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KENYA RIFT VALLEY GEOTHERMAL PROJECT: Hydrogeology and Geothermics of the Magadi-Longonot Sector.

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1. INTRODUCTION AND OBJECTIVES

This study was undertaken as the first in a series to investigate the regional hydrogeological context of geothermal prospects in the Rift Valley of Kenya between the Tanzanian border in the south (2° 15' S) and the Silale volcanic centre in the north (1° 12' N). A major focus of the study in the Magadi-Longonot sector has been the thermal springs (temperature up to 85°C) which discharge at the northern end of Little Magadi lake. It has been speculated (Baker, 1958; Jones et al., 1977) that these springs at least in part represent the discharge from a groundwater flow system originating at Lake Naivasha, which is sited on a culmination in the topography of the Rift Valley floor (elevation 1890 m) 100 km to the north. Southwards from Lake Naivasha the floor of the Rift Valley falls gradually towards Lake Magadi (Kenya) and Lake Natron (Tanzania), which occupy the low points (elevation 590 m) at the centres of a large internal drainage basin. Conversely, Glover (1972) has surmised that the Magadi thermal springs are locally derived, steam heated, groundwater associated with the lake brine. To test these conflicting hypotheses an isotopic survey of the springs and neighbourig groundwaters was undertaken as a major part of this study, thence to establish the relevance of the springs in a geothermal context. Almost all the thermal and ambient springs around the Lake have been included. A few smaller thermal springs (45°C to 55°C) which occur on or near the margins of the Rift Valley at the latitude of Longonot and Suswa have also been investigated. The fumaroles associated with the Longonot and Suswa volcanoes, although they are an important component, will be the subject of a separate report. In addition a piezometric study is being conducted which is as yet incomplete, and will be more fully reported elsewhere.

The hydrochemistry of the Lake Magadi basin has been studied in some detail by Eugster and Jones of the USA whose model for the chemical evolution of the alkaline springs and lake brine by evaporative concentration of meteoric recharge from the perennial marginal streams (Jones et al., 1977) is established as a type example of this particular hydrochemical trend (Drever, 1985). Additional hydrochemical work in the area is outlined by Glover (1972), who favoured an origin for the springs as locally steam-heated groundwater, and who in particular noted the potential value of the application of stable isotope studies to the Magadi system. A limited number of isotopic analyses have since been reported by Panichi and Tongiorgi (1974, unpublished) and Bwire-Ojiambo (1985), but in the main values for $\delta^{18}O$ only are given which cover an exceptionally wide range and no interpretation has been made. Previously, chemists and geologists associated either with the Magadi Soda Company (Stevens, 1932), or the Geological Surveys of Tanganyika and Kenya, had provided chemical analyses of the springs and brine of Lakes Magadi and Natron and speculated as to the origin of the water and solutes. A historical summary is given by Baker (1958) who himself proposed the 'surface leaching hypothesis' which incorporates the idea of recharge by groundwater flowing southwards from the Naivasha area, and a suggestion of heating 'by contact with igneous rock'. Baker's comparison of Magadi with other 'salt pan' or 'playa' environments also in some ways foreshadows the more elaborate exposition of the evaporative concentration theory of Jones et al. (1977).

The present study considers the chemical evolution of the Magadi thermal springs and the Rift margin springs in relation to the application of chemical geothermometry (Ellis, 1977). Hydrogeologically, the provenance of the Magadi thermal springs is considered in relation to its relevance to a geothermal assessment of the area. The latter objective has been tackled by a survey of the stable isotopic characteristics ($^2H/^1H$ and $^{18}O/^{16}O$ isotopic ratios) of the springwaters, groundwaters and lakewaters concerned.

2. GEOLOGY AND HYDROLOGY

Physiography and Hydrology:

The southern part of the Rift Valley is bounded by the Nguruman and Mau escarpments on the west. In the south-east a series of scarps eastwards from the Nkama plain mark the boundary of the Rift, which is more clearly defined by the Kikuyu escarpment at the latitude of Mt. Suswa. The Nguruman escarpment descends from a height of 1950 m via the Kirikiti platform at 1350 m to the Rift Valley floor at 900 m in the extreme west, from where the valley floor descends via a series of ridge and trough faulted escarpments to 590 m at Lake Magadi in the deepest part of the Rift. The Mau escarpment reaches a height of 2375 m to the north-west of Suswa, and the Kikuyu escarpment 2400 m to the east.

The Rift Valley floor is divided into many sub-parallel ridges and troughs trending approximately NNE, a physiographic expression of the recent grid faulting. The valley floor slopes southwards with a gradient of approximately 1:100 from Lake Naivasha to Lake Magadi and the surfaces of the fault blocks similarly dip gently southwards. At the latitude of Lake Magadi there are six main troughs: the Ewaso Ngiro plain, the Embaash (Kordiya) plain, the Magadi central trough, the Olkeri plain, the Koora plain, and the Nkama (Kuenia) plain. The Ewaso Ngiro plain is the basin of the only perennial river of the Rift in this sector, which has built out an extensive alluvial fan several kilometers onto the Rift Valley floor, its right bank tributary streams, of which R. Oloibortoto is the southernmost, draining the Nguruman escarpment to the west. All the troughs are bounded by fault escarpments and are generally allvium-filled discrete basins of internal surface drainage. The Magadi trough at its southern, deepest, end is filled by the alkaline saline Lakes Magadi and Little Magadi. The Toroka river drains the Kajiado escarpment in the east, into the Nkama depression, and Olkeju Ngiro drains into the Koora trough via Oltepesi and the northern slopes of Olorgasailie. Further north the Ewaso Kedong drains from the Kikuyu escarpment to the east of Suswa volcano. There is no surface drainage to, nor any outlet from, Lake Magadi. A number of springs and seepages occur around its margin, some of which have a significantly elevated temperature (maximum 86^{o}C at the northern extremity of Little Magadi). Due to extreme evaporation from the alkaline lake brine (Na^+, HCO_3^- + CO_3^{2-} type; salinity 290,000 mg/l) a surface layer of crystalline trona covers the lake surface. This is composed of crystalline carbonates of sodium (principally sodium sesquicarbonate, ($Na_2CO_3.NaHCO_3.2H_2O$) which is dredged by Magadi Soda Co. and treated before being calcined in large kilns to produce soda ash.

A number of isolated volcanic centres are located in this sector of the Rift, notably Ol Doinyo Nyokie (1169 m), Olorgasailie (1760 m), Ol Esayeti (1950 m), Suswa (2356 m) and Longonot (2777 m). Of thse the youngest and least eroded are Ol Doinyo Nyokie in the south, and Suswa and Longonot in the north.

Average annual rainfall varies from 627 mm at Naivasha to 430 mm at Magadi (Met. Dept. data 1931-1980). The average maximum daily temperature at Magadi is 35^{o}C (minimum 23^{o}C) and at Naivasha is 25^{o}C (minimum 9^{o}C). Relative humidity is low throughout the Rift (less than 75% at Naivasha, less than 60% at Magadi) and potential evaporation greatly exceeds rainfall. Monthly averaged potential evaporation at Naivasha exceeds rainfall by a factor of 2 to 8 for every month except April when potential evaporation still exceeds rainfall except in the wettest of years. The same figures are not recorded for Magadi where the excess of evaporation over rainfall must be considerably greater. However, rain is concentrated in two wet seasons: November-December and March-May. Individual storms can be extremely heavy. Detailed records would be required on a daily basis adequately to determine actual recharge under these difficult conditions. In all probability recharge is occurring, there being no general indications of annually declining groundwater levels. Nonetheless, it is believed that the catchement recharge figures quoted by McCann (1974) are inadequately supported by the available data and may be misleading.

Geology:

A simplified geological succession for the area is given in Table 1 (from Baker, 1958 and Randal, unpublished).

The Rift Valley is composed of a succession of Late Tertiary and Quaternary volcanics with intervening lacustrine beds and alluvium principally of reworked volcanic debris. The Rift is defined by the major Pliocene boundary faults of the Nguruman and Mau escarpments in the west and the Kikuyu escarpment in the east. The two major faults of the southern Nguruman escarpment each have a throw of 450 m. The only occurrence of Archean Basement rocks (granitic gneisses) in this general area is on the higher Nguruman escarpment. In the south east the boundary is less well defined, there being a succession of smaller escarpmnt faults with wider intermediate platforms between. A dense system of Middle and Upper Pleistocene grid faulting within the Rift dissects the valley floor into a series of NNE trending blocks and fault troughs. There are thus numerous fault bounded platforms subsidiary to the deepest central basin. On this pattern is superimposed a number of individual central volcanoes of which Olorgasailie predates rifting and the remainder, including Suswa and Longonot, postdate and/or are contemporaneous with the later grid faulting.

Olivine basalts of the Kirikiti plateau and elsewhere, and trachyandesites, alkali trachytes and nephelinites of Olorgasailie, were erupted at the inception of rifting and subsequent extension was characterised by extensive eruption of plateau type alkaline basalts in more than twenty flows. This activity terminated with the formation of a number of small ash and scouraceous lava cones as well as the larger Ol Doinyo Nyegi. A thin layer of lake beds (the Oloronga Beds), mainly reworked volcanic debris with a thickness up to 15 m, overlie the plateau basalts and preceded the extensive grid faulting which determines the present day topography. Succeeding Middle Pleistocene sediments include the Olorgasailie lake beds of diatomaceous clays and the fine silts and clays of the Ewaso Ngiro basin, sediments of the Kedong valley (predominantly clays and fine sandstones with minor poorly sorted conglomerate), and the silicified clays of the earliest Magadi Lake. Subsequent minor faulting disrupted these sediments and was followed in the Magadi area by extensive lacustrine deposition (the High Magadi Beds) to a level 12 m above the present lake surface, and by further sedimentation in the Ewaso Ngiro basin. At Magadi deposition of the Evaporite Series is thought to mark the onset of alkaline spring activity, which continues to the present day. The large central volcanoes of Suswa and Longonot date from the Lower and Middle Pleistocene and comprise phonolite, alkaline trachyte and rhyolite lavas and extensive pyroclastics.

3. SAMPLING AND ANALYTICAL RESULTS

Sampling points are indicated on Fig. 1 and site details are given in Table 2. Descriptive sheets for each site are attached as Appendix 1. At Magadi, most of the known thermal springs around the lake were sampled ($40^{o}C$ to $85^{o}C$) in addition to associated groundwaters (ambient springs and one pumped groundwater) and the Rift margin rivers Ewaso Ngiro and R. Oloibortoto. Further north, around the latitude of Longonot volcano, springs on the Rift margin in the vicinity of Kijabe in the east, and springs on the western Rift flanks at Maji ya Moto, were sampled. Moderately thermal springs (45°C to 55°C) occur at both these sites. Two samples of condensed steam were collected: one from a small fumarole on Mt. Margaret and one from a borehole at Akira Ranch on the western flank of Mt. Longonot, which discharges a steam/water mixture. A field survey to locate fumaroles associated with Longonot and Suswa calderas was undertaken concurrently by DGW and HT and a fuller investigation will follow. Samples of lakewater from Lake Naivasha have been collected, to augment the available isotopic data.

On collection, water samples were filtered through 0.45 μm filters and stored in two 30 ml bottles. One of these samples was acidified to pH ≃ 1 using concentrated hydrochloric acid and the other was left unacidified to allow chloride determination. A 1:10 dilution of untreated sample with distilled water was made to stabilise dissolved silica species. A 15 ml untreated sample was collected in a glass bottle for isotopic analysis. On site measurements included temperature (using a thermistor probe with digital display), electrical conductivity (using a portable conductivity cell), pH (using a pH electrode with digital display), and alkalinity (by titration with nitric acid). Samples were taken to the BGS hydrochemistry laboratories at Wallingford (UK) for chemical and isotopic analysis. The methods of Cook and Miles (1980), and Miles and Cook (1982), were used for chemical analysis and of Darling et al. (1982) for isotopic determination. Analytical results are tabulated in Tables 3, 4 and 5.

