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CHAPTER FOUR

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4.1 Introduction

The quality of ground water is of vital importance in arid and semi-arid areas where ground water forms the major sources for municipal, agricultural and domestic water supplies. The quality of ground water in the area under study is of almost equal importance as the quantity.

The study of water chemistry involves a description of the occurrence of the various constituents in ground water and the relation of these constituents to the aquifer material since the aquifer is the major source of solutes in water. The way in which solutes are taken up or precipitated, and the amounts present in solution in the ground water are influenced by several factors, especially the composition of water-bearing materials, biochemical activities associated with life cycles of plants animals, both microscopic and macroscopic and other environmental factors like climate, geological structure and position of aquifers.

Ground water quality data provides important clues to the geological conditions of the aquifer, water-rock interactions as well as giving indications of ground water recharge, discharge, movements, and storage.

Field determinations of approximate chemical characters of water are often useful. These include determination of specific electrical conductance, simple chemical tests for chloride, hardness, and alkalinity, hydrogen ion activity (pH) and colorimetric determination of some constituents like nitrates. Physical measurements in the field are also useful such as water temperature, color, taste, clarity and odour However, field testing is inherently less accurate than work done in a laboratory.

The general chemical analysis of ground water includes the determination of the concentrations of the major inorganic constituents dissolved in water. This includes the major cations, (positively charged ions) and anions (negatively charged ions) present in natural water. Biological analyses generally consist of tests in connection with water suitability for domestic use, pollution signs and bacterial population. The bacterial analysis generally consists of tests to detect the presence of the different coliform organisms. However, some bacterial analysis is also useful for an understanding of the biochemical conditions in the thermal and mineral waters associated with economic mineral deposits. Dissolved gases like CO_2, H_2S and O_2 are also reported in some ground water analysis together with some radionuclides.

Minor chemical constituents in ground water are useful for the study of tracer elements and for the understanding of solute sources. All the chemical constituents excluding HCO_3^-, Cl^-, SO_4^{2-}. Ca^{2+}, Mg^{2+}, Na^+ K^+ and NO_3^- are considered as minor in their occurrence due to their low concentration in relation to the other constituents dissolved in the natural water.

4.2. Collection and analysis of water samples

Ground water sampling technique is different from surface water sampling and far more important in the study of water chemistry in relation to the aquifer. With surface water sampling, location of sample and source can easily be defined while with ground water sampling the source of water could be from any of the different horizons penetrated by the same well. This makes ground water sampling more critical and could be a major source of

error in the whole process of obtaining water-quality information, especially when the sampling locations are limited to a few sites. The sampling of a major homogeneous aquifer is a simple matter, and the sampling locations could be far apart. Because most water-bearing materials are not homogeneous horizontally and vertically, obtaining truly representative samples depends to a great degree upon the sampling technique.

Ground-water sampling was carried out within the period of field work. Water was collected from various springs and wells for detailed chemical analysis, and at the same time, temperature, pH and electrical conductivity of the water were measured at the site, as well as subsequently in the laboratory. Special samples were taken for determination of dissolved H_2S and for bacterial counting from the Lower Fars aquifers. H_2S sample bottles of 100 ml. capacity were provided with a solution of 4 ml. 20 percent zinc acetate ($Zn(CH_3CO)_2$) and 1 ml sodium hydroxide (NaOH). These absorbents prevented the escape of H_2S from the water until the analysis was carried out in the laboratory.

Polythene bottles of one litre capacity were used for sampling. The majority of these bottles are without internal sealing caps which has produced air bubbles that might have affected the stability of the carbon or bicarbonate in the sample and hence the pH of water. All the samples collected within the period of field work were analysed in the analytical laboratory of the Institute of Applied Research on Natural Resources (IARNR) in Baghdad. The techniques used for water analysis are the standard methods of water analysis as specified by the American Public Health Association and others (1955). A total of

191 samples were collected from different wells, springs kahrez and water bodies. The locations of the sample points are shown in Figure 47.

The distribution of the sampled points in the area were selected according to the field information. The northern parts of south Sinjar plain is relatively more populated than the southern Jezira and so is the density of wells. Not all the visited locations were sampled. At every new location, the water temperature, specific electric conductance and well depth were considered for the selection of a new sample. If the new location was similar to the preceding, the second area was considered identical and no sample taken. Similarly, a new sample was collected in case of any differences in the physical characteristics of water or if the distance from the preceding sample exceeds five kilometres.

The details of chemical constituents and trace elements may differ in waters of similar temperature and specific electric conductance, but the aim of this study was to understand the overall picture of ground water chemistry and to identify the different waters. Also the time and expenses allocated for this study did not allow for any further detailed sampling or analysis.

In some locations two sampling points were selected from each of an adjacent pair of deep well and shallow hand dug wells. In other locations sample spacing was up to 30 km., especially in the absence of wells or water sources. A net of sites was selected for a second sampling in order to study seasonal variations in water quality. Fifty two such samples were collected and analysed by the IARNR in March 1975.

The analyses done by the Ingra Consulting Department was also used for this study; 37 analyses were used taken from 21 drilled wells, and in 16 wells two analyses are available.

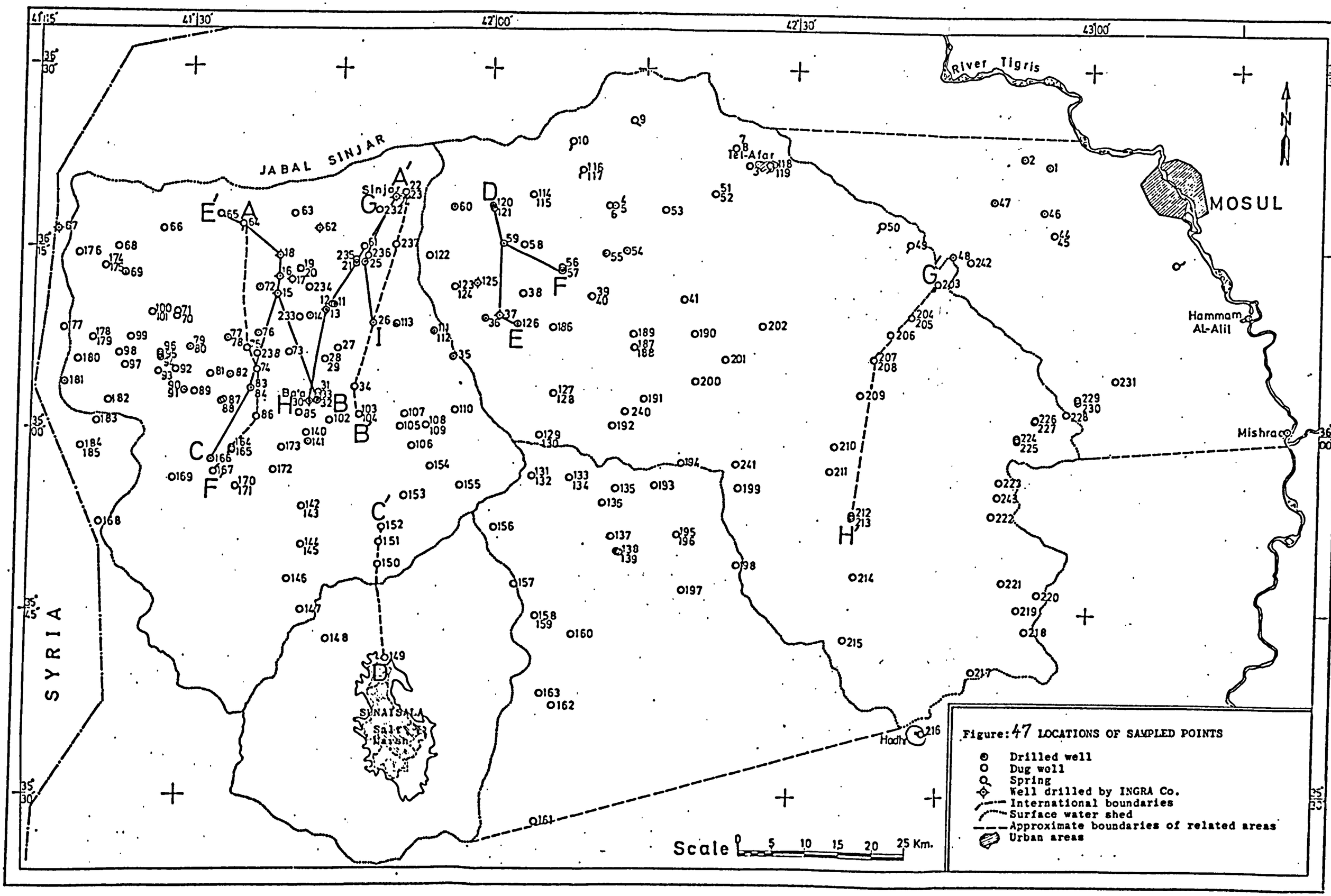

Figure: 47 LOCATIONS OF SAMPLED POINTS

- Drilled well
- Dug well
- Spring
- Well drilled by INGRA Co.
- International boundaries
- Surface water shed
- Approximate boundaries of related areas
- Urban areas

The samples collected by the Ground Water Department in Mosul on the completion of each new well were analysed in private laboratories in Baghdad. 27 such analyses were used from the drilled wells in the area of study over a period of about ten years, 1965-1975.

About 20 analyses of water taken from the Lower Fars formation were also used for this study. These water samples were collected by the author for the study of the thermal and mineral water in relation to the economic sulphur deposits in the area. Some selected analyses were taken from the mine field of Mishraq sulphur mine together with the analyses of the river Tigris water flowing across the structure. All the analyses done in the laboratories include the determination of the major elements in water together with its specific electric conductance, pH and physical properties. The major elements analysed in the laboratory includes the cations, Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} and the anions, HCO_3^{-}, Cl^{-} and SO_4^{2-}.

4.3 Interpretation of ground water analysis data:

All the available analyses including the new and old records were given equal value for the study of the source of mineralization and the classification of the different waters. The old records represent the results of analyses of waters collected at different times of the year over a period of about ten years. These samples collected within the period of field work represent the quality of water after the end of the wet season while most of the samples collected from the south Sinjar plain were taken within the period May to July 1974. They probably represent the water quality of the aquifer being recharged after the wet seasons of winter and spring.

Owing to the vast number of samples which need to be studied in detail, the interpretation was helped by the use of a computer. A detailed program was prepared to cover all the aspects of ground water interpretation which would otherwise have been tedious. An attempt has been made to distinguish the waters type collected from all the sites according to the main water-bearing materials from which they were derived. This problem was approached on both a geological and computer basis and the final results were correlated according to the different water facies developed over the area.

Of the 335 analyses of water samples in the area, only 10 analyses, in which the cation-anion imbalance was greater than 10 percent, were ignored. Five of the ignored analyses were from the results obtained from the IARNR, while 4 were provided by the Ground Water Department and one from Mishraq sulphur mine. A total of 104 analyses were available for the concentration of nitrates in ground water, 53 of these were analysed by the IARNR, 37 by Ingra Consulting Department, and 14 by the Ground Water Department in Mosul.

The dissolved H_2S gas and free CO_2 were determined for selected samples from over thirty locations in the Lower Fars formation. In some springs located in the northern and eastern parts of the area, the total available bacteria and the organic matters in water were analysed by the IARNR. These results were used for the study of the origin of the thermal and mineral waters in the area.

The only available hydrochemical study covering the whole of south Sinjar plain was the work done by Ralph M. Parsons Co. (1954) in their detailed report. Although their detailed chemical analyses were not available, the hydrochemical map

which shows the isoconcentration contours for the shallow and deep aquifers was reproduced as shown in Figure 48. This map was found very valuable for the comparison of water quality between the years of 1954 and the new analyses of 1974.

4.3.1. Computer interpretation of water analyses:

Two programs were devised by the author and a colleague from the Institute of Applied Research on Natural Resources, Mr Ramzi M. Haddad, to interpret and classify all the available water analyses from the area; both programs are listed in Appendix 3. The first program deals with the tabulation and interpretations of the different constituents in water, while the second program deals with the classification of ground water according to the ratio of various determined constituents. The preparation and application of these programs are explained below.

A The first computer program

The imput data are the concentrations of cations and anions in milliequivalent per litre as supplied from the analytical laboratory. The output of the program consists of four tables:-

1) Table 1, is the tabulation of 326 analyses. All the ion concentrations are in milliequivalent per litre. The sample number (SNO) does not have any relation to field or analysis number. The reference number (RFNO) of each sample indicates its analysis number in the laboratory, the type of source of water and the water bearing materials were allocated numbers for each character as follows: Ex. RFNO.10.25;

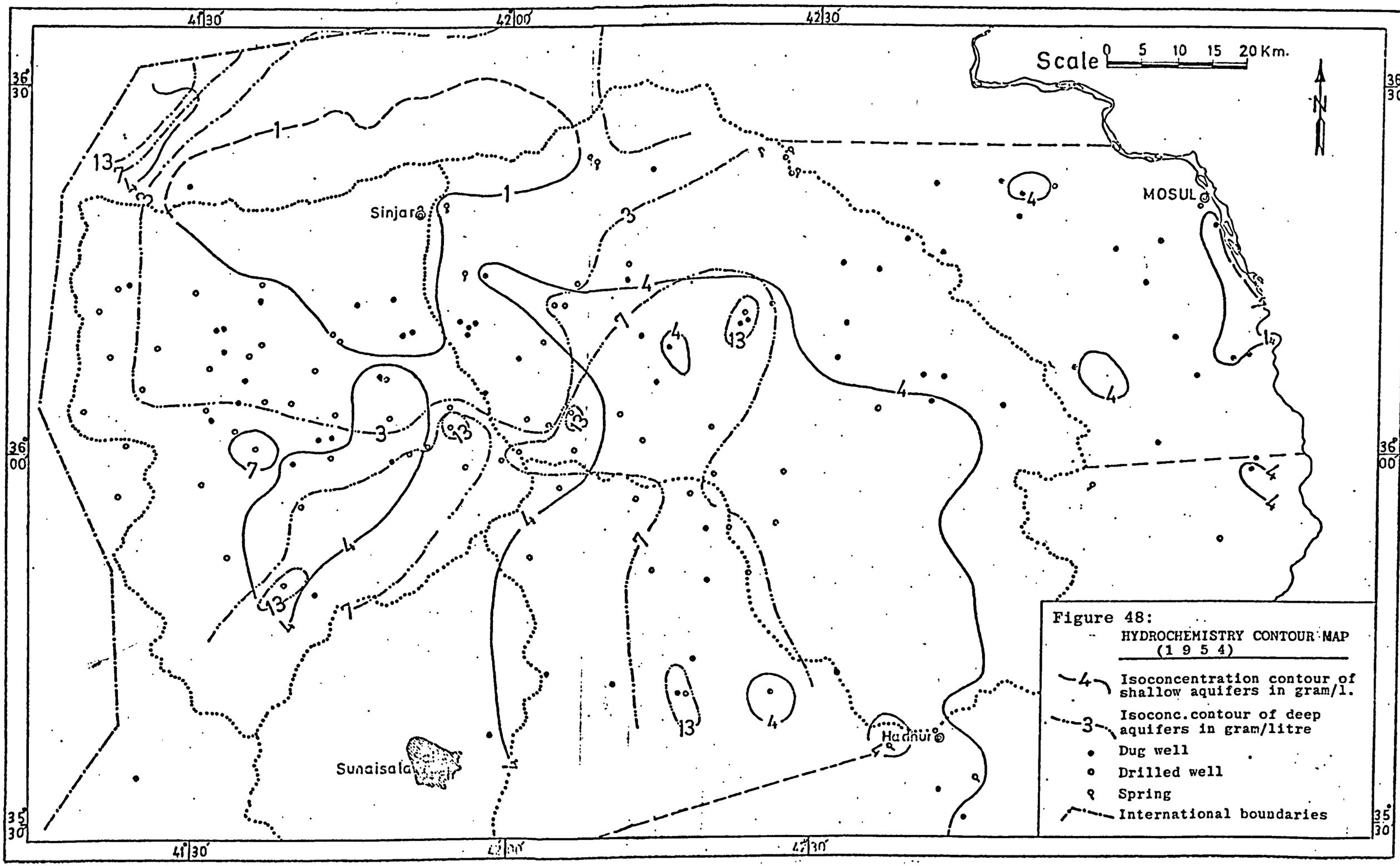
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Figure 48:
HYDROCHEMISTRY CONTOUR MAP
(1 9 5 4)
Isoconcentration contour of shallow aquifers in gram/l.
Isoconc.contour of deep aquifers in gram/litre
Dug well
Drilled well
Spring
International boundaries

10 is the analysis number or the sample location number in the field. The number 2 indicates the source of water. It could be from 1 to 5 as follows:- 1 = Hand dug well, 2 = Drilled well, 3 = Spring, 4 = Kahrez and 5 = River. Number 5 indicates the water bearing material for which the following numbers were allocated:- 1 = Alluvium aquifer and river water, 2 = Upper Fars aquifer, 3 = Lower Fars aquifer, 4 = Reworked Upper Fars and 5 = Mixed source and limestone aquifer.

The number 0.0 under NO_3 indicates that analyses for NO_3 were not carried out; the EC is the specific electric conductance measured in the laboratory in millimhos per centimeter at $25^{o}C$; CO_2 is the free carbon dioxide gas measured from water in milligram per litre; pH is the hydrogen ion concentration measured in the laboratory; TEMP is the field temperature of water in degrees centigrade, 0.0 indicates that no measurement has been made; DATE is the data of analyses. In fact the analyses of water samples collected in the field were carried out within a period of about two months but the majority of the water samples were analysed in June 1974, and March 1975.

The sample numbers (SNO) 1 to 243, Figure 48, were analysed by the IARNR, 191 of which were analysed in summer 1974 and 52 in March 1975. Samples 244 to 280 are the analyses obtained from Ingra Consulting Department report. The reference number (RFNO) opposite these analyses indicate Ingra well number together with the type of water-bearing materials. Samples 281 to 307 are the analyses made by the Ground Water Department in Mosul. The reference number opposite these samples indicate the number used by the above Department for their own record.

Samples 308 to 325 are the analyses of the thermal and mineral water from the Lower Fars aquifers. The reference number given for these analyses will be discussed in the Hydrogeochemistry chapter. Sample number 326 is the average of 44 analyses of water taken from the River Tigris at Mishraq sulphur mine.

2) Table 2 gives the cation concentrations in parts per million (PPM) and the percentage of each ion relative to the total cations in milliequivalent per litre. The total cations in milliequivalent per litre is shown under TOTAL CATION and the total soluble salt in water calculated from the result of analyses is shown under TSS in parts per million.

3) Table 3 provides the anion concentrations in parts per million (PPM) together with the percentage of each ion relative to the total anions in milliequivalent per litre. The total cations in milliequivalent per litre is shown under TOTAL ANIONS and the imbalance between the total cations and total anions is shown as percentage of error under % ERROR. The negative sign indicates that the total cations is less than the total anions.

4) Table 4 is the ratio and ionic strength tabulated as follows:-

TH is the total hardness calculated using the formula approved by the American Public Health Association (A.P.H.A., 1971) as shown in the statement 0034 of the program. All the ratios are in milliequivalent per litre. The ionic strength was calculated from the formula given by Hem (1970) as shown in the statement 0044 in the program.

The sodium adsorption ratio was calculated from the formula given by the U.S. Department of Agriculture Salinity Laboratory (1954) as stated in the statement 0035 in the program. All the results are tabulated under SAR column.

B Classification of ground water, second computer program:

The data cards of the first computer program were used as input data for this second program. It includes all the cations and anions expressed in milliequivalent per litre. Extensions of the concept of ion ratios to provide comprehensive classification of ground water over the whole area was made possible by the use of computer.

The complete program and the output tables are shown in Appendix 3. The purpose of this program is the quantitative study of the relationship among ions in terms of mathematical ratios to establish chemical similarities among the different waters. Fixed rules regarding selection of the most significant values to compare by ratios cannot be given, but some knowledge as to the types of aquifers, source of ions and the chemical behavious of water can aid in this selection. Water contamination with salt (sodium chloride) can be studied from the ratio of chloride to other ions. The predominant cations and anions in the Lower Fars water are different from the ions in the water of the Upper Fars or the alluvium.

The logarithm to the base 10, is taken for each of the cations and anions and the ratios were calculated by dividing the values of logarithms of each cation and anion. This is made to avoid dividing by zero which is

invalid in the computer. For this reason, all the values of cations and anions which are equal to zero (or not analysed) were given a value of 0.001.

The result of each of the seven selected ratios shown in the program was given a number which indicates if it were less than one, one or more than one. The procedure used to combine the seven ratios together in one code or group number is as follows:-

The results of the first ratio of Ca/Mg can be expressed as number 1,2 or 3

1 indicates that the ratio is less than 1
2 " " " " " equal to 1
3 " " " " " more than 1

The following six ratios were expressed by multiplying the allocated result by ten for each successive ratio, i.e. the second ratio of Mg/ (Na+K) indicated by either 10 (if it were less than 1), 20 (if it were equal to one) or 30 (if it were more than 1) and the third ratio of Ca/(Na+K) indicated by 100, 200 or 300 . The final results of the seven ratios are then added to form the group number for the sample.

The following example shows the procedure followed by the computer to name each sample:-

The sample collected from Shaikh Ibrahim spring, SN.50 represents a typical example of Lower Fars water. The concentration of the cations and anions in this sample can be expressed in the following simplified way:-

$$Ca > Mg > (Na + K), \quad SO_4 > HCO_3 > Cl$$

The results of the seven different ratios were interpreted by computer in the following sequence:-

1	Ca/Mg	=	3
2	Mg/(Na+K)	=	30
3	Ca/(Na+K)	=	300
4	(Na+K)/Cl	=	2000
5	Cl/SO_4	=	10000
6	SO_4/HCO_3	=	300000
7	Cl/HCO_3	=	1000000
		Total	1312333

The final group number given for this sample is the sum of the seven results. For this reason, the first number from the left in the code represents the seventh ratio and the seventh number represents the first ratio. The results of all the ratios and the group number are shown in Table 1 of the second computer program.

The final grouping of samples was made by correlating each of the group numbers through use of the second computer program. The similar groups were tabulated separately under Table 2_A p.357 then the average concentration of each of the cations and anions were tabulated opposite their group calculated in milliequivalent per litre and finally the average total dissolved salt were also tabulated under AV.TSS.

The final results which appear in Table 2_1 p.357 represent 36 different types of water. However, the main groups which represent most of the analyses are clearly identified. The minor groups represent waters in which slight deviation from the main group occur. This could either be due to a sudden

change in lithology or due to natural chemical reaction which takes place in ground water e.g. oxidation, reduction or ionic exchange.

Regrouping of the results provided by the computer is made to combine the minor groups with the major ones. The different types of water which show great similarity in their ionic constituents are grouped together. This is made by taking into consideration the similarities in the ratios of main ionic constituents, sample location and, where known, the lithology of the water-bearing materials.

The final number of groups which represent different waters in the area are shown in Table 12. Six main groups were clearly identified from the analyses. They are all shown in Table 12, as A,B, C, D, E and F. The groups A, B, C, and E represent waters from reworked Upper Fars, Lower Fars, Upper Fars and Alluvial aquifers respectively, while the groups D and F represent mixed waters. The origin of ionic constituents, gas contents, temperature and pH of ground water, together with the classification of water into different facies will be discussed in detail later in this chapter.

In general, the different groups of water can be represented in the same order as in the seven ratios used to identify each of them as follows:-

1) Group A, Reworked Upper Fars Water (99 analyses):

No. 3313313

$$Ca > Mg < (Na+K) > Cl < SO_4 > HCO_3$$

$$Ca > (Na+K) \qquad Cl > HCO_3$$

Table 12: Computer grouping of groundwater analyses.

Serial No.	Group number	Total No.	Group	Water Source	Prominent Salt & Remarks
1	3313313	57	A	RUF	$CaSO_4$, NaCl
2	1313333	48	B	LF	$CaSO_4$
3	3313333	37	C	UF	$CaSO_4$,$CaCl_2$
4	3313113	31	A	RUF	NaCl, Ca SO_4
5	3313111	22	D	Mixed	NaCl, Na_2SO_4 (B+C)
6	1113333	15	E	Alv.	Ca $(HCO_3)_2$
7	1312333	14	B	LF	$CaSO_4$
8	3331113	8	F	M	NaCl, $CaSO_4$ (B+E)
9	3313131	8	C	UF	$MgSO_4$,NaCl
10	3333113	8	F	M	NaCl
11	3311333	6	C	UF	$CaSO_4$,$CaCl_2$
12	3313331	6	C	UF	$MgCl_2$
13	1313111	6	D	M	$CaSO_4$,Ca $(HCO_3)_2$
14	3331111	6	F	M	Na_2SO_4, NaCl (B+E)
15	1122323	5	E	Alv	Ca$(HCO_3)_2$
16	3311313	5	A	RUF	$CaSO_4$
17	1311333	5	B	LF	$CaSO_4$
18	1313313	5	A	RUF	$CaSO_4$
19	1112333	4	E	Alv.	Ca $(HCO_3)_2$
20	3333111	3	D	M	NaCl (B+C)
21	2313333	3	C	UF	$CaSO_4$
22	1113313	3	E	Alv.	Ca $(HCO_3)_2$
23	3311331	3	C	UF	Mg SO_4
24	3331331	3	F	M	$MgCl_2$ (B+E)
25	1313113	2	D	M	Na_2SO_4 (B+C)
26	3331313	2	F	M	$CaCl_2$ (B+E)
27	3331112	1	F	M	NaCl (B+E)
28	1133213	1	B	LF	Ca$(HCO_3)_2$,$NaHCO_3$
29	3331333	1	C	UF	$CaCl_2$
30	3133113	1	F	M	NaCl (B+E)
31	3311113	1	A	RUF	Na_2SO_4,NaCl
32	1111333	1	E	Alv.	Ca$(HCO_3)_2$
33	1313131	1	B	LF	$MgSO_4$
34	1113331	1	E	Alv.	Mg$(HCO_3)_2$
35	1131313	1	A+B	M	Ca $(HCO_3)_2$, $CaCl_2$
36	1133113	1	A+E	M	$NaHCO_3$..

2) Group B, Lower Fars Water (69 analyses): No.1313333

$$Ca > Mg > (Na+K) \quad , \quad Cl < SO_4 > HCO_3$$
$$Ca > (Na+K) \quad , \quad Cl < HCO_3$$

3) Group C, Upper Fars Water (64 analyses): No.3313333

$$Ca > Mg > (Na+K) \quad , \quad Cl < SO_4 > HCO_3$$
$$Ca > (Na+K) \quad , \quad Cl > HCO_3$$

4) Group D, Mixed water of Lower and Upper Fars(33 analyses): No.3313111

$$Ca < Mg < (Na+K) \quad , \quad Cl < SO_4 > HCO_3$$
$$Ca < (Na+K) \quad , \quad Cl > HCO_3$$

5) Group E, Alluvial water (29 analyses): No.1113333

$$Ca > Mg > (Na+K) \quad , \quad Cl < SO_4 < HCO_3$$
$$Ca > (Na+K) \quad , \quad Cl < HCO_3$$

6) Group F, Mixed alluvial and Lower Fars waters (29 analyses): No.3331113

$$Ca > Mg < (Na+K) \quad , \quad Cl > SO_4 > HCO_3$$
$$Ca < (Na+K) \quad , \quad Cl > HCO_3$$

4.3.2. Hydrochemical facies based on computer interpretation:

The classification of ground water into different facies is shown in Figure 49. 243 analyses representing the recent samples analysed by the Institute of Applied Research on Natural Resources for the years 1974-1975 were used in this classification. The results of computer interpretation shown in Table 2 P.357 of the second program were used in Figure 49 after being finalized into six groups as in Table 12.

The quality of water in the different facies reflects the lithology of the water-bearing materials. The facies of

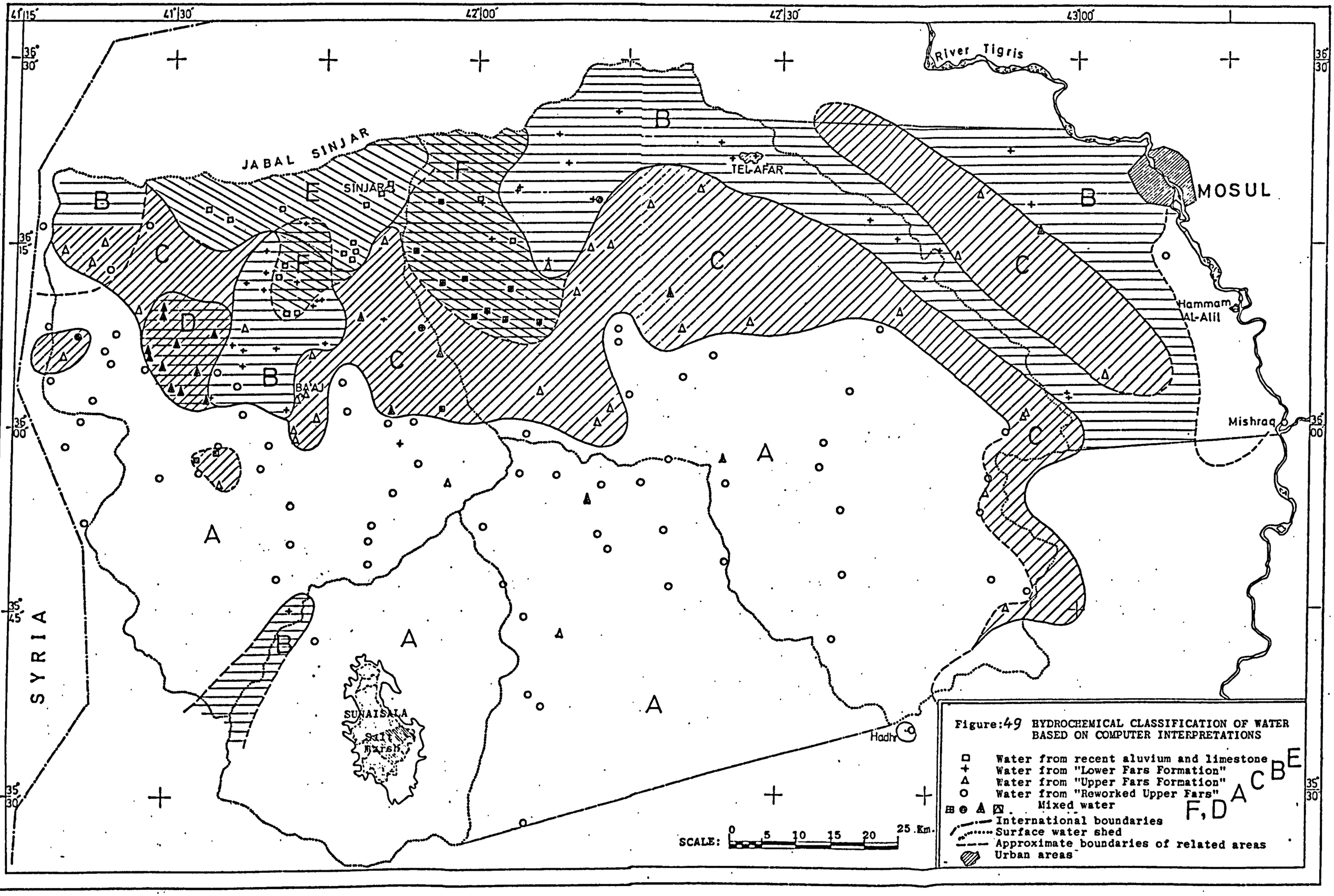


Figure: 49 HYDROCHEMICAL CLASSIFICATION OF WATER BASED ON COMPUTER INTERPRETATIONS

- Water from recent aluvium and limestone
- Water from "Lower Fars Formation"
- Water from "Upper Fars Formation"
- Water from "Reworked Upper Fars"
- Mixed water
- International boundaries
- Surface water shed
- Approximate boundaries of related areas
- Urban areas

A C B E F, D

the recent alluvial deposit (E) represent the distribution to the alluvium South of Jabal Sinjar. The facies of the Lower Fars formation (B) represents the extent of the formation over the area, while the extended tongues to the south represent the quality of water contributed from this formation. It mixes with the fresh water of the alluvial aquifer in the area between Balad Sinjar and the plunging zone of Sinjar anticline. This is represented by the facies F in Figure 49.

The presence of the B facies in the middle of Al-Ajij basin, within the Upper Fars facies (where no Lower Fars exists) could be due to the removal of the impermeable horizons within the Upper Fars formation in this area. The drilling in many deep wells proves the presence of thick alluvial deposits in this area. It indicates the extensive erosion of the Upper Fars by channelling and the deposition of locally thick alluvium which could have caused the inter-connection between the Upper and Lower Fars and the mixing of their waters by leakage. The possible deposition of the erosional products of the Lower Fars formation from the central parts of the Sinjar anticline in this area could also cause its water to be similar to the ground water of the Lower Fars formation.

The area surrounding Sunaisala basin to the west indicates the presence of Lower Fars type of water. The Lower Fars formation is exposed in this area over the hills marking the surface watershed.

The ground water of facies C and A indicates the rough boundary between the Upper Fars and the reworked Upper Fars. The main difference in these waters is the excess salt (NaCl) in the shallow aquifers of the reworked Upper Fars. In fact most of the samples collected from the area of

facies A were from shallow hand dug wells. For this reason, the deeper ground water could be similar to the surrounding fresher water of the facies C of Upper Fars aquifer. This has been proved in the area of Ba'aj and Blaij where deeper water is fresher than the shallower one. The water of the area of Lower Fars Hills to the west of the river Tigris shows some similarity with the reworked Upper Fars water. There is no indication of the existence of this material in this area but the type of water here shows this similarity due to the biochemical reaction which led to the reduction of sulphate and the domination of sodium and calcium bicarbonate. The detailed process concerning such change will be discussed in more detail in the next chapter.

The presence of the facies F within the facies of C and B of the Fars water indicates the mixing of the two waters and the formation of different quality water. There is a strong indication of ionic exchange in this area which will be discussed in more detail in the next chapter.

4.3.3. Hydrochemical facies based on Geological Interpretation:

In most of the hand dug wells and the deep drilled wells in the area under study, the water-bearing materials or aquifers are known, i.e. the lithology of the aquifer is known. In other deep wells however, the well penetrates several water bearing horizons having different lithology. In the vicinity of Sinjar anticline, the deep wells penetrate the alluvial and the Upper Fars aquifers, while further to the south near Blaij or Ba'aj, the deep wells penetrate both the reworked Upper Fars materials and the Upper Fars aquifers.

An attempt has been made to classify the ground water into different facies on the basis of geology, i.e. the lithology of the water-bearing materials. The source of water in such wells or springs is tabulated under RFNO in the first table of the first computer program (see 4.3.1). Five different sources of water were distinguished in the area. The main four are the Upper Fars, Lower Fars, Alluvial and reworked Upper Fars materials, while the fifth is the mixed type of water. All the different types of water are plotted on Figure 50 and a distinctive facies was developed for each group of water. These groups are similar to the groups discussed under the previous classification with the exception of the mixed water.

The main differences between the computer classification and the present geological classification can be seen by correlating Figures 49 and 50 as follows:-

1) - the Upper Fars aquifer water extends further to the east of Al-Tharthar basin and to its central parts as in Figure 49 while it is limited to the western parts of Al-Tharthar basin in Figure 50.

2) - no facies of the Upper Fars were distinguished over the Lower Fars facies on the hilly area of Lower Fars structures.

3) - the zone of mixing (F) between the fresh alluvial aquifer water and the mineralized Lower Fars water is much smaller in Figure 50.

4) - In Figure 50, the zone of mixing between the alluvial aquifer water and the Upper Fars water (Facies D) is partly represented by the facies (F)

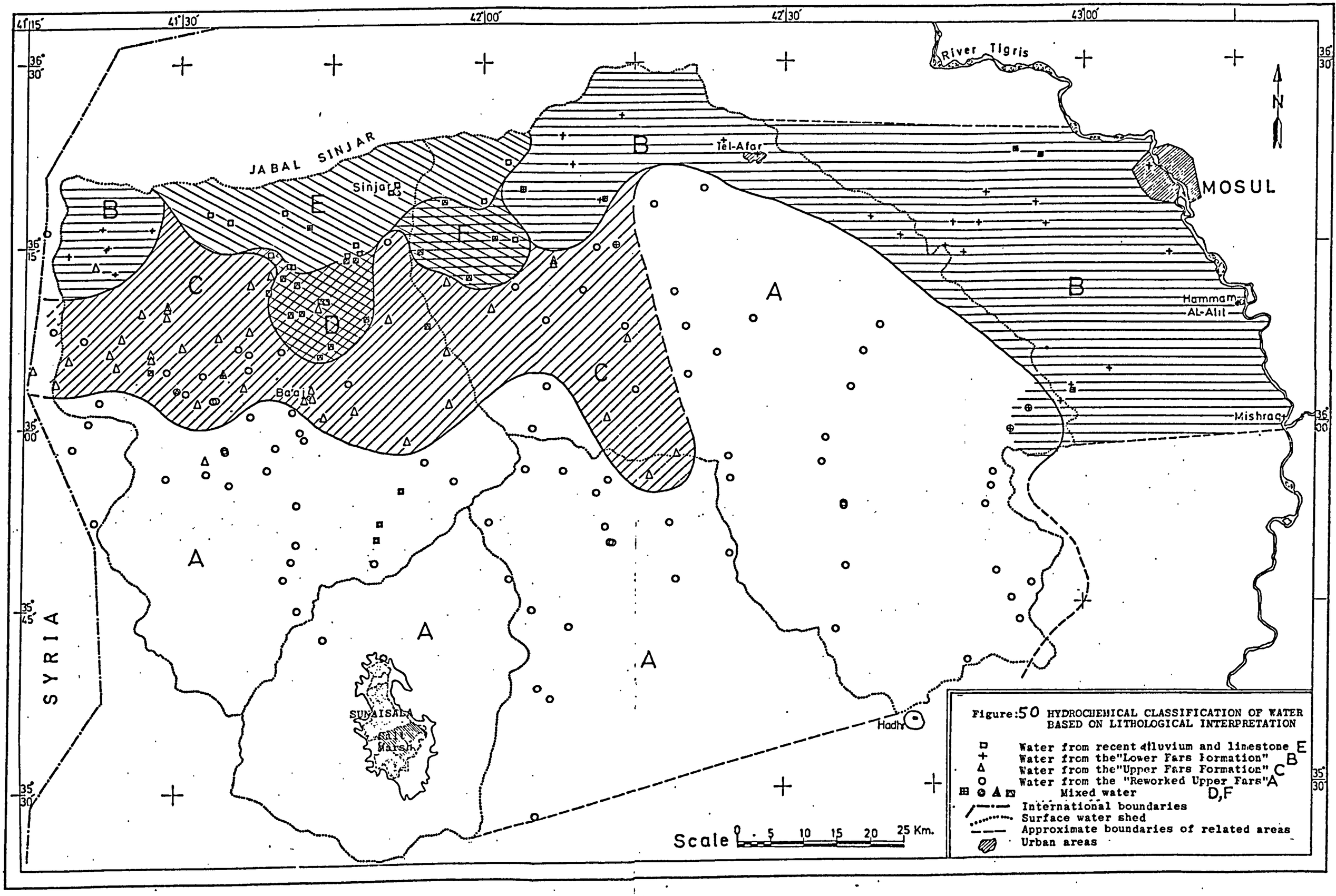
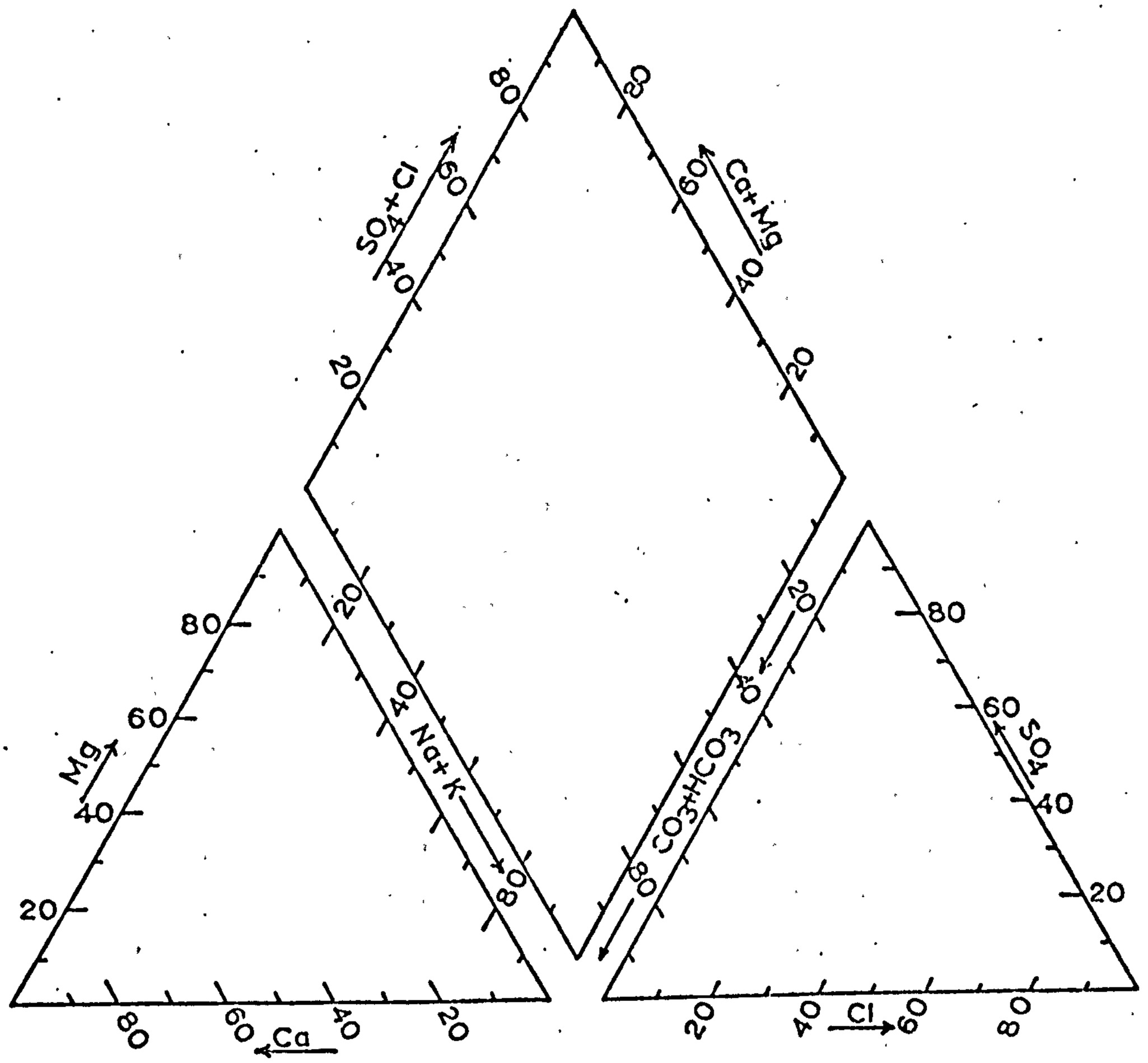


Figure: 50 HYDROCHEMICAL CLASSIFICATION OF WATER BASED ON LITHOLOGICAL INTERPRETATION

- Water from recent alluvium and limestone E
- Water from the "Lower Fars Formation" B
- Water from the "Upper Fars Formation" C
- Water from the "Reworked Upper Fars" A
- Mixed water D,F
- International boundaries
- Surface water shed
- Approximate boundaries of related areas
- Urban areas



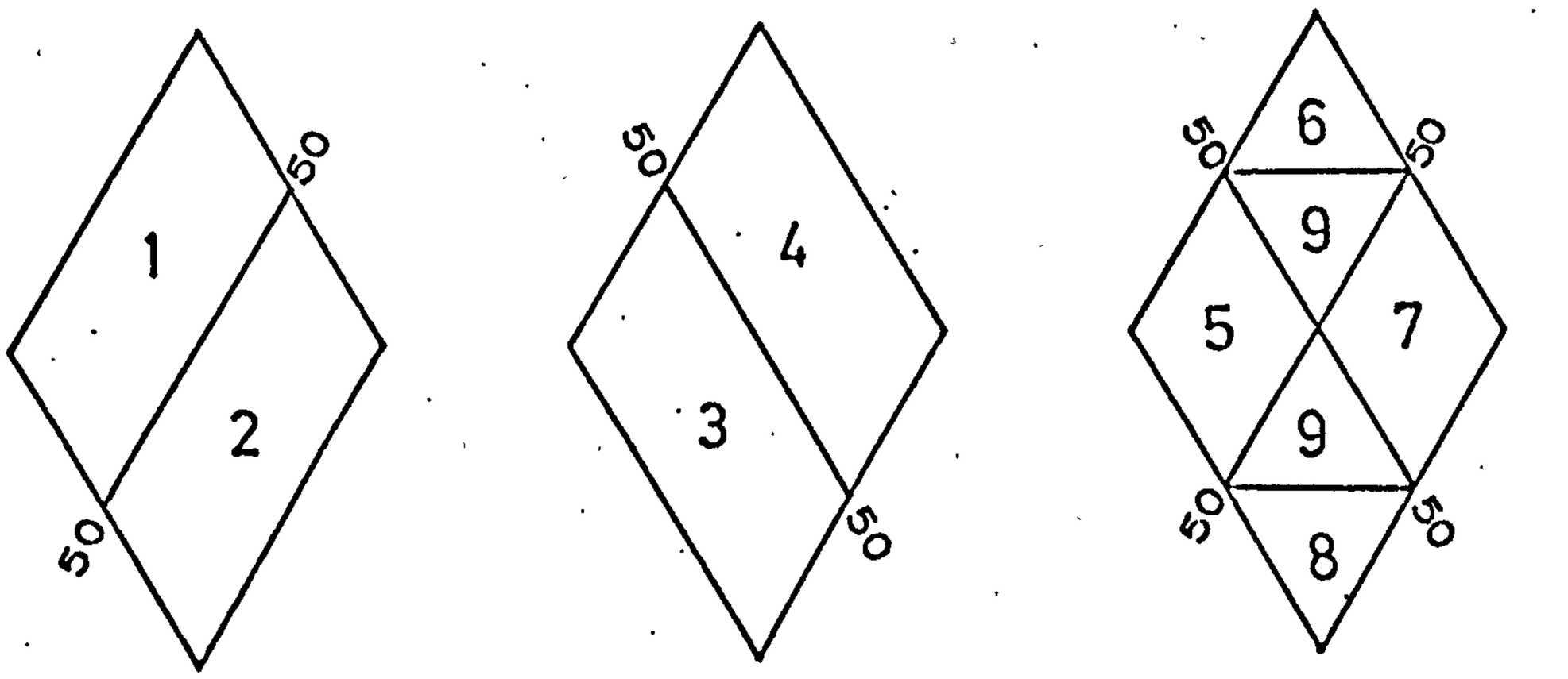


Figure 51 : Piper's trilinear diagram with the subdivisions of the diamond-shaped field used for the classification of water.

of Figure 49. However, this facies does not represent the facies D of Figure 49.

4.3.4. Classification of water based on Piper's trilinear diagram.

Piper (1944) developed a graphical procedure which appears to be an effective method of segregating analytical data for the study of ground water quality with respect to sources of the dissolved constituents in waters, changes in water quality with flow and the related geochemical problems.

The procedure is based on a multiple-trilinear diagram as shown in Figure 51. The two trilinear fields to the left and right of the diamond-shaped field are for plotting the percentage of the sum of each cation and anion present in water calculated in milliequivalents per litre. The intervening diamond-shaped field is for general interpretation of water quality. The position of the different types of waters in this field can be distinguished and classified according to the different subdivisions shown in Figure 51. The following explanation of each sub-division is based on Piper's work as follows: Area 1, alkaline earths, exceed alkalies; Area 2, alkalies exceed alkaline earths; Area 3, weak acids exceed strong acids; Area 4, strong acids exceed weak acids; Area 5,carbonate hardness ("Secondary alkalinity") is dominant; Area 6, non-carbonate hardness (Secondary salinity") dominates; Area 7, non carbonate alkali ("Primary salinity") dominates; Area 8, carbonate alkali ("Primary alkalinity") dominates, and in Area 9, no one cation anion pair exceeds 50 per cent.

This method has been used to interpret most of the analyses made for the study area. The diamond-shaped field illustrates and explains the following:-

1) - the correlation of the different waters of the Upper Fars aquifers and the water from the reworked Upper Fars materials
2) - the correlation of waters from the deep aquifers with that taken from shallow aquifers, i.e. bore-holes waters and dug wells waters
3) - indication of the different types of waters in the springs of the area
4) - comparison of the fresh water taken from the alluvial squifers with the mineralized waters taken from the Lower Fars aquifers
5) - changes of water quality with flow along several traverses across the area.

The general correlation of waters from the dug wells and drilled wells is shown in Figure 52. The segregation of the majority of analyses of the dug well waters in the top right part of the diamond-shaped field indicates its richness with $CaSO_4$ and NaCl in comparison with the waters of the deep aquifers taken from the drilled wells.

The relation between the different waters of the alluvial and Lower Fars aquifers is shown in Figure 53, where the gradual mineralization of the fresh alluvial aquifer is demonstrated by the direction of the arrow in the upper left area of the diamond-shaped field. This change is taking place due to dissolution as water flows across the aquifer. The highly mineralized waters of the Lower Fars aquifers indicate a gradual change towards decreasing mineralization after being saturated with sulphate. This could take place by the biochemical reduction of sulphate and other constituents in water.

The correlation of the waters of Upper Fars aquifers with those of the reworked Upper Fars materials is shown in Figure 54. Both of these waters occupy the same area

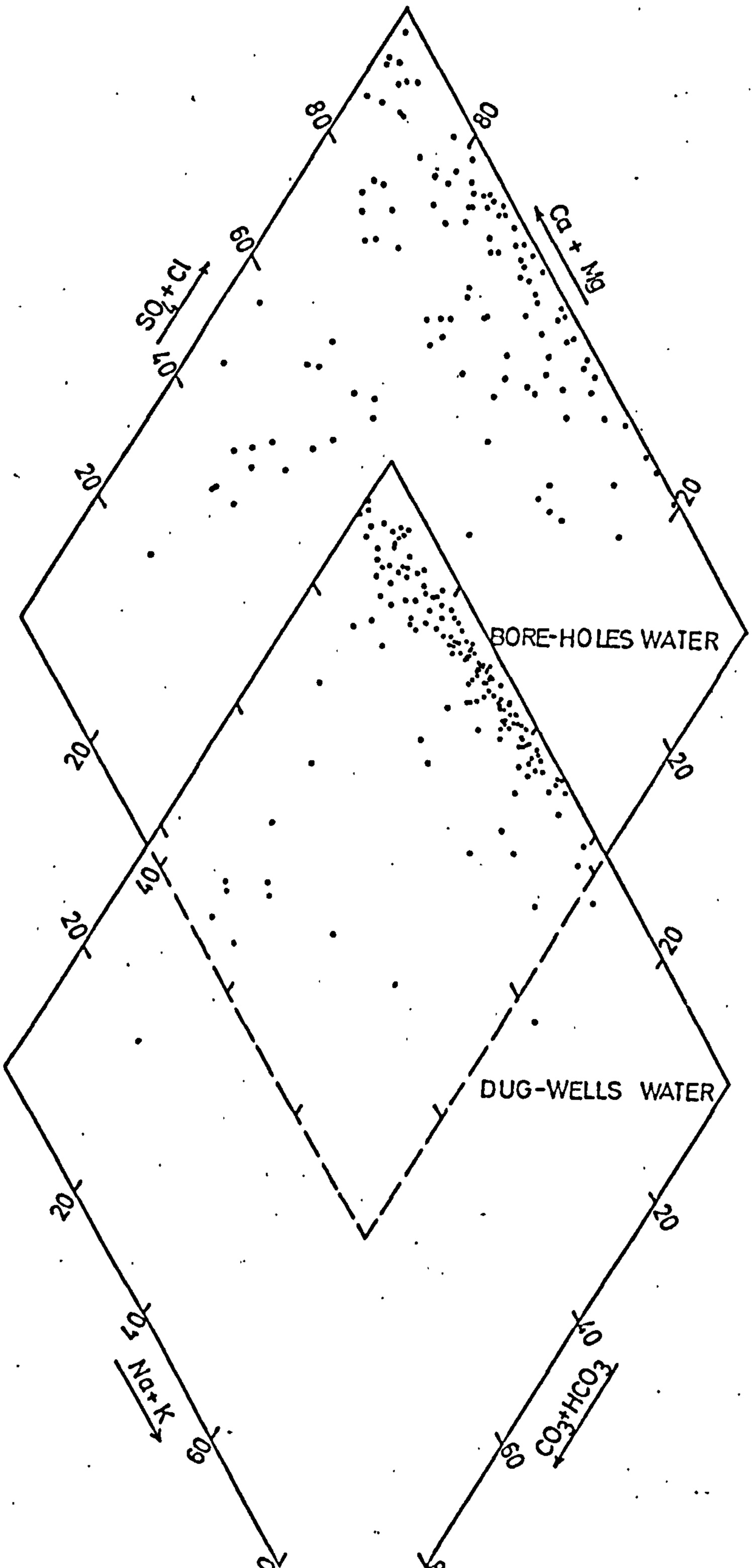


Figure 52: Trilinear diagrams of water from shallow and deep aquifers.

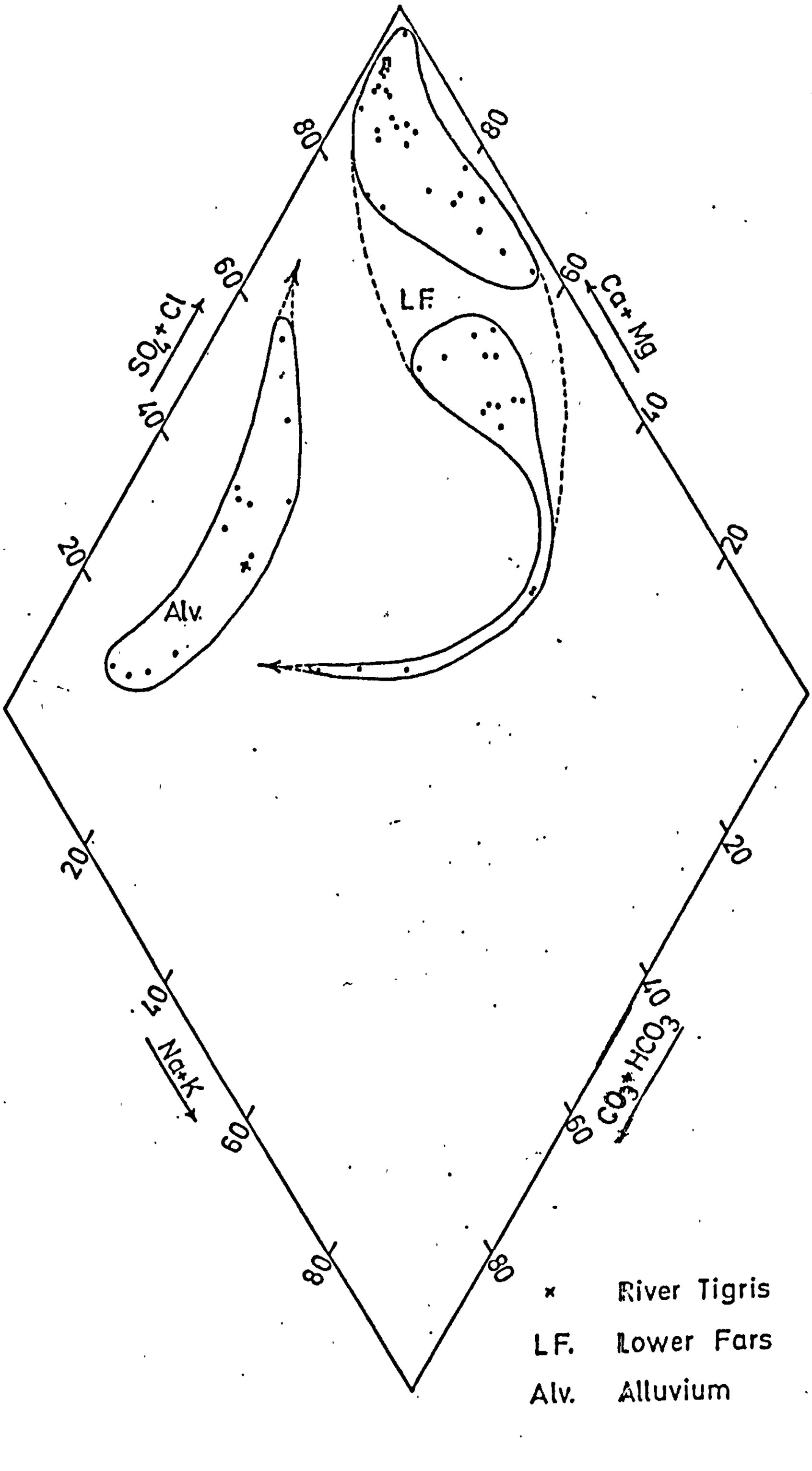


Figure 53:Trilinear diagram of water from the alluvium aquifers (Alv) and the Lower Fars Formation (LF) showing the direction in which water quality changes due to solution and reduction.

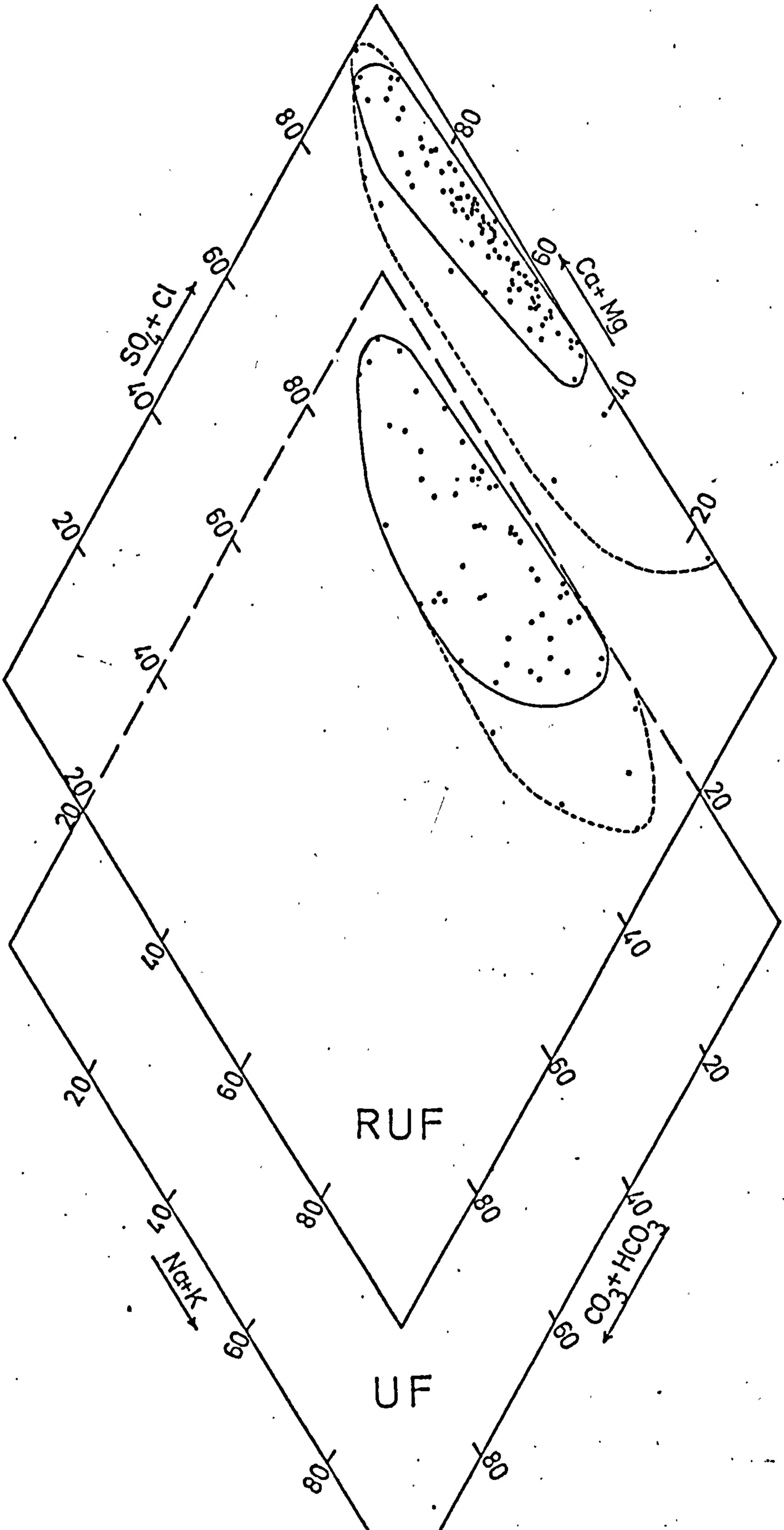


Figure 54: Triliniear diagram of water samples from the Upper Fars (UF) and reworked Upper Fars (RUF) aquifers.

classified by Piper where strong acids exceed the weak acids and the secondary salinity dominates; however, the majority of analyses taken from the reworked Upper Fars materials show higher percentage of dissolved $CaSO_4$ and NaCl in comparison with the analyses taken from the Upper Fars aquifers.

The analyses of waters taken from the different springs in the area is represented in Figure 55. The five separate groupings demonstrate the great difference in the quality of water of the alluvial aquifers and the Lower Fars aquifer, and also show the substantial variation in water quality of the Lower Fars aquifer at the different localities.

The changes that take place in water quality in the direction of ground water flow for the deep and shallow aquifers are demonstrated in the diamond-shaped field. Several traverses are selected in the direction of ground water flow along the lines shown in Figure 47. In general, water gains mineralization, mainly sodium chloride and calcium sulphate, as it flows southward. This is demonstrated by the following traverses:-

1) - lines AB and AC in Figure 56 represent waters from deep aquifers taken from the drilled wells shown in Figure 47. The changes in water mineralization, total dissolved salts (TDS) and the percentage of each ion is demonstrated by circles whose diameter represents the TDS in water. The direction of the arrow in Figure 56 is taken in the same direction as the ground water flow.

