	0.976	NH4+	0.975	FECL4-	0.975	ALF6---	0.800

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-5.741	MG++	1.61	-4.179	FE(OH)3	0.00	0.000
OH-	0.00	-7.177	NACL	0.00	-9.975	FE(OH)4-	0.00	0.000
H4SIO4	32.55	-3.470	KCL	0.00	-10.637	FECL+	0.00	0.000
H3SIO4-	0.01	-7.021	NASO4-	0.00	-8.417	FECL2	0.00	0.000
H2SIO4--	0.00	-12.467	KSO4-	0.00	-8.212	FECL++	0.00	0.000
NAH3SIO4	0.00	-10.085	CASO4	0.02	-6.776	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.07	-6.219	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.00	-8.991	FECL4-	0.00	0.000
H2CO3	34.45	-3.255	MGCO3	0.00	-9.245	FESO4	0.00	0.000
HCO3-	9.20	-3.822	CAHCO3+	0.02	-6.631	FESO4+	0.00	0.000
CO3--	0.00	-8.187	MGHCO3+	0.01	-6.847	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-10.098	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-8.985	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-16.061	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-7.943	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	2.07	-4.666	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.607	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.08	-5.362	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	0.65	-4.737	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	1.63	-4.149	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	1.01	-4.588	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	2.12	-4.276	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00042 IONIC BALANCE : CATIONS (MOL.EQ.)0.00033567
ANIONS (MOL.EQ.)0.00021685
DIFFERENCE (%) 43.01

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.96

QUARTZ	64.2
CHALCEDONY	34.4
NAK	519.5

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-18.866	99.999	ALBITE LOW	-17.986	99.999	ANALCIME	-14.329	99.999
ANHYDRITE	-5.133	-9.028	CALCITE	-8.893	-12.549	CHALCEDONY	-3.154	-3.470
MG-CHLORITE	-81.885	99.999	FLUORITE	-10.650	-15.065	GOETHITE	-5.947	99.999
LAUMONTITE	-29.207	99.999	MICROCLINE	-20.522	99.999	MAGNETITE	-32.436	99.999
CA-MONTMOR.	-96.160	99.999	K-MONTMOR.	-47.373	99.999	MG-MONTMOR.	-97.107	99.999
NA-MONTMOR.	-47.244	99.999	MUSCOVITE	-23.731	99.999	PREHNITE	-38.385	99.999
PYRRHOTITE	-117.779	99.999	PYRITE	-174.124	99.999	QUARTZ	-3.470	-3.470
WAIRAKITE	-25.901	99.999	WOLLASTONITE	12.043	3.694	ZOISITE	-37.175	99.999
EPIDOTE	-46.525	99.999	MARCASITE	-148.229	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

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99994007008209032003 MASHUHA BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	6.08/27.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	24.24	CO2			
NA	2.96	H2S		SAMPLING PRESSURE BARS ABS.	
K	0.75	H2		DISCHARGE ENTHALPY MJOUL/KG	
CA	1.89	O2		DISCHARGE KG/SEC.	10.0
MG	0.810	CH4			
CO2	25.30	N2		MEASURED TEMPERATURE DEGREES C	37.7
SO4	2.44			RESISTIVITY/TEMP. OHMM/DEG.C	294.1/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	1.10				
F	0.11	LITERS GAS PER KG			
DISS.SOLIDS	43.70	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0 0.0	0.0
NH3	0.0000	PH/DEG.C		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0
		NA		0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0

IONIC STRENGTH = 0.00040 IONIC BALANCE : CATIONS (MOL.EQ.)0.00030821
ANIONS (MOL.EQ.)0.00028192
DIFFERENCE (%) 8.91

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	24.24	CO2	25.30	CO2	0.00	CO2	0.264E-01
NA	2.96	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	0.75	H2	0.00	H2	0.00	H2	0.000E+00
CA	1.89	O2	0.00	O2	0.00	O2	0.000E+00
MG	0.810	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	2.44	N2	0.00	N2	0.00	N2	0.000E+00
CL	1.10	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.11					H2O	0.324E+00
DISS.S.	43.70					TOTAL	0.350E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

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ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.976	KSO4-	0.976	FE++	0.907	FECL+	0.975
OH-	0.975	F-	0.975	FE+++	0.806	AL+++	0.806
H3SIO4-	0.975	CL-	0.975	FEOH+	0.976	ALOH++	0.906
H2SIO4--	0.906	NA+	0.975	FE(OH)3-	0.976	AL(OH)2+	0.976
H2BO3-	0.975	K+	0.975	FE(OH)4--	0.906	AL(OH)4-	0.976
HCO3-	0.975	CA++	0.907	FEOH++	0.906	ALSO4+	0.976
CO3--	0.906	MG++	0.908	FE(OH)2+	0.976	AL(SO4)2-	0.976
HS-	0.975	CAHCO3+	0.976	FE(OH)4-	0.976	ALF++	0.906
S--	0.906	MGHCO3+	0.975	FESO4+	0.976	ALF2+	0.976
HSO4-	0.976	CAOH+	0.976	FECL++	0.906	ALF4-	0.976
SO4--	0.906	MGOH+	0.976	FECL2+	0.976	ALF5--	0.906
NASO4-	0.976	NH4+	0.975	FECL4-	0.975	ALF6---	0.801

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.021	MG++	0.80	-4.484	FE(OH)3	0.00	0.000
OH-	0.00	-6.753	NACL	0.00	-9.400	FE(OH)4-	0.00	0.000
H4SIO4	38.75	-3.395	KCL	0.00	-10.495	FECL+	0.00	0.000
H3SIO4-	0.02	-6.588	NASO4-	0.00	-8.062	FECL2	0.00	0.000
H2SIO4--	0.00	-11.697	KSO4-	0.00	-8.240	FECL++	0.00	0.000
NAH3SIO4	0.00	-9.396	CASO4	0.03	-6.727	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.05	-6.394	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.00	-8.566	FECL4-	0.00	0.000
H2CO3	23.61	-3.420	MGCO3	0.00	-9.103	FESO4	0.00	0.000
HCO3-	11.83	-3.712	CAHCO3+	0.03	-6.499	FESO4+	0.00	0.000
CO3--	0.00	-7.785	MGHCO3+	0.01	-7.020	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-9.696	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-8.833	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-16.381	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-8.073	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	2.38	-4.606	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.688	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.11	-5.223	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	1.10	-4.508	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	2.96	-3.890	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	0.75	-4.717	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	1.87	-4.331	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00040 IONIC BALANCE : CATIONS (MOL.EQ.)0.00030726
ANIONS (MOL.EQ.)0.00028094
DIFFERENCE (%) 8.95

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.91

QUARTZ	70.9
CHALCEDONY	41.0
NAK	323.5

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-18.518	99.999	ALBITE LOW	-17.668	99.999	ANALCIME	-14.088	99.999
ANHYDRITE	-5.216	-9.023	CALCITE	-8.984	-12.202	CHALCEDONY	-3.090	-3.395
MG-CHLORITE	-81.488	99.999	FLUORITE	-10.618	-14.842	GOETHITE	-5.715	99.999
LAUMONTITE	-28.773	99.999	MICROCLINE	-20.118	99.999	MAGNETITE	-31.918	99.999
CA-MONTMOR.	-93.879	99.999	K-MONTMOR.	-46.146	99.999	MG-MONTMOR.	-94.869	99.999
NA-MONTMOR.	-46.050	99.999	MUSCOVITE	-23.176	99.999	PREHNITE	-38.017	99.999
PYRRHOTITE	-114.380	99.999	PYRITE	-168.860	99.999	QUARTZ	-3.395	-3.395
WAIRAKITE	-25.634	99.999	WOLLASTONITE	11.795	4.275	ZOISITE	-36.869	99.999
EPIDOTE	-45.977	99.999	MARCASITE	-147.446	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820906 2004 MVUMVU BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE				
PH/DEG.C	7.34/26.0	GAS (VOL.%)		REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SIO2	45.92	CO2				
NA	18.89	H2S		SAMPLING PRESSURE	BARS ABS.	
K	6.27	H2		DISCHARGE ENTHALPY	MJOUL/KG	
CA	58.40	O2		DISCHARGE	KG/SEC.	5.0
MG	2.790	CH4				
CO2	189.00	N2		MEASURED TEMPERATURE	DEGREES C	28.5
SO4	10.95			RESISTIVITY/TEMP.	OHMM/DEG.C	27.8/19.0
H2S	0.00			EH/TEMP.	MV/DEG.C	0.000/ 0.0
CL	4.08					
F	0.46	LITERS GAS PER KG				
DISS.SOLIDS	240.80	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
AL	0.0000					
B	0.0000					
FE	0.0000	CONDENSATE (PPM)		0.0	0.0	0.0
NH3	0.0000	PH/DEG.C		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0
		NA		0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0

IONIC STRENGTH = 0.00575 IONIC BALANCE : CATIONS (MOL.EQ.)0.00404941
ANIONS (MOL.EQ.)0.00420456
DIFFERENCE (%) -3.76

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	45.92	CO2	189.00	CO2	0.00	CO2	0.432E-01
NA	18.89	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	6.27	H2	0.00	H2	0.00	H2	0.000E+00
CA	58.40	O2	0.00	O2	0.00	O2	0.000E+00
MG	2.790	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	10.95	N2	0.00	N2	0.00	N2	0.000E+00
CL	4.08	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.46					H2O	0.912E+00
DISS.S.	240.80					TOTAL	0.955E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.922	KSO4-	0.916	FE++	0.708	FECL+	0.913
OH-	0.912	F-	0.912	FE+++	0.482	AL+++	0.482
H3SIO4-	0.913	CL-	0.912	FEOH+	0.915	ALOH++	0.705
H2SIO4--	0.705	NA+	0.913	FE(OH)3-	0.915	AL(OH)2+	0.916
H2BO3-	0.911	K+	0.912	FE(OH)4--	0.703	AL(OH)4-	0.914
HCO3-	0.913	CA++	0.708	FEOH++	0.703	ALSO4+	0.914
CO3--	0.700	MG++	0.718	FE(OH)2+	0.916	AL(SO4)2-	0.914
HS-	0.912	CAHCO3+	0.917	FE(OH)4-	0.916	ALF++	0.705
S--	0.703	MGHCO3+	0.913	FESO4+	0.915	ALF2+	0.916
HSO4-	0.914	CAOH+	0.917	FECL++	0.703	ALF4-	0.914
SO4--	0.697	MGOH+	0.918	FECL2+	0.915	ALF5--	0.700
NASO4-	0.916	NH4+	0.911	FECL4-	0.913	ALF6---	0.448

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-7.258	MG++	2.50	-3.987	FE(OH)3	0.00	0.000
OH-	0.17	-5.008	NACL	0.00	-7.790	FE(OH)4-	0.00	0.000
H4SIO4	71.99	-3.126	KCL	0.00	-8.896	FECL+	0.00	0.000
H3SIO4-	1.45	-4.818	NASO4-	0.03	-6.660	FECL2	0.00	0.000
H2SIO4--	0.00	-8.451	KSO4-	0.03	-6.705	FECL++	0.00	0.000
NAH3SIO4	0.02	-6.882	CASO4	2.21	-4.789	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.62	-5.287	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	3.31	-4.480	FECL4-	0.00	0.000
H2CO3	27.66	-3.351	MGCO3	0.08	-6.045	FESO4	0.00	0.000
HCO3-	218.24	-2.447	CAHCO3+	22.88	-3.645	FESO4+	0.00	0.000
CO3--	0.38	-5.200	MGHCO3+	0.47	-5.262	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.02	-6.524	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.01	-6.566	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-17.715	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-8.464	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	8.85	-4.036	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-8.107	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.46	-4.620	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	4.08	-3.939	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	18.88	-3.086	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	6.26	-3.795	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	47.34	-2.928	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00524 IONIC BALANCE : CATIONS (MOL.EQ.)0.00378200
ANIONS (MOL.EQ.)0.00393747
DIFFERENCE (%) -4.03