4. THE MAGADI SPRINGS

Heat Discharge:

Estimates of heat discharge made in the vicinity of Lake Magadi are reported in Table 6. Only the minor springs on the western shore of the main lake were not visited. Total visible heat discharge around Lake Magadi is in the region of 250 MW (thermal), of which over 90% is contributed by the thermal springs on the northern shore of Little Magadi. If additional springs discharge to the lake bottoms the total heat loss in the area may be significantly greater. 250 MW is a realistic minimum estimate. In comparison, the natural rate of heat discharge via manifestations associated with the Olkaria geothermal field has been estimated as 9 x 10^4 kcal/sec, equivalent to 376 MW and 130 MW at Eburru (Glover, 1972).

		Thermal discharge kW	Thermal discharge MW
Lake Magadi			
Southern springs (to discrete stream channel)			6.3
Eastern springs	Bird Rock	70	0.75
	Grahams Lagoon (E1, E2)	600	
	E3	80	
NW Lagoon (intermittent seeps and springs over > 1 km)			2.2
NE Lagoon (springs to discrete stream channels)			2.0
Little Magadi (discrete springs to discrete stream channels)			230.0
		Total:	241 MW

Table 6. Heat discharge at Magadi (above 30°C).

Isotopic Characteristics:

Isotopic determinations ($\delta^{18}O$, $\delta^{2}H$) are listed in Table 3 and illustrated in Figure 2, which includes for reference the standard world meteoric relationship of Craig (1961), and for comparison several values reported by Bwire-Ojiambo (1985) and Panichi and Tongiorgi (unpublished). A possible local meteoric relationship, based on three rainfall samples collected at Olorgasailie during the short rains of November 1985, is also indicated. A fuller investigtion of meteoric isotopic characteristics throughout the project area is underway.

The isotopic character of the springwaters largely coincides with a field defined by local meteoric sources: the marginal streams Ewaso Ngiro and Oloibortoto, a pumped groundwater from Oltepesi in the adjacent Legemunge plain, and the weighted average value of Olorgasailie rainfall. The Magadi springs, demonstrably meteoric in character, fall no more than 15‰ $\delta^{18}O$ to the right of Craig's meteoric line. Limited, if any, evaporative enrichment is indicated for the springwaters (maximum total salinity 45,000 mg/l) in contrast to the extremely enriched and evaporated lake brine (salinity approximately 300,000 mg/l). Supportive evidence for the lack of an evaporative trend from the dilute marginal streams to the more saline Magadi springs comes from a plot of Cl^- v. $\delta^{18}O$ (Fig. 3) which illustrates that an increase in salinity by three orders of magnitude is not accompanied by any isotopic enrichment.

The spring recharge areas suggested by Jones et al. (1977) are however confirmed in a general way. Both underground percolation from the rift margin streams and local meteoric recharge to groundwater of the Rift Valley basins may contribute. However, the hypothesis of long distance groundwater movement along the Rift from Lake Naivasha is not supported. Bwire-Ojiambo's data for Lake Naivasha would allow a small component of long distance flow to Magadi, but chemical implications deny such a mixing pattern (see below). The range of $\delta^{18}O$ reported by Bwire-Ojiambo for the Magadi springs is extreme and is not supported by the BGS determinations, although location details are not given by Bwire-Ojiambo and direct comparison is therefore not possible. Note that enrichment in $\delta^{18}O$ of the lake brines at Magadi is not accompanied by enrichment in $\delta^{2}H$ to give the usual evaporative gradient. This is accounted for by their extreme salinity, under which conditions increased evaporation actually results in reversal to an isotopically lighter residual brine (see Gat, 1980).

The hydrochemical evolutionary trends detailed by Eugster (1970) and elaborated by Jones et al. (1977) for the Magadi basin are described as being controlled by specific chemical equilibria at successively higher salinities determined by continuing evaporative concentration. The complicating effects of recirculation of lake brines and solution of existing precipitates are detailed as important mechanisms and the latter is supported by the data reported here (see below). Nevertheless, the hypothesis of evolution of the Magadi springwaters by evaporative concentration is disproven by the isotopic data.

A relationship between isotopic character and altitude has been sought but not found. Neither is there any apparent relationship between isotopic character and latitude.

Hydrochemistry:

The springs around Lake Magadi are alkaline Na-HCO_3 brines with chloride a subordinate anion and a salinity range of 30,000 mg/l to 45,000 mg/l. Their hydrochemistry has been described in some detail by Jones et al. who investigated the relationship between the dilute stream waters on the Rift margins, shallow groundwater of the Rift, the saline thermal and ambient springs, the concentrated brines of the lake and the residual brines interstitial to the crystalline trona deposits. The present subject of interest is more specifically the thermal springs; their evolution is important because the provenance of the springwaters holds clues to the source of heat, and their chemistry, in suitable circumstances, may allow estimation of 'base temperatures' or the maximum temperature attained prior to discharge. The isotopic determinations presented above augment the work of Jones et al. (op.cit), in particular in relation to the thermal springs.

With three exceptions the present data show a direct inverse relationship between dissolved chloride, Cl^-, and discharge temperature (Fig. 4). E3 is interpreted as a local spring at ambient temperature unrelated to the thermal system. This linear relationship between Cl^- and temperature implies that the Magadi springs discharge a mixture of two components. A thermal, relatively less saline component on the one hand, appears to mix in varying proportions with a cooler saline component prior to discharge. Discharge along the shores of the NW Lagoon occurs as a series of dispersed seeps and very minor springs which by this model appear to have cooled by conduction on ascent from a little over 90°C.

The dependence of silica solubility on temperature controls the levels of SiO_2 in solution above about 100°C, and dissolved SiO_2 is commonly preserved in solution on subsequent cooling or mixing. A plot of dissolved chloride versus silica (Fig. 5) supports the inverse mixing relationship and confirms that the NW Lagoon springs have cooled on ascent.

Note that the order of this mixing series - (the non-thermal component increasing from the NW Lagoon springs, through the Little Magadi and NE Lagoon springs, to the Magadi South springs and finally to the Magadi East springs) - bears no relationship to the order of mixing with Naivasha lakewater that could be interpreted from the isotope data alone. Naivasha lakewater is thereby discredited as a possible source for any component of the Magadi springs.

The nature of the two components which mix in varying proportions prior to discharge as the Magadi springs is sought. If limits on the dissolved chloride content of the thermal component could be set, its likely silica concentration and thereby the likely maximum temperature at depth could be deduced.

Assuming the non-thermal component to have a temperature of 30-35°C (35°C is the average maximum daily temperature) its chloride content is estimated to be in the range 7600 to 7400 mg/l. The surface brines of Lake Magadi have a chloride content of 37,000 mg/l to 96,000 mg/l (Jones et al., 1977) and available data suggest the Little Magadi lakebrine to have a chloride content around 24,000 mg/l to 28,000 mg/l. It appears likely that the saline, cooler, end-member of the proposed mixing series responsible for the thermal brines derives from a groundwater body distinct and separated from the lakewater itself, possibly isolated by the early lacustrine deposits. The only exploratory borehole drilled by Magadi Soda Co. to penetrate lavas beneath the lake deposits discharge a brine of 20,000 mg/l chloride under artesian pressure. This is considerably less saline than the brines pumped from other exploratory boreholes and is further indication that a discrete groundwater body occurs beneath the lakebeds.

However, it is the thermal component of the mixing series which is the major concern of this geothermal study. The Olkaria geothermal field is thought to derive from a deep hydrothermal circulation system with a base temperature of

245°C to 250°C and a chloride concentration of about 450 mg/l (at atmospheric pressure and boiling point). Brine from the steam/brine mixture of the early exploratory well X2 had a chloride concentration of 456 mg/l. Mahon (1972) cites considerable evidence to suggest an extensive body of deep hot chloride groundwater that underlies a large part of the Rift valley between Lakes Magadi and Baringo [e.g. Olkaria brine 245-250°C, 450 mg/l Cl^-; Lake Elmenteita spring 45°, 490 mg/l Cl^-; Lake Bogoria brines 140-300°C, 230-325 mg/l and 1200-1600 mg/l Cl^-; Ol Kokwe brine, Lake Baringo 97°C, 263 mg/l Cl^-]. If either the same or a similar deep hot groundwater were contributing the thermal component to the Magadi mixing series then its temperature would be in excess of 200°C (204°C at 450 mg/l Cl^-, from the linear relationship of Fig. 4). If a more saline thermal component similar to the proposed source of the more saline boiling springs at Bogoria were responsible, then the base temperature might still be in excess of 180°C (181°C at 1400 mg/l Cl^-, from Fig. 4). Similar consideration of the dissolved silica content of the thermal component (Truesdell and Fournier, 1977) implies a base temperature in excess of 170°C (172°C using data from Little Magadi 3).

The basis for proposing a large body of thermal chloride groundwater underlying an extensive area of the Rift Valley is based on chemical similarities and a simplified relationsip between the piezometric surface of the deep groundwater and the topography of the Rift floor. Mahon (1972) has suggested that isotopic characteristics (δ^2H, $\delta^{18}O$) of the thermal manifestations should be investigated to support or refute the claim. A regional survey of the thermal springs, meteoric sources and lakewaters throughout the project area from Magadi to Silale has been carried out (Burgess, 1986) the results of which will be basic to any consideration of regional groundwater flow in the Rift. This regional isotopic study will also be of relevance to the proposed character of the thermal component at Magadi. Meanwhile it is demonstrated that the thermal component mixes with a cooler more saline, presumably shallow, water in the region of Magadi in varying proportions to produce the thermal springs. The thermal component prior to mixing is likely to have a temperature in excess of 170°C and possibly in excess of 200°C. Consideration of the ($HCO_3^- + CO_3^{2-}$) contents and Cl/B ratios with respect to chloride content in the mixing series suggests the thermal component to have relatively lower alkalinity and higher levels of boron, which suggests that the thermal component may itself be steam-heated.

5. THE RIFT MARGIN THERMAL SPRINGS

Heat loss:

The thermal springs on the eastern Rift margin at Kijabe and on the western flanks of Majiyamoto have neither significantly elevated temperatures (maximum 52°C at Majiyamoto) nor high flowrates. Their rate of heat discharge is therefore negligible in comparison to the springs of the Magadi area. Above an ambient temperature of about 25°C heat loss at Majiyamoto is less than 1 MW (900 kW) and at Kijabe springs is only 150 kW. The thermal borehole pumped at Kijabe Rift Valley Academy produces about 100 kW thermal energy.

Isotopic characteristics:

Isotopic characteristics (Fig. 6) show that the springwaters represent local meteoric recharge. Only the surface runoff collected from a Masai dam on Suswa indicates possible minor evaporation. The marginal and flank springs are isotopically lighter than the Magadi springs. This reflects the higher altitude of their catchment areas. Altitude is not the only controlling factor however;

runoff from Suswa is significantly heavier than the marginal springs at similar altitudes, presumably reflecting the pattern of condensation and precipitation of rainfall in the Rift which is as yet inadequately documented.

Hydrochemistry:

The ambient marginal springs and streams in this sector are dilute Na-HCO_3 type waters similar to the marginal streams from the Nguruman escarpment. This is reflected in the character of the thermal springs (and the pumped thermal groundwater at Kijabe) which have a similar, low, salinity. Only the Rift Valley Academy groundwater (No. 25) appears more evolved with lower relative Mg^{2+} and Ca^{2-} and slightly higher SiO_2. In this case only may the dissolved SiO_2 be appropriate for geothermometry and a maximum temperature a little over 100°C is indicated. The other thermal springs give no chemical indication of temperatures higher than their discharge temperatures. They are interpreted as isolated occurrences of meteoric recharge reaching only moderate depths along fault channels.