The sodium adsorption ratio (SAR) of water was defined by the U.S. Department of Agriculture Salinity Laboratory (1954), as

$$SAR = \frac{(Na^{+})}{\frac{(Ca^{2+}) + (Mg^{2+})}{2}}$$

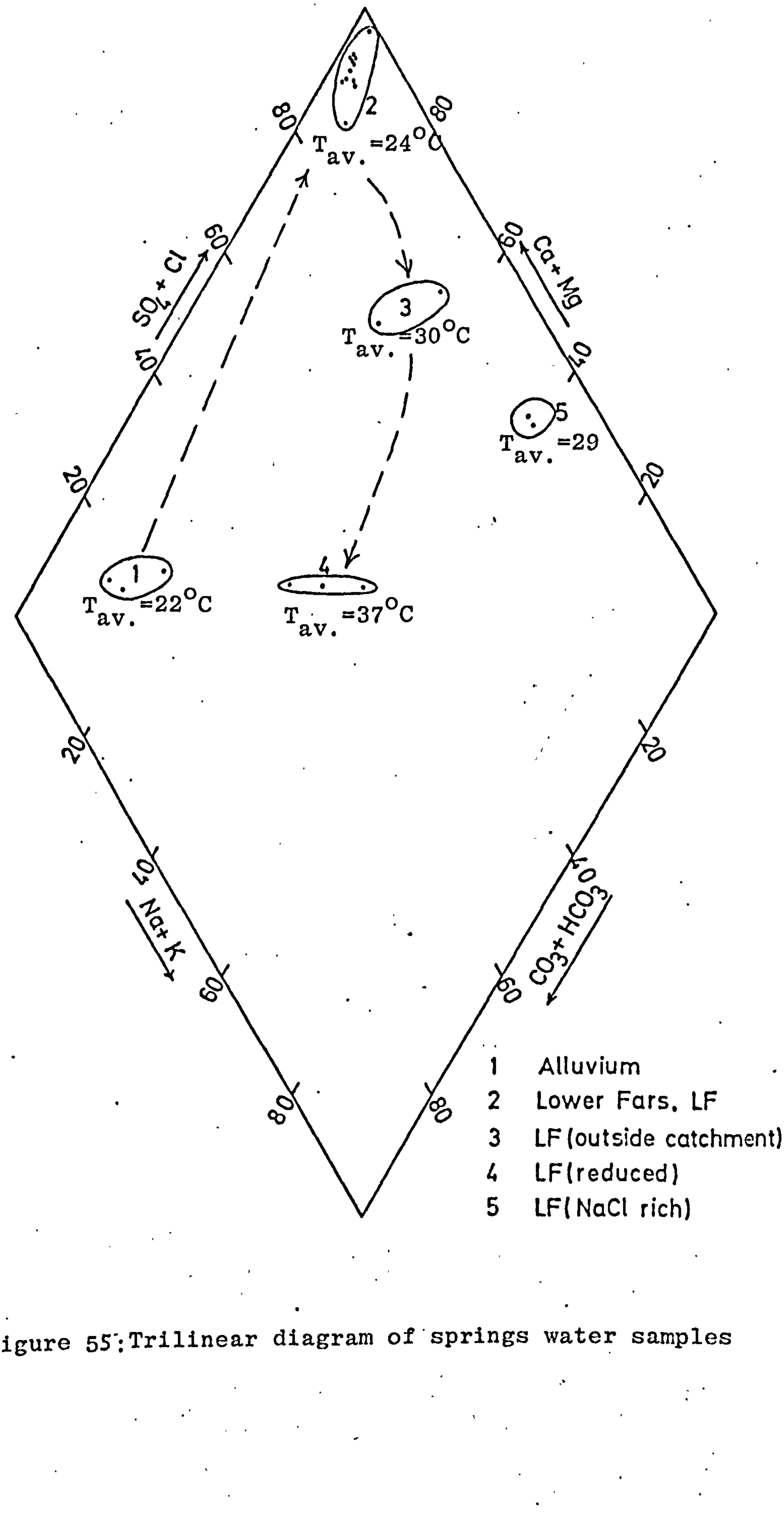


Figure 55: Trilinear diagram of springs water samples

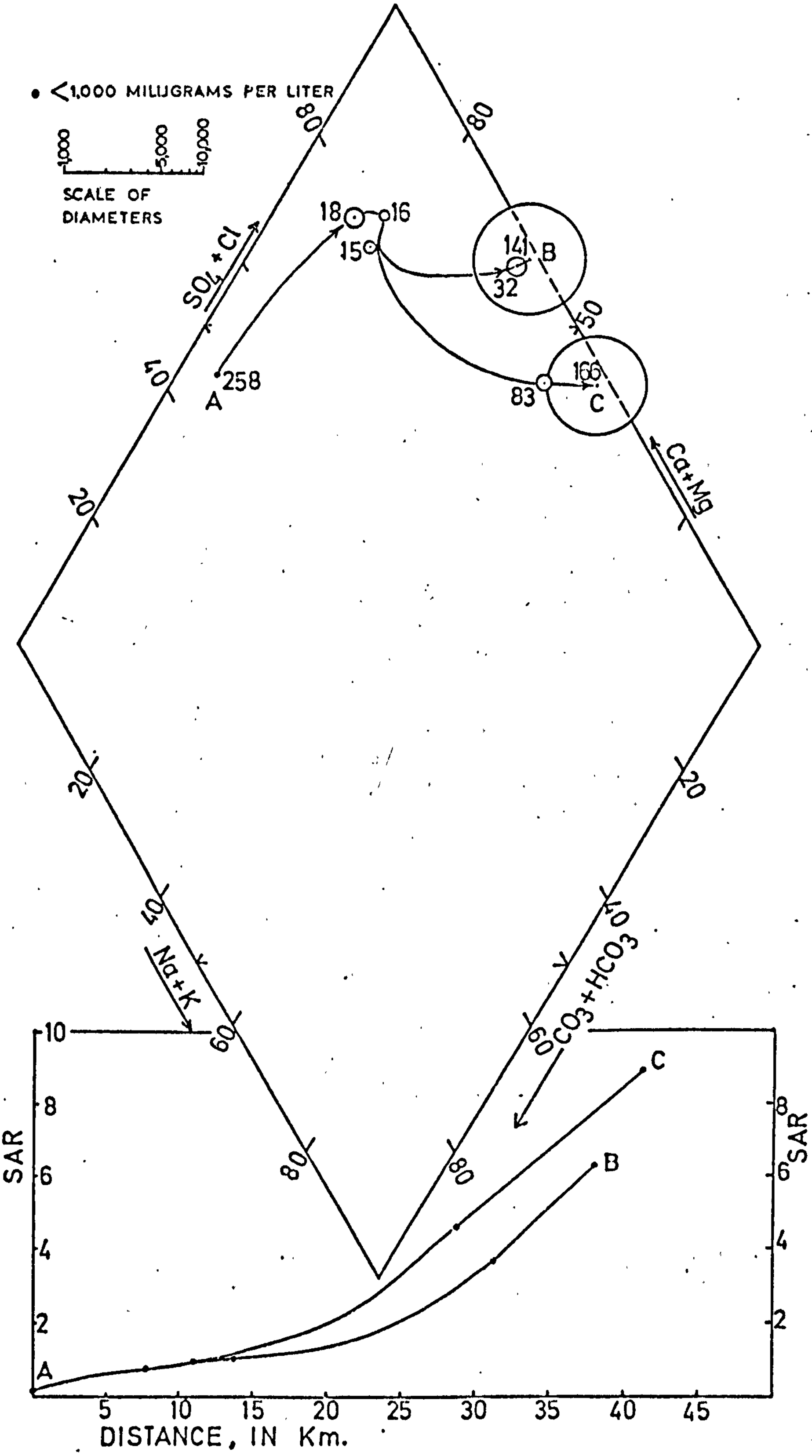


Figure 56: Trilinear diagram of water from deep aquifers along the lines AB & AC compared with its sodium adsorption ratio (SAR).

Where ion concentrations are expressed in milliequivalents per litre. The value of SAR is significant for irrigation water. The cation-exchange reactions in soil can be predicted from SAR. High values for SAR imply a hazard of sodium replacing adsorbed calcium and magnesium. The replacement is expected in areas where sodium chloride salt is rich in the aquifer materials (ex. reworked Upper Fars and Lower Fars) or when salt concentration increases in the shallow aquifer due to evapotranspiration. Therefore, the SAR index can indicate the changes in ground water quality. The distances covered by ground water flow are also shown in relation to SAR:

The SAR of the different waters is shown along each traverse taken along the direction of ground water flow, and increases from less than 1 to 6 along the line AB and to 9 along the line AC.

2) - lines DE and DF are located in the Tharthar basin and shown in Figure 57. The increase in water mineralization towards well 57 could be due to the mixing of the alluvial and the Lower Fars waters as demonstrated in Figure 49. The change of water quality towards calcium sulphate type of water is almost certainly due to mixing with Lower Fars type waters, though the changes in analyses 37 and 126 is towards sodium chloride rather than calcium sulphate type of water. This could be due to ionic exchange as demonstrated by the increase in the SAR in the same direction.

3) - lines GH and GI in Figure 58 represent a classical example of ground water quality which has been affected by ionic exchange. The fresh water of Sinjar mountain area represented by analyses 22 and 24 changes in two major directions affected by the aquifer lithology and the amount of mixing between the different waters. The changes in the direction GI are due to the ionic exchange of calcium and magnesium by sodium, and are demonstrated by the increase in the SAR in analyses 26. While the changes in the direction GH is due to the dissolution of calcium sulphate towards analyses 30.

4) - line A'B' in Figure 59 represents waters from the shallow aquifers. The sudden increase in mineralization between location 23 and 237 is due to dissolution of gypsum from the uppermost parts of the Upper Fars formation. The ionic exchange of calcium for sodium takes place in the southern direction as water flows within the sodium chloride rich deposits of the reworked Upper Fars as shown by analyses 34 and 103 and confirmed by the increase in the SAR in the same direction.

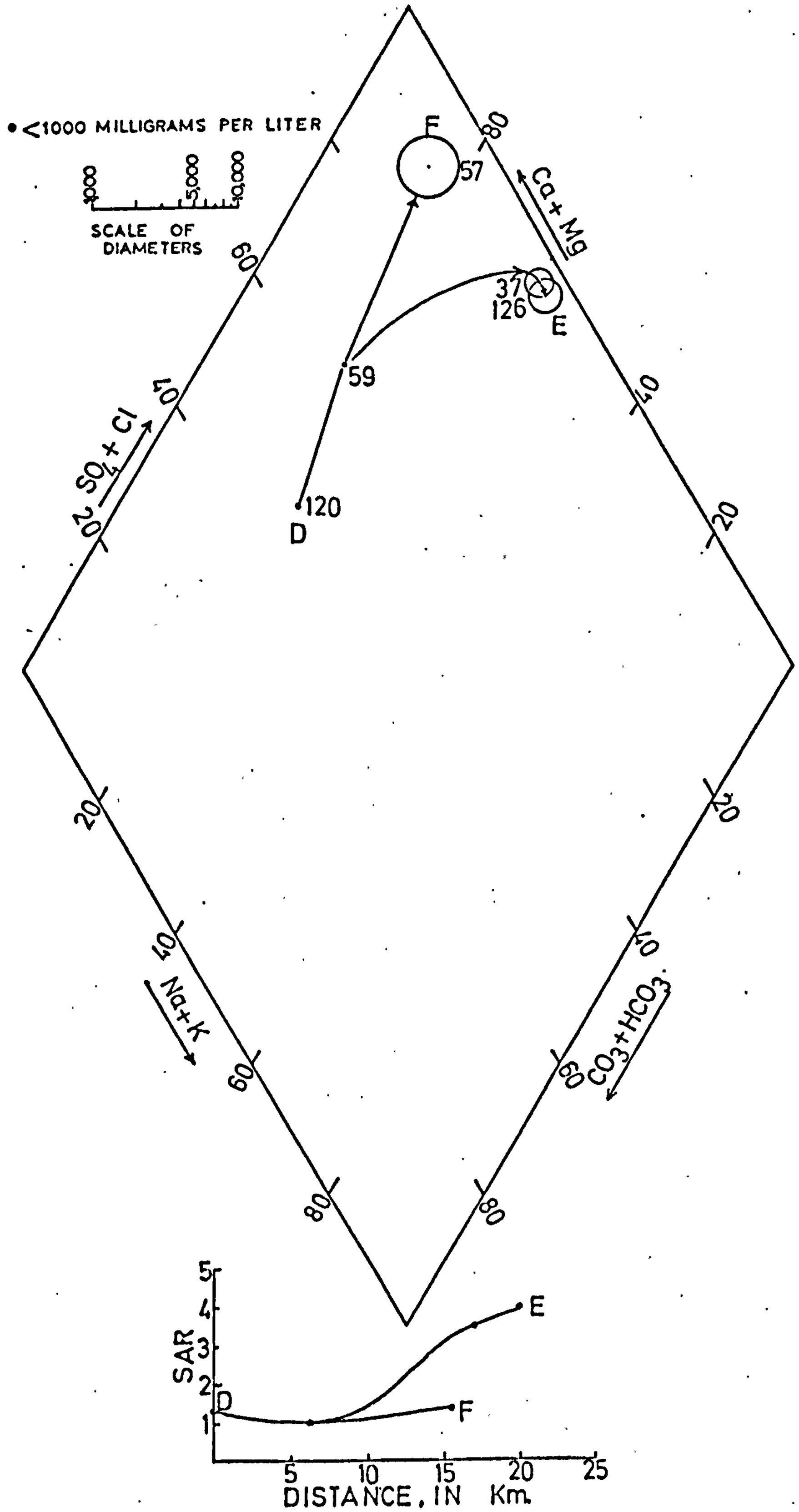


Figure 57:Trilinear diagram of water from wells in the deep aquifers along the lines DE & DF compared with the sodium adsorption ratio (SAR).

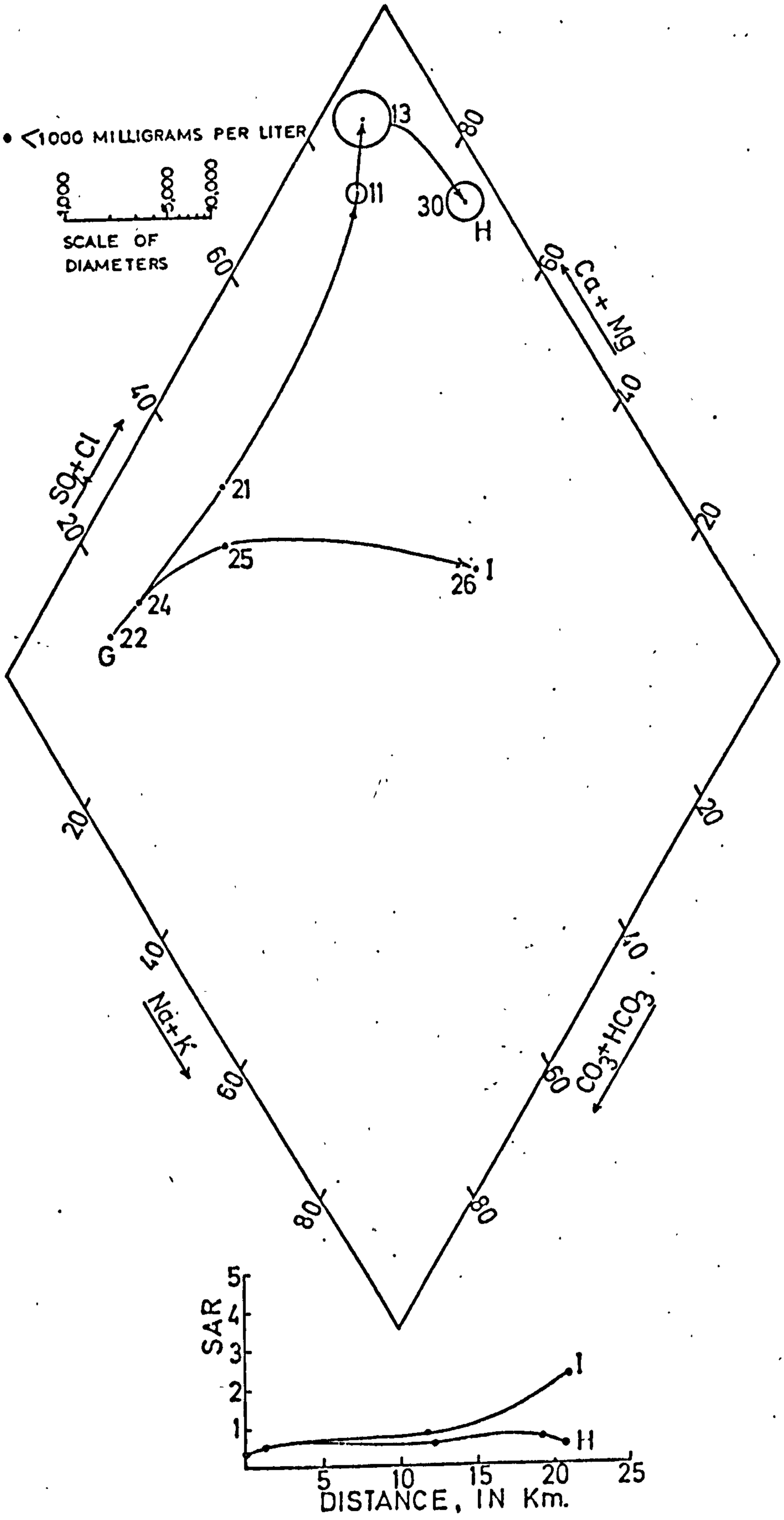


Figure 58: Trilinear diagram of water from deep aquifers along the lines GII & GI compared with its sodium adsorption ratio (SAR).

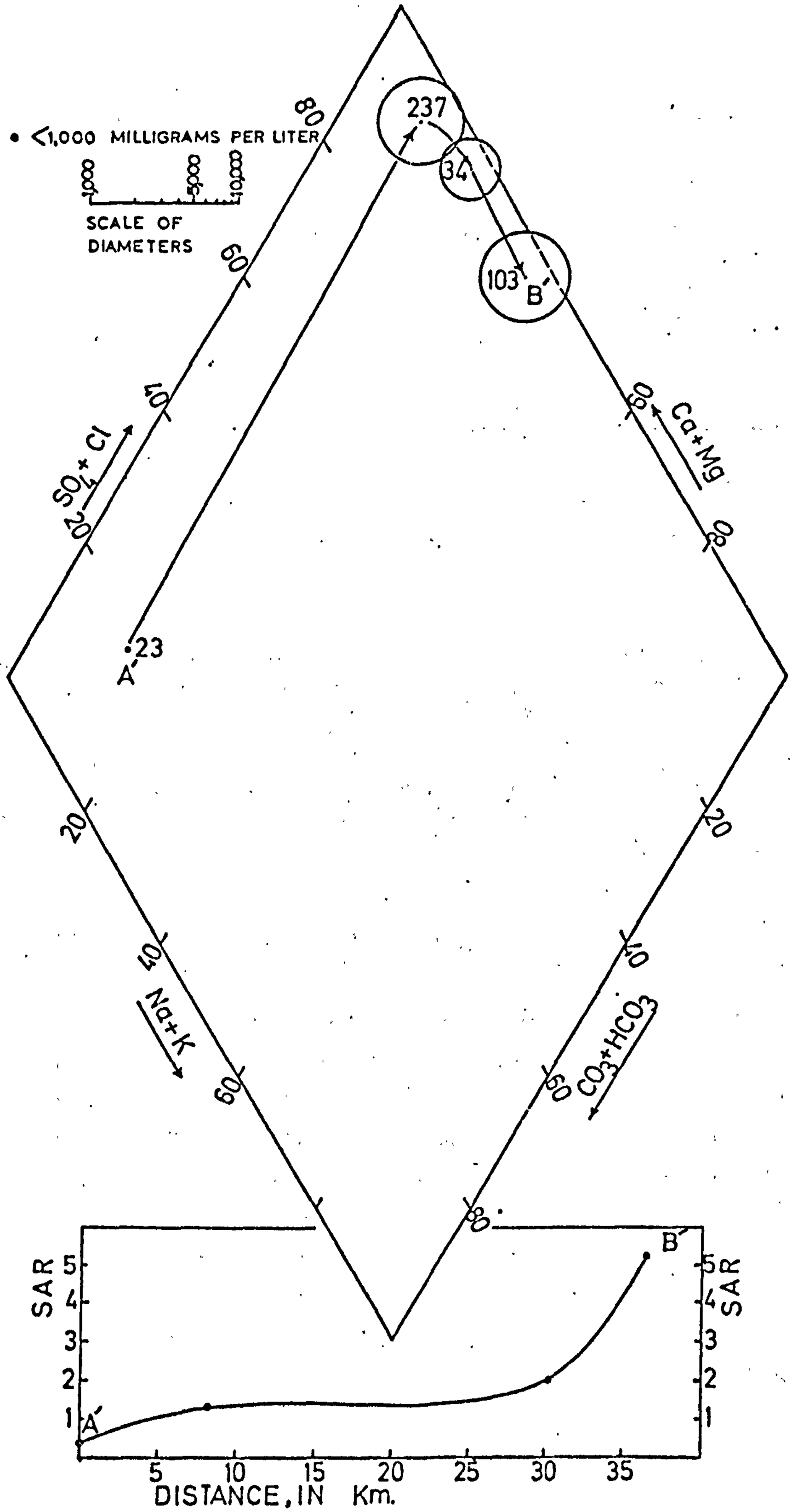


Figure 59: Trilinear diagram of water from shallow aquifers along the line AB. Compared with its Sodium adsorption ratio (SAR).

5) - line C'D' in Figure 60 represents the changes which could take place when water from Al-Ajij basin flows towards Sunaisala basin. The major changes in water quality are the exchange of calcium sulphate by sodium chloride and the increase in the total mineralization of water. The ionic exchange represented by the increase of SAR from less than 1 to more than 60 takes place as water flows towards the salt playa of Sunaisala.Evaporation could be the main reason for this increase in salinity.

6) - line E'F' in Figure 61 represents shallow ground-water flowing from Jabal Sinjar towards the south. The same trends of change are taking place as in the deep aquifer along the traverse AC in Figure 56 with the exception that the total mineralization is higher in the shallow aquifer.

7) - line G'H' in Figure 62 represents the flow of shallow ground water towards Wadi Al-Tharthar. The mineralization increases in the direction of flow as water passes through the reworked Upper Fars materials. The significant increase in mineralization could be due to the concentration of water by evapotranspiration. The depth of water in the shallow aquifers in this region is less than 5 metres.

4.3.5. Total dissolved salts in ground water

The concentration of the total dissolved salts in the shallow and deep ground waters are shown in Figure 63. It was not possible to distinguish between the waters of the shallow and deeper aquifers over most of the studied area. The map representing the hydrochemistry of the area for July 1974 is shown in Figure 63 represented in grams per litre. The fresh water of the limestone and alluvial aquifers around Jabal Sinjar gradually become more saline as it flows towards the south. In some localities exceptionally high mineralization is due to the localisation of water within lenses of sodium chloride or calcium sulphate rich materials of the reworked Upper Fars.

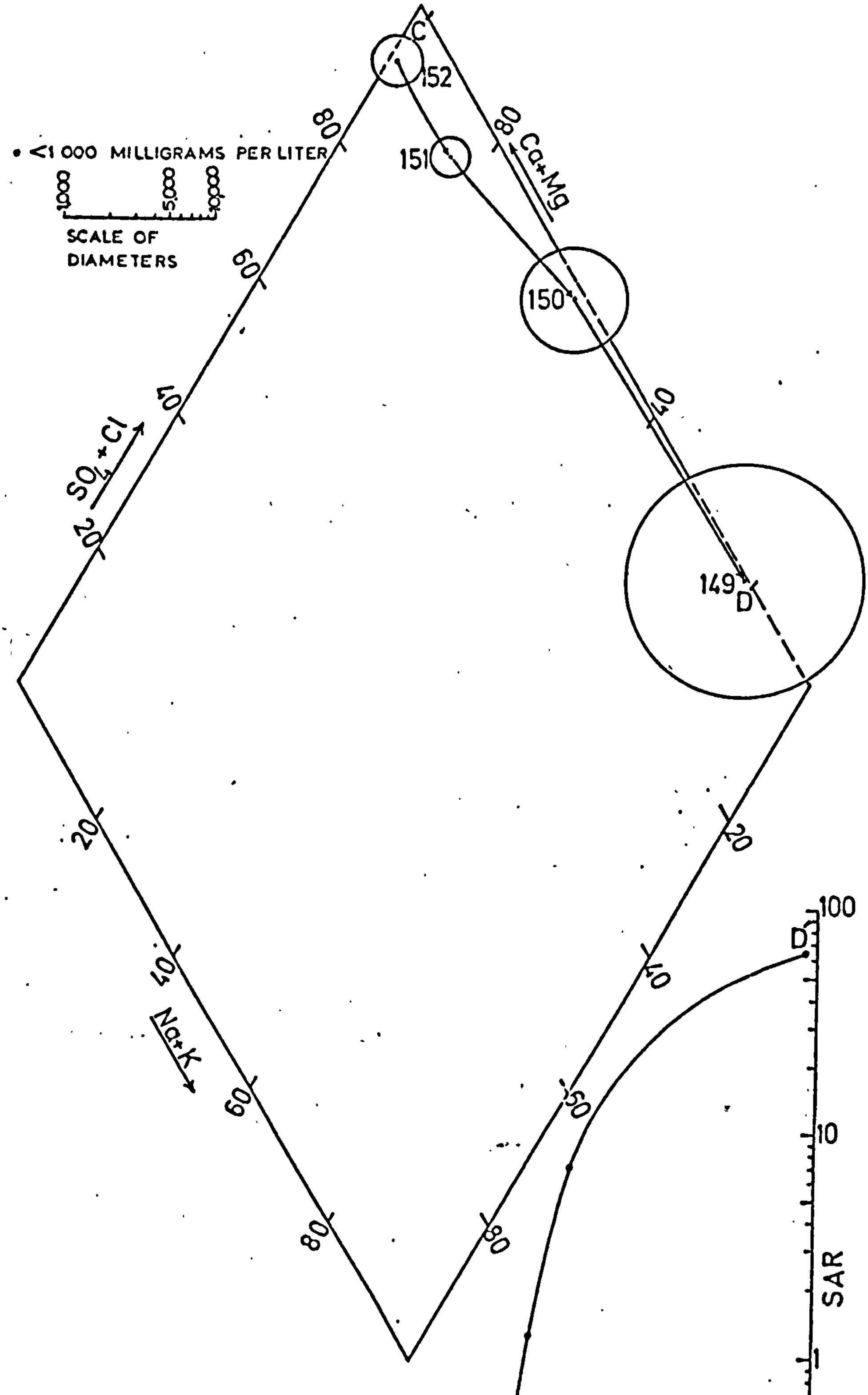


Figure 60: Trilinear diagram of water from shallow aquifers, compared with its sodium adsorption ratio (SAR)

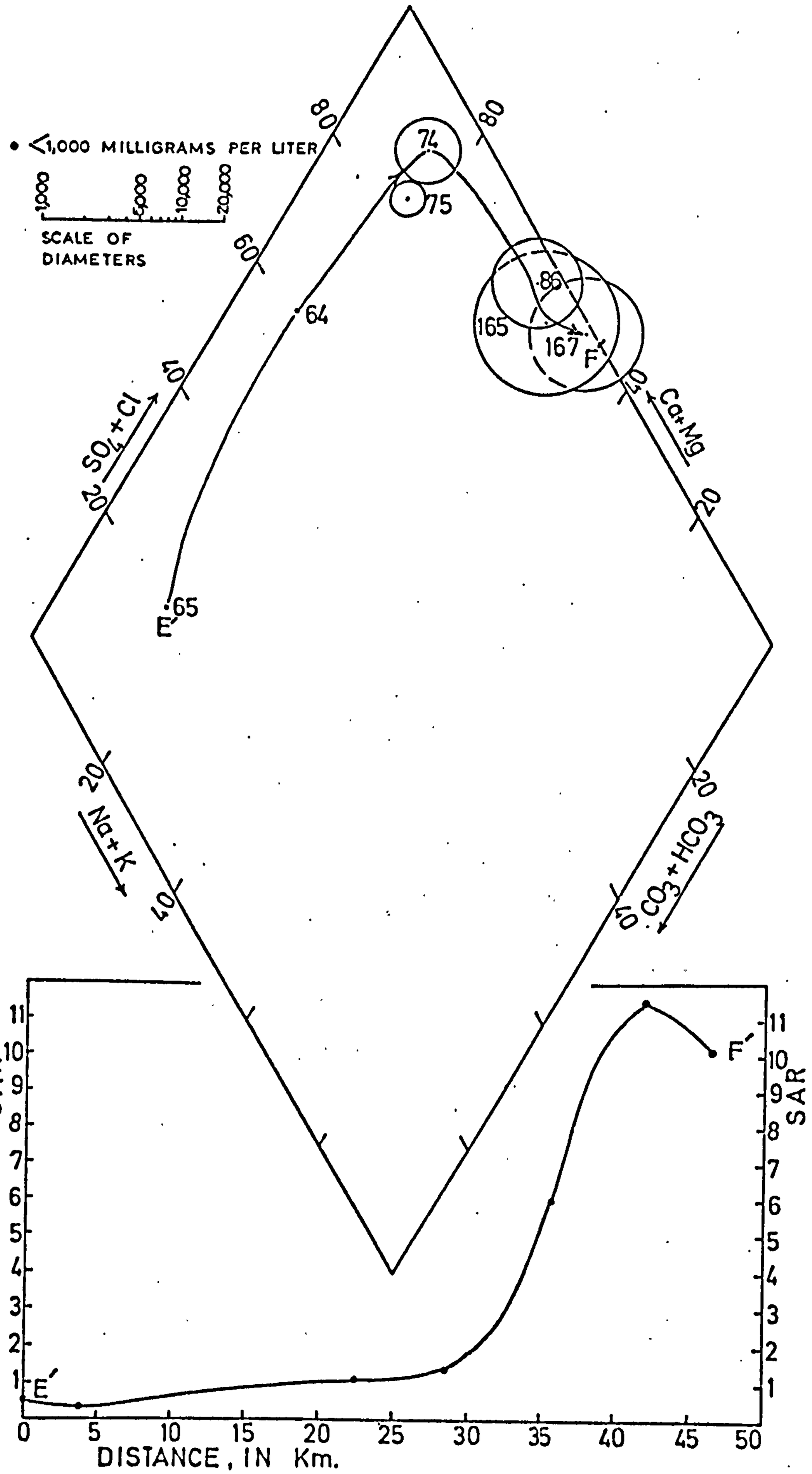


Figure 61: Trilinear diagram of water from shallow aquifers along the line EF. compared with its sodium adsorption ratio, SAR.

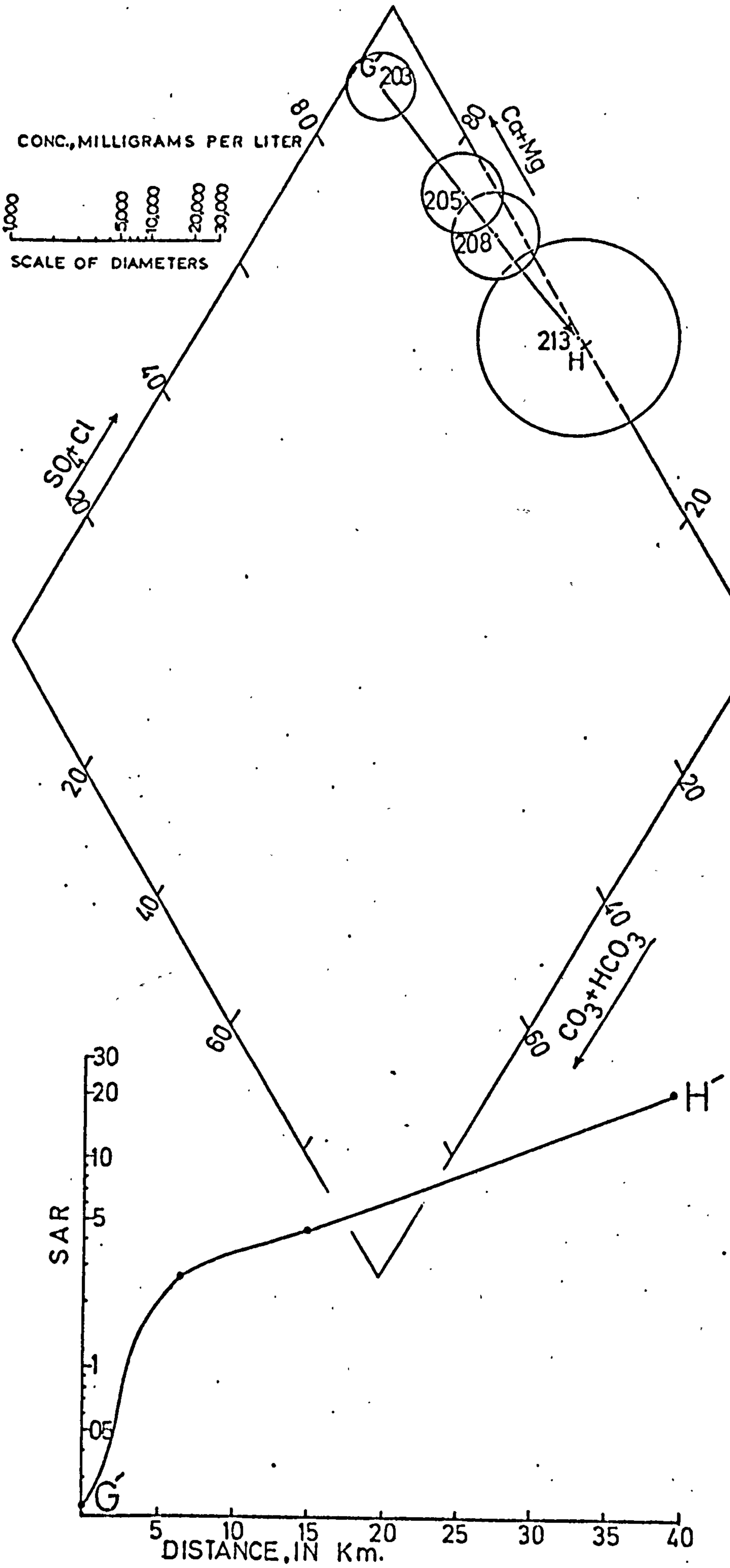
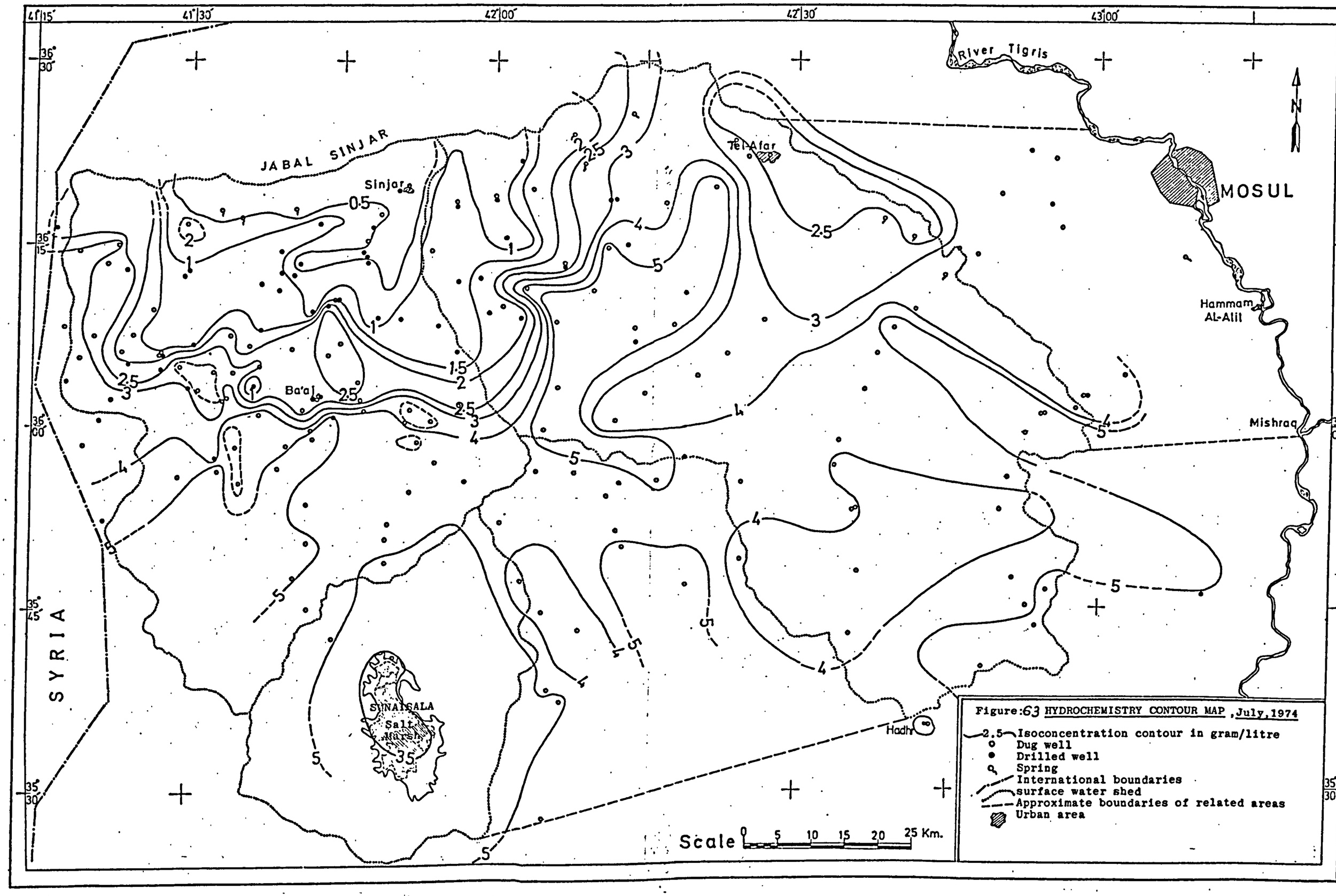


Figure 62:Trilinear diagram compared with sodium adsorption ratio along the line GH.

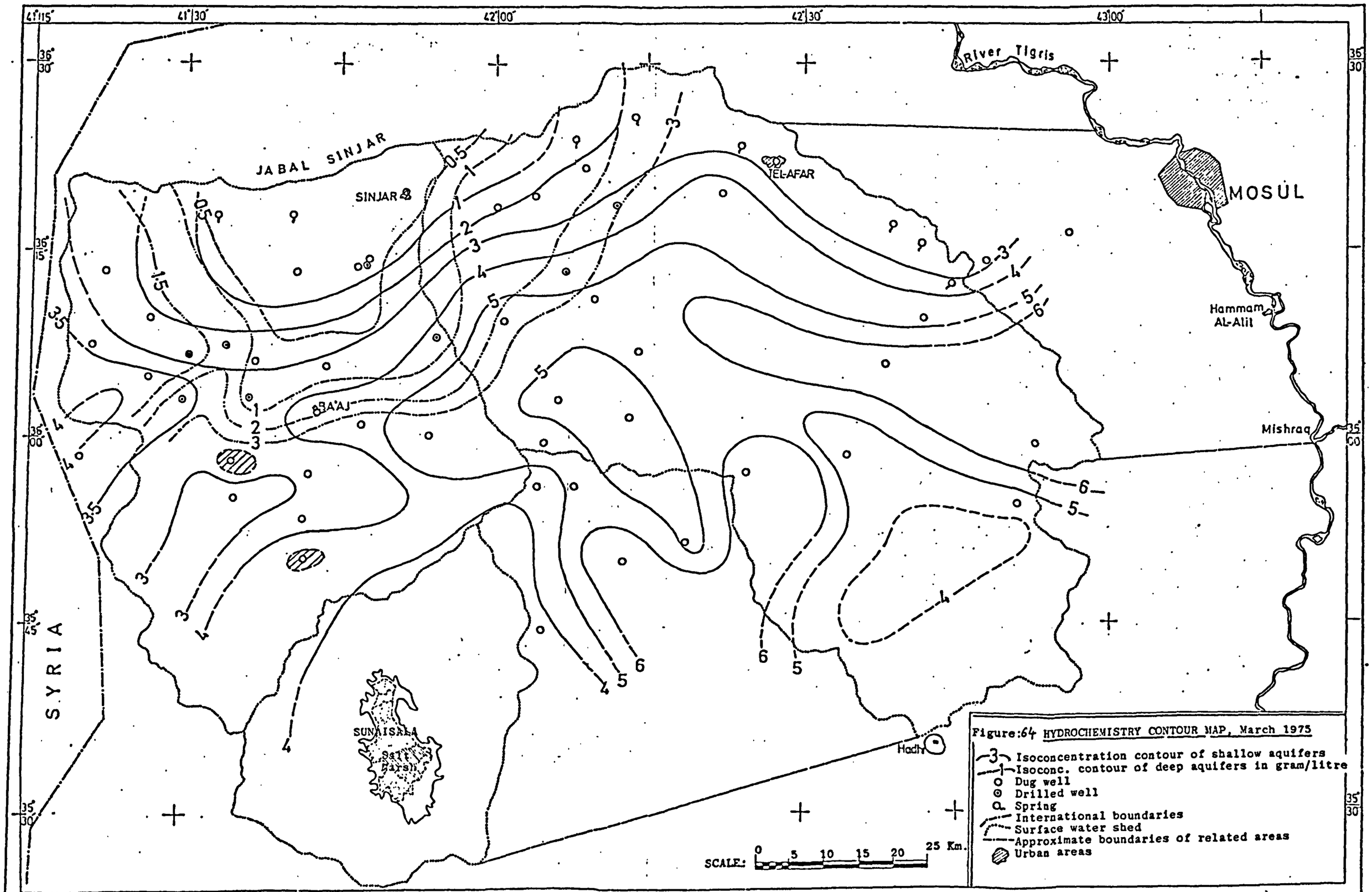

41°15'
41°30'
42°00'
42°30'
43°00'
36°30'
36°15'
36°00'
35°45'
35°30'
JABAL SINJAR
Sinjar
Tel Afar
River Tigris
MOSUL
Hammam AL-Alil
Mishraq
Ba'aj
SYRIA
SINAISALA
Salt Marsh
Hadhr
0.5
1
1.5
2
2.5
3
4
5
Scale 0 5 10 15 20 25 Km.
Figure:63 HYDROCHEMISTRY CONTOUR MAP, July, 1974
2.5 Isoconcentration contour in gram/litre
Dug well
Drilled well
Spring
International boundaries
surface water shed
Approximate boundaries of related areas
Urban area

In Wadi Al-Tharthar, the mineralization of water increases from less than 0.5 gm/l to over 5 gm/l as water flows from Jabal Sinjar towards the southeast. In Wadi Al-Ajij, the mineralization of ground water similarly increases towards the southwest as it flows towards Syria. While in Sunaisala basin, the increase in water salinity reaches a maximum in the central part of the basin. It increases from about 5 gm/l at the basin periphery, to over 100 gm/l in its centre. Thick deposition of sodium chloride salts is taking place in this basin due to evaporation.

The distribution of fresh water of less than 1.0 gm/l total dissolved salts in tongue-like patterns confirms the general conclusions drawn from the maps of aquifer transmissibility, specific capacity, and hydrochemical facies.

4.4 Annual variations in ground water quality

The analyses of ground water samples collected in the period of the field work and analysed in June, July and August 1974 represent the period when the general ground-water-levels began to decline. The replenishment of ground water from the surface decreases in May and June and dimished in July each year. For this reason the map in Figure 63 representing the hydrochemistry of ground water in July 1974 is thought to represent the end of the period of recharge to the aquifers. While the map in Figure 64, interpreted from the second set of samples represents the period when the replenishment takes place in the wet season. However, March 1975 cannot represent the period of minimum ground water levels in the aquifers. Some recharge had already reached the shallow aquifers in March but the total amount of replenishment took place in April and June due to the increase in precipitation and decrease in the soil moisture deficit.


41°15'
41°30'
42°00'
42°30'
43°00'
36°30'
36°15'
35°00'
35°45'
35°30'
River Tigris
JABAL SINJAR
SINJAR
TEL-AFAR
MOSUL
Hammam Al-Alil
Mishraq
BA'AJ
SYRIA
SUNAISALA
Salt Marsh
Hadh
SCALE: 0 5 10 15 20 25 Km.
Figure:64 HYDROCHEMISTRY CONTOUR MAP, March 1975
Isoconcentration contour of shallow aquifers
Isoconc. contour of deep aquifers in gram/litre
Dug well
Drilled well
Spring
International boundaries
Surface water shed
Approximate boundaries of related areas
Urban areas

In general the mineralization of ground water in July was found lower than in March in those drilled wells penetrating the deep aquifer, while it is higher in the shallow aquifers.

The following conclusions were drawn by comparing the two maps of Figure 63 and 64.

1) - it was possible to draw isoconcentration contours for the deep aquifers in the period of March 1975. This shows that the deeper ground water is less mineralized than the shallow ground water. It ranges between less than 0.5 gm/litre near the mountain to over 3 gm/litre in the central parts of Ajij basin. Also the changes in deep ground water mineralization is gradual and represented by smoother contours.

2) - the extent of fresh water (less than 1 gm/litre TDS) to the south of Jabal Sinjar is wider in July than in March 1975. This could be due to the delayed replenishment which is derived from the alluvial deposits over and around the mountain.

3) - the mineralization of the shallow aquifer waters in Wadi Al-Ajij is lower in March 1975 than in July 1974. This indicates that recharge to the shallow aquifers can take place within one or two months of the rainy season. Also the mineralization of the shallow aquifers around Sunaisala basin reflects the same picture.

4) - the mineralization of ground water around the area of Jabal Zimbar and Tel Afar is lower in July 1974 than In March 1975 and could be due to the replenishment of aquifers towards the end of the wet season, April and May.

The long term variation in ground water quality can be seen by comparing the mineralization of water sampled in the year 1954 and represented in Figure 48 with that analysed in July 1974 and March 1975. Though these are only few isoconcentration contours appear in Figure 48, there appears to be a

tendency for an increase in mineralization of the shallow aquifers. This could be due to the increase in the number of drilled wells in the area which has led to higher abstraction and subsequently higher infiltration due to losses from irrigation water. The continuous evaporation from the shallow and surface water can increase the mineralization of the infiltrating water.

4.5 Relation of specific conductance of water to total dissolved salts and other constituents:

Specific electrical conductance (EC) is the conductance of a body of unit length and unit cross section at a specified temperature. The American Society for testing and Materials (1964, p. 383) has defined electrical conductivity of water as the "reciprocal of the resistance in ohms measured between opposite faces of a centimeter cube of an aqueous solution at a specified temperature". Because conductance is the reciprocal of resistance, the units in which specific conductance is reported are reciprocal ohms, or mhos.

All the measurements made in the field for the specific conductance of water were reported in micromhos, All the measurements made in the laboratory for the analysed samples appear in Table 1 of the first computer program (Appendix 3) under EC, reported in millimhos per centimeter.

Pure liquid water has a very low EC, for the presence of charged ionic species in solution makes it conductive. The measurement of conductance provides some indication of ion concentration in water.

The relationship between ionic concentration in water and its conductance is fairly simple in dilute solution of single salts. But the complexity of ionic constituents in natural water make this relationship more complicated.

Since every different ionic constituent has different electrical charges, their effect on specific conductance of water is directly related to the concentration of each ion. Furthermore, natural waters may contain a variety of both ionic and undissociated species, and the amounts and proportions of each may range widely.

Figure 65 is a plot of the TDS of the ground waters of the area against EC. Those points which do not lie on the mean curve are waters with dominating sodium chloride or calcium sulphate salts. For this reason, the dotted lines are prepared separately to be used when the type of dominating salt in water is known.

A reasonably well-defined relationship is indicated for the range; so that for any given conductance value the TDS can be estimated from the relationship:- KA = S where K is conductance in micromhos, S is dissolved solids in milligrams per litre, and A the conversion factor. It is apparent from Figure 65 that the above relationship is valid and can provide a good estimation of the TDS from the measurement of conductance.

For the analyses of natural waters given in this thesis, the range of A is about 0.56 to 0.98. The higher value of A is associated with waters high in sulphate concentration while the low values are associated with waters high in sodium chloride. The values of A for waters dominated by sodium or sulphates are measured separately and tabulated as shown in Table 13 below:-

No.	EC (micromhos/cm)	TDS(ppm) SO_4-rich	TDS(ppm) Na-rich	A SO_4-rich	A Na-rich
1	500	430	280	0.86	0.56
2	1,000	880	610	0.88	0.61
3	3,000	2,700	2,050	0.9	0.68
4	5,000	4,550	3,550	.914	0.71

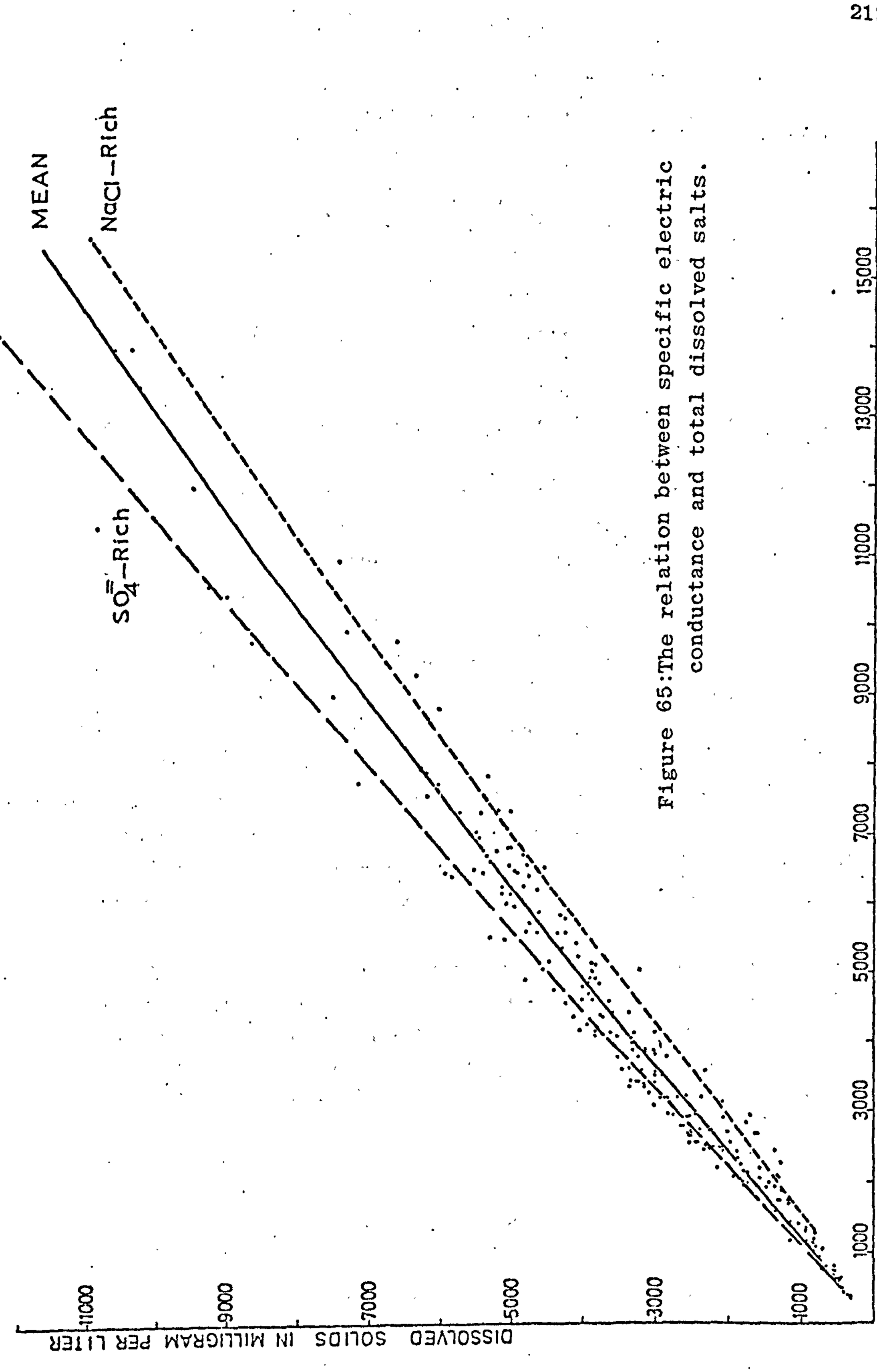


Figure 65:The relation between specific electric conductance and total dissolved salts.

No.	EC (micromhos/cm)	TDS(ppm) SO_4-rich	TDS(ppm) Na-rich	A SO_4-rich	A Na-rich
5	7,000	6,400	5,100	0.91	0.73
6	10,000	9,300	7,600	0.93	0.76
7	15,000	14,300	12,000	0.95	0.8
8	50,000	49,000	44,000	0.98	0.88

Table 13: Relation of water conductivity to total dissolved salts.

Figure 66 shows the relationship of specific conductance to sulphate and chloride concentration for the same set of analyses used in Figure 65. A remarkable difference appears in Figure 66 between the relationship of sulphate and chloride to water conductance. These sources would be useful for estimating or extrapolating the ionic concentration in water when the general characteristics of the water are already known. Figure 67 shows the relationship of specific conductance to sodium concentration for the same set of analyses previously used. The general relationship is close to the relation of conductance and total dissolved solids.The slope of the straight portion of the curve extends to about 8,000 micromhos conductance then decreases slightly up to 11,000 micromhos. It tends to straighten again above 11,000 micromhos conductance, but with a more gentle slope.

The measurements of specific conductance were corrected to a standard temperature of 25°C. The response of the conductance value to temperature change is somewhat different for different salts and different concentrations, but in dilute solutions for most ions an increase of 1°C increases conductance by about 2 percent, Hem (1970).

4.6 Relation of water quality to depth:

The solubility of the different salts in ground water can be affected by the flow of water, its temperature, and the

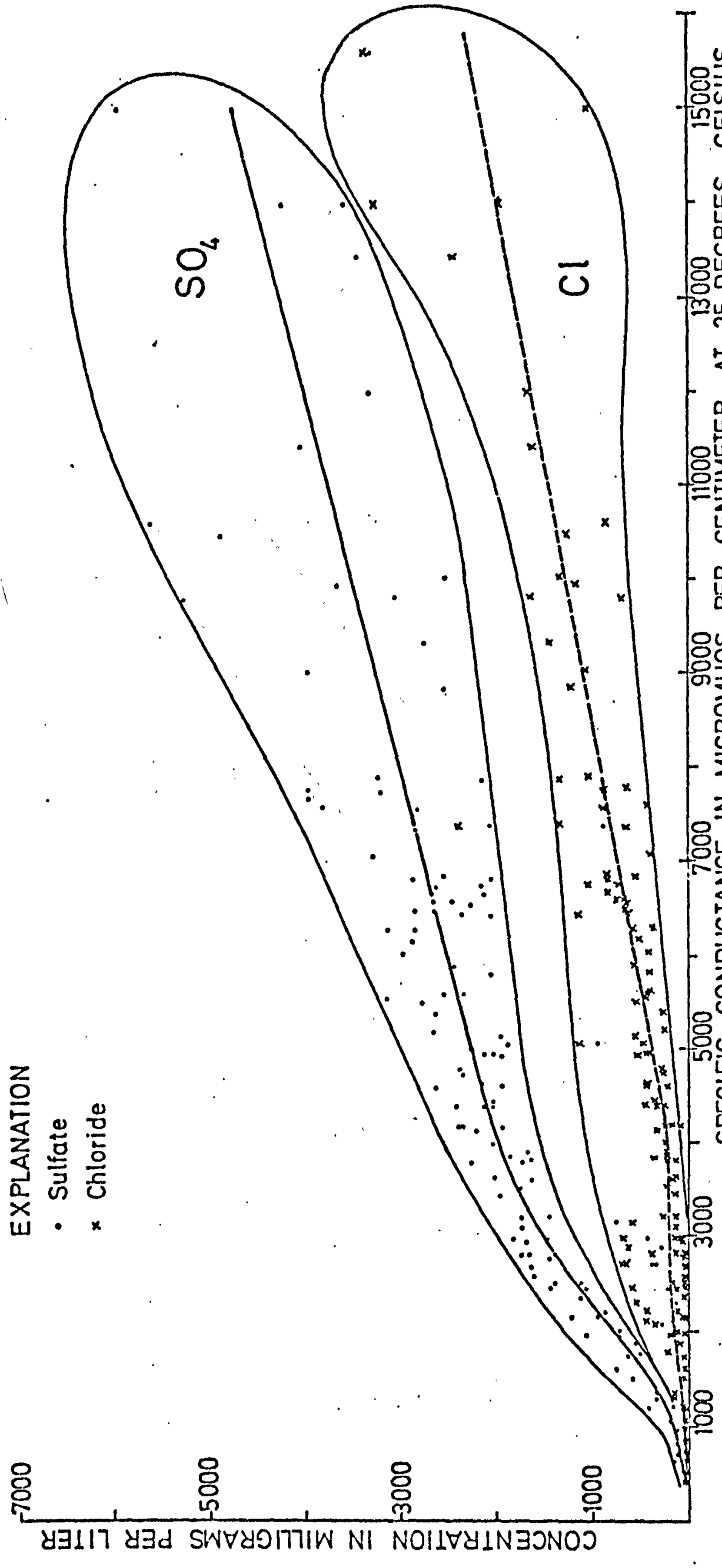


Figure 66: Specific electric conductance in relation to concentration of SO_4 and Cl in water.

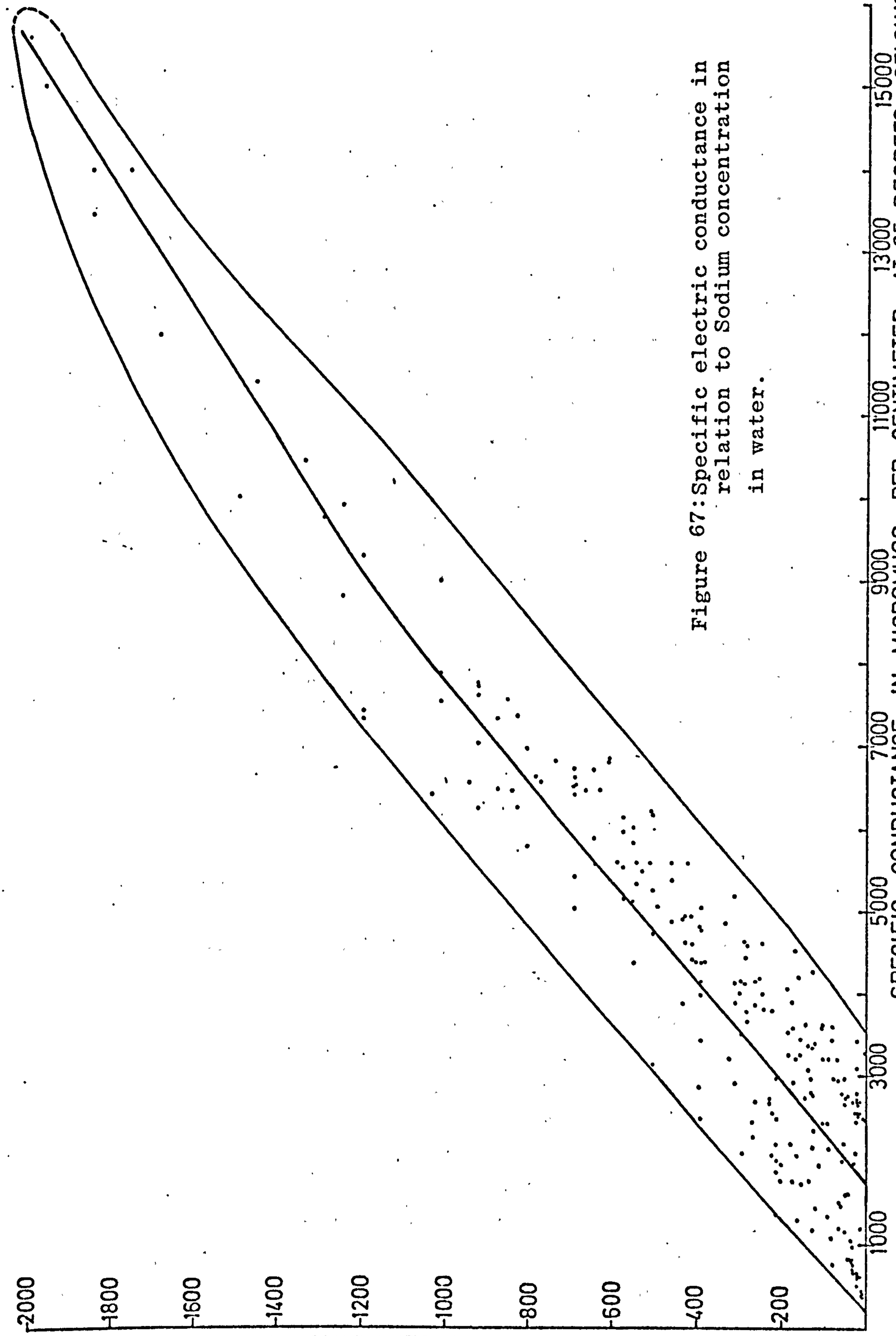


Figure 67:Specific electric conductance in relation to Sodium concentration in water.

presence of other dissolved salts which may affect the mobility of the ions in water. The main control of total dissolved salts in ground water is the lithology of the water-bearing materials and the speed of ground-water flow. In most cases, the flow of ground water is slow in the deeper horizons compared with its flow at shallow levels. This is attributed to a decrease of hydraulic conductivity with depth and also the decrease of water circulation in the aquifer. The shallow aquifers receive more recharge of fresh water than deeper aquifers. The relation between flow and salt solubility is rather complicated, but it is generally agreed that the solution effect increase with time, i.e. solution effect of slowly moving ground water is higher than in the faster flowing water and hence its total dissolved salt content is expected to be higher.

In the area under study, the lithology of the water bearing materials prove to be the major control on ground water quality. The mineralization of ground water may be increased or decreased in relation to depth. This is made clear by the examples shown in Table 14. In the first four locations, the mineralization of ground water decreases with depth. The high salinity of the shallow water may be due to one or more of the following factors:-

1) - excessive evaporation in the soil and subsoil
2) - localization of reworked materials rich in sodium chloride or calcium sulphate. Such areas like buried salt playas can locally carry waters of very high salinity though in most cases such areas are disconnected from the main aquifer.

The waters compared in the first four locations were collected from drilled wells and nearby hand-dug wells. In examples 5 and 6, water samples were collected from the same well at different depths. The samples were collected as drilling progressed, i.e. the second sample could be contaminated

Ser. No.	Location	Source	SN	Temp °C	Tot. Depth (m)	Elec.Cond. micromhos/cm	T.D.S. (ppm)	Remarks
1	Blaij	Ingra BH	28	25	200	2450 *2002	1602.2	85m. sealed from top
		GWD BH		22	90	3500	2872	first two water horizons sealed
		Dug well			3	12,500	(9000)	NaCl taste
2	Ba'aj	Ingra BH	24	24	140	2150	1820.2 *1446	Ingra No. 28 bore hole
		GWD BH			124	1800	(1500)	
		Dug well			5	7500	(5350)	
3	Kharab Bajar	GWD BH	21	25.5	204	752 (680)	570	
		Dug well	22	22.5	15	3370	3268	
4	Am'mash	BH	?			4700	4102.2	
		Dug well	29		5	10,000	(8000)	reworked Upper Fars
5	Aldabona	BH			?	2700	(2400)	Lower Fars aquifers
		BH			?	10,000	(8500)	
		BH			205	69,615	(60,000)	
6	Botha	GWD BH	Ser.No. 17		22	9,300	6306	pH = 7.
	Al-Sharkiya	GWD BH	16		39	20,800	14,178	pH = 7.4
		GWD BH	15		80	34,000	27,210	pH = 7.1

(9000) TDS Estimated from the relation with EC curve. * old analyses

Table 14: Relation of water quality to depth

with water from the first aquifer and so might the third sample. In these two localities, the salinity of groundwater increases with depth. The well at locality 5 (Aldabona) penetrates thin alluvial deposits overlying the Lower Fars formation. The increase of water conductivity from 2700 micromhos per centimeter in the shallow aquifers to 69,615 micromhos per centimeter at 200 m. depth indicates the presence of halite within the Lower Fars formation. The well at locality 6 (Botha Al-Sharqiya) shows a gradual increase in the ground water mineralization. The first water-bearing horizon was located at 8 to 22 m. below surface. It represents the water of the reworked Upper Fars materials in which the total dissolved salts was 6306 ppm. The second water bearing materials were at a depth of 37 to 39 m. in which the water has 14,178 ppm. TDS, while the third water bearing materials were penetrated at a depth of 77 to 80 m. and the salinity of water in this horizon was found to be very high (27,210 ppm. TDS).

In general, the mineralization of groundwater is found to increase or decrease in the different locations as follows:-

1) - when the alluvial deposits overlie Upper Fars or Lower Fars aquifer, it usually carries fresher water, i.e. water mineralization increases with depth, e.g. recent alluvial aquifer south of Jabal Sinjar.

2) - when the reworked Upper Fars materials overlies the Upper Fars aquifers, the salinity of ground water decreases with depth.

3) - the common situation with the Lower Fars aquifers is for increased mineralization with depth, with the exception of areas where reduction is taking place. These will be discussed in the next chapter.

4) - the mineralization of ground water in the Upper Fars aquifer generally increases with depth, especially if a connection exists with the underlying Lower Fars saline ground water.

4.7 Corrosion protection of well structures:

Most natural waters are either corrosive or encrusting The two effects can occur together, but the rate at which they take place depends on several factors such as the pH of water, presence or absence of oxidation agents, flow of solutions over corroded areas, electric effects, formation of coating films or protective deposits and temperature of the corrosive reaction.

For a detailed understanding of the fundamental conditions under which corrosion occurs, the reader is referred to Johnson-UOP (1972). The ground water of the Fars aquifer is mineralized over most of the area and it is known that dissolved minerals in ground water increase its electrical conductivity. The chance of corrosion damage to the well structure is greater where the ground water carries large amounts of minerals in solution. Wells of 1000 to 5,000 ppm, TDS should be protected by anti-corrosive devices. Particular attention should be given to wells with salinity of 2500-5,000 ppm.

Cathodes and anodes are used to develop galvanic members in some of the wells drilled and constructed by Ingra Consulting Department. Zinc and Magnesium electrodes are set into the wells. These electrodes have very high electro-chemical potential. Their electrochemical potential is more negative than the potential of the well metallic construction. Such electrodes play the role of anodes with themselves dissolving (wearing out) instead of the metal of well pipe and pump The life time of the electrodes depend on their mass and on ground water salinity.

For screen protection, magnesium electrodes, 60 mm in diameter and 1 m long have been used in some wells drilled by Ingra Consulting Department. The pumps and pumping tubing are protected with zinc-electrodes of section 45 mm x 13 mm and 1.5 m long. They contain 99.99% zinc, while the composition of the magnesium-electrode is 90.8% Mg, 5.8% Al, 3.1% zinc and 0.3% of other impurities.

The efficiency of the anticorrosive protection can be tested by measuring the self-potential of the metallic structure with respect of $Cu/CuSO_4$ electrodes. The metallic structure of the well is protected when the electrical potential is equal to or higher than 850 mv.