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.70

QUARTZ	97.1
CHALCEDONY	67.1
NAK	371.6

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-17.338	99.999	ALBITE LOW	-16.590	99.999	ANALCIME	-13.277	99.999
ANHYDRITE	-5.566	-7.270	CALCITE	-9.389	-8.433	CHALCEDONY	-2.864	-3.126
MG-CHLORITE	-80.384	99.999	FLUORITE	-10.542	-12.397	GOETHITE	-1.782	99.999
LAUMONTITE	-27.321	99.999	MICROCLINE	-18.735	99.999	MAGNETITE	-29.925	99.999
CA-MONTMOR.	-86.277	99.999	K-MONTMOR.	-42.038	99.999	MG-MONTMOR.	-87.412	99.999
NA-MONTMOR.	-42.041	99.999	MUSCOVITE	-21.326	99.999	PREHNITE	-36.878	99.999
PYRRHOTITE	-101.261	99.999	PYRITE	-149.145	99.999	QUARTZ	-3.126	-3.126
WAIRAKITE	-24.787	99.999	WOLLASTONITE	10.914	8.312	ZOISITE	-35.966	99.999
EPIDOTE	-43.838	99.999	MARCASITE	-125.526	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

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9999400700820906200S MAHORO BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE				
PH/DEG.C	6.40/26.0	GAS (VOL.%)		REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SIO2	33.48	CO2				
NA	15.61	H2S		SAMPLING PRESSURE	BARS ABS.	
K	2.47	H2		DISCHARGE ENTHALPY	KJOUL/KG	
CA	8.11	O2		DISCHARGE	KG/SEC.	10.0
MG	3.070	CH4				
CO2	93.40	N2		MEASURED TEMPERATURE	DEGREES C	45.0
SO4	12.76			RESISTIVITY/TEMP.	OHMM/DEG.C	71.4/19.0
H2S	0.00			EH/TEMP.	MV/DEG.C	0.000/ 0.0
CL	1.83					
F	0.40	LITERS GAS PER KG				
DISS.SOLIDS	80.40	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
AL	0.0000					
B	0.0000					
FE	0.0000	CONDENSATE (PPM)		0.0	0.0	0.0
NH3	0.0000	PH/DEG.C		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0
		NA		0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0

IONIC STRENGTH = 0.00186 IONIC BALANCE : CATIONS (MOL.EQ.)0.00138790
ANIONS (MOL.EQ.)0.00143308
DIFFERENCE (%) -3.20

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	33.48	CO2	93.40	CO2	0.00	CO2	0.848E-01
NA	15.61	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	2.47	H2	0.00	H2	0.00	H2	0.000E+00
CA	8.11	O2	0.00	O2	0.00	O2	0.000E+00
MG	3.070	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	12.76	N2	0.00	N2	0.00	N2	0.000E+00
CL	1.83	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.40					H2O	0.556E+00
DISS.S.	80.40					TOTAL	0.641E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

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ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.951	KSO4-	0.949	FE++	0.813	FECL+	0.948
OH-	0.948	F-	0.948	FE+++	0.639	AL+++	0.639
H3SIO4-	0.948	CL-	0.947	FEOH+	0.949	ALOH++	0.812
H2SIO4--	0.812	NA+	0.948	FE(OH)3-	0.949	AL(OH)2+	0.949
H2BO3-	0.947	K+	0.947	FE(OH)4--	0.811	AL(OH)4-	0.948
HCO3-	0.948	CA++	0.813	FEOH++	0.811	ALSO4+	0.948
CO3--	0.810	MG++	0.817	FE(OH)2+	0.949	AL(SO4)2-	0.948
HS-	0.948	CAHCO3+	0.949	FE(OH)4-	0.949	ALF++	0.812
S--	0.811	MGHCO3+	0.948	FESO4+	0.949	ALF2+	0.949
HSO4-	0.948	CAOH+	0.949	FECL++	0.811	ALF4-	0.948
SO4--	0.809	MGOH+	0.950	FECL2+	0.949	ALF5--	0.810
NASO4-	0.949	NH4+	0.947	FECL4-	0.948	ALF6---	0.622

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.359	MG++	2.84	-3.933	FE(OH)3	0.00	0.000
OH-	0.01	-6.147	NACL	0.00	-8.324	FE(OH)4-	0.00	0.000
H4SIO4	53.45	-3.255	KCL	0.00	-9.699	FECL+	0.00	0.000
H3SIO4-	0.10	-5.968	NASO4-	0.03	-6.629	FECL2	0.00	0.000
H2SIO4--	0.00	-10.612	KSO4-	0.01	-7.004	FECL++	0.00	0.000
NAH3SIO4	0.00	-8.082	CASO4	0.50	-5.435	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.92	-5.118	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.02	-6.764	FECL4-	0.00	0.000
H2CO3	63.14	-2.992	MGCO3	0.00	-7.420	FESO4	0.00	0.000
HCO3-	66.69	-2.961	CAHCO3+	0.93	-5.038	FESO4+	0.00	0.000
CO3--	0.01	-6.651	MGHCO3+	0.16	-5.716	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-8.465	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-7.659	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-16.070	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-7.580	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	11.64	-3.917	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.376	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.40	-4.681	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	1.83	-4.287	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	15.60	-3.168	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	2.47	-4.200	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	7.59	-3.723	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00181 IONIC BALANCE : CATIONS (MOL.EQ.)0.00136493
ANIONS (MOL.EQ.)0.00140990
DIFFERENCE (%) -3.24

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.80

QUARTZ	84.0
CHALCEDONY	54.1
NAK	253.7

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-17.894	99.999	ALBITE LOW	-17.098	99.999	ANALCIME	-13.658	99.999
ANHYDRITE	-5.387	-7.821	CALCITE	-9.178	-10.555	CHALCEDONY	-2.972	-3.255
MG-CHLORITE	-80.850	99.999	FLUORITE	-10.571	-13.221	GOETHITE	-5.255	99.999
LAUMONTITE	-28.000	99.999	MICROCLINE	-19.388	99.999	MAGNETITE	-30.917	99.999
CA-MONTMOR.	-89.811	99.999	K-MONTMOR.	-43.953	99.999	MG-MONTMOR.	-90.881	99.999
NA-MONTMOR.	-43.910	99.999	MUSCOVITE	-22.188	99.999	PREHNITE	-37.390	99.999
PYRRHOTITE	-107.792	99.999	PYRITE	-158.845	99.999	QUARTZ	-3.255	-3.255
WAIRAKITE	-25.172	99.999	WOLLASTONITE	11.337	5.650	ZOISITE	-36.360	99.999
EPIDOTE	-44.902	99.999	MARCASITE	-134.374	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820907200 6 KITENGE BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)

PH/DEG.C	6.10/26.0
SIO2	28.48
NA	14.75
K	1.73
CA	8.35
MG	3.410
CO2	56.50
SO4	41.37
H2S	0.00
CL	3.00
F	0.11
DISS.SOLIDS	97.30
AL	0.0000
B	0.0000
FE	0.0000
NH3	0.0000

STEAM SAMPLE

GAS (VOL.%)	
CO2	
H2S	
H2	
O2	
CH4	
N2	

REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SAMPLING PRESSURE	BARS ABS.	
DISCHARGE ENTHALPY	KJOUL/KG	
DISCHARGE	KG/SEC.	4.0
MEASURED TEMPERATURE	DEGREES C	47.1
RESISTIVITY/TEMP.	OHMM/DEG.C	71.4/19.0
EH/TEMP.	MV/DEG.C	0.000/ 0.0

	LITERS GAS PER KG CONDENSATE/DEG.C	MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
CONDENSATE (PPM)		0.0	0.0	0.0
PH/DEG.C		0.0	0.0	0.0
CO2		0.0	0.0	0.0
H2S		0.0	0.0	0.0
NA		0.0	0.0	0.0
		0.0	0.0	0.0
		0.0	0.0	0.0
		0.0	0.0	0.0
CONDENSATE WITH NAOH (PPM)		0.0	0.0	0.0
CO2		0.0	0.0	0.0
H2S		0.0	0.0	0.0

IONIC STRENGTH = 0.00212 IONIC BALANCE : CATIONS (MOL.EQ.)0.00135471
ANIONS (MOL.EQ.)0.00137733
DIFFERENCE (%) -1.66

DEEP WATER (PPM)

SIO2	28.48	CO2	56.50
NA	14.75	H2S	0.00
K	1.73	H2	0.00
CA	8.35	O2	0.00
MG	3.410	CH4	0.00
SO4	41.37	N2	0.00
CL	3.00	NH3	0.00
F	0.11		
DISS.S.	97.30		
AL	0.0000		
B	0.0000		
FE	0.0000		

DEEP STEAM (PPM)

CO2	0.00
H2S	0.00
H2	0.00
O2	0.00
CH4	0.00
N2	0.00
NH3	0.00

H2O (%)	0.00
BOILING PORTION	0.00

GAS PRESSURES (BARS ABS.)

CO2	0.633E-01
H2S	0.000E+00
H2	0.000E+00
O2	0.000E+00
CH4	0.000E+00
N2	0.000E+00
NH3	0.000E+00
H2O	0.425E+00
TOTAL	0.488E+00

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.950	KSO4-	0.947	FE++	0.807	FECL+	0.946
OH-	0.946	F-	0.946	FE+++	0.630	AL+++	0.630
H3SIO4-	0.946	CL-	0.945	FEOH+	0.947	ALOH++	0.806
H2SIO4--	0.806	NA+	0.946	FE(OH)3-	0.947	AL(OH)2+	0.947
H2BO3-	0.945	K+	0.945	FE(OH)4--	0.805	AL(OH)4-	0.947
HCO3-	0.946	CA++	0.807	FEOH++	0.805	ALSO4+	0.947
CO3--	0.803	MG++	0.812	FE(OH)2+	0.947	AL(SO4)2-	0.947
HS-	0.946	CAHCO3+	0.948	FE(OH)4-	0.947	ALF++	0.806
S--	0.805	MGHCO3+	0.946	FESO4+	0.947	ALF2+	0.947
HSO4-	0.947	CAOH+	0.948	FECL++	0.805	ALF4-	0.947
SO4--	0.802	MGOH+	0.948	FECL2+	0.947	ALF5--	0.803
NASO4-	0.947	NH4+	0.945	FECL4-	0.946	ALF6---	0.611

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.045	MG++	2.87	-3.928	FE(OH)3	0.00	0.000
OH-	0.00	-6.586	NACL	0.00	-8.214	FE(OH)4-	0.00	0.000
H4SIO4	45.52	-3.325	KCL	0.00	-9.684	FECL+	0.00	0.000
H3SIO4-	0.04	-6.414	NASO4-	0.08	-6.178	FECL2	0.00	0.000
H2SIO4--	0.00	-11.412	KSO4-	0.03	-6.688	FECL++	0.00	0.000
NAH3SIO4	0.00	-8.553	CASO4	1.49	-4.962	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	2.58	-4.669	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.00	-7.539	FECL4-	0.00	0.000
H2CO3	51.50	-3.081	MGCO3	0.00	-8.168	FESO4	0.00	0.000
HCO3-	27.43	-3.347	CAHCO3+	0.33	-5.491	FESO4+	0.00	0.000
CO3--	0.00	-7.350	MGHCO3+	0.06	-6.124	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-8.930	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-8.129	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-15.105	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.01	-6.844	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	38.17	-3.401	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.667	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.11	-5.223	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	3.00	-4.073	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	14.73	-3.193	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	1.72	-4.356	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	7.78	-3.712	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00203 IONIC BALANCE : CATIONS (MOL.EQ.)0.00131341
ANIONS (MOL.EQ.)0.00133540
DIFFERENCE (%) -1.66

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.85

QUARTZ	77.4
CHALCEDONY	47.4
NAK	216.8

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-18.203	99.999	ALBITE LOW	-17.380	99.999	ANALCIME	-13.870	99.999
ANHYDRITE	-5.299	-7.301	CALCITE	-9.077	-11.250	CHALCEDONY	-3.031	-3.325
MG-CHLORITE	-81.152	99.999	FLUORITE	-10.593	-14.300	GOETHITE	-5.491	99.999
LAUMONTITE	-28.381	99.999	MICROCLINE	-19.750	99.999	MAGNETITE	-31.425	99.999
CA-MONTMOR.	-91.818	99.999	K-MONTMOR.	-45.035	99.999	MG-MONTMOR.	-92.848	99.999
NA-MONTMOR.	-44.965	99.999	MUSCOVITE	-22.675	99.999	PREHNITE	-37.694	99.999
PYRRHOTITE	-111.138	99.999	PYRITE	-163.901	99.999	QUARTZ	-3.325	-3.325
WAIRAKITE	-25.398	99.999	WOLLASTONITE	11.566	4.961	ZOISITE	-36.605	99.999
EPIDOTE	-45.443	99.999	MARCASITE	-138.969	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