Such isolated moderate temperature low salinity thermal springs are common features wherever regional faults separate terrains of different altitude. They represent no significant geothermal resource.

6. SUMMARY AND DISCUSSION

The following conclusions with implications for geothermal assessment are drawn:

The Magadi springwaters are entirely meteoric in origin. They represent a mixing series between a non-thermal (presumed ambient temperature) saline component (chloride content approximately 7500 mg/l) and a less saline thermal component. The thermal component has a base temperature in excess of 170°C and possibly in excess of 200°C. It has been demonstrated that the provenance of the thermal water is NOT lakewater from Naivasha. Indeed, it has been shown that meteoric sources in the vicinity of Magadi itself (local rainfall, streams draining the Rift Valley scarps, local shallow groundwater) could be the ultimate source of the deep themal water. With the likelihood that a relatively saline body of groundwater at ambient temperature occurs below the lacustrine beds in the vicinity of Little Magadi lake and Lake Magadi, recharge to the deep thermal groundwater may be envisaged via the major faults bounding the Rift Valley and the subsidiary troughs marginal to the deepest central basins. Such a mechanism would further imply a heat source localised at Magadi. The fact that there are no indications of recent volcanicity at Magadi does not invalidate such as idea.

If this model is correct (a heat source local to Magadi, demonstrable meteoric recharge, possibility of reservoir base temperature in excess of 200°C) then the central Magadi trough becomes a reasonable geothermal prospect which would merit further investigation.

An alternative possibility for the provenance of the thermal component remains: the suggestion (Mahon, 1972) that a deep thermal groundwater body underlies an extensive area of the Rift Valley. Should this occur, the thermal component of the Magadi springs may still represent a long range discharge from the culmination of the Rift Valley at Naivasha, but would be the result of groundwater flow from the deep Olkaria geothermal brine, rather than from Lake Naivasha. Further isotope studies in progress will investigate the existence of such a widespread body of deep thermal groundwater. A preferred interpretation at present is the local evolution of a thermal brine at Magadi (local meteoric recharge, local heat source) under similar conditions to other isolated occurrences elsewhere in the Rift.

Another major conclusion is not directly relevant to a geothermal assessment, but is pertinent to the hydrology of the Lake Magadi basin:

The mechanism favoured by Eugster (1970) and Jones et al. (1977) for evolution of the Magadi lake brines is successive concentration by evaporation from meteoric recharge, and chemical modifications concommitent with the increasing salinity and pH. Isotopic characterisation of waters representing the successive stages of this supposed evaporative sequence do not support the hypothesis. No marked evapotrative trend is evident on a plot of $\delta^{18}O$ v. $\delta^{2}H$ (Fig. 2). Neither is there evidence for enrichment in $\delta^{18}O$ at increasing levels of dissolved chloride (Fig. 3). Concentration by evaporative enrichment is responsible for evolution of the extreme salinities of the lakebrines from the groundwaters recharging the lake - the last step in the evolutionary trend proposed by Jones et al. (1977). However, the high salinities observed in all the springs around the lake, including the thermal springs, must derive predominantly by dissolution of evaporite deposits in the old lake sediments. The consequences for the proposals of Jones et al. (1977) are not elaborated here (note they do list a number of mechanisms which could complicate their hypothesis, and include mention of recycling of solutes by dissolution of pre-existing evaporites, but only as a minor control). It should be stressed however that cation geothermometry is not applicable to brines which are derived by dissolution of evaporites, irrespective of the further complications presented by their application to one component of a mixing series with inexact knowledge of the end-member concentrations. Application of the silica geothermometer is still permissible, as described previously.

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Table 1. Geological Succession (from Baker, 1958)

Recent	Evaporite Series - Boulder beds
	----------- erosion -----------
Upper Pleistocene	High Magadi Beds - Ewaso Ngiro alluvium
	------- minor faulting, erosion -------
Middle Pleistocene	Olorgasailie Lake Beds
	- grid faulting, erosion -
Lower Pleistocene	Oloronga Beds Minor volcanic vents; Ol Doinyo Nyegi Orthophyre trachytes
	----- rift faulting, [Nguruman 2] -----
Pliocene	Lengitoto trachyte & sediments Ol Keju Nero & Kirikiti basalts Olorgasailie volcanics
	- rift faulting [Nguruman 1], erosion -
Pre-Cambrian (Archean)	Basement gneisses

Locality	Ref. No.	Altitude (m)	Temperature (^{o}C)	Flowrate (l/s)	pH	Salinity[†] (mg/l)	Cl
MAGADI*							
Little Magadi 1	1	610	84.6	5	8.85	34510	5250
" " 2	2	610	80.7	6	9.07	39610	5950
" " 3	3	610	85.3	3	n.d.	37200	5550
" " 4	4	610	81.3	5	(9.47)	39610	5950
" " 5	5	610	78.6	3	(9.24)	33940	5200
" " 6	6	615	72.4	1000	9.1	38040	5600
" " 7	7	615	82.0	4	9.18	35820	5300
" " 8	8	615	82.6	0.5	9.13	39160	5350
NW Lagoon 1	9	600	45.0	1.5	8.82	31560	4900
" 2	10	600	43.5	2	8.81	31320	5100
NE Lagoon 1	11	640	66.6	5	8.96	38150	5850
" 2	12	640	60.5	5	9.13	43310	6900
Magadi E 1	13	595	39.5	5	9.56	41970	6400
" 2	14	595	38.5	0.2	9.56	41710	6550
" 3	15	595	34.0	4	9.86	23680	3550
Bird Rock 1	16	595	40.8	1	9.58	43230	6450
" " 2	17	595	40.5	0.2	9.65	n.d.	6850
Magadi S 1	18	590	45.3	4	9.57	42460	6450
Lake Brine	19	595	n.d.	-	n.d.	n.d.	n.d.
R. Ewasongiro	20	655	25.7	500	8.20	315	15
R. Oloibortoto	21	800	21.5	1000	8.00	72	4
Oltepesi BH	22	990	n.k.	n.k.	8.8	615	26
Olorgasailie	23	980	-	-	n.d.	n.d.	n.d.
LONGONOT*							
L. Naivasha	24	1890	n.d.	-	(7.90)		13
Kijabe RVA	25				7.95	366	5
Kijabe Spring	26	2190	43.3	1	9.05	331	5
Kijabe Stream	27	2200	16.9		7.05	175	11
Mayers Farm	28		27.9	25	(7.90)	378	21
Mt. Margaret	29	1850	87.2	n.d.	7	n.d.	n.d.
Suswa	30	2000	n.d.	-	(7.91)		7
Akira Ranch	31	1720	n.d.	0.2	7	n.d.	n.d.
R. Ewasongiro	32	1885	22.2	750	7.85	136	7
Majiya Moto 1	33	1935	51.2	3	7.25	261	15
" " 2	34	1935	52.5	3	7.25	251	14

* collection during November 1985; analysis January/February 1986

† sum of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^- + CO_3^{2-}, SO_4^{2-}

Table 2. Sample locations (see Appendix I for fuller details).

Locality	Ref. No.	Altitude (m)	Temperature (^oC)	Cl^- (mg/l)	SiO_2 (mg/l)	$\delta^{18}O$ (% SMOW)	δ^2H (% SMOW)
MAGADI							
Little Magadi 1	1	610	84.6	5250	79.8	- 1.2	-4
" " 2	2	610	80.7	5950	86.0	- 1.0	-4
" " 3	3	610	85.3	5550	84.3	- 0.9	-6
" " 4	4	610	81.3	5950	86.0	- 0.5	-4
" " 5	5	610	78.6	5200	78.7	- 1.1	-7
" " 6	6	615	72.4	5600	88.6	- 1.1	-6
" " 7	7	615	82.0	5300	88.1	- 1.2	-6
" " 8	8	615	82.6	5350	88.0	- 1.2	-5
NW Lagoon 1	9	600	45.0	4900	105.2	- 3.1	-17
" 2	10	600	43.5	5100	101.2	- 3.2	-20
NE Lagoon 1	11	640	66.6	5850	83.4	- 1.0	-7
" 2	12	640	60.5	6900	86.8	- 0.6	-4
Magadi E 1	13	595	39.5	6400	50.9	- 2.4	-16
" 2	14	595	38.5	6550	48.3	- 2.5	-16
" 3	15	595	34.0	3550	35.7	- 1.8	-16
Bird Rock 1	16	595	40.8	6450	54.8	- 2.4	-14
" " 2	17	595	40.5	6850	53.5	- 2.5	-15
Magadi S 1	18	590	45.3	6450	68.4	- 2.5	-23
Lake Brine	19	595	n.d.	(67600)*	(880)*	+11.4	-17
R. Ewasongiro	20	655	25.7	15	105.2	- 1.5	-6
R. Oloibortoto	21	800	21.5	4	16.7	- 4.2	-22
Oltepesi BH	22	990	n.k.	26	82.8	- 4.2	-25
Olorgasailie	23	980	-	n.d.	n.d.	- 1.3	-2.7
LONGONOT							
L. Naivasha	24	1890	n.d.	13	9.4	+ 5.6	+34
Kijabe RVA	25			5	77.4	- 5.3	-20
Kijabe Spring	26	2190	43.3	5	40.6	- 4.2	-19
Kijabe Stream	27	2200	16.9	11	67.2	- 4.3	-18
Mayers Farm	28		27.9	21	65.9	- 4.8	-28
Mt. Margaret	29	1850	87.2	n.d.	n.d.		-36
Suswa	30	2000	n.d.	7	13.9	+ 0.6	+8
Akira Ranch	31	1720	n.d.	0	0.2		-14
R. Ewasongiro	32	1885	22.2	7	53.0	- 2.9	-12
Majiya Moto 1	33	1935	51.2	15	44.3	- 5.2	-31
" " 2	34	1935	52.5	14	52.0	- 5.2	-27

* average values from 9 surface brines of Jones et al. (1977)

Table 3. Stable isotope analytical results.

Locality		Ref. No.	Temperature °C	Na	K	Ca	Mg	HCO_3+CO_3 mg/1	Cl	SO_4	SiO_2	Ionic Bal. %
Little Magadi	1	1	84.6	10000	186	1	<0.4	18910	5250	163	79.8	
	2	2	80.7	11500	197	1	<0.4	21800	5950	159	86.0	
	3	3	85.3	10900	185	1	<0.4	20400	5550	160	84.3	
	4	4	81.3	11400	195	1	<0.4	21900	5950	159	86.0	
	5	5	78.6	10300	174	1	<0.4	18100	5200	162	78.7	
	6	6	72.4	11400	176	1	<0.4	20700	5600	155	88.6	
	7	7	82.0	10300	158	1	<0.4	19900	5300	153	88.1	
	8	8	82.6	10500	165	0	<0.4	23000	5350	141	88.0	
NW Lagoon	1	9	45.0	9640	112	1	<0.4	16700	4900	204	105.2	
	2	10	43.5	9120	105	1	0.4	16800	5100	194	101.2	
NE Lagoon	1	11	66.6	11100	157	1	<0.4	20900	5850	134	83.4	
	2	12	60.2	12500	173	1	<0.4	23600	6900	129	86.8	
Magadi E	1	13	39.5	12200	100	1	<0.4	23100	6400	160	50.9	
	2	14	38.5	12000	97	1	<0.4	22900	6550	157	48.3	
	3	15	34.0	7000	75	1	<0.4	13000	3550	52	35.7	
Bird Rock	1	16	40.8	12700	109	1	<0.4	23800	6450	169	54.8	
	2	17	40.5	12600	109	1	<0.4	n.d.	6850	169	53.5	
Magadi S	1	18	45.3	12300	115	1	<0.4	23400	6450	189	68.4	
Lake Brine		19									(880)*	
Ewaso Ngiro		20	25.7	59	16.2	17	4.0	193	15	11	105.2	
Oloibortoto		21	21.5	6	2.6	6	3.9	46	4	3	16.7	
Oltopesie b/h		22	n.d.	162	15.8	9	1.8	390	26	11	82.8	

Table 4. Chemical analytical results for the Magadi springs and associated waters.
(a) Major constituents.