None of the wells constructed by the Groundwater Department of Mosul are protected from corrosion, even though they penetrate aquifers with mineralized, corrosive water. Furthermore, the well screen is not galvanized. The type of casing used in all these wells is ordinary mild steel as shown in Plate 11. This has led to very fast deterioration of the well screen and pump tubing due to corrosion. In wells penetrating the Lower Fars aquifers, the well screen has to be changed every year, e.g. Al-Dirnaj, SN 36, with TDS= 4070 ppm; in others casing was maintained or changed every two years. Cathodic protection may last for an average of 10 to 15 years in such areas.

In some areas of saline ground water, with prominent NaCl salt, encrustation is the major problem. In areas like Sibayat Harrosh (SN.46) and Al-Rashidia (SN.67) where TDS is about 2100 ppm, NaCl was deposited in the pumping tubing and the well efficiency is very low. Clogging of screen perforations by encrustation is probably the main reason for the decrease in yield with time in such areas.

CHAPTER FIVE

HYDROGEOCHEMISTRY

5.1 Chemical characteristics of water in relation to source

5.1.1 Sulphate reduction and sulphur deposition in the Lower Fars formation

5.1.2 Thermal and mineral water

5.2 Ionic exchange

5.3 Nitrate concentration and pollution signs

5.4 Conclusions on water quality and use

5.1 Chemical characteristics of water in relation to source

The lithology and texture of the water bearing materials play the most significant role in controlling the different types of chemical reactions responsible for composition of natural water. The lithology of the different water bearing materials was discussed under Geology in Chapter 2. The constituents of natural water most likely to be derived directly from solution of minerals in rocks and in soil are dissolved cations and silica. Although cations-anions balance must be maintained in all solutions, the anions may be derived in large parts from nonlithologic sources. For example, the bicarbonate present in most water is derived mostly from carbon-dioxide that has been extracted from the air and liberated in the soil through biochemical activity. Halite is the main source of chloride, while gypsum and anhydrite are the main source of sulphate.

The presence of several aquifers in the area under study, and the interconnection of ground waters by leakage, makes the relationship between mineral composition of ground water and that of aquifers rather complicated. The source of the main ionic constituents of the ground waters analysed and classified in the last Chapter is explained in brief herein. For detailed understanding of major and minor elements contained in natural waters, the reader is referred to Hem (1970).

Calcium

Calcium is the principal cation in the alluvial and Fars aquifers. The most common forms of calcium in the area under study are carbonates. The alluvial deposits over and around Sinjar anticline are mainly limestones with

some sands and clay. The presence of thin beds of limestone within the Upper Fars and thick beds within the Lower Fars formations provides the main source of calcium in ground waters of these formations. However, gypsum and anhydrite provide the main source of calcium in waters located in aquifers of the Lower Fars formation.

Limestone consists mostly of calcite with admixtures of magnesium and other impurities. The usual dissolved form of calcium can be represented as the ion Ca^{+2}. The ion pairs $CaHCO_3^+$ can exist in waters with bicarbonate concentration near 1000 mg/l (Greenwald, 1941), while in solutions where sulphate concentrations exceed 1,000 mg/l, more than half the calcium could be present in the form of the $CaSO_4$ ion pair. Both generalizations assume calcium concentration is small compared with the bicarbonate or sulphate contents.

It is apparent from the classification of ground water discussed in the last chapter that the calcium is the dominating cation in the waters of the reworked Upper Fars, Lower Fars, Upper Fars and alluvial aquifers. While it is dominated by sodium and potassium in the mixed waters of groups D and F (see Figures 50 and 51). The average contents of calcium in each group is shown in Table 2 of the second computer program (see Appendix 3), P.357

Magnesium

The predominant ionic form of magnesium in natural water is Mg^{+2}. The ion pair $MgSO_4$ (aq) has about the same solubility as the species $CaSO_4$ (aq), and magnesium complexes with carbonates or bicarbonate have approximately the same stability as the similar species of calcium. The sulphate and bicarbonate ion pairs are significant only when the solution contains more than 1,000 mg/l of sulphate

or bicarbonate. The waters of the Fars and reworked Upper Fars aquifers contain over 1000mg/l sulphate, while the alluvial and mixed water contain less than 1,000 mg/l sulphates. None of the waters analysed shows over 1,000 mg/l bicarbonate contents.

The average magnesium contents in the different groups of waters is shown in Table 2 of the second computer program (see Appendix 3). The magnesium contents in waters of Upper Fars, Lower Fars and alluvial aquifer is higher than the sodium and potassium while it is lower in the reworked Upper fars, and mixed waters. This is due to the presence of thick dolomite in the Lower Fars formation and a considerable quantity of magnesium in the limestone and dolomitic limestones of the Upper Fars formation and alluvial deposits which are derived from these rocks.

Sodium and Potassium

Owing to the low concentration of potassium in most natural waters and to the similarity with sodium in its ionic behaviour, potassium is added to sodium for the correlation and classification of ground waters of the area under study. However, the potassium ion is substantially larger than the sodium ions, sodium is the most abundant member of the alkali-metal group present in natural water. The highest concentration of sodium is found in the brines associated with the halite beds within the Lower Fars formation. In one abandoned well drilled by Ingra Consulting Department in the town of Hadhr, the total dissolved salts was found equal to 305,200 mg/l. This water contains 173,200 mg/l chloride, 1272 mg/l sulphate and 412 mg/l nitrates. The other constituents were not analysed but sodium concentration in this sample is expected to be equal to or not less than 120,000 mg/l.

The maximum concentration of sodium analysed from water of the reworked Upper Fars on the periphery of Sunaisala salt playa was 10,580 mg/l (analysis No.149 in Table 2 of the first computer program). The maximum concentration of sodium analysed by the Ground Water Department was analysis No.303 of Table 2 with Na^+ = 15,106 mg/l. This water was taken from a borehole drilled in the Lower Fars formation in the village of Al-Dabbora.

The concentration of sodium and potassium is predominant in group D and F of the mixed type of water covering the area shown in Figures 50 and 51, whereas calcium or magnesium dominate in the other groups of water. The primary source of sodium in ground water is from the soluble sodium chloride salt. Lower Fars formation provides the richest halite beds in the area, where the sodium chloride present in the Upper Fars and reworked Upper Fars materials are depositional products of evapo-transpiration in the shallow aquifers or direct evapo-ration from ground surface as in Sunaisala salt playa.

Alkalinity

Alkalinity is the capacity of a solution to neutralize acid. It may be reported in terms of an equivalent quantity of calcium carbonate. It most natural waters, the alkalinity is practically all produced by dissolved carbonate and bicarbonate ions. Therefore it is useful to express the results of the concentrations of bicarbonate and carbonate determined as alkalinity. The dissociation of bicarbonate to carbonate ions is effectively large above a pH of 8.2. Below this value all carbonate ions add hydrogen to become bicarbonates. The pH of ground water determined in the field and the laboratory does not exceed 8.2 except in the results of the old analyses made by Ingra and Ground Water Departments.

Therefore,the carbonate in ground water is not determined. The bicarbonate contents in all the water samples are expressed as HCO_3^- in Table 1 of the first computer program. The average value of bicarbonate content in each of the different groups of waters is shown in Table 2 of the second computer program. The maximum concentration of HCO_3 in ground water of the area is 14.25 meq/l determined from the waters of the Mishraq sulphur structure (SN.312 & 315 in Table 1, 1st computer program). However, exceptionally high bicarbonate in such areas is due to the biochemical reduction of sulphate in the thermal aquifers of the Lower Fars formation.

Chloride

Chlorine is the most important and most widely distributed of the halogens in natural water. It is present as chloride ion, Cl^-; the most important source of chloride being the evaporites of the Lower Fars formation. Chloride is mainly present either as sodium chloride crystals in rocks or as a solution of sodium and chloride ions. The average concentration of chloride in the different groups of ground water of the area under study is shown in Table 2 of the second computer program.

Generally speaking,chloride concentration is lower than sulphate in most of the ground water groups except group F of the mixed water where chloride is greater than the sulphate concentration. The concentration of chloride is higher than the bicarbonates in waters of the reworked Upper Fars and the mixed water of groups D and F, while it is lower than the bicarbonates in the water of the Lower Fars formation and the alluvial aquifers.

The high concentration of chloride in the shallow aquifers is mainly due to the evaporation from the capillary zone of the subsoil.

Sulphates:

The anion sulphate (SO_4^{-2}) is the fully oxidized form of the element sulphur. The most extensive and important source of sulphate are evaporite sediments. Calcium sulphate as gypsum ($CaSO_4$, $2H_2O$), or anhydrite ($CaSO_4$) makes up a considerable part of the Lower Fars formation and the reworked Upper Fars. The concentration of sulphate ion in ground waters of the reworked Upper Fars, Lower Fars and Upper Fars aquifers and group D of the mixed water is higher than the other anions. It is lower than the other anions in the alluvial aquifers waters and group F of the mixed water.

The solubility of calcium sulphate in pure water decreases with an increase of temperature, and the solubility of the most common sulphates in pure water are shown below:-

$MgSO_4$	260 gram/litre at 0^oC 738 gram/litre at 100^oC
K_2SO_4	68.5 gram/litre at 0^oC 120 gram/litre at 25^oC
$CaSO_4$	2.09 gram/litre at 30^oC 1.619 gram/litre at 100^oC

The presence of different dissolved salts in water affects the solubility and saturation point of each element. Sulphate concentration in ground waters of the area under study is generally higher than 1000 mg/l. The maximum concentration of sulphate found is the area of Ksaibiya, on the periphery of Sunaisala salt playa (SN.149) where SO_4^{-2} = 9927.8 mg/l. This water sample was collected from a shallow hand dug well in which the static water level is about 3 metres below ground surface. The high concentration of sulphate and other salts in this area is considered to be due to evaporation.

The composition of the soil covering most of the area surrounding the anticlines and over Hadhr plateau is mainly gypsiferous (see Figure 10) and infiltration of rainfall through such soil can dissolve substantial amounts of gypsum. This usually produces higher concentrations of sulphate in the shallow aquifers, particularly over the reworked Upper Fars materials.

Almost all waters associated with the gypsum and anhydrite of the Lower Fars formation are saturated with respect to sulphates. The fibrous gypsum of the Lower Fars formation exposed in most of the western Tigris structures (Plate 12) is readily soluble in water. The majority of the massive gypsum have suffered recrystalization whereby macrocrystalline gypsum is developed as shown in Plate 13.

Total Hardness:

The total hardness of ground water calculated as $CaCO_3$ is tabulated under TH in Table 4 of the first computer program. This hardness as $CaCO_3$ can also be referred to as "calcium + magnesium hardness" or "total hardness". It is computed by multiplying the sum of milliequivalents per litre of calcium and magnesium by 50 and is principally due to the solution of calcium and magnesium in water.

The enrichment of the alluvial deposits with calcium carbonates and limestone boulders, and the presence of soluble evaporites of gypsum and anhydrite in the Lower Fars formation, provide good sources for hardness in waters of the study area. Magnesium carbonate present in the dolomite and dolomitic limestone of the Lower Fars formation is the main source for magnesium in ground water. Calcium and magnesium are both relatively insoluble

in pure water, but the presence of H^+ controls their solubility in natural waters. The most common source of hydrogen in water is dissociation of carbonic acid (H_2CO_3). The following reaction explains the process of its formation:-

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3$$

$$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$$

$$CaCO_3 + H^+ \rightleftharpoons Ca^{2+} + HCO_3^-$$

This dissociation cannot continue unless CO_2 is removed from the system. If CO_2 is in abundance, as is the case of alluvial water or Lower Fars reduced ground water, the dissociation will proceed only as far as the bicarbonate stage. If the pH is increased, then the ratio of carborate (CO_3^{2-}) to bicarbonate (HCO_3^-) ions increases and calcium carbonate may be precipitated. In general the total hardness in the area of study is very high in the ground water of the Lower Fars aquifers, up to 11,584 in SNO.303, and relatively low, being as low as 170.134 in SNO.23 in the ground water of the alluvial aquifers.

Hydrogen ion concentration (pH)

The abbreviation 'pH' represents the negative base -10 logarithm of the hydrogen-ion activity in moles per litre. Pure water can be dissociated into H^+ and OH^-. At neutrality, $[H^+] = [OH^-]$ and pH = 7.00 at 25^oC. The pH of natural water is related to the type of reactions which occur in water among solute, solid and gaseous or other liquid species. The dissociation equilibrium and nonequilibrium reactions involve hydrogen ions.

The most important reaction in establishing pH in natural water is the solution of carbon dioxide in water. The first

and second reactions shown under "Total Hardness" produce H^+ and influences the pH of water. Other reactions involving dissociation of acidic solutes or hydrolysis reactions can influence or indeed are influenced by pH.

One of the important reactions which takes place in the Lower Fars aquifer under reducing conditions is:-

$$H_2S\ (aq) = HS^- + H^+$$

and

$$HSO_4^- = SO_4^{-2} + H^+$$

These reactions explain the low pH of the Lower Fars aquifer water present under reducing conditions. The pH values of ground water in the area of study were measured in the field at the time of sampling as well as in the laboratory for 62 water samples. All the results are plotted in Figure 68. It is apparent from this figure that the measurements of pH made in the laboratory are higher than the field results for the samples with values of pH less than 7.6. The difference in measurements is about half a unit in water samples with pH value of 7.0, decreasing gradually as the pH increases. The pH measurements of the samples with values greater than 7.6 seem to produce higher results in the field than in the laboratory, though only three samples show this variation.

The main reason for the difference in the results of pH measurements in the field and the laboratory is probably due to the escape of CO_2 gas from the water sample in the period between sampling and analysis. The water sample bottles were not tightly closed, they have no inner seals and the escape of gases from the sample bottle is particularly likely when the sample temperature increases. The average air temperature, which reaches up to 40^oC, is about 15^oC higher than the ground water temperature. The increase in the sample water temperature can cause the escape of most of the dissolved gases in water.

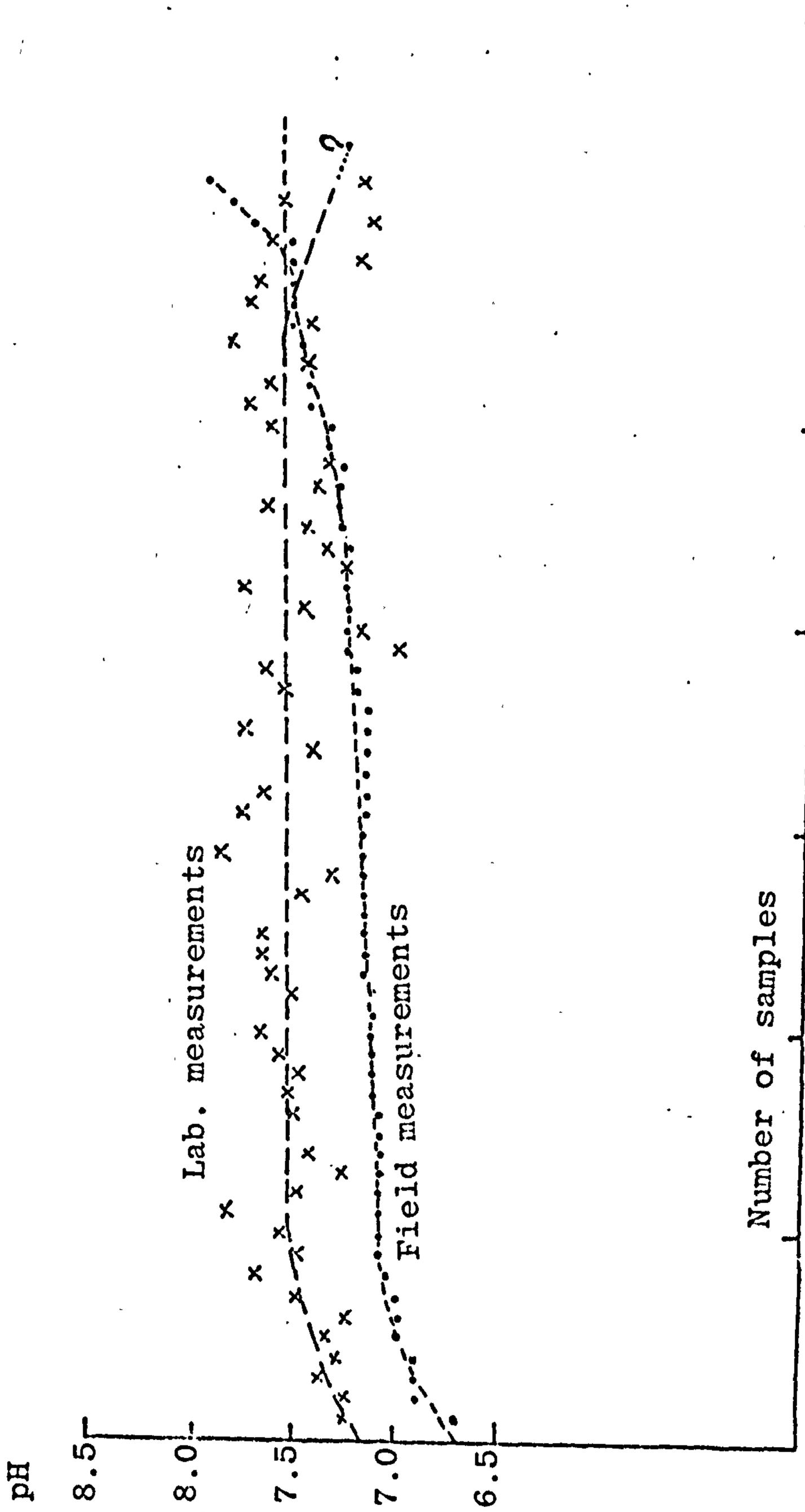


Figure 68: Variation of pH measurements in the field and laboratory.

5.1.1. Sulphate reduction and sulphur deposition in the Lower Fars formation.

Economic sulfur deposits were found recently in anticlinal structures in northern Iraq. The largest deposits were found in the Mishraq anticline (Figure 13), in which the deposits, consisting of limestone and elemental sulfur in bedded anhydrite and gypsum, are geologically similar to elemental sulfur deposits in Sicily, Poland, the U.S.S.R. and the United States.

In the area of the Lower Fars structures, ground water and gases were collected from sulfur-bearing anticlines and springs and were analyzed for their mineral and hydrocarbon contents as well as for concentrations of sulfate-reducing bacteria; the temperatures of these waters were also recorded. These data were correlated with the lithology of the stratigraphic units and with the intensity of biological activity. Field and laboratory evidence suggests that sulfate reduction and simultaneous oxidation of hydrocarbons, mainly gases, is taking place at different depths, dependent upon the physical conditions controlling metabolism of anaerobic bacteria.

Gas samples analyzed at various times before and after sulfur mining in the Mishraq district demonstrate the effect of increases in temperature on bacterial activity. The sulfate-reducing bacteria, Desulfovibrio desulfuricans, were identified in most of the springs and wells that were sampled and proved to be the most important agent in the oxidation of hydrocarbons and the reduction of sulphate both necessary processes for the generation of sulphur deposits. Minable deposits of sulphur occur where the temperatures required for bacterial metabolism exist.

The lower part of the Lower Fars formation is the sulphur bearing productive series, in which sulphur deposits are mainly localized in three horizons, each about 30 m thick. These deposits are located in the top,middle and bottom of the productive series. They are separated by silty marls and shale beds. The uppermost horizon is considered of lesser economic importance than the lower two, Plate 14. Present mining in Mishraq is from the second and third zones only, and the average sulphur content in some parts of the commercial zones is more than 25 percent . Rich sulphur deposits are found in the jointed and faulted zones of the structure, Plate 15. Pure sulphur was found to occur in the following three forms: orthorhombic bipyramidal crystals varying in size from a few millimetres to a few centimetres, Plate 15, cryptocrystalline form. Sulphur crystals associated with radiating forms of secondary crystalline calcite are also common . Calcite is found in association with sulphur in the form of rhombohedron cyrstals enclosing sulphur crystals and filling cavities and fractures in the cavernous bituminous limestones. Interbedded crystalline sulphur and calcite is very common in limestone, shale, marls, and clays. The alteration of gypsum into sulphur and calcite is shown in Plate 17.

5.1.1.i. Ground water distribution in the sulphur-bearing anticlines:

The Lower Fars formation is karstified, so most ground water is in cavities, caves, channels, and joints within the limestone. Some water is found in the sandstone beds and in fractured claystone. The bulk of ground water is

in the productive series, in which most of the ground water is flowing within the secondary limestone beds. The crests of the anticlines were highly fractured and jointed, creating passages for water from one horizon to another in the productive series. The sedimentary limestone and anhydrite are less important aquifers as their permeability is low.

The replenishment of aquifers takes place through exposed, jointed, permeable beds of limestone and sandstone or via cavities and sinkholes in the north-western part of the area. Some supply comes also from the overlying permeable Upper Fars formation where the higher region has a greater rainfall (350-400 mm per annum, Figure 5) than that farther south. Some supply comes locally from the Euphrates Limestone where connecting faults and joints are present.

The general pattern of ground-water flow was inferred from water-level data derived from existing wells and springs, and the ground-water flow system in the economically important Mishraq structure was studied in detail. It was found that the movement of ground water, although in fractures and cavities, is greatest in strongly faulted and jointed anticlines. The complicated system of interconnected openings has been amplified by the alteration of anhydrite and gypsum to calcite, aragonite, and sulphur, producing an assemblage of reduced molecular volume. In general, the dominant pattern of ground water flow follows the topography, toward the southeast, and discharges into the River Tigris, Figure 69.

The hydraulic conductivity in the sulphur-bearing zones in the Mishraq area was calculated from several pumping and recharge tests carried out in many wells. A minimal flow rate of less than one metre per day was observed in massive gypsum and limestone. It increases up to 5 m per day in the sulphur bearing area and further increases east-

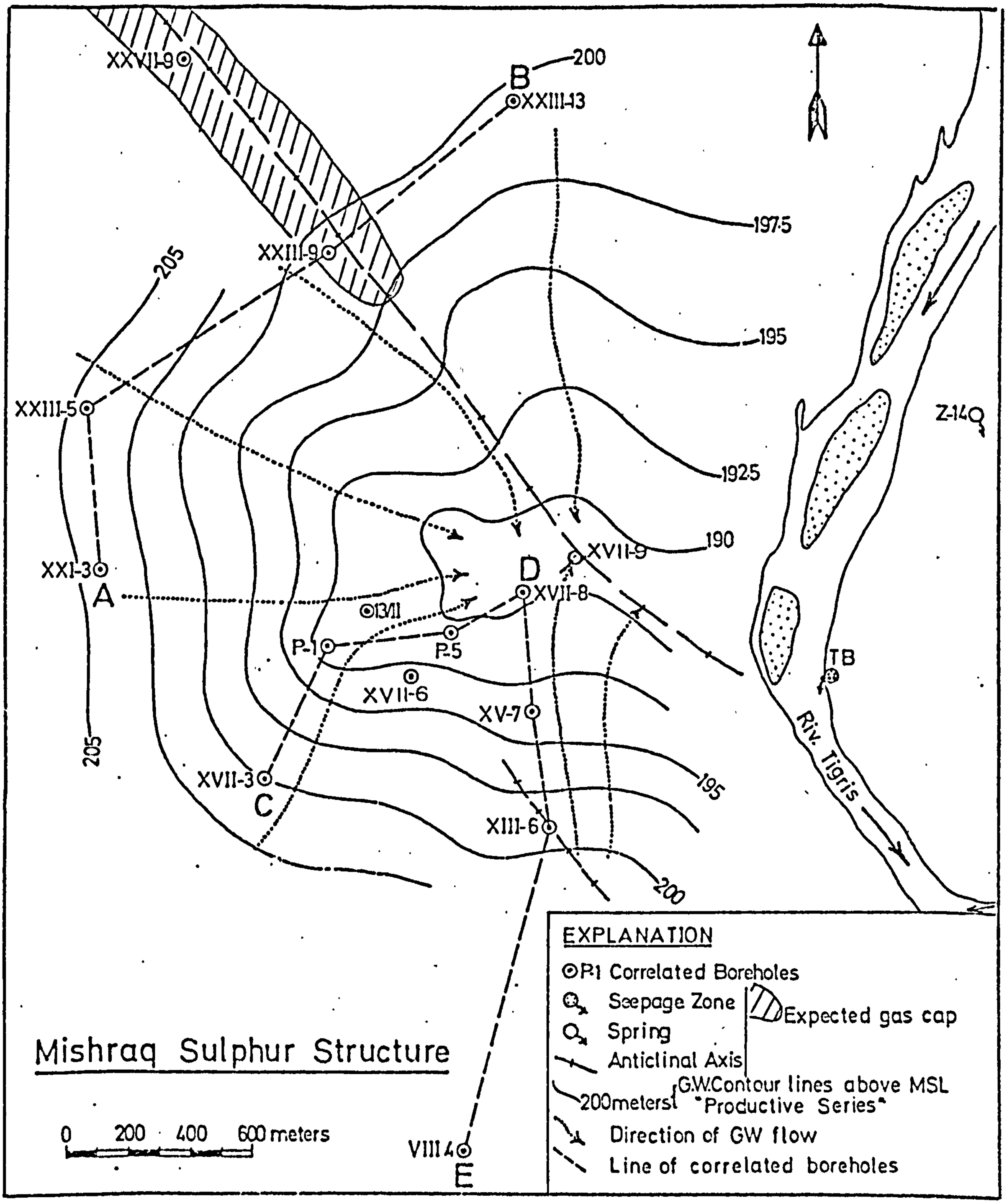


Figure 69: Ground water levels in the "Productive Series" and location of sampled boreholes, Mishraq Sulphur structure.

ward to as much as 30 m per day in the zone near the river Tigris. This latter zone is in hydraulic continuity with the river and is greatly affected by freshwater seepage.

It was possible to draw a generalized flow diagram of ground-water movement for each of the three sulphur horizons of the productive series from which the total quantity of ground water flow in each of them was calculated. The greatest percentage of flow, about 3,500 m^3 per day (57% of the total) was in the uppermost horizon. The flow in the second horizon was 25 percent of the total, or about 1,500 m^3 per day. There was about 18 percent of the total flow in the third horizon (about 1,100 m^3 per day). All the above results were drawn from the results of pumping and recharge tests conducted before the beginning of sulphur mining.

5.1.1.ii Ground-water temperature in the Lower Fars aquifers:

Ground water from the Lower Fars aquifers ranges widely in temperature, depending upon the type of aquifer in which it occurs. Generally the temperature of the water in the sulphate and carbonate members ranges from 21° to 25°C, whereas the water in the productive member ranges from 25° to 31°C in most anticlines. At Hammam Ali hot springs it reaches 50°C.

Sulphur is now being mined by injection of superheated water (130°-160°C). Ground water temperatures decrease away from the mined area but are still as high as 73°C in seepage areas along the far banks of the River Tigris.

The temperature of ground water measured in the field is shown in Table 1 p.321 of the first computer program. Details of temperatures and source of heat in ground water will be discussed under "Thermal Water" later in this chapter.

5.1.1. iii Ground water quality in the sulphur-bearing anticlines:

Ground water was sampled from the various springs and wells for detailed chemical analysis, and at the same time special samples were taken for determination of dissolved H_2S and for bacterial counting. Temperature, pH, and electrical conductivity were measured at the time of sampling, as well as in the laboratory.

The analytical results of samples collected from Mishraq sulphur structures are shown in Table 1 of the first computer program (Serial Number 309-323). The locations of sampled and correlated boreholes are shown in Figure 69. The samples numbers in Table 1 (p.327) refer to the following locations:-

Serial Number	Location
309	Seepage area by River Tigris east bank (TB)
310	Average 5 determinations from the overburden
311	Average 17 determinations from "Productive boreholes"
312	Large spring, Z14, in the east bank of Tigris
313	Borehole No.XX1-3
314	" No.XXIII-5
315	" No.XXIII-9
316	" No.XXIII-13
317	" No.P-1
318	" No.P-5
319	" No.XVII-8
320	" No.XVII-3
321	" No.XV-7
322	" No.XIII-6
323	" No.VIII-4

These analyses are correlated with other analyses collected from different locations. The analyses shown in Table 1 of the first computer program are collected from the following locations:-

Serial Number	Location
308 & 43	Main spring 'Ain Zahra' in Hammam Ali
324	Main spring 'Ain Kibrit' in Mosul
325	Tel Al-Hashim 'Ain Jarab' 3 km west of Hammam Ali
42	Ain Al-Baidha, near Lazaga
46	Dirnaj water supply well
230	Mustantik water supply well

Total dissolved salts in ground water generally increase with depth as shallow aquifers receive infiltrating meteoric fresh water, deeper aquifers have less recharge and a slower flow, and both factors produce a higher salinity. Within the intermediate zone, sulphate-ion reduction and sulphur deposition are taking place.

In contrast, at Hammam Ali, total salinity is higher in water of the upper aquifer and lower in the deeper aquifer (Figure 16). In this area many hot springs are discharging the deeper aquifers which correspond to the productive series of Mishraq, mainly recrystallized bituminous limestone. The major difference in temperature here is due to the difference in rate of sulphate reduction. Sulphate is being reduced here at a greater depth beneath the semipermeable overburden, resulting in lower salinity in the lower aquifer (see the resistivity log in Figure 16). Seepage of hydrocarbon gases from below has accelerated this reaction.

5.1.1. iv Gases and their formation:

Gas seepage is common in northern Iraq, and pockets of gas provide serious drilling problems in some structures. Table 15 lists the original composition of gas in the Mishraq

Table 15: Gas Constituents Collected from Mishraq Sulphur Structure (in percent)

Ser. No.	Date	H_2S	$CH_4+C_2H_6$	CO_2	O_2	CO	Remarks
1	4.1.71	23.5	62.6	13.1	0.8	-	BH. XXVII-9
2	9.1.71	36.5	49.0	13.5	0.8	0.5	The original gas
3	22.1.71	44.59	39.33	15.2	0.33	055	preserved in the struct-
4	6.3.71	46.2	36.25	17.3	0.25	-	ure before exploitation
5	12.5.73	53.0	39.7	4.5	2.8	-	Exploitation BH 13/II

structure. Samples 1 to 4 are from well XXVII-9, located

over the gas cap in the crest of the anticline; they were taken at a depth of 83 metres during the bleeding of the well. Analysis 5, of a sample taken after sulphur mining began, is from well 13/II located on one limb of the anticline. The gases emanate from two sources. The first is the gas originally contained in the Euphrates Limestone and the overlying Lower Fars formation. Although much of the original gas has long since escaped along fractures and joints, drilling for oil in various anticlines has encountered pockets of gases, mostly hydrocarbons and hydrogen sulphide. The second source of gas, considered to be the main supply of hydrogen sulphide and carbon dioxide, results from the biological oxidation of hydrocarbons and the reduction of sulphate. Methane can be produced in large quantities as an end produce of catabolism of bacteria and allied microorganisms. However, the production of liquid and solid paraphenic hydrocarbons ranging from $C_{10}H_{22}$ to $C_{25}H_{52}$ by sulphate reducing bacteria was reported by Jankowski & ZoBell (1944). Further work has established that naphthenic hydrocarbons are also produced by sulphate reducers.

Sulphate reducing bacteria are known to be capable of producing hydrogen sulphide at a rate as rapid as 1,000 mg/l/day (Miller, 1949); furthermore, Kem and Thode (1968) found that the production of H_2S is maximum when the sulphate reduction rate is minimum. These laboratory findings are borne out by the field observations in Iraq. The presence of hydrocarbons in the form of asphalt or gases were reported in many deep drillings for oil in Mishraq and other structures. Also large quantities of bitumen and gases are currently escaping to the surface in the area of Hammam Ali hot springs. The maximum amount of H_2S is in the aquifer at Mishraq, where sulphate reduction is slower than at Hammam Ali. The gases are seeping to the surface in larger quantities in the Hammam Ali hot springs than at Mishraq.

and dissolved H_2S in the ground water at Hammam Ali was far less abundant than at Mishraq, where it reaches 650 mg/l. The gases in Hammam Ali burn in air with a reddish-brown flame, indicating the presence of hydrocarbons.

The initial injection of super-heated water into the Mishraq deposit for sulphur mining has accelerated sulphate reduction, as does the production of H_2S and CO_2; this is shown in analysis 5, Table 15. Reduction ends when rock temperatures reach 100°C, which is too high for biological activity. Gases in most anticlines accumulate beneath impervious layers of marl and massive gypsum and escape along fractures and other weak, permeable zones. The escape of H_2S from the system has two contrasting results; the first is that the rate of reaction is maintained or accelerated because excess quantities of H_2S can poison the bacteria. Escape of H_2S from well XXVII-9 over a period of 63 days led to increased oxidation of hydrocarbons, increased production of H_2S and CO_2, and a decrease in oxygen content (Fig.70). The other results of the escape of H_2S is a decreased rate of accumulation of elemental sulphur; if most of the gas escapes, the area will be poor in sulphur, as at Hammam Ali.

5.1.1.v. Bacteria

Sulphate-reducing bacteria, particularly Desulfovibrio-desulfuricans, have been found in elemental sulphur deposits in the U.S.S.R. and in the United States (Ivanov, 1968; Feely and Kulp, 1957). Desulfovibrio consumes organic material for its carbon and hydrogen requirements and sulphate ions for its oxygen supply, emitting carbon dioxide and hydrogen sulphide as metabolic wastes. Where liquid or gaseous hydrocarbons penetrate beds and aquifers rich in dissolved sulphate, gypsum, or anhydrite, these

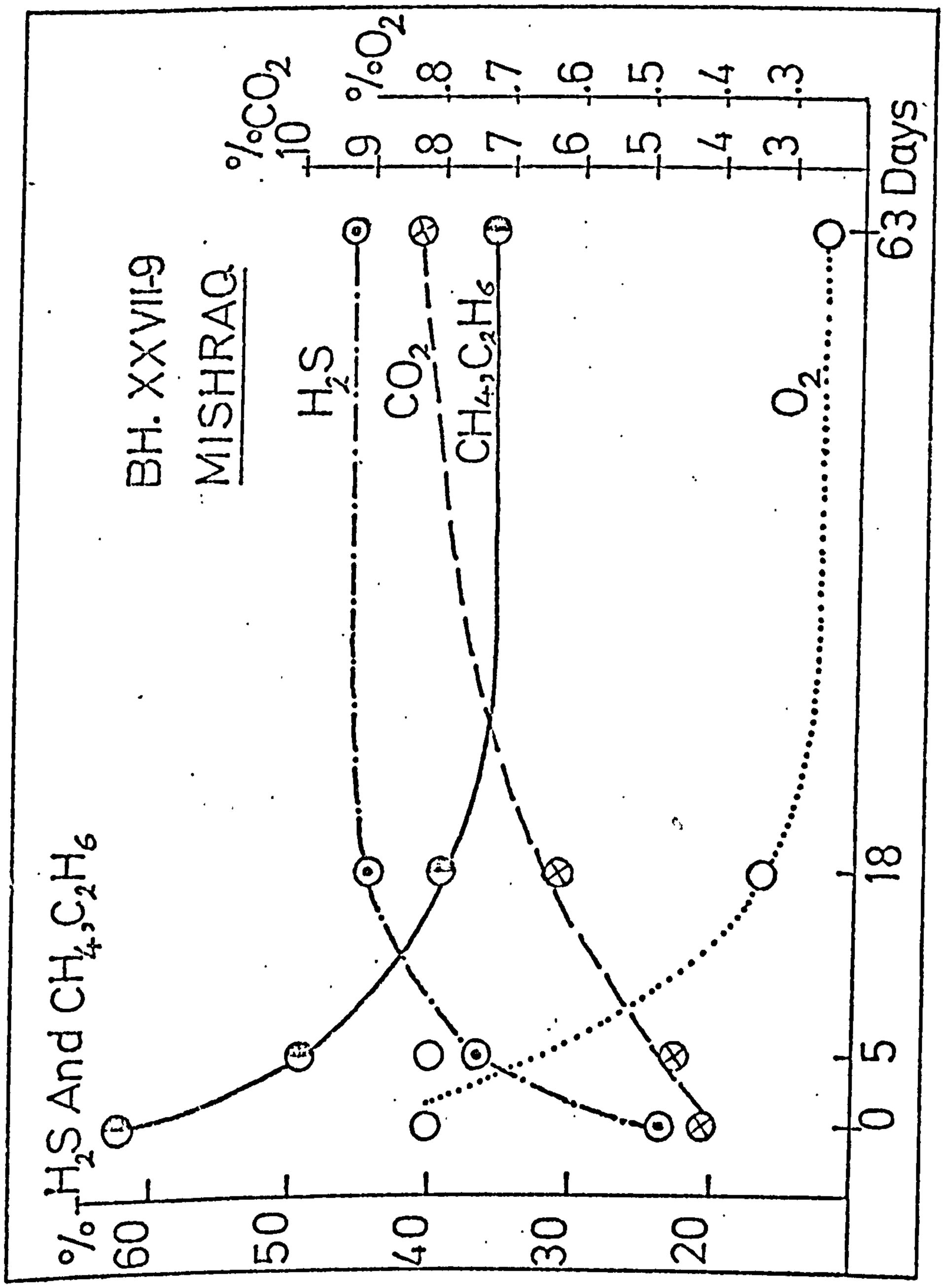


Figure 70: Variation with aging in composition of gas from borehole XXVII-9, Mishraq anticline

sulphate-reducing bacteria can covert masses of sulphate to calcite and elemental sulphur, provided the hydrogen sulphide can be oxidized before diffusing out of the structure in which these reactions take place. The process of sulphate reduction, emission of H_2S, and oxidation of H_2S can take place in the same structure at different depths or in the same horizon or aquifer at different periods.

Engler and Hofer (1909) postulated the following biochemical reaction:-

$$CaSO_4 + C_nH_{2n+2} \xrightarrow{\text{Desulfovibrio desulfiricans}} CaS + CO_2 + 2H_2O \qquad (1)$$

or

$$CaS + 2CO_2 + 2H_2O \longrightarrow H_2S + Ca(HCO_3)_2 \qquad (2)$$

$$CaSO_4 + CH_4 \xrightarrow{\text{Desulfovibrio Desulfuricans}} CaCO_3 + H_2S + H_2O \qquad (3)$$

$$SO_4^{=} + CH_4 \xrightarrow{\text{bacteria}} (HS)^- + H_2O + (HCO_3)^- \qquad (4)$$

$$SO_4^{=} + CH_4 + 2H \xrightarrow{\text{bacteria}} H_2S + CO_2 + 2H_2O + 22.8 \text{ kcal} \qquad (5)$$

These reactions show that the bacteria reduce the sulphate content and increase the carbonate content of ground water and simultaneously change the composition of gases in the system. Because these conditions exist in the sulphur-bearing-anticlines of Iraq, the ground water issuing from wells and springs was sampled to determine whether or not Desulfovibrio were present and abundant. The sulphate reducing bacteria were grown on Starkey's medium and the most probable numbers were determined after 10 days' incubation at 25°C. Positive tubes were recognized by blackening (Abd-el-Malek and Rizk, 1958). The most probable number of Desulfovibrio desulfuricans was recognized by means of Hoskin's table,(1934). All determinations were

carried out in the laboratory of the Institute of Applied Research on Natural Resources in Baghdad.

Positive determinations were obtained for 6 samples,(Table16). The most favourable temperatures for bacterial growth apparently range from 26° to 48°C, although sulphate-reducing bacteria are known to be active at temperatures as high as 63°C. (Butlin, 1953). Sulphate reduction has been found to be directly proportional to temperature in the range 11.1° to 40.3°C (Kem and Thode, 1968).

Sample No.	Location	Bacteria count/ml	H_2S Conc. meq/l	H_2S Conc. ppm	Temp °C	Remarks
308	Hammam Ali	1600	3.7	63.5	48	Main spring
309	Mishraq TB	920	18.95	324	73	Seepage area
42	Ain Baidha	540	5.31	90.8	30	Mixed water
230	Mustantik	130	9.47	161.8	23.5	BH. in Lr.Fars
46	Dirnaj	49	11.33	193.6	27	BH. in Lr.Fars
324	Ain Kibrit	8	9.97	170.3	24	Main spring

Table 16: Bacteria Counts, H_2S Concentration and Temperature of Ground Water Samples from Lower Fars aquifers.

Sulphate reduction in the aquifers of Iraq, particularly those of the Lower Fars formation, can be helpful as a natural process for water treatment. Artificial cultivation of anaerobic bacteria in the aquifers, in which the conditions for their growth are provided, can improve the quality of the water, which at present contains too much sulphate for human or agricultural use in many areas.

5.1.1. vi. Sulphate Reduction

In the present study the variability of sulphate-ion concentration and water quality at different depths and in different structures was correlated with bio-chemical activity and the effect of gas movement through the aquifers. Two localities were studied in detail, the Mishraq sulphur structure and the Hammam Ali hot spring area. The geology

is nearly the same in both areas but the water-rock interactions, temperatures, and sulphur concentrations differ substantially.

Mishraq sulphur structure

The chemical compositions of ground water and of associated gases in the Mishraq anticline were determined while the structure was being explored for commercial sulphur deposits. Minable sulphur was deposited both in the limbs of the anticline and in its crest, where gas accumulated under pressure. The richest part of the structure is its southwest limb, in which sulphur has been commercially exploited since 1973.

Figure 69 shows the traverse lines of wells which were correlated for their water quality and sulphate reduction. Line A-B of Figure 69 and Figure 71 is perpendicular to the direction of major ground-water flow, where hydrologic factors should be uniform but where structure, gas composition, and pressure determine the sites of sulphur deposition. The line crosses the axis of the anticline in the zone where gas has accumulated and some sulphur was deposited. Lines (C-D and E-D) (Fig.69) in Figures 72 and 73, respectively, are wholly in the commercial sulphur zone (except for well VIII-4) and are parallel to the general trend of ground water flow in the aquifer. Figures 71,72 and 73 correlate the concentrations of SO_4, HCO_3, and the dissolved gases, H_2S and CO_2, as well as the corresponding pH and temperature. Bacterial sampling was not possible from these wells,nor was the measurement of Eh, because air-lifting methods for well testing aerated the water.

In traverse A-B of Figure 69, perpendicular to ground water flow (Fig.71), it is clear that sulphate ions were reduced and that CO_2, H_2S and HCO_2 were generated at the crest of

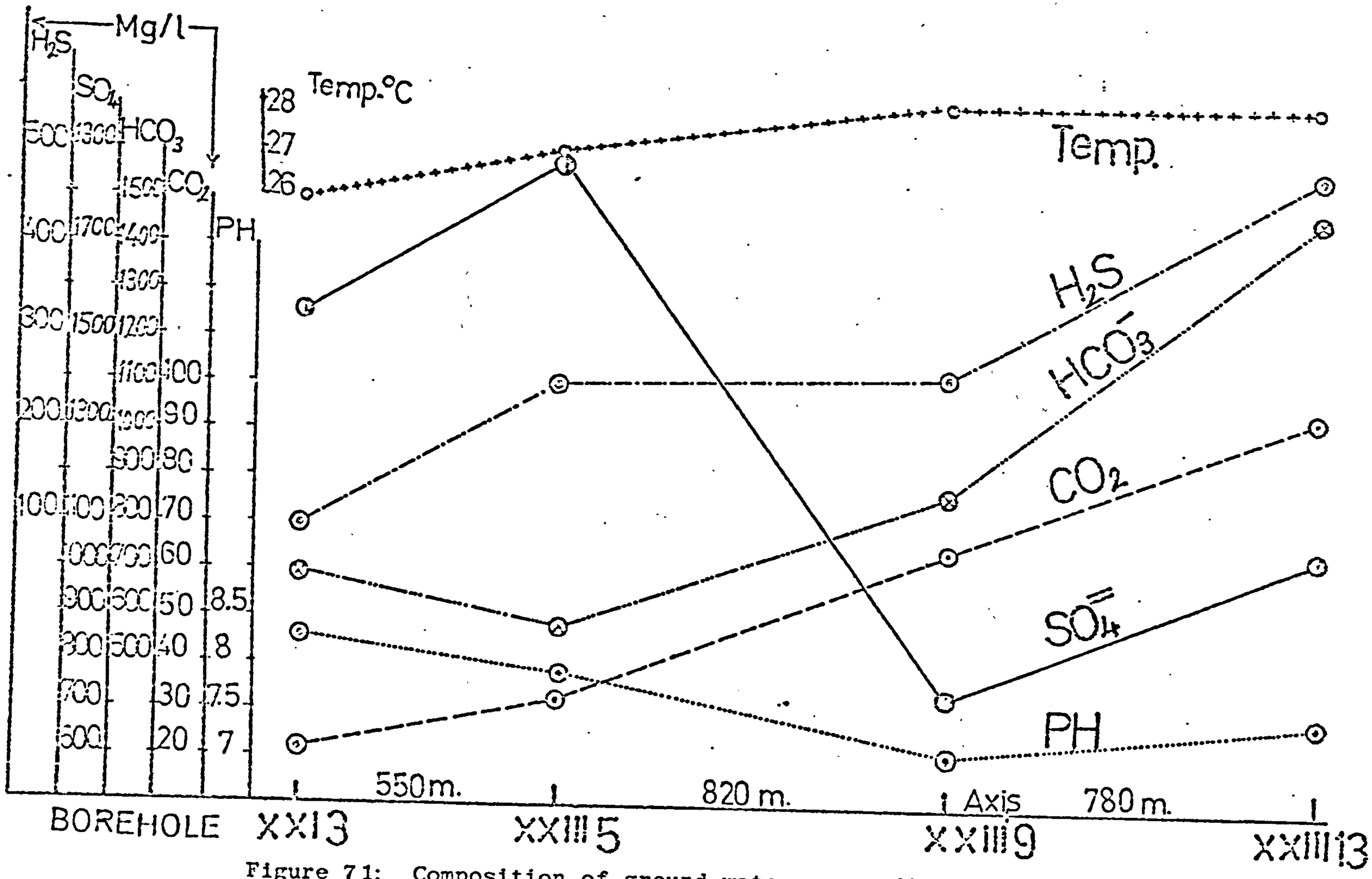


Figure 71: Composition of ground water perpendicular to the direction of principal flow along line AB of Figure 68.

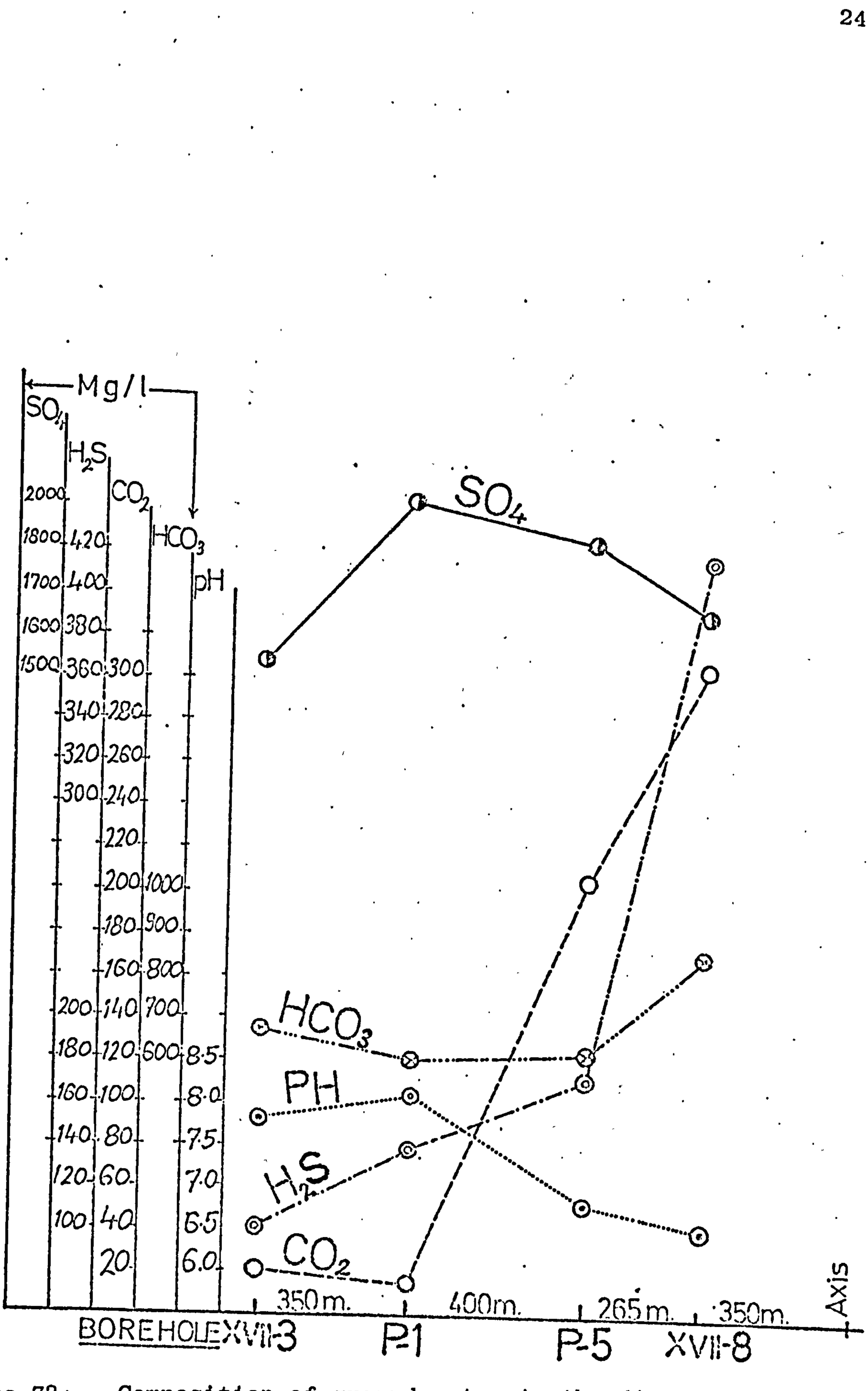


Figure 72: Composition of ground water in the direction of principal flow along line C-D of Figure 68.

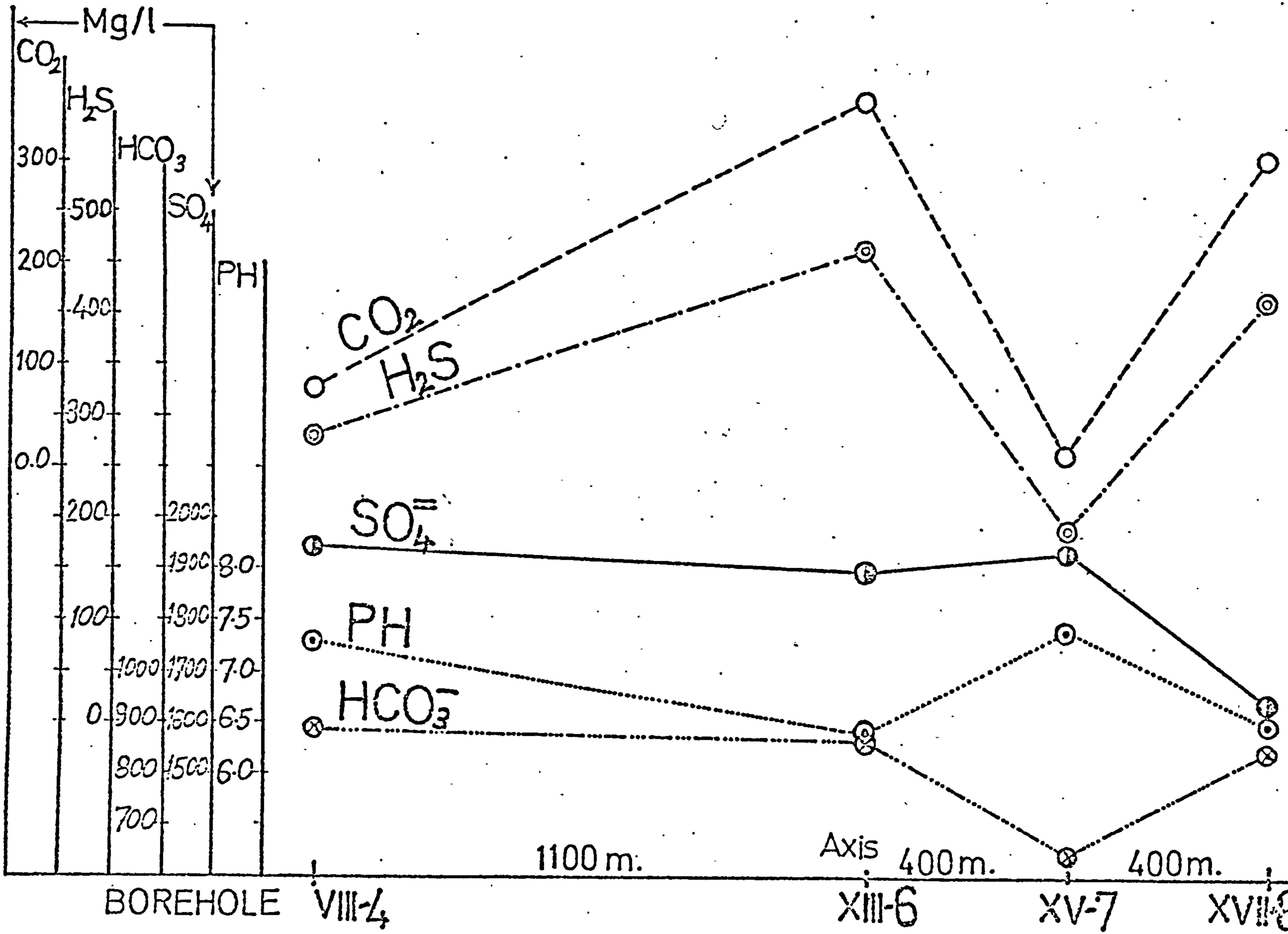


Figure 73: Composition of ground water in the direction of principal flow along line E-D of Figure 68.

the anticline. Large amounts of elemental sulphur were deposited in this part of the structure, considered to be an area where oxygenated waters of the upper aquifers mixed with hydrogen sulphide gas generated below. Precipitation of elemental sulphur is postulated as follows:-

$$H_2S + \tfrac{1}{2}O_2 \longrightarrow S + H_2O + \text{energy} \qquad (6)$$

Hydraulic continuity was provided by an extensive system of faults, joints and openings. Along traverse E-D of Figure 69 (Fig.73) well XIII-6 is in a minor anticline where much gas accumulated in the ground water; the flow of ground water in this zone is slow compared to the area to the north around well XVII-8 in which sulphate ions are being reduced and much sulphur was deposited..

In general, the deposition of sulphur in the limbs and crest of the Mishraq anticline is related to the various factors controlling bacterial activity and to the factors promoting oxidation of hydrogen sulphide. The supply of hydrocarbon gases was greatest in the crest, their upward movement from the Lower Fars formation and the Euphrates Limestone having been facilitated by faults,joints, or solution openings. Most sulphur was deposited where hydrogen sulphide was oxidized by descending meteoric waters. The crest itself, although tapping hydrocarbons and hydrogen sulphide, contains less elemental sulphur than near-crest areas and the upper limbs of the structure, probably because the crest was sealed by thick beds of gypsum and marl and was, therefore a zone where oxygen-bearing water could not penetrate.

Hammam Ali hot springs

The Hammam Ali area is about 20km north of the Mishraq anticline (Fig.1). It is virtually devoid of elemental sulphur. Instead, its water, bitumens, and gases,

including hydrogen sulphide, are escaping through a permeable zone directly to the surface. The temperature of the water at the surface is 48°C, well above any temperature recorded in the original aquifer waters at Mishraq. This high temperature is attributed to a high rate of exothermal metabolic activity of contained bacteria, present here in larger numbers than in the waters of the Mishraq structure (Table 16). High metabolic activity at Hammam Ali is also indicated by the relatively low concentration of sulphate ions in the spring waters.

Further evidence of the relationship between bacterial activity and the temperature of aquifer waters is shown by the geophysical log of a well drilled recently near the main springs at Hammam Ali, and the log of well XVII-6 occurred at each of the sulphur-bearing horizons, one at 140 m and one at 180 m depth. At Hammam Ali the resistivity log shows an abrupt change at 180 m depth, indicating an abrupt change in salinity without doubt the result of biological activity.

Oxidation of Sulphur and Hydrogen Sulphide

Where oxygen is available, sulphur oxidizing bacteria, Thiobacilli thioxidans, can produce sulphur dioxide:-

$$S + O_2 \longrightarrow SO_2 \qquad (7)$$

This is demonstrated at Mishraq, where the sulphur is leached from the upper horizon of the productive series and close to the River Tigris. As shown in the section on ground-water flow, the maximum amount of ground water was flowing through the first sulphur horizon and the maximum hydraulic conductivity was closest to the River

Tigris. This abundant, thoroughly fresh water caused the sulphur to be leached from this part of the Mishraq deposit, leading to uncommercial sulphur of less than 10 percent concentration in that horizon. This was observed from the core of the boreholes in the area and can also be seen in the thin section of this core, in which the older sulphur deposit is being corroded and oxidized in most parts of the horizon, Plate 14.

The surface waters undoubtedly are bringing in the sulphur-oxidation bacteria. Escaping hydrogen sulphide can also be oxidized to sulphur dioxide, sulphurous acid, and sulphuric acid where oxygenated media, aquifers, or soils are encountered

$$2H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O \qquad (8)$$

$$SO_2 + H_2O \rightarrow H_2SO_3 \qquad (9)$$

$$H_2SO_3 + \tfrac{1}{2}O_2 \longrightarrow H_2SO_4 + 54.6 \text{ k.cal} \qquad (10)$$

At Lazaga, a shallow deposit containing high grade ore, sulphur is being leached away from those upper parts of the structure in the deposit closest to the River Tigris, where oxygenated river water is in hydraulic continuity with the underground cavern and fissure system. Water in the deposit as measured from an observation well in part of the structure (National Iraqi Mineral Company, 1972) has a pH as low as 4.5, considerably below that occurring in any part of the Mishraq deposit presently containing hydrogen sulphide gas. Gases escaping from the Lazaga deposits near its crest are being converted to sulphuric acid in overlying soils, with some soil containing as much as 27 percent sulphuric acid. This particular area is known locally as "Smemega" and is located in Wadi Kafour near Ain Baidha, Figure 2.

5.1.2 Thermal and mineral water:

The temperature of ground water was measured in all the existing wells and springs over the area (Figure 2). The geothermal gradient in Hammam Ali and Mishraq was estimated from the temperature logs (Figure 16). The variable gradient in the different aquifers cannot represent the normal geothermal gradient of the whole area. In Hammam Ali, Figure 16, the temperature gradient increases from $1^{o}C/5$ metres to $1^{o}C/10$ m at depth of 83 m. and to about $1^{o}C/75$ m at a depth of 195 metres. While in Mishraq the temperature gradient is substantially different in the different aquifers. The temperature usually decreases in the upper confining beds of gypsum and marl where solution effect of ground water takes place, a marked increase in temperature occurred at each of the sulphur bearing horizons, at 140 m and 180 m depth (Figure 16).

In general, the temperature of ground water in Mishraq is lower than that of Hammam Ali. The overburden water temperature ranges between 22 to $25^{o}C$ and its average is $23^{o}C$ over the area. In the "productive series" it ranges from 25 to $31^{o}C$ with average of $28.3^{o}C$. In Hammam Ali, the temperature of the main spring (Ain Zahra) reaches up to $50^{o}C$ and it is about $40^{o}C$ in the smaller spring (Ain Fasosa). The temperature of the River Tigris (1 to $24^{o}C$) has been correlated with that of the spring over a period of three years. Ain Zahra and Ain Fasosa temperatures were nearly constant, varying between 47 to $50^{o}C$ and 38 to $40^{o}C$ respectively, (Al-Sawaf, 1973).

A temperature over $25^{o}C$ is taken as a standard for thermal water for this area. However, the mean annual temperature in Mosul is about $20^{o}C$ and in Sinjar is about $21^{o}C$, the remainder of the area is flatter and expected to have at least $23^{o}C$ mean annual temperature. On this basis the

majority of the deep ground waters in the structures to the west of the River Tigris is thermal water. Its depth though, is different in the various structures. The temperature of ground water in the overlying Upper Fars formation to the west of the area is generally high, reaching up to 25.5°C in the deep aquifers with an average temperature of between 20 and 24°C. However, the temperature of ground water in Tal-Akoul (SN.26) and Al-Kahirah (SN.27) were 26 and 27°C respectively. The water in these two wells were pumped with old jack-pumps.The friction in the cylinders could have caused the increase of temperature. There is no evidence of any biochemical reaction in water with a temperature less than 26°C. Rock temperatures increase with depth below the land surface due to geothermal gradient. Where water circulates at a considerable depth it normally attains a higher temperature. The chemical and biochemical reactions within the aquifers can increase the water temperature far beyond the geothermal gradient of the area.

The ground water of the Lower Fars aquifers is mainly mineralized. The analyses of water from the different aquifers, shown in Table 1 of the 1st computer program, are compared according to the international standards for mineral waters. Table 17 is the minimum contents of balneological elements in the mineral water.

Table 17: International standared for Mineral water.

Contents	International standared mg/l	Accepted in USSR	Contents	Inter. stand.	Accepted in USSR
$FreeCO_2$	250	750	Br^-	5	24
H_2S	1	10	I	1	10
Li^+	1	5	HSO_4^{2}	1	1
Sr^+	10	10	HBO_4	5	50
Ba^{+2}	5	5	SO_2	5	50
Fe^{+2} Fe^{+3}	10	10	Rd	3.5 mache	10 mache
F^-	2	2			

The thermal and mineral waters of the Lower Fars formation have long been known for their therapeutic use and ameliorating effects on chronic and refractory diseases, like asthma, rheumatism, gout and arthritis, as well as for contagious diseases. The spa of Hammam Ali was first mentioned by the Venetian traveller, Marco Polo (1254-1324), who visited the area on his way to the East. It has been used for more than seven centuries, and the number of its visitors has greatly increased in recent years.

The other important spring for hydrotherapy is Ain Kirbit (meaning the sulphur spring) in the town of Mosul. Its water has long been used in curing dermatic diseases, like leprosy and for its sedative and aseptic effect. Other springs like Ain Aljarab (3 km west of Hammam Ali) and Ain Baidha have been used by the local inhabitants for the same purpose. All the springs in this area originate from the aquifers of the Lower Fars formation. The deepest expected source of water is that of Hammam Ali (250-300 m). For this reason, the discharge of all the springs are controlled by the total annual replenishment reaching the aquifer. This discharge can increase or double in the wet years. On the other hand, some springs run dry by the end of summer in the dry years. The discharge of Hammam Ali springs collectively ranges between 16 and 45 cubic metres per hour; it is at a maximum when the water levels in the aquifer increase towards the end of spring and at a minimum by the end of Autumn each year. It was possible to reach the aquifer from which the thermal water of Ain Fasosa originates, which is about 183 metres deep in the well near the springs of Hammam Ali where part of the productive series was penetrated by the well to a depth of about 200 metres. The source of the hotter spring water of Ain Zahra is probably from the lowest part of the productive series, which is about 250 metres deep in that area.

5.1.2. i Source of heat in ground water:

The temperature of ground water in the different aquifers was studied in relation to ground water quality, gas contents, pH, bacterial population and lithology of the water bearing materials. The temperature of ground water in the area of Lower Fars aquifers is generally higher than normal water temperature of the surrounding areas or overlying aquifers in the same area. Temperature generally increases with depth but is mainly controlled by the biochemical reaction within the aquifer water. This reaction results from the intermixing in the aquifers of the Lower Fars formation of the uprising hydrocarbon gases from underlying formations. Bacteria play a major role in this reaction, using the hydrocarbons for their metabolism, reducing the sulphate in water and creating numerous zones of thermal water and gas pockets in the area.