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9999400700820907200 7 MABAYI BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	7.60/27.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	18.68	CO2			
NA	5.58	H2S		SAMPLING PRESSURE BARS ABS.	
K	0.98	H2		DISCHARGE ENTHALPY KJOUL/KG	
CA	29.52	O2		DISCHARGE KG/SEC.	10.0
MG	17.190	CH4			
CO2	134.00	N2		MEASURED TEMPERATURE DEGREES C	37.7
SO4	9.75			RESISTIVITY/TEMP. OHMM/DEG.C	38.5/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	3.15				
F	0.18	LITERS GAS PER KG			
DISS.SOLIDS	142.50	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0	0.0 0.0
NH3	0.0000	PH/DEG.C		0.0	0.0 0.0
		CO2		0.0	0.0 0.0
		H2S		0.0	0.0 0.0
		NA		0.0	0.0 0.0
				0.0	0.0 0.0
				0.0	0.0 0.0
				0.0	0.0 0.0
		CONDENSATE WITH NAOH (PPM)		0.0	0.0 0.0
		CO2		0.0	0.0 0.0
		H2S		0.0	0.0 0.0

IONIC STRENGTH = 0.00460 IONIC BALANCE : CATIONS (MOL.EQ.)0.00308617
ANIONS (MOL.EQ.)0.00313301
DIFFERENCE (%) -1.51

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	18.68	CO2	134.00	CO2	0.00	CO2	0.101E-01
NA	5.58	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	0.98	H2	0.00	H2	0.00	H2	0.000E+00
CA	29.52	O2	0.00	O2	0.00	O2	0.000E+00
MG	17.189	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	9.75	N2	0.00	N2	0.00	N2	0.000E+00
CL	3.15	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.18					H2O	0.203E+00
DISS.S.	142.50					TOTAL	0.213E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

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ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.933	KSO4-	0.928	FE++	0.745	FECL+	0.926
OH-	0.925	F-	0.925	FE+++	0.536	AL+++	0.536
H3SIO4-	0.926	CL-	0.924	FEOH+	0.927	ALOH++	0.742
H2SIO4--	0.742	NA+	0.926	FE(OH)3-	0.927	AL(OH)2+	0.928
H2BO3-	0.924	K+	0.924	FE(OH)4--	0.741	AL(OH)4-	0.927
HCO3-	0.926	CA++	0.745	FEOH++	0.741	ALSO4+	0.927
CO3--	0.738	MG++	0.753	FE(OH)2+	0.928	AL(SO4)2-	0.927
HS-	0.925	CAHCO3+	0.929	FE(OH)4-	0.928	ALF++	0.742
S--	0.741	MGHCO3+	0.926	FESO4+	0.927	ALF2+	0.928
HSO4-	0.927	CAOH+	0.929	FECL++	0.741	ALF4-	0.927
SO4--	0.736	MGOH+	0.929	FECL2+	0.927	ALF5--	0.738
NASO4-	0.928	NH4+	0.924	FECL4-	0.926	ALF6---	0.506

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-7.490	MG++	16.21	-3.176	FE(OH)3	0.00	0.000
OH-	0.06	-5.490	NACL	0.00	-8.850	FE(OH)4-	0.00	0.000
H4SIO4	29.44	-3.514	KCL	0.00	-10.035	FECL+	0.00	0.000
H3SIO4-	0.43	-5.340	NASO4-	0.00	-7.414	FECL2	0.00	0.000
H2SIO4--	0.00	-9.009	KSO4-	0.00	-7.759	FECL++	0.00	0.000
NAH3SIO4	0.00	-7.912	CASO4	0.70	-5.286	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	1.71	-4.846	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.94	-5.027	FECL4-	0.00	0.000
H2CO3	10.76	-3.761	MGCO3	0.36	-5.364	FESO4	0.00	0.000
HCO3-	170.10	-2.555	CAHCO3+	4.15	-4.386	FESO4+	0.00	0.000
CO3--	0.46	-5.116	MGHCO3+	1.82	-4.671	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-7.407	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.02	-6.396	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-19.168	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-9.229	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	7.88	-4.086	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-9.078	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.18	-5.028	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	3.15	-4.051	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	5.58	-3.615	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	0.98	-4.601	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	27.29	-3.167	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00449 IONIC BALANCE : CATIONS (MOL.EQ.)0.00302574
ANIONS (MOL.EQ.)0.00307296
DIFFERENCE (%) -1.55

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 3.00

QUARTZ	60.5
CHALCEDONY	30.7
NAK	267.7

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-19.067	99.999	ALBITE LOW	-18.170	99.999	ANALCIME	-14.169	99.999
ANHYDRITE	-5.088	-7.514	CALCITE	-8.845	-8.542	CHALCEDONY	-3.190	-3.514
MG-CHLORITE	-82.126	99.999	FLUORITE	-10.670	-13.419	GOETHITE	-6.075	99.999
LAUMONTITE	-29.461	99.999	MICROCLINE	-20.756	99.999	MAGNETITE	-32.727	99.999
CA-MONTMOR.	-97.480	99.999	K-MONTMOR.	-48.083	99.999	MG-MONTMOR.	-98.402	99.999
NA-MONTMOR.	-47.938	99.999	MUSCOVITE	-24.053	99.999	PREHNITE	-38.604	99.999
PYRRHOTITE	-119.679	99.999	PYRITE	-177.097	99.999	QUARTZ	-3.514	-3.514
WAIRAKITE	-26.059	99.999	WOLLASTONITE	12.186	8.171	ZOISITE	-37.360	99.999
EPIDOTE	-46.842	99.999	MARCASITE	-150.915	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
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PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	7.00/ 0.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	59.18	CO2			
NA	389.06	H2S		SAMPLING PRESSURE BARS ABS.	
K	68.46	H2		DISCHARGE ENTHALPY MJOUL/KG	
CA	63.60	O2		DISCHARGE KG/SEC.	1.0
MG	54.870	CH4			
CO2	1228.00	N2		MEASURED TEMPERATURE DEGREES C	63.1
SO4	8.46			RESISTIVITY/TEMP. OHMM/DEG.C	7.4/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	82.75				
F	2.69	LITERS GAS PER KG			
DISS.SOLIDS	1313.80	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0 0.0	0.0
NH3	0.0000	PH/DEG.C		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0
		NA		0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0

IONIC STRENGTH = 0.02846 IONIC BALANCE : CATIONS (MOL.EQ.)0.02600515
ANIONS (MOL.EQ.)0.02373203
DIFFERENCE (%) 9.14

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	59.18	CO2	1228.00	CO2	0.00	CO2	0.713E+00
NA	389.06	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	68.46	H2	0.00	H2	0.00	H2	0.000E+00
CA	63.60	O2	0.00	O2	0.00	O2	0.000E+00
MG	54.865	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	8.46	N2	0.00	N2	0.00	N2	0.000E+00
CL	82.74	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	2.69					H2O	0.140E+01
DISS.S.	1313.80					TOTAL	0.212E+01
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.856	KSO4-	0.836	FE++	0.501	FECL+	0.826
OH-	0.823	F-	0.823	FE+++	0.251	AL+++	0.251
H3SIO4-	0.826	CL-	0.819	FEOH+	0.833	ALOH++	0.492
H2SIO4--	0.492	NA+	0.826	FE(OH)3-	0.833	AL(OH)2+	0.836
H2BO3-	0.815	K+	0.819	FE(OH)4--	0.486	AL(OH)4-	0.830
HCO3-	0.826	CA++	0.501	FEOH++	0.486	ALSO4+	0.830
CO3--	0.478	MG++	0.528	FE(OH)2+	0.836	AL(SO4)2-	0.830
HS-	0.823	CAHCO3+	0.839	FE(OH)4-	0.836	ALF++	0.492
S--	0.486	MGHCO3+	0.826	FESO4+	0.833	ALF2+	0.836
HSO4-	0.830	CAOH+	0.839	FECL++	0.486	ALF4-	0.830
SO4--	0.470	MGOH+	0.842	FECL2+	0.833	ALF5--	0.478
NASO4-	0.836	NH4+	0.815	FECL4-	0.826	ALF6---	0.191

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.847	MG++	42.90	-2.753	FE(OH)3	0.00	0.000
OH-	0.11	-5.186	NACL	0.41	-5.152	FE(OH)4-	0.00	0.000
H4SIO4	93.55	-3.012	KCL	0.02	-6.565	FECL+	0.00	0.000
H3SIO4-	0.97	-4.993	NASO4-	0.23	-5.715	FECL2	0.00	0.000
H2SIO4--	0.00	-8.881	KSO4-	0.13	-6.031	FECL++	0.00	0.000
NAH3SIO4	0.18	-5.828	CASO4	0.47	-5.465	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	3.75	-4.506	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	4.05	-4.393	FECL4-	0.00	0.000
H2CO3	407.36	-2.183	MGCO3	2.22	-4.579	FESO4	0.00	0.000
HCO3-	1223.00	-1.698	CAHCO3+	78.56	-3.110	FESO4+	0.00	0.000
CO3--	1.03	-4.766	MGHCO3+	36.87	-3.364	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.01	-6.982	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.11	-5.587	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-17.014	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-8.268	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	4.86	-4.296	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-6.854	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	2.68	-3.850	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	82.48	-2.633	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	388.82	-1.772	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	68.41	-2.757	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	30.69	-3.116	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.02640 IONIC BALANCE : CATIONS (MOL.EQ.)0.02493504
ANIONS (MOL.EQ.)0.02266281
DIFFERENCE (%) 9.55

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.61

QUARTZ	109.4
CHALCEDONY	79.5
NAK	267.0

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-16.869	99.999	ALBITE LOW	-16.163	99.999	ANALCIME	-12.960	99.999
ANHYDRITE	-5.742	-8.040	CALCITE	-9.603	-8.503	CHALCEDONY	-2.768	-3.012
MG-CHLORITE	-80.092	99.999	FLUORITE	-10.528	-11.286	GOETHITE	-4.320	99.999
LAUMONTITE	-26.761	99.999	MICROCLINE	-18.180	99.999	MAGNETITE	-28.984	99.999
CA-MONTMOR.	-83.408	99.999	K-MONTMOR.	-40.476	99.999	MG-MONTMOR.	-84.602	99.999
NA-MONTMOR.	-40.516	99.999	MUSCOVITE	-20.625	99.999	PREHNITE	-36.493	99.999
PYRRHOTITE	-95.105	99.999	PYRITE	-140.190	99.999	QUARTZ	-3.012	-3.012
WAIRAKITE	-24.487	99.999	WOLLASTONITE	10.543	7.266	ZOISITE	-35.693	99.999
EPIDOTE	-42.846	99.999	MARCASITE	-117.321	99.999			

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PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE				
PH/DEG.C	6.88/26.0	GAS (VOL.%)		REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SIO2	73.36	CO2				
NA	833.18	H2S		SAMPLING PRESSURE	BARS ABS.	
K	161.59	H2		DISCHARGE ENTHALPY	MJOUL/KG	
CA	96.84	O2		DISCHARGE	KG/SEC.	0.0
MG	118.540	CH4				
CO2	2145.00	N2		MEASURED TEMPERATURE	DEGREES C	48.3
SO4	21.47			RESISTIVITY/TEMP.	OHMM/DEG.C	2.5/19.0
H2S	0.00			EH/TEMP.	MV/DEG.C	0.000/ 0.0
CL	552.50					
F	2.00	LITERS GAS PER KG				
DISS.SOLIDS	2815.50	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
AL	0.0000					
B	0.0000					
FE	0.0000	CONDENSATE (PPM)		0.0	0.0	0.0
NH3	0.0000	PH/DEG.C		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0
		NA		0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0