Locality		Ref. No.	Li	B	Br	F
				mg/l		
Little Magadi	1	1	1.17	7.71		
	2	2	1.20	8.53		
	3	3	1.13	8.04		
	4	4	1.18	8.67		
	5	5	1.15	7.48		
	6	6	0.98	8.26		
	7	7	0.84	7.60		
	8	8	0.91	7.77		
NW Lagoon	1	9	0.45	7.70		
	2	10	0.41	6.89		
NE Lagoon	1	11	0.78	7.83		
	2	12	0.80	9.00		
Magadi E	1	13	0.16	6.83		
	2	14	0.16	6.96		
	3	15	0.15	2.69		
Bird Rock	1	16	0.17	7.42		
	2	17	0.17	7.22		
Magadi S	1	18	0.16	7.44		
Lake Brine		19				
Ewaso Ngiro		20	<0.01	<0.03		
Oloibortoto		21	<0.01	<0.03		
Oltepesie B/H		22	0.11	0.08		

Table 4. Chemical analytical results for the Magadi thermal springs and associated waters.
(b) Minor constituents

Locality	Ref.	Li	B	Br	F	Cl/Li	Cl/B
			mg/l				
Lake Naivasha	24	b.d.	b.d.			-	-
Kijabe RVA	25	0.011	b.d.				-
Kijabe spring	26	b.d.	b.d.			-	-
Kijabe stream	27	b.d.	b.d.			-	-
Mayers Farm	28	0.012	b.d.				-
Suswa	30	b.d.	0.05			-	
R. Ewasongiro	32	b.d.	b.d.			-	-
Majiyamoto 1	33	b.d.	b.d.			-	-
Majiyamoto 2	34	b.d.	b.d.			-	-

Table 5. Chemical analytical results for the Rift Margin Springs (Longonot sector) and associated waters.
(b) Minor constituents

Locality	Ref. No.	Temperature °C	Na	K	Ca	Mg	HCO_3+CO_3 mg/l	Cl	SO_4	SiO_2	Ionic Bal. %
Lake Naivasha	24	amb.	41	23.8	22	7.8		13	1	9.4	
Kijabe RVA	25		100	7.1	1	0.2	251	5	2	77.4	
Kijabe spring	26	43.3	83	1.4	0	<0.2	240	5	2	40.6	
Kijabe stream	27	16.9	39	8.0	4	1.3	106	11	6	67.2	
Mayers Farm	28	27.9	32	8.4	10	2.8	300	21	4	65.9	
Suswa	30	amb.	5	13.4	5	1.3	88	7	3	13.9	
R. Ewasogiro	32	22.2	24	11.8	9	1.5	78	7	5	53.0	
Majiyamoto 1	33	51.2	36	13.6	21	8.6	143	15	24	44.3	
Majiyamoto 2	34	52.5	33	13.2	22	8.8	135	14	25	52.0	

Table 5. Chemical analytical results for the Rift Margin springs (Longonot sector) and associated waters.
(a) Major constituents

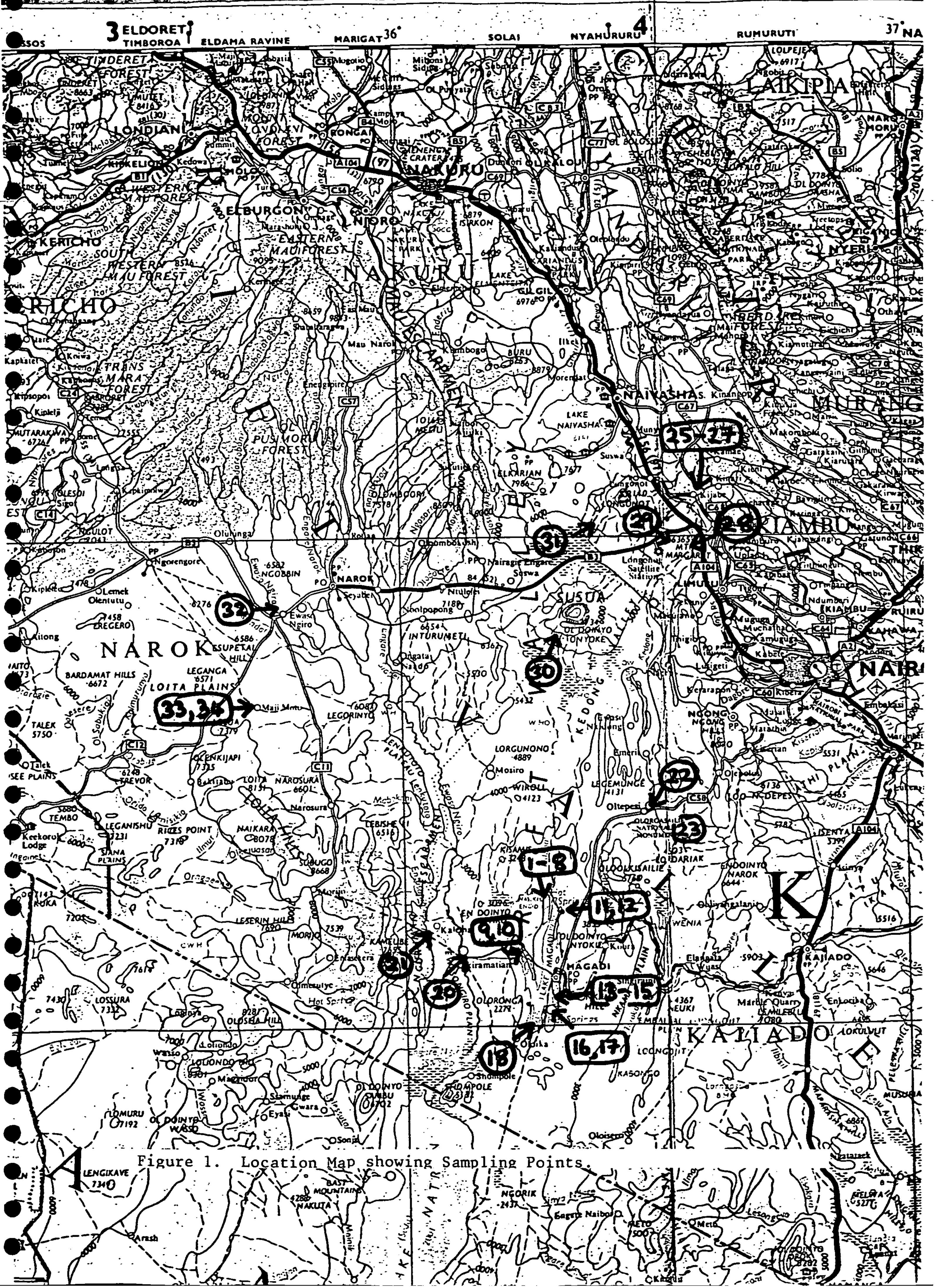
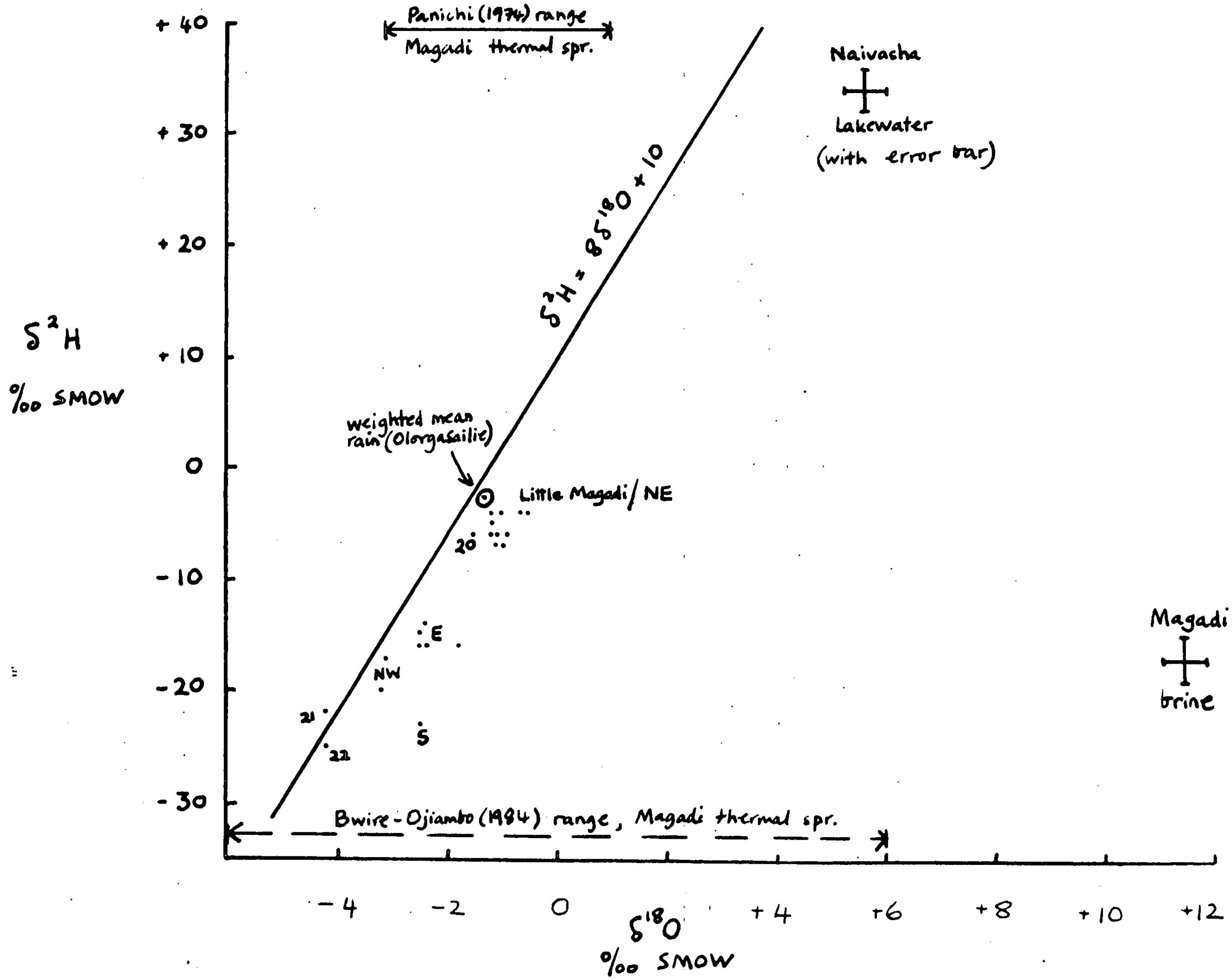


Figure 1. Location Map showing Sampling Points.

Figure 2. $\delta^{18}O$ v. $\delta^{2}H$, Magadi Springs.