The reactions responsible for the deposition of economic sulphur in this area were postulated previously under 5.1.1.v. Furthermore, Tausson and Aleshina (1932) postulated that general tendency is for anaerobic sulphate reducing bacteria to convert hydrocarbons, for example

$$4C_{10}H_{22} \xrightarrow{\text{bacteria}}$$

$$4CH_3C_6H_{10}CH(CH_3)_2 + 4H_2O + CaS + 184.4 \text{ k. Cal}$$

The reactions involved in the above processes are exothermic and can provide substantial amounts of energy which are responsible for the formation of thermal water. The thermal waters, whose temperature exceed 25°C, are tabulated in Table 18. The elements related to temperature, which could be controlled by the biochemical reduction of sulphate in

No	Sam. No.	Source	Temp °C	pH	CO_2 ppm	H_2S ppm	HCO_3 ppm	SO_4 ppm	TDS ppm	Location
1	26	Mix	25.5	7.9	5.5	-	156.2	218.54	5697	Kharab Bajar
2	35	UF	26	7.75	4.4	-	129.95	505.28	1183	Tel-Akoul
3	36	UF	27	7.5	4.4	-	76.26	340.05	1624	Al —Kahirah
4	42	LF	30	7.1	132	132	496.0	1676.3	4375	Ain Al-Baidha
5	43	"	48.5	7.13	55	63	435.0	99.42	1030	Hammam Ali, A
6	46	"	27	7.3	132	194	604	2317.5	4069	Al-Dirnaj
7	76	"	25.5	7.8	8.25	-	160.5	817.5	1494	Tel-Saki
8	83	UF	25.5	7.45	3.3	-	68.94	330	800	Tel-Khalil
9	123	UF	27.5	7.57	7.15	-	95.18	212.8	1291	Beeski
10	203	LF	25.7	7.05	19.8	10	213.53	1976	2032	Adayah
11	308	"	40	7.0	59.0	60	546.1	70	1160	Ain Fasosa
12	309	"	73	7.0	187	495	674.2	1263.2	3195	TB, Mishraq
13	310	"	23	-	-	51	278.2	1609	2703	Overburden
14	311	"	28.3	-	-	322	821.8	1681	5030	Productive
15	312	"	32	7.0	257	648	869.4	1738.7	8537	Z14 Mishraq
16	313	"	26	8.3	22	99	695.5	1552.8	4188	Mishraq XXI-3
17	314	"	27	7.9	33	252	585.7	1873.2	4515	" XXIII-5
18	315	"	-	7.05	65	260	869.4	737.3	3824	" XXIII-9
19	316	"	28	7.45	95	482	1473.4	1047	6416	" XXIII-13
20	317	"	-	8.1	17.6	137	604	1913.5	4838	" P-1
21	318	"	-	6.8	206	171	616.2	1818.4	4556	" P-5
22	319	"	29	6.5	304	415	848.0	1644.6	4836	" XVII-8
23	320	"	28	7.8	20	100	616.8	1539.8	4646	" XVII-3
24	321	"	-	7.4	16	187	640.6	1938.5	5250	" XV-7
25	322	"	30.5	6.4	425	444	862.7	1917.8	5597	" XIII-6
26	323	"	27	7.45	50	246	866.3	1950	4923	" VIII-4
27	324	"	25.5	6.4	140	170	576.5	1308.8	5799	Ain Kibrit
28	325	"	26	6.65	108	111	625.35	150.33	1280	Ain Jarab

Table 18: Thermal and Mineral waters of the area

ground water, are shown together with the dissolved gases, pH and total dissolved solids in Table 18. The twenty eight analyses were selected from the area under study, four of which were sampled from wells in the Upper Fars formation, one from mixed source of alluvial and Upper Fars aquifers and the rest were from aquifers in the Lower Fars formation. The water in the springs and aquifers of this formation have several unusual characteristics. It is a good example of ground water located in a saliferous, evaporitic formation dominated by gypsum and anhydrite, interbedded with limestone and marl. The peculiarity of this water is that variations in quality and gas content are solely related to the water-rock interaction and biochemical processes which take place within the aquifers.

The highest concentration of gases *ris* in the thermal waters of Mishraq. They are lower in the hot water of Hammam Ali due to their escape to the surface. The variations in quality of ground water can be seen from the locations of the springs water analyses in Piper's diamond shaped field, Figure 55. The changes in ground water temperature is indicated in the different springs. The area number 1 is for springs issuing from alluvial deposits (fresh water) have an average temperature of about 22°C. The water of the alluvial or similar waters could gain mineralization and heat when flowing into the Lower Fars formation as indicated in area No.2 of the diamond shaped field of Figure 55. When sulphate reduction takes place in such waters, the temperature of ground water increases with the decrease of sulphates. Subsequently, the bicarbonates, CO_2 and H_2S increase and pH decreases. The decrease in pH is another indication of the formation of CO_2 gas in water. CO_2 and organic acid formed by the microbial oxidation of hydrocarbons may decrease the pH of the media from 0.2 to 2 units. (ZoBell, 1950). This can be seen in the direction of arrow along

which the process can result in water softening.

The process of sulphate reduction does not necessarily reduce the sulphate concentration in water. Its concentration is controlled by the existence of excess $CaSO_4$ in the environment, i.e. if reduction takes place in gypsum or anhydrite horizon, more sulphate will come into solution due to its high solubility, eg. Al-Dirnaj. If reduction takes place in limestone aquifers, thermal water results with a very low sulphate content, as is the case in Hammam Ali. However, the direct reduction of sulphate by hydrocarbons at room temperature is not possible (Feely and Kulp, 1937, and Dhannoun and Fyfe, 1972). The presence of sulphate reducing bacteria is essential to precede any sulphate reduction. The bacterial counting is found to be at a maximum in the hot water of Hammam Ali (see Table 16) while it decreases in the cooler water which are richer in sulphate. Such water lacks organic matter or is located in aquifers free of hydrocarbons (Al-Sawaf, 1977).

5.2 Ionic exchange in ground water:

Ion exchange is the replacement of adsorbed ions by another type of ion in solution. The effect of such exchange on water is to replace one kind of solute ion with another ion. Certain substances are able to adsorb cations and/or anions on or near their surfaces, and these ions may be exchanged for other ions in water which come in contact with the substances. Some types of clay have exchange capacities of as much as 100meq/100 g. and clay minerals with high cations exchange capacities are montmorillonite and vermiculite.

Holden (1970) defined the ionic exchange as a reversable exchange of ions between a solid and a liquid in which there is no substantial change in the structure of the soil. Under

certain circumstances ion exchange may take place between solids without the involvement of a solution phase. The degree to which replacement takes place between ions depends upon the typesof ions involved, the concentration of the solution, the material on which the exchangeable ion is held, and the degree of saturation of that ion (Kelly,1948).
The four common cations in natural waters have a tendency to be replaced in the following sequence Na $>$ K $>$ Mg $>$ Ca.
For example, when the concentration of calcium and magnesium ions in solution exceeds the concentration of sodium ions, both the calcium and magnesium ions may be exchanged with sodium ions held on exchangeable substances in the water bearing materials, causing a reduction in the ratio (Ca+Mg)/Na in the ground water. The reaction, which may be written

$$2NaX + CaSO_4 \longrightarrow CaX + Na_2SO_4,$$

is usually displaced to the right, as is the case with water softening reactions. The reversal of the above reaction may occur in aquifers when ground waters having a high sodium concentration come in contact with minerals containing adsorbed calcium or magnesium.

The process of ionic exchange can explain the variations in the ionic ratios of the different types of waters classified in the area under study (see 4.3.1.B). The conversion of calcium bicarbonate ground water in the alluvial aquifers to a sodium chloride and bicarbonate type in the mixed facies (F) is due to ionic exchange. The increase of sodium at the expense of calcium and magnesium results in a softening of the ground water. The source of sodium chloride in this area is the shallow soil horizons in which salt concentration is taking place due to evapo-transpiration.

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The mixing of the Lower Fars type of water ($CaSO_4$) with the Upper Fars waters ($CaSO_4$,$CaCl_2$) in areas rich with sodium chloride can result in ionic exchange whereby a sodium sulphate type of water results, as is the case in group D water, (see 4.3.1.B), *p.183*.

The process of ionic exchange of calcium by sodium can result in high concentration of calcium adsorbed on the clay minerals. This will lead to the deposition of calcium carbonates and sulphates especially in shallow areas affected by evaporation. The calcium sulphates may be deposited in crystalline form as selenite or in the macrocrystalline form of gypsum as shown in Plate 10. Inclusions of clay minerals within the crystals of gypsum and the formation of systematic crystals are clear indications of the in situ formation of the secondary gypsum.

The deposition of secondary gypsum in the reworked Upper Fars materials is mainly due to the excessive evaporation which takes place near the surface. The thick horizons of gypsiferous clays and silt can carry substantial quantities of ground water and provide a relatively good aquifer.

5.3 Nitrate concentration and pollution indications:

Nitrates (NO_3) are extremely soluble substances, though nitrate contents of natural waters unaffected by pollution is usually less than 5 mg/l (Holden, 1970). Very limited amounts of nitrates are derived from the water bearing materials; and the principal source is organic processes in the soil or the aquifer. Leguminous plants are capable of utilizing the nitrogen of the air and fixing it in the soil as nitrate. The other important source is the oxidation by bacteria of nitrogen or nitrogenous substances in

decomposing organic matter or sewage. The bacterial oxidation of ammonia to nitrite and thence to nitrate (nitrification) occurs in all fertile soils and well oxygenated natural waters, i.e., waters containing abundant dissolved air. Such water is located in the Upper soil layers or shallow aquifers, with the nitrifiers being strict aerobes which can only occur in such oxygen-ated waters.

High nitrate concentration in ground water can indicate the presence of pollution. The International Standards for Drinking Water (W.H.O., 1963) gives 45 mg/l (as NO_3, i.e. 10.2 mg/l as N) and European Standards for Drinking Water 50 mg/l (as (NO_3, i.e. 11.3 mg/l as N) as levels above which trouble may arise. Nitrates in well water could be a cause of cyanosis (methaemoglobinaemia) in newly born infants ("blue" babies). Although such cases are usually caused by using water to make up artificial feeds, cows milk may be the cause when the water drunk by the cow itself contains a high amount of nitrate. One case is reported in a breast fed infant through the mother drinking water having a high nitrate content (Donahoe, 1949). The values for nitrate that have been reported as toxic have varied from 15 to 250 mg/l or more, expressed as nitrogen.

The concentration of nitrate were analysed in about one hundred water samples, 38 of which were carried out by Ingra Consulting Department in the year 1966 and 12 analyses were carried out by the Ground water Department over different periods of time. The remainder of the analyses were carried out by the Institute of Applied Research on Natural Resources in the years 1974 and 1975. All the results of analyses are tabulated in Table 1 of the first computer program (Appendix 3). It was possible to differentiate between the concentration of nitrates in the shallow and deep aquifers in the area of south Sinjar basin.

The concentration of nitrates, expressed in mg/l of the shallow aquifers is shown in Figure 74, where the shaded areas are extremely high concentrations with NO_3 being over 1,000 mg/l. In such areas, local pollution is probably taking place through the large diameter hand-dug wells. The concentration of nitrates in the shallow aquifers, over most of the area is higher than 50 mg/l. This indicates that most of the shallow aquifers are polluted, with the source of pollution being undoubtedly from the ground surface. Shallow wells, which derive their water from superficial deposits of soil and subsoil, are particularly prone to yielding supplies containing high nitrates. The ground surface surrounding the hand-dug wells contain excessive amounts of organic materials and urine due to the concentration of humans and stock around the water supply wells for stock watering. Also, the accumulation of organic matters is at a maximum within the village in which water supply wells exist. The majority of the huts in the villages have no septic tanks or toilets, and this has led to the accumulation of waste in the villages and around the water supply wells. The urine and waste accumulated on the ground surface finds its way to the shallow aquifers by either direct or indirect methods. The windblown dust and sand carries plenty of waste materials when blowing through the villages. Dust and waste can directly percipitate in the hand dug wells for the majority of the hand dug wells are not covered or protected from such direct pollution. The direct flow of runoff water from ground surface into the well is also possible in the wells located in depressions and wadis. Such flow can again cause direct pollution of the shallow aquifers

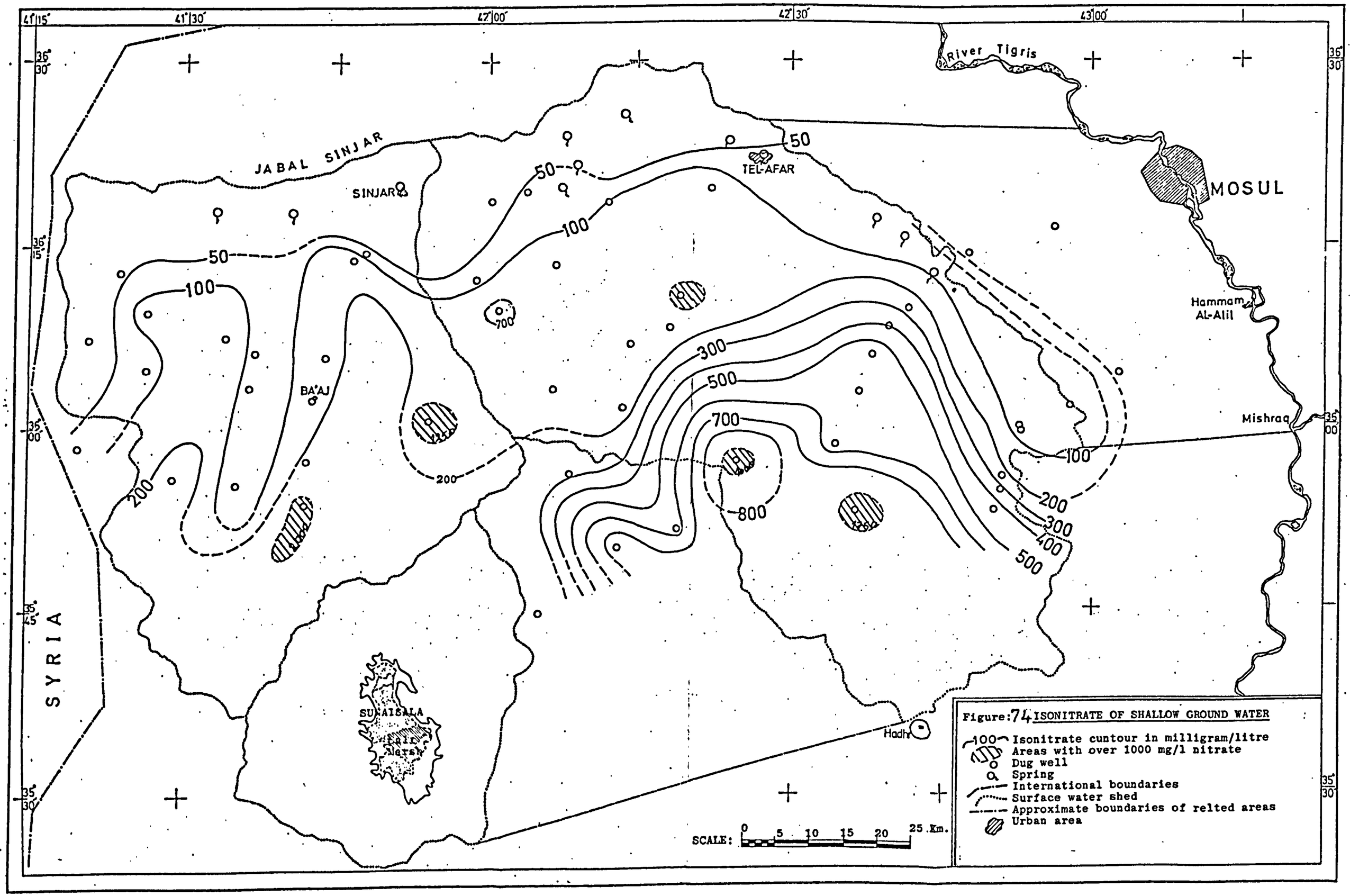


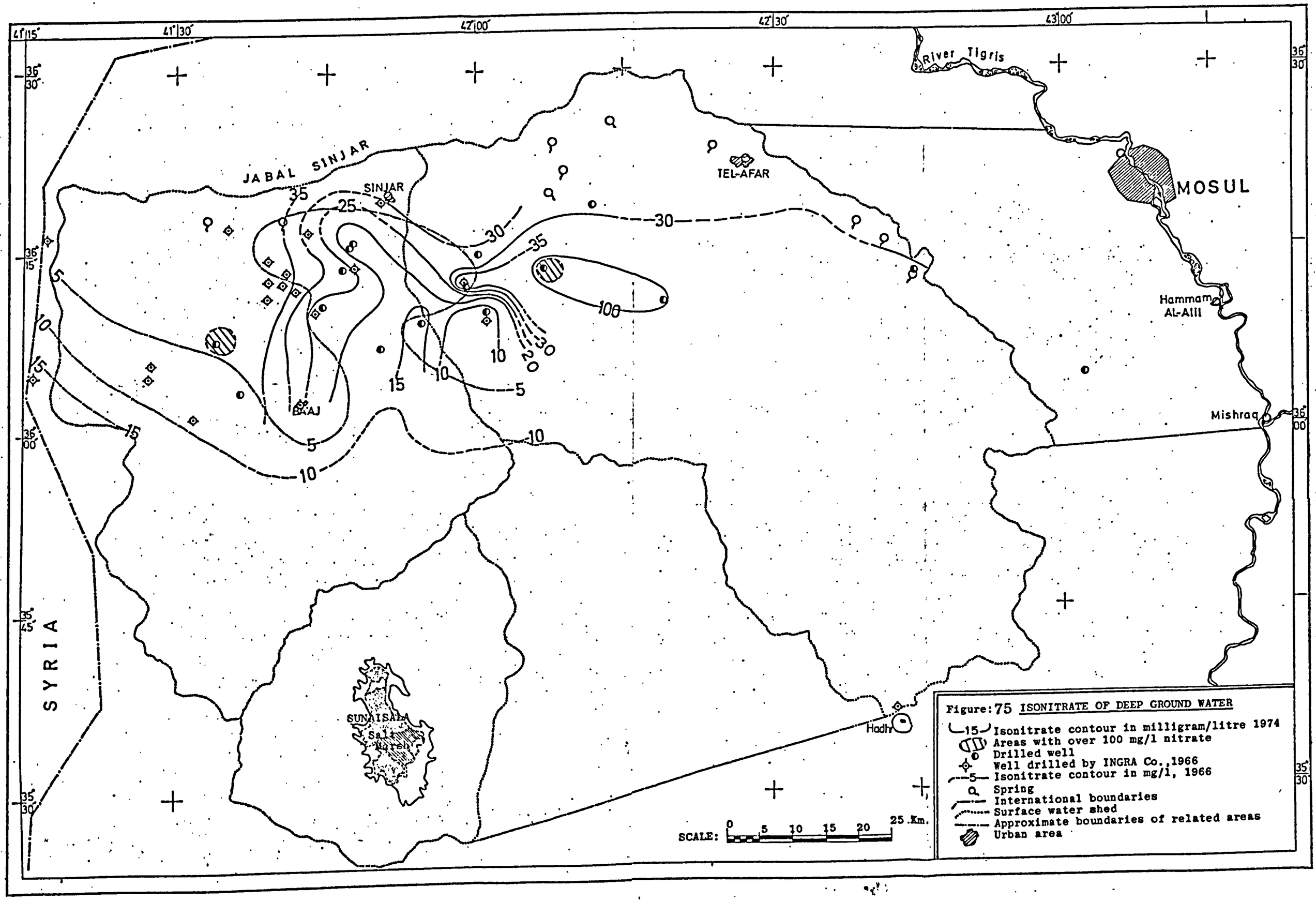
Figure: 74 ISONITRATE OF SHALLOW GROUND WATER

- 100 Isonitrate cuntour in milligram/litre
- Areas with over 1000 mg/l nitrate
- Dug well
- Spring
- International boundaries
- Surface water shed
- Approximate boundaries of relted areas
- Urban area

The infiltration of rainfall and irrigation water through ground surface to the shallow aquifers is yet another source of pollution. The concentration of nitrate in the hand dug well of the village of Al-Theiba was 1250 mg/l (SN.91) and it may not be pure coincidence that the infiltration rate in this area (1.53 m/d) was higher than that measured in other locations (see Figure 24). The water bearing materials in this location contain about 7 metres of silty and calcareous clay covered with 3 metres of gypsiferous clay and another 3 metres of loam and soil. However, no agricultural activity or any irrigation takes place in these areas of extremely high nitrate contents. Furthermore, no fertilizers are used in any part of the south Sinjar plain, the pollution of the shallow aquifers is alarming especially in the areas where shallow aquifers provide the only water supply through the hand dug wells. The maximum concentration of nitrates in the ground water of the shallow aquifer was 2000 mg/l found in the hand dug well of Khwaitla (SN.114), Ser. No. 145 in Table 3 of the first computer program.

The concentration of nitrates, expressed in mg/l, of the deeper aquifer waters are shown in Figure 75. The deep drilled wells which were sampled for nitrates determination were very limited. However, a remarkable difference was found in the total concentration of nitrate between the period of 1966 and 1974.

The wells drilled by Ingra Consulting Department were analysed for nitrate contents as well as other dissolved solids in the periods of well completion during 1966. These wells show a low concentration of nitrate ranging between traces to 21 mg/l. The majority though range


River Tigris
MOSUL
TEL-AFAR
JABAL SINJAR
SINJAR
BAAJ
Hammam Al-Alil
Mishraq
SUNAISAL
Salt Marsh
Hadh
SYRIA
41°15'
41°30'
42°00'
42°30'
43°00'
36°30'
36°15'
36°00'
35°45'
35°30'
SCALE: 0 5 10 15 20 25 Km.
Figure: 75 ISONITRATE OF DEEP GROUND WATER
15 Isonitrate contour in milligram/litre 1974
Areas with over 100 mg/l nitrate
Drilled well
Well drilled by INGRA Co.,1966
5 Isonitrate contour in mg/l, 1966
Spring
International boundaries
Surface water shed
Approximate boundaries of related areas
Urban area

between 5 to 10 mg/l. While the determination of nitrates made in 1974 shows an increase in concentration reaching over 100 mg/l. The greater part of the area to the south of the town of Sinjar contains from 10 to 30 mg/l nitrates (see Figure 75) in this area of the deeper aquifers, and the concentration of nitrates appears to decline in the direction of ground water flow. Its higher concentrations are attributed to the direct contact of the catchment areas of the deep aquifers with the polluted surface waters or shallow aquifers. The decline in the concentration of nitrates in the direction of ground water flow is probably due to the activity of nitrate-reducing bacteria or due to the presence of ferruginous sands within the Upper Fars aquifers. The nitrates may be reduced by nitrate reducing bacteria to nitrites and finally to free nitrogen. Further study is needed to isolate or identify such bacteria from the deeper aquifers. Nitrate can also be reduced to ammonia by passage through ferriginous sands.

The shaded areas in Figure 75 in which the nitrate concentration exceeds 100 mg/l are expected to be limited to a narrow zone in which leakage of the shallow polluted ground water probably reaches the deeper aquifers in the zones affected by pumping. It could alternatively be due to the direct mixing of waters supplied to the well from the shallow and deeper aquifers.

5.4 Summary and conclusions of water quality and use:

The poor quality of ground water over most of the study area forms the major problem concerning water suitability for the different uses. The main problems are the high dissolved salts and pollution of the shallow aquifers.

With the exception of the area extending some 20 km. to the south of Jabal Sinjar, the total dissolved salts in ground water of the shallow and deeper aquifers are beyond the standard for drinking water. The permitted

upper limit for drinking water is 1000 mg/l total dissolved salts, with 500 mg/l being desirable. The recommended limit of sulphates in drinking water is 250 mg/l, but sulphates concentration in ground water is several times the recommended limit except in the waters of the alluvial aquifers and mixed source. Some ground water of relatively low sulphate content is present in aquifers of the Lower Fars formation in which sulphate reduction takes place.

The shallow aquifers are polluted over most of the area.The only suitable water for drinking purposes is found around the belt extending about 15 km. south of Sinjar anticline (see Figure 74).

In all the water supply wells in the study area, no sensible protective measures have been taken to prevent contamination of the supplies. It seems that almost all waters in the shallow aquifers, and some in the deeper aquifers, are polluted. Supply from these sources that are intended for human comsumption should be chlorinated.

Waters with exceptionally high H_2S concentration must be aerated before it can be used for human consumption. In some areas of the Lower Fars aquifer, wells have to be shut or the water treated before it can be used for human consumption. In one well drilled in the Lower Fars aquifer, high H_2S caused the death of stock watered from the ground water immediately after pumping from the aquifer. This has caused the well to be abandoned. In other areas, pumped ground water from the Lower Fars aquifer has to be left exposed to the atmosphere for some time before it can be used for stock watering.

The thermal and mineral waters of the Lower Fars aquifers have been used externally for several types of treatments. However, the methods and facilities available for human use in such areas are still very primitive.

The mineralized water of the Lower Fars formation plays a significant role in the deposition of econimic sulphur in several anticlines to the west of the River Tigris.

Ground water in most of the aquifers in the area of study is suitable for irrigation. However, the types of crops and waters should be studied in conjection with the available water and soil before intiating any irrigation project.

CHAPTER SIX

EVALUATION OF GROUND WATER RESOURCES

6.1 Introduction

6.2 Replenishment of ground water

6.3 Ground water abstraction

6.4 Hydrologic budget

6.1 Introduction

The study of the water resources of any specified basin has to start with a detailed quantitative study of the various components of the hydrological cycle. This depends on long term measurements of basic components and on the accuracy of such data. In the area under study the basic data for such a quantitative study is insufficient. Raingauges are not sufficient and not properly distributed while the amount of evapotranspiration is not known for any meteorological station around the area. Values for open pan evaporation are available from Mosul, Sinjar, and Tel-Afar meteorological stations, and the rate of water infiltration into the soil was measured at three different locations over the area.

The quantitative assessment of water resources and the ground-water budget should involve accurate measurement of the following:-

1) the amount of surface water and ground water replenishment,
2) the measurement of evapotranspiration,
3) the amount of surface water and ground water runoff from the basin,
4) the changes in ground water storage and soil moisture contents,
5) the amount of water abstracted from the basin,

Some of these measurements were calculated from the available data in the meteorological stations but the remainder were estimated taking into consideration all the factors which could possibly affect their variation. The

basic meteorological data are given in Table 1 and the mean annual precipitation is shown in Figure 5. The depth to water in the different basins is shown in Figure 20 and the drainage system is shown in Figure 4.

6.2. Replenishment of ground water:

The recharge to ground water in any particular aquifer must be estimated before it can be evaluated and before the consequences of the utilization can be forecast. In the area under study, the major source of recharge to aquifers is direct precipitation through infiltration from the ground surface within the intake area. However, a substantial amount of water may locally replenish the aquifer through direct percolation of stream runoff. The majority of stream beds are covered with thick coarse alluvial deposits, which can retain substantial amounts of water after the high flows in the wadis which may occur after heavy rainfall.

Most recharge from precipitation occurs during the winter and spring months. The rainfall exceeds the amount of evapotranspiration in the months of November to March each year (Figure 76). During this period the amount of evapotranspiration is small and soil moisture is maintained at or above field capacity by frequent rains. During the months of summer and early fall, evapotranspiration and soil moisture requirements are so great that hardly any precipitation percolates to the water table to contribute to ground water recharge. In addition to the excessive evaporation, all except the most permeable soil will generally cease to allow the passage of recharge water when rainfall is less than 100 to 250 mm. The exact amount of recharge depends on the

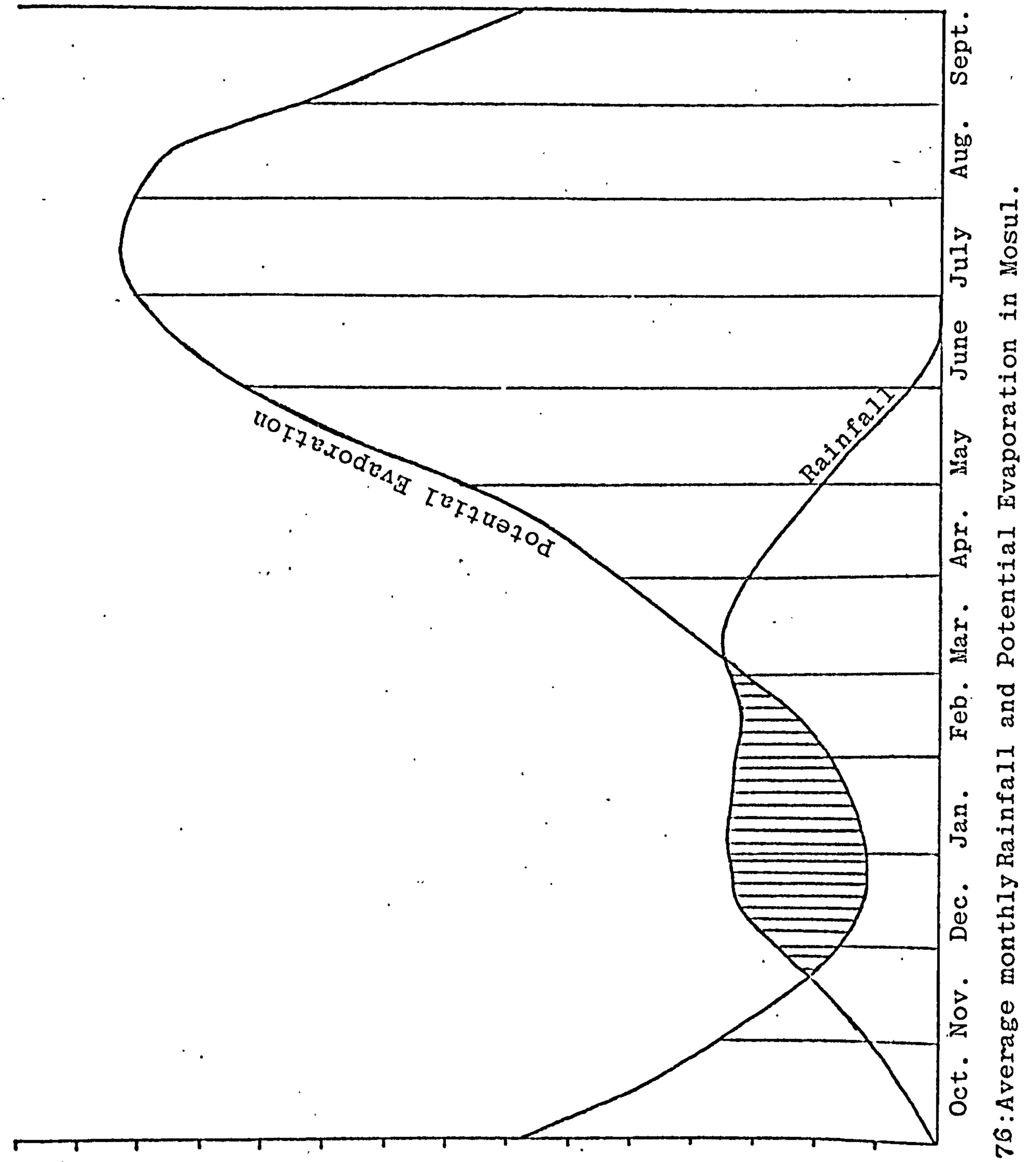


Figure 76:Average monthly Rainfall and Potential Evaporation in Mosul.

permeability of the soil, the specific retention of the soil, the vegetation cover, and the distribution of rainfall in relation to temperature. Soil that has a specific retention of 15 percent and is depleted of moisture to a depth of 1 metre will require some 150 mm. of rain merely to make up the soil-moisture deficiency. However, soil is not well developed over most of the area under study and the alluvial cover around Jabal Sinjar has low specific retention and very high permeability. Substantial amounts of water infiltrate through a number of alluvial fans in this region to provide adequate replenishment supplies for the deeper aquifers via percolation. The soil cover in the southern parts of the study area contain appreciable amounts of clay, and extensive infiltration does not occur through such soil except when it is covered with sandy loam or sand dunes.

The total amount of annual rainfall over the different basins has been calculated from the isohyetal map shown in Figure 5, the results being tabulated in Table 19. The average annual rainfall shown was based on only a few stations which makes it somewhat unreliable. The total annual rainfall over each basin was calculated by subdividing the basin into smaller areas according to the extent of the isohyets, the totals of rainfall over each smaller area was then added to form the total basin annual precipitation.

The relationship between the total monthly rainfall and potential evaporation is shown for the stations of Mosul and Sinjar in Figures 76 and 77 respectively. The amount of water provided by precipitation was calculated from the area under the curve and subtracted from the amount of potential evaporation under the same area. According to Figure 76 (Mosul), the total amount of water gained to the area is equal to 36 percent of the total rainfall within the winter period starting 20th November and ending on 5th March. Over

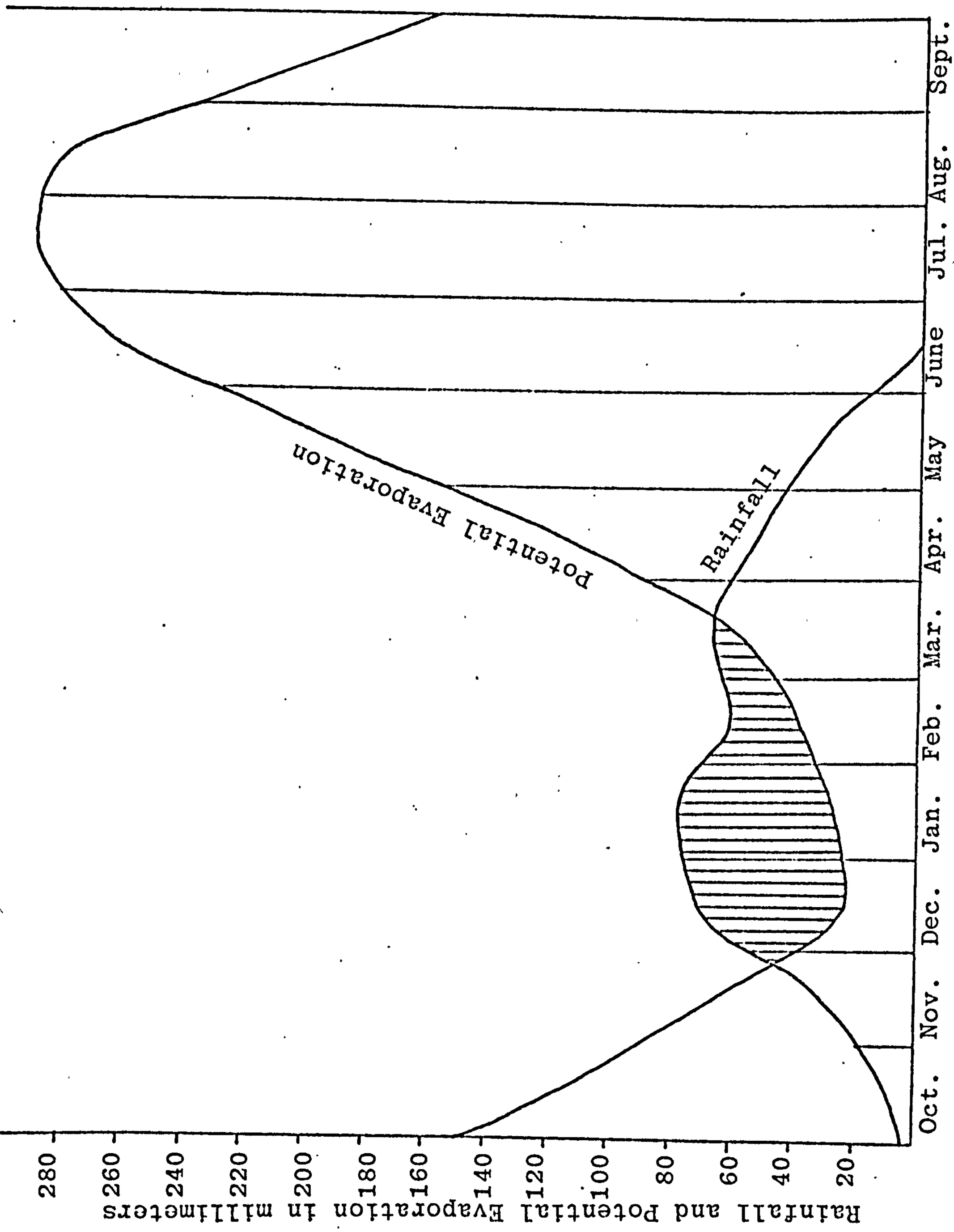


Figure 77: Average monthly Rainfall and Potential Evaporation in Sinjar.

such a period the amount of rainfall exceeds the potential evaporation. In Figure 7.7 (Sinjar), the total amount of water gained to the area is equal to 39 percent of the total rainfall within the period starting 26th November and ending on 19th March, while according to Figure 9 there is no water gain in the area of Anah. The percentage of water loss in the different basins was estimated by taking into consideration the increase in evaporation and the decrease in rainfall towards the south.

The amount of surface runoff is not known in any part of the area under study. Most of the wadis shown in Figure 4 flow in winter and spring especially after heavy rainfall. However, no measurements have been made in any wadi during the period of field work in the summer of 1974 except for those near the main springs and Sinjar anticline. The amounts of surface water runoff from the different basins were estimated as shown in Table 19 by taking into consideration the physiographic features, soil type and geology of the basin. The 20 percent runoff over the Lower Fars structures (Wadi-Qasab) represents the percentage of water runoff with respect to total annual rainfall calculated from Figure 76. While this value is higher than the estimated value for Wadi Al-Ajij and Wadi Al-Tharthar, it is double the expected runoff over the flat Jezira and Sunaisala basins.

6.3 Ground water abstraction:

The abstraction of ground water from the deeper aquifers is restricted to the wells drilled by the Ground Water Department, Ralph M. Parsons and Ingra Consulting Department. Abstraction from the shallow aquifers on the other hand is taking place from several hundred shallow hand-dug wells

located in almost every village in the area under study. The yield of the water supply wells ranges between 50 m^3/d up to 850 m^3/d, while the production of the hand dug wells is much smaller except for those wells fitted with pumps. Dug wells located in the recent alluvial aquifer or over kahris produce up to 500 m^3/d. Most of the ground water is abstracted for public supply. No one is allowed to operate the pumps on any deep well for agricultural water supply, except for the deep well drilled recently for the cooperative farms of Kirkubat and Irfa'i (Mazra'at Al-Anwar). In such farms, about 1,000 m^3/d is needed for irrigation and livestock watering. Therefore, the total abstraction in most of the deep wells is limited to about 50 to 100 m^3/d. Many wells are abstracting waters for irrigation in the vicinity of Sinjar anticline from the shallow aquifers. The maximum amount of water used for irrigation in the other parts of the area comes from the main springs such as Sinjar, Jaddala, Tel-Afar and Sikainia. In many localities on the peripheries of Sinjar mountain, the springs are discharging from thick alluvium deposited updip from the massive Sinjar limestone formation. The amount of ground water discharged through the alluvium or as surface runoff cannot be measured in areas such as Sinjar where the water is flowing through several gullies and even beneath the town. In such areas the amount of water abstracted was calculated in the same way as the ground water recharge was estimated in Figure 77. The potential evaporation in Sinjar is equal to about 60 percent of the total rainfall during the period when rainfall exceeds potential evaporation. Having subtracted the evaporation loss from the rainfall, the ground water recharge into the different aquifer over Jabal Sinjar is estimated as 5 percent of the remaining precipitation. The surface and shallow subsurface discharge can then be calculated as follows:-

Total surface catchment area to the north of the town of Sinjar = 40 Km.

Total annual rainfall is about 430 mm.

$\therefore$ $(40 \times 10^6) \times 0.43 = 1.72 \times 10^7$ m^3 total annual rainfall

$(1.72 \times 10^7) \times 0.60 = 1.032 \times 10^7$ m^3 total annual loss due to potential evaporation

$(1.72 \times 10^7) - (1.032 \times 10^7) = 6.88 \times 10^6$ m^3 water gain

$(6.88 \times 10^6) \times 0.05 = 5.16 \times 10^5$ m^3 total annual loss due to infiltration into deeper aquifer

$(6.88 \times 10^6) - (5.16 \times 10^5) = 6.364 \times 10^6$ m^3 total annual flow across the town of Sinjar

This amount is equivalent to about 14,000 m^3/d assuming that the flow is uniform over the year. In actual fact the flow is at a maximum in spring and a minimum in autumn each year. The amount of flow of water across Jaddala was calculated by the same method and the average discharge was found to be some 20,000 m^3/d. However, it was possible to measure the discharge in this area by the use of a defined channel in which the velocity of water was estimated and the total discharge is found to be nearer 26,000 m^3/d. This measurement was made at the end of June, 1974 when the discharge might be expected to be near its maximum. This discharge could decline to 14,000 m^3/d in the autumn.

The measurement of discharge over the other small catchments of Sinjar mountain indicates that the value of 30 to 35 percent runoff is justified bearing in mind that about 50 percent of this runoff will soon infiltrate into the permeable alluvium in the alluvial fans on the periphery of Sinjar mountain. This will leave only about 15 percent of the water produced by precipitation for surface water runoff which is a loss from the basin. Therefore the amount of water loss in Ajij and Tharthar basins is calculated as 15 percent of the total water gained from rainfall, and the total losses from the main springs and alluvial fans to the

south of Sinjar was estimated on this basis.

The total amount of daily abstraction from each well visited in the area was reported from the local information taking into consideration the size of the village and the type of farms where water has been used for irrigation. The abstraction from the hand dug wells was estimated from the yield of the well and the mean values of water abstraction. In many wells, the discharge was measured volumetrically, but in other deep wells, and when the water is being pumped to a tank, the amount of abstraction was estimated from the volume of the tank and the duration of pump operation. All the wells drilled by Ingra Consulting Department were supplied with 22 m^3 capacity tanks. The actual amount of water abstraction for the whole year was calculated by assuming that 25 percent of the total summer abstraction has been abstracted in the wet seasons, i.e. the recorded abstraction of the six months starting with June is equal to 75 percent of the total annual abstraction. On this basis the total annual abstraction was calculated for the different basins. However, the actual abstraction could amount to double the values shown in Table 19. Because the greater part of the water abstracted is for public and livestock supply, most can be lost from the basin, i.e. the returning water down to the aquifers is negligible.

6.4 Hydrologic budget:

A hydraulic budget is a quantitative statement of the water balance between the total gains and losses of a specified basin, over a certain period of time. Under normal conditions, the water entering a basin is equated with the water leaving the basin, plus or minus changes in basin

storage. This applies to both surface and subsurface waters and can be represented in more detailed form in the following equation:-

$$P = R + E + U \pm S_s \pm S_g$$

where: P = precipitation, R = streamflow or surface runoff E = evapotranspiration, U = subsurface underflow, S_s = change in soil moisture, S_g = change in ground water storage. All quantities are volumetric calculated for a certain period of time.

Precipitation in the form of rain or snow is the main source of water entering the basin, it constitutes the only water gain for the basin. Water losses include all waters leaving the basin; the greatest amount of water losses in areas of arid or semi-arid conditions being due to evapotranspiration, while stream flow forms the major cause for water loss from the basins of moist and humid condition. Subsurface underflow is evident under karstic conditions like the Lower Fars aquifers and when the aquifers outcrop in the area of recharge. The soil moisture content reflects the changes in its storage, while the changes in ground water levels indicate changes in storage of water in the aquifers.

The amount of water required to saturate the soil before any substantial recharge can infiltrate down to reach the water table could amount to the volume of water retained by soil in the end of the wet season. That is to say, the loss of rainfall water to the soil moisture deficit is equivalent to the gain of water infiltrating into the ground water reservoir when the rainfall ceases. This supposition is applicable only when the amount of rainfall and potential evaporation are similar, together with the average temperature in the periods before and after the wet months in which rainfall exceeds evaporation.

The changes in ground water storage in the different aquifers is not known. Monthly or seasonal measurements are needed for a sufficient period of time to estimate the changes in ground water storage. Nevertheless, the long term effect on permanent ground water storage can be estimated from the water level measurements over several years. The maps shown in Figures 21 and 22 for the ground water level for the years 1954 and 1974 show no substantial changes in the general ground water levels. This indicates that the aquifers are saturated with respect to their capacity of storage and the annual water gain to each basin is equivalent to the annual water loss.

The components of water budget for each basin are estimated whenever the essential data are insufficient for ground water resources. The annual changes in ground water storage includes the artificial recharge or discharge of water to or from the basin concerned. In the area under study, no record is available for the exact amount of water pumped from the River Tigris to supply the village of Tel-Afar. The capacity of fresh water pipes can supply 2,000 gallon/min., this could amount to 4.8×10^6 m^3/ann. This quantity, however small, could affect the water level or ground water quality in the region near Tel-Afar. About 50 percent of this water is expected to reach the shallow aquifers by infiltrating through the alluvial deposits. The amount of fresh water brought by the villagers from the River Tigris for human consumption is negligible. The amount of water loss from the different basins due to ground water under flow is estimated to be about 5 percent of the total water gained to the basin, except in the Karstic area of Lower Fars aquifers (Wadi Qasab) where the ground water losses are mainly through the anticlinal structures discharging into the river Tigris. The value of 10 percent is assigned to this area in which the ground

water flow along one anticlinal structure (Mishraq Sulphur anticline) exceeds 10,000 m^3/d.

The water surplus is the gain in the amount of water in the basin naturally or artificially in excess of the basin losses. The water surplus shown in Table 19 is the product of the total amount of water gained by precipitation minus the total estimated losses of water from the basin and total abstraction. Naturally, such a quantity of surplus water cannot be stored in the aquifers every year while the total abstraction does not exceed 10 percent of the annual water surplus, the vast amount of water gained by each of Al-Ajij and Al-Tharthar basins in the wet seasons is evaporated from the soil and surface marshes in the flat southern parts of Jezira and in Sunaisala salt playa. The bulk of ground water flowing through the shallow aquifers is evaporated in the areas where the water table approaches or reaches the ground surface. Vast amounts of salt are being deposited every year in several salt playas in the southern parts of the area under study of which Sunaisala seems to be the biggest, covering an area of about 100 km^2. Some ground water is discharged directly to the main wadis in the spring and early summer periods but its quantity is not sufficient to create measurable flow in summer and autumn seasons except in the area where ground water discharge is concentrated at a main spring or cave as in many locations over the Lower Fars area.

The permanent storage in the Upper Fars aquifers of Wadi Al-Ajij and Wadi Al-Tharthar was estimated for the top 100 m. of the formation which is considered as the main permeable part of this formation. The average thickness of the permeable horizons which function as aquifers in Wadi Al-Ajij was estimated from the geophysical logging in two wells (see 2.2.2)and found equal to about 50 percent. The effective porosity of these horizons

	Drainage Basin	Tot. Area Km^2	Avr. ann. Rfl. mm	Tot.ann. Rainfal. (m^3)	Estim.% of ann.loss				Tot.ann. Recharge (m^3)	Tot.ann. Abstract. (m^3)±20%	Tot.Water Surplus (m^3)	% ann. Abst.	Estimated permanent storage (m^3)
					P.Eva	Surf. runo.	G.W. runo.	Tot.					
1	Al-Ajij	3670	330	$1.17x10^9$	70	15	5	90	$1.17x10^8$	$1.0x10^7$	$1.07x10^8$	10	$1.8x10^{10}$
2	Al-Tharthar	5490	330	$1.65x10^9$	70	15	5	90	$1.65x10^8$	$5.0x10^6$	$1.6x10^8$	3	$1.0x10^{10}$
3	Al-Qasab	1910	350	$6.7x10^8$	65	20	10	95	$3.35x10^7$	$3.0x10^6$	$3.05x10^7$	9	$4.0x10^9$
4	Flat Jezira	2120	230	$4.88x10^8$	80	10	5	95	$2.44x10^7$	$2.0x10^5$	$2.42x10^7$	1	$2.0x10^9$
5	Sunaisala	1480	220	$3.26x10^8$	80	10	5	95	$1.63x10^7$	$3.0x10^3$	$1.63x10^7$	0.02	$1.5x10^9$

Table 19: Quantitative measurements of water resource in the area under study

is about 10 percent which makes a total of permanent storage in these aquifer of about 1.8×10^{10} m^3. The average thickness of aquifers in the Tharthar basin was estimated from the geological logging of some wells and found equal to about 20 metres. However, it is much higher towards the northern and western parts of the area. The porosity of these horizons is about the same as in Al-Ajij basin. The value of 10 percent as effective porisity was assigned for all the basins covered with Upper Fars formation but the thickness of the aquifers in the first 100 m. of this formation was estimated as being 10 metres of the total thickness for the flat Jezira and Sunaisala basins.

The porosity of the Lower Fars was estimated from the geophysical logging in Mishraq and Hammam Ali and found equal to about 20 percent, however, this high value is restricted only to the cavernous limestone and gypsum which make about 10 percent of the upper 100m. of the formation. The estimated permanent storage in each basin in the study area is shown in Table 19.

CHAPTER SEVEN

Conclusions and recommendations for water resources management

7.1 Introduction

7.2 Ground water resources management

7.3 Recommendations for water resources management

7.1 Introduction

Every effort has been made to estimate the annual recharge and water losses from the different basins, particularly Al-Ajij and Al-Tharthar catchments. Nevertheless, continuing extensive study of the water resources in these areas is inevitable. Essential data concerning quantities and availability of surface water resources are needed for the study of the possible use of surface water supplies in conjunction with the ground water resources. In general, the 'safe yield' based on perennial replenishment adequate for extensive irrigation projects in the northern reaches of the Al-Ajij and Al-Tharthar basins where the alluvial aquifers provide substantial quantities of water. In the central parts of the area the safe yield is probably small but sufficient to supply domestic and livestock needs and provide a moderate amount of water for irrigation. However, the southern parts of the study area yield relatively small quantities of ground water and these tend to possess high amounts of dissolved salts.

The practical sustained yield is the amount of water which can be withdrawn annually without producing undesirable effects. This can be limited to an amount less than annual recharge but should not exceed the long-term annual recharge. If the water discharge exceeds the annual recharge, then it must come from storage within the aquifer. In all the basins studied, the premenent storage is many times greater than the annual recharge or withdrawal (See table 19) therefore in any one year the withdrawals can exceed annual recharge without causing permanent depletion. For example on a long term basis when series of wet and dry years tend to average out, the withdrawal becomes an overdraft only if the mean annual recharge is exceeded.

Safe yield will vary from place to place. The relatively permeable zones capable of greatest yield are areas in the vicinity of Sinjar mountain and other areas in which the aquifer consist either of recent alluvium or sandy Upper Fars beds. Complete data for ground water studies in such areas should be collected from appropriately spaced observation points. Comprehensive pumping tests with adequate equipment, should be made in areas in which the essential elements limiting the accuracy of the recharge and safe yield estimations are not known. Such basic hydrological data can them be used in the planning of ground water development.

7.2 Ground Water Resources Management:

The results and conclusions drawn from this study suggest that on a gross basis considerably more development can be made of the potential ground water resources without exhausting the supplies or ruining them for generations to come. The northern parts of Jezira offer vast opportunities for development of its ground water resources as well as its surface water supplies. However, ground water resources are critical in semi-arid areas like the Jezira and their development should therefore be carefully planned and executed with great care. Local shortage of water may develop because of the failure to encourage the development and management in accordance with the availability of ground water.

Ground water can be developed on a local basis for the increasing demands of irrigation, particularly in the central and southern parts of the area, below isohyet 250 mm, where dry farming methods have been recently prohibited by the Government. Optimum development and management can be achieved by keeping a balance of water input and output quantities within certain basins. Water wastage should be minimized particularly when irrigating by ground water in the central and southern parts of the area.

The major aquifers in the area under study are in an early stage of development and Table 19 clearly demonstrates that there remains a very large quantity of water surplus in the main basins.

Safe yield defines that basin draft on a ground water supply which can be continued indefinitely without harming the supply. Safe yield of ground water basin is the amount of water which can be withdrawn from it annually without producing

undesirable results such as depletion or quality deterioration.

The main quantity of water which can be extracted from an underground reservoir, yet still maintain that supply unimpaired, depends upon the safe yield. The following factors should be considered in determining the safe yield of a ground water basin:-

1 - the quantity of water supply available to the basin.
2 - the quality of the ground water,
3 - economics of pumpage
4 - water rights in and near the basin.

An overdraft situation may exist if any one of these factors is modified to create an undesired results. Safe yield should not exceed the long-term mean annual water supply to the basin, and for this reason, long term determination of hydrological parameters is essential for basin development.

Safe yield can also be exceeded if draft or a basin produces a ground water of inferior quality. Lowered ground water levels could lead to pumping of underlying saline waters, or poor quality water from the overlying polluted aquifers.. Economic considerations may govern safe yield in areas where the cost of pumping becomes excessive such as the Lower Fars areas. Fresh water supply transferred from the river Tigris should be considered in such areas where the ground water is highly mineralized and corrosive.

Legal restrictions on pumpage would have to be established before the safe yield could be determined. At the present, legalisation concerning ground and surface water pumpage does not exist in Iraq, but would be essential for any practicable management of the finite aquifer resources.

7.3 Recommendations for water resources management:

The development of water resources in the different basins of the area under study should involve both surface and ground water resources. Each of these resources needs detailed study and quantification before it can be considered for development on a major scale. A suggested general outline for the utilization of these water resources would involve phased development of each basin. This could be done by the careful study of existing reports and well records together with the initial phase of development of the surface and ground water as follows:-

A) Development and management of surface water resources:

1) The quantity of surface water available for ground water recharge and surface runoff can be determined by the measurement of surface runoff in the main wadis. Combined weirs are recommended to be constructed in Wadi Al-Tharthar and Wadi Al-Ajij in the areas of Hadhr and A'sailah respectively. These weirs should be fitted with automatic level recorders for the measurement of discharge across the wadi. The combined type of weir will enable the measurement of high and low discharges to be taken continuously. The high discharges are likely to occur in winter and spring seasons, while the very low discharges are found in the summer and autumn seasons.

The surface water runoff in the area can be controlled, if proved sufficient, by the construction of small dams on the main valleys. This could provide substantial quantities of water to be used for irrigation, domestic or ground-water recharge purposes. Significant quantities of water are expected to exist in areas of high runoff where clayey soil is accentuated by the physiographic features of the area.

2) The quality of the surface water can be studied by periodical sampling of key streams and springs so as to determine any seasonal variations in water quality and to control water pollution whenever it exists.

3) The measurement of total rainfall and potential evapotranspiration is essential for the estimation of surface water for each basin. Meteorological stations should thus be installed in the central and southern parts of the area, particularly in Ba'aj, Ethrai and Hadhr.

4) Educationàl programmes and corrective steps should be undertaken to reduce organic pollution of domestic water resources, and to protect the recharge areas in the north and northeastern parts of the area from surface pollution.

5) All the major springs need to be protected from direct pollution especially the springs which form the main water supply for the area like Jaddala, Shaikh Ibrahim, Adaiya, Terme and Sino.

B) Development and management of ground water resources:

The following steps are necessary for the initiation of any major project:-

1) ground-water levels should be measured for a network of deep and shallow wells distributed all over the area. Such periodic measurement can be monthly or seasonally, providing that the measurements are taken for key wells in which the surface elevation, total depth, aquifer type and screen type are known. These measurements are essential for the estimation of annual recharge, fluctuation and storage of ground water.

2) the quality of ground water can be studied from a network of representative wells distributed over the shallow and deep aquifers. Periodic sampling is essential in water supply wells in which the aquifers are underlain or overlain by potentially leaky horizons of thermal or mineral waters. Seasonal analyses from such wells will help to understand the source of aquifer replenishment and contamination.

3) the application of geophysical survey methods are useful to study the extent and distribution of mineralized water within the interbedded aquifers and in the zones of mixing of fresh and brackish waters. The presence and extent of the clayey horizons within the aquifers of the Upper Fars Formation can also be identified by the use of borehole gamma-ray logging in the drilled wells. The application of resistivity survey is useful in the areas where aquifers are not deep. Similarly, the vertical and horizontal extent of an aquifer and the presence of prevailing axes of strata with high hydraulic conductivity values can also be determined by resistivity surveys.

4) the properties of the different aquifers penetrated by the deep wells can be determined by performing pumping or recharge tests in the existing water supply wells. If the well is to be used as a main water supply well as in Kharab Bajar such testing should be maintained for a sufficiently long period of time that any boundary conditions can be identified.

Tests should be thorough, made with adequate equipment, and competently observed. The nearby wells can be used as observation points providing that the depth of penetration of these wells is known. Other observation points can be constructed near the pumping well within a suitable distance to allow the determination of aquifer properties from the extent and shape of the cone of depression. In areas where several disconnected aquifers exist, the observation wells can be grouped in sets so that each pipe penetrates certain horizon, as is the case in Mishraq Sulphur mine where observation wells penetrate three different aquifers.

5) aquifers can be developed individually providing that management of each aquifer takes into consideration the effect on other aquifers. Areas in need of supply where prospects are not adverse to development of ground water should receive the earliest consideration. Particular attention should be given to indicators of water quality and pollution in each aquifer. The dissolved gases should be determined together with detailed water analyses from waters taken from Lower Fars aquifers.

Maintenance of ground water quality at acceptable levels is one of the major requirements for successful utilization of ground water resources. In some wells there is evidence that saline waters are entering and mixing with the fresh water of the lower aquifers, e.g. Blaij, Abu-Sanam and Al-Kahirah. Wherever the cone of depression drops below the shallow aquifers, there is a cause for concern that the reversed gradient may eventually induce inflow or leakage of polluted or saline water of the shallow aquifers.

Finally, it can be conclusively shown that the aquifers underlying the Sinjar Plain area have a significant though as yet unquantified potential for ground-water resource development. The area is currently in a primitive or youthful stage of ground water exploitation though localised overdevelopment emphasises the need for implementation of careful management practices.

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APPENDIX 1

Ser. No.	Source	Total depth (m)	Static water level	Location
1	DW	68.4	68.0	Althalja
2	BH	-	-	Alrihania
3	DW	40	-	Znazil
4	DW	47	46.5	Alba'la
5	DW	-	-	Telafar Farm
6	BH	96	4.5	Ain H'san
7	DW	8	4.0	near "
8	S	-	-	Sinjar Highway
9	S	-	-	Ain Terme
10	S	-	-	Tel Mutar Alia
11	DW	8	7.0	2km west " "
12	DW	-	-	3km " " Sufla
13	S	-	-	Kulat
14	BH	100	9.0	Kurkubat Farm
15	DW	-	-	" "
16	BH	80	-	Kurkubat village
17	BH	-	-	Kubur Alhajir
18	BH	-	-	" "
19	DW	-	17.5	1km west "
20	BH	-	-	Kawalah
21	BH	120	-	Azir Sharqi
22	BH	125	-	" Gharbi
23	BH	125	-	Khurbat Tatar
24	BH	136	-	Kakhurt
25	DW	-	24.4	Sibayit Murki
26	DW	-	23.2	Kurkubat Alia
27	BH	-	-	Rambosi Gharbi
28	S	-	-	Sinjar
29	BH	-	-	"
30	BH	110	-	Rambosi Sharki

Ser. No.	Source	Total depth (m)	Static water level	Location
31	DW	-	20	Near Rambosi
32	BH	-	-	Kharab Bajar
33	DW	-	14	" "
34	DW	-	10.3	Kharab Arnah
35	BH	-	-	Ba'aj
36	DW	14.2	7.4	Kharab Alajaz
37	DW	11.85	4.8	M'sherfat Allogha
38	DW	-	3.0	Als'dairah
39	BH	-	-	Tel-A'Kool
40	BH	-	-	Alkahirah
41	BH	200	-	B'laij
42	DW	-	4.60	Am' mash
43	DW	17.4	14.0	Tel- J'aab
44	BH	-	-	Abu Samam Wastani
45	S	-	-	Ain Albaidha
46	S	-	-	Hamam Ali (zahra)
47	S	-	-	" " (Fasosa)
48	DW	-	15.4	Tel Kaisoom
49	DW	-	24.2	Alsahaji
50	DW	24.0	22.5	"
51	BH	-	46	Aldirnaj
52	BH	-	-	Tel Khazaf
53	DW	-	-	Alshuhada
54	DW	-	27.5	Almawali
55	DW	-	16.0	Tel Zalat
56	BH	-	-	Halawa
57	BH	-	-	Abu Shuk'ka
58	S	-	-	Almuhalabia
59	S	-	-	Shaikh Ibrahim
60	DW	4.0	2.0	Kasir M'Hrab

Ser. No.	Source	Total depth (m)	Static water level	Location
61	DW	12	5.5	Alshari'a Junubia
62	BH	-	-	Sibayet Aziz Agha
63	DW	-	14.5	Alasja'i
64	DW	-	13.80	Abtakh
65	DW	-	22	Sibayet Harrosh
66	DW	-	6.5	H'sainiat Junubia
67	BH	-	-	Tel-Banat
68	K	-	-	Khailow
69	S	-	-	Ain Ghazal
70	S	-	-	Ba'shouk
71	BH			Hamadan
72	BH	172	10.90	Sinjar Camp 6
73	BH			Sinjar Camp No.8
74	BH			Sinjar Camp No.7
75	DW	13.0	9.0	Azat Khadher Farm
76	DW	6.20	4.5	Rambosi Junubi
77	DW	13.5	9.0	Daoud Khader Farm
78	DW	13.0	11.0	Mohammad Abid Farm
79	DW	15.3	11.0	Sulaiman Murad Farm
80	DW	11.3	8.8	Shala'aan
81	K	-	-	Zoumani
82	K	-	-	Kasirki
83	DW	-	-	Z'rafki
84	BH	115	-	Alwardia
85	S	-	-	Jaddalah
86	S	-	-	Almajnonia
87	K	-	-	Alskainia
88	DW	-	42	Alholafai'i
89	BH	265	-	Umm Jrais
90	DW	7.20	5.30	Umm Althaiban

Ser. No.	Source	Total depth (m)	Static water level	Location
91	BH	-	-	Umm Thiban Shakia
92	BH	-	-	Abu Takia, S
93	BH	-	-	" " Mid.
94	BH	-	16	" " N.
95	BH	-	-	Tel Kutah
96	DW	16.60	13.6	1 km W. Hwaidir
97	DW	15.5	14.0	Hwaidir
98	DW	22	18.65	J'your Sharki
99	DW	-	18.1	" Gharbi
100	DW	22.9	20.4	Dibshia
101	BH	-	21.4	Tel Saki
102	BH	-	29.1	Alrashidia
103	BH	-	30.65	Abu Louyan
104	DW	-	14.7	Shaikhat Almijfil
105	BH	-	14.1	Abu Rasain
106	BH	-	10.20	Tel Khalil
107	DW	5.8	2.50	Mistarihat Hassan
108	DW	5.5	4.4	Tel Ghazal
109	DW	9.50	6.50	Zoumani
110	DW	10.20	7.70	Almurrah
111	DW	12.0	9.30	Bothah Gharbia
112	BH	9.90	9.50	Mistarehat Aldekh
113	DW	11.35	9.50	Albuwair
114	DW	14.50	11.30	Rabi'a
115	BH	-	11.15	Mis'ida
116	DW	-	18.8	Umm Alzanabir
117	DW	-	17.40	Altammah
118	DW	25.0	23.5	Murzokat Almurkab
119	BH	24.5	22.4	Bab Alkhair
120	DW	-	20.0	M'tallat Almurkab

Ser. No.	Source	Total depth (m)	Static water level	Location
121	BH	-	-	Alkhaznah
122	DW	38.8	33.7	Aljallodia
123	DW	43.0	41.8	Halakal Almurkab
124	BH	-	34.1	Murkab Altair
125	DW	-	47.5	A'raidha
126	DW	13.7	7.7	Almahmodia
127	DW	20	13.7	Botha Alrawia
128	DW	15.3	14.3	Alhrairah
129	DW	19.0	12.5	Bear Almalih
130	DW	11.9	10.0	Alsalhia
131	DW	12.0	9.0	Botha Shimalia
132	DW	13.65	12.3	Dibshia Abu Skairah
133	BH	-	-	Tel Amir
134	BH	-	6.24	Al-theibah
135	DW	12.65	6.3	Jlaimeed
136	BH	-	11	I'rfai
137	DW	12.6	11.3	Abu Khashb
138	BH	7.75	6.3	Dailo Khan
139	DW	10.7	5.7	Althalathat
140	S	-	-	Umm Shababeet
141	S	-	-	Sino
142	S	-	-	Tel Afar
143	S	-	-	Ain Kibrit
144	DW	-	2.0	Alhatimia
145	DW	-	13.0	Beeski Shimalia
146	BH	145	-	Khnaisi
147	DW	-	3.5	H'thail
148	DW	6.0	4.2	Umm Alzanabir
149	DW	27.4	26.0	Alsukkaria
150	DW	-	36.4	Almushafi

Ser. No.	Source	Total depth (m)	Static water level	Location
151	DW	-	15.5	Sultanah
152	BH	-	-	Tel Althalei
153	DW	8.6	7.0	Thrai
154	DW	4.4	-	Khams Tlool
155	BH	55	-	Almadinah
156	DW	9.5	6.7	Srouj
157	BH	-	-	Shaikho
158	DW	3.9	3.1	Alsab'bah
159	BH	-	-	Almistariha
160	DW	5.5	4.1	Botha Alghail
161	DW	15.6	14.5	Khwiaitla
162	DW	14.4	13.4	Kharbat I'saila
163	DW	4.2	3.1	I'sailah
164	DW	3.8	2.9	I'sailan
165	DW	4.3	3.2	Almalha
166	_	-	-	Sunaisala
167	DW	4.2	3.66	K'saibia
168	DW	26.5	25.8	M'aizilah
169	DW			Alsaidia
170	DW	7.0	5.6	Abu Haiya
171	DW	7.9	6.5	Botha Alsakar, W
172	DW	13.7	12.1	Kharab Althaiba
173	DW	10.3	7.2	Almiram Kabir
174	DW	15	13.2	Tel Alneel
175	DW	-	11.0	Sabayet Thraya
176	DW	12.6	12.3	Hamid Almisil
177	DW	4.0	2.3	Alnamlah
178	DW	7.4	4.5	Aldwaim
179	DW	6.0	4.6	Twaal
180	DW	8.2	2.7	Abu Rasain

Ser. No.	Source	Total depth (m)	Static water level	Location
181	DW	4.0	2.15	Abu Jarad
182	"	16.0	4.8	Safyan
183	"	6.8	2.6	Umm Alhram
184	"	12.0	4.0	Dwaizania
185	BH	-	-	Tel Alshaikh
186	DW	17.0	16.0	Hamdania
187	BH	-	-	Twaimean
188	DW	19.2	16.9	Alzahouria
189	DW	6.2	3.7	Almishrif
190	DW	6.2	5.1	Rijim Albotha
191	DW	-	5.2	Botha Alhiyal
192	BH	-	-	Kh'shani
193	DW	44.4	39.4	Musherfat Umm
194	DW	19.4	16.6	Alghilfis
195	BH	-	4.0	Rashid
196	DW	43.5	40.5	Sofan
197	DW	28.5	26.5	Bir S'iabi
198	BH	300	-	Aliat Tel Sfouk
199	BH	-	16.6	Marzokat "
200	DW	24	22.4	Almun'naia
201	BH	-	-	J'ghaifi
202	DW	15.4	12.5	F'raih
203	DW	-	2.0	Abu Braij
204	DW	4.6	4.3	Abu Rasain
205	"	3.0	2.4	Tel Daghash
206	S	-	-	Tre'tea'a
207	DW	8.5	4.4	Alsaddahia
208	"	-	4.0	Mohammad So'an
209	"	7.56	4.5	Botha M'kaibra
210	"	11.6	10.1	Amtakh

Ser No.	Source	Total depth (m)	Static water level	Location
211	DW	9.3	7.5	Alkhaznah
212	BH			Sebayet Murzoga
213	DW	16.2	5.85	Hamdan
214	"		2.7	Seiha
215	"	6.0	4.0	D'haila
216	"	5.0	3.9	A'sailah
217	"	7.4	2.9	Alsalha
218	"	5.0	3.2	Alm'saltan
219	"	2.9	1.7	Umm Alshatin
220	"	6.7	5.0	Dam Kraidi
221	"	7.3	5.8	Musherfat Jisir
222	BH	-	-	Harshan Shwa
223	DW	3.7	2.4	S'laibi
224	"	4.3	2.3	Tel A'zear, W
225	"	4.2	3.7	" " E
226	"	4.5	2.2	Zayid
227	"	-	20.8	Haradah
228	"	-	-	Har'ada
229	S	-	-	Adaiya
230	BH	-	-	"
231	DW	-	3.4	Tel Sirwal
232	DW	8.8	5.3	Umm H'jarah
233	"	-	3.5	" Sufla
234	"	5.5	4.2	Alfatsah
235	"	6.8	5.4	Tel Faris
236	"	13.3	10.2	Tel Abta, N.
237	"	5.8	3.4	" " , S
238	"	-	-	" " S
239	"	-	1.5	Rijim Mraijez
240	"	6.10	5.4	Alathouri

Ser. No.	Source	Total depth (m)	Static water level	Location
241	DW	7.0	6.9	Hadhr
242	"	7.0	6.4	M'sherfat Hadhr
243	"	10.8	7.9	Sadiat Alshahid
244	"	8.4	5.5	" Wadi Hamrah
245	"	11.4	10.0	Sadia Shimalia
246	"	7.1	5.1	Malhat Bakarah
247	"	2.6	1.3	Se'hil
248	"	5.5	5.0	Ras Alsahil
249	"	5.9	3.2	Alta'ish, S.
250	"	6.7	6.2	J'yaai
251	"	16.1	12.5	Tel Shehaat
252	"	7.3	6.4	Dal'lawia
253	"	9.2	3.4	Mustantik
254	"	15.6	13.8	Alhar'ram
255	BH			Sinjar Camp

APPENDIX 2

Observation during pumping and recovery in Ain Al-Il'san SN.6

Pumping started at 12.20 and terminated at 16.20
Initial water level: 4.5 m. below ground surface.
Final water level : 38.5 m.below ground surface
Discharge rate: 130.9 m^3/d, initial discharge was 393 m^3/d maintained for 5 mins. was decreased to 196.4 m^3/d for 10 mins. and finally decreases to 130.91 m^3/d and maintained constant for the rest of the pumping test.