IONIC STRENGTH = 0.05990 IONIC BALANCE : CATIONS (MOL.EQ.)0.05355978
ANIONS (MOL.EQ.)0.05385948
DIFFERENCE (%) -0.56

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	73.37	CO2	2145.00	CO2	0.00	CO2	0.116E+01
NA	833.18	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	161.58	H2	0.00	H2	0.00	H2	0.000E+00
CA	96.84	O2	0.00	O2	0.00	O2	0.000E+00
MG	118.530	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	21.47	N2	0.00	N2	0.00	N2	0.000E+00
CL	552.45	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	2.00					H2O	0.197E+01
DISS.S.	2815.50					TOTAL	0.313E+01
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.815	KSO4-	0.782	FE++	0.394	FECL+	0.766
OH-	0.760	F-	0.760	FE+++	0.166	AL+++	0.166
H3SIO4-	0.766	CL-	0.753	FEOH+	0.778	ALOH++	0.381
H2SIO4--	0.381	NA+	0.766	FE(OH)3-	0.778	AL(OH)2+	0.782
H2BO3-	0.746	K+	0.753	FE(OH)4--	0.373	AL(OH)4-	0.772
HCO3-	0.766	CA++	0.394	FEOH++	0.373	ALSO4+	0.772
CO3--	0.362	MG++	0.431	FE(OH)2+	0.782	AL(SO4)2-	0.772
HS-	0.760	CAHCO3+	0.789	FE(OH)4-	0.782	ALF++	0.381
S--	0.373	MGHCO3+	0.766	FESO4+	0.778	ALF2+	0.782
HSO4-	0.772	CAOH+	0.789	FECL++	0.373	ALF4-	0.772
SO4--	0.351	MGOH+	0.793	FECL2+	0.778	ALF5--	0.362
NASO4-	0.782	NH4+	0.746	FECL4-	0.766	ALF6---	0.103

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.942	MG++	81.54	-2.474	FE(OH)3	0.00	0.000
OH-	0.21	-4.916	NACL	5.96	-3.992	FE(OH)4-	0.00	0.000
H4SIO4	115.05	-2.922	KCL	0.31	-5.375	FECL+	0.00	0.000
H3SIO4-	1.80	-4.723	NASO4-	0.90	-5.123	FECL2	0.00	0.000
H2SIO4--	0.00	-8.417	KSO4-	0.55	-5.394	FECL++	0.00	0.000
NAH3SIO4	0.60	-5.292	CASO4	0.77	-5.245	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	11.61	-4.016	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	9.03	-4.045	FECL4-	0.00	0.000
H2CO3	612.65	-2.005	MGCO3	8.06	-4.020	FESO4	0.00	0.000
HCO3-	2185.76	-1.446	CAHCO3+	150.80	-2.826	FESO4+	0.00	0.000
CO3--	2.60	-4.364	MGHCO3+	112.74	-2.879	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.01	-6.732	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.35	-5.076	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-16.738	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-7.973	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	10.55	-3.959	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.010	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	2.00	-3.978	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	548.69	-1.810	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	830.55	-1.442	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	161.26	-2.385	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	33.20	-3.082	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.05592 IONIC BALANCE : CATIONS (MOL.EQ.)0.05143728
ANIONS (MOL.EQ.)0.05174058
DIFFERENCE (%) -0.59

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.55

QUARTZ	119.7
CHALCEDONY	90.0
NAK	279.7

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-16.515	99.999	ALBITE LOW	-15.841	99.999	ANALCIME	-12.723	99.999
ANHYDRITE	-5.894	-7.901	CALCITE	-9.793	-8.291	CHALCEDONY	-2.692	-2.922
MG-CHLORITE	-79.951	99.999	FLUORITE	-10.526	-11.681	GOETHITE	-3.920	99.999
LAUMONTITE	-26.347	99.999	MICROCLINE	-17.759	99.999	MAGNETITE	-28.188	99.999
CA-MONTMOR.	-81.340	99.999	K-MONTMOR.	-39.336	99.999	MG-MONTMOR.	-82.572	99.999
NA-MONTMOR.	-39.407	99.999	MUSCOVITE	-20.116	99.999	PREHNITE	-36.239	99.999
PYRRHOTITE	-89.937	99.999	PYRITE	-132.800	99.999	QUARTZ	-2.922	-2.922
WAIRAKITE	-24.282	99.999	WOLLASTONITE	10.249	7.475	ZOISITE	-35.533	99.999
EPIDOTE	-42.021	99.999	MARCASITE	-110.523	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820908201O CIBITOKE BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE				
PH/DEG.C	5.98/26.0	GAS (VOL.%)		REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SIO2	28.96	CO2				
NA	47.23	H2S		SAMPLING PRESSURE	BARS ABS.	
K	20.72	H2		DISCHARGE ENTHALPY	MJOUL/KG	
CA	96.99	O2		DISCHARGE	KG/SEC.	5.0
MG	57.940	CH4				
CO2	810.00	N2		MEASURED TEMPERATURE	DEGREES C	30.6
SO4	316.75			RESISTIVITY/TEMP.	OHMM/DEG.C	10.5/19.0
H2S	0.00			EH/TEMP.	MV/DEG.C	0.000/ 0.0
CL	6.65					
F	1.00	LITERS GAS PER KG				
DISS.SOLIDS	767.70	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
AL	0.0000					
B	0.0000					
FE	0.0000	CONDENSATE (PPM)		0.0	0.0	0.0
NH3	0.0000	PH/DEG.C		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0
		NA		0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
				0.0	0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0	0.0	0.0
		CO2		0.0	0.0	0.0
		H2S		0.0	0.0	0.0

IONIC STRENGTH = 0.01783 IONIC BALANCE : CATIONS (MOL.EQ.)0.01084649
ANIONS (MOL.EQ.)0.01130578
DIFFERENCE (%) -4.15

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	28.96	CO2	810.00	CO2	0.00	CO2	0.968E+00
NA	47.23	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	20.72	H2	0.00	H2	0.00	H2	0.000E+00
CA	96.99	O2	0.00	O2	0.00	O2	0.000E+00
MG	57.935	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	316.74	N2	0.00	N2	0.00	N2	0.000E+00
CL	6.65	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	1.00					H2O	0.437E+00
DISS.S.	767.70					TOTAL	0.140E+01
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.889	KSO4-	0.876	FE++	0.598	FECL+	0.870
OH-	0.868	F-	0.868	FE+++	0.350	AL+++	0.350
H3SIO4-	0.870	CL-	0.866	FEOH+	0.874	ALOH++	0.592
H2SIO4--	0.592	NA+	0.870	FE(OH)3-	0.874	AL(OH)2+	0.876
H2BO3-	0.863	K+	0.866	FE(OH)4--	0.587	AL(OH)4-	0.872
HCO3-	0.870	CA++	0.598	FEOH++	0.587	ALSO4+	0.872
CO3--	0.582	MG++	0.617	FE(OH)2+	0.876	AL(SO4)2-	0.872
HS-	0.868	CAHCO3+	0.878	FE(OH)4-	0.876	ALF++	0.592
S--	0.587	MGHCO3+	0.870	FESO4+	0.874	ALF2+	0.876
HSO4-	0.872	CAOH+	0.878	FECL++	0.587	ALF4-	0.872
SO4--	0.576	MGOH+	0.880	FECL2+	0.874	ALF5--	0.582
NASO4-	0.876	NH4+	0.863	FECL4-	0.870	ALF6---	0.296

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-5.914	MG++	36.04	-2.829	FE(OH)3	0.00	0.000
OH-	0.00	-6.667	NACL	0.00	-7.431	FE(OH)4-	0.00	0.000
H4SIO4	46.30	-3.317	KCL	0.00	-8.338	FECL+	0.00	0.000
H3SIO4-	0.03	-6.495	NASO4-	0.99	-5.080	FECL2	0.00	0.000
H2SIO4--	0.00	-11.522	KSO4-	1.28	-5.023	FECL++	0.00	0.000
NAH3SIO4	0.00	-8.203	CASO4	41.21	-3.519	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	97.80	-3.090	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.17	-5.768	FECL4-	0.00	0.000
H2CO3	780.44	-1.900	MGCO3	0.05	-6.266	FESO4	0.00	0.000
HCO3-	332.89	-2.263	CAHCO3+	28.04	-3.557	FESO4+	0.00	0.000
CO3--	0.03	-6.293	MGHCO3+	7.48	-4.057	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-8.165	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-7.231	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-14.232	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.08	-6.076	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	207.83	-2.665	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-6.624	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	1.00	-4.281	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	6.65	-3.727	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	47.04	-2.689	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	20.35	-3.284	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	73.67	-2.736	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.01528 IONIC BALANCE : CATIONS (MOL.EQ.)0.00957272
ANIONS (MOL.EQ.)0.01002392
DIFFERENCE (%) -4.60

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.85

QUARTZ	78.0
CHALCEDONY	48.1
NAK	426.6

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-18.170	99.999	ALBITE LOW	-17.350	99.999	ANALCIME	-13.848	99.999
ANHYDRITE	-5.308	-5.863	CALCITE	-9.087	-9.487	CHALCEDONY	-3.025	-3.317
MG-CHLORITE	-81.119	99.999	FLUORITE	-10.590	-11.643	GOETHITE	-5.467	99.999
LAUMONTITE	-28.341	99.999	MICROCLINE	-19.712	99.999	MAGNETITE	-31.373	99.999
CA-MONTMOR.	-91.604	99.999	K-MONTMOR.	-44.922	99.999	MG-MONTMOR.	-92.637	99.999
NA-MONTMOR.	-44.853	99.999	MUSCOVITE	-22.623	99.999	PREHNITE	-37.661	99.999
PYRRHOTITE	-110.792	99.999	PYRITE	-163.375	99.999	QUARTZ	-3.317	-3.317
WAIRAKITE	-25.373	99.999	WOLLASTONITE	11.542	5.551	ZOISITE	-36.578	99.999
EPIDOTE	-45.389	99.999	MARCASITE	-138.492	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
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PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	7.94/26.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	34.53	CO2			
NA	35.17	H2S		SAMPLING PRESSURE BARS ABS.	
K	1.75	H2		DISCHARGE ENTHALPY MJOUL/KG	
CA	39.21	O2		DISCHARGE KG/SEC.	0.0
MG	60.160	CH4			
CO2	35.70	N2		MEASURED TEMPERATURE DEGREES C	22.7
SO4	25.77			RESISTIVITY/TEMP. OHMM/DEG.C	15.6/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	0.00				
F	1.85	LITERS GAS PER KG			
DISS.SOLIDS	406.90	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0 0.0	0.0
NH3	0.0000	PH/DEG.C		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0
		NA		0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0

IONIC STRENGTH = 0.00840 IONIC BALANCE : CATIONS (MOL.EQ.)0.00833043
ANIONS (MOL.EQ.)0.00129534
DIFFERENCE (%) 146.17

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	34.53	CO2	35.70	CO2	0.00	CO2	0.356E-02
NA	35.17	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	1.75	H2	0.00	H2	0.00	H2	0.000E+00
CA	39.21	O2	0.00	O2	0.00	O2	0.000E+00
MG	60.155	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	25.77	N2	0.00	N2	0.00	N2	0.000E+00
CL	0.00	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	1.85					H2O	0.559E+00
DISS.S.	406.90					TOTAL	0.562E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.911	KSO4-	0.903	FE++	0.670	FECL+	0.899
OH-	0.898	F-	0.898	FE+++	0.434	AL+++	0.434
H3SIO4-	0.899	CL-	0.897	FEOH+	0.902	ALOH++	0.666
H2SIO4--	0.666	NA+	0.899	FE(OH)3-	0.902	AL(OH)2+	0.903
H2BO3-	0.895	K+	0.897	FE(OH)4--	0.663	AL(OH)4-	0.901
HCO3-	0.899	CA++	0.670	FEOH++	0.663	ALSO4+	0.901
CO3--	0.659	MG++	0.683	FE(OH)2+	0.903	AL(SO4)2-	0.901
HS-	0.898	CAHCO3+	0.904	FE(OH)4-	0.903	ALF++	0.666
S--	0.663	MGHCO3+	0.899	FESO4+	0.902	ALF2+	0.903
HSO4-	0.901	CAOH+	0.904	FECL++	0.663	ALF4-	0.901
SO4--	0.656	MGOH+	0.905	FECL2+	0.902	ALF5--	0.659
NASO4-	0.903	NH4+	0.895	FECL4-	0.899	ALF6---	0.392