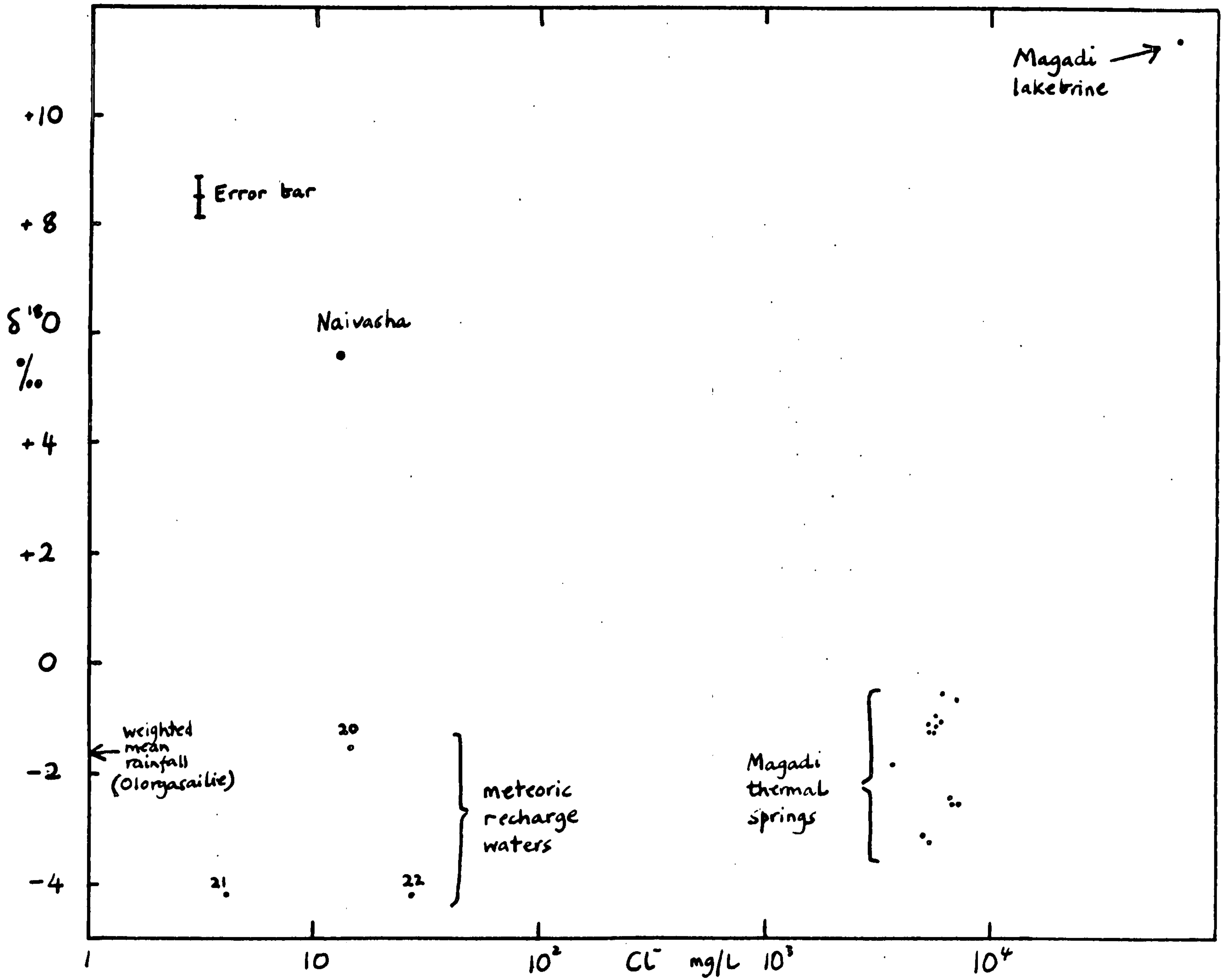


Figure 3. Dissolved Chloride v. δ^2H, Magadi Region.

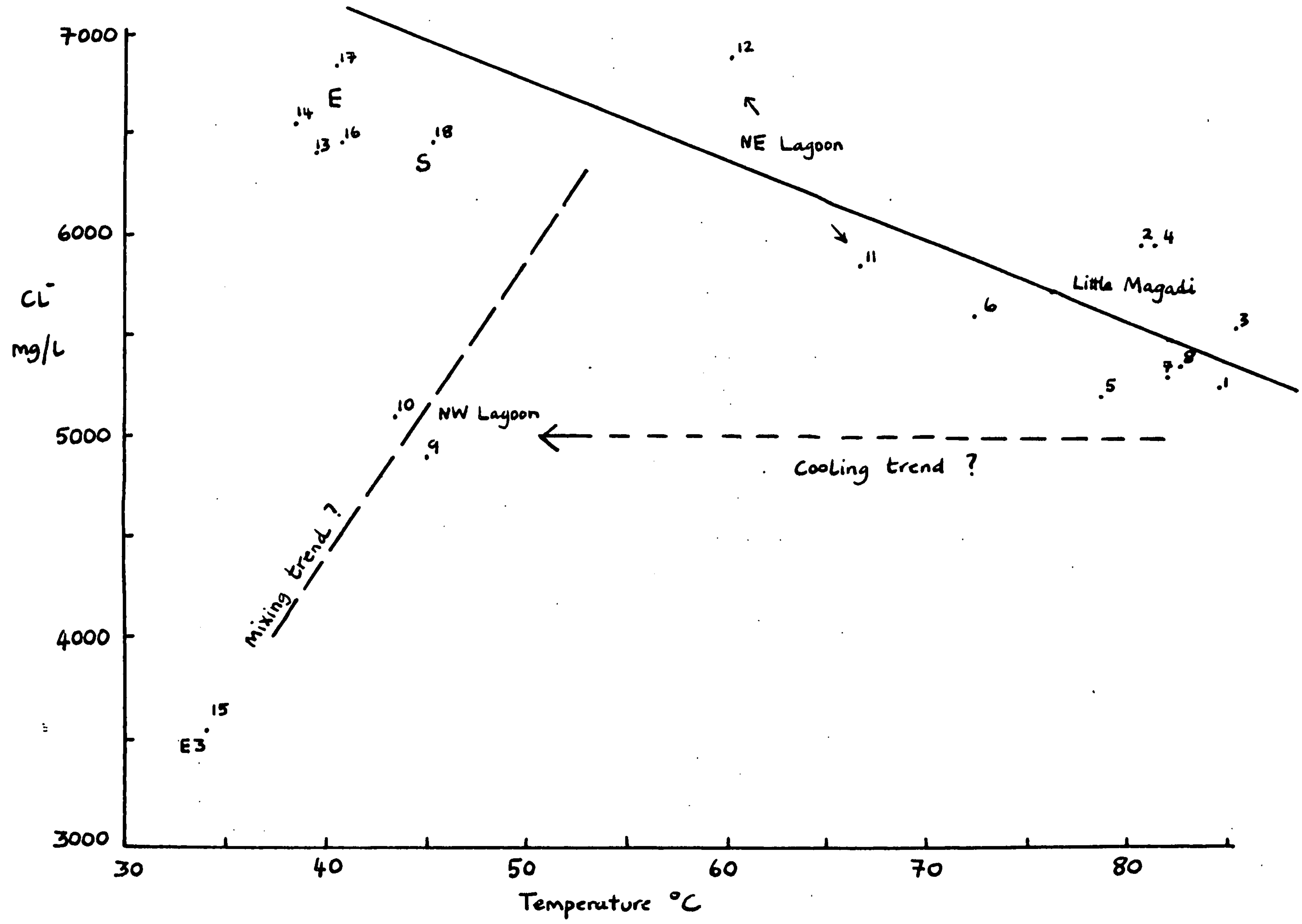


Figure 4. Dissolved Chloride v. Discharge Temperature, Magadi Springs.

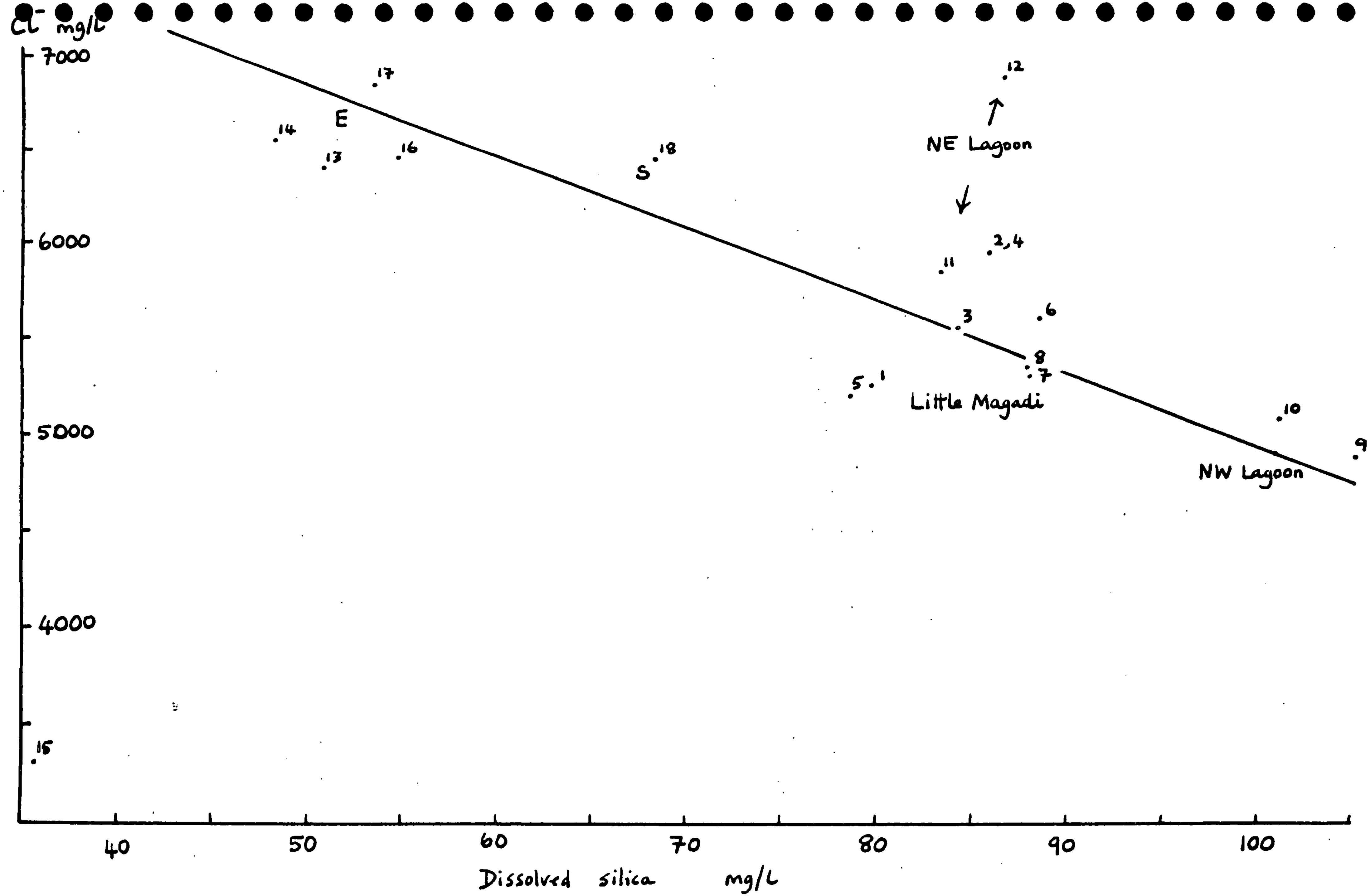


Figure 5. Dissolved Chloride v. Dissolved Silica, Magadi Springs.