Recovery in the pumping well			
t (min)	s' (m)	t/t'	s'' (m)
4.1	2.12	59.54	30.88
5.36	3.63	43.4	30.37
8	5.37	31.0	28.63
11	7.44	22.82	26.56
15.5	9.68	16.5	24.32
20	11.57	13.0	22.43
25	13.35	10.6	20.65
30	14.91	9.0	19.09
36	16.53	7.66	17.47
42	17.90	6.71	16.1
48	19.20	6.0	14.8
54	20.22	5.44	13.78
60	21.25	5.0	12.75
70	22.75	4.43	11.25
80	24.09	4.0	9.91
90	25.26	3.66	8.74
105	26.81	3.29	7.2
135	29.29	2.77	4.72
165	31.21	2.45	2.8
210	33.55	2.14	0.45

Observation during pumping and recovery in Kurkubat Sufla SN.14.

Pumping started at about 14.00 and terminated at 19.17
Initial water level: 9.00 m. below ground surface
Final water level : 26.91 m. below ground surface
Distance of observation well: 24m. from the pumping well
Initial water level in the observation well: about 20.20m below ground surface
Final water level in the observation well : 18.45 m below ground surface
Discharge rate: 432 m^3/d.

Recovery in the Pumping well	
t (min)	s' (m)
2.5	2.74
3.5	3.91
4.5	4.53
6.0	4.97
8	5.22
10	5.39
12	5.54
15	5.66
20	5.75
25	5.82
30	5.92
40	5.99
50	6.06
60	6.11
80	6.24
100	6.32
120	6.37
150	6.44
180	6.50
240	6.60
600	6.85
660	6.89

Recovery in the observation well	
t (min)	s' (m)
1.5	1.3
2.5	2.4
4.0	4.0
6	6.3
8	8.4
11	11.2
15	15.8
20	20.8
25.	25.7
30	30.5
35	35.4
45	44.5
60	57.7
75	71.0
90	83.9
105	96.3
135	121.7
165	141.8
195	161.5
600	231.5
645	232.5

Observation during pumping and recovery in Sinjar Camp,
Well No.7, SN.74.
Pumping started at 7.43 and terminated at 11.14 on 2 July 1974
Initial water level: 20.30 m. below ground surface
Final water level : 22.80 m below ground surface
Intake depth: 76 to 90 m.
Discharge rate: 510.55 m^3/d
Water temperature: 24.5°C, constant throughout the test

Recovery Data			
t (min)	t/t'	s (m)	s' (m)
3.25	65.9	4.35	
10	22.1	15.32	17.48
12	18.58	17.50	15.3
14	16.07	19.01	13.79
16	14.2	20.15	12.65
18	12.72	21.15	11.65
20	11.55	21.97	10.83
22	10.6	22.69	10.11
24	9.8	23.25	9.55
26	9.11	23.75	9.06
28	8.53	24.12	8.68
30	8.03	24.45	8.35
35	7.03	25.04	7.76
40	6.27	25.40	7.4
45	5.69	25.65	7.16
50	5.22	25.95	6.85
62	4.4	26.22	6.58
75	3.81	26.33	6.47
91	3.32	26.40	6.40
105	3.01	26.53	6.27
175	2.206		

Observation during pumping and recovery in a large diameter hand dug well, Daoud Khadher Farm, SN.77.

Pumping started at about 6.00 a.m., and terminated at 10.45
Second pumping started at 13.25
Initial water level: 10.00 m. below ground surface
Final water level: 11.70 m. below ground surface
Discharge rate: 518.4 m^3/d
Well diameter: about 2m.

Pumping test			
t (min)	s (cm)	t (min)	s (cm)
2.0	1.8	40	62.0
3.5	4.0	45	68.5
5	6.4	50	74.5
7	9.9	55	81.0
9	13.7	60	86.2
11	17.4	70	96.4
13	21.4	80	106.6
15	24.8	90	115.1
17	28.2	100	122.9
19	31.3	110	129.8
21	34.3	120	132.4
25	41.6	130	135.3
30	48.2	130	138.9
35	56.2		

Recovery test			
t' (min)	s' (cm)	t' (min)	s' (cm)
0.4	2.3	39	72.7
1.4	4.7	41	75.7
3.0	8.2	43	78.2
4	10.1	45	81.4
5	12.6	47	83.8
6	14.7	49	86.7
7	16.8	51	89.3
8	18.9	53	91.5
9	21.1	55	93.8
10	23.3	57	96.2
11	25.3	59	98.6
12	27.3	61	100.7
13	29.3	63	103.2
14	31.4	65	105.4
15	33.2	70	110.4
17	37.3	75	114.4
19	41.3	80	120.9
21	44.9	85	125.5
23	48.2	90	129.2
25	51.7	95	133.2
27	54.4	100	137.4
29	58.1	105	141
31	61.3	110	144.1
33	63.9	120	151.3
35	67.3	130	157
37	70.3	145	164.9
		160	171.3

Observation during pumping and recovery in Al-Louyan, SN.103

Pumping started at 9.00 a.m. and terminated at 13.16
Initial water level, 33.5 m. below ground surface
Final water level 51.77 m. below ground surface
Discharge rate: 50.11, 77.76, 103.88. Three steps
Water temperature = 24°C constant

Pumping test			
t (min)	s (m)	t (min)	s (m)
3	2.12	3rd step	
6	2.163	137	4.296
9	2.204	138	4.499
13	2.278	139	4.641
18	2.295	140	4.767
25	2.331	141.5	4.841
35	2.346	143	4.921
45	2.356	145	4.969
60	2.369	147	4.984
2nd step		150	5.021
62	3.109	153	5.083
63	3.223	157	5.098
64	3.38	161	5.103
65.6	3.484	166	5.118
67	3.603	171	5.136
70	3.769	176	5.154
75	3.849	186	5.184
80	3.893	196	5.214
85	3.956	211	5.241
90	3.967	226	5.244
100	3.981	241	5.245
120	4.035	256	5.245
136	4.035		

Recovery test			
t' (min)	s' (m)	t' (min)	s' (m)
0.37	0.42	9.0	3.733
0.75	0.855	10	3.793
1.25	1.37	12	3.883
1.75	1.735	14	3.953
2.5	2.095	16	4.003
3	2.54	18	4.043
3.5	2.742	22	4.095
4.0	2.922	26	4.129
4.5	2.055	30	4.156
5	3.18	40	4.197
5.5	3.274	50	4.234
6	3.361	60	4.256
6.5	3.439	90	4.281
7	3.499	125	4.293
7.5	3.56	260	4.314
8.0	3.652	840	4.36

Observation during pumping and recovery in Tel-Alamir SN.133

Pumping began at 10.20 and terminated at 11.25
Initial water level: 6.24 m below ground surface
Final water level: 8.41 m below ground surface
Discharge rate: 22.46 m^3/d, increased to 23.33 m^3/d

Recovery in pumping well

t (min)	s' (m)	t (min)	s' (m)
0.15	0.19	9.5	1.42
0.40	0.40	10.0	1.45
1.0	0.495	11.0	1.50
1.5	0.50	12.5	1.57
2.0	0.685	14	1.63
2.5	0.754	16	1.70
3.0	0.82	18	1.75
3.5	0.88	20	1.80
4.0	0.95	22	1.83
4.5	1.01	25	1.88
5.0	1.06	30	1.93
5.5	1.11	35	1.97
6.0	1.16	40	1.99
6.5	1.20	45	2.02
7.0	1.24	55	2.05
7.5	1.28	65	2.08
8.0	1.32	80	2.10
8.5	1.36	95	2.12
9.0	1.39		

Observation during pumping and recovery in Irfa'i (SN.136).

Pumping started at 11.00 a.m. and terminated at 16.42
Initial water level: 10.44 m below ground surface
Final water level : 28.98 m below ground surface
Intake depth: 65 m.
Discharge rate: 820.8 m^3/d
Water temperature: 23.5°C, constant through the test

Recovery Data

t (min)	s'' (m)
2	12.30
4	15.88
6	16.91
8	17.16
11	17.33
15	17.45
20.5	17.55
30	17.68
40	17.76
60	17.86
80	17.93
100	17.97

```
HASP-II JOB STATISTICS --    850 CARDS READ --   1,799 LINES PRINTED --      0 CARDS PUNCHED --   2.88 MINUTES EXECUTION TIME


//UCFB03RH JOB (220,RM00,1,3),'RAMZI',                          X JOB 415
//             TIME=(0001,00),REGION=0220K                       HASPHASP
// EXEC FORTRANG
//C.SYSIN  DD  *
IEF236I ALLOC. FOR UCFB03RH C
IEF237I 346   ALLOCATED TO SYSTEPM
IEF237I 349   ALLOCATED TO SYSPRINT
IEF237I 352   ALLOCATED TO SYSPUNCH
IEF237I 232   ALLOCATED TO SYSLIN
IEF237I 300   ALLOCATED TO SYSIN
IEF142I - STEP WAS EXECUTED - COND.CODE 0000
IEF285I   SYS76329.T202308.RFC00.UCFB03RH.SYSUT4       PASSED
IEF285I   VOL SER NOS= 4SCR4 .
                          ************************************************************
                          * UCFB03RH  STEP C        PGM=FORTG    TOOK  1MIN 10.34SEC *
                          * SIZE=100KB   COND-CODE=0    CPU-TIME USED       15.30SEC *
                          ************************************************************

IEF236I ALLOC. FOR UCFB03RH L
IEF237I 346   ALLOCATED TO SYSPRINT
IEF237I 232   ALLOCATED TO SYSUT1
IEF237I 232   ALLOCATED TO SYSLIN
IEF237I 231   ALLOCATED TO MODLIB
IEF237I 231   ALLOCATED TO PGMLIB
IEF237I 232   ALLOCATED TO SYSLMOD
IEF237I 235   ALLOCATED TO SYSLIB
IEF237I 134   ALLOCATED TO
IEF237I 134   ALLOCATED TO
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   SYS76329.T202308.RFC00.UCFB03RH.SYSUT1       DELETED
IEF285I   VOL SER NOS= 4SCR4 .
IEF285I   SYS76329.T202306.RFC00.UCFB03RH.SYSUT4       DELETED
IEF285I   VOL SER NOS= 4SCR4 .
IEF285I   UCMODLIB                                     KEPT
IEF285I   VOL SER NOS= 4UMOD .
IEF285I   UCPGMLIB                                     KEPT
IEF285I   VOL SER NOS= 4UMOD .
IEF285I   SYS76329.T202308.RFC00.UCFB03RH.GOSET        PASSED
IEF285I   VOL SER NOS= 4SCR4 .
IEF285I   SYS1.G.FORTLIB                               KEPT
IEF285I   VOL SER NOS= 4SLIB .
IEF285I   SYS1.AAGMK4.SINGLE                           KEPT
IEF285I   VOL SER NOS= 4A001 .
IEF285I   SYS1.FORTSSP3.SINGLE                         KEPT
IEF285I   VOL SER NOS= 4A001 .
```

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                                ************************************************************
                                * UCFB03RH  STEP L         PGM=LINKLINK TOOK        13.36SEC *
                                * SIZE=106KB   COND-CODE=0    CPU-TIME USED         1.22SEC *
                                ************************************************************

//G.FT06F001  DD  SYSOUT=(C,,C)
//G.SYSIN  DD  *
IEF236I ALLOC. FOR UCFB03RH G
IEF237I 232   ALLOCATED TO PGM=*.DD
IEF237I 346   ALLOCATED TO FT03F001
IEF237I 302   ALLOCATED TO FT05F001
IEF237I 370   ALLOCATED TO FT06F001
IEF237I 392   ALLOCATED TO FT07F001
IEF237I 232   ALLOCATED TO DELETE
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   SYS76329.T202308.RF000.UCFB03RH.GOSET        PASSED
IEF285I   VOL SER NOS= 4SCR4 .
IEF285I   SYS76329.T202308.RF000.UCFB03RH.GOSET        PASSED
IEF285I   VOL SER NOS= 4SCR4 .

                                ************************************************************
                                * UCFB03RH  STEP G         PGM=MAIN     TOOK  1MIN 20.70SEC *
                                * SIZE=100KB   COND-CODE=0    CPU-TIME USED        20.68SEC *
                                ************************************************************

IEF285I   SYS76329.T202308.RF000.UCFB03RH.GOSET        DELETED
IEF285I   VOL SER NOS= 4SCR4 .


                                ************************************************************
                                *                    WED 24 NOV 1976                       *
                                * JOB  UCFB03RH   (CLASS K)   STARTED  22HR 48MIN 35.98SEC *
                                * TOTAL ELAPSED TIME TAKEN:                2MIN 45.88SEC *
                                * TOTAL  C.P.U. TIME TAKEN:                   37.20SEC *
                                * DISK I/O COUNT:    594          TAPE I/O COUNT:      6 *
                                * HASP NUMBER:       415          CARDS READ:        850 *
                                * NOMINAL SIZE:    106KB          LINES PRINTED:    1699 *
                                * PARTITION:  I4 ( 240KB)        CARDS PUNCHED:     NIL *
                                * LOADPOINT (HEX):08F020         A/C UNITS USED:  0.457 *
                                ************************************************************
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C     PROGRAMMER ** RAMZI H. HADDAD **
C     I=SERIAL NUMBER =SNO. GIVEN IN TABLES
C     A=CA IN MEQ/L , AA=CA IN PPM
C     B=MG IN MEQ/L , BB=MG IN PPM
C     C=NA IN MEQ/L , CC=NA IN PPM
C     D=K IN MEQ/L , DD=K IN PPM
C     E=HCO3 IN MEQ/L , EE=HCO3 IN PPM
C     F=CL IN MEQ/L , FF=CL IN PPM
C     G=SO4 IN MEQ/L , GG=SO4 IN PPM
C     H=NO3 IN MEQ/L , HH=NO3 IN PPM
C     TCC=TOTAL CATIONS IN MEQ/L FOR CALCULATIONS.=Z(I)
C     TAA=TOTAL ANIONS IN MEQ/L FOR CALCULATIONS.=Y(I)
C     AAP=%CA
C     BBP=%MG
C     CCP=%NA
C     DDP=%K
C     EEP=%HCO3
C     FFP=%CL
C     GGP=%SO4
C     HHP=%NO3
C     TH=TOTAL HARDNESS IN PPM
C     SAR=SODIUM ADSORPTION RATIO
C     PE=%ERROR IN COMPARISON OF CATIONS AND ANIONS
C     RM=CA/MG RATIO
C     RS=SO4/CL RATIO
C     RCL=(CL-NA)/CL RATIO
C     RNA=NA/CA RATIO
C     U=IONIC STRENGTH
C     TSS=TOTAL SOLUBLE SOLIDS IN PPM
C     FT=FIELD TEMPRATURE
C     CCO=CO2 IN PPM
C     PH=HYDROGENE ION CONCENTRATION
C     EC=ELECTRIC CONDUCTIVITY(MMHOS)
C     DS=DATE OF SAMPLING
0001        DIMENSION A(400),B(400),C(400),D(400),E(400),F(400),G(400),H(400),
           *AA(400),BB(400),CC(400),DD(400),TCC(400),EE(400),FF(400),GG(400),H
           *H(400),TAA(400),AAP(400),BBP(400),CCP(400),DDP(400),EEP(400),FFP(4
           *00),GGP(400),HHP(400),PE(400),SAR(400),TH(400),RM(400),RS(400),RCL
           *(400),RNA(400),U(400),TSS(400),FT(400),CCO(400),PH(400),EC(400),DS
           *(400),Z(400),Y(400),RFN(400)
0002     10  FORMAT(I4,8F8.3)
0003     40  FORMAT(I6,F8.2,12F8.2,F9.4)
0004     60  FORMAT(5X,I5,2X,8F10.2,2F13.2)
0005     80  FORMAT(5X,I5,2X,8F10.2,2F13.2)
0006     100 FORMAT(5X,I5,5F15.3,F20.4,F15.2)
0007     110 FORMAT(I4,2F8.2,F7.2,F8.2,F10.4,F6.2)
0008        N=325
0009        DO 35 I=1,N
0010     35 READ(5,10)J,A(I),B(I),C(I),D(I),E(I),F(I),G(I),H(I)
0011        DO 36 I=1,N
0012     36 READ(5,110)J,FT(I),CCO(I),PH(I),EC(I),DS(I),RFN(I)
0013        DO 200 I=1,N
0014        AA(I)=20.04*A(I)
0015        BB(I)=12.16*B(I)
```

```
0016              CC(I)=23.00*C(I)
0017              DD(I)=39.10*D(I)
0018              EE(I)=61.01*E(I)
0019              FF(I)=35.46*F(I)
0020              GG(I)=48.03*G(I)
0021              HH(I)=62.01*H(I)
0022              TCC(I)= A(I)+ B(I)+ C(I)+ D(I)
0023              TAA(I)= E(I)+ F(I)+ G(I)+ H(I)
0024              Z(I)=TCC(I)
0025              Y(I)=TAA(I)
0026              AAP(I)=( A(I)*100)/TCC(I)
0027              BBP(I)=( B(I)*100)/TCC(I)
0028              CCP(I)=( C(I)*100)/TCC(I)
0029              DDP(I)=( D(I)*100)/TCC(I)
0030              EEP(I)=( E(I)*100)/TAA(I)
0031              FFP(I)=( F(I)*100)/TAA(I)
0032              GGP(I)=( G(I)*100)/TAA(I)
0033              HHP(I)=( H(I)*100)/TAA(I)
0034              TH(I)=(2.497*AA(I))+(4.115*BB(I))
0035              SAR(I)=C(I)/(((A(I)+B(I))/2)**0.5)
0036              PE(I)=100*(TCC(I)-TAA(I))/(TCC(I)+TAA(I))
0037              TCC(I)=AA(I)+BB(I)+CC(I)+DD(I)
0038              TAA(I)=EE(I)+FF(I)+GG(I)+HH(I)
0039              TSS(I)=TCC(I)+TAA(I)
0040              PM(I)=A(I)/B(I)
0041              RS(I)=G(I)/F(I)
0042              RCL(I)=(F(I)-C(I))/F(I)
0043              RNA(I)=C(I)/A(I)
0044          200 U(I)=.001*(((F(I)+E(I)+H(I)+C(I)+D(I))/2)+G(I)+A(I)+B(I))
0045              CONTINUE
0046              WRITE(6,20)
0047          30  FORMAT(1H1,' TABLE  ((I))          IONS  IN  MEQ/L')
0048              WRITE(6,31)
0049          31  FORMAT(///,'  SNO. RFNO.    CA       MG       NA       K     HCO3
                 *  CL       SO4      NO3      EC      CO2      PH      TEMP      DATE')
0050              WRITE(6,32)
0051          32  FORMAT('  **** *****   *****   *****   *****   ****  ******   ***
                 ***  ******   *****   *****   *****   *****   *****    **** ')
0052              DO 210 I=1,N
0053              IF(I-51)210,300,301
0054          301 IF(I-101)210,300,302
0055          302 IF(I-151)210,300,303
0056          303 IF(I-201)210,300,304
0057          304 IF(I-251)210,300,305
0058          305 IF(I-301)210,300,306
0059          306 IF(I-351)210,300,210
0060          300 WRITE(6,307)
0061          307 FORMAT(1H1,'       TABLE   ((1))     CONTINUE ')
0062              WRITE(6,308)
0063          308 FORMAT(///,'  SNO. RFNO.    CA       MG       NA       K     HCO3
                 *  CL       SO4      NO3      EC      CO2      PH      TEMP      DATE')
0064              WRITE(6,309)
0065          309 FORMAT('  **** *****   *****   *****   *****   ****  ******   ***
                 ***  ******   *****   *****   *****   *****   *****    **** ')
```

```
0066          210  WRITE(6,40)I,RFN(I),A(I),B(I),C(I),D(I),E(I),F(I),G(I),H(I),EC(I),
                  *CCO(I),PH(I),FT(I),DS(I)
0067               CONTINUE
0068               WRITE(6,50)
0069          50   FORMAT(1H1,' TABLE   ((2))       CATIONS  IN  PPM ')
0070               WRITE(6,51)
0071          51   FORMAT(///,'      SNO.        CA        %CA        MG        %MG
                  *    NA        %NA          K         %K    TOTAL CATION     TSS ')
0072               WRITE(6,52)
0073          52   FORMAT('      ****       ****      *****      ****      *****      *
                  ****      *****        ***       ****    *************   *********')
0074               DO 230 I=1,N
0075               IF(I-51)230,400,401
0076          401  IF(I-101)230,400,402
0077          402  IF(I-151)230,400,403
0078          403  IF(I-201)230,400,404
0079          404  IF(I-251)230,400,405
0080          405  IF(I-301)230,400,406
0081          406  IF(I-351)230,400,230
0082          400  WRITE(6,407)
0083          407  FORMAT(1H1,'      TABLE    ((2))    CONTINUE ')
0084               WRITE(6,408)
0085          408  FORMAT(///,'      SNO.        CA        %CA        MG        %MG
                  *    NA        %NA          K         %K    TOTAL CATION     TSS ')
0086               WRITE(6,409)
0087          409  FORMAT('      ****       ****      *****      ****      *****      *
                  ****      *****        ***       ****    *************   *********')
0088          230  WRITE(6,60)I,AA(I),AAP(I),BB(I),BBP(I),CC(I),CCP(I),DD(I),DDP(I),Z
                  *(I),TSS(I)
0089               CONTINUE
0090               WRITE(6,70)
0091          70   FORMAT(1H1,' TABLE  ((3))      ANIONS  IN  PPM ')
0092               WRITE(6,71)
0093          71   FORMAT(///,'      SNO.        HCO3      %HCO3        CL        %CL
                  *    SO4       %SO4         NO3       %NO3    TOTAL ANIONS      %ERROR ')
0094               WRITE(6,72)
0095          72   FORMAT('      ****       *****      *****      ****      *****      **
                  ****      ******      *****     ******  ************     ******* ')
0096               DO 250 I=1,N
0097               IF(I-51)250,500,501
0098          501  IF(I-101)250,500,502
0099          502  IF(I-151)250,500,503
0100          503  IF(I-201)250,500,504
0101          504  IF(I-251)250,500,505
0102          505  IF(I-301)250,500,506
0103          506  IF(I-351)250,500,250
0104          500  WRITE(6,507)
0105          507  FORMAT(1H1,'      TABLE    (((3)))      CONTINUE')
0106               WRITE(6,508)
0107          508  FORMAT(///,'      SNO.        HCO3      %HCO3        CL        %CL
                  *    SO4       %SO4         NO3       %NO3    TOTAL ANIONS      %ERROR ')
0108               WRITE(6,509)
0109          509  FORMAT('      ****       *****      *****      ****      *****      **
                  ****      ******      *****     ******  ************     ******* ')
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FORTRAN IV G LEVEL  20                  MAIN              DATE = 76329         22/48/39

0110          250  WRITE(6,80)I,EE(I),EEP(I),FF(I),FFP(I),GG(I),GGP(I),HH(I),HHP(I),Y
                  *(I),PE(I)
0111               CONTINUE
0112               WRITE(6,93)
0113          93   FORMAT(1H1,'  TABLE   ((4))    RATIOS,       AND IONIC STRENGTH.')
0114               WRITE(6,94)
0115          94   FORMAT(///,'     SNO.          TH          CA/MG          SO4/CL
                  *   (CL-NA)/CL          NA/CA          IONIC STRENGTH          SAR')
0116               WRITE(6,95)
0117          95   FORMAT('     *****       ********       ********       ********* *
                  ************       ********      **************          *****')
0118               DO 260 I=1,N
0119               IF(I-51)260,600,601
0120          601  IF(I-101)260,600,602
0121          602  IF(I-151)260,600,603
0122          603  IF(I-201)260,600,604
0123          604  IF(I-251)260,600,605
0124          605  IF(I-301)260,600,606
0125          606  IF(I-351)260,600,260
0126          600  WRITE(6,607)
0127          607  FORMAT(1H1,'     TABLE    ((4))     CONTINUE')
0128               WRITE(6,608)
0129          608  FORMAT(///,'     SNO.          TH          CA/MG          SO4/CL
                  *   (CL-NA)/CL          NA/CA          IONIC STRENGTH          SAR')
0130               WRITE(6,609)
0131          609  FORMAT('     *****       ********       ********       ********* *
                  ************       ********      **************          *****')
0132          260  WRITE(6,100)I, TH(I),RM(I),RS(I),RCL(I),RNA(I),U(I),SAR(I)
0133               CONTINUE
0134               STOP
0135               END
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FORTRAN IV G LEVEL  20                  MAIN              DATE = 76329         22/48/39

  *OPTIONS IN EFFECT*   ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
  *OPTIONS IN EFFECT*   NAME = MAIN     , LINECNT =       56
  *STATISTICS*     SOURCE STATEMENTS =      135,PROGRAM SIZE =    75362
  *STATISTICS*  NO DIAGNOSTICS GENERATED
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TABLE ((1)) IONS IN MEQ/L

SNO.	RFNO.	CA	MG	NA	K	HCO3	CL	SC4	NO3	EC	CC2	PH	TEMP	DATE
****	*****	*****	*****	*****	****	******	*****	******	*****	*****	*****	*****	*****	****
1	1.15	19.40	7.90	52.00	0.83	4.63	57.50	20.52	0.0	7.38	34.65	6.85	19.00	6.1974
2	2.25	9.14	5.67	0.80	0.03	7.00	0.63	8.72	0.0	1.19	37.40	7.18	18.20	6.1974
3	3.13	30.19	8.45	2.50	0.06	2.06	1.08	36.00	0.0	2.80	9.90	7.40	15.00	6.1974
4	4.25	21.00	13.44	17.00	0.11	0.85	6.25	42.32	0.0	4.00	5.50	7.55	24.50	6.1974
5	4.25	32.00	12.00	3.00	0.0	2.60	3.75	36.21	1.57	3.20	8.80	7.50	0.0	3.1975
6	5.13	30.04	9.56	3.40	0.08	2.38	2.30	37.60	0.0	2.97	9.90	7.42	21.00	6.1974
7	6.33	29.82	7.14	0.90	0.07	2.04	0.63	34.36	0.0	2.66	11.00	7.30	23.00	6.1974
8	6.33	31.00	7.80	1.05	0.0	3.80	0.75	34.45	0.93	2.80	7.70	7.25	0.0	3.1975
9	7.33	30.24	5.04	0.75	0.05	1.78	0.55	33.36	0.0	2.57	11.00	7.45	22.50	6.1974
10	8.33	19.74	5.20	1.40	0.04	3.25	1.08	22.21	0.0	1.96	14.30	7.30	25.00	6.1974
11	9.15	13.86	3.94	2.00	0.03	3.54	1.00	15.61	0.0	1.60	11.00	7.45	23.00	6.1974
12	9.11	12.92	4.73	1.80	0.03	5.13	1.00	13.39	0.0	1.60	34.10	7.25	23.00	6.1974
13	10.25	27.09	6.93	2.10	0.03	4.00	1.38	31.26	0.0	2.75	28.60	7.18	23.00	6.1974
14	11.25	4.83	2.10	1.60	0.02	3.88	1.20	2.43	0.0	0.81	7.70	7.63	23.00	6.1974
15	12.25	10.50	4.41	2.80	0.04	3.75	1.50	12.33	0.0	1.50	15.40	7.42	24.50	6.1974
16	13.02	10.08	4.31	2.60	0.04	3.54	1.46	12.60	0.0	1.46	11.00	7.40	23.00	6.1974
17	14.25	4.83	1.90	1.50	0.03	4.25	0.75	2.57	0.0	0.70	11.00	7.50	24.50	6.1974
18	15.25	13.02	4.62	2.20	0.04	4.19	1.08	14.02	0.0	1.60	18.70	7.28	23.00	6.1974
19	16.25	4.83	1.05	1.00	0.03	3.63	0.83	2.03	0.0	0.64	11.00	7.45	22.50	6.1974
20	16.11	4.40	1.80	1.05	0.0	3.80	0.75	1.82	0.0	0.65	6.60	7.88	0.0	3.1975
21	17.25	4.41	1.47	1.00	0.02	3.75	0.75	2.02	0.0	0.62	6.60	7.80	22.00	6.1974
22	18.31	3.78	0.63	0.50	0.03	4.13	0.50	0.30	0.0	0.41	11.00	7.35	22.00	6.1974
23	18.31	2.60	0.80	0.50	0.0	3.60	0.50	0.26	0.0	0.38	5.50	7.80	0.0	3.1975
24	19.21	3.70	0.84	0.60	0.03	4.13	0.45	0.76	0.0	0.44	9.90	7.55	22.00	6.1974
25	20.25	4.62	1.80	1.50	0.03	4.50	1.38	1.42	0.0	0.76	12.10	7.65	21.00	6.1974
26	21.25	2.52	2.10	3.50	0.03	2.56	1.05	4.55	0.0	0.76	5.50	7.90	25.50	6.1974
27	22.15	29.40	16.60	6.00	0.04	2.88	2.63	44.08	0.0	3.37	17.60	7.30	22.50	6.1974
28	23.15	29.40	14.70	5.50	0.07	2.66	3.75	40.83	0.0	3.34	11.00	7.30	22.00	6.1974
29	23.15	28.99	17.00	6.25	0.0	3.30	3.72	41.66	2.02	3.62	3.62	7.38	0.0	3.1975
30	24.22	13.44	7.14	6.80	0.07	1.25	3.75	22.81	0.05	2.25	5.50	7.50	24.00	6.1974
31	24.12	33.00	29.00	13.75	0.07	1.80	7.50	54.55	1.57	5.20	5.20	7.48	0.0	3.1975
32	24.22	7.14	4.20	8.80	0.07	0.75	5.50	14.80	0.0	1.95	3.30	7.75	0.0	6.1974
33	24.14	25.20	48.30	40.00	0.26	9.00	17.90	82.47	0.0	7.79	58.30	7.30	0.0	6.1000
34	25.14	22.90	6.93	7.70	0.06	1.88	2.50	34.54	0.0	2.92	15.40	7.30	23.50	6.1974
35	26.22	3.68	4.94	8.80	0.05	2.13	5.90	10.52	0.0	1.77	4.40	7.75	25.50	6.1974
36	27.22	7.67	7.67	11.40	0.07	1.25	19.63	7.08	0.0	2.70	4.40	7.50	25.50	6.1974
37	28.22	9.48	6.93	10.00	0.08	0.91	18.63	7.90	0.0	2.70	3.30	7.50	25.00	6.1974
38	29.14	20.00	15.75	30.00	0.04	3.38	33.13	29.93	0.0	5.47	13.20	7.60	0.0	6.1974
39	30.14	27.30	30.50	22.00	0.07	3.38	6.25	68.87	0.0	6.20	25.30	7.28	23.00	6.1974
40	30.14	26.00	40.00	27.51	0.0	4.85	7.75	78.88	0.0	6.50	0.0	8.00	0.0	3.1975
41	31.24	25.20	25.75	35.00	0.11	1.13	26.25	59.25	0.0	7.00	6.60	7.40	23.50	6.1974
42	32.33	36.55	13.86	18.50	0.87	8.13	23.75	34.90	0.0	5.61	132.00	7.10	30.00	6.1974
43	33.33	5.90	2.21	5.20	0.70	7.13	5.75	2.07	0.0	1.43	55.00	7.13	48.50	6.1974
44	35.13	32.03	11.03	4.00	0.19	3.31	34.10	3.75	0.0	3.19	13.20	7.20	20.50	6.1974
45	35.13	33.00	15.00	3.50	0.0	4.50	4.00	36.20	4.15	3.60	14.30	7.50	0.0	3.1975
46	36.23	30.00	24.70	7.00	0.14	9.90	2.25	48.25	0.0	3.90	132.00	7.30	27.00	6.1974
47	37.13	29.40	18.90	12.50	0.10	3.63	8.75	45.83	0.0	4.12	34.10	6.90	20.00	6.1974
48	39.23	29.40	15.56	5.20	0.11	3.63	3.20	40.08	0.0	3.40	27.50	7.20	23.50	6.1974
49	40.33	29.80	7.90	0.80	0.05	2.25	0.63	33.89	0.0	2.70	13.20	7.28	24.50	6.1974
50	41.33	29.80	7.90	0.60	0.09	2.25	0.55	38.57	0.0	2.53	11.00	7.23	24.30	6.1974

TABLE ((1)) CONTINUE

SNO.	RFNO.	CA	MG	NA	K	HCO3	CL	SO4	NO3	EC	CO2	PH	TEMP	DATE
51	42.14	30.00	25.00	12.25	0.0	2.60	5.87	52.56	2.94	4.60	8.80	7.50	21.50	3.1975
52	42.14	27.30	32.03	25.00	0.24	3.25	12.50	65.49	0.0	5.56	13.20	7.50	0.0	6.1974
53	43.14	28.35	26.25	11.00	0.29	2.38	5.00	48.87	0.0	4.19	13.20	7.37	21.30	6.1974
54	44.25	27.30	20.00	9.75	0.08	1.88	3.75	47.26	0.0	3.80	7.70	7.43	23.30	6.1974
55	45.14	29.40	31.50	23.00	0.13	4.75	14.75	58.01	0.0	5.51	20.90	7.30	20.70	6.1974
56	46.12	18.50	10.30	4.00	0.06	3.38	2.00	25.59	0.0	2.44	16.50	7.25	22.70	6.1974
57	46.22	20.36	14.00	5.75	0.0	3.70	3.75	29.10	2.18	2.80	11.00	7.58	0.0	3.1975
58	47.41	7.25	3.68	1.70	0.05	5.75	1.13	4.12	0.0	1.04	30.80	7.25	21.50	6.1974
59	48.25	6.93	3.57	2.30	0.03	4.13	1.63	5.88	0.0	1.14	13.20	7.50	22.50	6.1974
60	46.25	9.90	4.20	7.00	0.03	3.75	10.30	6.12	0.0	2.06	13.20	7.48	19.00	6.1974
61	50.11	4.41	1.63	1.50	0.0	4.13	0.63	2.12	0.0	0.65	6.60	7.65	21.50	6.1974
62	52.25	25.68	11.47	2.20	0.07	2.63	1.45	33.43	0.0	2.68	12.10	7.70	22.00	6.1974
63	53.31	3.64	0.96	1.00	0.0	4.38	0.75	0.75	0.0	0.51	7.70	7.58	22.50	6.1974
64	54.31	5.31	1.07	0.60	0.0	2.67	0.50	3.75	0.0	0.62	17.60	7.12	22.50	6.1674
65	55.41	3.04	0.77	0.70	0.0	3.38	0.50	0.36	0.0	0.40	5.50	7.85	23.00	6.1974
66	56.13	19.26	14.12	19.00	0.14	1.75	6.25	41.06	0.0	3.90	3.30	7.45	23.00	6.1974
67	57.23	25.68	9.97	0.90	0.07	2.25	0.63	31.02	0.0	2.53	7.15	7.65	22.50	6.1974
68	58.13	27.61	17.65	6.80	0.14	1.88	3.00	43.95	0.0	3.43	6.60	7.50	20.00	6.1974
69	59.23	18.91	12.63	17.00	0.10	1.25	5.00	37.72	0.0	3.43	3.30	7.70	24.00	6.1974
70	60.22	5.01	6.59	6.80	0.04	2.38	1.73	13.18	0.0	1.72	4.95	7.90	24.30	6.1974
71	61.22	5.05	6.29	6.60	0.05	2.25	1.63	13.77	0.0	1.71	4.40	7.70	24.50	6.1974
72	62.22	7.83	6.33	5.80	0.04	4.00	1.58	13.60	0.0	1.75	6.60	7.80	24.20	6.1974
73	63.14	14.60	12.58	6.30	0.0	5.75	5.00	23.34	0.0	2.73	14.30	7.50	22.00	6.1974
74	64.14	23.96	14.34	6.00	0.06	3.75	3.25	35.79	0.0	2.08	15.40	7.40	22.00	6.1974
75	65.14	14.72	8.65	3.80	0.06	3.88	2.00	19.70	0.0	2.13	12.10	7.50	23.00	6.1974
76	66.22	8.77	10.02	4.80	0.05	2.63	3.00	17.02	0.0	1.93	8.25	7.80	25.50	6.1974
77	67.22	7.19	10.74	13.60	0.04	4.00	5.00	22.54	0.0	2.91	4.95	7.80	24.50	6.1974
78	67.22	7.65	10.40	17.00	0.0	4.00	5.00	23.15	2.66	2.50	7.70	7.95	0.0	3.1975
79	68.22	4.28	5.91	7.60	0.03	4.00	2.75	12.83	0.0	1.75	4.40	7.75	24.00	6.1974
80	68.22	4.00	6.20	9.40	0.0	4.00	2.75	11.64	0.0	1.88	5.50	7.83	0.0	3.1974
81	69.14	25.68	53.10	56.00	0.07	3.88	19.25	110.07	0.0	9.80	14.30	7.50	21.50	6.1974
82	70.25	17.33	11.34	14.00	0.11	2.25	5.95	29.94	0.0	3.21	4.95	7.80	23.50	6.1974
83	71.22	2.78	1.88	7.00	0.05	1.13	4.50	6.87	0.0	1.29	3.30	7.45	25.50	6.1974
84	71.22	3.40	1.80	9.40	0.0	1.50	4.50	7.16	0.60	1.35	11.00	7.80	0.0	3.1975
85	73.14	25.60	9.00	1.00	0.19	3.13	0.50	30.93	0.0	2.47	9.90	7.49	17.50	6.1974
86	74.14	27.18	16.69	28.00	0.11	2.63	11.30	53.30	0.0	5.61	8.80	7.40	21.00	6.1974
87	75.14	23.65	17.28	17.00	0.06	3.38	2.54	49.85	0.0	4.17	8.80	7.65	21.00	6.1974
88	76.14	31.24	48.36	63.00	0.12	2.13	45.30	83.93	0.0	11.42	7.70	7.30	22.00	6.1974
89	77.14	26.54	28.03	40.00	0.34	3.00	24.25	66.62	0.0	7.76	11.00	7.60	22.00	6.1974
90	78.25	19.05	19.47	24.00	0.10	2.63	15.75	40.24	0.0	5.14	8.80	7.40	0.0	6.1974
91	78.25	14.00	20.00	25.00	0.0	4.00	16.50	38.80	0.0	5.18	0.0	7.60	0.0	3.1975
92	79.14	29.53	53.50	60.00	0.09	3.13	23.75	116.70	0.0	10.60	7.15	7.30	22.50	6.1974
93	80.15	12.27	12.41	14.00	0.07	1.25	11.60	23.84	0.0	3.21	3.85	7.65	0.0	6.1974
94	81.22	5.05	6.51	9.30	0.0	3.75	3.00	14.89	0.0	2.00	5.50	7.93	0.0	6.1974
95	81.12	6.12	6.16	9.70	0.05	4.50	2.88	16.42	0.0	2.06	11.00	7.87	0.0	6.1974
96	81.15	3.60	3.15	5.60	0.05	5.13	0.95	6.81	0.0	1.18	8.25	8.00	0.0	6.1974
97	82.22	12.20	9.12	10.00	0.05	2.00	5.13	23.31	0.0	2.71	4.40	7.44	0.0	6.1974
98	83.12	12.58	8.73	9.70	0.07	2.25	4.13	23.17	0.0	2.57	7.15	7.48	22.50	6.1974
99	84.12	8.26	8.05	9.30	0.05	1.88	3.25	18.33	0.0	2.20	5.50	7.78	0.0	6.1974
100	85.12	8.09	9.63	7.80	0.05	1.88	3.75	18.38	0.0	2.20	3.30	7.35	24.00	6.1974

TABLE ((1)) CONTINUE

SNO.	RFNO.	CA	MG	NA	K	HCO3	CL	SO4	NO3	EC	CO2	PH	TEMP	DATE
****	*****	*****	*****	*****	****	******	*****	******	*****	*****	*****	*****	*****	****
101	85.12	10.60	10.00	9.40	0.0	3.70	3.75	22.15	1.93	2.50	16.50	7.52	0.0	3.1975
102	86.12	33.38	20.97	20.00	0.12	3.00	13.50	48.36	0.0	5.61	14.30	7.59	20.00	6.1974
103	87.12	22.00	21.00	24.00	0.0	2.50	9.50	50.07	0.0	4.40	4.40	7.80	0.0	3.1975
104	87.12	20.54	20.12	22.00	0.70	2.00	7.63	48.74	0.0	4.74	6.05	7.40	21.50	6.1974
105	88.14	29.32	16.70	19.00	0.29	1.88	14.50	40.41	0.0	4.93	7.15	7.50	20.00	6.1974
106	89.12	23.11	4.28	1.10	0.12	1.69	0.50	25.59	0.0	2.09	6.05	7.70	16.00	6.1974
107	90.14	17.76	26.40	65.00	0.24	2.88	37.50	73.02	0.0	10.03	8.80	7.45	21.00	6.1974
108	91.14	36.00	28.00	73.04	0.0	5.50	50.00	68.87	20.16	12.00	6.60	7.65	0.0	3.1975
109	91.14	37.24	35.10	80.00	0.27	1.50	70.00	71.48	0.0	13.46	6.60	7.23	22.00	6.1974
110	92.22	6.10	4.39	22.00	0.27	1.25	16.38	15.58	0.0	3.13	3.30	7.65	23.50	6.1974
111	93.25	5.63	3.96	4.00	0.14	5.00	3.25	5.66	0.0	1.31	6.05	7.70	23.00	6.1974
112	93.25	4.40	4.20	3.55	0.0	4.00	2.58	5.08	0.0	1.09	0.0	7.90	0.0	3.1975
113	94.22	15.84	6.72	5.00	0.05	2.25	1.63	22.45	0.0	2.15	15.50	7.95	22.20	6.1974
114	95.15	18.00	6.06	2.50	0.17	2.88	1.00	21.38	0.0	2.00	11.00	7.70	20.00	6.1974
115	95.15	19.97	9.40	2.35	0.10	3.20	1.00	24.20	0.85	2.20	8.80	7.43	0.0	3.1975
116	96.33	31.33	5.44	1.20	0.10	3.13	0.88	32.56	0.0	2.57	15.40	7.50	0.0	6.1974
117	96.33	32.00	6.25	1.10	0.0	3.00	0.75	32.24	0.30	2.70	11.00	7.50	0.0	3.1975
118	97.33	29.30	7.10	0.90	0.15	2.13	0.55	33.07	0.0	2.57	6.05	7.50	24.00	6.1974
119	97.33	31.60	5.80	0.90	0.0	2.00	0.75	33.46	0.50	2.72	5.50	7.80	0.0	3.1975
120	98.21	5.35	3.85	2.80	0.0	5.75	1.50	3.87	0.0	1.20	18.70	7.85	23.00	6.1974
121	98.15	16.00	7.20	5.30	0.0	2.20	1.75	23.20	0.55	2.35	5.50	8.00	21.30	3.1975
122	99.15	4.70	1.50	12.80	0.03	4.75	12.10	3.76	0.0	2.10	9.90	7.20	20.50	6.1974
123	100.22	5.35	4.71	11.60	0.06	1.56	15.50	4.43	0.0	2.29	7.15	7.57	27.50	6.1974
124	100.22	5.60	6.60	11.70	0.0	1.50	16.50	4.43	0.60	2.45	4.40	7.90	0.0	3.1975
125	101.25	6.00	3.21	17.20	0.0	4.90	17.00	6.05	0.0	2.88	12.10	7.70	26.00	6.1974
126	102.24	10.30	7.92	12.00	0.07	1.06	19.50	9.05	0.0	2.96	4.40	7.80	24.00	6.1974
127	103.14	31.03	30.00	26.50	3.27	4.25	15.50	60.00	0.0	6.83	31.90	7.50	20.50	6.1974
128	103.14	37.00	13.00	10.76	0.0	5.80	8.75	45.50	2.05	4.62	17.60	7.62	0.0	3.1975
129	104.14	16.60	17.66	52.00	0.10	3.94	18.00	58.72	0.0	7.36	12.10	7.03	23.00	6.1974
130	104.14	17.00	15.50	45.00	0.0	11.20	17.67	49.30	0.0	6.46	0.0	8.05	0.0	3.1975
131	105.24	18.73	15.52	41.00	0.10	1.25	21.00	51.30	0.0	6.60	4.40	7.70	25.00	6.1974
132	105.24	15.00	14.00	35.00	0.0	1.70	11.25	43.00	0.0	5.82	3.30	7.37	0.0	3.1975
133	106.14	30.00	19.26	29.00	0.10	1.75	19.00	54.82	0.0	6.50	9.35	7.22	23.00	6.1974
134	106.14	32.00	22.00	28.00	0.0	3.30	20.25	54.30	4.76	6.75	1.10	7.70	0.0	3.1975
135	107.24	24.61	17.12	18.00	0.15	1.63	10.00	42.30	0.0	4.45	5.50	7.45	23.00	6.1974
136	108.14	23.54	26.00	36.00	0.07	2.80	10.60	64.84	0.0	6.30	11.00	7.50	21.50	6.1974
137	109.14	32.10	18.19	22.50	0.09	1.75	12.00	48.90	0.0	5.61	11.00	7.35	0.0	6.1974
138	110.14	30.00	19.80	33.50	0.10	1.63	19.30	55.06	0.0	6.60	4.62	7.67	0.0	6.1974
139	110.14	34.00	24.00	44.00	0.0	2.50	25.00	58.50	12.50	7.58	4.40	7.48	0.0	3.1975
140	111.14	26.80	20.33	20.00	0.10	2.80	7.50	54.50	0.0	5.40	15.40	7.28	21.00	6.1974
141	112.24	26.80	39.60	37.00	0.12	1.75	11.75	79.20	0.0	7.60	10.50	7.70	23.50	6.1974
142	113.14	31.00	11.00	12.26	0.0	2.80	6.25	35.90	1.53	3.80	9.90	7.07	0.0	3.1975
143	113.14	34.24	8.60	7.50	0.11	2.13	6.40	34.90	0.0	3.90	9.90	7.50	18.50	3.1974
144	114.14	26.22	19.80	40.00	0.14	2.13	11.00	68.50	0.0	7.08	9.90	7.20	0.0	6.1974
145	114.14	35.00	49.00	85.00	0.0	1.70	29.40	123.40	32.26	15.00	0.0	7.50	0.0	3.1975
146	115.14	35.31	16.10	31.50	0.29	3.00	23.00	43.00	0.0	6.81	16.50	7.30	20.00	6.1974
147	116.14	30.00	4.92	1.50	0.21	3.00	1.40	30.25	0.0	2.76	14.30	7.35	20.50	6.1974
148	117.14	29.43	21.94	34.00	0.11	2.00	23.00	56.70	0.0	6.68	9.90	7.52	21.50	6.1974
149	118.14	21.00	67.40	460.00	6.00	2.88	450.00	206.70	0.0	48.11	24.20	7.25	22.50	6.1974
150	119.14	35.31	16.10	36.00	0.10	1.38	37.50	42.70	0.0	7.40	8.80	6.90	22.00	6.1974

TABLE ((1)) CONTINUE

SNO.	RFNO.	CA	MG	NA	K	HCO3	CL	SC4	NO3	EC	CO2	PH	TEMP	DATE
****	*****	*****	*****	*****	****	******	*****	******	*****	*****	*****	*****	*****	****
151	120.15	20.54	4.40	4.40	0.10	2.00	3.25	22.50	0.0	2.43	9.90	7.08	20.00	6.1974
152	121.15	30.00	3.42	0.30	0.06	2.13	1.00	29.10	0.0	2.50	11.00	7.40	18.00	6.1974
153	122.15	27.00	1.07	0.0	0.11	2.38	1.00	25.10	0.0	2.14	9.90	7.45	15.50	6.1974
154	123.14	29.43	19.80	30.00	0.09	2.13	29.50	44.80	0.0	6.76	12.10	7.25	19.50	6.1974
155	124.14	27.82	6.42	2.50	0.44	2.25	3.50	30.78	0.0	2.98	16.50	7.10	21.00	6.1974
156	125.14	31.03	19.30	28.00	0.10	2.00	18.00	47.61	0.0	6.57	13.20	7.50	22.00	6.1974
157	126.14	32.10	10.70	18.00	0.52	2.75	12.25	42.26	0.0	4.96	22.00	7.38	22.00	6.1974
158	127.14	32.10	12.84	19.00	0.12	2.13	12.00	44.02	0.0	4.96	13.20	7.25	20.50	6.1974
159	127.14	32.00	9.00	17.00	0.0	1.80	7.50	44.30	1.35	4.40	3.30	7.90	0.0	3.1975
160	128.14	30.00	11.80	11.50	0.27	1.75	7.00	40.10	0.0	4.16	11.00	7.23	21.50	6.1974
161	129.14	32.10	22.47	26.50	0.51	1.75	23.50	52.74	0.0	6.87	9.90	7.35	22.50	6.1974
162	130.14	31.03	23.54	54.00	0.73	1.88	34.00	59.54	0.0	8.85	13.20	7.60	20.50	6.1974
163	131.14	31.03	7.50	11.50	0.64	1.38	6.00	38.56	0.0	3.88	10.50	7.25	26.00	6.1974
164	132.14	30.82	1.71	0.0	0.22	1.88	0.90	29.80	0.0	2.45	11.00	7.25	24.00	6.1974
165	132.14	40.00	72.00	86.50	0.0	9.80	95.00	68.70	0.0	15.60	0.0	7.60	0.0	3.1975
166	133.22	15.00	7.50	30.00	0.10	1.00	31.75	19.63	0.0	5.07	3.30	7.75	23.50	6.1974
167	134.14	30.00	22.50	52.00	0.11	2.04	40.00	57.30	0.0	9.33	16.50	7.30	22.00	6.1974
168	135.24	31.03	17.70	30.00	0.11	0.90	31.75	43.10	0.0	6.45	4.40	7.70	24.50	6.1974
169	136.14	30.00	17.12	28.00	0.09	2.81	16.00	50.75	0.0	5.91	22.00	7.50	21.50	6.1974
170	137.14	32.10	3.75	1.50	0.20	1.81	4.60	30.16	0.0	2.96	9.35	7.50	19.00	6.1974
171	137.14	34.00	5.00	4.50	0.0	1.80	7.50	29.84	0.73	3.20	7.70	6.40	0.0	3.1975
172	138.14	41.73	25.70	30.00	0.07	1.50	38.00	44.80	0.0	7.88	7.70	7.60	19.50	6.1974
173	139.14	27.82	24.61	4.00	0.15	2.50	2.50	49.33	0.0	4.90	5.50	7.80	19.00	6.1974
174	140.12	23.54	12.84	3.00	0.14	1.50	1.65	35.23	0.0	2.92	8.80	7.40	24.00	6.1974
175	140.12	25.00	13.00	5.75	0.0	2.40	2.40	35.25	0.76	2.98	12.10	7.40	0.0	3.1975
176	141.14	25.68	22.50	3.50	0.17	1.63	2.50	40.40	0.0	3.41	4.95	7.51	20.00	6.1974
177	142.24	24.10	12.84	13.50	0.10	1.50	7.00	38.70	0.0	3.90	3.30	7.81	24.00	6.1974
178	143.14	21.40	11.80	13.00	0.10	1.38	5.50	36.40	0.0	3.51	6.05	7.45	23.00	6.1974
179	143.14	25.00	14.00	12.26	0.0	2.54	6.25	36.87	0.66	3.66	2.20	7.60	0.0	3.1975
180	144.12	28.90	15.00	13.00	0.09	1.63	4.25	46.43	0.0	4.01	3.30	7.70	22.30	6.1974
181	145.22	30.00	14.45	19.00	0.10	1.75	11.50	45.01	0.0	4.64	3.85	7.90	23.50	6.1974
182	146.14	32.10	14.45	17.00	0.07	1.63	19.25	39.30	0.0	5.06	2.75	7.80	22.50	6.1974
183	148.14	28.90	9.63	10.50	0.07	1.13	10.00	34.20	0.0	4.61	5.50	7.30	22.00	6.1974
184	148.14	32.10	10.70	18.00	0.11	1.40	12.25	40.53	0.0	4.40	7.70	6.80	0.0	3.1975
185	147.22	33.00	13.00	17.50	0.0	1.80	12.87	42.60	1.14	3.82	3.85	7.70	23.00	6.1974
186	149.14	55.65	14.98	52.00	0.37	3.44	85.00	34.88	0.0	10.96	25.30	7.25	21.00	6.1974
187	150.22	19.80	24.10	40.00	0.10	1.50	16.50	59.21	0.0	6.30	3.30	7.88	22.50	6.1974
188	150.22	29.00	14.00	36.50	0.0	2.54	18.50	58.96	2.84	6.50	0.0	7.75	21.00	3.1975
189	151.14	30.00	25.15	25.00	0.82	2.13	14.25	59.80	0.0	6.19	8.80	7.60	22.00	6.1974
190	152.14	27.82	31.57	24.00	0.74	2.88	11.50	62.24	0.0	6.04	8.80	7.70	20.50	6.1974
191	153.14	30.00	11.77	13.00	0.47	2.38	7.00	41.93	0.0	4.24	12.10	7.50	20.00	6.1974
192	154.22	22.04	8.77	5.30	0.06	2.50	2.50	28.32	0.0	2.74	12.10	7.70	20.00	6.1974
193	155.22	27.82	25.68	44.00	0.10	1.25	29.00	67.00	0.0	7.91	3.90	7.50	24.00	6.1974
194	156.22	23.54	20.33	38.00	0.11	1.44	20.50	53.32	0.0	6.52	4.40	7.80	24.00	6.1974
195	157.14	32.10	14.98	24.00	1.30	1.63	16.00	47.37	0.0	5.88	5.50	7.40	20.50	6.1974
196	157.14	32.00	19.00	25.00	0.0	1.50	15.00	48.60	9.27	6.00	3.30	7.45	0.0	3.1975
197	158.14	36.40	31.00	56.00	0.14	2.13	46.50	63.36	0.0	9.82	8.80	7.60	20.70	6.1974
198	159.14	33.20	7.49	12.50	1.33	1.63	10.00	38.34	0.0	4.45	8.80	7.20	20.70	6.1974
199	160.14	27.82	16.58	21.50	0.12	2.50	6.00	55.17	0.0	5.09	7.70	7.50	21.30	6.1974
200	161.14	33.20	11.77	14.50	0.96	2.88	11.50	42.24	0.0	4.88	11.00	7.80	0.0	6.1974

TABLE ((1)) CONTINUE

SNO.	RFNO.	CA	MG	NA	K	HCO3	CL	SC4	NO3	EC	CO2	PH	TEMP	DATE
201	162.14	31.70	1.28	0.20	0.67	2.50	0.75	29.22	0.0	2.49	13.20	7.52	20.00	6.1974
202	165.33	30.50	9.10	7.50	0.11	2.38	4.25	37.67	0.0	3.59	4.95	7.90	0.0	6.1974
203	166.15	32.30	9.75	1.00	0.10	3.50	1.40	41.14	0.0	3.10	19.80	7.05	25.70	6.1974
204	166.15	30.00	26.00	14.76	0.0	2.60	8.12	58.20	4.35	5.75	17.60	7.80	0.0	3.1975
205	166.15	30.70	14.64	12.50	1.67	2.70	7.00	45.50	0.0	4.43	6.60	7.20	21.00	6.1974
206	167.14	31.80	21.20	30.01	0.09	3.20	22.00	54.60	5.52	6.54	7.20	7.25	22.50	6.1974
207	168.14	30.00	32.00	40.00	0.0	2.20	27.50	61.13	9.30	7.65	0.0	7.80	0.0	3.1975
208	168.14	30.70	16.96	22.00	0.43	2.10	15.50	45.14	0.0	5.28	5.50	7.20	21.00	6.1974
209	169.14	29.70	19.10	23.50	0.09	2.30	17.00	47.90	4.88	5.36	7.70	7.05	21.70	6.1974
210	170.14	28.30	22.30	23.50	0.11	1.79	9.98	58.30	0.0	5.62	5.50	7.30	21.80	6.1974
211	171.14	29.70	16.96	20.00	0.11	1.60	7.25	48.30	0.0	4.90	7.70	7.10	22.50	6.1974
212	172.14	36.00	10.60	17.00	0.18	2.50	12.50	42.43	0.0	4.83	11.00	6.95	21.00	6.1974
213	173.14	68.80	126.98	200.10	0.30	2.30	256.00	82.26	28.23	25.42	22.00	6.65	21.50	6.1974
214	174.14	33.90	5.30	8.00	0.70	2.80	6.00	36.12	0.0	3.52	6.60	7.48	26.00	6.1974
215	175.14	30.70	13.25	13.00	0.56	2.50	5.50	45.66	0.0	4.16	9.90	7.70	20.50	6.1974
216	176.13	30.70	8.50	8.00	1.40	1.70	5.75	38.12	0.0	3.27	6.60	7.45	23.00	6.1974
217	177.14	31.84	36.00	54.00	0.33	2.85	33.00	76.01	0.0	9.95	11.00	7.30	21.50	6.1974
218	178.14	28.60	28.62	38.00	0.22	2.10	22.50	63.02	0.0	7.38	9.40	7.30	22.50	6.1974
219	179.14	28.60	25.40	12.50	0.13	2.10	5.00	52.86	0.0	4.64	5.00	7.40	21.50	6.1974
220	180.14	30.70	22.30	32.00	0.11	3.30	30.00	46.82	0.0	6.86	6.05	7.20	22.00	6.1974
221	181.14	38.70	13.80	25.00	0.18	4.10	25.00	41.35	0.0	6.24	16.50	7.10	21.00	6.1974
222	182.14	30.70	11.66	13.50	0.20	2.60	8.00	42.08	7.48	4.16	7.70	7.25	21.30	6.1974
223	183.14	30.70	10.10	25.50	0.14	2.00	14.50	51.84	5.52	5.62	4.40	7.40	22.00	6.1974
224	184.15	32.86	21.70	30.00	0.24	2.40	34.00	48.26	0.40	6.66	9.40	7.30	20.00	6.1974
225	184.14	38.00	52.00	77.04	0.0	3.20	92.00	74.70	2.14	14.00	5.50	7.20	0.0	3.1975
226	185.15	29.70	58.30	58.03	0.17	4.10	35.00	101.23	0.0	10.48	13.20	7.30	21.00	6.1974
227	186.15	29.70	48.80	44.02	0.52	4.00	30.00	82.66	0.0	9.03	13.20	7.30	0.0	6.1974
228	187.13	35.00	10.60	8.00	1.07	3.50	7.75	37.52	1.34	4.08	17.60	7.20	19.50	6.1974
229	188.13	30.70	16.96	4.50	0.15	8.85	2.50	39.87	0.0	3.61	73.60	7.20	0.0	6.1974
230	189.25	31.80	11.68	3.50	0.15	4.50	4.00	40.83	0.0	3.43	20.90	7.10	23.50	6.1974
231	190.13	28.60	25.44	5.50	0.90	2.80	3.75	49.55	3.71	4.29	4.40	7.50	22.00	6.1974
232	191.25	4.24	1.26	1.00	0.0	4.50	1.25	1.42	0.0	0.64	6.60	7.50	22.50	6.1974
233	11.15	5.20	2.20	1.80	0.0	3.70	1.50	2.36	0.0	0.82	8.80	7.60	0.0	3.1975
234	11.15	5.20	3.60	1.60	0.0	3.30	1.00	3.94	1.57	0.80	5.50	7.85	0.0	3.1975
235	50.11	6.00	2.80	1.55	0.0	4.60	1.50	2.24	2.18	0.97	7.70	7.50	0.0	3.1975
236	50.11	5.00	2.40	1.90	0.0	4.70	1.00	2.73	0.97	0.82	7.70	7.45	0.0	3.1975
237	50.14	30.00	29.00	7.26	0.0	3.50	4.38	51.48	0.0	4.43	14.30	6.95	0.0	3.1975
238	64.14	24.00	14.00	7.25	0.0	4.00	3.75	34.76	1.29	3.20	22.00	7.55	0.0	3.1975
239	81.14	24.00	18.00	17.00	0.0	6.00	8.75	43.13	1.25	4.40	9.90	7.58	0.0	3.1975
240	153.14	29.00	15.00	10.76	0.0	2.30	3.75	40.14	1.90	4.00	5.50	7.55	0.0	3.1975
241	160.14	34.00	54.00	80.00	0.0	4.00	55.00	87.92	16.13	14.00	8.80	7.65	0.0	3.1975
242	164.13	34.00	5.53	4.50	0.0	4.40	5.00	33.75	4.03	3.60	13.20	7.50	0.0	3.1975
243	182.14	29.00	23.00	17.00	0.0	3.90	7.75	49.51	4.19	4.80	6.60	7.90	0.0	3.1975
244	1.23	31.20	4.36	0.74	0.0	2.28	0.76	33.02	0.03	0.0	0.0	7.90	0.0	11.1965
245	1.23	32.00	2.80	3.74	0.0	4.08	0.90	33.60	0.09	0.0	0.0	8.00	0.0	5.1966
246	2.22	26.60	5.67	11.40	0.0	1.56	6.54	35.64	0.34	0.0	0.0	7.70	0.0	7.1965
247	2.22	29.84	4.11	13.14	0.0	1.59	6.88	38.31	0.20	0.0	0.0	8.00	0.0	5.1966
248	5.22	11.30	7.24	35.76	0.0	0.80	31.70	21.77	0.04	0.0	0.0	7.60	0.0	11.1965
249	5.22	11.43	7.32	41.67	0.0	0.84	32.43	27.17	0.24	0.0	0.0	7.80	0.0	5.1966
250	6.22	8.60	4.44	3.00	0.0	3.10	1.18	11.78	0.08	0.0	0.0	7.90	0.0	5.1965