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-7.526	MG++	56.53	-2.633	FE(OH)3	0.00	0.000
OH-	0.19	-4.955	NACL	0.00	-16.280	FE(OH)4-	0.00	0.000
H4SIO4	53.60	-3.254	KCL	0.00	-18.158	FECL+	0.00	0.000
H3SIO4-	1.59	-4.776	NASO4-	0.06	-6.315	FECL2	0.00	0.000
H2SIO4--	0.00	-8.189	KSO4-	0.01	-7.192	FECL++	0.00	0.000
NAH3SIO4	0.03	-6.583	CASO4	1.87	-4.863	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	14.06	-3.932	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.63	-5.198	FECL4-	0.00	0.000
H2CO3	2.65	-4.370	MGCO3	0.48	-5.242	FESO4	0.00	0.000
HCO3-	43.26	-3.149	CAHCO3+	2.44	-4.617	FESO4+	0.00	0.000
CO3--	0.15	-5.606	MGHCO3+	1.78	-4.682	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.01	-6.665	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.23	-5.247	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-18.438	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-8.759	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	13.17	-3.863	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.895	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	1.85	-4.011	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	0.00	-12.550	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	35.15	-2.816	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	1.75	-4.350	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	37.43	-3.030	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00803 IONIC BALANCE : CATIONS (MOL.EQ.)0.00814322
ANIONS (MOL.EQ.)0.00111355
DIFFERENCE (%) 151.88

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.80

QUARTZ	84.1
CHALCEDONY	54.2
NAK	135.0

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-17.888	99.999	ALBITE LOW	-17.093	99.999	ANALCIME	-13.654	99.999
ANHYDRITE	-5.388	-7.250	CALCITE	-9.179	-8.990	CHALCEDONY	-2.971	-3.254
MG-CHLORITE	-80.845	99.999	FLUORITE	-10.571	-11.319	GOETHITE	-5.251	99.999
LAUMONTITE	-27.993	99.999	MICROCLINE	-19.382	99.999	MAGNETITE	-30.908	99.999
CA-MONTMOR.	-89.777	99.999	K-MONTMOR.	-43.936	99.999	MG-MONTMOR.	-90.848	99.999
NA-MONTMOR.	-43.892	99.999	MUSCOVITE	-22.179	99.999	PREHNITE	-37.384	99.999
PYRRHOTITE	-107.733	99.999	PYRITE	-158.756	99.999	QUARTZ	-3.254	-3.254
WAIRAKITE	-25.168	99.999	WOLLASTONITE	11.333	8.594	ZOISITE	-36.356	99.999
EPIDOTE	-44.893	99.999	MARCASITE	-134.293	99.999			

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PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	6.12/32.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	38.76	CO2			
NA	10.63	H2S		SAMPLING PRESSURE BARS ABS.	
K	4.23	H2		DISCHARGE ENTHALPY MJOUL/KG	
CA	5.75	O2		DISCHARGE KG/SEC.	20.0
MG	1.780	CH4			
CO2	82.40	N2		MEASURED TEMPERATURE DEGREES C	46.8
SO4	9.89			RESISTIVITY/TEMP. OHMM/DEG.C	105.3/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	2.00				
F	0.29	LITERS GAS PER KG			
DISS.SOLIDS	0.00	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0 0.0	0.0
NH3	0.0000	PH/DEG.C		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0
		NA		0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0

IONIC STRENGTH = 0.00130 IONIC BALANCE : CATIONS (MOL.EQ.)0.00099738
ANIONS (MOL.EQ.)0.00097203
DIFFERENCE (%) 2.57

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	38.76	CO2	82.40	CO2	0.00	CO2	0.105E+00
NA	10.63	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	4.23	H2	0.00	H2	0.00	H2	0.000E+00
CA	5.75	O2	0.00	O2	0.00	O2	0.000E+00
MG	1.780	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	9.89	N2	0.00	N2	0.00	N2	0.000E+00
CL	2.00	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.29					H2O	0.711E+00
DISS.S.	0.00					TOTAL	0.816E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.958	KSO4-	0.956	FE++	0.837	FECL+	0.955
OH-	0.955	F-	0.955	FE+++	0.678	AL+++	0.678
H3SIO4-	0.955	CL-	0.955	FEOH+	0.956	ALOH++	0.836
H2SIO4--	0.836	NA+	0.955	FE(OH)3-	0.956	AL(OH)2+	0.956
H2BO3-	0.955	K+	0.955	FE(OH)4--	0.835	AL(OH)4-	0.956
HCO3-	0.955	CA++	0.837	FEOH++	0.835	ALSO4+	0.956
CO3--	0.834	MG++	0.840	FE(OH)2+	0.956	AL(SO4)2-	0.956
HS-	0.955	CAHCO3+	0.956	FE(OH)4-	0.956	ALF++	0.836
S--	0.835	MGHCO3+	0.955	FESO4+	0.956	ALF2+	0.956
HSO4-	0.956	CAOH+	0.956	FECL++	0.835	ALF4-	0.956
SO4--	0.833	MGOH+	0.957	FECL2+	0.956	ALF5--	0.834
NASO4-	0.956	NH4+	0.955	FECL4-	0.955	ALF6---	0.665

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.122	MG++	1.66	-4.167	FE(OH)3	0.00	0.000
OH-	0.01	-6.275	NACL	0.00	-8.377	FE(OH)4-	0.00	0.000
H4SIO4	61.93	-3.191	KCL	0.00	-9.379	FECL+	0.00	0.000
H3SIO4-	0.08	-6.090	NASO4-	0.02	-6.851	FECL2	0.00	0.000
H2SIO4--	0.00	-10.945	KSO4-	0.02	-6.821	FECL++	0.00	0.000
NAH3SIO4	0.00	-8.365	CASO4	0.33	-5.610	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.52	-5.367	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.01	-7.252	FECL4-	0.00	0.000
H2CO3	72.73	-2.931	MGCO3	0.00	-8.029	FESO4	0.00	0.000
HCO3-	42.34	-3.159	CAHCO3+	0.51	-5.296	FESO4+	0.00	0.000
CO3--	0.00	-7.098	MGHCO3+	0.07	-6.111	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-8.692	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-7.978	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-15.521	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-7.347	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	9.21	-4.018	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.218	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.29	-4.823	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	2.00	-4.249	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	10.63	-3.335	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	4.22	-3.966	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	5.45	-3.867	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00127 IONIC BALANCE : CATIONS (MOL.EQ.)0.00098415
ANIONS (MOL.EQ.)0.00095854
DIFFERENCE (%) 2.64

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.75

QUARTZ	90.4
CHALCEDONY	60.4
NAK	408.9

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-17.616	99.999	ALBITE LOW	-16.844	99.999	ANALCIME	-13.467	99.999
ANHYDRITE	-5.472	-8.042	CALCITE	-9.278	-11.121	CHALCEDONY	-2.919	-3.191
MG-CHLORITE	-80.603	99.999	FLUORITE	-10.555	-13.629	GOETHITE	-5.028	99.999
LAUMONTITE	-27.659	99.999	MICROCLINE	-19.062	99.999	MAGNETITE	-30.436	99.999
CA-MONTMOR.	-88.033	99.999	K-MONTMOR.	-42.991	99.999	MG-MONTMOR.	-89.131	99.999
NA-MONTMOR.	-42.970	99.999	MUSCOVITE	-21.754	99.999	PREHNITE	-37.127	99.999
PYRRHOTITE	-104.621	99.999	PYRITE	-154.108	99.999	QUARTZ	-3.191	-3.191
WAIRAKITE	-24.976	99.999	WOLLASTONITE	11.128	5.108	ZOISITE	-36.155	99.999
EPIDOTE	-44.387	99.999	MARCASITE	-130.058	99.999			

ORKUSTOFNUN JHB BURUNDI 1982
1982-12-16 HA

9999400700820909201 3 MUGARA III BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	6.10/30.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	42.66	CO2			
NA	11.69	H2S		SAMPLING PRESSURE BARS ABS.	
K	3.00	H2		DISCHARGE ENTHALPY MJOUL/KG	
CA	4.60	O2		DISCHARGE KG/SEC.	20.0
MG	1.410	CH4			
CO2	71.80	N2		MEASURED TEMPERATURE DEGREES C	46.0
SO4	11.61			RESISTIVITY/TEMP. OHMM/DEG.C	117.6/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	3.35				
F	0.36	LITERS GAS PER KG			
DISS.SOLIDS	77.40	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0 0.0	0.0
NH3	0.0000	PH/DEG.C		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0
		NA		0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0

IONIC STRENGTH = 0.00122 IONIC BALANCE : CATIONS (MOL.EQ.)0.00092521
ANIONS (MOL.EQ.)0.00093611
DIFFERENCE (%) -1.17

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	42.66	CO2	71.80	CO2	0.00	CO2	0.987E-01
NA	11.69	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	3.00	H2	0.00	H2	0.00	H2	0.000E+00
CA	4.60	O2	0.00	O2	0.00	O2	0.000E+00
MG	1.410	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	11.61	N2	0.00	N2	0.00	N2	0.000E+00
CL	3.35	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.36					H2O	0.833E+00
DISS.S.	77.40					TOTAL	0.932E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.958	KSO4-	0.957	FE++	0.839	FECL+	0.956
OH-	0.956	F-	0.956	FE+++	0.683	AL+++	0.683
H3SIO4-	0.956	CL-	0.956	FEOH+	0.957	ALOH++	0.838
H2SIO4--	0.838	NA+	0.956	FE(OH)3-	0.957	AL(OH)2+	0.957
H2BO3-	0.955	K+	0.956	FE(OH)4--	0.838	AL(OH)4-	0.956
HCO3-	0.956	CA++	0.839	FEOH++	0.838	ALSO4+	0.956
CO3--	0.837	MG++	0.842	FE(OH)2+	0.957	AL(SO4)2-	0.956
HS-	0.956	CAHCO3+	0.957	FE(OH)4-	0.957	ALF++	0.838
S--	0.838	MGHCO3+	0.956	FESO4+	0.957	ALF2+	0.957
HSO4-	0.956	CAOH+	0.957	FECL++	0.838	ALF4-	0.956
SO4--	0.836	MGOH+	0.957	FECL2+	0.957	ALF5--	0.837
NASO4-	0.957	NH4+	0.955	FECL4-	0.956	ALF6---	0.670

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.108	MG++	1.29	-4.275	FE(OH)3	0.00	0.000
OH-	0.01	-6.218	NACL	0.00	-8.067	FE(OH)4-	0.00	0.000
H4SIO4	68.15	-3.149	KCL	0.00	-9.276	FECL+	0.00	0.000
H3SIO4-	0.09	-6.029	NASO4-	0.02	-6.711	FECL2	0.00	0.000
H2SIO4--	0.00	-10.877	KSO4-	0.02	-6.869	FECL++	0.00	0.000
NAH3SIO4	0.00	-8.262	CASO4	0.34	-5.601	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.53	-5.359	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.00	-7.391	FECL4-	0.00	0.000
H2CO3	64.92	-2.980	MGCO3	0.00	-8.199	FESO4	0.00	0.000
HCO3-	35.42	-3.236	CAHCO3+	0.38	-5.424	FESO4+	0.00	0.000
CO3--	0.00	-7.194	MGHCO3+	0.04	-6.280	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-8.708	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-8.005	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-15.310	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.01	-7.199	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	10.91	-3.945	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.063	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.36	-4.722	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	3.35	-4.025	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	11.69	-3.294	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	2.99	-4.116	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	4.35	-3.965	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00119 IONIC BALANCE : CATIONS (MOL.EQ.)0.00091223
ANIONS (MOL.EQ.)0.00092280
DIFFERENCE (%) -1.15