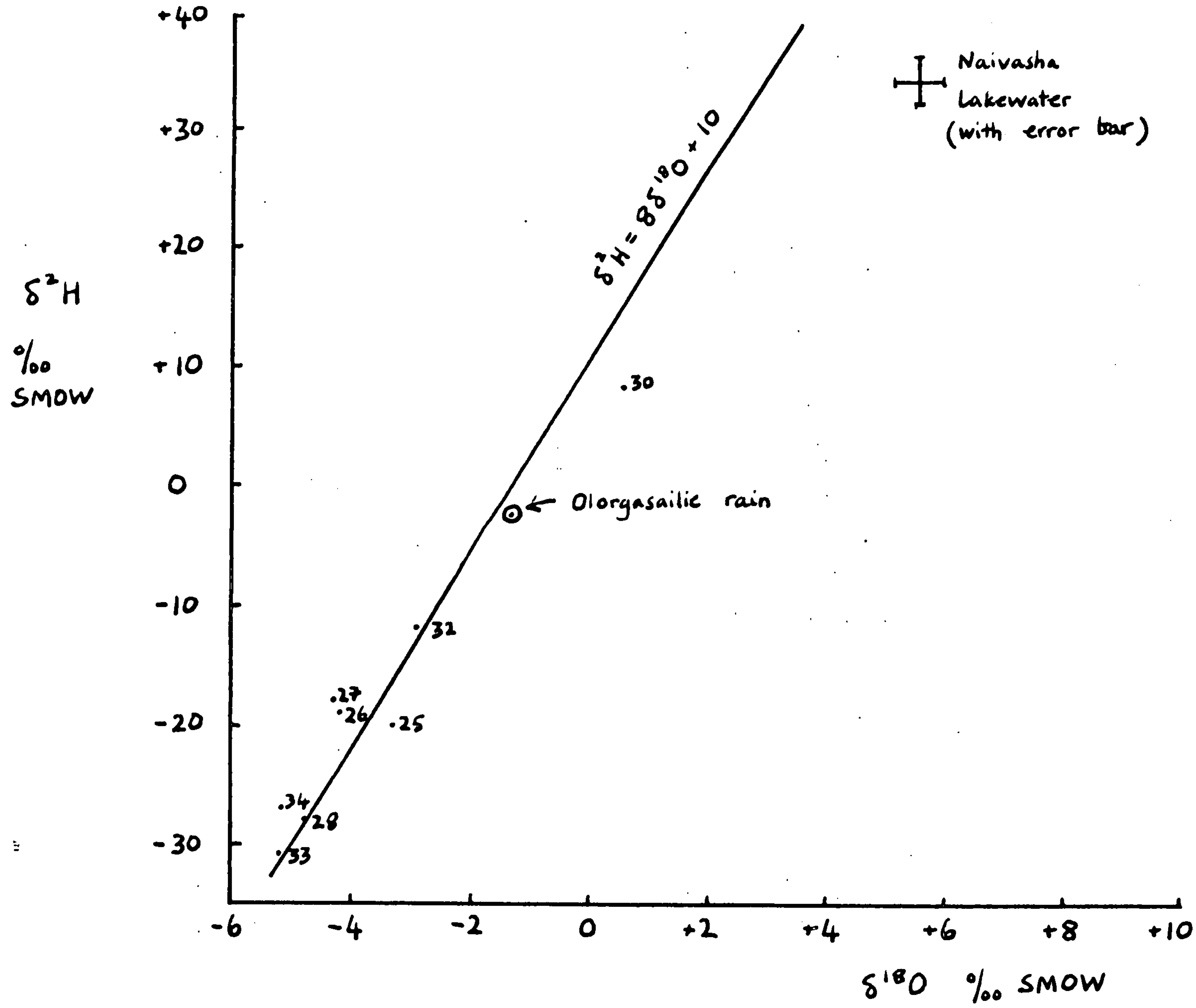


Figure 6. <u>$\delta^{18}O$ v. δ^2H, Longonot Region.</u>

Appendix I: Sample Location Details

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB　　Sample No: 85/965
   Date : 5/11/85
   Sample type: warm spring(s)
   Temperature: 40.8 °C [illegible]

2. Place name : Bird Rock Lagoon, Magadi (No. 1)
   Grid Ref. : AH 948 794　　1:50,000 No.: 160/4
   Altitude (m): 595 m
   Access notes: Direct access motorable track
   spring discharges into lake 1m from shore

3. Description of springs
   " Bird Rock Springs"
   Area of discharge 2 minor springs 5m apart (cf 85/966)
   Number of springs
   Flow rates (liters/second) 1 L/s
   Temperature (Max) 40.8
   Temperature (Range) —
   Conductivity (μmhos) 19,300
   pH 9.58
   Gas (amount and constancy) none
   Smell —
   Type of encrustation/alteration —
   Photograph WGB
   Notes

4. ~~Description of streams~~
   ~~Approx. flow rate (liter/second)~~
   ~~Conductivity (μmhos)~~
   ~~pH~~
   ~~Photograph~~
   ~~Notes (and Temperature)~~

....../2.

5. ~~Description of borehole sample~~
   ~~Sample depth~~
   ~~Discharge rate~~
   ~~pH~~
   ~~Conductivity (μmhos)~~
   ~~Stratigraphy/lithology~~
   ~~Notes (and Temperature)~~

6. ~~Descriptive notes of other samples (rainwater, lakewater)~~

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)
   none

   Other notes
   refer to other Magadi springs

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/966
Date : 5/11/85
Sample type: warm spring
Temperature: 40·5°C

2. Place name : Bird Rock Lagoon, Magadi (No.2)
Grid Ref. : AH 948 794 1:50,000 No.: 160/4
Altitude (m): 595m
Access notes: Direct access motorable track
spring discharges at lakeshore

3. Description of springs
"Bird Rock Springs"

Area of discharge 2 minor springs 5m apart (cf 85/965)
Number of springs
Flow rates (liters/second) 0·2 l/s
Temperature (Max) 40·5
Temperature (Range) –
Conductivity (μmhos) 19,300
pH
Gas (amount and constancy) –
Smell –
Type of encrustation/alteration –
Photograph WGB
Notes 5m south of Bird Rock 1

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/967
   Date : 6/11/85
   Sample type: Hot springs
   Temperature: 84.6 °C (1)

2. Place name : Little Magadi (1)
   Grid Ref. : AJ 973092 1:50,000 No.: 160/2
   Altitude (m): 610 m
   Access notes: via motorable track northwards to west of Magadi then to east of Little Magadi to escarpment edge above spring.

3. Description of springs

Area of discharge: Seeps & small springs over 500m along base of escarpment
Number of springs: 9
Flow rates (liters/second): 5 l/s (total ~ 50 l/s)
Temperature (Max): 84.6 °C
Temperature (Range): 70.5 - 84.6 °C
Conductivity (μmhos): 19,400
pH: 8.85 at 23°C
Gas (amount and constancy): —
Smell: —
Type of encrustation/alteration: —
Photograph
Notes: Seeps & springs discharge N/S along base of fault escarpment from phenocrystic lava

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/968
   Date : 6/11/85
   Sample type: Hot Spring
   Temperature: 80.7 °C

2. Place name : Little Magadi (2)
   Grid Ref. : AJ 970 094 — 1:50,000 No.: 160/2
   Altitude (m): 610 m
   Access notes: Walk across mudflat from Little Magadi 1

3. Description of springs

Area of discharge	One discrete spring
Number of springs	1
Flow rates (liters/second)	6
Temperature (Max)	80.7 °C
Temperature (Range)	—
Conductivity (µmhos)	19,430
pH	9.07 at 23 °C
Gas (amount and constancy)	—
Smell	—
Type of encrustation/alteration	—
Photograph	WGB
Notes	From lava faulted oblique to regional N/S trend

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (µmhos)
pH
Photograph
Notes (and Temperature)

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (µmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/969
   Date : 7/11/85
   Sample type: River
   Temperature: 25.5 °C

2. Place name : Ewaso Ngiro (Nguruman Game Outpost)
   Grid Ref. : AH 774957 — 1:50,000 No.: 160/3
   Altitude (m): 655 m
   Access notes: By road over bridge just east of Nguruman Game Out Post

3. Description of springs

   Area of discharge
   Number of springs
   Flow rates (liters/second)
   Temperature (Max)
   Temperature (Range)
   Conductivity (µmhos)
   pH
   Gas (amount and constancy)
   Smell
   Type of encrustation/alteration
   Photograph
   Notes

4. Description of streams

   Approx. flow rate (liter/second) ~ 500 l/s
   Conductivity (µmhos) 390
   pH 8.2 at 22 °C
   Photograph ✓
   Notes (and Temperature) River temperature 25.5 °C, air temp. 27.7 °C, flow moderately turbid, brown + muddy

   see 85/[illegible]

..../2.

5. Description of borehole sample

   Sample depth
   Discharge rate
   pH
   Conductivity (µmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)

   Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/970
   Date : 7/11/85
   Sample type: River
   Temperature: 21.5 °C

2. Place name : R. Oloitortoto
   Grid Ref. : AJ 712001 — 1:50,000 No.: 160/3
   Altitude (m): 800 m
   Access notes: At end of motorable track to Nguruman escarpment.

3. Description of springs

   Area of discharge
   Number of springs
   Flow rates (liters/second)
   Temperature (Max)
   Temperature (Range)
   Conductivity (μmhos)
   pH
   Gas (amount and constancy)
   Smell
   Type of encrustation/alteration
   Photograph
   Notes

4. Description of streams

   Approx. flow rate (liter/second) ~ 1000 L/s
   Conductivity (μmhos) 91.5
   pH 7.9 at 22°C
   Photograph x
   Notes (and Temperature) River presumed fed from Nguruman escarpment springs (1000 - 1400 m). Marble, quartz-mica schist and gneissic cobbles from scarp abundant.

..../2.

5. Description of borehole sample

   Sample depth
   Discharge rate
   pH
   Conductivity (μmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)

   Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/971
Date : 7/11/85
Sample type: spring
Temperature: 45·0 °C

2. Place name : Magadi NW Lagoon (1)
Grid Ref. : AH 903954 1:50,000 No.: 160/3
Altitude (m): 600 m
Access notes: Short (25 m) walk north along lakeside from causeway road.

3. Description of springs

Area of discharge: intermittent seeps and springs over > 1 km
Number of springs: Many
Flow rates (liters/second): 0·1 – 2·0 L/s 1–2 L/s
Temperature (Max): 45·0 °C 45·0 °C
Temperature (Range): 30 – 45 °C
Conductivity (μmhos): > 20 mS
pH: 8·82 at 22 °C
Gas (amount and constancy): —
Smell: —
Type of encrustation/alteration: minor
Photograph: X
Notes: Ambient temperature 26·3 °C

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/972
   Date : 7/11/85
   Sample type: spring (hot)
   Temperature: 43.5 °C

2. Place name : Magadi NW Lagoon (2)
   Grid Ref. : AH 904953 — 1:50,000 No.: 160/3
   Altitude (m): 600m
   Access notes: Adjacent to causeway road on lakeside.