TABLE ((1)) CONTINUE

SNO.	RFNO.	CA	MG	NA	K	HCO3	CL	SC4	NO3	EC	CO2	PH	TEMP	DATE
****	*****	*****	*****	*****	****	******	*****	******	*****	*****	*****	*****	*****	****
251	6.22	9.00	4.28	4.18	0.0	3.28	1.52	12.70	0.05	0.0	0.0	8.00	0.0	4.1966
252	7.25	4.10	2.88	2.44	0.0	3.41	1.52	4.50	0.07	0.0	0.0	8.00	0.0	4.1966
253	7.25	4.04	2.38	1.90	0.0	4.33	0.76	3.89	0.07	0.0	0.0	7.90	0.0	3.1965
254	11.25	10.20	4.44	2.40	0.0	3.85	1.18	12.00	0.13	0.0	0.0	8.00	0.0	3.1965
255	11.25	10.60	4.03	0.44	0.0	3.90	1.52	8.29	0.02	0.0	0.0	8.00	0.0	5.1966
256	12.25	5.10	1.73	1.40	0.0	3.26	0.87	4.00	0.12	0.0	0.0	7.90	0.0	4.1965
257	12.25	4.60	2.22	1.70	0.0	3.11	1.18	4.20	0.16	0.0	0.0	8.00	0.0	4.1966
258	13.21	4.30	1.23	0.35	0.0	2.88	0.37	2.20	0.05	0.0	0.0	7.70	0.0	6.1965
259	13.21	5.40	1.40	1.04	0.0	2.88	0.76	4.20	0.02	0.0	0.0	7.80	0.0	4.1966
260	14.25	3.60	2.06	1.90	0.0	3.47	1.18	2.90	0.09	0.0	0.0	7.80	0.0	5.1965
261	14.25	4.30	1.48	3.40	0.0	4.57	0.99	3.60	0.08	0.0	0.0	8.20	0.0	4.1966
262	15.21	3.04	1.32	0.78	0.0	3.28	0.76	1.10	0.0	0.0	0.0	8.00	0.0	3.1966
263	15.21	3.50	1.07	2.57	0.0	4.20	0.76	1.77	0.03	0.0	0.0	8.20	0.0	5.1966
264	16.25	7.53	4.20	17.50	0.0	4.88	17.26	6.59	0.08	0.0	0.0	8.30	0.0	11.1965
265	16.25	4.80	3.16	20.70	0.0	3.20	16.98	8.40	0.08	0.0	0.0	8.40	0.0	5.1966
266	18.25	13.20	4.93	1.90	0.0	3.92	0.85	14.70	0.0	0.0	0.0	7.80	0.0	3.1965
267	18.25	13.22	3.95	3.40	0.0	4.26	1.30	15.00	0.10	0.0	0.0	8.00	0.0	4.1966
268	19.21	3.40	1.81	1.04	0.0	3.38	0.76	2.10	0.11	0.0	0.0	8.20	0.0	2.1965
269	19.21	3.40	1.40	2.65	0.0	3.47	0.99	3.00	0.06	0.0	0.0	8.30	0.0	4.1966
270	20.25	29.34	6.91	1.26	0.0	2.07	0.99	34.60	0.13	0.0	0.0	7.90	0.0	2.1965
271	20.25	31.34	5.02	6.79	0.0	2.54	1.52	39.06	0.12	0.0	0.0	7.90	0.0	4.1966
272	21.22	29.70	4.93	1.70	0.0	3.95	0.99	31.35	0.07	0.0	0.0	7.90	0.0	4.1965
273	21.22	29.50	3.45	6.22	0.0	2.98	0.99	34.20	0.10	0.0	0.0	7.80	0.0	5.1966
274	28.22	6.68	4.52	11.40	0.0	0.82	5.58	16.16	0.05	0.0	0.0	7.80	0.0	7.1965
275	28.22	7.00	4.20	12.50	0.0	0.93	5.53	17.17	0.02	0.0	0.0	7.60	0.0	4.1966
276	29.22	9.38	7.07	14.66	0.0	0.84	19.12	11.00	0.03	0.0	0.0	0.0	0.0	11.1965
277	93.22	12.50	14.06	10.10	0.0	1.39	11.34	23.86	0.18	0.0	0.0	0.0	0.0	9.1966
278	101.23	24.20	21.00	15.20	0.0	3.95	9.02	47.63	0.53	0.0	0.0	0.0	0.0	4.1966
279	102.23	25.50	13.16	11.96	0.0	2.06	2.62	43.93	0.02	0.0	0.0	0.0	0.0	5.1966
280	109.22	5.54	6.33	9.57	0.0	3.18	3.30	14.55	0.0	0.0	0.0	0.0	0.0	3.1966
281	168.22	3.60	4.50	3.50	0.05	1.61	1.80	8.00	0.46	1.03	0.0	8.00	0.0	3.1974
282	169.22	19.26	16.70	15.90	0.20	1.00	3.00	50.00	0.41	4.00	0.0	7.90	0.0	5.1974
283	170.25	11.70	10.75	2.10	0.04	2.00	1.00	20.00	0.36	1.50	0.0	7.70	0.0	2.1974
284	171.25	3.60	6.96	4.90	0.04	3.20	2.40	8.99	0.27	1.00	0.0	7.90	0.0	1.1974
285	173.22	3.40	4.40	3.70	0.02	2.00	2.70	6.20	0.28	1.10	0.0	8.00	0.0	5.1974
286	174.22	3.40	5.40	4.20	0.02	1.80	4.20	8.00	0.18	1.30	0.0	7.80	0.0	1.1974
287	175.22	7.88	7.90	4.80	0.04	2.20	7.00	11.00	0.11	1.89	0.0	7.60	0.0	5.1974
288	178.22	5.99	6.60	4.40	0.03	1.40	6.20	10.00	0.10	1.63	0.0	7.80	0.0	7.1974
289	179.22	4.40	4.30	3.90	0.02	2.40	3.10	6.81	0.24	1.15	0.0	7.90	0.0	9.1974
290	183.21	2.10	1.50	0.80	0.02	1.60	1.00	1.20	0.26	0.37	0.0	7.90	0.0	8.1974
291	178.23	25.65	16.80	3.40	0.40	1.80	2.00	42.50	0.51	3.11	0.0	7.70	0.0	10.1974
292	2.22	4.70	2.19	11.40	0.0	3.70	8.20	7.64	0.0	1.99	0.0	7.20	0.0	12.1974
293	3.25	14.40	7.15	9.52	0.0	1.80	2.70	24.40	0.0	2.40	0.0	7.90	0.0	11.1974
294	4.25	13.60	6.83	6.96	0.0	1.64	2.11	22.38	0.0	2.42	0.0	7.70	0.0	11.1974
295	5.25	15.20	6.33	5.60	0.0	1.48	1.69	22.38	0.0	2.29	0.0	7.20	0.0	5.1974
296	6.25	21.96	4.36	0.61	0.0	3.28	1.41	22.78	0.0	2.35	0.0	7.20	0.0	2.1974
297	7.22	3.24	23.52	1.39	0.0	2.46	18.90	6.81	0.0	1.05	0.0	7.90	0.0	3.1974
298	12.22	13.60	15.13	20.80	0.0	1.97	37.50	9.20	0.0	4.68	0.0	7.00	0.0	1.1974
299	15.25	43.90	55.76	375.20	0.0	1.31	330.40	108.90	0.0	34.00	0.0	7.10	0.0	5.1974
300	16.22	3.00	62.20	160.30	0.0	2.13	108.12	118.90	0.0	20.80	0.0	7.40	0.0	3.1974

TABLE ((1)) CONTINUE

SNO.	RENO.	CA	MG	NA	K	HCO3	CL	SO4	NO3	EC	CO2	PH	TEMP	DATE
301	17.22	3.00	30.10	54.03	0.0	4.19	33.00	66.83	0.0	9.30	0.0	7.50	0.0	5.1974
302	18.22	37.13	27.06	25.62	0.0	2.13	42.60	45.97	0.0	7.30	0.0	7.50	0.0	6.1965
303	24.23	111.80	119.70	656.80	0.0	4.43	902.00	47.50	0.0	69.61	0.0	8.80	0.0	7.1965
304	25.23	29.90	164.50	13.00	0.0	13.00	153.00	41.22	0.0	6.90	0.0	7.70	0.0	9.1969
305	27.23	29.94	5.18	0.80	0.0	4.59	0.90	31.56	0.28	2.67	0.0	7.80	0.0	4.1965
306	28.25	7.34	26.00	0.87	0.0	1.72	30.00	2.50	0.0	0.70	0.0	7.30	0.0	2.1969
307	29.25	2.35	2.71	1.83	0.05	2.79	0.90	2.46	0.29	0.0	0.0	7.90	0.0	6.1974
308	1.33	6.60	1.55	5.00	0.0	8.44	5.60	0.55	0.0	0.0	90.00	7.00	48.00	6.1974
309	2.33	28.70	5.00	12.84	0.0	11.05	9.20	26.30	0.0	0.0	187.00	7.00	73.00	6.1974
310	3.23	31.52	4.92	2.43	0.0	4.56	1.23	33.50	0.0	0.0	0.0	0.0	23.00	5.1971
311	4.23	33.20	18.45	35.20	0.0	13.47	25.04	35.00	0.0	0.0	0.0	0.0	28.30	5.1971
312	5.23	41.20	16.90	77.91	0.0	14.25	87.60	36.20	0.0	0.0	257.00	7.00	32.00	5.1971
313	6.23	24.50	13.80	24.83	0.0	11.40	19.80	32.33	0.0	0.0	22.00	8.30	26.00	6.1971
314	7.23	32.16	21.00	24.73	0.50	9.60	15.99	39.00	0.0	0.0	33.00	7.90	27.00	8.1971
315	8.23	13.00	14.75	36.97	0.38	14.25	25.70	15.35	0.0	0.0	65.00	7.05	0.0	8.1971
316	9.23	24.50	23.98	65.25	0.44	24.15	44.96	21.80	0.0	0.0	95.00	7.45	28.00	8.1971
317	10.23	30.70	18.84	27.70	0.64	9.90	22.95	39.84	0.0	0.0	17.60	8.10	0.0	3.1971
318	11.23	35.15	12.90	25.81	0.0	10.10	18.80	37.86	0.0	0.0	206.00	6.80	0.0	2.1971
319	12.23	29.00	20.28	30.67	0.38	13.90	23.00	34.24	0.0	0.0	304.00	6.50	25.00	5.1971
320	13.23	25.35	19.61	31.30	0.77	10.11	28.00	32.06	0.0	0.0	20.00	7.80	28.00	6.1971
321	14.23	30.20	19.38	36.97	0.20	10.50	27.40	40.36	0.0	0.0	16.00	7.40	0.0	6.1971
322	15.23	40.00	14.08	35.67	0.77	14.14	28.00	39.93	0.0	0.0	425.00	6.40	30.50	7.1971
323	16.23	33.10	14.36	29.36	0.13	14.20	16.60	40.60	0.0	0.0	50.00	7.45	27.00	8.1971
324	17.33	25.25	13.44	51.11	4.48	9.45	53.40	27.25	0.0	0.0	140.00	6.40	25.50	6.1974
325	18.33	7.90	5.60	8.70	0.38	10.25	5.84	3.13	0.0	0.0	108.00	6.65	26.00	6.1974
326	19.51	2.04	1.64	0.46	0.0	2.84	0.56	1.33	0.0	0.48	0.0	7.80	25.00	7.1971

TABLE ((2)) CATICNS IN PPM

SNO.	CA	%CA	MG	%MG	NA	%NA	K	%K	TOTAL CATION	TSS
****	****	*****	****	*****	****	*****	***	****	**********	*********
1	388.78	24.21	96.06	9.86	1196.00	64.89	32.45	1.04	80.13	5020.29
2	183.17	58.44	68.95	36.25	18.40	5.12	1.17	0.19	15.64	1139.92
3	605.01	73.28	102.75	20.51	57.50	6.07	2.35	0.15	41.20	2660.66
4	420.84	40.74	163.43	26.07	391.00	32.98	4.30	0.21	51.55	3285.68
5	641.28	68.09	145.92	25.53	69.00	6.38	0.0	0.0	47.00	2984.32
6	602.00	69.73	116.25	22.19	78.20	7.89	3.13	0.19	43.08	2832.27
7	597.59	78.62	86.82	18.82	20.70	2.37	2.74	0.18	37.93	2504.96
8	621.24	77.79	94.85	19.57	24.15	2.63	0.0	0.0	39.85	2710.97
9	606.01	83.81	61.29	13.97	17.25	2.08	1.95	0.14	36.08	2416.88
10	395.59	74.83	63.23	19.71	32.20	5.31	1.56	0.15	26.38	1795.91
11	277.75	69.89	47.91	19.87	46.00	10.09	1.17	0.15	19.83	1374.02
12	258.92	66.32	57.52	24.28	41.40	9.24	1.17	0.15	19.48	1350.57
13	542.88	74.94	84.27	19.17	48.30	5.81	1.17	0.08	36.15	2471.02
14	96.79	56.49	25.54	24.56	36.80	18.71	0.78	0.23	8.55	555.89
15	210.42	59.15	53.63	24.85	64.40	15.77	1.56	0.23	17.75	1204.20
16	202.00	59.19	52.41	25.31	59.80	15.27	1.56	0.23	17.03	1188.70
17	96.79	58.47	23.10	23.00	34.50	18.16	1.17	0.36	8.26	564.89
18	260.92	65.49	56.18	23.24	50.60	11.07	1.56	0.20	19.88	1336.57
19	96.79	69.90	12.77	15.20	23.00	14.47	1.17	0.43	6.91	482.13
20	88.18	60.69	21.89	24.83	24.15	14.48	0.0	0.0	7.25	480.06
21	88.38	63.91	17.88	21.30	23.00	14.49	0.78	0.29	6.90	482.44
22	75.75	76.52	7.66	12.75	11.50	10.12	1.17	0.61	4.94	380.19
23	52.10	66.67	9.73	20.51	11.50	12.82	0.0	0.0	3.90	323.19
24	74.15	71.57	10.21	16.25	13.80	11.61	1.17	0.58	5.17	403.77
25	92.58	58.11	21.89	22.64	34.50	18.87	1.17	0.38	7.95	541.83
26	50.50	30.52	25.54	25.77	80.50	42.94	1.17	0.37	8.15	569.66
27	589.18	56.50	201.86	31.90	138.00	11.53	1.56	0.08	52.04	3316.73
28	589.18	59.19	178.75	29.60	126.50	11.07	2.74	0.14	49.67	3153.49
29	580.96	55.49	206.72	32.54	143.75	11.96	0.0	0.0	52.24	3390.86
30	269.34	48.96	86.82	26.01	156.40	24.77	2.74	0.26	27.45	1823.20
31	661.32	43.52	352.64	38.25	316.25	18.14	2.74	0.09	75.82	4445.32
32	143.09	35.33	51.07	20.78	202.40	43.54	2.74	0.35	20.21	1350.93
33	505.01	22.15	587.33	42.46	920.00	35.16	10.17	0.23	113.76	7167.36
34	458.92	60.92	84.27	18.44	177.10	20.48	2.35	0.16	37.59	2584 93
35	73.75	21.06	60.07	28.28	202.40	50.37	1.95	0.29	17.47	1182.61
36	153.71	28.61	93.27	28.61	262.20	42.52	2.74	0.26	26.81	1624.30
37	189.98	35.79	84.27	26.16	230.00	37.75	3.13	0.30	26.49	1602.95
38	400.80	30.40	191.52	23.94	690.00	45.60	1.56	0.06	65.79	4102.42
39	547.09	34.18	370.88	38.19	506.00	27.54	2.74	0.09	79.87	5162.37
40	521.04	27.80	486.40	42.78	632.73	29.42	0.0	0.0	93.51	5999.48
41	505.01	29.28	313.12	29.92	805.00	40.67	4.30	0.13	86.06	5472.97
42	732.46	52.38	168.54	19.86	425.50	26.51	34.02	1.25	69.78	4374.95
43	118.24	42.11	26.87	15.77	119.60	37.12	27.37	5.00	14.01	1030.40
44	641.88	67.79	134.12	23.34	92.00	8.47	7.43	0.40	47.25	2466.68
45	661.32	64.08	182.40	29.13	80.50	6.80	0.0	0.0	51.50	3336.63
46	601.20	48.51	300.35	39.94	161.00	11.32	5.47	0.23	61.84	4069.26
47	589.18	48.28	229.82	31.03	287.50	20.53	3.91	0.16	60.90	3843.36
48	589.18	58.02	194.07	31.50	119.60	10.26	4.30	0.22	50.67	3167.13
49	597.19	77.30	96.06	20.49	18.40	2.08	1.95	0.13	38.55	2500.96
50	597.19	77.62	96.06	20.58	13.80	1.56	3.52	0.23	38.39	2719.87

TABLE ((2)) CONTINUE

SNO.	CA	%CA	MG	%MG	NA	%NA	K	%K	TOTAL CATION	TSS
51	601.20	44.61	304.00	37.17	281.75	18.22	0.0	0.0	67.25	4260.49
52	547.09	32.28	389.48	37.87	575.00	29.56	9.38	0.28	84.57	5307.97
53	568.13	43.03	319.20	39.84	253.00	16.69	11.34	0.44	65.59	3821.40
54	547.09	47.79	243.20	35.01	224.25	17.07	3.13	0.14	57.13	3535.24
55	589.18	34.99	383.04	37.49	529.00	27.37	5.08	0.15	84.03	5105.35
56	370.74	56.30	125.25	31.35	92.00	12.17	2.35	0.18	32.86	2096.55
57	408.01	50.76	170.24	34.90	132.25	14.34	0.0	0.0	40.11	2602.07
58	145.29	57.18	44.75	29.02	39.10	13.41	1.95	0.39	12.68	819.85
59	138.68	54.01	43.41	27.83	52.90	17.93	1.17	0.23	12.83	828.55
60	198.40	46.85	51.07	19.88	161.00	33.13	1.17	0.14	21.13	1299.61
61	88.38	58.49	19.82	21.62	34.50	19.89	0.0	0.0	7.54	518.83
62	514.63	65.14	139.48	29.10	50.60	5.58	2.74	0.18	39.42	2524.95
63	72.95	65.00	11.67	17.14	23.00	17.86	0.0	0.0	5.60	437.46
64	106.41	76.07	13.01	15.33	13.80	8.60	0.0	0.0	6.98	493.96
65	60.92	67.41	9.36	17.07	16.10	15.52	0.0	0.0	4.51	327.62
66	385.97	36.67	171.70	26.88	437.00	36.18	5.47	0.27	52.52	3300.65
67	514.63	70.13	121.24	27.23	20.70	2.46	2.74	0.19	36.62	2308.80
68	553.30	52.89	214.62	33.81	156.40	13.03	5.47	0.27	52.20	3261.80
69	378.96	38.88	153.58	25.97	391.00	34.95	3.91	0.21	48.64	2952.70
70	100.40	27.17	80.13	35.74	156.40	36.88	1.56	0.22	18.44	1178.08
71	101.20	28.07	76.49	34.96	151.80	36.69	1.95	0.28	17.99	1187.89
72	156.91	39.15	76.97	31.65	133.40	29.00	1.56	0.20	20.00	1322.12
73	292.58	43.61	152.97	37.57	144.90	18.82	0.0	0.0	33.48	2239.58
74	480.16	54.01	174.37	32.33	138.00	13.53	2.35	0.14	44.36	2857.90
75	294.99	54.06	105.18	31.77	87.40	13.96	2.35	0.22	27.23	1743.75
76	175.75	37.10	121.84	42.39	110.40	20.30	1.95	0.21	23.64	1494.25
77	144.09	22.77	130.60	34.02	312.80	43.08	1.56	0.13	31.57	2092.99
78	153.31	21.83	126.46	29.67	391.00	48.50	0.0	0.0	35.05	2368.95
79	85.77	24.02	71.87	33.16	174.80	42.65	1.17	0.17	17.82	1291.39
80	80.16	20.41	75.39	31.63	216.20	47.96	0.0	0.0	19.60	1272.38
81	514.63	19.04	645.70	39.38	1288.00	41.53	2.74	0.05	134.85	8657.04
82	347.29	40.51	137.89	26.51	322.00	32.73	4.30	0.26	42.78	2597.76
83	55.71	23.74	22.86	16.05	161.00	59.78	1.95	0.43	11.71	800.00
84	68.14	23.29	21.89	12.33	216.20	64.38	0.0	0.0	14.60	938.41
85	513.02	71.53	109.44	25.15	23.00	2.79	7.43	0.53	35.79	2347.15
86	544.69	37.76	202.95	23.19	644.00	38.90	4.30	0.15	71.98	4517.09
87	473.95	40.78	210.12	29.80	391.00	29.32	2.35	0.10	57.99	3767.99
88	626.05	21.89	588.06	33.88	1449.00	44.14	4.69	0.08	142.72	8435.24
89	531.86	27.96	340.84	29.53	920.00	42.15	13.29	0.36	94.91	6048.69
90	381.76	30.42	236.76	31.09	552.00	38.33	3.91	0.16	62.62	3826.10
91	280.56	23.73	243.20	33.90	575.00	42.37	0.0	0.0	59.00	3791.45
92	591.78	20.63	650.56	37.38	1380.00	41.92	3.52	0.06	143.12	9264.09
93	265.93	33.38	150.91	31.22	322.00	35.22	2.74	0.18	39.75	2374.21
94	101.20	24.21	79.16	31.21	213.90	44.58	0.0	0.0	20.86	1444.60
95	122.64	27.78	74.91	27.96	223.10	44.03	1.95	0.23	22.03	1587.93
96	72.14	29.03	38.30	25.40	128.80	45.16	1.95	0.40	12.40	914.96
97	244.49	38.89	110.90	29.07	230.00	31.88	1.95	0.16	31.37	2010.85
98	252.10	40.48	106.16	28.09	223.10	31.21	2.74	0.23	31.08	1980.67
99	165.53	32.19	97.89	31.37	213.90	36.24	1.95	0.19	25.66	1589.61
100	162.12	31.64	117.10	37.66	179.40	30.50	1.95	0.20	25.57	1591.04

TABLE ((2)) CONTINUE

SNO.	CA	%CA	MG	%MG	NA	%NA	K	%K	TOTAL CATION	TSS
****	****	*****	****	*****	****	*****	***	****	**********	*********
101	212.42	35.33	121.60	22.33	216.20	31.33	0.0	0.0	30.00	2092.48
102	668.93	44.82	255.00	28.16	460.00	26.86	4.69	0.16	74.47	4373.09
103	440.88	32.64	255.36	31.34	552.00	35.82	0.0	0.0	67.00	4142.49
104	411.62	32.42	244.66	31.76	506.00	34.72	27.37	1.10	63.36	3923.21
105	587.57	44.89	203.07	25.57	437.00	29.09	11.34	0.44	65.31	3808.74
106	463.12	80.78	52.04	14.96	25.30	3.84	4.69	0.42	28.61	1914.30
107	355.91	16.23	321.02	24.13	1495.00	59.41	9.38	0.22	109.40	7193.92
108	721.44	26.27	340.48	20.43	1679.92	53.30	0.0	0.0	137.04	9408.33
109	746.29	24.40	426.82	23.00	1840.00	52.42	10.56	0.18	152.61	9030.55
110	122.24	18.62	53.38	13.40	506.00	67.16	10.56	0.82	32.76	2097.59
111	112.83	41.01	46.15	28.84	92.00	29.13	5.47	1.02	13.73	950.60
112	88.18	36.21	51.07	34.57	81.65	29.22	0.0	0.0	12.15	800.42
113	317.43	57.37	81.72	24.34	115.00	18.11	1.95	0.18	27.61	1789.45
114	360.72	67.34	73.69	22.67	57.50	9.35	6.65	0.64	26.73	1736.61
115	400.20	62.76	114.30	29.54	54.05	7.39	3.91	0.31	31.82	2018.19
116	627.85	82.30	66.15	14.29	27.60	3.15	3.91	0.26	38.07	2511.54
117	641.28	81.32	76.00	15.88	25.30	2.80	0.0	0.0	39.35	2519.29
118	587.17	78.24	86.34	18.96	20.70	2.40	5.86	0.40	37.45	2437.88
119	633.26	82.51	70.53	15.14	20.70	2.35	0.0	0.0	38.30	2511.19
120	107.21	44.58	46.82	32.08	64.40	23.33	0.0	0.0	12.00	808.30
121	320.64	56.14	87.55	25.26	121.90	18.60	0.0	0.0	28.50	1874.77
122	94.19	24.70	18.24	7.88	294.40	67.26	1.17	0.16	19.03	1307.46
123	107.21	24.63	57.27	21.69	266.80	53.41	2.35	0.28	21.72	1291.21
124	112.22	23.43	80.26	27.62	269.10	48.95	0.0	0.0	23.90	1388.16
125	120.24	22.72	39.03	12.15	395.60	65.13	0.0	0.0	26.41	1747.22
126	206.41	34.00	96.31	26.15	276.00	39.62	2.74	0.23	30.29	1772.27
127	621.84	34.17	364.80	33.04	609.50	29.19	127.86	3.60	90.80	5414.72
128	741.48	60.90	158.08	21.40	247.48	17.71	0.0	0.0	60.76	4123.66
129	332.66	19.22	214.75	20.45	1196.00	60.21	3.91	0.12	86.36	5446.30
130	340.68	21.94	188.48	20.00	1035.00	58.06	0.0	0.0	77.50	5241.93
131	375.35	24.86	188.72	20.60	943.00	54.41	3.91	0.13	75.35	4795.84
132	300.60	23.44	170.24	21.88	805.00	54.69	0.0	0.0	64.00	3843.77
133	601.20	38.28	234.20	24.58	667.00	37.01	3.91	0.13	78.36	4919.82
134	641.28	39.02	267.52	26.83	644.00	34.15	0.0	0.0	82.00	5375.39
135	493.18	41.10	208.18	28.59	414.00	30.06	5.86	0.25	59.88	3606.94
136	471.74	27.50	316.16	30.37	828.00	42.05	2.74	0.08	85.61	5279.61
137	643.28	44.04	221.19	24.96	517.50	30.87	3.52	0.12	72.88	4266.45
138	601.20	35.97	240.77	23.74	770.50	40.17	3.91	0.12	83.40	5044.73
139	681.36	33.33	291.84	23.53	1012.00	43.14	0.0	0.0	102.00	6609.10
140	537.07	39.86	247.21	30.24	460.00	29.75	3.91	0.15	67.23	4302.61
141	537.07	25.89	481.54	38.25	851.00	35.74	4.69	0.12	103.52	6201.69
142	621.24	57.13	133.76	20.27	281.98	22.59	0.0	0.0	54.26	3248.58
143	686.17	67.87	104.58	17.05	172.50	14.87	4.30	0.22	50.45	3000.69
144	525.45	30.43	240.77	22.98	920.00	46.43	5.47	0.16	86.16	5501.75
145	701.40	20.71	595.84	28.99	1955.00	50.30	0.0	0.0	169.00	12325.82
146	707.61	42.44	195.78	19.35	724.50	37.86	11.34	0.35	83.20	4703.13
147	601.20	81.02	59.83	13.29	43.70	5.13	8.21	0.57	37.03	2398.52
148	589.78	34.43	266.79	25.67	782.00	39.78	4.30	0.13	85.48	5303.77
149	420.84	3.79	819.58	12.16	10580.00	82.97	234.60	1.08	554.40	38115.52
150	707.61	40.35	195.78	18.40	828.00	41.14	3.91	0.11	87.51	5200.12

TABLE ((2)) CONTINUE

SNO.	CA	%CA	MG	%MG	NA	%NA	K	%K	TOTAL CATION	TSS
****	****	*****	****	*****	****	*****	***	****	**********	*******
151	411.62	69.77	53.50	14.95	101.20	14.95	3.91	0.34	29.44	1888.17
152	601.20	88.81	41.59	10.12	6.90	0.89	2.35	0.18	33.78	2215.12
153	541.08	95.81	13.01	3.80	0.0	0.0	4.30	0.39	28.18	1944.61
154	589.78	37.10	240.77	24.96	690.00	37.82	3.52	0.11	79.32	4851.82
155	557.51	74.83	78.07	17.27	57.50	6.72	17.20	1.18	37.18	2450.03
156	621.84	39.56	234.69	24.61	644.00	35.70	3.91	0.13	78.43	4551.45
157	643.28	52.35	130.11	17.45	414.00	29.35	20.33	0.85	61.32	3839.64
158	643.28	50.11	156.12	20.04	437.00	29.66	4.69	0.19	64.06	3910.86
159	641.28	55.17	109.44	15.52	391.00	29.31	0.0	0.0	58.00	3728.93
160	601.20	56.00	143.49	22.03	264.50	21.47	10.56	0.50	53.57	3300.73
161	643.28	39.35	273.23	27.54	609.50	32.48	19.94	0.63	81.58	5019.14
162	621.84	28.39	286.25	21.54	1242.00	49.41	28.54	0.67	109.30	6358.67
163	621.84	61.24	91.20	14.80	264.50	22.70	25.02	1.26	50.67	3151.55
164	617.63	94.11	20.79	5.22	0.0	0.0	8.60	0.67	32.75	2224.93
165	801.60	20.15	875.52	36.27	1989.50	42.58	0.0	0.0	198.50	10932.87
166	300.60	28.52	91.20	14.26	690.00	57.03	3.91	0.19	52.60	3215.40
167	601.20	28.68	273.60	21.51	1196.00	49.71	4.30	0.11	104.61	6370.07
168	621.84	39.36	215.23	22.45	690.00	38.05	4.30	0.14	78.84	4782.23
169	601.20	39.89	208.18	22.76	644.00	37.23	3.52	0.12	75.21	4633.21
170	643.28	85.49	45.60	9.99	34.50	3.99	7.82	0.53	37.55	2453.33
171	681.36	78.16	60.80	11.49	103.50	10.34	0.0	0.0	43.50	2699.91
172	836.27	42.80	312.51	26.36	690.00	30.77	2.74	0.07	97.50	5432.25
173	557.51	49.17	299.26	43.50	92.00	7.07	5.86	0.27	56.58	3565.13
174	471.74	59.56	156.13	32.49	69.00	7.59	5.47	0.35	39.52	2544.47
175	501.00	57.14	158.08	29.71	132.25	13.14	0.0	0.0	43.75	2763.04
176	514.63	49.53	273.60	43.39	80.50	6.75	6.65	0.33	51.85	3003.88
177	482.96	47.68	156.13	25.41	310.50	26.71	3.91	0.20	50.54	3152.00
178	428.86	46.22	143.49	25.49	299.00	28.08	3.91	0.22	46.30	2902.77
179	501.00	48.77	170.24	27.31	281.58	23.92	0.0	0.0	51.26	3141.60
180	579.16	50.71	182.40	26.32	299.00	22.81	3.52	0.16	56.99	3544.26
181	601.20	47.21	175.71	22.74	437.00	29.90	3.91	0.16	63.55	3894.21
182	643.28	50.46	175.71	22.71	391.00	26.72	2.74	0.11	63.62	3882.36
183	579.16	58.86	117.10	19.61	241.50	21.38	2.74	0.14	49.10	3006.66
184	643.28	52.70	130.11	17.57	414.00	29.55	4.30	0.18	60.91	3658.15
185	661.32	51.97	158.08	20.47	402.50	27.56	0.0	0.0	63.50	3904.86
186	1115.23	45.24	182.16	12.18	1196.00	42.28	14.47	0.30	123.00	7407.11
187	396.79	23.57	293.06	28.69	920.00	47.62	3.91	0.12	84.00	5134.21
188	581.16	36.48	170.24	17.61	839.50	45.91	0.0	0.0	79.50	5409.83
189	601.20	37.05	305.82	31.06	575.00	30.88	32.06	1.01	80.97	5021.53
190	557.51	33.07	383.89	37.53	552.00	28.53	28.93	0.88	84.13	5095.22
191	601.20	54.21	143.12	21.31	299.00	23.53	18.38	0.85	55.24	3469.02
192	441.68	60.53	106.64	24.25	121.90	14.65	2.35	0.17	36.17	2273.95
193	557.51	28.50	312.27	26.31	1012.00	45.08	3.91	0.10	97.60	6208.30
194	471.74	28.71	247.21	24.80	874.00	46.35	4.30	0.13	81.98	4973.00
195	643.28	44.35	182.16	20.70	552.00	33.16	50.83	1.80	72.38	4370.25
196	641.28	42.11	231.04	25.00	575.00	32.89	0.0	0.0	76.00	4979.82
197	729.46	29.46	376.56	25.09	1288.00	45.33	5.47	0.11	123.54	7221.91
198	665.33	60.90	91.08	13.74	287.50	22.93	52.00	2.44	54.52	3391.42
199	557.51	42.14	201.61	25.11	494.50	32.57	4.69	0.18	66.02	4273.41
200	665.33	54.94	143.12	19.48	333.50	23.99	37.54	1.59	60.43	3791.77

TABLE ((21) CONTINUE

SNO.	CA	%CA	MG	%MG	NA	%NA	K	%K	TOTAL CATION	TSS
****	****	*****	****	*****	****	*****	***	****	**********	*********
201	635.27	93.65	15.56	3.78	4.60	0.59	26.20	1.98	33.85	2264.18
202	611.22	64.60	110.66	19.28	172.50	15.89	4.30	0.23	47.21	3003.87
203	647.29	74.86	118.56	22.60	23.00	2.32	3.91	0.23	43.15	3031.89
204	601.20	42.40	316.16	36.74	339.48	20.86	0.0	0.0	70.76	4768.49
205	615.23	51.59	178.02	24.60	287.50	21.00	65.30	2.81	59.51	3744.36
206	637.27	38.27	257.79	25.51	690.23	36.11	3.52	0.11	83.10	5528.89
207	601.20	29.41	389.12	31.37	920.00	39.22	0.0	0.0	102.00	6532.45
208	615.23	43.80	206.23	24.20	506.00	31.39	16.81	0.61	70.09	4190.10
209	595.19	41.03	232.26	26.38	540.50	32.46	3.52	0.12	72.39	4717.85
210	567.13	38.14	271.17	30.05	540.50	31.67	4.30	0.15	74.21	4646.34
211	595.19	44.48	206.23	25.40	460.00	29.95	4.30	0.16	66.77	3940.27
212	721.44	56.44	128.90	16.62	391.00	26.65	7.04	0.28	63.78	3882.06
213	1378.75	17.37	1544.08	32.05	4602.30	50.51	11.73	0.08	396.18	22456.41
214	679.36	70.77	64.45	11.06	184.00	16.70	27.37	1.46	47.90	3073.60
215	615.23	53.38	161.12	23.04	299.00	22.60	21.90	0.97	57.51	3637.85
216	615.23	63.17	103.36	17.49	184.00	16.46	54.74	2.88	48.60	3095.84
217	638.07	26.06	437.76	29.47	1242.00	44.20	12.90	0.27	122.17	7325.55
218	573.14	29.97	348.02	29.99	874.00	39.82	8.60	0.23	95.44	5756.58
219	573.14	42.92	308.86	38.12	287.50	18.76	5.08	0.20	66.63	4018.88
220	615.23	36.07	271.17	26.20	736.00	37.60	4.30	0.13	85.11	5140.59
221	775.55	49.82	167.81	17.77	575.00	32.18	7.04	0.23	77.68	4648.07
222	615.23	54.76	141.79	20.80	310.50	24.08	7.82	0.36	56.06	4002.57
223	615.23	46.21	122.82	15.20	586.50	38.38	5.47	0.21	66.44	4798.38
224	658.51	38.75	263.87	25.59	690.00	35.38	9.38	0.28	84.80	5316.56
225	761.52	22.75	632.32	31.13	1771.52	46.12	0.0	0.0	167.04	10343.85
226	595.19	20.31	708.93	35.88	1334.69	39.69	6.65	0.12	146.20	8998,76
227	595.19	24.14	593.41	35.66	1012.46	35.78	20.33	0.42	123.04	7508,99
228	701.40	64.02	128.90	19.39	184.00	14.63	41.84	1.96	54.67	3429.66
229	615.23	58.69	206.23	32.42	103.50	8.60	5.86	0.29	52.31	3474.37
230	637.27	67.47	142.03	24.78	80.50	7.43	5.86	0.32	47.13	3243.11
231	573.14	47.32	309.35	42.09	126.50	9.10	35.19	1.49	60.44	3957.93
232	84.97	65.23	15.32	19.38	23.00	15.38	0.0	0.0	6.50	510.36
233	104.21	56.52	26.75	23.91	41.40	19.57	0.0	0.0	9.20	564,64
234	104.21	50.00	43.78	34.62	36.80	15.38	0.0	0.0	10.40	708,17
235	120.24	57.97	34.05	27.05	35.65	14.98	0.0	0.0	10.35	766.54
236	100.20	53.76	29.18	25.81	43.70	20.43	0.0	0.0	9.30	686 56
237	601.20	45.28	352.64	43.77	166.98	10.96	0.0	0.0	66.26	3962,25
238	480.96	53.04	170.24	30.94	166.75	16.02	0.0	0.0	45.25	2944,48
239	480.96	40.68	218.88	30.51	391.00	28.81	0.0	0.0	59.00	3916,22
240	581.16	52.96	182.40	27.39	247.48	19.65	0.0	0.0	54.76	3330.08
241	681.36	20.24	656.64	32.14	1840.00	47.62	0.0	0.0	168.00	10595.35
242	681.36	77.22	67.24	12.56	103.50	10.22	0.0	0.0	44.03	3168.76
243	581.16	42.03	279.68	33.33	391.00	24.64	0.0	0.0	69.00	4402.38
244	625.25	85.95	53.02	12.01	17.02	2.04	0.0	0.0	36.30	2449.15
245	641.28	83.03	34.05	7.27	86.02	9.70	0.0	0.0	38.54	2661.57
246	533.06	60.91	68.95	12.98	262.20	26.10	0.0	0.0	43.67	2924.17
247	597.99	63.37	49.98	8.73	302.22	27.90	0.0	0.0	47.09	3143.59
248	226.45	20.81	88.04	13.33	822.48	65.86	0.0	0.0	54.30	3357.95
249	229.06	18.92	89.01	12.12	958.41	68.97	0.0	0.0	60.42	3797.55
250	172.34	53.62	53.99	27.68	69.00	18.70	0.0	0.0	16.04	1097.06

TABLE ((2)) CONTINUE

SNO.	CA	%CA	MG	%MG	NA	%NA	K	%K	TOTAL CATION	TSS
251	180.36	51.55	52.04	24.51	96.14	23.94	0.0	0.0	17.46	1195.64
252	82.16	43.52	35.02	30.57	56.12	25.90	0.0	0.0	9.42	655.72
253	80.96	48.56	28.94	28.61	43.70	22.84	0.0	0.0	8.32	635.90
254	204.41	59.86	53.99	26.06	55.20	14.08	0.0	0.0	17.04	1174.75
255	212.42	70.34	49.00	26.74	10.12	2.92	0.0	0.0	15.07	962.79
256	102.20	61.97	21.04	21.02	32.20	17.01	0.0	0.0	8.23	584.74
257	92.18	53.99	27.00	26.06	39.10	19.95	0.0	0.0	8.52	601.51
258	86.17	73.13	14.96	20.92	8.05	5.95	0.0	0.0	5.88	411.58
259	108.22	68.88	17.02	17.86	23.92	13.27	0.0	0.0	7.84	554.78
260	72.14	47.62	25.05	27.25	43.70	25.13	0.0	0.0	7.56	539.31
261	86.17	46.84	18.00	16.12	78.20	37.04	0.0	0.0	9.18	674.16
262	60.92	59.14	16.05	25.68	17.94	15.18	0.0	0.0	5.14	374.81
263	70.14	49.02	13.01	14.99	59.11	35.99	0.0	0.0	7.14	512.33
264	150.90	25.76	51.07	14.37	402.50	59.87	0.0	0.0	29.23	1854.93
265	96.19	16.75	38.43	11.03	476.10	72.23	0.0	0.0	28.66	1816.47
266	264.53	65.90	59.95	24.61	43.70	9.49	0.0	0.0	20.03	1343.52
267	264.93	64.27	48.03	19.20	78.20	16.53	0.0	0.0	20.57	1423.81
268	68.14	54.40	22.01	28.96	23.92	16.64	0.0	0.0	6.25	454.91
269	68.14	45.64	17.02	18.79	60.95	35.57	0.0	0.0	7.45	540.73
270	587.97	78.22	84.03	18.42	28.98	3.36	0.0	0.0	37.51	2532.27
271	628.05	72.63	61.04	11.63	156.17	15.74	0.0	0.0	43.15	2937.62
272	595.19	81.75	59.95	13.57	39.10	4.68	0.0	0.0	36.33	2480.41
273	591.18	75.31	41.95	8.81	143.06	15.88	0.0	0.0	39.17	2641.93
274	133.87	29.56	54.56	20.00	262.20	50.44	0.0	0.0	22.60	1478.19
275	140.28	29.54	51.07	17.72	287.50	52.74	0.0	0.0	23.70	1557.60
276	187.98	30.15	85.97	22.73	337.18	47.12	0.0	0.0	31.11	1870.56
277	250.50	34.10	170.97	38.35	232.30	27.55	0.0	0.0	36.66	2297.85
278	484.97	40.07	255.36	34.77	349.60	25.17	0.0	0.0	60.40	3971.30
279	511.02	50.38	160.03	26.00	275.08	23.63	0.0	0.0	50.62	3275.91
280	111.02	25.84	76.97	29.52	220.11	44.64	0.0	0.0	21.44	1437.18
281	72.14	29.88	54.72	37.34	89.70	32.37	1.95	0.41	12.05	793.34
282	385.97	37.00	203.07	32.08	365.70	30.54	7.82	0.38	52.06	3556.88
283	234.47	47.58	130.72	43.72	48.30	8.54	1.56	0.16	24.59	1555.45
284	72.14	23.23	84.63	44.90	112.70	31.61	1.56	0.26	15.50	599.91
285	68.14	29.51	53.50	38.19	85.10	32.12	0.78	0.17	11.52	740.43
286	68.14	26.11	65.66	41.47	96.60	32.26	0.78	0.15	13.02	885.33
287	157.92	38.22	96.06	38.31	110.40	23.28	1.56	0.19	20.62	1283.54
288	120.04	35.19	80.26	38.78	101.20	25.85	1.17	0.18	17.02	1094.43
289	80.18	34.97	52.29	34.07	89.70	30.90	0.78	0.16	12.62	829.26
290	42.08	47.51	18.24	33.94	18.40	18.10	0.78	0.45	4.42	286.34
291	514.03	55.46	204.29	36.32	78.20	7.35	15.64	0.86	46.25	3065.79
292	94.19	25.70	26.63	11.97	262.20	62.33	0.0	0.0	18.29	1266.48
293	289.53	46.35	86.94	23.01	218.96	30.64	0.0	0.0	31.07	1971.97
294	272.54	49.65	83.05	24.94	160.08	25.41	0.0	0.0	27.39	1765.46
295	304.61	56.03	76.97	23.33	128.60	20.64	0.0	0.0	27.13	1735.51
296	440.08	81.54	53.02	16.19	14.03	2.27	0.0	0.0	26.93	1851.36
297	64.93	11.51	286.00	83.55	31.97	4.94	0.0	0.0	28.15	1530.26
298	272.54	27.46	183.98	30.55	478.40	41.99	0.0	0.0	49.53	2826.74
299	879.76	9.24	678.04	11.74	8629.60	79.01	0.0	0.0	474.86	27213.76
300	60.12	1.33	756.35	27.58	3686.90	71.09	0.0	0.0	225.50	14178.02

TABLE ((2)) CONTINUE

SNO.	CA	%CA	MG	%MG	NA	%NA	K	%K	TOTAL CATION	TSS
****	****	*****	****	*****	****	*****	***	****	**********	*********
301	60.12	3.44	366.02	34.55	1242.69	62.01	0.0	0.0	87.13	6298.99
302	744.68	41.34	329.05	30.13	593.26	28.53	0.0	0.0	89.81	5511.88
303	2240.47	12.59	1455.55	13.48	15116.39	73.94	0.0	0.0	889.30	49793.02
304	599.20	14.42	2091.32	79.32	299.00	6.27	0.0	0.0	207.40	11096.81
305	600.00	83.35	62.99	14.42	18.40	2.23	0.0	0.0	35.92	2526.52
306	147.09	21.46	316.16	76.00	20.01	2.54	0.0	0.0	34.21	1772.07
307	47.09	33.86	32.95	39.05	42.09	26.37	1.95	0.72	6.94	462.36
308	139.26	48.71	23.71	14.39	115.00	36.90	0.0	0.0	13.55	1013.89
309	575.15	61.67	60.80	10.74	295.32	27.59	0.0	0.0	46.54	3194.85
310	631.66	77.12	94.15	16.93	55.89	5.95	0.0	0.0	40.87	2702.52
311	606.21	36.62	224.35	22.00	809.60	41.98	0.0	0.0	83.85	5029.93
312	825.65	30.29	265.50	12.43	1701.70	57.28	0.0	0.0	134.00	8537.22
313	499.00	39.19	167.81	21.72	571.09	39.08	0.0	0.0	63.53	4188.32
314	644.49	40.99	255.36	26.77	570.17	31.60	19.55	0.64	78.45	4515.43
315	260.52	19.97	179.36	22.66	850.31	56.79	14.86	0.58	65.10	3823.02
316	499.98	21.48	299.38	20.93	1593.75	57.20	17.20	0.39	114.07	6414.04
317	615.22	39.42	227.03	24.19	637.10	35.57	25.02	0.82	77.88	4837.77
318	704.41	47.59	156.86	17.47	533.63	34.94	0.0	0.0	73.86	4556.16
319	561.12	35.30	246.60	25.56	705.41	38.66	14.86	0.48	79.33	4836.16
320	528.01	32.51	238.46	25.46	719.90	40.63	30.11	1.00	77.02	4646.01
321	605.21	34.81	235.66	22.34	850.31	42.62	7.82	0.23	86.75	5249.70
322	801.60	44.19	171.21	15.55	820.41	39.41	30.11	0.85	90.52	5596.73
323	663.32	43.01	174.62	18.66	675.28	38.15	5.08	0.17	76.95	4923.30
324	506.01	26.78	163.43	14.26	1175.53	54.21	175.17	4.75	94.28	5799.06
325	159.32	35.94	60.80	22.75	200.10	39.58	14.86	1.73	21.98	1416.85
326	40.08	49.28	19.94	39.61	10.59	11.11	0.0	0.0	4.14	328.41

TABLE ((3)) ANIONS IN PPM

SNO.	HCO3	%HCO3	CL	%CL	SO4	%SO4	NO3	%NO3	TOTAL ANIONS	%ERROR
1	282.48	5.60	2038.95	69.57	985.57	24.83	0.0	0.0	82.65	-1.55
2	427.07	42.81	22.34	3.85	418.82	53.33	0.0	0.0	16.35	-2.22
3	125.68	5.26	38.30	2.76	1729.08	91.98	0.0	0.0	39.14	2.56
4	51.86	1.72	221.62	12.65	2022.63	85.63	0.0	0.0	49.42	2.11
5	158.63	5.89	132.97	8.50	1739.17	82.05	97.36	3.56	44.13	3.15
6	145.20	5.63	81.56	5.44	1805.93	88.93	0.0	0.0	42.28	0.94
7	124.46	5.51	22.34	1.70	1650.21	92.79	0.0	0.0	37.03	1.20
8	231.84	9.52	26.59	1.88	1654.63	86.28	57.67	2.33	39.93	-0.10
9	108.60	4.99	19.50	1.54	1602.28	93.47	0.0	0.0	35.69	0.54
10	198.28	12.25	38.30	4.07	1066.75	83.69	0.0	0.0	26.54	-0.30
11	215.98	17.57	35.46	4.96	749.75	77.47	0.0	0.0	20.15	-0.80
12	312.98	26.28	35.46	5.12	643.12	68.60	0.0	0.0	19.52	-0.10
13	244.04	10.92	48.93	3.77	1501.42	85.32	0.0	0.0	36.64	-0.67
14	236.72	51.66	42.55	15.98	116.71	32.36	0.0	0.0	7.51	6.48
15	228.79	21.33	53.19	8.53	592.21	70.14	0.0	0.0	17.58	0.48
16	215.98	20.11	51.77	8.30	605.18	71.59	0.0	0.0	17.60	-1.65
17	259.29	56.14	26.59	9.91	123.44	33.95	0.0	0.0	7.57	4.36
18	255.63	21.72	38.30	5.60	673.38	72.68	0.0	0.0	19.29	1.51
19	221.47	55.93	29.43	12.79	97.50	31.28	0.0	0.0	6.49	3.13
20	231.84	59.65	26.59	11.77	87.41	28.57	0.0	0.0	6.37	6.46
21	228.79	57.52	26.59	11.50	97.02	30.98	0.0	0.0	6.52	2.83
22	251.97	83.77	17.73	10.14	14.41	6.09	0.0	0.0	4.93	0.10
23	219.64	82.57	17.73	11.47	12.49	5.96	0.0	0.0	4.36	-5.57
24	251.97	77.34	15.96	8.43	36.50	14.23	0.0	0.0	5.34	-1.62
25	274.54	61.64	48.93	18.90	68.20	19.45	0.0	0.0	7.30	4.26
26	156.19	31.37	37.23	12.87	218.54	55.76	0.0	0.0	8.16	-0.06
27	175.71	5.81	93.26	5.30	2117.16	88.89	0.0	0.0	49.59	2.41
28	162.29	5.63	132.97	7.94	1961.06	86.43	0.0	0.0	47.24	2.51
29	201.33	6.51	131.91	7.34	2000.93	82.17	125.26	3.98	50.70	1.50
30	76.26	4.49	132.97	13.46	1095.56	81.87	3.10	0.18	27.86	-0.74
31	109.82	2.73	265.95	11.39	2639.25	83.49	97.36	2.39	65.82	7.06
32	45.76	3.56	195.03	26.13	710.84	70.31	0.0	0.0	21.05	-2.04
33	549.09	8.23	634.73	16.37	3961.03	75.40	0.0	0.0	109.37	1.97
34	114.70	4.83	88.65	6.42	1658.96	88.75	0.0	0.0	38.52	-1.74
35	129.95	11.48	209.21	31.81	505.28	56.71	0.0	0.0	18.55	-3.00
36	76.26	4.47	696.08	70.21	340.05	25.32	0.0	0.0	27.96	-2.10
37	55.52	3.32	660.62	67.89	379.44	28.79	0.0	0.0	27.44	-1.76
38	206.21	5.09	1174.79	49.86	1437.54	45.05	0.0	0.0	66.44	-0.49
39	206.21	4.31	221.62	7.96	3307.83	87.73	0.0	0.0	78.50	0.87
40	295.90	5.30	274.81	8.47	3788.61	86.23	0.0	0.0	91.48	1.10
41	68.94	1.30	930.82	30.30	2845.78	68.39	0.0	0.0	86.63	-0.33
42	496.01	12.17	842.17	35.56	1676.25	52.26	0.0	0.0	66.78	2.20
43	435.00	47.69	203.89	38.46	99.42	13.85	0.0	0.0	14.95	-3.25
44	201.94	8.04	1209.19	82.85	180.11	9.11	0.0	0.0	41.16	6.89
45	274.54	9.21	141.84	8.19	1738.69	74.10	257.34	8.50	48.85	2.64
46	604.00	16.39	79.78	2.73	2317.45	79.88	0.0	0.0	60.40	1.18
47	221.47	6.24	310.27	15.03	2201.21	78.73	0.0	0.0	58.21	2.26
48	221.47	7.74	113.47	6.82	1925.04	85.44	0.0	0.0	46.91	3.85
49	137.27	6.12	22.34	1.71	1627.74	92.17	0.0	0.0	36.77	2.36
50	137.27	5.44	19.50	1.33	1852.52	93.23	0.0	0.0	41.37	-3.74

TABLE (((3))) CONTINUE

SNO.	HCO3	%HCO3	CL	%CL	SO4	%SO4	NO3	%NO3	TOTAL ANIONS	%ERROR
****	*****	*****	****	*****	*****	******	*****	******	**********	*******
51	158.63	4.06	208.15	9.18	2524.46	82.16	182.31	4.60	63.97	2.50
52	198.28	4.00	443.25	15.39	3145.48	80.61	0.0	0.0	81.24	2.01
53	145.20	4.23	177.30	8.89	2347.23	86.88	0.0	0.0	56.25	7.89
54	114.70	3.55	132.97	7.09	2269.90	89.36	0.0	0.0	52.89	3.85
55	289.80	6.13	523.03	19.03	2786.22	74.84	0.0	0.0	77.51	4.04
56	206.21	10.91	70.92	6.46	1229.09	82.63	0.0	0.0	30.97	2.96
57	225.74	9.55	132.97	9.68	1397.67	75.14	135.18	5.63	38.73	1.75
58	350.81	52.27	40.07	10.27	197.88	37.45	0.0	0.0	11.00	7.09
59	251.97	35.48	57.80	14.00	282.42	50.52	0.0	0.0	11.64	4.86
60	228.79	18.59	365.24	51.07	293.94	30.34	0.0	0.0	20.17	2.32
61	251.97	60.03	22.34	9.16	101.82	30.81	0.0	0.0	6.88	4.58
62	160.46	7.01	51.42	3.87	1605.64	89.12	0.0	0.0	37.51	2.48
63	267.22	74.49	26.59	12.76	36.02	12.76	0.0	0.0	5.88	-2.44
64	162.90	38.58	17.73	7.23	180.11	54.19	0.0	0.0	6.92	0.43
65	206.21	79.72	17.73	11.79	17.29	8.49	0.0	0.0	4.24	3.09
66	106.77	3.57	221.62	12.74	1972.11	83.69	0.0	0.0	49.06	3.41
67	137.27	6.64	22.34	1.86	1489.89	91.50	0.0	0.0	33.90	3.86
68	114.70	3.85	106.38	6.14	2110.92	90.01	0.0	0.0	48.83.	3.34
69	76.26	2.84	177.30	11.37	1811.69	85.79	0.0	0.0	43.97	5.04
70	145.20	13.77	61.35	10.01	633.04	76.23	0.0	0.0	17.29	3.22
71	137.27	12.75	57.80	9.24	661.37	78.02	0.0	0.0	17.65	0.95
72	244.04	20.86	56.03	8.24	653.21	70.91	0.0	0.0	19.18	2.09
73	350.81	16.87	177.30	14.67	1121.02	68.47	0.0	0.0	34.09	-0.90
74	228.79	8.76	115.24	7.60	1718.59	83.64	0.0	0.0	42.79	1.80
75	236.72	15.17	70.92	7.82	946.19	77.01	0.0	0.0	25.58	3.12
76	160.46	11.61	106.38	13.25	817.47	75.14	0.0	0.0	22.65	2.14
77	244.04	12.68	177.30	15.85	1082.60	71.46	0.0	0.0	31.54	0.05
78	244.04	11.49	177.30	14.36	1111.89	66.50	164.95	7.64	34.81	0.34
79	244.04	20.43	97.51	14.04	616.22	65.53	0.0	0.0	19.58	-4.71
80	244.04	21.75	97.51	14.95	559.07	63.30	0.0	0.0	18.39	3.19
81	236.72	2.91	682.60	14.45	5286.66	82.64	0.0	0.0	133.20	0.62
82	137.27	5.90	210.99	15.60	1438.02	78.50	0.0	0.0	38.14	5.73
83	68.94	9.04	159.57	36.00	329.97	54.96	0.0	0.0	12.50	-3.26
84	91.51	10.90	159.57	32.70	343.89	52.03	37.21	4.36	13.76	2.96
85	190.96	9.06	17.73	1.45	1485.57	89.50	0.0	0.0	34.56	1.75
86	160.46	3.91	400.70	16.81	2560.00	79.28	0.0	0.0	67.23	3.41
87	206.21	6.06	90.07	4.55	2354.29	89.38	0.0	0.0	55.77	1.95
88	129.95	1.62	1606.34	34.49	4031.16	63.89	0.0	0.0	131.36	4.14
89	183.03	3.20	859.90	25.83	3159.76	70.97	0.0	0.0	93.87	0.55
90	160.46	4.49	558.49	26.87	1932.73	68.65	0.0	0.0	58.62	3.30
91	244.04	6.75	585.09	27.82	1863.56	65.43	0.0	0.0	59.30	-0.25
92	190.96	2.18	842.17	16.54	5605.10	81.28	0.0	0.0	143.58	-0.16
93	76.26	3.41	411.34	31.62	1145.03	64.98	0.0	0.0	36.69	4.00
94	228.79	17.33	106.38	13.86	715.17	68.81	0.0	0.0	21.64	-1.84
95	274.54	18.91	102.12	12.10	788.65	68.99	0.0	0.0	23.80	-3.86
96	312.98	39.80	33.69	7.37	327.08	52.83	0.0	0.0	12.89	-1.94
97	122.02	6.57	181.91	16.85	1119.58	76.58	0.0	0.0	30.44	1.50
98	137.27	7.61	146.45	13.98	1112.85	78.41	0.0	0.0	29.55	2.52
99	114.70	8.01	115.24	13.85	880.39	78.13	0.0	0.0	23.46	4.48
100	114.70	7.83	132.97	15.62	882.79	76.55	0.0	0.0	24.01	3.15

TABLE (((3))) CONTINUE

SNO.	HCO3	%HCO3	CL	%CL	SO4	%SO4	NO3	%NO3	TOTAL ANIONS	%ERROR
101	225.74	11.73	132.97	11.89	1063.86	70.25	119.68	6.12	31.53	-2.49
102	183.03	4.63	478.71	20.81	2322.73	74.56	0.0	0.0	64.86	6.90
103	152.52	4.03	336.87	15.31	2404.86	80.67	0.0	0.0	62.07	3.82
104	122.02	3.43	270.56	13.07	2340.98	83.50	0.0	0.0	58.37	4.10
105	114.70	3.31	514.17	25.53	1940.89	71.16	0.0	0.0	56.79	6.98
106	103.11	6.00	17.73	1.77	1248.30	92.23	0.0	0.0	28.18	0.76
107	175.71	2.54	1329.75	33.07	3507.15	64.39	0.0	0.0	113.40	-1.80
108	335.55	3.81	1773.00	34.59	3307.83	47.65	1250.12	13.95	144.53	-2.66
109	91.51	1.05	2482.20	48.96	3433.18	49.99	0.0	0.0	142.98	3.26
110	76.26	3.76	580.83	49.32	748.21	46.91	0.0	0.0	33.21	-0.68
111	305.05	35.95	115.24	23.36	271.85	40.69	0.0	0.0	13.91	-0.65
112	244.04	34.31	91.49	22.13	243.99	43.57	0.0	0.0	11.66	2.06
113	137.27	8.55	57.80	6.19	1078.27	85.26	0.0	0.0	26.33	2.37
114	175.71	11.40	35.46	3.96	1026.88	84.64	0.0	0.0	25.26	2.83
115	195.23	10.94	35.46	3.42	1162.33	82.74	52.71	2.91	29.25	4.21
116	190.96	8.56	31.20	2.41	1563.86	89.03	0.0	0.0	36.57	2.01
117	183.03	8.27	26.59	2.07	1548.49	88.84	18.60	0.83	36.29	4.05
118	129.95	5.96	19.50	1.54	1588.35	92.50	0.0	0.0	35.75	2.32
119	122.02	5.45	26.59	2.04	1607.08	91.15	31.00	1.36	36.71	2.12
120	350.81	51.71	53.19	13.49	185.88	34.80	0.0	0.0	11.12	3.81
121	134.22	7.94	62.05	6.32	1114.20	83.75	34.11	1.99	27.70	1.42
122	289.80	23.05	429.07	58.71	180.59	18.24	0.0	0.0	20.61	-3.99
123	95.18	7.26	549.63	72.13	212.77	20.61	0.0	0.0	21.49	0.53
124	91.51	6.51	585.09	71.65	212.77	19.24	37.21	2.61	23.03	1.85
125	298.95	17.53	602.82	60.82	290.58	21.65	0.0	0.0	27.95	-2.83
126	64.67	3.58	691.47	65.86	424.67	30.56	0.0	0.0	29.61	1.14
127	259.29	5.33	549.63	19.44	2881.80	75.24	0.0	0.0	79.75	6.48
128	353.86	9.34	310.27	14.09	2185.36	72.27	127.12	3.30	62.10	-1.09
129	240.38	4.88	638.28	22.32	2820.32	72.80	0.0	0.0	80.66	3.41
130	683.31	14.33	626.58	22.60	2367.88	63.07	0.0	0.0	78.17	-0.43
131	76.26	1.70	744.66	28.55	2463.94	69.75	0.0	0.0	73.55	1.21
132	183.72	3.04	398.92	20.11	2065.29	76.85	0.0	0.0	55.95	6.71
133	106.77	2.32	673.74	25.14	2623.00	72.54	0.0	0.0	75.57	1.81
134	201.33	3.99	718.06	24.51	2608.03	65.73	295.17	5.76	82.61	-0.37
135	99.45	3.02	354.60	18.54	2031.67	78.43	0.0	0.0	53.93	5.23
136	170.83	3.58	375.88	13.55	3114.26	82.87	0.0	0.0	78.24	4.50
137	106.77	2.79	425.52	19.15	2348.67	78.05	0.0	0.0	62.65	7.55
138	99.45	2.15	684.38	25.40	2644.53	72.46	0.0	0.0	75.99	4.65
139	152.52	2.54	886.50	25.38	2809.75	59.39	775.12	12.69	98.50	1.75
140	170.83	4.32	255.95	11.57	2617.63	84.10	0.0	0.0	64.80	1.84
141	106.77	1.89	416.65	12.68	3803.98	85.44	0.0	0.0	92.70	5.51
142	170.83	6.02	221.62	13.45	1724.20	77.24	94.88	3.29	46.48	7.72
143	129.95	4.90	226.94	14.74	1676.25	80.36	0.0	0.0	43.43	7.48
144	129.95	2.61	390.06	13.48	3290.05	83.92	0.0	0.0	81.63	2.70
145	103.72	0.91	1042.52	15.74	5926.90	66.07	2000.44	17.27	186.76	-4.99
146	183.03	4.35	815.58	33.33	2065.29	62.32	0.0	0.0	69.00	9.33
147	183.03	8.66	49.64	4.04	1452.91	87.30	0.0	0.0	34.65	3.32
148	122.02	2.45	815.58	28.15	2723.30	69.40	0.0	0.0	81.70	2.26
149	175.71	0.44	15957.00	68.23	9927.80	31.34	0.0	0.0	659.58	-8.66
150	84.19	1.69	1329.75	45.97	2050.88	52.34	0.0	0.0	81.58	3.51