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.72

QUARTZ	94.6
CHALCEDONY	64.7
NAK	325.4

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-17.438	99.999	ALBITE LOW	-16.682	99.999	ANALCIME	-13.316	99.999
ANHYDRITE	-5.531	-8.063	CALCITE	-9.348	-11.312	CHALCEDONY	-2.884	-3.149
MG-CHLORITE	-80.459	99.999	FLUORITE	-10.546	-13.524	GOETHITE	-4.873	99.999
LAUMONTITE	-27.443	99.999	MICROCLINE	-18.853	99.999	MAGNETITE	-30.113	99.999
CA-MONTMOR.	-86.906	99.999	K-MONTMOR.	-42.382	99.999	MG-MONTMOR.	-88.031	99.999
NA-MONTMOR.	-42.375	99.999	MUSCOVITE	-21.480	99.999	PREHNITE	-36.966	99.999
PYRRHOTITE	-102.497	99.999	PYRITE	-150.963	99.999	QUARTZ	-3.149	-3.149
WAIRAKITE	-24.854	99.999	WOLLASTONITE	10.992	5.027	ZOISITE	-24.032	99.999
EPIDOTE	-44.041	99.999	MARCASITE	-127.188	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820909201 4 KUMUYANGE BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE	
PH/DEG.C	5.85/30.0	GAS (VOL.%)	
SIO2	24.72	CO2	
NA	0.83	H2S	
K	1.08	H2	
CA	1.60	O2	
MG	0.940	CH4	
CO2	47.30	N2	
SO4	1.15		
H2S	0.00		
CL	0.00		
F	0.04	LITERS GAS PER KG	
DISS.SOLIDS	33.90	CONDENSATE/DEG.C	
AL	0.0000		
B	0.0000		
FE	0.0000	CONDENSATE (PPM)	
NH3	0.0000	PH/DEG.C	
		CO2	
		H2S	
		NA	
		CONDENSATE WITH NAOH (PPM)	
		CO2	
		H2S	

REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SAMPLING PRESSURE	BARS ABS.	
DISCHARGE ENTHALPY	MJOUL/KG	
DISCHARGE	KG/SEC.	4.0
MEASURED TEMPERATURE	DEGREES C	40.1
RESISTIVITY/TEMP.	OHMM/DEG.C	444.4/19.0
EH/TEMP.	MV/DEG.C	0.000/ 0.0

MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0

IONIC STRENGTH = 0.00034 IONIC BALANCE : CATIONS (MOL.EQ.)0.00022041
ANIONS (MOL.EQ.)0.00027944
DIFFERENCE (%) -23.62

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	24.72	CO2	47.30	CO2	0.00	CO2	0.576E-01
NA	0.83	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	1.08	H2	0.00	H2	0.00	H2	0.000E+00
CA	1.60	O2	0.00	O2	0.00	O2	0.000E+00
MG	0.940	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	1.15	N2	0.00	N2	0.00	N2	0.000E+00
CL	0.00	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.04					H2O	0.335E+00
DISS.S.	33.90					TOTAL	0.393E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.978	KSO4-	0.977	FE++	0.913	FECL+	0.977
OH-	0.977	F-	0.977	FE+++	0.818	AL+++	0.818
H3SIO4-	0.977	CL-	0.977	FEOH+	0.977	ALOH++	0.913
H2SIO4--	0.913	NA+	0.977	FE(OH)3-	0.977	AL(OH)2+	0.977
H2BO3-	0.977	K+	0.977	FE(OH)4--	0.913	AL(OH)4-	0.977
HCO3-	0.977	CA++	0.913	FEOH++	0.913	ALSO4+	0.977
CO3--	0.913	MG++	0.914	FE(OH)2+	0.977	AL(SO4)2-	0.977
HS-	0.977	CAHCO3+	0.978	FE(OH)4-	0.977	ALF++	0.913
S--	0.913	MGHCO3+	0.977	FESO4+	0.977	ALF2+	0.977
HSO4-	0.977	CAOH+	0.978	FECL++	0.913	ALF4-	0.977
SO4--	0.912	MGOH+	0.978	FECL2+	0.977	ALF5--	0.913
NASO4-	0.977	NH4+	0.977	FECL4-	0.977	ALF6---	0.814

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-5.805	MG++	0.93	-4.417	FE(OH)3	0.00	0.000	
OH-	0.00	-6.953	NACL	0.00	-17.982	FE(OH)4-	0.00	0.000	
H4SIO4	39.53	-3.386	KCL	0.00	-18.372	FECL+	0.00	0.000	
H3SIO4-	0.02	-6.788	NASO4-	0.00	-8.934	FECL2	0.00	0.000	
H2SIO4--	0.00	-12.108	KSO4-	0.00	-8.401	FECL++	0.00	0.000	
NAH3SIO4	0.00	-10.146	CASO4	0.01	-7.115	FECL2+	0.00	0.000	
H3BO3	0.00	0.000	MGSO4	0.03	-6.641	FECL3	0.00	0.000	
H2BO3-	0.00	0.000	CACO3	0.00	-8.724	FECL4-	0.00	0.000	
H2CO3	50.92	-3.086	MGCO3	0.00	-9.126	FESO4	0.00	0.000	
HCO3-	15.46	-3.596	CAHCO3+	0.04	-6.443	FESO4+	0.00	0.000	
CO3--	0.00	-7.886	MGHCO3+	0.01	-6.831	AL+++	0.00	0.000	
H2S	0.00	0.000	CAOH+	0.00	-9.962	ALOH++	0.00	0.000	
HS-	0.00	0.000	MGOH+	0.00	-8.960	AL(OH)2+	0.00	0.000	
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000	
H2SO4	0.00	-16.252	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000	
HSO4-	0.00	-8.172	FE++	0.00	0.000	ALSO4+	0.00	0.000	
SO4--	1.12	-4.934	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000	
HF	0.00	-7.966	FEOH+	0.00	0.000	ALF++	0.00	0.000	
F-	0.04	-5.725	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000	
CL-	0.00	-12.550	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000	
NA+	0.83	-4.442	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000	
K+	1.08	-4.559	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000	
CA++	1.58	-4.404	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000	

IONIC STRENGTH = 0.00034 IONIC BALANCE : CATIONS (MOL.EQ.)0.00021976
ANIONS (MOL.EQ.)0.00027878
DIFFERENCE (%) -23.68

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.90

QUARTZ	71.7
CHALCEDONY	41.8
NAK	805.2

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-18.479	99.999	ALBITE LOW	-17.633	99.999	ANALCIME	-14.061	99.999
ANHYDRITE	-5.226	-9.416	CALCITE	-8.995	-12.369	CHALCEDONY	-3.083	-3.386
MG-CHLORITE	-81.445	99.999	FLUORITE	-10.615	-15.913	GOETHITE	-5.688	99.999
LAUMONTITE	-28.724	99.999	MICROCLINE	-20.072	99.999	MAGNETITE	-31.858	99.999
CA-MONTMOR.	-93.621	99.999	K-MONTMOR.	-46.009	99.999	MG-MONTMOR.	-94.617	99.999
NA-MONTMOR.	-45.914	99.999	MUSCOVITE	-23.114	99.999	PREHNITE	-37.976	99.999
PYRRHOTITE	-113.986	99.999	PYRITE	-168.254	99.999	QUARTZ	-3.386	-3.386
WAIRAKITE	-25.604	99.999	WOLLASTONITE	11.767	3.782	ZOISITE	-36.835	99.999
EPIDOTE	-45.908	99.999	MARCASITE	-142.917	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820909201S MUHWESA BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	6.29/30.0	GAS (VOL.%)	REFERENCE TEMP. DEGREES C	0.0 (QTZ)	
SIO2	22.99	CO2			
NA	0.81	H2S	SAMPLING PRESSURE BARS ABS.		
K	1.39	H2	DISCHARGE ENTHALPY MJOUL/KG		
CA	5.07	O2	DISCHARGE KG/SEC.	0.0	
MG	3.530	CH4			
CO2	34.10	N2	MEASURED TEMPERATURE DEGREES C	37.3	
SO4	6.29		RESISTIVITY/TEMP. OHMM/DEG.C	161.3/19.0	
H2S	0.00		EH/TEMP. MV/DEG.C	0.000/ 0.0	
CL	0.45				
F	0.05	LITERS GAS PER KG			
DISS.SOLIDS	41.90	CONDENSATE/DEG.C	MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)	0.0	0.0	0.0
NH3	0.0000	PH/DEG.C	0.0	0.0	0.0
		CO2	0.0	0.0	0.0
		H2S	0.0	0.0	0.0
		NA	0.0	0.0	0.0
			0.0	0.0	0.0
			0.0	0.0	0.0
			0.0	0.0	0.0
		CONDENSATE WITH NAOH (PPM)	0.0	0.0	0.0
		CO2	0.0	0.0	0.0
		H2S	0.0	0.0	0.0

IONIC STRENGTH = 0.00089 IONIC BALANCE : CATIONS (MOL.EQ.)0.00060876
ANIONS (MOL.EQ.)0.00050044
DIFFERENCE (%) 19.53

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	22.99	CO2	34.10	CO2	0.00	CO2	0.279E-01
NA	0.81	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	1.39	H2	0.00	H2	0.00	H2	0.000E+00
CA	5.07	O2	0.00	O2	0.00	O2	0.000E+00
MG	3.530	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	6.29	N2	0.00	N2	0.00	N2	0.000E+00
CL	0.45	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.05					H2O	0.296E+00
DISS.S.	41.90					TOTAL	0.324E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.966	KSO4-	0.965	FE++	0.868	FECL+	0.965
OH-	0.964	F-	0.964	FE+++	0.734	AL+++	0.734
H3SIO4-	0.965	CL-	0.964	FEOH+	0.965	ALOH++	0.867
H2SIO4--	0.867	NA+	0.965	FE(OH)3-	0.965	AL(OH)2+	0.965
H2BO3-	0.964	K+	0.964	FE(OH)4--	0.867	AL(OH)4-	0.965
HCO3-	0.965	CA++	0.868	FEOH++	0.867	ALSO4+	0.965
CO3--	0.866	MG++	0.870	FE(OH)2+	0.965	AL(SO4)2-	0.965
HS-	0.964	CAHCO3+	0.965	FE(OH)4-	0.965	ALF++	0.867
S--	0.867	MGHCO3+	0.965	FESO4+	0.965	ALF2+	0.965
HSO4-	0.965	CAOH+	0.965	FECL++	0.867	ALF4-	0.965
SO4--	0.866	MGOH+	0.965	FECL2+	0.965	ALF5--	0.866
NASO4-	0.965	NH4+	0.964	FECL4-	0.965	ALF6---	0.724

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.240	MG++	3.42	-3.851	FE(OH)3	0.00	0.000
OH-	0.00	-6.573	NACL	0.00	-10.387	FE(OH)4-	0.00	0.000
H4SIO4	36.74	-3.418	KCL	0.00	-10.639	FECL+	0.00	0.000
H3SIO4-	0.04	-6.411	NASO4-	0.00	-8.267	FECL2	0.00	0.000
H2SIO4--	0.00	-11.304	KSO4-	0.00	-7.616	FECL++	0.00	0.000
NAH3SIO4	0.00	-9.790	CASO4	0.15	-5.966	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.14	-5.432	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.00	-7.710	FECL4-	0.00	0.000
H2CO3	25.80	-3.381	MGCO3	0.00	-8.028	FESO4	0.00	0.000
HCO3-	21.76	-3.448	CAHCO3+	0.14	-5.853	FESO4+	0.00	0.000
CO3--	0.00	-7.291	MGHCO3+	0.06	-6.148	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-9.121	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-8.050	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-16.504	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-7.946	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	5.83	-4.217	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-8.288	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.05	-5.581	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	0.45	-4.896	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	0.81	-4.453	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	1.39	-4.449	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	4.97	-3.907	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00087 IONIC BALANCE : CATIONS (MOL.EQ.)0.00060240
ANIONS (MOL.EQ.)0.00049406
DIFFERENCE (%) 19.76

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.92

QUARTZ	68.8
CHALCEDONY	39.0
NAK	967.1

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-18.624	99.999	ALBITE LOW	-17.765	99.999	ANALCIME	-14.161	99.999
ANHYDRITE	-5.190	-8.248	CALCITE	-8.955	-11.321	CHALCEDONY	-3.109	-3.418
MG-CHLORITE	-81.605	99.999	FLUORITE	-10.627	-15.161	GOETHITE	-5.787	99.999
LAUMONTITE	-28.905	99.999	MICROCLINE	-20.241	99.999	MAGNETITE	-32.078	99.999
CA-MONTMOR.	-94.570	99.999	K-MONTMOR.	-46.518	99.999	MG-MONTMOR.	-95.547	99.999
NA-MONTMOR.	-46.412	99.999	MUSCOVITE	-23.344	99.999	PREHNITE	-38.127	99.999
PYRRHOTITE	-115.430	99.999	PYRITE	-170.479	99.999	QUARTZ	-3.418	-3.418
WAIRAKITE	-25.714	99.999	WOLLASTONITE	11.871	5.094	ZOISITE	-36.960	99.999
EPIDOTE	-46.143	99.999	MARCASITE	-144.932	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820909201 6 SOURCE DU NIL BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	6.80/30.0	GAS (VOL.%)	REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SIO2	7.21	CO2			
NA	0.64	H2S	SAMPLING PRESSURE	BARS ABS.	
K	0.51	H2	DISCHARGE ENTHALPY	KJOUL/KG	
CA	2.05	O2	DISCHARGE	KG/SEC.	0.0
MG	1.340	CH4			
CO2	17.60	N2	MEASURED TEMPERATURE	DEGREES C	16.8
SO4	1.23		RESISTIVITY/TEMP.	OHMM/DEG.C	434.8/19.0
H2S	0.00		EH/TEMP.	MV/DEG.C	0.000/ 0.0
CL	0.00				
F	0.03	LITERS GAS PER KG			
DISS.SOLIDS	18.20	CONDENSATE/DEG.C	MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)	0.0	0.0	0.0
NH3	0.0000	PH/DEG.C	0.0	0.0	0.0
		CO2	0.0	0.0	0.0
		H2S	0.0	0.0	0.0
		NA	0.0	0.0	0.0
			0.0	0.0	0.0
			0.0	0.0	0.0
			0.0	0.0	0.0
		CONDENSATE WITH NAOH (PPM)	0.0	0.0	0.0
		CO2	0.0	0.0	0.0
		H2S	0.0	0.0	0.0