3. Description of springs

   Area of discharge: intermittent springs and seeps over > 1km
   Number of springs: many (small)
   Flow rates (liters/second): 0.1 – 2.0 l/s (2 l/s)
   Temperature (Max): 45.0 °C (43.5 °C)
   Temperature (Range): 30 – 45 °C
   Conductivity (μmhos): 19.89 mS
   pH: 8.81 at 22 °C
   Gas (amount and constancy): —
   Smell: —
   Type of encrustation/alteration: minor
   Photograph: x
   Notes: Ambient temperature 26.3 °C

4. Description of streams

   Approx. flow rate (liter/second)
   Conductivity (μmhos)
   pH
   Photograph
   Notes (and Temperature)

5. Description of borehole/sample

   Sample depth
   Discharge rate
   pH
   Conductivity (μmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   none

   Hydrothermal alteration (general description, ?sample)

   Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/973
Date : 8/11/85
Sample type: Hot spring
Temperature: 85.3 °C

2. Place name : Little Magadi (3)
Grid Ref. : AJ 967092 1:50,000 No.: 160/2
Altitude (m): 610 m
Access notes: Easy walking from Little Magadi 1. spring is directly on shoreline

3. Description of springs

Area of discharge 2 main springs 10 m apart on shore
Number of springs 3 discrete springs (one from lakefloor)
Flow rates (liters/second) 1-3 L/s (3 L/s)
Temperature (Max) 85.5 °C (85.3 °C)
Temperature (Range) 84-86 °C
Conductivity (μmhos) 19.57 mS
pH
Gas (amount and constancy) no
Smell no
Type of encrustation/alteration none
Photograph x
Notes discharge from vesicular basalt.
Spring 10m to NE 84.3 °C, 1 L/s; from lake bottom 85.5 °C

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/974
   Date : 8/11/85
   Sample type: Hot spring
   Temperature: 81.3 °C

2. Place name : Little Magadi (4)
   Grid Ref. : AJ968090 1:50,000 No.: 160/2
   Altitude (m): 610 m
   Access notes: Easy walking from Little Magadi 1
   One spring from shore, several assoc. from lake.

3. Description of springs

   Area of discharge } several springs seen rising in lake
   Number of springs } 2-3 m from shore over ~ 20 m
   Flow rates (liters/second) 5 L/s
   Temperature (Max) 81.3
   Temperature (Range) –
   Conductivity (μmhos) 19.99 mS
   pH
   Gas (amount and constancy) no
   Smell no
   Type of encrustation/alteration no
   Photograph x
   Notes

4. Description of streams

   Approx. flow rate (liter/second)
   Conductivity (μmhos)
   pH
   Photograph
   Notes (and Temperature)

....../2.

5. Description of borehole sample

   Sample depth
   Discharge rate
   pH
   Conductivity (μmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)

   none

   Other notes

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB
Date : 8/11/85
Sample type: Hot spring
Temperature: 78.6 °C

Sample No: 85/975

2. Place name : Little Magadi (5)
Grid Ref. : AJ 965099 1:50,000 No.: 160/2
Altitude (m): 610 m
Access notes: Easy walking from Little Magadi 1

3. Description of springs

Area of discharge } One discrete spring is source of
Number of springs } rivulet
Flow rates (liters/second) 3 l/s
Temperature (Max) 78.6 °C
Temperature (Range) –
Conductivity (μmhos) 19.7 mS
pH
Gas (amount and constancy) –
Smell –
Type of encrustation/alteration –
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/976
   Date : 8/11/85
   Sample type: Hot spring discharge (river)
   Temperature:

2. Place name : Little Magadi (6 : hot river)
   Grid Ref. : AJ 962098 1:50,000 No.: 160/2
   Altitude (m): 615 m
   Access notes: Easy walking from Little Magadi 1

3. Description of springs

   Area of discharge: Over 1000m on either side of river
   Number of springs: 5 major springs, many seeps
   Flow rates (liters/second): 0.5 – ~5 L/s
   Temperature (Max): 83.2 °C
   Temperature (Range): 82 - 83 °C
   Conductivity (µmhos): 19.6 mS
   pH: 9.1 at 22 °C
   Gas (amount and constancy): –
   Smell: –
   Type of encrustation/alteration: –
   Photograph: ✓
   Notes: Air temperature 28.7 °C.

4. Description of streams

   Approx. flow rate (liter/second): < 1000 L/s
   Conductivity (µmhos): –
   pH
   Photograph
   Notes (and Temperature): 72.4 °C, river takes springwater at 82 – 83 °C from discrete springs, hot pools and seepages over about 1 km (to north of sampling point).

....../2.

5. ~~Description of borehole/sample~~

   Sample depth
   Discharge rate
   pH
   Conductivity (µmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. ~~Descriptive notes of other samples (rainwater, lakewater)~~

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)

   none

   Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/977
Date : 8/11/85
Sample type: Hot spring
Temperature: 82.0°C

2. Place name : Little Magadi (7)
Grid Ref. : AJ 961 101 — 1:50,000 No.: 160/2
Altitude (m): 615 m
Access notes: Easy walking from Little Magadi 1

3. Description of springs

Area of discharge } see 85/976
Number of springs }
Flow rates (liters/second) 4.0 L/s
Temperature (Max) 82.0 °C
Temperature (Range)
Conductivity (μmhos)
pH 9.18 at 22 °C
Gas (amount and constancy) —
Smell —
Type of encrustation/alteration —
Photograph
Notes Air temp. 28.7°C. Major spring discharging from base of scarp on west side of river.

4. Description of streams

Approx. flow rate (liter/second) }
Conductivity (μmhos) }
pH } see 85/976
Photograph }
Notes (and Temperature) }

5. Description of borehole/sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB
   Sample No: 85/978
   Date : 8/11/85
   Sample type: Hot spring
   Temperature: 82.6 °C

2. Place name : Little Magadi (8)
   Grid Ref. : AJ 962 105
   1:50,000 No.: 160/2
   Altitude (m): 615 m
   Access notes: Easy walking from Little Magadi 1

3. Description of springs

   Area of discharge / Number of springs: see 85/976 ; 85/978 + seeps at base of small scarp on E of main estuary
   Flow rates (liters/second): 0.5 l/s , total 10-20 l/s
   Temperature (Max): 82.6 °C
   Temperature (Range): 82.0 - 82.8 °C
   Conductivity (µmhos): 19.6 mS
   pH: 9.13 at 22 °C
   Gas (amount and constancy): —
   Smell: —
   Type of encrustation/alteration: —
   Photograph
   Notes

4. Description of streams

   Approx. flow rate (liter/second)
   Conductivity (µmhos)
   pH
   Photograph
   Notes (and Temperature)

....../2.

5. Description of boreholes

   Sample depth
   Discharge rate
   pH
   Conductivity (µmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)

   none

   Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/979
Date : 9/11/85
Sample type: Hot spring
Temperature: 45.3 °C

2. Place name : Lake Magadi South (1)
Grid Ref. : AH 919783 1:50,000 No.: 160/3
Altitude (m): 590 m
Access notes: By motorable track via eastern shore of lake from Magadi

3. Description of springs

Area of discharge / Number of springs: several springs & seeps over area 750 (N-S) m x 100 m (E-W)
Flow rates (liters/second): Total ≈ 100 L/s 3-4 L/s
Temperature (Max): 45.3 °C 45.3 °C
Temperature (Range): 41 – 45 °C
Conductivity (µmhos): 19.45 mS
pH: 9.57 at 22 °C
Gas (amount and constancy): minor amount
Smell: —
Type of encrustation/alteration
Photograph: ✓
Notes: Ambient temperature 30.5 °C
springs discharge from fissures in (cemented surface)

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (µmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (µmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/980

1. Sampled by : WGB
Date : 9/11/85
Sample type: Warm spring
Temperature: 39.5 °C

2. Place name : Lake Magadi East (1) (Grahams Lagoon)
Grid Ref. : AH963834 1:50,000 No.: 160/4
Altitude (m): 595 m
Access notes: Steep walk down from southern end of Magadi airstrip.

3. Description of springs

Area of discharge } several small springs & seepages
Number of springs } of which 85/980 is the dominant 5 L/s
Flow rates (liters/second) 0.5 – 5.0 L/s
Temperature (Max) 39.5 °C
Temperature (Range) 38 – 39 °C
Conductivity (μmhos)
pH 9.56 at 22 °C
Gas (amount and constancy) —
Smell —
Type of encrustation/alteration —
Photograph x
Notes Ambient shade temperature 27.4 °C

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. [illegible]

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Description [illegible] lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type [illegible] activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/981

1. Sampled by : WGB
Date : 9/11/85
Sample type: Warm spring
Temperature: 39.5

2. Place name : Lake Magadi East (2) (Grahams Lagoon)
Grid Ref. : AH 964 835 1:50,000 No.: 160/4.
Altitude (m): 595 m
Access notes: Steep walk down from southern end of Magadi airstrip. 100 m north of 85/980.

3. Description of springs

Area of discharge }
Number of springs } 20 m seepage area with 3-4 small springs. 85/981 most northerly.
Flow rates (liters/second) < 0.5 L/s
Temperature (Max) 39.5
Temperature (Range) 38.2 - 39.5
Conductivity (μmhos)
pH 9.56 at 22°C
Gas (amount and constancy) —
Smell —
Type of encrustation/alteration —
Photograph x
Notes Ambient shade temperature 27.4°C

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/982

1. Sampled by : WGB
Date : 10/11/85
Sample type: ~~Hot~~ spring
Temperature: 66.6 °C

2. Place name : Magadi NE Lagoon (1)
Grid Ref. : BJ 001059 1:50,000 No.: 160/4
Altitude (m): 640m
Access notes: 5 mile cross country walk from road at southern end of Olentonai Escarpment

3. Description of springs

Area of discharge / Number of springs: 3 spring discharge zones over ~1km assoc. with narrow 'graben' at N of NE Lagoon 85/982 from middle zone (85/982)
Flow rates (liters/second): Total 5 L/s
Temperature (Max): 66.6 °C
Temperature (Range): 65-67 °C
Conductivity (µmhos): 19.66 mS
pH: 8.96 at 22 °C
Gas (amount and constancy): —
Smell: —
Type of encrustation/alteration: —
Photograph: ✓
Notes: All zones on E side of small graben & ? controlled by W'ward downthrowing fault zone well exposed immediately E of 85/982 displacing pyroclastics against chilled lower margin of upper lava.

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (µmhos)
pH
Photograph
Notes (and Temperature)

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (µmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)
none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/983
Date : 10/11/85
Sample type: Hot Spring
Temperature: 60.2 °C

2. Place name : Magadi NE Lagoon (2)
Grid Ref. : AJ 999054 — 1:50,000 No.: 160/4
Altitude (m): 640 m
Access notes: 5 mile cross country walk from road at southern end of Olentonai Escarpment

3. Description of springs

Area of discharge } see 85/982
Number of springs }
Flow rates (liters/second) Total 5 l/s (85/983)
Temperature (Max) 60.5 °C
Temperature (Range) 60.2 – 60.5 °C
Conductivity (μmhos) 19.99 mS
pH 9.13 at 22°C
Gas (amount and constancy) —
Smell —
Type of encrustation/alteration —
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

5. Description of boreholes

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

..../2.

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/984
Date : 11/11/85
Sample type: Warm Spring
Temperature: 34·0 °C

2. Place name : L. Magadi East (3)
Grid Ref. : AH 999 888 1:50,000 No.: 160/4
Altitude (m): 595 m
Access notes: Easy walk road/rail crossing E of Magadi

3. Description of springs

Area of discharge ~ 2m diam
Number of springs ~3
Flow rates (liters/second) Total 3-4 l/s
Temperature (Max) 34·0 °C
Temperature (Range) 34·0 °C
Conductivity (μmhos) 19·66 mS
pH 9·86 at 22 °C
Gas (amount and constancy) —
Smell —
Type of encrustation/alteration —
Photograph
Notes Two other springs to north towards road
1) 33·1, 0·3 l/s 2) 34·2 °C, 0·5 l/s

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/985

Date : 11/11/85

Sample type: Pumped borehole

Temperature: — (taken from storage tank)

2. Place name : Olorgasailie (Oltepesic b/h)

Grid Ref. : BJ 181 278 — 1:50,000 No.: 160/2

Altitude (m): 990m

Access notes: Motorable tracks to Oltepesi village, (b/h), and to Olorgasailie (tank) from main road.