TABLE (((3))) CONTINUE

SNO.	HCO3	%HCO3	CL	%CL	SO4	%SO4	NO3	%NO3	TOTAL ANIONS	%ERROR
****	*****	*****	****	*****	*****	******	*****	******	**********	*******
151	122.02	7.21	115.24	11.71	1080.67	81.08	C.0	0.0	27.75	2.96
152	129.95	6.61	35.46	3.10	1397.67	90.29	C.0	C.0	32.23	2.35
153	145.20	8.36	35.46	3.51	1205.55	88.13	C.0	C.0	28.48	-0.53
154	129.95	2.79	1046.07	38.60	2151.74	58.62	C.0	0.0	76.43	1.86
155	137.27	6.16	124.11	9.58	1478.36	84.26	C.0	0.0	36.53	0.88
156	122.02	2.96	638.28	26.62	2286.71	70.42	0.0	0.0	67.61	7.41
157	167.78	4.80	434.38	21.39	2029.75	73.80	0.0	0.0	57.26	3.42
158	129.95	3.66	425.52	20.64	2114.28	75.70	0.0	0.0	58.15	4.84
159	109.82	3.28	265.95	13.65	2127.73	80.62	83.71	2.46	54.95	2.70
160	108.77	3.58	248.22	14.33	1926.00	82.09	C.0	C.0	48.85	4.61
161	106.77	2.24	833.31	30.13	2533.10	67.62	C.C	0.0	77.99	2.25
162	114.70	1.97	1205.64	35.63	2859.71	62.40	0.0	0.0	95.42	6.78
163	84.19	3.00	212.76	13.06	1852.04	83.94	C.0	C.0	45.94	4.90
164	114.70	5.77	31.91	2.76	1431.29	91.47	0.0	C.0	32.58	0.26
165	597.90	5.65	3368.70	54.76	3299.66	39.60	0.0	0.0	173.50	6.72
166	61.01	1.91	1125.85	60.61	942.83	37.48	C.0	0.0	52.38	0.21
167	124.46	2.05	1418.40	40.27	2752.12	57.68	0.0	0.0	99.34	2.58
168	54.91	1.19	1125.85	41.91	2070.09	56.90	0.0	0.0	75.75	2.00
169	171.44	4.04	567.36	23.00	2437.52	72.96	0.0	0.0	69.56	3.90
170	110.43	4.95	162.12	12.58	1448.58	82.47	0.0	0.0	36.57	1.32
171	109.82	4.51	265.95	18.81	1433.21	74.84	45.27	1.83	39.87	4.35
172	91.51	1.78	1247.48	45.08	2151.74	53.14	0.0	0.0	84.30	7.26
173	152.52	4.60	88.65	4.60	2369.32	90.80	C.0	C.0	54.33	2.03
174	91.51	3.91	58.51	4.30	1692.10	91.79	0.0	0.0	38.38	1.46
175	246.42	5.88	85.10	5.88	1693.06	86.38	47.13	1.86	40.81	3.48
176	99.45	3.66	88.65	5.61	1940.41	90.73	0.0	0.0	44.53	7.59
177	91.51	3.18	248.22	14.83	1858.76	81.99	0.C	C.0	47.20	3.42
178	84.19	3.19	195.03	12.71	1748.29	84.10	0.0	0.0	43.28	3.37
179	154.97	5.48	221.62	13.49	1770.87	79.60	40.93	1.42	46.32	5.06
180	99.45	3.12	150.70	8.12	2230.03	88.76	0.0	0.0	52.31	4.28
181	106.77	3.00	407.79	19.74	2161.83	77.26	0.0	0.0	58.26	4.34
182	99.45	2.71	682.60	31.99	1887.58	65.30	0.0	0.0	60.18	2.78
183	68.94	2.49	354.60	22.06	1642.63	75.45	0.0	0.0	45.33	3.99
184	85.41	2.58	434.38	22.61	1946.66	74.81	C.0	0.0	54.18	5.85
185	109.82	3.08	456.37	22.03	2046.08	72.93	70.69	1.95	58.41	4.18
186	209.87	2.79	3014.10	68.93	1675.29	28.28	0.0	0.0	123.32	-0.13
187	91.51	1.94	585.09	21.37	2843.86	76.69	C.0	0.0	77.21	4.21
188	154.97	3.07	656.01	22.33	2831.85	71.17	176.11	3.43	82.84	-2.06
189	129.95	2.60	505.30	18.71	2872.19	78.50	0.0	0.0	76.18	3.05
190	175.71	3.76	407.79	15.01	2989.39	81.23	0.0	0.0	76.62	4.67
191	145.20	4.64	248.22	13.04	2013.90	81.72	0.0	0.0	51.31	3.59
192	152.52	7.50	88.65	7.50	1360.21	84.99	0.0	0.0	33.32	4.10
193	76.26	1.29	1028.34	29.82	3218.01	68.89	0.0	C.0	97.25	0.18
194	87.85	1.91	726.93	27.24	2560.96	70.85	0.0	0.0	75.26	4.27
195	99.45	2.51	567.36	24.62	2275.18	72.88	0.0	C.0	65.00	5.37
196	91.51	2.02	531.90	20.17	2334.26	65.35	574.83	12.46	74.37	1.08
197	129.95	1.90	1648.89	41.52	3043.18	56.58	0.0	0.0	111.99	4.90
198	99.45	3.26	354.60	20.01	1841.47	76.73	0.0	C.0	49.97	4.35
199	152.52	3.93	212.76	9.42	2649.81	86.65	0.0	0.0	63.67	1.81
200	175.71	5.09	407.79	20.31	2028.79	74.60	0.0	0.0	56.62	3.26

TABLE (((3))) CONTINUE

SNO.	HCO3	%HCO3	CL	%CL	SO4	%SO4	NO3	%NO3	TOTAL ANIONS	%ERROR
****	*****	*****	****	*****	*****	******	*****	******	**********	*******
201	152.52	7.70	26.59	2.31	1403.44	89.99	0.0	0.0	32.47	2.08
202	145.20	5.37	150.70	9.59	1809.29	85.03	0.0	0.0	44.30	3.18
203	213.53	7.60	49.64	3.04	1975.95	89.36	0.0	0.0	46.04	-3.24
204	158.63	3.55	287.94	11.08	2795.35	79.43	269.74	5.94	73.27	-1.74
205	164.73	4.89	248.22	12.68	2185.36	82.43	0.0	0.0	55.20	3.76
206	195.23	3.75	780.12	25.79	2622.44	63.99	342.29	6.47	85.32	-1.32
207	134.22	2.20	975.15	27.46	2936.07	61.05	576.69	9.29	100.13	0.93
208	128.12	3.35	549.63	24.71	2168.07	71.95	0.0	0.0	62.74	5.53
209	140.32	3.19	602.82	23.58	2300.64	66.45	302.61	6.77	72.08	0.21
210	109.21	2.55	353.89	14.24	2800.15	83.20	0.0	0.0	70.07	2.87
211	97.62	2.80	257.08	12.69	2319.85	84.51	0.0	0.0	57.15	7.76
212	152.52	4.35	443.25	21.77	2037.91	73.88	0.0	0.0	57.43	5.24
213	140.32	0.62	9077.76	69.42	3950.55	22.31	1750.54	7.65	368.79	3.58
214	170.83	6.23	212.76	13.36	1734.84	80.41	0.0	0.0	44.92	3.21
215	152.52	4.66	195.03	10.25	2193.05	85.09	0.0	0.0	53.66	3.46
216	103.72	3.73	203.89	12.62	1830.90	83.65	0.0	0.0	45.57	3.22
217	173.88	2.55	1170.18	29.50	3650.76	67.95	0.0	0.0	111.86	4.41
218	128.12	2.40	797.85	25.68	3026.85	71.92	0.0	0.0	87.62	4.27
219	128.12	3.50	177.30	8.34	2538.86	88.16	0.0	0.0	59.96	5.27
220	201.33	4.12	1063.80	37.44	2248.76	58.44	0.0	0.0	80.12	3.02
221	250.14	5.82	886.50	35.49	1986.04	58.69	0.0	0.0	70.45	4.88
222	158.63	4.32	283.68	13.30	2021.10	69.95	463.83	12.43	60.16	-3.53
223	122.02	2.71	514.17	19.63	2489.87	70.19	342.29	7.47	73.86	-5.29
224	146.42	2.82	1205.64	39.97	2317.93	56.74	24.80	0.47	85.06	-0.15
225	195.23	1.86	3262.32	53.48	3587.84	43.42	132.70	1.24	172.04	-1.47
226	250.14	2.92	1241.10	24.94	4862.07	72.14	0.0	0.0	140.33	2.05
227	244.04	3.42	1063.80	25.67	3979.76	70.91	0.0	0.0	116.86	2.58
228	213.53	6.98	274.81	15.47	1802.08	74.88	83.09	2.67	50.11	4.35
229	539.94	17.28	88.65	4.88	1914.96	77.84	0.0	0.0	51.22	1.05
230	274.54	9.12	141.84	8.11	1961.06	82.77	0.0	0.0	49.33	-2.28
231	170.83	4.68	132.97	6.27	2379.89	82.85	230.06	6.20	59.81	0.52
232	274.54	62.76	44.32	17.43	68.20	19.80	0.0	0.0	7.17	-4.90
233	225.74	48.54	53.19	19.84	113.35	31.22	0.0	0.0	7.56	9.79
234	201.33	33.64	35.46	10.19	189.24	40.16	97.36	16.00	9.81	2.92
235	280.65	43.73	53.19	14.26	107.59	21.29	135.18	20.72	10.52	-0.81
236	286.75	50.00	35.46	10.64	131.12	29.04	60.15	10.32	9.40	-0.53
237	213.53	5.90	155.31	7.38	2472.58	86.73	0.0	0.0	59.36	5.49
238	244.04	9.13	132.97	8.56	1669.52	79.36	79.99	2.95	43.80	1.63
239	366.06	10.15	310.27	14.80	2071.53	72.94	77.51	2.11	59.13	-0.11
240	140.32	4.78	132.97	7.80	1927.92	82.47	117.82	3.95	48.09	6.49
241	244.04	2.45	1950.30	33.73	4222.80	53.92	1000.22	9.89	163.05	1.50
242	268.44	9.33	177.30	10.60	1621.01	71.53	249.90	8.54	47.18	-3.45
243	237.94	5.97	274.81	11.86	2377.96	75.76	259.62	6.41	65.35	2.72
244	139.10	6.32	26.55	2.11	1585.95	91.49	1.86	0.08	36.09	0.29
245	248.92	10.55	31.91	2.33	1613.81	86.89	5.58	0.23	38.67	-0.17
246	95.18	3.54	231.91	14.84	1711.79	80.85	21.08	0.77	44.08	-0.47
247	97.01	3.38	243.96	14.64	1840.03	81.55	12.40	0.43	46.98	0.12
248	48.81	1.47	1124.08	58.37	1045.61	40.08	2.48	0.07	54.31	-0.01
249	51.25	1.38	1149.97	53.44	1304.97	44.78	14.88	0.40	60.68	-0.21
250	189.13	19.21	41.84	7.31	565.79	72.99	4.96	0.50	16.14	-0.31

TABLE (((3))) CONTINUE

SNO.	HCO3	%HCO3	CL	%CL	SO4	%SO4	NO3	%NO3	TOTAL ANIONS	%ERROR
251	200.11	18.69	53.90	8.66	609.98	72.36	3.10	0.28	17.55	-0.26
252	208.04	35.89	53.90	16.00	216.13	47.37	4.34	C.74	9.50	-0.42
253	264.17	47.85	26.95	8.40	186.84	42.98	4.34	C.77	9.05	-4.20
254	234.89	22.44	41.84	6.88	576.36	69.93	8.06	0.76	17.16	-0.35
255	237.94	28.40	53.90	11.07	398.17	60.38	1.24	C.15	13.73	4.65
256	198.89	39.52	30.85	10.55	192.12	48.48	7.44	1.45	8.25	-0.12
257	189.74	35.95	41.84	13.64	201.73	49.55	9.92	1.85	8.65	-0.76
258	175.71	51.43	13.12	6.61	110.47	41.07	3.10	0.89	5.60	2.44
259	175.71	36.64	26.95	9.67	201.73	53.44	1.24	C.25	7.86	-0.13
260	211.70	45.42	41.84	15.45	139.29	37.96	5.58	1.18	7.64	-0.53
261	278.82	49.46	35.11	10.71	172.91	38.96	4.96	C.87	9.24	-0.33
262	200.11	63.81	26.95	14.79	52.83	21.40	0.0	0.0	5.14	0.00
263	256.24	62.13	26.95	11.24	85.01	26.18	1.86	C.44	6.76	2.73
264	297.73	16.71	612.04	59.09	335.73	22.93	4.96	0.27	29.21	0.03
265	195.23	11.17	602.11	59.25	403.45	29.31	4.96	0.28	28.66	0.00
266	239.16	20.13	30.14	4.37	706.04	75.50	0.0	0.0	19.47	1.42
267	259.90	20.62	46.10	6.29	720.45	72.60	6.20	0.48	20.66	-0.22
268	206.21	53.23	26.95	11.97	100.86	33.07	6.82	1.73	6.35	-0.79
269	211.70	46.14	35.11	13.16	144.09	39.89	3.72	0.80	7.52	-0.47
270	126.29	5.48	35.11	2.62	1661.84	91.56	8.06	0.34	37.79	-0.37
271	154.97	5.87	53.90	3.52	1876.05	90.33	7.44	C.28	43.24	-0.10
272	240.99	10.86	35.11	2.72	1505.74	86.22	4.34	C.19	36.36	-0.04
273	181.81	7.79	35.11	2.59	1642.63	89.37	6.20	0.26	38.27	1.16
274	50.03	3.63	197.87	24.68	776.16	71.47	3.10	0.22	22.61	-0.02
275	56.74	3.93	196.09	23.38	824.67	72.60	1.24	C.08	23.65	0.11
276	51.25	2.71	677.99	61.70	528.33	35.50	1.86	0.10	30.99	0.19
277	84.80	3.78	402.12	30.84	1145.99	64.89	11.16	C.49	36.77	-0.15
278	240.99	6.46	315.85	14.76	2287.67	77.92	32.87	0.87	61.13	-0.60
279	125.68	4.24	92.91	5.39	2109.96	90.34	1.24	C.04	48.63	2.01
280	194.01	14.84	117.02	15.40	718.05	69.76	0.0	C.0	21.43	0.02
281	98.23	13.56	63.83	15.16	384.24	67.40	28.52	3.88	11.87	0.75
282	61.01	1.84	106.38	5.51	2401.50	91.89	25.42	C.75	54.41	-2.21
283	122.02	8.56	35.46	4.28	960.60	85.62	22.32	1.54	23.36	2.57
284	195.23	21.53	85.10	16.15	431.79	60.50	16.74	1.82	14.86	2.11
285	122.02	17.89	95.74	24.15	297.79	55.46	17.36	2.50	11.18	1.50
286	109.82	12.69	148.93	29.62	384.24	56.42	11.16	1.27	14.18	-4.26
287	134.22	10.83	248.22	34.47	528.33	54.16	6.82	C.54	20.31	0.76
288	85.41	7.91	219.85	35.03	490.30	56.50	6.20	0.56	17.70	-1.96
289	146.42	19.12	109.93	24.70	327.08	54.26	14.88	1.91	12.55	0.28
290	97.62	39.41	35.46	24.63	57.64	29.56	16.12	6.40	4.06	4.25
291	109.82	2.65	70.92	4.27	2041.27	90.79	31.63	1.09	46.81	-0.60
292	225.74	18.94	290.77	41.97	366.95	39.10	0.0	C.0	19.54	-3.30
293	109.82	6.23	95.74	9.34	1171.93	84.43	C.0	C.0	28.90	3.62
294	100.06	6.28	74.82	8.08	1074.91	85.65	C.0	0.0	26.13	2.35
295	90.29	5.79	59.93	6.61	1074.91	87.59	0.0	C.0	25.55	3.00
296	200.11	11.94	50.00	5.13	1094.12	82.93	0.0	0.0	27.47	-0.99
297	150.03	8.73	670.19	67.09	327.08	24.17	0.0	0.0	28.17	-0.04
298	120.19	4.05	1329.75	77.05	441.88	18.90	0.0	C.0	48.67	0.88
299	79.92	0.30	11715.98	74.99	5230.46	24.72	0.0	C.0	440.61	3.74
300	129.95	0.93	3833.93	47.18	5710.77	51.89	0.0	0.0	229.15	-0.80

TABLE (((3))) CONTINUE

SNO.	HCO3	%HCO3	CL	%CL	SO4	%SO4	NO3	%NO3	TOTAL ANIONS	%ERROR
****	*****	*****	****	*****	*****	******	*****	******	**********	*******
301	250.14	3.94	1170.18	31.75	3209.84	64.30	0.0	0.0	103.93	-6.79
302	120.95	2.35	1510.60	46.37	2207.94	50.68	0.0	0.0	90.70	-0.49
303	271.27	0.52	28439.91	93.92	2281.42	5.56	0.0	0.0	853.93	1.97
304	793.13	6.27	5425.38	73.33	1979.80	19.89	0.0	0.0	207.22	0.04
305	260.04	12.30	31.91	2.41	1515.83	84.54	17.36	0.75	37.33	-1.92
306	104.94	5.03	1063.30	87.67	120.07	7.31	0.0	0.0	34.22	-0.01
307	170.22	43.32	31.91	13.98	118.15	38.20	17.98	4.50	6.44	3.74
308	514.92	57.85	198.58	38.38	26.42	3.77	0.0	0.0	14.59	-3.70
309	674.16	23.74	326.23	19.76	1263.19	56.50	0.0	0.0	46.55	-0.01
310	279.21	11.61	43.62	2.13	1609.00	85.26	0.0	0.0	39.29	1.97
311	821.89	18.32	887.92	34.06	1681.05	47.61	0.0	0.0	73.51	6.57
312	869.39	10.22	3106.29	63.46	1733.69	26.22	0.0	0.0	138.05	-0.75
313	675.51	17.94	702.11	31.17	1552.81	50.89	0.0	0.0	63.53	0.0
314	585.70	14.96	567.01	24.76	1873.17	60.38	0.0	0.0	64.59	9.69
315	969.39	25.77	911.32	46.47	737.26	27.76	0.0	0.0	55.30	8.14
*316	1473.39	26.56	1594.28	49.46	1047.05	23.98	0.0	0.0	90.91	11.30 *
317	604.00	13.62	813.31	31.57	1913.51	54.81	0.0	0.0	72.69	3.45
318	616.20	15.13	666.65	28.16	1818.42	56.71	0.0	0.0	66.76	5.05
319	848.04	19.54	815.58	22.33	1644.55	49.13	0.0	0.0	71.14	5.44
320	616.81	14.41	992.88	39.90	1539.84	45.69	0.0	0.0	70.17	4.66
321	643.60	13.42	971.00	35.71	1938.49	51.57	0.0	0.0	78.26	5.15
322	942.68	17.23	992.88	34.12	1917.84	48.65	0.0	0.0	82.07	4.90
323	866.34	19.89	580.64	23.25	1950.02	56.96	0.0	0.0	71.40	3.74
324	576.54	10.49	1893.56	59.27	1308.82	30.24	0.0	0.0	90.10	2.27
325	625.35	53.33	207.09	30.39	151.33	16.29	0.0	0.0	19.22	6.70
326	173.27	60.04	19.86	11.34	63.88	28.12	0.0	0.0	4.73	-6.65

TABLE ((4)) RATIOS. AND IONIC STRENGTH.

SNO.	TH	CA/MG	SO4/CL	(CL-NA)/CL	NA/CA	IONIC STRENGTH	SAR
1	1366.076	2.456	0.357	C.096	2.68C	0.1053	14.07
2	741.C82	1.612	13.841	-C.270	C.088	0.0278	0.29
3	1933.527	3.573	33.333	-1.315	0.083	0.0775	0.57
4	1723.353	1.563	6.771	-1.720	0.81C	0.0889	4.19
5	2201.736	2.667	9.656	C.2CO	0.C94	0.0857	0.64
6	1981.564	3.142	16.348	-C.478	C.113	0.0813	0.76
7	1849.462	4.176	54.540	-0.429	0.030	0.0731	0.21
8	1941.535	3.974	45.933	-C.4C0	C.034	0.0765	0.24
9	1765.398	6.000	60.655	-0.364	0.025	0.0702	0.18
10	1247.985	3.796	20.565	-C.296	0.071	0.0500	0.40
11	890.703	3.518	15.610	-1.000	0.144	C.0367	0.67
12	883.196	2.732	13.390	-C.8C0	0.139	0.0350	0.61
13	1702.345	3.909	22.652	-C.522	0.078	0.0650	0.51
14	346.773	2.300	2.025	-0.333	C.331	0.0127	0.86
15	746.C88	2.381	8.220	-C.867	0.267	0.0313	1.03
16	720.067	2.339	8.630	-C.781	0.258	0.0308	0.97
17	336.765	2.542	3.427	-1.000	0.311	C.0126	0.82
18	882.696	2.818	12.981	-1.037	0.169	0.0354	0.74
19	294.233	4.600	2.446	-0.205	0.207	C.0107	0.58
20	310.244	2.444	2.427	-C.400	0.239	0.0108	0.60
21	294.232	3.000	2.693	-C.333	0.227	0.0107	0.58
22	220.675	6.CCO	0.600	C.0	0.132	0.0073	0.34
23	170.134	3.25C	0.520	0.0	0.192	0.0060	0.38
24	227.180	4.405	1.689	-C.333	0.162	0.0079	0.40
25	321.253	2.567	1.029	-0.087	0.325	0.0115	0.84
26	231.181	1.200	4.333	-2.333	1.389	0.0127	2.30
27	2301.808	1.771	16.760	-1.281	0.204	0.0959	1.25
28	2206.735	2.CCO	10.988	-C.467	0.187	0.0909	1.17
29	2301.307	1.705	11.199	-C.680	0.216	0.0953	1.30
30	1029.309	1.882	6.083	-C.813	0.506	0.0493	2.12
31	3102.428	1.138	7.227	-0.833	0.417	C.1293	2.47
32	567.446	1.700	2.691	-C.6CO	1.232	0.0337	3.70
33	3877.857	0.522	4.607	-1.235	1.587	0.1895	6.60
34	1492.678	3.304	13.816	-2.080	0.336	0.0704	1.99
35	431.336	0.745	1.783	-C.492	2.391	0.0276	4.24
36	767.600	1.CCC	0.361	C.419	1.486	0.0386	4.12
37	821.144	1.368	0.424	C.463	1.C55	0.0391	3.49
38	1788.901	1.270	0.903	C.C94	1.50C	0.0990	7.10
39	2892.258	0.895	11.019	-2.520	0.806	0.1425	4.09
40	3302.572	0.650	10.178	-2.550	1.058	0.1649	4.79
41	2549.492	0.979	2.257	-0.333	1.389	0.1414	6.93
42	2522.488	2.637	1.469	C.221	0.506	0.1109	3.68
43	405.820	2.670	0.360	C.096	0.881	C.0156	2.58
44	2154.699	2.904	0.110	0.883	0.125	0.0676	0.86
45	2401.891	2.200	9.050	C.125	C.106	0.0923	0.71
46	2737.143	1.215	21.444	-2.111	C.233	0.1126	1.34
47	2416.896	1.556	5.238	-0.429	0.425	0.1066	2.54
48	2269.784	1.842	12.525	-C.625	0.177	0.0915	1.09
49	1886.490	3.772	53.794	-C.270	0.027	0.0735	0.18
50	1886.490	3.772	70.127	-C.091	0.020	0.0780	0.14

TABLE ((4)) CONTINUE

SNO.	TH	CA/MG	SO4/CL	(CL-NA)/CL	NA/CA	IONIC STRENGTH	SAR
*****	********	********	*********	**********	********	**********	*****
51	2752.154	1.200	8.954	-1.087	0.408	0.1194	2.34
52	2968.816	0.852	5.239	-1.000	0.916	0.1453	4.59
53	2732.137	1.080	9.774	-1.200	0.388	0.1128	2.11
54	2366.855	1.365	12.603	-1.600	0.357	0.1023	2.00
55	3047.380	0.933	3.933	-0.559	0.782	0.1402	4.17
56	1441.132	1.796	12.795	-1.000	0.216	0.0591	1.05
57	1719.348	1.454	7.760	-0.523	0.282	0.0711	1.39
58	546.930	1.970	3.646	-0.504	0.234	0.0194	0.73
59	525.413	1.941	3.607	-0.411	0.332	0.0204	1.00
60	705.556	2.357	0.594	0.320	0.707	0.0208	2.64
61	302.238	2.706	3.365	-1.381	0.340	0.0113	0.86
62	1858.963	2.239	23.055	-0.517	0.086	0.0738	0.51
63	230.182	3.792	1.000	-0.333	0.275	0.0084	0.66
64	319.252	4.963	7.500	-0.200	0.113	0.0120	0.34
65	190.651	3.948	0.720	-0.400	0.230	0.0065	0.51
66	1670.309	1.364	6.570	-2.040	0.987	0.0880	4.65
67	1783.905	2.576	49.238	-0.429	0.035	0.0686	0.21
68	2264.776	1.564	14.650	-1.267	0.246	0.0951	1.43
69	1578.237	1.497	7.544	-2.400	0.899	0.0809	4.28
70	580.452	0.760	7.618	-2.921	1.357	0.0303	2.82
71	567.443	0.803	8.448	-3.049	1.307	0.0204	2.77
72	708.555	1.237	8.608	-2.671	0.741	0.0335	2.18
73	1360.064	1.161	4.668	-0.260	0.432	0.0590	1.71
74	1916.504	1.671	11.012	-0.846	0.250	0.0806	1.37
75	1169.418	1.702	9.850	-0.900	0.258	0.0479	1.11
76	940.234	0.875	5.673	-0.600	0.547	0.0410	1.57
77	897.198	0.669	4.508	-1.720	1.892	0.0518	4.54
78	903.204	0.736	4.630	-2.400	2.222	0.0555	5.66
79	509.897	0.724	4.665	-1.764	1.776	0.0302	3.37
80	510.397	0.645	4.233	-2.418	2.350	0.0299	4.16
81	3942.061	0.484	5.718	-1.909	2.181	0.2284	8.92
82	1434.625	1.528	5.032	-1.353	0.808	0.0698	3.70
83	233.183	1.479	1.527	-0.556	2.518	0.0179	4.59
84	260.204	1.889	1.591	-1.089	2.765	0.0204	5.83
85	1731.365	2.844	61.860	-1.000	0.039	0.0679	0.24
86	2195.223	1.629	4.717	-1.478	1.030	0.1182	5.98
87	2048.105	1.369	19.626	-5.693	0.719	0.1023	3.76
88	3983.100	0.646	1.853	-0.391	2.017	0.2188	9.99
89	2730.633	0.947	2.747	-0.649	1.507	0.1550	7.66
90	1927.505	0.978	2.555	-0.524	1.260	0.1000	5.47
91	1701.325	0.700	2.352	-0.515	1.786	0.0955	6.06
92	4154.727	0.552	4.914	-1.526	2.032	0.2432	9.31
93	1285.005	1.069	2.055	-0.207	1.055	0.0630	3.91
94	578.451	0.776	4.963	-2.100	1.842	0.0345	3.87
95	614.480	0.994	5.701	-2.368	1.585	0.0373	3.91
96	337.764	1.143	7.168	-4.855	1.556	0.0194	3.05
97	1066.836	1.338	4.544	-0.949	0.820	0.0532	3.06
98	1066.336	1.441	5.610	-1.349	0.771	0.0526	2.97
99	816.138	1.026	5.640	-1.862	1.126	0.0419	3.26
100	886.692	0.840	4.901	-1.080	0.964	0.0428	2.62

TABLE ((4)) CONTINUE

SNO.	TH	CA/MG	SO4/CL	(CL-NA)/CL	NA/CA	IONIC STRENGTH	SAR
*****	********	********	*********	**********	********	**********	*****
101	1030.806	1.060	5.907	-1.507	0.887	0.0521	2.93
102	2719.634	1.592	3.582	-0.481	0.599	0.1210	3.84
103	2151.682	1.048	5.271	-1.526	1.091	0.1111	5.18
104	2034.590	1.021	6.388	-1.883	1.071	0.1056	4.88
105	2302.809	1.756	2.787	-0.310	0.648	0.1043	3.96
106	1370.584	5.400	51.980	-1.200	0.048	0.0551	0.30
107	2209.720	0.673	1.947	-0.733	3.660	0.1700	13.83
108	3202.510	1.286	1.377	-0.461	2.029	0.2072	12.91
109	3619.830	1.061	1.021	-0.143	2.148	0.2197	13.30
110	524.911	1.390	0.951	-0.343	3.607	0.0460	9.61
111	479.876	1.422	1.742	-0.231	0.710	0.0214	1.83
112	430.336	1.048	1.969	-0.376	0.807	0.0187	1.71
113	1128.839	2.357	13.773	-2.067	0.316	0.0495	1.49
114	1203.949	2.970	21.380	-1.500	0.139	0.0487	0.72
115	1469.656	2.124	24.200	-1.350	0.118	0.0573	0.61
116	1839.956	5.759	37.000	-0.364	0.038	0.0720	0.28
117	1914.015	5.120	42.987	-0.467	0.034	0.0731	0.25
118	1821.439	4.127	60.127	-0.636	0.031	0.0713	0.21
119	1871.481	5.448	44.613	-0.200	0.028	0.0729	0.21
120	460.361	1.390	2.580	-0.867	0.523	0.0181	1.31
121	1160.914	2.222	13.257	-2.029	0.331	0.0513	1.56
122	310.245	3.133	0.311	-0.058	2.722	0.0248	7.27
123	503.394	1.136	0.286	0.252	2.168	0.0288	5.17
124	610.476	0.848	0.268	0.291	2.089	0.0318	4.74
125	460.862	1.869	0.356	-0.012	2.867	0.0348	8.02
126	911.714	1.301	0.464	0.385	1.165	0.0436	3.98
127	3053.887	1.034	3.871	-0.710	0.854	0.1458	4.80
128	2501.974	2.846	5.200	-0.230	0.291	0.1092	2.15
129	1714.338	0.940	3.262	-1.889	3.133	0.1300	12.56
130	1626.272	1.097	2.790	-1.547	2.647	0.1187	11.16
131	1713.842	1.207	2.443	-0.952	2.189	0.1172	9.91
132	1451.135	1.071	3.822	-2.111	2.333	0.0960	9.19
133	2464.934	1.558	2.885	-0.526	0.967	0.1290	5.84
134	2702.119	1.455	2.681	-0.383	0.875	0.1365	5.39
135	2088.137	1.437	4.230	-0.800	0.731	0.0989	3.94
136	2478.935	0.905	6.117	-2.396	1.529	0.1391	7.23
137	2516.476	1.765	4.075	-0.875	0.701	0.1174	4.49
138	2491.955	1.515	2.853	-0.726	1.117	0.1321	6.71
139	2902.275	1.417	2.340	-0.760	1.294	0.1585	8.17
140	2358.347	1.318	7.267	-1.667	0.746	0.1168	4.12
141	3322.586	0.677	6.740	-2.149	1.381	0.1709	6.42
142	2101.657	2.818	5.744	-0.962	0.395	0.0893	2.68
143	2143.694	3.981	5.453	-0.172	0.219	0.0858	1.62
144	2302.803	1.324	6.227	-2.636	1.526	0.1412	8.34
145	4203.273	0.714	4.197	-1.891	2.429	0.2816	13.12
146	2572.525	2.193	1.870	-0.370	0.892	0.1233	6.21
147	1747.384	6.098	21.607	-0.357	0.063	0.0684	0.45
148	2570.513	1.341	2.465	-0.478	1.155	0.1376	6.71
149	4423.422	0.312	0.459	-0.022	21.505	0.7545	69.19
150	2572.525	2.193	1.139	0.040	1.020	0.1316	7.10

TABLE [(4)] CONTINUE

SNO.	TH	CA/MG	SO4/CL	(CL-NA)/CL	NA/CA	IONIC STRENGTH	SAR
*****	********	********	*********	**********	********	**********	*****
151	1247.986	4.668	6.923	-C.354	0.214	0.0523	1.25
152	1672.326	8.772	29.100	C.7C0	0.01C	0.0643	0.C7
153	1404.616	25.224	25.100	1.0C0	C.0	0.0549	0.0
154	2463.432	1.486	1.519	-C.017	1.C1S	0.1249	6.05
155	1713.355	4.333	8.794	0.286	0.C90	0.0694	0.60
156	2518.477	1.608	2.645	-C.556	0.902	0.1220	5.58
157	2141.689	3.000	3.450	-C.469	0.561	0.1018	3.89
158	2248.771	2.500	3.668	-C.583	0.592	0.1056	4.01
159	2051.621	3.556	5.907	-1.267	0.531	0.0991	3.75
160	2091.648	2.542	5.729	-0.643	0.383	0.0922	2.52
161	2730.640	1.429	2.244	-C.128	0.826	0.1334	5.07
162	2730.639	1.318	1.751	-C.588	1.740	0.1594	10.34
163	1928.024	4.137	6.427	-0.917	0.371	0.0868	2.62
164	1627.793	18.023	33.111	1.CCC	0.0	0.0628	0.0
165	5604.355	0.556	0.723	0.089	2.162	0.2763	11.56
166	1125.885	2.000	0.618	C.055	2.000	0.0736	8.94
167	2627.059	1.333	1.432	-C.300	1.733	0.1569	10.15
168	2438.416	1.753	1.357	C.055	0.967	0.1232	6.08
169	2357.852	1.752	3.172	-C.750	0.933	0.1213	5.77
170	1793.922	8.560	6.557	C.674	0.C47	0.07C1	0.35
171	1951.547	6.800	3.979	C.4CO	0.132	0.0761	1.02
172	3374.148	1.624	1.179	C.211	C.715	0.1470	5.17
173	2623.552	1.130	19.732	-C.600	0.144	0.1063	0.78
174	1820.430	1.833	21.352	-C.818	0.127	0.0748	0.70
175	1901.495	1.923	14.688	-1.396	0.230	0.0789	1.32
176	2410.886	1.141	16.160	-C.4C0	0.136	0.0925	0.71
177	1848.453	1.877	5.529	-C.929	0.560	0.0867	3.14
178	1661.305	1.814	6.618	-1.364	C.607	0.0796	3.19
179	1951.533	1.786	5.899	-0.962	0.490	0.0867	2.78
180	2196.727	1.927	10.925	-2.059	C.45C	0.0958	2.77
181	2224.250	2.076	3.914	-C.652	0.633	0.1056	4.03
182	2329.333	2.221	2.042	C.117	0.53C	0.1048	3.52
183	1928.021	3.001	3.420	-0.050	C.363	0.0836	2.39
184	2141.689	3.000	3.309	-0.469	C.561	0.0992	3.89
185	2301.814	2.538	3.310	-C.360	0.53C	0.1053	3.65
186	3534.292	3.715	0.410	C.388	C.934	0.1759	8.75
187	2196.712	0.822	3.588	-1.424	2.020	0.1322	8.54
188	2151.693	2.071	3.187	-C.973	1.259	0.1321	7.87
189	2759.660	1.193	4.196	-C.754	0.833	0.1360	4.76
190	2971.819	0.881	5.412	-1.087	0.863	0.1412	4.40
191	2090.147	2.549	5.990	-C.857	0.433	0.0951	2.84
192	1541.714	2.513	11.328	-1.120	0.240	0.0643	1.35
193	2677.093	1.083	2.310	-0.517	1.582	0.1577	8.51
194	2195.217	1.158	2.601	-C.854	1.614	0.1272	8.11
195	2355.854	2.143	2.961	-C.500	0.748	0.1159	4.95
196	2552.005	1.684	3.240	-C.667	C.781	0.1250	4.95
197	3372.640	1.174	1.363	-0.204	1.538	0.1831	9.65
198	2036.110	4.433	3.834	-C.250	0.377	0.0918	2.77
199	2221.744	1.678	9.195	-2.583	0.773	0.1146	4.56
200	2250.274	2.821	3.673	-0.261	0.437	0.1021	3.06

TABLE ((4)) CONTINUE

SNO.	TH	CA/MG	SO4/CL	(CL-NA)/CL	NA/CA	IONIC STRENGTH	SAR
201	1650.312	24.766	38.960	C.723	0.006	0.0643	0.05
202	1981.565	3.352	8.864	-C.765	0.246	0.0844	1.69
203	2104.161	3.313	29.386	0.286	0.031	0.0862	0.22
204	2802.193	1.154	7.167	-C.818	0.492	0.1291	2.79
205	2268.785	2.097	6.500	-0.786	0.407	0.1028	2.63
206	2652.079	1.500	2.482	-C.364	0.944	0.1380	5.83
207	3102.423	0.938	2.223	-C.455	1.333	0.1626	7.18
208	2384.874	1.810	2.912	-0.419	0.717	0.1128	4.51
209	2441.916	1.555	2.818	-C.382	0.791	0.1206	4.76
210	2531.982	1.269	5.842	-1.355	0.830	0.1266	4.67
211	2334.833	1.751	6.662	-1.759	0.673	0.1094	4.14
212	2331.841	3.356	3.394	-C.360	0.472	0.1051	3.52
213	9796.613	0.542	0.321	C.218	2.908	0.5215	20.22
214	1961.554	6.396	6.020	-C.333	0.236	0.0841	1.81
215	2199.231	2.317	8.302	-1.364	0.423	C.1004	2.77
216	1951.549	3.612	6.630	-C.391	0.261	0.0857	1.81
217	3394.650	0.884	2.303	-C.636	1.696	0.1889	9.27
218	2863.237	0.999	2.801	-0.689	1.329	0.1516	7.10
219	2702.113	1.126	10.572	-1.500	0.437	0.1167	2.41
220	2652.078	1.377	1.561	-0.067	1.042	0.1325	6.22
221	2627.072	2.804	1.654	C.0	0.646	0.1210	4.88
222	2119.670	2.633	5.260	-C.688	0.440	0.1003	2.93
223	2041.611	3.040	3.575	-C.759	0.831	0.1165	5.65
224	2730.141	1.514	1.419	0.118	0.913	0.1363	5.74
225	4503.508	0.731	0.812	C.163	2.027	0.2519	11.48
226	4403.418	0.509	2.892	-0.658	1.954	0.2379	8.75
227	3928.055	0.609	2.762	-0.467	1.482	0.2006	7.03
228	2261.801	3.302	4.841	-0.032	0.229	0.0939	1.68
229	2384.874	1.810	15.948	-C.800	0.147	0.0955	0.92
230	2175.715	2.723	10.207	C.125	0.110	0.0904	0.75
231	2704.115	1.124	13.213	-C.467	0.192	C.1119	1.06
232	275.217	3.365	1.136	C.200	0.236	0.0103	0.60
233	370.291	2.364	1.573	-C.200	C.346	0.0133	0.94
234	440.345	1.444	3.940	-C.600	0.308	0.0165	0.76
235	440.346	2.143	1.493	-C.033	0.258	0.0160	0.74
236	370.291	2.083	2.730	-C.900	0.280	0.0144	0.99
237	2952.308	1.034	11.753	-C.658	0.242	0.1180	1.34
238	1901.493	1.714	9.269	-C.933	0.302	0.0809	1.66
239	2101.647	1.333	4.929	-0.943	C.708	0.1016	3.71
240	2201.731	1.933	10.704	-1.869	0.371	0.0925	2.29
241	4403.426	0.630	1.599	-C.455	2.353	0.2535	12.06
242	1978.067	6.148	6.750	C.100	0.132	0.0822	1.01
243	2602.038	1.261	6.388	-1.194	0.586	0.1179	3.33
244	1779.410	7.156	43.447	C.026	C.024	0.0705	0.18
245	1741.383	11.429	37.333	-3.156	0.117	0.0728	0.90
246	1614.777	4.691	5.450	-C.743	0.429	0.0778	2.84
247	1698.846	7.260	5.568	-C.910	0.440	0.0832	3.19
248	927.728	1.561	0.687	-0.128	3.165	0.0745	11.75
249	938.236	1.561	0.838	-0.285	3.646	0.0835	13.61
250	652.513	1.937	9.983	-1.542	0.349	0.0285	1.17

TABLE ((4)) CONTINUE

SNO.	TH	CA/MG	SO4/CL	(CL-NA)/CL	NA/CA	IONIC STRENGTH	SAR
251	664.523	2.103	8.355	-1.750	0.464	0.0305	1.62
252	349.274	1.424	2.961	-0.605	0.595	0.0152	1.31
253	321.252	1.697	5.118	-1.500	0.470	0.0138	1.06
254	732.577	2.297	10.169	-1.034	0.235	0.0304	0.89
255	732.077	2.630	5.454	0.711	0.042	0.0259	0.16
256	341.770	2.948	4.598	-0.609	0.275	0.0137	0.76
257	341.268	2.072	3.559	-0.441	0.370	0.0141	0.92
258	276.719	3.456	6.216	0.054	0.081	0.0097	0.21
259	340.269	3.857	5.526	-0.368	0.193	0.0133	0.56
260	283.222	1.748	2.458	-0.610	0.528	0.0119	1.13
261	289.228	2.905	3.636	-2.434	0.791	0.0139	2.00
262	218.172	2.303	1.447	-0.026	0.257	0.0079	0.53
263	228.681	3.271	2.329	-2.382	0.734	0.0101	1.70
264	586.961	1.793	0.405	-0.014	2.324	0.0386	7.23
265	398.313	1.519	0.495	-0.219	4.313	0.0368	10.38
266	907.215	2.677	17.294	-1.235	0.144	0.0362	0.63
267	859.177	3.347	11.538	-1.615	0.257	0.0367	1.16
268	260.705	1.878	2.763	-0.368	0.306	0.0100	0.64
269	240.189	2.429	3.030	-1.677	0.779	0.0114	1.71
270	1813.934	4.246	34.949	-0.273	0.043	0.0731	0.30
271	1819.441	6.243	25.697	-3.467	0.217	0.0809	1.59
272	1732.872	6.024	31.667	-0.717	0.057	0.0693	0.41
273	1648.808	8.551	34.545	-5.283	0.211	0.0723	1.53
274	560.439	1.478	2.896	-1.043	1.707	0.0363	4.82
275	560.440	1.667	3.105	-1.260	1.786	0.0379	5.28
276	823.145	1.327	0.575	0.233	1.563	0.0448	5.11
277	1329.038	0.889	2.104	0.109	0.808	0.0619	2.77
278	2261.771	1.152	5.280	-0.685	0.628	0.1072	3.20
279	1934.521	1.938	16.767	-3.565	0.469	0.0909	2.72
280	593.964	0.875	4.530	-1.900	1.727	0.0348	3.93
281	405.316	0.800	4.444	-1.167	1.083	0.0200	1.94
282	1799.408	1.153	16.667	-4.300	0.826	0.0962	3.75
283	1123.379	1.088	20.000	-1.100	0.179	0.0452	0.63
284	528.410	0.517	3.746	-1.042	1.361	0.0250	2.13
285	390.304	0.773	2.296	-0.370	1.088	0.0183	1.87
286	440.343	0.630	1.905	0.0	1.235	0.0220	2.00
287	789.617	0.997	1.571	0.314	0.609	0.0339	1.71
288	629.992	0.908	1.613	0.290	0.735	0.0287	1.75
289	435.340	1.023	2.197	-0.258	0.886	0.0203	1.87
290	180.141	1.400	1.200	0.200	0.381	0.0066	0.60
291	2124.166	1.527	21.250	-0.700	0.133	0.0890	0.74
292	344.771	2.146	0.932	-0.390	2.426	0.0262	6.14
293	1078.348	2.014	9.037	-2.526	0.661	0.0530	2.90
294	1022.304	1.991	10.607	-2.299	0.512	0.0482	2.18
295	1077.348	2.401	13.243	-2.314	0.368	0.0483	1.71
296	1317.042	5.037	16.156	0.567	0.028	0.0517	0.17
297	1339.031	0.138	0.360	0.926	0.429	0.0449	0.38
298	1437.622	0.899	0.245	0.445	1.529	0.0681	5.49
299	4986.887	0.787	0.330	-0.136	8.547	0.5620	53.15
300	3262.507	0.048	1.100	-0.483	53.433	0.3194	28.08

TABLE ((4)) CONTINUE

SNO.	TH	CA/MG	SO4/CL	(CL-NA)/CL	NA/CA	IONIC STRENGTH	SAR
*****	********	********	*********	**********	********	**********	*****
301	1656.274	0.100	2.025	-0.637	18.010	0.1455	13.28
302	7217.918	1.372	1.079	0.399	0.690	0.1452	4.52
303	11584.047	0.934	0.059	0.181	5.875	1.0106	61.05
304	5727.509	0.182	0.269	0.915	0.435	0.3251	1.32
305	1757.391	5.780	35.067	0.111	0.027	0.0700	0.19
306	1649.299	0.232	0.083	0.971	0.119	0.0521	0.21
307	253.198	0.967	2.733	-1.033	0.779	0.0104	1.15
308	427.833	3.385	0.093	0.107	0.758	0.0186	2.42
309	1686.335	5.740	2.859	-0.396	0.447	0.0765	3.13
310	1023.521	4.555	27.736	-0.976	0.077	0.0760	0.55
311	2434.411	1.637	1.398	-0.406	1.166	0.1205	7.14
312	2907.299	2.438	0.413	0.111	1.891	0.1842	14.45
313	1936.521	1.834	1.633	-0.254	0.997	0.0990	5.64
314	2660.087	1.531	2.439	-0.550	0.771	0.1176	4.81
315	1329.594	0.981	0.597	-0.439	2.844	0.0817	9.53
316	2490.892	1.926	0.495	-0.451	2.663	0.1376	13.27
317	2478.946	1.630	1.736	-0.267	0.902	0.1200	5.57
318	2404.396	2.725	2.014	-0.373	0.734	0.1133	5.27
319	2415.834	1.391	1.499	-0.333	1.095	0.1165	6.24
320	2249.761	1.293	1.145	-0.113	1.235	0.1121	6.60
321	2483.946	1.558	1.473	-0.349	1.224	0.1275	7.43
322	2706.135	2.841	1.426	-0.274	0.892	0.1333	6.86
323	2374.870	2.305	2.446	-0.769	0.887	0.1182	6.03
324	1936.022	1.879	0.510	0.043	2.024	0.1252	11.62
325	645.507	1.580	0.536	-0.490	1.101	0.0286	3.43
326	194.144	1.244	2.375	0.179	0.225	0.0065	0.34

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#JOB,            UCFR04RH,TIME=60,PAGES=60
C      PROGRAMMER ** RAMZI H. HADDAD **
C      I=SERIAL NUMBER =SNO. GIVEN IN TABLES
C      A=CA IN MEQ/L , AA=CA IN PPM
C      B=MG IN MEQ/L , BB=MG IN PPM
C      C=NA IN MEQ/L , CC=NA IN PPM
C      D=K IN MEQ/L , DD=K IN PPM
C      E=HCO3 IN MEQ/L , EE=HCO3 IN PPM
C      F=CL IN MEQ/L , FF=CL IN PPM
C      G=SO4 IN MEQ/L , GG=SO4 IN PPM
C      H=NO3 IN MEQ/L , HH=NO3 IN PPM
C      AAL=LOGAA
C      BBL=LOG(BB)
C      CDL=LOG(CC+DD)
C      EEL=LOG(EE)
C      FFL=LOG(FF)
C      GGL=LOG(GG)
C      ABL=RATIO OF LOGS CA TO MG =P
C      BCDL=RATIO OF LOGS MG TO (NA+K) =Q
C      ACDL=RATIO OF LOGS CA TO (NA+K) =R
C      FGL=RATIO OF LOGS CL TO SO4  =T
C      GEL=RATIO OF LOGS SO4 TO HCO3   =U
C      FEL=RATIO OF LOGS CL TO HCO3  =X
C      CDFL=RATIO OF LOGS (NA+K) TO CL =S
C      GR=GROUP NUMBER
1            DIMENSION A(400),B(400),C(400),D(400),E(400),F(400),G(400),H(400),
     *GR(400),CD(400),AAL(400),BBL(400),CDL(400),EEL(400),FFL(400),GGL(4
     *00),ABL(400),BCDL(400),ACDL(400),FGL(400),GEL(400),FEL(400),CDFL(4
     *00),P(400),Q(400),R(400),T(400),U(400),X(400),S(400),AA(400),BB(40
     *0),CC(400),DD(400),EE(400),FF(400),GG(400),TSS(400),AX(400),BX(400
     *),CDX(400),EX(400),FX(400),GX(400),HH(400)
2      10  FORMAT(I4,8F8.3)
3     205  FORMAT(5X,I4,7F10.4,F20.0)
4          N=525
5          DO 20 I=1,N
6     20   READ(5,10)J,A(I),B(I),C(I),D(I),E(I),F(I),G(I),H(I)
7          CONTINUE
8          DO 21 I=1,N
9          AA(I)=20.04*A(I)
10         BB(I)=12.16*B(I)
11         CC(I)=23.00*C(I)
12         DD(I)=39.10*D(I)
13         EE(I)=61.01*E(I)
14         FF(I)=35.46*F(I)
15         GG(I)=48.03*G(I)
16         HH(I)=62.01*H(I)
17         TSS(I)=AA(I)+BB(I)+CC(I)+DD(I)+EE(I)+FF(I)+GG(I)+HH(I)
18         AX(I)=A(I)
19         BX(I)=B(I)
20         CDX(I)=C(I)+D(I)
21         EX(I)=E(I)
22         FX(I)=F(I)
23      21 GX(I)=G(I)
24         CONTINUE
25         DO 40 I=1,N
26         IF(E(I)-1.0)140,140,600
27    140  E(I)=1.001
28    600  IF(A(I)-1.0)141,141,601
29    141  A(I)=1.001
30    601  IF(B(I)-1.0)142,142,602
31    142  B(I)=1.001
32    602  IF(F(I)-1.0)143,143,603
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      145  F(I)=1.001
      605  IF(G(I)-1.0)144,144,40
      144  G(I)=1.001
      40   CD(I)=C(I)+D(I)
           CONTINUE
           DO 145 I=1,N
           IF(CD(I)-1.0)146,146,145
      146  CD(I)=1.001
      145  CONTINUE
           DO 50 I=1,N
           H(I)=0.0
           AAL(I)=ALOG( A(I))
           BBL(I)=ALOG( B(I))
           CDL(I)=ALOG(CD(I))
           EEL(I)=ALOG( E(I))
           FFL(I)=ALOG( F(I))
      50   GGL(I)=ALOG( G(I))
           CONTINUE
           DO 100 I=1,N
           ABL(I)=AAL(I)/BBL(I)
           P(I)=ABL(I)
           IF(APL(I)-1.0)100,101,102
      100  ABL(I)=1.0
           GO TO 103
      101  ABL(I)=2.0
           GO TO 103.
      102  ABL(I)=3.0
      103  BCDL(I)=ABL(I)/CDL(I)
           Q(I)=BCDL(I)
           IF(BCDL(I)-1.0)104,105,106
      104  BCDL(I)=10.0
           GO TO 107
      105  BCDL(I)=20.0
           GO TO 107
      106  BCDL(I)=30.0
      107  ACDL(I)=AAL(I)/CDL(I)
           R(I)=ACDL(I)
           IF(ACDL(I)-1.0)108,109,110
      108  ACDL(I)=100.0
           GO TO 300
      109  ACDL(I)=200.0
           GO TO 300
      110  ACDL(I)=300.0
      300  CDFL(I)=CDL(I)/FFL(I)
           S(I)=CDFL(I)
           IF(CDFL(I)-1.0)301,302,303
      301  CDFL(I)=1000.0
           GO TO 111
      302  CDFL(I)=2000.0
           GO TO 111
      303  CDFL(I)=3000.0
      111  FGL(I)=FFL(I)/GGL(I)
           T(I)=FGL(I)
           IF(FGL(I)-1.0)112,113,114
      112  FGL(I)=10000.0
           GO TO 115
      113  FGL(I)=20000.0
           GO TO 115
      114  FGL(I)=30000.0
      115  GEL(I)=GGL(I)/FEL(I)
           U(I)=GEL(I)
           IF(GEL(I)-1.0)116,117,118
      116  GEL(I)=100000.0
           GO TO 119
      117  GEL(I)=200000.0
           GO TO 119
      118  GEL(I)=300000.0
      119  FEL(I)=FFL(I)/EEL(I)
           X(I)=FEL(I)
           IF(FEL(I)-1.0)120,121,122
      120  FEL(I)=1000000.0
           GO TO 130
      121  FEL(I)=2000000.0
           GO TO 130
      122  FEL(I)=3000000.0
      130  GR(I)=APL(I)+BCDL(I)+ACDL(I)+FGL(I)+GEL(I)+FEL(I)+CDFL(I)
           CONTINUE
           WRITE(6,805)
      805  FORMAT(1H1,'      TABLE ((1)) ')
           WRITE(6,200)
      200  FORMAT    ( '      SNO.      CA/MG MG/(NA+K) CA/(NA+K) (NA+K)/CL     C
     *L/SO4  SO4/HCO3    CL/HCO3          GROUP NUMBER')
           WRITE(6,201)
      201  FORMAT('       ====      ===== ========= ========= =========     ====
     *     ========    =======          ============ ')
           DO 500 I=1,N
           IF(I-51)500,400,401
      401  IF(I-101)500,400,402
      402  IF(I-151)500,400,403
      403  IF(I-201)500,400,404
      404  IF(I-251)500,400,405
      405  IF(I-301)500,400,406
      406  IF(I-351)500,400,500
      400  WRITE(6,202)
      202  FORMAT(1H1,'      TABLE ((1)) CONTINUE  ')
           WRITE(6,203)
      203  FORMAT('       SNO.      CA/MG MG/(NA+K) CA/(NA+K) (NA+K)/CL     CL/SO
     *4  SO4/HCO3    CL/HCO3          GROUP NUMBER ')
           WRITE(6,204)
      204  FORMAT('       ====      ===== ========= ========= =========     ====
     *     ========    =======          ============ ')
      500  WRITE(6,205)I,P(I),Q(I),R(I),S(I),T(I),U(I),X(I),GR(I)
           CONTINUE
           K=1
           JJM=0
           KJ=1
           I=1
           JJ=1
           KKK=1
           XTS=TSS(I)
           XAX=AX(I)
           XBX=BX(I)
           XCDX=CDX(I)
           XEX=EX(I)
           XFX=FX(I)
           XGX=GX(I)
      650  XX=GR(I)
           KJ=KJ+1
           DO 700 I=KJ,N
           IF(GR(I)-XX)660,655,660
      655  JJ=JJ+1
           XTS=XTS+TSS(I)
           XAX=XAX+AX(I)
           XBX=XBX+BX(I)
           XCDX=XCDX+CDX(I)
           XEX=XEX+EX(I)
           XFX=XFX+FX(I)
           XGX=XGX+GX(I)
           GR(I)=5.0
           GO TO 700
      660  IF(KKK-1)670,665,670
      665  IF(GR(I)-5.0)675,700,675
```

```
      675  KJJ=I
      670  KKK=KKK+1
      700  CONTINUE
           XTS=XTS/JJ
           XAX=XAX/JJ
           XBX=XBX/JJ
           XCDX=XCDX/JJ
           XLX=XLX/JJ
           XFX=XFX/JJ
           XGX=XGX/JJ
           IF(K-1)802,801,802
      801  WRITE(6,754)
      754  FORMAT(1H1,'  TABLE  ((2))     GROUNDWATER GROUPS AND THEIR GENERA
     $LIZED CHARACTERISTICS  ')
           WRITE(6,752)
      752  FORMAT(///,'  TOTAL NO      GROUP     AV.TSS      AV.CA      AV.MG  AV
     $(NA+K)      AV.CL     AV.SO4    AV.HCO3  ')
           WRITE(6,753)
      753  FORMAT('  ========      =====     ======      =====      =====  ======
     $==      =====    ======   =======  ')
      802  WRITE(6,755)JJ,XX,XTS,XAX,XBX,XCDX,XFX,XGX,XEX
      755  FORMAT(/,4X,I4,2X,F10.0,7F10.2)
           K=K+1
           JJM=JJM+JJ
           KJ=KJJ
           I=KJ
           KKK=1
           JJ=1
           XTS=TSS(I)
           XAX=AX(I)
           XBX=BX(I)
           XCDX=CDX(I)
           XEX=EX(I)
           XFX=FX(I)
           XGX=GX(I)
           IF(JJM-N)770,800,800
      770  GO TO 650
      800  CONTINUE
           STOP
           END