IONIC STRENGTH = 0.00040 IONIC BALANCE : CATIONS (MOL.EQ.)0.00025267
ANIONS (MOL.EQ.)0.00032022
DIFFERENCE (%) -23.58

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	7.21	CO2	17.60	CO2	0.00	CO2	0.312E-02
NA	0.64	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	0.51	H2	0.00	H2	0.00	H2	0.000E+00
CA	2.05	O2	0.00	O2	0.00	O2	0.000E+00
MG	1.340	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	1.23	N2	0.00	N2	0.00	N2	0.000E+00
CL	0.00	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.03					H2O	0.401E-01
DISS.S.	18.20					TOTAL	0.432E-01
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.978	KSO4-	0.977	FE++	0.913	FECL+	0.977
OH-	0.977	F-	0.977	FE+++	0.817	AL+++	0.817
H3SIO4-	0.977	CL-	0.977	FEOH+	0.977	ALOH++	0.912
H2SIO4--	0.912	NA+	0.977	FE(OH)3-	0.977	AL(OH)2+	0.977
H2BO3-	0.977	K+	0.977	FE(OH)4--	0.912	AL(OH)4-	0.977
HCO3-	0.977	CA++	0.913	FEOH++	0.912	ALSO4+	0.977
CO3--	0.912	MG++	0.914	FE(OH)2+	0.977	AL(SO4)2-	0.977
HS-	0.977	CAHCO3+	0.977	FE(OH)4-	0.977	ALF++	0.912
S--	0.912	MGHCO3+	0.977	FESO4+	0.977	ALF2+	0.977
HSO4-	0.977	CAOH+	0.977	FECL++	0.912	ALF4-	0.977
SO4--	0.912	MGOH+	0.977	FECL2+	0.977	ALF5--	0.912
NASO4-	0.977	NH4+	0.977	FECL4-	0.977	ALF6---	0.813

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-6.804	MG++	1.33	-4.261	FE(OH)3	0.00	0.000
OH-	0.00	-7.045	NACL	0.00	-18.645	FE(OH)4-	0.00	0.000
H4SIO4	11.52	-3.921	KCL	0.00	-18.964	FECL+	0.00	0.000
H3SIO4-	0.01	-6.944	NASO4-	0.00	-9.242	FECL2	0.00	0.000
H2SIO4--	0.00	-11.771	KSO4-	0.00	-8.957	FECL++	0.00	0.000
NAH3SIO4	0.00	-10.380	CASO4	0.01	-7.222	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.01	-6.920	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	0.00	-8.207	FECL4-	0.00	0.000
H2CO3	6.59	-3.974	MGCO3	0.00	-8.355	FESO4	0.00	0.000
HCO3-	17.90	-3.533	CAHCO3+	0.02	-6.792	FESO4+	0.00	0.000
CO3--	0.01	-7.015	MGHCO3+	0.02	-6.751	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-10.141	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.00	-9.120	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-19.395	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-9.684	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	1.21	-4.899	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-9.483	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.02	-5.881	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	0.00	-12.550	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	0.64	-4.555	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	0.51	-4.885	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	2.04	-4.293	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00040 IONIC BALANCE : CATIONS (MOL.EQ.)0.00025269
ANIONS (MOL.EQ.)0.00032023
DIFFERENCE (%) -23.58

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 3.31

QUARTZ	29.1
CHALCEDONY	0.0
NAK	598.7

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-21.014	99.999	ALBITE LOW	-19.948	99.999	ANALCIME	-15.823	99.999
ANHYDRITE	-4.748	-9.272	CALCITE	-8.520	-11.388	CHALCEDONY	-3.533	-3.921
MG-CHLORITE	-84.792	99.999	FLUORITE	-10.921	-16.115	GOETHITE	-7.144	99.999
LAUMONTITE	-31.928	99.999	MICROCLINE	-22.999	99.999	MAGNETITE	-35.303	99.999
CA-MONTMOR.	-109.773	99.999	K-MONTMOR.	-54.701	99.999	MG-MONTMOR.	-110.457	99.999
NA-MONTMOR.	-54.378	99.999	MUSCOVITE	-27.082	99.999	PREHNITE	-40.856	99.999
PYRRHOTITE	-136.047	99.999	PYRITE	-203.647	99.999	QUARTZ	-3.921	-3.921
WAIRAKITE	-27.650	99.999	WOLLASTONITE	13.525	5.353	ZOISITE	-39.306	99.999
EPIDOTE	-49.785	99.999	MARCASITE	-174.762	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

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99994007008209102017 GASENYI BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE			
PH/DEG.C	7.08/28.0	GAS (VOL.%)		REFERENCE TEMP. DEGREES C	0.0 (QTZ)
SIO2	79.20	CO2			
NA	568.86	H2S		SAMPLING PRESSURE BARS ABS.	
K	33.84	H2		DISCHARGE ENTHALPY MJOUL/KG	
CA	20.81	O2		DISCHARGE KG/SEC.	0.0
MG	8.040	CH4			
CO2	1099.00	N2		MEASURED TEMPERATURE DEGREES C	59.5
SO4	120.96			RESISTIVITY/TEMP. OHMM/DEG.C	4.6/19.0
H2S	0.00			EH/TEMP. MV/DEG.C	0.000/ 0.0
CL	125.00				
F	5.03	LITERS GAS PER KG			
DISS.SOLIDS	1549.00	CONDENSATE/DEG.C		MEASURED DOWNHOLE TEMP. DEGREES C/METERS	FLUID INFLOW DEPTH (METERS)
AL	0.0000				
B	0.0000				
FE	0.0000	CONDENSATE (PPM)		0.0 0.0	0.0
NH3	0.0000	PH/DEG.C		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0
		NA		0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
				0.0 0.0	0.0
		CONDENSATE WITH NAOH (PPM)		0.0 0.0	0.0
		CO2		0.0 0.0	0.0
		H2S		0.0 0.0	0.0

IONIC STRENGTH = 0.02922 IONIC BALANCE ; CATIONS (MOL.EQ.)0.02709672
ANIONS (MOL.EQ.)0.02749875
DIFFERENCE (%) -1.47

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	79.21	CO2	1099.00	CO2	0.00	CO2	0.441E+00
NA	568.86	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	33.84	H2	0.00	H2	0.00	H2	0.000E+00
CA	20.81	O2	0.00	O2	0.00	O2	0.000E+00
MG	8.039	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	120.96	N2	0.00	N2	0.00	N2	0.000E+00
CL	124.99	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	5.03					H2O	0.218E+01
DISS.S.	1549.00					TOTAL	0.263E+01
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

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ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.847	KSO4-	0.826	FE++	0.478	FECL+	0.815
OH-	0.811	F-	0.811	FE+++	0.231	AL+++	0.231
H3SIO4-	0.815	CL-	0.807	FEOH+	0.823	ALOH++	0.469
H2SIO4--	0.469	NA+	0.815	FE(OH)3-	0.823	AL(OH)2+	0.826
H2BO3-	0.803	K+	0.807	FE(OH)4--	0.462	AL(OH)4-	0.819
HCO3-	0.815	CA++	0.478	FEOH++	0.462	ALSO4+	0.819
CO3--	0.454	MG++	0.507	FE(OH)2+	0.826	AL(SO4)2-	0.819
HS-	0.811	CAHCO3+	0.830	FE(OH)4-	0.826	ALF++	0.469
S--	0.462	MGHCO3+	0.815	FESO4+	0.823	ALF2+	0.826
HSO4-	0.819	CAOH+	0.830	FECL++	0.462	ALF4-	0.819
SO4--	0.446	MGOH+	0.833	FECL2+	0.823	ALF5--	0.454
NASO4-	0.826	NH4+	0.803	FECL4-	0.815	ALF6---	0.170

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-7.183	MG++	4.54	-3.729	FE(OH)3	0.00	0.000
OH-	0.37	-4.661	NACL	1.10	-4.724	FE(OH)4-	0.00	0.000
H4SIO4	122.73	-2.894	KCL	0.02	-6.622	FECL+	0.00	0.000
H3SIO4-	3.25	-4.467	NASO4-	8.00	-4.173	FECL2	0.00	0.000
H2SIO4--	0.00	-7.978	KSO4-	1.50	-4.956	FECL++	0.00	0.000
NAH3SIO4	0.84	-5.146	CASO4	2.93	-4.666	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	10.09	-4.077	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	3.01	-4.522	FECL4-	0.00	0.000
H2CO3	227.98	-2.435	MGCO3	0.59	-5.154	FESO4	0.00	0.000
HCO3-	1275.23	-1.680	CAHCO3+	27.53	-3.565	FESO4+	0.00	0.000
CO3--	2.18	-4.441	MGHCO3+	4.44	-4.283	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.01	-6.995	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.04	-5.978	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-16.043	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.01	-7.096	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	103.31	-2.968	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-6.789	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	5.02	-3.578	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	124.31	-2.455	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	566.72	-1.608	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	33.40	-3.068	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	7.82	-3.710	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.02827 IONIC BALANCE ; CATIONS (MOL.EQ.)0.02659402
ANIONS (MOL.EQ.)0.02694900
DIFFERENCE (%) -1.33

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 2.52

QUARTZ 123.1
CHALCEDONY 93.4
NAK 148.4

OXIDATION POTENTIAL (VOLTS) ; EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-16.408	99.999	ALBITE LOW	-15.743	99.999	ANALCIME	-12.652	99.999
ANHYDRITE	-5.945	-7.349	CALCITE	-9.857	-8.813	CHALCEDONY	-2.669	-2.894
MG-CHLORITE	-79.925	99.999	FLUORITE	-10.527	-11.367	GOETHITE	-3.788	99.999
LAUMONTITE	-26.224	99.999	MICROCLINE	-17.631	99.999	MAGNETITE	-27.929	99.999
CA-MONTMOR.	-80.730	99.999	K-MONTMOR.	-39.000	99.999	MG-MONTMOR.	-81.980	99.999
NA-MONTMOR.	-39.079	99.999	MUSCOVITE	-19.966	99.999	PREHNITE	-36.170	99.999
PYRRHOTITE	-88.259	99.999	PYRITE	-130.425	99.999	QUARTZ	-2.894	-2.894
WAIRAKITE	-24.224	99.999	WOLLASTONITE	10.157	7.441	ZOISITE	-35.495	99.999
EPIDOTE	-41.762	99.999	MARCASITE	-108.333	99.999			

ORKUSTOFNUN JHD BURUNDI 1982
1982-12-16 HA

9999400700820910201 8 TANGANYKAVATN BURUNDI

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE
PH/DEG.C	8.80/27.0	GAS (VOL.%)
SIO2	5.82	CO2
NA	65.64	H2S
K	33.29	H2
CA	14.42	O2
MG	41.650	CH4
CO2	292.00	N2
SO4	6.61	
H2S	0.00	
CL	29.25	
F	0.75	
DISS.SOLIDS	374.40	
AL	0.0000	
B	0.0000	
FE	0.0000	
NH3	0.0000	