3. Description of springs

Area of discharge

Number of springs

Flow rates (liters/second)

Temperature (Max)

Temperature (Range)

Conductivity (μmhos)

pH

Gas (amount and constancy)

Smell

Type of encrustation/alteration

Photograph

Notes

4. Description of streams

Approx. flow rate (liter/second)

Conductivity (μmhos)

pH

Photograph

Notes (and Temperature)

5. [illegible]

Sample depth ?

Discharge rate ?

pH 8.8 at 22°C

Conductivity (μmhos) —

Stratigraphy/lithology

Notes (and Temperature) Pump installed + no access to b/h;

6. Description [illegible] (groundwater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Vol[illegible]

Hydrothermal alteration (general description, ?sample)

none

Other notes

..../2.

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/986

1. Sampled by : WGB
   Date : 11/11/85
   Sample type: Lake Magadi 'liquor'
   Temperature: —

2. Place name : Magadi Lake causeway
   Grid Ref. : AH 970921 1:50,000 No.: 160/4
   Altitude (m): 595 m
   Access notes: From motorable causeway

3. Description of springs

   Area of discharge
   Number of springs
   Flow rates (liters/second)
   Temperature (Max)
   Temperature (Range)
   Conductivity (µmhos)
   pH
   Gas (amount and constancy)
   Smell
   Type of encrustation/alteration
   Photograph
   Notes

4. Description of streams

   Approx. flow rate (liter/second)
   Conductivity (µmhos)
   pH
   Photograph
   Notes (and Temperature)

5. Description of borehole sample

   Sample depth
   Discharge rate
   pH
   Conductivity (µmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

   30 cc. (untreated) collected in glass bottle for isotopic analysis, from surface brine.

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)

   —

   Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/987

1. Sampled by : WGB
   Date : 7, 8, 10/11/85
   Sample type: rainfall
   Temperature:

2. Place name : Olorgasailie
   Grid Ref. : BJ 156 256
   1:50,000 No.: 160/2
   Altitude (m): 980 m
   Access notes: Motorable track from Nairobi - Magadi road

3. Description of springs

   Area of discharge
   Number of springs
   Flow rates (liters/second)
   Temperature (Max)
   Temperature (Range)
   Conductivity (µmhos)
   pH
   Gas (amount and constancy)
   Smell
   Type of encrustation/alteration
   Photograph
   Notes

4. Description of streams

   Approx. flow rate (liter/second)
   Conductivity (µmhos)
   pH
   Photograph
   Notes (and Temperature)

5. Description of borehole, etc.

   Sample depth
   Discharge rate
   pH
   Conductivity (µmhos)
   Stratigraphy/lithology
   Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

   rainfall of short rains collected 09.00 am following heavy rain over preceding 24 hrs
   6-7/11 5.8 mm
   7-8/11 25.8 mm
   9-10/11 3.5 mm

7. Description of geological setting

   Faulting (field evidence, photo interpretation)

   Volcanism (age and type of associated activity)

   Hydrothermal alteration (general description, ?sample)

   Other notes

..../2.

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/988

1. Sampled by : WGB
Date : 16/11/85
Sample type: Hot spring
Temperature: 51·2 °C

2. Place name : Maji ya Moto (1) upper spr.
Grid Ref. : ZP 013521   1:50,000 No.: 146/3
Altitude (m): 1935 m
Access notes: Easy few 100 m walk from village after motorable track from Narok - Keekorok road

3. Description of springs

Area of discharge: 2 discrete springs ~ 1 m diam each
Number of springs: 2 springs as source of warm stream
Flow rates (liters/second): 2-3 L/s ; total ~8 L/s
Temperature (Max): 51 - 52 °C Max. 52·5 °C
Temperature (Range)
Conductivity (μmhos): 390
pH: 7·25 at 25 °C
Gas (amount and constancy): —
Smell: —
Type of encrustation/alteration: —
Photograph: ✓
Notes: Spring bed covered with disaggregated grains of granitic/gneissic rock

4. Description of streams

Approx. flow rate (liter/second): 8 L/s
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. Description of [illegible]

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/489
Date : 16/11/85
Sample type: Hot spring
Temperature: 52.5 °C

2. Place name : Maji ya Moto (2, lower spring)
Grid Ref. : ZP 013522 1:50,000 No.: 146/3
Altitude (m): 1935 m
Access notes: see 85/488

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (μmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

(all of the above:) see 85/488

4. Description of streams

Approx. flow rate (liter/second) 8 l/s
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

....../2.

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/440
Date : 16/11/85
Sample type: river
Temperature: 22.2 °C

2. Place name : Ewaso Ngiro
Grid Ref. : [illegible] 0?0?[illegible]0 1:50,000 No.: 146/2
Altitude (m): ~18[illegible] m
Access notes: At roadcrossing of Narok - Keekorok road with Ewaso Ngiro SW of Narok.

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (µmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second) ~ 750 l/s
Conductivity (µmhos) 184
pH 7.85 at 25 °C
Photograph x
Notes (and Temperature) see 85/469

Ambient shade temp. 27.2 °C
Discharge muddy

..../2.

5. [illegible]

Sample depth
Discharge rate
pH
Conductivity (µmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Description [illegible] lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanic [illegible] and [illegible] activity)

Hydrothermal alteration (general description, ?sample)

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB — Sample No: 85/991
Date : 17/11/85
Sample type: Warm spring
Temperature: 43·3

2. Place name : Kijabe
Grid Ref. : BJ 318980 — 1:50,000 No.: 134/3
Altitude (m): 2190 m
Access notes: Short clamber from motorable track. off Kijabe – Kijabe Railway Stn. road. Spring is directly above makeshift shower.

3. Description of springs

Area of discharge: One minor spring
Number of springs: + other seepages in area (possibly others)
Flow rates (liters/second): 1 l/s
Temperature (Max): 43·3 °C
Temperature (Range): 39 – 43 °C
Conductivity (µmhos): 372
pH: 9·05 at 24 °C
Gas (amount and constancy): —
Smell: —
Type of encrustation/alteration: —
Photograph: ✓
Notes: Spring piped to ad hoc shower & then flows to stream.

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (µmhos)
pH
Photograph
Notes (and Temperature)

....../2.

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (µmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85|992

1. Sampled by : WGB
Date : 17/11/85
Sample type: cold spring
Temperature: 16.9°C

2. Place name : Kijabe
Grid Ref. : BJ 318 981
1:50,000 No.: 134/3
Altitude (m): 2200 m
Access notes: upstream from 85/991, 'spring" from below aqueduct under railway.

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (µmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

see 85/991 for close by warm springs

4. ~~Description of streams~~

~~Approx. flow rate (liter/second)~~
~~Conductivity (µmhos)~~
~~pH~~
~~Photograph~~
~~Notes (and Temperature)~~

5. ~~Description of borehole sample~~

~~Sample depth~~
~~Discharge rate~~
~~pH~~
~~Conductivity (µmhos)~~
~~Stratigraphy/lithology~~
~~Notes (and Temperature)~~

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/993
Date : 17/11/85
Sample type: pumped borehole
Temperature: ~ 35 °C

2. Place name : Kijabe Rift Valley Academy
Grid Ref. : 1:50,000 No.: 134/3
Altitude (m): 2200
Access notes: On RVA 'campus' - main supply b/h

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (µmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (µmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. [illegible] borehole c.4635

Sample depth ? borehole 110m deep
Discharge rate 1385 gph
pH 7.95 at 24 °C
Conductivity (µmhos) -
Stratigraphy/lithology
Notes (and Temperature) 30-40 °C (estimate)
Ambient T 24 °C ; RWL 18.6 m; sampled from side valve

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/444

1. Sampled by : WGB
Date : 18/11/85
Sample type: Fumarole condensate
Temperature: 87.2 °C

2. Place name : Mt. Margaret
Grid Ref. : BJ 273887
1:50,000 No.: 148/1
Altitude (m): 1850 m
Access notes: 20 minutes walk from track to NW side of Mt. Margaret.

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (μmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

Altered ground, steaming, on ledge to west of (dry) valley. Condensate (neutral pH) collected using plastic funnels. see field notes.

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)
see field notes

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WG&B — Sample No: 85/495
Date : 18/11/85
Sample type: warm spring
Temperature: 27.9°C

2. Place name : Mayers Farm (base of Kikuyu Escarpment)
Grid Ref. : [illegible] — 1:50,000 No.: 148/1
Altitude (m): ~ [illegible]
Access notes: Springs above Mayers old farmhouse. Major supply of region.

3. Description of springs

Area of discharge: several m^2
Number of springs: several, to large ponds
Flow rates (liters/second): 20-30 l/s
Temperature (Max): 27.9°C
Temperature (Range): 26 - 28 °C
Conductivity (µmhos): 243
pH
Gas (amount and constancy): —
Smell: —
Type of encrustation/alteration: —
Photograph
Notes

4. ~~Description of streams~~

~~Approx. flow rate (liter/second)~~
~~Conductivity (µmhos)~~
~~pH~~
~~Photograph~~
~~Notes (and Temperature)~~

..../2.

5. [illegible]

Sample depth
Discharge rate
pH
Conductivity (µmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Description [illegible] (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanics [illegible]

Hydrothermal alteration (general description, ?sample)

none

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB Sample No: 85/996
Date : 18/11/85
Sample type: Condensate
Temperature: N/A (borehole discharge not accessible)

2. Place name : Akira Ranch
Grid Ref. : [illegible] 1:50,000 No.: 133/4
Altitude (m): ~ 17[illegible] m
Access notes: track (motorable with difficulty) from Nairobi - Narok road towards Naivasha

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (µmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (µmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. Description of borehole sample:

Sample depth Condensate from steam/water b/h discharge
Discharge rate < .5 l/s
pH neutral
Conductivity (µmhos) —
Stratigraphy/lithology
Notes (and Temperature) capped with oil drum, discharge piped uphill then back to condense to storage tank

6. Descriptive notes of other samples (rainwater, lakewater)

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK, MERD DATASHEET FOR WATER SAMPLES

Sample No: 85/44?

1. Sampled by : (WGB)
Date : 19/11/85
Sample type: surface pond
Temperature: –

2. Place name : Suswa wells
Grid Ref. : BJ 022693
1:50,000 No.: 147/2
Altitude (m): 2000 m
Access notes:

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (μmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

..../2.

5. Description of borehole sample

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

Maasai have ponded surface runoff to use as watering points.

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

Other notes

KENYA RIFT VALLEY GEOTHERMAL PROJECT

BGS/GOK; MERD DATASHEET FOR WATER SAMPLES

1. Sampled by : WGB   Sample No: 85/998
Date : 20/11/85
Sample type: lakewater
Temperature: —

2. Place name L.Naivasha Crescent Island
Grid Ref. : BK 109150   1:50,000 No.: 133/4
Altitude (m): 1890 m
Access notes: Sample collected from shore close to jctty

3. Description of springs

Area of discharge
Number of springs
Flow rates (liters/second)
Temperature (Max)
Temperature (Range)
Conductivity (μmhos)
pH
Gas (amount and constancy)
Smell
Type of encrustation/alteration
Photograph
Notes

4. Description of streams

Approx. flow rate (liter/second)
Conductivity (μmhos)
pH
Photograph
Notes (and Temperature)

5. [illegible]

Sample depth
Discharge rate
pH
Conductivity (μmhos)
Stratigraphy/lithology
Notes (and Temperature)

6. Descriptive notes of other samples (rainwater, lakewater)

Sample taken for isotope analysis

7. Description of geological setting

Faulting (field evidence, photo interpretation)

Volcanism (age and type of associated activity)

Hydrothermal alteration (general description, ?sample)

Other notes