REFERENCE TEMP.	DEGREES C	0.0 (QTZ)
SAMPLING PRESSURE	BARS ABS.	
DISCHARGE ENTHALPY	MJOUL/KG	
DISCHARGE	KG/SEC.	0.0
MEASURED TEMPERATURE	DEGREES C	28.0
RESISTIVITY/TEMP.	OHMM/DEG.C	15.4/19.0
EH/TEMP.	MV/DEG.C	0.000/ 0.0

LITERS GAS PER KG CONDENSATE/DEG.C

	MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
CONDENSATE (PPM)	0.0	0.0	0.0
PH/DEG.C	0.0	0.0	0.0
CO2	0.0	0.0	0.0
H2S	0.0	0.0	0.0
NA	0.0	0.0	0.0
	0.0	0.0	0.0
	0.0	0.0	0.0
	0.0	0.0	0.0
CONDENSATE WITH NAOH (PPM)	0.0	0.0	0.0
CO2	0.0	0.0	0.0
H2S	0.0	0.0	0.0

IONIC STRENGTH = 0.00951 IONIC BALANCE : CATIONS (MOL.EQ.)0.00733074
ANIONS (MOL.EQ.)0.00755984
DIFFERENCE (%) -3.08

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	5.82	CO2	292.00	CO2	0.00	CO2	0.435E-03
NA	65.64	H2S	0.00	H2S	0.00	H2S	0.000E+00
K	33.29	H2	0.00	H2	0.00	H2	0.000E+00
CA	14.42	O2	0.00	O2	0.00	O2	0.000E+00
MG	41.647	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	6.61	N2	0.00	N2	0.00	N2	0.000E+00
CL	29.25	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	0.75					H2O	0.239E-01
DISS.S.	374.40					TOTAL	0.243E-01
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.914	KSO4-	0.906	FE++	0.681	FECL+	0.903
OH-	0.902	F-	0.902	FE+++	0.450	AL+++	0.450
H3SIO4-	0.903	CL-	0.900	FEOH+	0.905	ALOH++	0.677
H2SIO4--	0.677	NA+	0.903	FE(OH)3-	0.905	AL(OH)2+	0.906
H2BO3-	0.899	K+	0.900	FE(OH)4--	0.674	AL(OH)4-	0.904
HCO3-	0.903	CA++	0.681	FEOH++	0.674	ALSO4+	0.904
CO3--	0.670	MG++	0.694	FE(OH)2+	0.906	AL(SO4)2-	0.904
HS-	0.902	CAHCO3+	0.908	FE(OH)4-	0.906	ALF++	0.677
S--	0.674	MGHCO3+	0.903	FESO4+	0.905	ALF2+	0.906
HSO4-	0.904	CAOH+	0.908	FECL++	0.674	ALF4-	0.904
SO4--	0.666	MGOH+	0.909	FECL2+	0.905	ALF5--	0.670
NASO4-	0.906	NH4+	0.899	FECL4-	0.903	ALF6---	0.407

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-8.877	MG++	35.94	-2.830	FE(OH)3	0.00	0.000
OH-	0.10	-5.223	NACL	0.00	-7.317	FE(OH)4-	0.00	0.000
H4SIO4	8.58	-4.049	KCL	0.00	-7.807	FECL+	0.00	0.000
H3SIO4-	0.70	-5.134	NASO4-	0.02	-6.734	FECL2	0.00	0.000
H2SIO4--	0.00	-7.945	KSO4-	0.03	-6.656	FECL++	0.00	0.000
NAH3SIO4	0.03	-6.616	CASO4	0.12	-6.068	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	0.82	-5.167	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	4.32	-4.365	FECL4-	0.00	0.000
H2CO3	1.17	-4.724	MGCO3	13.15	-3.807	FESO4	0.00	0.000
HCO3-	371.28	-2.216	CAHCO3+	1.15	-4.943	FESO4+	0.00	0.000
CO3--	14.98	-3.603	MGHCO3+	6.07	-4.148	AL+++	0.00	0.000
H2S	0.00	0.000	CAOH+	0.00	-7.709	ALOH++	0.00	0.000
HS-	0.00	0.000	MGOH+	0.04	-6.045	AL(OH)2+	0.00	0.000
S--	0.00	0.000	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-23.249	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.00	-11.281	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	5.83	-4.217	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-10.181	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	0.75	-4.404	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	29.25	-3.084	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	65.63	-2.544	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	33.28	-3.070	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	12.20	-3.517	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.00956 IONIC BALANCE : CATIONS (MOL.EQ.)0.00735466
ANIONS (MOL.EQ.)0.00758331
DIFFERENCE (%) -3.06

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 3.41

QUARTZ	20.4
CHALCEDONY	-8.4
NAK	465.0

OXIDATION POTENTIAL (VOLTS) : EH H2S= 99.999 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-21.640	99.999	ALBITE LOW	-20.519	99.999	ANALCIME	-16.257	99.999
ANHYDRITE	-4.668	-8.076	CALCITE	-8.460	-7.460	CHALCEDONY	-3.641	-4.049
MG-CHLORITE	-85.744	99.999	FLUORITE	-11.022	-12.581	GOETHITE	-7.450	99.999
LAUMONTITE	-32.724	99.999	MICROCLINE	-23.714	99.999	MAGNETITE	-36.087	99.999
CA-MONTMOR.	-113.361	99.999	K-MONTMOR.	-56.645	99.999	MG-MONTMOR.	-113.961	99.999
NA-MONTMOR.	-56.263	99.999	MUSCOVITE	-27.988	99.999	PREHNITE	-41.617	99.999
PYRRHOTITE	-140.776	99.999	PYRITE	-211.643	99.999	QUARTZ	-4.049	-4.049
WAIRAKITE	-28.179	99.999	WOLLASTONITE	13.946	10.020	ZOISITE	-39.973	99.999
EPIDOTE	-50.830	99.999	MARCASITE	-181.904	99.999			

APPENDIX 3.

Results of analysis of cold groundwater from Burundi supplied by REGIDESO.

BULLETIN D'ANALYSE CHIMIQUE

Mois de AVRIL 1981

Semaine: ---

REGIDESO

- NGOZI -

		1	2	3	4	5	6	7	8
		15/04/81 OCIBU	15/04/81 Mission	15/04/81 SP1	15-04-81 SP2				
		Date: Lieu:	Date: Lieu:	Date: Lieu:	Date: Lieu:	Date: Lieu:	Date: Lieu:	Date: Lieu:	Date: Lieu:
Tempér. Eau	°C	20°	20°	19°	19°				
Couleur "ALPHA unités"		-	-	-	-				
Turbidité "ITU"		4	4	6	8				
PH		7,9	8,2	8,2	8,2				
Gaz carb. libre	CO_2 mg/l	26,4	26,4	39,6	39,6				
p valeur		0	0	0					
m valeur		0,2	0,2	0,2	0,2				
dureté part. aux bicarb.	°dH	0,56	0,56	0,56	0,56				
dureté totale "EDTA"	°dH	0,7	0,7	0,7	0,7				
Oxygène dissous	mg/l	6,4	6,4	6,4	6,4				
Chlore libre	mg/l	0	0	0	0				
Permang. de K	mg/l	2,84	2,84	2,84	2,84				
Fe^{+++}	mg/l	0	0	0	0				
Mn^{++}	mg/l	-	-	-	-				
Cl^-	mg/l	-	-	-	-				
SO_4^{--}	mg/l	-	-	-	-				
NO_3^-	mg/l	-	-	-	-				
NO_2^-	mg/l	-	-	-	-				
PO_4^{---}	mg/l	-	-	-	-				
Subst. en susp.	mg/l	-	-	-	-				
Conductivité	MS	640	820	620	740				

Chef de Service Laboratoire

B U L L E T I N D'A N A L Y S E C H I M I Q U E

M o i s : ....Juillet..... 1981..

~~BULLETIN~~ N° ..R U G O M B O.

		DATE 23 et 07 m 81 Lieu MYAMIRME 1	DATE 23 et 07 m 81 Lieu B.P.NYAVA 2	DATE ..... Lieu 3	DATE ..... Lieu 4
Température de l'eau		-	-		
Couleur "ALPHA unités"		0	0		
Turbidité "I T U"		0	0		
p H		6,8	7,2		
Gaz carbonique	mg/l	4,2	0		
p Valeur		0	2		
m Valeur		2	6		
Dureté part. aux bicam	° dH	5,2	6,8		
Dureté totale "EDTA"	° dH	5,2	6,8		
Oxygène dissous	mg/l	2	8		
Chlore libre	mg/l	0	0		
Permang. de K.	mg/l	-	-		
Fe^{+++}	mg/l	0	0		
Mn Min^{++}	mg/l	5	5		
Cl^{-}	mg/l	24,6	26,8		
SO_4^{--}	mg/l	15	15		
$NO^{-}3$	mg/l	3,5	3,5		
$NO^{-}2$	mg/l	0,65	0,65		
$PO^{-}4$	mg/l	0,4	0,4		
Subst. en susp.	mg/l	0	0		
Conductivité	M S	360	420		

Chef de service Laboratoire .

Vénuste K A J I B W A M I

B U L L E T I N D'A N A L Y S E C H I M I Q U E

M o i s : ..... 198...

BULLETIN N° .....

		DATE 29 [illegible] 1 Lieu [illegible] (MWISALE)	DATE 2 Lieu	DATE 3 Lieu	DATE 4 Lieu
Température de l'eau		-			
Couleur "ALPHA unités"		0			
Turbidité "I T U"		0			
p H		7,2			
Gaz carbonique	mg/l	2,8			
p Valeur		0			
m Valeur		2			
Dureté part. aux bicam	° dH	5,8			
Dureté totale "EDTA"	° dH	5,8			
Oxygène dissous	mg/l	4			
Chlore libre	mg/l	0			
Permang. de K.	mg/l	-			
Fe^{+++}	mg/l	0			
Mn^{++}	mg/l	22,4			
Cl^{-}	mg/l	15			
SO_4^{--}	mg/l	20,8			
$NO^{-}3$	mg/l	20			
$NO^{-}2$	mg/l	0,5			
$PO^{-}4$	mg/l	0,4			
Subst. en susp.	mg/l	0			
Conductivité	M S	600			

Chef de service Laboratoire .

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B U L L E T I N D'A N A L Y S E C H I M I Q U E

M o i s : ..... 198...

BULLETIN N° .....

		DATE 5/03 Lieu Missia Kigwena 1	DATE Lieu 2	DATE Lieu 3	DATE Lieu 4
Température de l'eau		—			
Couleur "ALPHA unités"		0			
Turbidité "I T U"		0			
p H		7,2			
Gaz carbonique	mg/l	18,5			
p Valeur		0			
m Valeur		0,05			
Dureté part. aux bicam	° dH	1			
Dureté totale "EDTA"	° dH	1			
Oxygène dissous	mg/l	—			
Chlore libre	mg/l	0			
Permang. de K.	mg/l	11			
Fe^{+++}	mg/l	0			
Mn^{++}	mg/l	0			
Cl^{-}	mg/l	5,31			
SO_4^{--}	mg/l	12			
NO^{-}_3	mg/l	01			
NO^{-}_2	mg/l	0			
PO^{-}_4	mg/l	0,42			
Subst. en susp.	mg/l	0			
Conductivité	M S	850			

Chef de service Laboratoire .

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B U L L E T I N D'A N A L Y S E C H I M I Q U E

M o i s : ....Avril..... 1982.

BULLETIN N° ....✓.....

		DATE 8/04/82 Lieu Captage Magenoli	DATE 2 Lieu	DATE 3 Lieu	DATE 4 Lieu
Température de l'eau		20			
Couleur "ALPHA unités"		0			
Turbidité "I T U"		0			
p H		6,8			
Gaz carbonique	mg/l	1,4			
p Valeur		0			
m Valeur		0,1			
Dureté part. aux bicam	° dH	1,4			
Dureté totale "EDTA"	° dH	14			
Oxygène dissous	mg/l	5			
Chlore libre	mg/l	0			
Permang. de K.	mg/l	16,43			
Fe^{+++}	mg/l	0			
Min^{++}	mg/l	0			
Cl^{-}	mg/l	117,01			
SO_4^{--}	mg/l	17			
$NO^{-}3$	mg/l	8			
$NO^{-}2$	mg/l	0,2			
$PO^{-}4$	mg/l	0			
Subst. en susp.	mg/l	0			
Conductivité	M S	1400			

Chef de service Laboratoire .

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