           ENTRY
```

TABLE ((1))

SNO.	CA/MG	MG/(NA+K)	CA/(NA+K)	(NA+K)/CL	CL/SO4	SO4/HCO3	CL/HCO3	GROUP NUMBER
1	1.4347	0.5210	0.7475	0.9791	1.5410	1.9715	2.6458	5551115.
2	1.2752	1755.5540	2212.6710	1.0000	0.0005	1.1129	0.0005	1512555.
3	1.5966	2.2704	3.6250	12.2141	0.0215	4.9585	0.1065	1515555.
4	1.1718	0.9150	1.0721	1.5495	0.4893	3745.6170	1832.7550	5515515.
5	1.3947	2.2619	3.1546	0.8512	0.3602	3.7565	1.3855	5511555.
6	1.5072	1.8104	2.7285	1.4972	0.2296	4.1829	0.9606	1515555.
7	1.7272	1965.9000	3395.5030	1.0000	0.0005	4.9609	0.0014	1512555.
8	1.6718	42.1010	70.3825	48.7950	0.0005	2.6513	0.0007	1515555.
9	2.1078	1617.5600	3409.4910	1.0000	0.0005	6.0827	0.0017	1512555.
10	1.6091	4.5215	6.1796	4.7580	0.0248	2.6506	0.0655	1515555.
11	1.9173	1.9366	3.7151	708.1035	0.0004	2.1758	0.0008	1515555.
12	1.6467	2.5714	4.2342	604.3755	0.0004	1.5868	0.0006	1515555.
13	1.7042	2.5602	4.3635	2.3476	0.0936	2.4851	0.2325	1515555.
14	2.1226	1.5379	3.2644	2.6460	0.2055	0.6549	0.1345	1115555.
15	1.5846	1.4216	2.2527	2.5743	0.1614	1.9005	0.3068	1515555.
16	1.5816	1.5049	2.3801	2.5652	0.1494	2.0043	0.2994	1515555.
17	2.4556	1.5093	3.7052	425.5081	0.0011	0.6524	0.0007	1115555.
18	1.6770	1.8976	3.1825	10.4790	0.0291	1.8430	0.0537	1515555.
19	32.2776	1.6506	53.2789	29.5614	0.0014	0.5492	0.0008	1115555.
20	2.5206	12.0472	30.3667	48.7950	0.0017	0.4406	0.0007	1115555.
21	3.6516	19.4556	74.9350	19.8040	0.0014	0.5519	0.0008	1115555.
22	1329.8500	1.0000	1329.8500	1.0000	1.0000	0.0007	0.0007	1122525.
23	955.6050	1.0000	955.6050	1.0000	1.0000	0.0008	0.0008	1122525.
24	1308.4570	1.0000	1308.4570	1.0000	1.0000	0.0007	0.0007	1122525.
25	2.6037	1.5822	5.5907	1.4204	0.9185	0.2551	0.2141	1115555.
26	1.2457	0.5802	0.7328	25.8514	0.0322	1.6118	0.0519	1515115.
27	1.2055	1.5622	1.8800	1.8598	0.2554	5.5792	0.9142	1515555.
28	1.2579	1.5651	1.9687	1.2995	0.5565	5.7916	1.5510	5515555.
29	1.1884	1.5460	1.8375	1.5950	0.5522	5.1258	1.1005	5515555.
30	1.3218	1.0200	1.3482	1.4580	0.4227	14.0143	5.9255	5515555.
31	1.0364	1.2822	1.3314	1.5035	0.5029	6.8161	3.4279	5515555.
32	1.5498	0.6575	0.9086	1.2804	0.6326	2694.8840	1704.9100	5515115.
33	0.6322	1.0493	0.6752	1.2810	0.6558	2.0082	1.3129	5515151.
34	1.6174	0.5448	1.5281	2.2562	0.2587	5.6111	1.4515	5515515.
35	0.8157	0.7526	0.5976	1.2204	0.7542	5.1125	2.5474	5515111.
36	1.0000	0.8351	0.8351	0.8195	1.5210	8.7714	13.5415	5551112.
37	1.1619	0.8578	0.9754	0.7900	1.4151	2067.0590	2925.0530	5551115.
38	1.0967	0.8102	0.8804	0.9720	1.0299	2.7908	2.8742	5551115.
39	0.9676	1.1046	1.0687	1.6884	0.4550	5.4751	1.5047	5515551.
40	0.8852	1.1129	0.9850	1.6187	0.4688	2.7663	1.2968	5515151.
41	0.9954	0.9129	0.9068	1.0890	0.8006	35.5975	26.7564	5515111.
42	1.3668	0.8871	1.2142	0.9356	0.8917	1.6952	1.5116	5511515.
43	2.2363	0.4468	1.0000	1.0147	2.4042	0.3704	0.8905	1155215.
44	1.4441	1.6756	2.4197	0.4059	2.6702	1.1045	2.9486	5551555.
45	1.2912	2.1617	2.7910	0.9037	0.3863	2.5862	0.9217	1511555.
46	1.0606	1.6314	1.7305	2.4240	0.2092	1.6909	0.3537	1515555.
47	1.1503	1.1600	1.3344	1.1681	0.5671	2.9668	1.6824	5515555.
48	1.2205	1.6591	2.0250	1.4354	0.3151	2.8628	0.9022	1515555.
49	1.6423	2067.0590	3394.8330	1.0000	0.0005	4.5445	0.0012	1512555.
50	1.6423	2067.0590	3394.8550	1.0000	0.0005	4.5041	0.0012	1512555.

TABLE (11) CONTINUE

SNO.	CA/MG	MG/(NA+K)	CA/(NA+K)	(NA+K)/CL	CL/SO4	SO4/HCO3	CL/HCO3	GROUP NUMBER
51	1.0566	1.2047	1.3575	1.4157	0.4467	4.1464	1.8523	3313333.
52	0.9339	1.0758	1.0243	1.2782	0.6040	3.5480	2.1429	3313331.
53	1.0236	1.3481	1.3798	1.5061	0.4138	4.4853	1.8561	3313333.
54	1.1039	1.3108	1.4469	1.7291	0.3428	6.1078	2.0938	3313333.
55	0.9800	1.0983	1.0764	1.1672	0.6628	2.6061	1.7272	3313331.
56	1.2511	1.6044	2.0824	2.0215	0.2138	2.6622	0.5691	1313333.
57	1.1419	1.5087	1.7228	1.3234	0.3921	2.5764	1.0103	3313333.
58	1.5204	2.3282	3.5399	4.5788	0.0863	0.8094	0.0699	1113333.
59	1.5212	1.5044	2.2886	1.7313	0.2758	1.2491	0.3445	1313333.
60	1.5975	0.7359	1.1755	0.8562	1.2674	1.3706	1.7644	
61	3.0371	1.2050	3.6597	405.5037	0.0013	0.5298	0.0007	1113333.
62	1.3304	2.9761	3.9592	2.2063	0.1059	3.6293	0.3842	1313333.
63	1292.1070	1.0000	1292.1070	1.0000	1.0000	0.0007	0.0007	1122323.
64	24.6768	67.6648	1669.7510	1.0000	0.0008	1.3459	0.0010	1312333.
65	1111.9630	1.0000	1111.9630	1.0000	1.0000	0.0008	0.0008	1122323.
66	1.1173	0.8469	1.0021	1.6107	0.4943	6.6585	3.2747	3313313.
67	1.4114	2299.8000	3246.0210	1.0000	0.0003	4.2554	0.0012	1312333.
68	1.1559	1.4818	1.7128	1.7634	0.2904	5.9927	1.7403	3313333.
69	1.1591	0.8933	1.0354	1.7640	0.4433	16.2684	7.2126	3313313.
70	0.6546	0.9806	0.8581	3.5080	0.2126	2.9739	0.6321	1313111.
71	0.8806	0.9706	0.8547	3.8778	0.1863	3.2339	0.6025	1313111.
72	1.1152	1.0457	1.1662	3.8580	0.1753	1.8028	0.3500	1313333.
73	1.0588	1.3757	1.4566	1.1436	0.5109	1.8009	0.9201	1313333.
74	1.1928	1.4781	1.7630	1.5286	0.3294	2.7068	0.8917	1313333.
75	1.2464	1.5974	1.9910	1.9486	0.2526	2.1984	0.5112	1313333.
76	0.9422	1.4535	1.3752	1.4572	0.3876	2.9312	1.1361	3313331.
77	0.8310	0.9085	0.7550	1.6236	0.5166	2.2472	1.1610	3313111.
78	0.8669	0.8266	0.7182	1.7604	0.5122	2.2665	1.1610	3313111.
79	0.8184	0.8743	0.7155	2.0088	0.3964	1.8407	0.7297	1313111.
80	0.7598	0.8143	0.6187	2.2150	0.4122	1.7705	0.7297	1313111.
81	0.8171	0.9965	0.8061	1.3615	0.6291	3.4673	2.1813	3313111.
82	1.1746	0.9174	1.0777	1.4842	0.5247	4.1917	2.1992	3313313.
83	1.6197	0.5252	0.5255	1.2985	0.7805	15.7685	12.3065	3313113.
84	2.0820	0.2623	0.5462	1.4898	0.7641	4.8549	3.7095	3313113.
85	1.4758	12.6511	18.6406	173.9696	0.0003	3.0076	0.0009	1313333.
86	1.1735	0.8457	0.9899	1.3758	0.6099	4.1117.	2.5076	3313113.
87	1.1101	1.0045	1.1151	3.0452	0.2385	3.2097	0.7654	1313333.
88	0.8873	0.9357	0.8303	1.0870	0.8608	5.8588	5.0432	3313111.
89	0.9836	0.9015	0.8868	1.1596	0.7593	3.8221	2.9022	3313111.
90	0.9927	0.9330	0.9261	1.1543	0.7461	3.8210	2.8510	3313111.
91	0.8809	0.9307	0.8199	1.1482	0.7663	2.6390	2.0222	3313111.
92	0.8507	0.9716	0.8265	1.2930	0.6655	4.1713	2.7761	3313111.
93	1.0266	0.9525	0.9779	1.0788	0.7729	14.2122	10.9840	3313113.
94	0.8644	0.8401	0.7262	2.0298	0.4068	2.0433	0.8312	1313111.
95	0.9964	0.7984	0.7955	2.1529	0.3780	1.8606	0.7033	1313111.
96	1.1164	0.6626	0.7397	1731.8200	0.0005	1.1733	0.0006	1313113.
97	1.1316	0.9579	1.0840	1.4113	0.5193	4.5429	2.3590	3313313.
98	1.1686	0.9506	1.1109	1.6071	0.4513	3.8756	1.7490	3313313.
99	1.0125	0.9330	0.9446	1.8965	0.4052	4.6074	1.8671	3313113.
100	0.9231	1.0992	1.0146	1.5589	0.4540	4.6117	2.0938	3313331.

TABLE ((1)) CONTINUE

SNO.	CA/MG	MG/(NA+K)	CA/(NA+K)	(NA+K)/CL	CL/SO4	SO4/HCO3	CL/HCO3	GROUP NUMBER
101	1.0253	1.0276	1.0536	1.6953	0.4267	2.3678	1.0103	3313333.
102	1.1528	1.0138	1.1687	1.1533	0.6710	3.3305	2.3691	3313333.
103	1.0153	0.9580	0.9726	1.4117	0.5753	4.2709	2.4570	3313113.
104	1.0069	0.9614	0.9680	1.5365	0.5229	5.6070	2.9317	3313113.
105	1.1999	0.9513	1.1415	1.1067	0.7229	5.8597	4.2361	3313313.
106	2.1598	7.3118	15.7920	198.8701	0.0003	6.2004	0.0019	1313333.
107	0.8709	0.7835	0.6886	1.1528	0.8447	4.0563	3.4263	3313111.
108	1.0754	0.7766	0.8351	1.0969	0.9243	2.4826	2.2948	3313113.
109	1.0166	0.8114	0.8249	1.0322	0.9951	10.5297	10.4781	3313113.
110	1.2224	0.4767	0.5827	1.1099	1.0192	12.3059	12.5503	3333113.
111	1.2557	0.9687	1.2164	1.2054	0.6800	1.0770	0.7323	1313313.
112	1.0324	1.1527	1.1694	1.3367	0.5831	1.1724	0.6837	1313333.
113	1.4501	1.1764	1.7059	3.3145	0.1570	3.8567	0.6025	1313333.
114	1.6042	1.8346	2.9431	982.1721	0.0003	2.8951	0.0009	1313333.
115	1.3563	2.5005	3.3914	896.1736	0.0003	2.7394	0.0009	1313333.
116	2.0337	6.8558	13.1270	262.3887	0.0003	3.0526	0.0009	1313333.
117	1.8912	19.2275	36.3626	95.3196	0.0003	3.1615	0.0009	1313333.
118	1.7252	40.1746	69.2278	48.7941	0.0003	4.6271	0.0013	1313333.
119	1.9544	1750.0250	3453.4870	1.0000	0.0003	5.0644	0.0014	1312333.
120	1.2441	1.3093	1.6289	2.5324	0.2996	0.7736	0.2318	1113333.
121	1.4045	1.1637	1.6625	2.9801	0.1700	3.9877	0.7094	1313333.
122	3.6168	0.1589	0.6065	1.0255	1.8025	0.8500	1.6001	3133113.
123	1.0822	0.6309	0.6828	0.8961	1.8415	3.3471	6.1635	3331113.
124	0.9129	0.7672	0.7004	0.8774	1.8835	3.6708	6.9139	3331111.
125	1.5363	0.4099	0.6298	1.0041	1.5740	1.1527	1.7828	3333113.
126	1.1270	0.8508	0.9363	0.8385	1.3485	37.8032	50.9773	3331113.
127	1.0099	1.0023	1.0122	1.2581	0.6694	2.8297	1.8943	3313333.
128	1.4078	1.0796	1.5199	1.0953	0.5682	2.1718	1.2339	3313333.
129	0.9784	0.7263	0.7107	1.3677	0.7097	2.9705	2.1079	3313111.
130	1.0337	0.7200	0.7445	1.3255	0.7368	1.6134	1.1887	3313113.
131	1.0686	0.7379	0.7885	1.2206	0.7742	17.6464	13.6438	3313113.
132	1.0261	0.7923	0.7617	1.4689	0.6435	7.0882	4.5613	3313113.
133	1.1498	0.8776	1.0090	1.1448	0.7354	7.1550	5.2615	3313313.
134	1.1212	0.9276	1.0401	1.1077	0.7551	5.3457	2.5196	3313313.
135	1.1278	0.9798	1.1050	1.2589	0.6149	7.6646	4.7129	3313313.
136	0.9695	0.9087	0.8810	1.5187	0.5659	4.0519	2.2929	3313111.
137	1.1958	0.9505	1.1127	1.2546	0.6388	6.9508	4.4404	3313313.
138	1.1392	0.8495	0.9678	1.1873	0.7385	8.2042	6.0586	3313113.
139	1.1096	0.8598	0.9319	1.1756	0.7911	4.4408	3.5129	3313113.
140	1.0917	1.0059	1.0959	1.4893	0.5040	3.8852	1.9569	3313333.
141	0.8939	1.0179	0.9099	1.4669	0.5636	7.8125	4.4028	3313131.
142	1.4321	0.9567	1.3701	1.3677	0.5118	3.4777	1.7799	3313313.
143	1.6421	1.0603	1.7410	1.0933	0.5225	4.6983	2.4550	3313333.
144	1.0941	0.8086	0.8847	1.5398	0.5673	5.5901	3.1713	3313113.
145	0.9135	0.8760	0.8003	1.3140	0.7021	9.0750	6.3717	3313111.
146	1.2826	0.8053	1.0304	1.1032	0.8536	3.4236	2.6540	3313313.
147	2.1347	2.1538	4.5550	2.2192	0.0987	3.1055	0.3063	1313333.
148	1.0951	0.8750	0.9582	1.1257	0.7765	5.8253	4.5236	3313113.
149	0.7231	0.6853	0.4955	1.0057	1.1459	5.0400	5.7755	3333111.
150	1.2826	0.7748	0.9938	0.9895	0.9654	11.6560	11.2528	3311113.

TABLE ((1)) CONTINUE

SNO.	CA/MG	MG/(NA+K)	CA/(NA+K)	(NA+K)/CL	CL/SO4	SO4/HCO3	CL/HCO3	GROUP NUMBER
151	2.0399	0.4851	2.0095	1.2761	0.5786	4.4919	1.7004	3313313.
152	2.7660	1229.7570	3401.5220	1.0000	0.0005	4.4579	0.0013	1312333.
153	48.7130	67.6648	3296.1510	1.0000	0.0005	3.7168	0.0012	1312333.
154	1.1327	0.8771	0.9935	1.0059	0.8901	5.0286	4.4760	3313113.
155	1.7886	1.7242	3.0839	0.8608	0.3656	4.2258	1.5448	3311333.
156	1.1604	0.8474	1.0297	1.1541	0.7482	5.5732	4.1699	3313313.
157	1.4635	0.8120	1.1884	1.1650	0.6692	3.7009	2.4768	3313313.
158	1.3590	0.8651	1.1756	1.1875	0.6566	5.0053	3.2864	3313313.
159	1.5775	0.7755	1.2235	1.4061	0.5315	6.4496	3.4279	3313313.
160	1.3781	1.0010	1.3795	1.2670	0.5272	6.5963	3.4772	3313333.
161	1.1146	0.9442	1.0524	1.0441	0.7961	7.0859	5.6414	3313313.
162	1.0875	0.7892	0.8582	1.1350	0.8629	6.4757	5.5861	3313113.
163	1.7048	0.8071	1.3759	1.3933	0.4906	11.3393	5.5630	3313313.
164	6.3893	536.5447	3428.4910	1.0000	0.0005	5.3773	0.0016	1312333.
165	0.6626	0.9589	0.8271	0.9794	1.0766	1.8532	1.9952	3331111.
166	1.3440	0.5918	0.7954	0.9846	1.1615	2977.3430	3458.2230	3331113.
167	1.0924	0.7876	0.8605	1.0717	0.9112	5.6782	5.1741	3313113.
168	1.1954	0.8440	1.0088	0.9847	0.9188	3765.8850	3458.2230	3311313.
169	1.1975	0.8515	1.0197	1.2030	0.7060	3.8008	2.6835	3313313.
170	2.6244	2.4909	6.5375	0.3477	0.4480	5.7414	2.5720	3311333.
171	2.1911	1.0700	2.3445	0.7465	0.5933	5.7773	3.4279	3311333.
172	1.1493	0.9559	1.0963	0.9557	0.9567	9.3774	8.9714	3311313.
173	1.0383	2.2508	2.3370	1.5431	0.2350	4.2547	1.0000	2313333.
174	1.2375	2.2308	2.7606	2.2849	0.1406	8.7847	1.2351	3313333.
175	1.2549	1.4664	1.8402	1.9980	0.2457	4.0692	1.0000	2313333.
176	1.0425	2.3947	2.4963	1.4190	0.2477	7.5706	1.8754	3313313.
177	1.2467	0.9780	1.2192	1.3413	0.5323	9.0164	4.7992	3313313.
178	1.2412	0.9594	1.1908	1.5091	0.4745	11.1604	5.2929	3313313.
179	1.2197	1.0530	1.2843	1.5477	0.5080	5.8699	1.9659	3313333.
180	1.2422	1.0530	1.3079	1.7775	0.3770	7.8553	2.9615	3313333.
181	1.2735	0.9054	1.1531	1.2077	0.6416	6.8027	4.3643	3313313.
182	1.2989	0.9413	1.2226	0.9594	0.8056	7.5141	6.0533	3311313.
183	1.4852	0.9605	1.4266	1.0241	0.6519	28.9011	18.8400	3313313.
184	1.4635	0.8183	1.1976	1.1560	0.6768	11.0025	7.4465	3313313.
185	1.3632	0.8961	1.2216	1.1203	0.6810	6.3830	4.3466	3313313.
186	1.4849	0.6858	1.0195	0.8910	1.2508	2.8749	3.5959	3331313.
187	0.9382	0.8621	0.8088	1.3168	0.6869	10.0652	6.9159	3313111.
188	1.2759	0.7556	0.9561	1.2529	0.7157	4.3755	3.1301	3313113.
189	1.0547	0.9919	1.0462	1.2237	0.6494	5.4105	3.5137	3313313.
190	0.9634	1.0760	1.0366	1.3137	0.5912	3.9053	2.3089	3313331.
191	1.3795	0.9481	1.3079	1.3564	0.5209	4.3086	2.2442	3313313.
192	1.4244	1.2933	1.8421	1.8523	0.2740	3.6490	1.0000	2313333.
193	1.0247	0.8572	0.8783	1.1245	0.8008	18.8450	15.0903	3313113.
194	1.0487	0.8274	0.8677	1.2053	0.7596	10.9047	8.2832	3313113.
195	1.2816	0.8378	1.0737	1.1653	0.7187	7.8963	5.6748	3313313.
196	1.1770	0.9147	1.0767	1.1886	0.6973	9.5782	6.6789	3313313.
197	1.0468	0.8526	0.8924	1.0491	0.9254	5.4870	5.0778	3313113.
198	1.7395	0.7665	1.3334	1.1408	0.6315	7.4634	4.7128	3313313.
199	1.1843	0.9156	1.0820	1.7154	0.4468	4.3768	1.9554	3313313.
200	1.4206	0.9004	1.2791	1.1212	0.6524	3.5309	2.3089	3313313.

TABLE ((1)) CONTINUE

SNO.	CA/MG	MG/(NA+K)	CA/(NA+K)	(NA+K)/CL	CL/SO4	SO4/HCO3	CL/HCO3	GROUP NUMBER
201	14.0011	246.8835	3456.6460	1.0000	0.0003	3.6832	0.0011	1312333.
202	1.5477	1.0081	1.6841	1.4026	0.3987	4.1851	1.6687	3313333.
203	1.5260	25.6933	36.4608	0.2833	0.0905	2.9670	0.2686	1311333.
204	1.0439	1.2103	1.2635	1.2853	0.5154	4.2551	2.1918	3313333.
205	1.2759	1.0123	1.2916	1.3624	0.5097	3.8436	1.9591	3313333.
206	1.1328	0.8970	1.0161	1.1014	0.7728	3.4390	2.6575	3313313.
207	0.9814	0.9395	0.9220	1.1131	0.8058	5.2165	4.2034	3313111.
208	1.2096	0.9101	1.1009	1.1348	0.7194	5.1349	3.6942	3313313.
209	1.1497	0.9332	1.0729	1.1156	0.7523	4.6453	3.4016	3313313.
210	1.0767	0.9819	1.0573	1.3743	0.5659	6.9830	3.9514	3313313.
211	1.1979	0.9432	1.1299	1.5150	0.5109	8.2498	4.2149	3313313.
212	1.5179	0.8302	1.2601	1.1259	0.6739	4.0902	2.7565	3313313.
213	0.6735	0.9139	0.7983	0.9558	1.2574	5.2946	6.6576	3331111.
214	2.1127	0.7709	1.6287	1.2074	0.4995	3.4837	1.7402	3313313.
215	1.3252	0.9911	1.3134	1.5293	0.4461	4.1703	1.8605	3313313.
216	1.6001	0.9551	1.5282	1.2810	0.4805	6.8612	3.2965	3313313.
217	0.9657	0.8970	0.8662	1.1426	0.8073	4.1352	3.3385	3313111.
218	0.9998	0.9206	0.9204	1.1702	0.7514	5.5846	4.1965	3313111.
219	1.0367	1.2755	1.3223	1.5758	0.4056	5.3477	2.1692	3313333.
220	1.1030	0.8949	0.9871	1.0200	0.8843	3.2216	2.8488	3313113.
221	1.3929	0.8136	1.1332	1.0022	0.8648	2.6379	2.2813	3313313.
222	1.3942	0.9304	1.3083	1.2587	0.5561	3.9137	2.1763	3313313.
223	1.4307	0.7128	1.0555	1.2132	0.6773	5.6960	3.8580	3313313.
224	1.1349	0.9027	1.0244	0.9668	0.9097	4.4280	4.0280	3311313.
225	0.9206	0.9095	0.8373	0.9608	1.0483	3.7084	3.8875	3331111.
226	0.8341	1.0004	0.8345	1.1430	0.7700	3.2725	2.5198	3313131.
227	0.8723	1.0241	0.8933	1.1162	0.7700	3.1863	2.4534	3313131.
228	1.5060	1.0707	1.6124	1.0768	0.5649	2.8955	1.6345	3313333.
229	1.2096	1.8420	2.2281	1.6773	0.2486	1.6903	0.4202	1313333.
230	1.4075	1.8984	2.6720	0.9339	0.3737	2.4662	0.9217	1311333.
231	1.0362	1.7434	1.8065	1.4044	0.3387	3.7907	1.2837	3313333.
232	6.2505	251.1340	1444.7010	0.0045	0.6364	0.2331	0.1484	1111333.
233	2.0910	1.3414	2.8049	1.4497	0.4722	0.6563	0.3099	1113333.
234	1.2671	2.7254	3.5078	470.0488	0.0007	1.1485	0.0008	1313333.
235	1.7402	2.3494	4.0884	1.0809	0.5028	0.5285	0.2657	1113333.
236	1.8384	1.3640	2.5075	641.9150	0.0010	0.6490	0.0006	1113333.
237	1.0101	1.6986	1.7157	1.3421	0.3748	3.1460	1.1790	3313333.
238	1.2042	1.3322	1.6043	1.4988	0.3725	2.5597	0.9534	1313333.
239	1.0995	1.0202	1.1217	1.3062	0.5762	2.1009	1.2106	3313333.
240	1.2434	1.1398	1.4173	1.7975	0.3580	4.4531	1.5869	3313333.
241	0.6840	0.9103	0.8047	1.0935	0.8952	3.2291	2.8907	3313111.
242	2.0620	1.1370	2.3445	0.9545	0.4574	2.3751	1.0863	3311333.
243	1.0759	1.1067	1.1905	1.3836	0.5248	2.8672	1.5046	3313333.
244	2.3365	1472.6120	3440.7460	1.0000	0.0003	4.2432	0.0012	1312333.
245	3.3660	0.7806	2.6274	1319.2110	0.0003	2.4995	0.0007	1313313.
246	1.8908	0.7130	1.3482	1.2959	0.5255	8.0359	4.2231	3313313.
247	2.4026	0.5408	1.3184	1.3355	0.5290	7.8616	4.1589	3313313.
248	1.2249	0.5535	0.6779	1.0349	1.1220	3080.8270	3456.6460	3333113.
249	1.2239	0.5337	0.6532	1.0721	1.0556	3302.4280	3479.4160	3333113.
250	1.4435	1.3569	1.9586	6.6376	0.0671	2.1800	0.1463	1313333.

TABLE ((1)) CONTINUE

SNO.	CA/MG	MG/(NA+K)	CA/(NA+K)	(NA+K)/CL	CL/SO4	SO4/HCO3	CL/HCO3	GROUP NUMBER
251	1.5112	1.0165	1.5362	3.4160	0.1647	2.1397	0.3525	1313333.
252	1.3339	1.1059	1.5018	2.1303	0.2704	1.2261	0.3413	1313333.
253	1.6102	1.3509	2.1753	641.9150	0.0007	0.9269	0.0007	1113333.
254	1.5580	1.7027	2.6527	5.2894	0.0666	1.8433	0.1228	1313333.
255	1.6939	1393.8980	2361.0790	0.0024	0.1980	1.5541	0.3077	1311333.
256	2.9724	1.6290	4.8421	336.5039	0.0007	1.1731	0.0008	1313333.
257	1.9135	1.5029	2.8759	3.2059	0.1153	1.2648	0.1459	1313333.
258	7.0460	207.0356	1458.7530	1.0000	0.0012	0.7874	0.0009	1112333.
259	5.0120	8.5789	42.9977	39.2244	0.0007	1.3567	0.0009	1313333.
260	1.7724	1.1260	1.9957	3.8779	0.1555	0.8558	0.1330	1113333.
261	3.7206	0.3204	1.1919	1223.8920	0.0008	0.8430	0.0007	1113313.
262	4.0048	277.6580	1111.9630	1.0000	0.0105	0.0802	0.0008	1112333.
263	18.5160	0.0717	1.3272	943.9961	0.0018	0.3979	0.0007	1113313.
264	1.4068	0.5014	0.7054	1.0048	1.4649	1.2267	1.7969	3333113.
265	1.3633	0.3797	0.5177	1.0699	1.3307	1.8297	2.4348	3333113.
266	1.6173	2.4055	4.0199	641.9150	0.0004	1.9675	0.0007	1313333.
267	1.8794	1.1225	2.1096	4.6644	0.0969	1.8686	0.1810	1313333.
268	2.0626	15.1279	31.2023	39.2244	0.0013	0.6092	0.0008	1113333.
269	3.6371	0.3453	1.2557	974.6526	0.0009	0.8830	0.0008	1113313.
270	1.7481	8.3658	14.6204	231.1340	0.0003	4.8710	0.0014	1313333.
271	2.1351	0.8423	1.7985	4.5746	0.1142	3.9318	0.4492	1313313.
272	2.1257	3.0065	6.3908	530.6787	0.0003	2.5080	0.0007	1313333.
273	2.7329	0.6775	1.8517	1827.9440	0.0003	3.2349	0.0009	1313313.
274	1.2589	0.6199	0.7804	1.4156	0.6178	2782.8040	1719.3330	3313113.
275	1.3560	0.5682	0.7704	1.4769	0.6015	2843.4350	1710.3300	3313113.
276	1.1445	0.7284	0.8337	0.9100	1.2306	2398.1240	2951.0160	3331113.
277	0.9555	1.1430	1.0922	0.9523	0.7655	9.6331	7.3741	3311331.
278	1.0466	1.1188	1.1709	1.2373	0.5693	2.8124	1.6011	3313333.
279	1.2567	1.0385	1.3051	2.5764	0.2546	5.2339	1.3327	3313333.
280	0.9278	0.6170	0.7580	1.8918	0.4414	2.3379	1.0320	3313111.
281	0.8516	1.0949	0.9325	2.3371	0.2827	4.3664	1.2342	3313131.
282	1.0307	1.0132	1.0445	2.5294	0.2808	3912.3970	1098.7170	3313333.
283	1.0357	3.1216	3.2329	760.8787	0.0003	4.3219	0.0014	1313333.
284	0.6602	1.2146	0.8019	1.8246	0.3986	1.8881	0.7527	1313131.
285	0.8260	1.1278	0.9315	1.3226	0.5444	2.6323	1.4330	3313131.
286	0.7257	1.1712	0.8499	1.0033	0.6901	3.3377	2.4415	3313131.
287	0.9988	1.3107	1.3091	0.8104	0.8115	3.0412	2.4680	3311331.
288	0.9486	1.2679	1.2027	0.8158	0.7924	6.8433	5.4226	3311331.
289	1.0158	1.0677	1.0846	1.2074	0.5898	2.1913	1.2923	3313333.
290	1.8298	405.5037	742.0005	1.0000	0.0055	0.3879	0.0021	1112333.
291	1.1500	2.1134	2.4304	1.9260	0.1849	6.3790	1.1792	3313333.
292	1.9742	0.3221	0.6359	1.1566	1.0348	1.5542	1.6083	3333113.
293	1.3559	0.6730	1.1836	2.2687	0.3109	5.4349	1.6898	3313313.
294	1.3585	0.9903	1.3453	2.5984	0.2402	6.2830	1.5094	3313313.
295	1.4747	1.0711	1.5796	3.2852	0.1688	7.9282	1.3384	3313333.
296	2.0980	1472.6120	3089.5180	0.0029	0.1099	2.6316	0.2893	1311333.
297	0.3723	9.5095	3.5699	0.1120	1.5321	2.1312	3.2651	3331331.
298	0.9608	0.8951	0.8600	0.8374	1.6332	3.2730	3.3454	3331111.
299	0.9405	0.6784	0.6380	1.0219	1.2366	17.3702	21.4804	3333111.
300	0.2660	0.8135	0.2164	1.0841	0.9801	6.3195	6.1958	3313111.
301	0.3227	0.8534	0.2754	1.1410	0.8521	2.9782	2.4781	3313111.
302	1.0959	1.0169	1.1144	0.8645	0.9801	5.0627	4.9620	3311333.
303	0.9357	0.7376	0.7271	0.9701	1.7321	2.5439	4.4928	3331111.
304	0.6659	1.9095	1.3247	0.5099	1.3527	1.4499	1.9612	3331331.
305	2.0666	1644.9620	3399.5200	1.0000	0.0003	2.2652	0.0007	1312333.
306	0.6118	3258.4070	1993.5290	0.0003	3.7119	1.6896	6.2715	3331331.
307	0.6570	1.5793	1.0335	631.3319	0.0011	0.8773	0.0010	1113331.
308	2.6257	0.4149	1.1725	0.9342	1722.9300	0.0005	0.8077	1131313.
309	2.0898	0.6305	1.3191	1.1502	0.6787	1.3604	0.9237	1313113.
310	1.7850	2.1767	3.8863	4.2490	0.0590	2.3143	0.1364	1313333.
311	1.1690	0.8186	0.9570	1.1058	0.9058	1.3672	1.2384	3313113.
312	1.3152	0.6491	0.8537	0.9738	1.2462	1.3509	1.6835	3331113.
313	1.2249	0.8171	1.0009	1.0758	0.8589	1.4283	1.2269	3313313.
314	1.1400	0.9425	1.0744	1.1654	0.7566	1.6198	1.2256	3313313.
315	0.9531	0.7434	0.7085	1.1152	1.1087	1.0280	1.2220	3333111.
316	1.1663	0.8779	1.0239	1.0673	0.8503	1.6073	1.3667	3313313.
317	1.3920	0.7867	1.0950	1.1080	0.8074	1.5714	1.2687	3313313.
318	1.1072	0.8760	0.9699	1.0957	0.8874	1.3425	1.1913	3313113.
319	1.0863	0.8582	0.9322	1.0407	0.9610	1.4908	1.4403	3313113.
320	1.1497	0.8199	0.9426	1.0921	0.8953	1.5726	1.4079	3313113.
321	1.3348	0.7355	1.0259	1.0791	0.9057	1.3919	1.2579	3313313.
322	1.3134	0.7874	1.0341	1.2045	0.7505	1.3959	1.0589	3313313.
323	1.2427	0.6466	0.8036	1.0101	1.2056	1.4715	1.7711	3333113.
324	1.2842	0.7295	0.9369	1.2501	1.5466	0.4903	0.7583	1133113.
325	1.4412	494.7437	713.0178	1.0000	0.0035	0.2732	0.0010	1112333.

TABLE (21) GROUNDWATER GROUPS AND THEIR GENERALIZED CHARACTERISTICS

TOTAL NO	GROUP	AV.TDS	AV.CA	AV.MG	AV(NA+K)	AV.CL	AV.SO4	AV.HCO3
8	3331113.	3426.54	16.26	9.33	29.92	35.64	17.33	3.45
14	1312333.	2158.65	26.57	4.82	0.69	0.73	28.21	2.71
48	1313333.	1963.25	18.84	7.64	3.29	1.55	25.57	3.61
57	3313313.	3821.13	28.58	15.47	19.08	11.70	41.53	3.05
6	3311333.	3211.20	32.84	9.96	7.04	11.16	34.45	2.50
15	1113333.	593.47	4.81	2.20	1.59	1.04	2.57	4.24
5	1122323.	374.45	3.35	0.80	0.67	0.54	0.49	3.92
2	1313113.	742.31	3.06	2.63	4.59	1.00	5.68	3.85
37	3313333.	3458.04	26.58	17.38	10.98	5.62	42.46	2.71
31	3313113.	4637.00	23.02	17.59	33.97	21.57	44.26	3.53
8	3313131.	4786.92	10.47	31.16	27.44	13.89	55.85	3.64
22	3313111.	6301.99	19.93	30.30	48.10	26.43	65.44	2.88
1	3331112.	1624.31	7.67	7.67	11.47	19.63	7.08	1.25
6	3313331.	3959.37	21.45	24.21	17.98	8.63	48.33	3.13
5	3311313.	4757.67	34.85	18.68	25.37	29.35	42.07	2.91
1	1133213.	1050.40	5.90	2.21	5.90	5.75	2.07	7.13
1	3331333.	2466.68	32.03	11.03	4.19	34.10	3.75	3.31
5	1311333.	2405.16	25.93	8.96	1.86	2.47	29.85	3.94
2	3331313.	4353.36	32.77	9.59	29.70	47.65	20.50	3.59
6	1313111.	1327.04	4.92	6.28	8.26	2.46	13.79	3.48
8	3333113.	2717.16	9.64	5.64	27.76	24.17	15.11	3.63
5	1313313.	2477.31	25.43	4.05	6.75	3.17	27.76	3.13
1	3133113.	1307.46	4.70	1.50	12.83	12.10	3.76	4.75
6	3331111.	16290.18	46.30	65.40	175.54	216.50	47.80	3.87
3	3333111.	23050.75	25.97	45.97	292.85	268.70	110.32	6.15
1	3311113.	5200.12	35.31	16.10	36.10	37.50	42.70	1.38
3	2313333.	2867.38	24.95	15.46	5.09	2.47	37.63	2.47
1	1111333.	510.36	4.24	1.26	1.00	1.25	1.42	4.50
4	1112333.	350.28	2.87	1.42	0.60	0.67	1.48	2.65
3	1113313.	575.74	3.73	1.32	2.87	0.91	2.79	4.08
3	3311331.	1558.61	8.79	9.52	6.46	8.18	14.95	1.66
1	1313131.	999.91	3.60	6.96	4.94	2.40	8.99	3.20
3	3331331.	4799.71	13.49	71.34	5.09	67.30	16.84	3.73
1	1113331.	462.36	2.35	2.71	1.68	0.90	2.46	2.79
1	1131313.	1010.89	6.60	1.95	5.00	5.60	0.55	8.44
1	1133113.	1416.85	7.90	5.00	9.08	5.84	3.15	10.25

CORE USAGE OBJECT CODE= 8520 BYTES,ARRAY AREA= 72000 BYTES,TOTAL AREA AVAILABLE=

COMPILE TIME= 1.91 SEC,EXECUTION TIME= 11.15 SEC, WATFIV - VERSION 1 LEVEL 2 AUGUST

DATE: FRI 27 FEB 1976 TIME OF DAY: 17.15 WATFIV BATCH (OS JOB NO):

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*STOP
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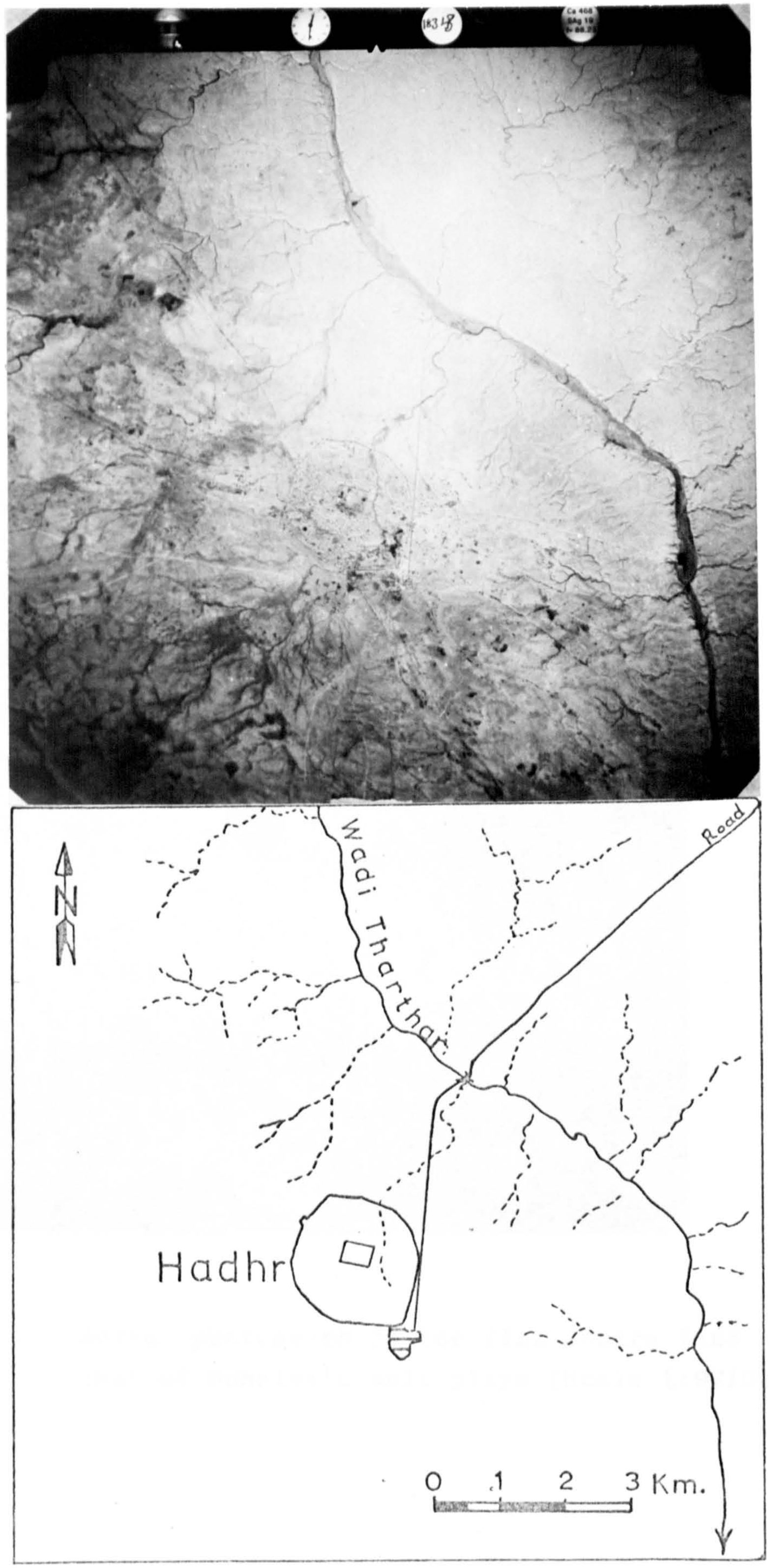

Plate 1: Aerial photograph of Wadi Al-Tharthar and surrounding area showing the ruins of Hadhr (Scale 1:97100).

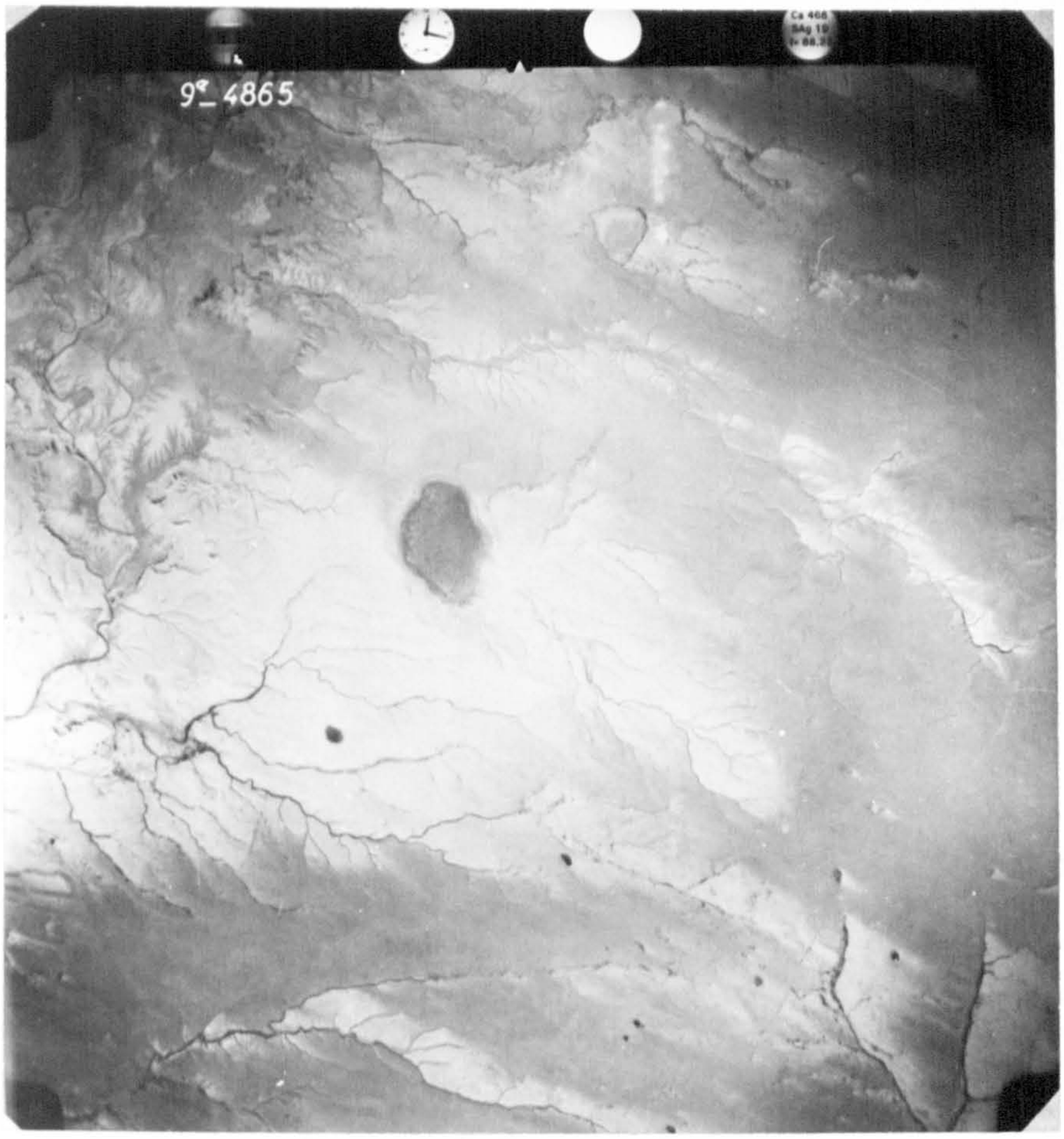

Plate 2: Aerial photograph of the flat Jezira land east of Sunaisala salt playa (Scale 1:97100)

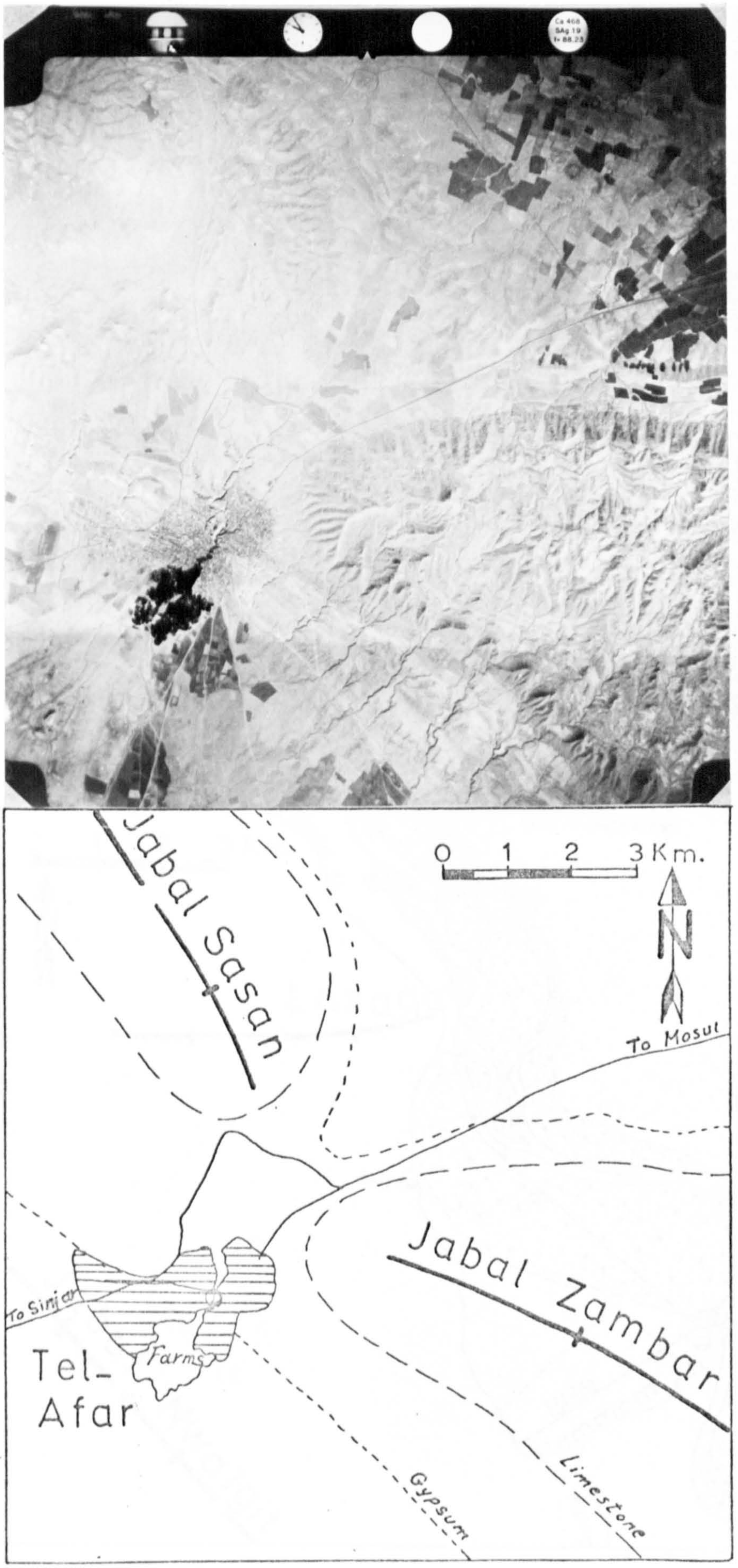

Plate 3: Aerial photograph of the town of Tel-Afar showing the plunging of Jabal Sasan and Jabal Zambar structures (Scale 1:97,100).

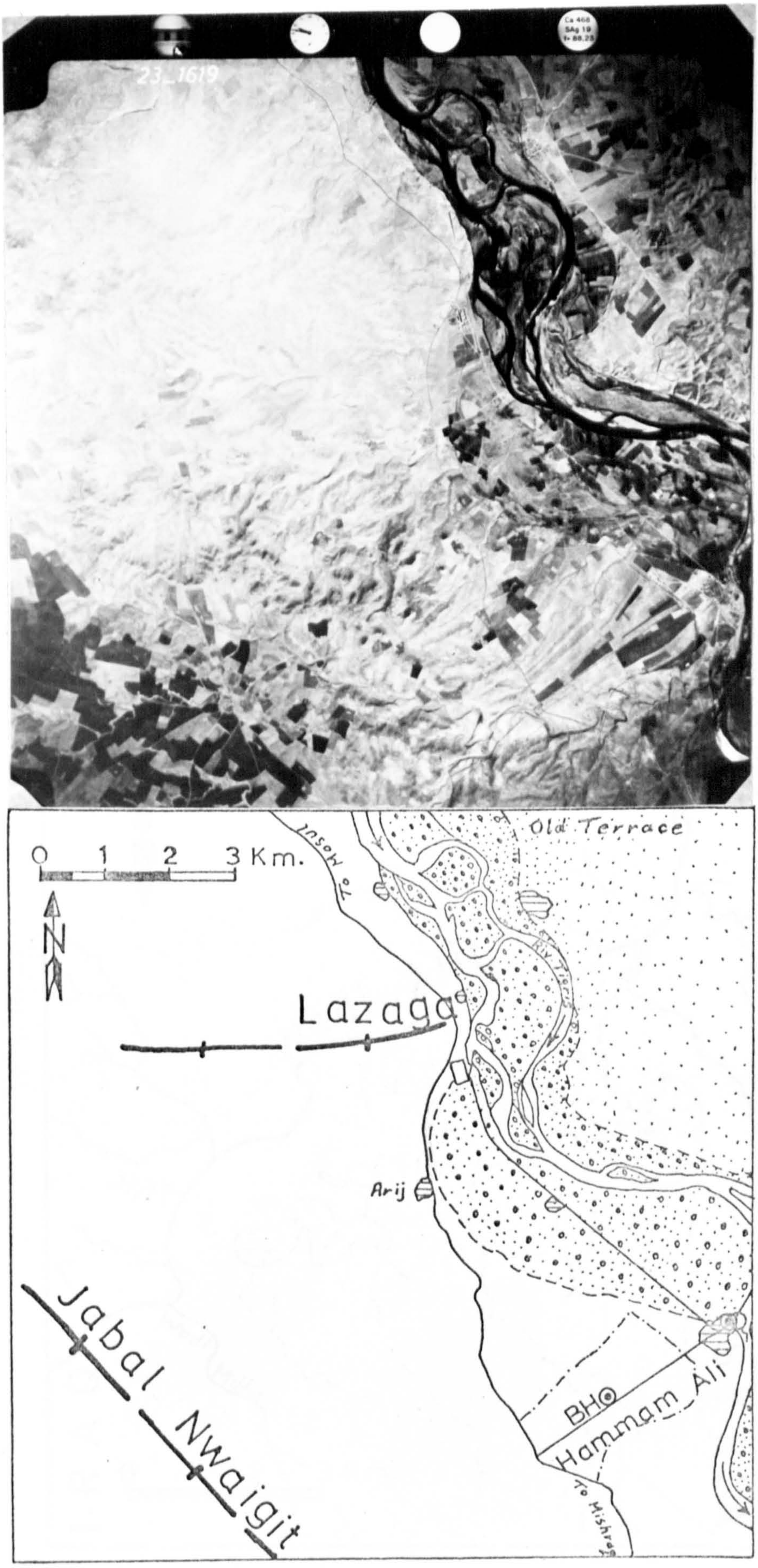

Plate 4: Aerial photograph of broided channel of river Tigris showing the anticlines of Jabal Nwaigit and Lazaga with the village of Hammam Ali, and borehole (BH) drilled in the College of Agriculture (Scale 1:97,100)

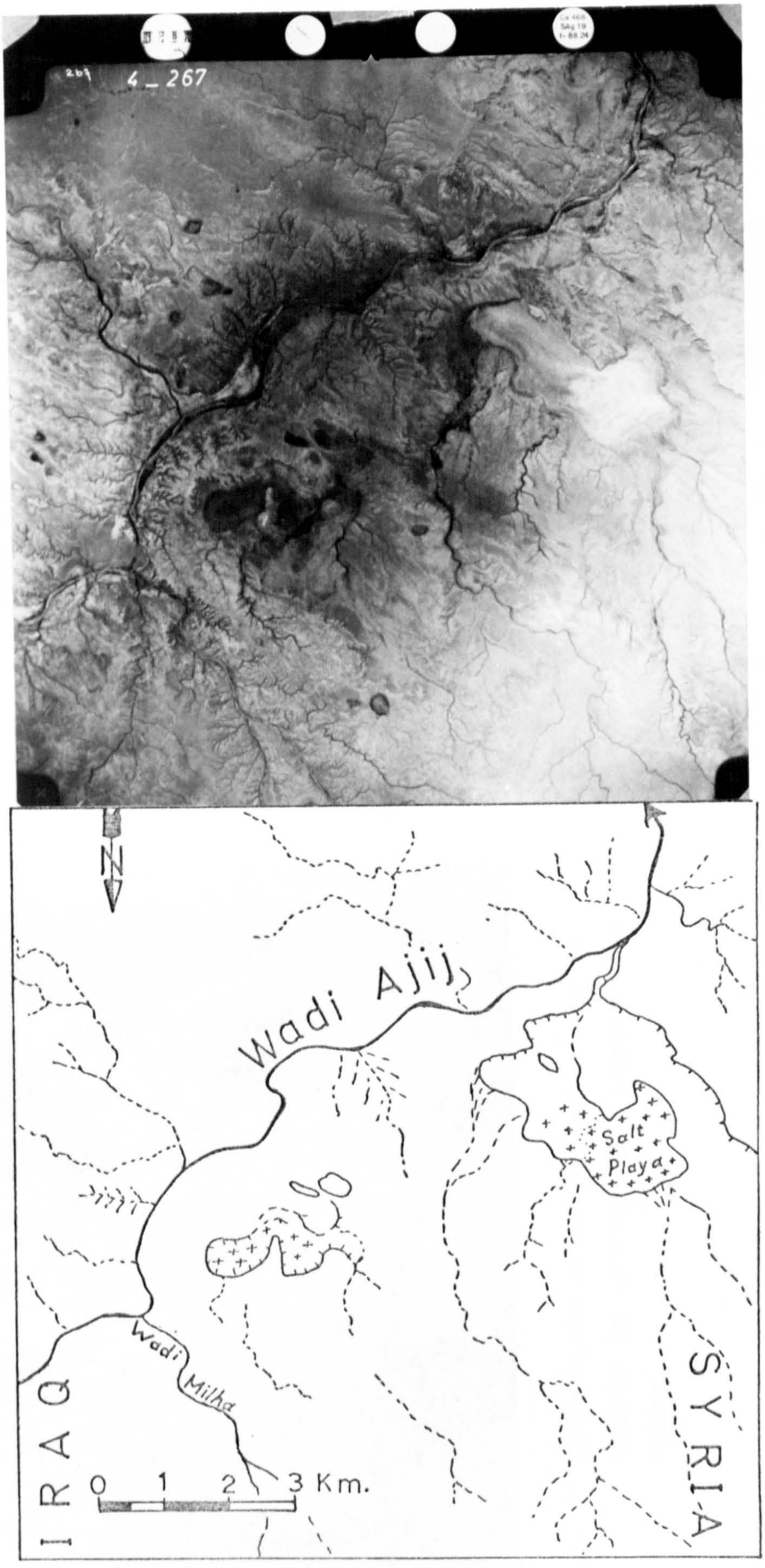

Plate 5: Aerial photograph of Wadi Ajij area showing the salt playas (Sabhka) in Iraq and Syria (Scale 1:97,100).

Plate 6: Wadi Al-Tharthar near Hadhr showing the collapsed boulders of Upper Fars sandstone after seasonal flooding

Plate 7: Mud cracks developed after the wet season in intermittant stream near Hadhr.

Plate 8: Water tanker used by Hadhr Muncipality obtaining water supply from a nearby sink hole.

Plate 9: Aerial photograph of Lower Fars hills south of the town of Mosul.

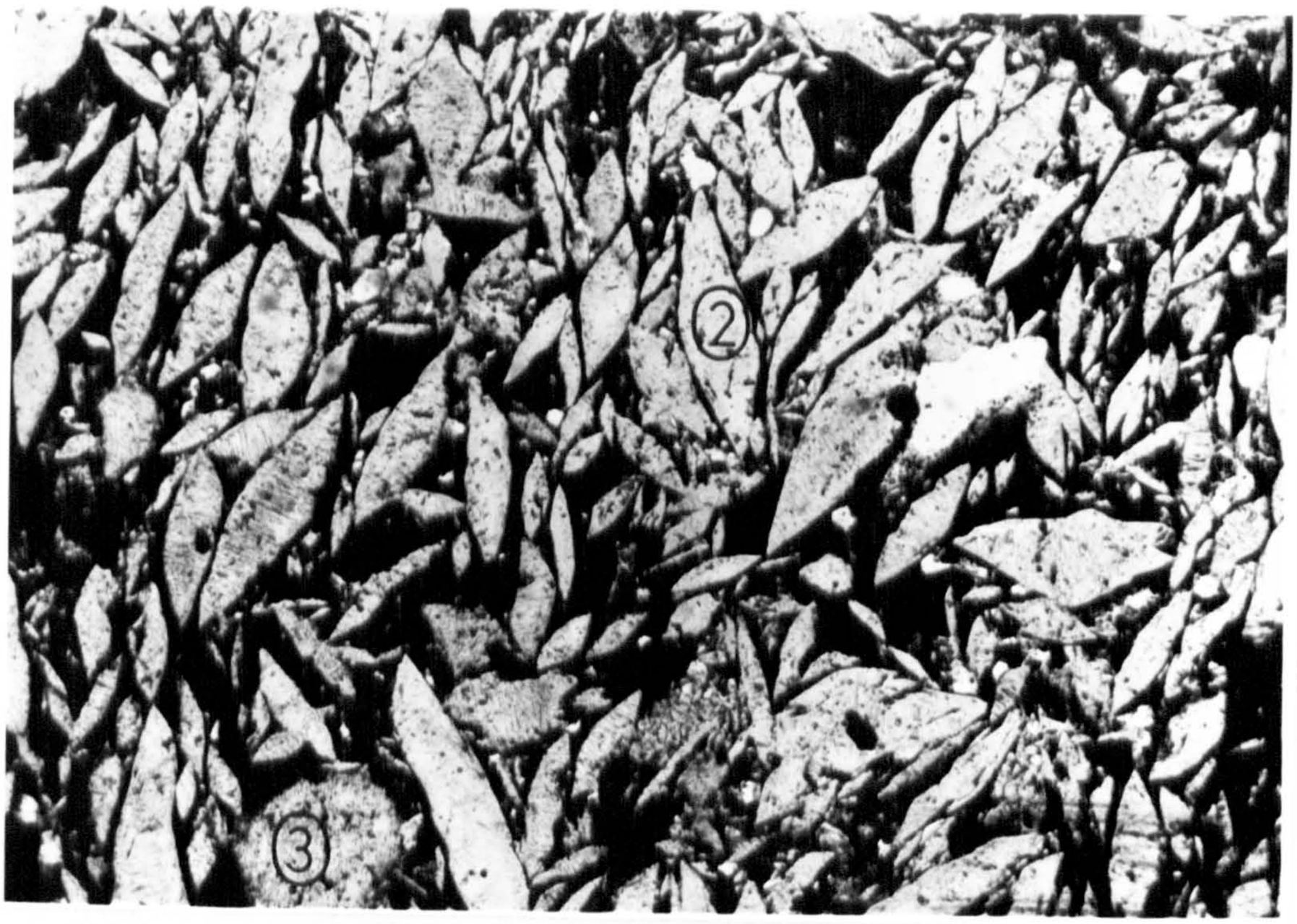

Plate 10: Thin section in the reworked Upper Fars deposit (X25).

1 - Clay of the Upper Fars formation (opaque)
2 - Secondary gypsum deposits with clay inclusions.
3 - Corroded crystal of gypsum.

Plate 11: Type of casing used by the Ground Water Department in Mosul for lining boreholes drilled in the Upper Fars formation.

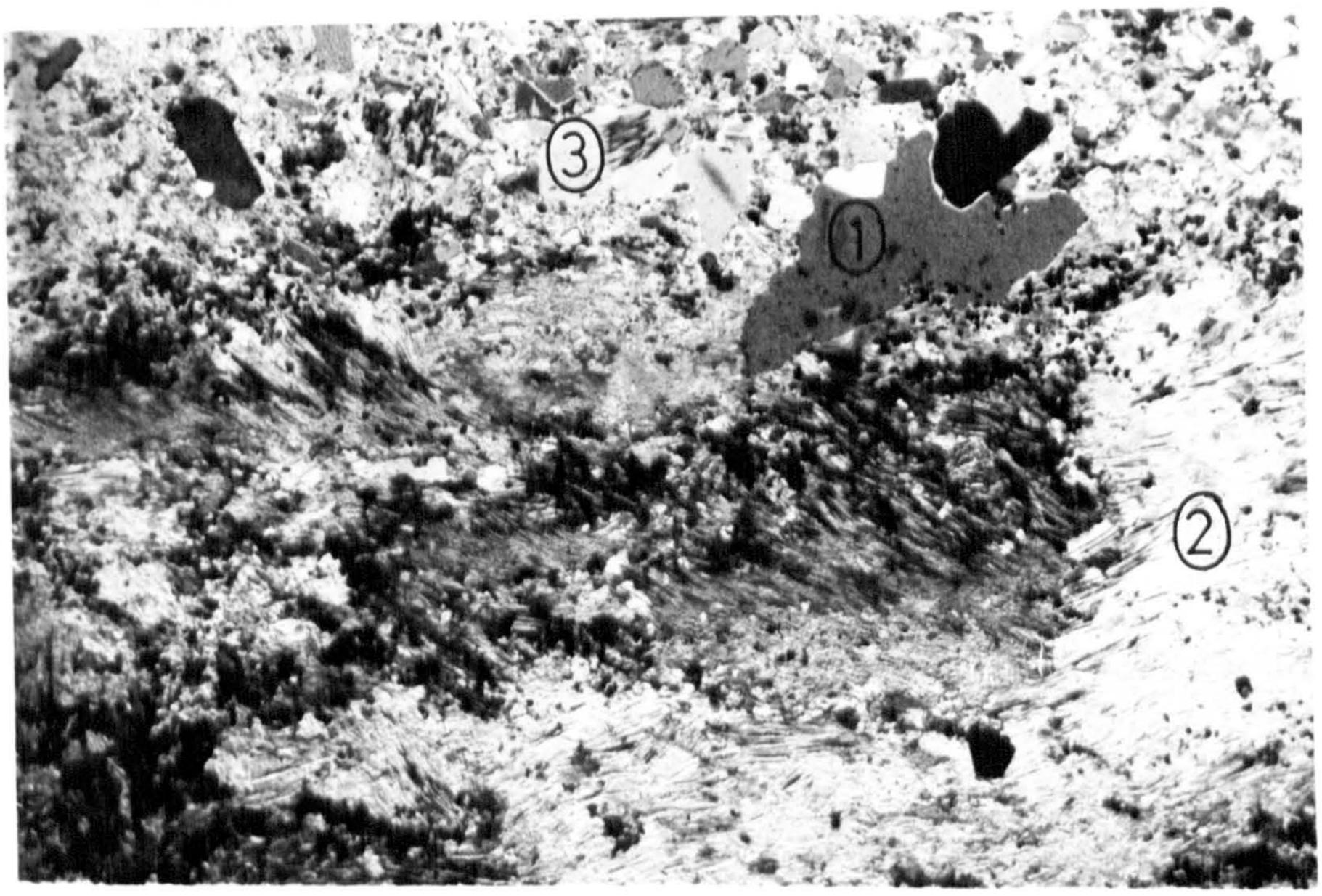

Plate 12: Thin section showing the fibrous gypsum of the Lower Fars formation taken from outcrop near the town of Mosul (X25)

1- Recrystalized gypsum crystals
2- Fibrous gypsum
3- Alteration of fibrous gypsum into coarse crystals by recrystallization.

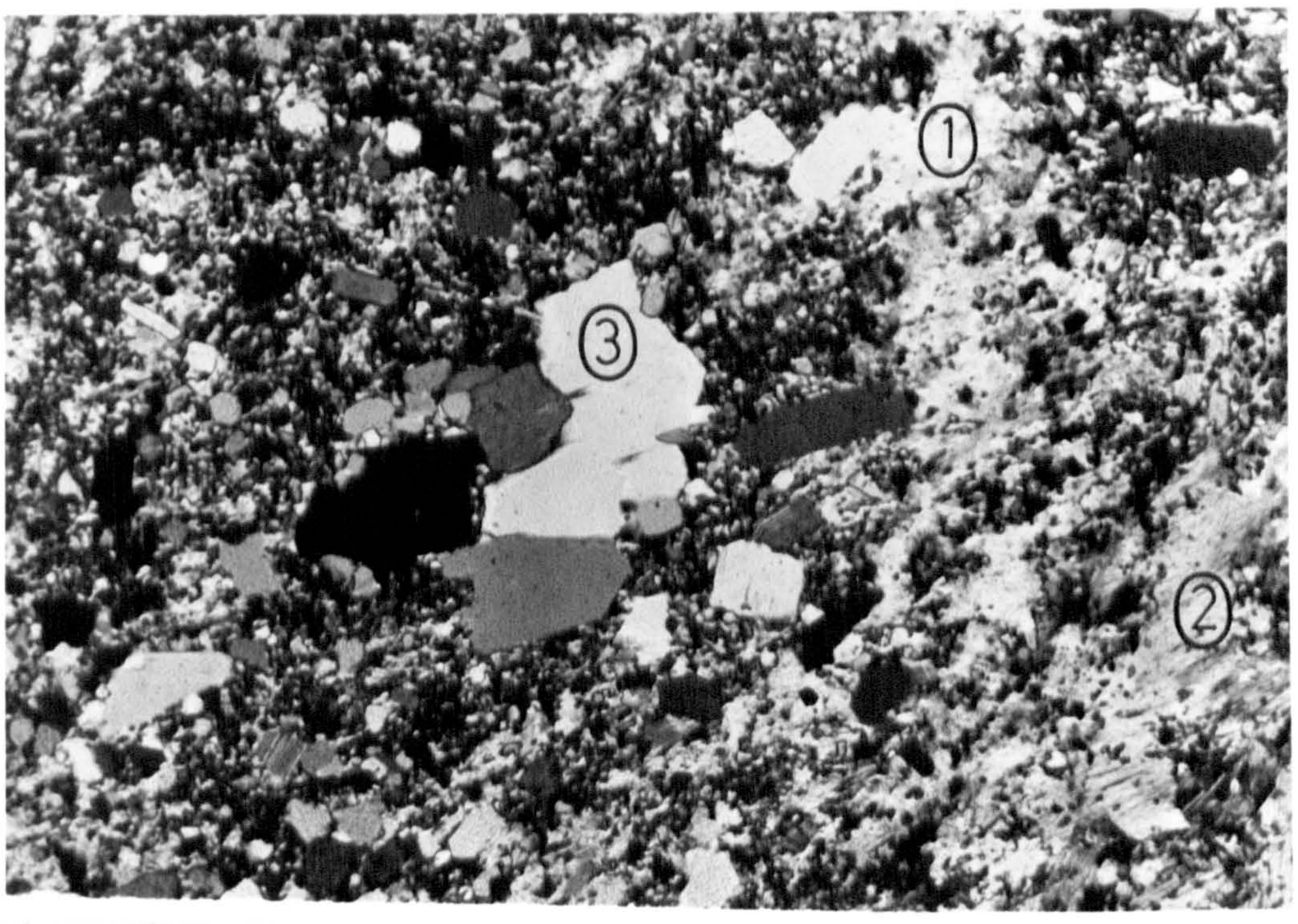

Plate 13: Thin section showing the recrystallization in gypsum of the Lower Fars formation taken from the same rock sample as in Plate 12 (X25)

1 - Cryptocrystalline gypsum
2 - Fibrous gypsum
3 - Macroscopic recrystallized gypsum crystals.

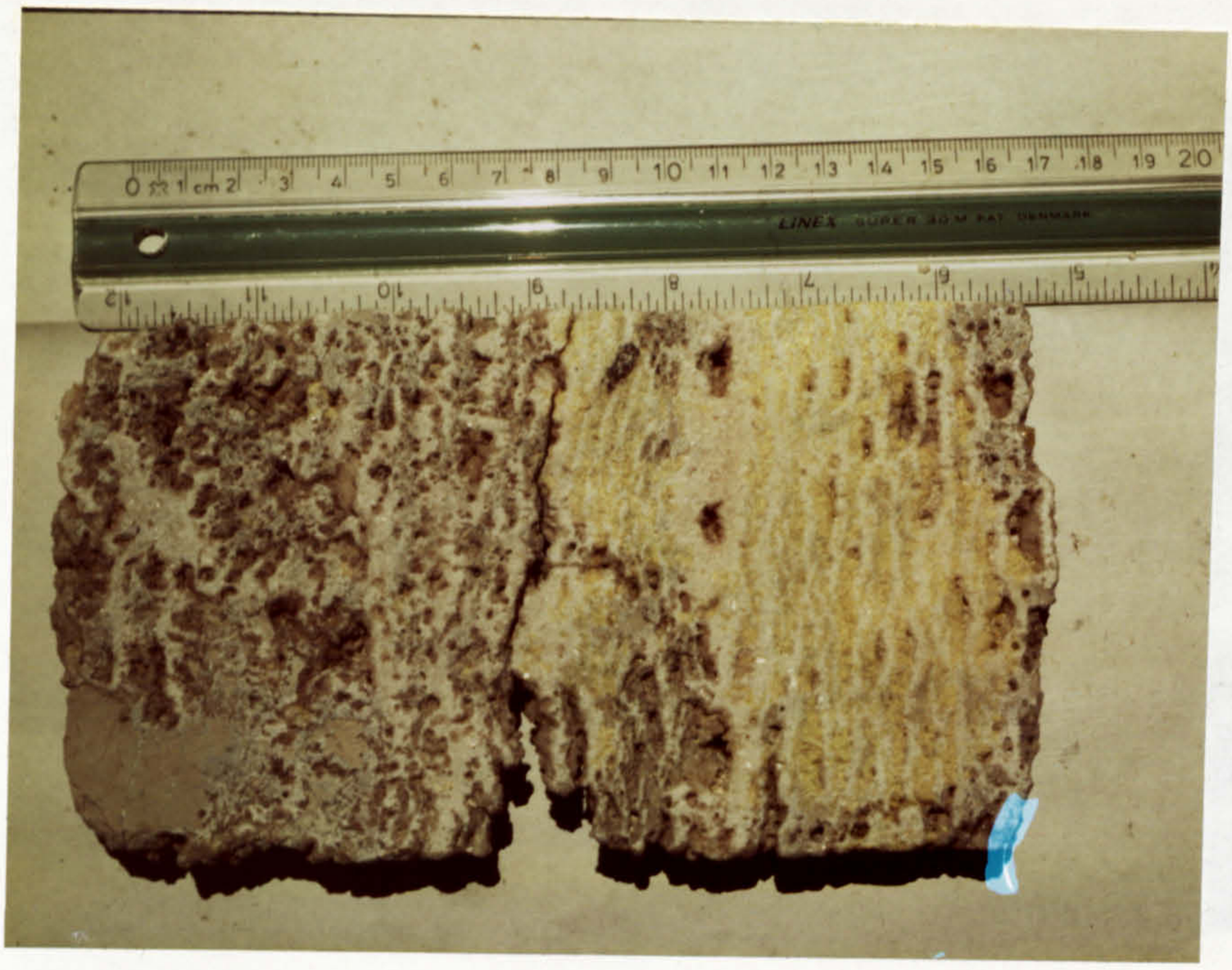

Plate 14: Core sample taken from the first horizon of the Productive Series of Mishraq sulphur structure showing the leaching of sulphur from the secondary limestone.

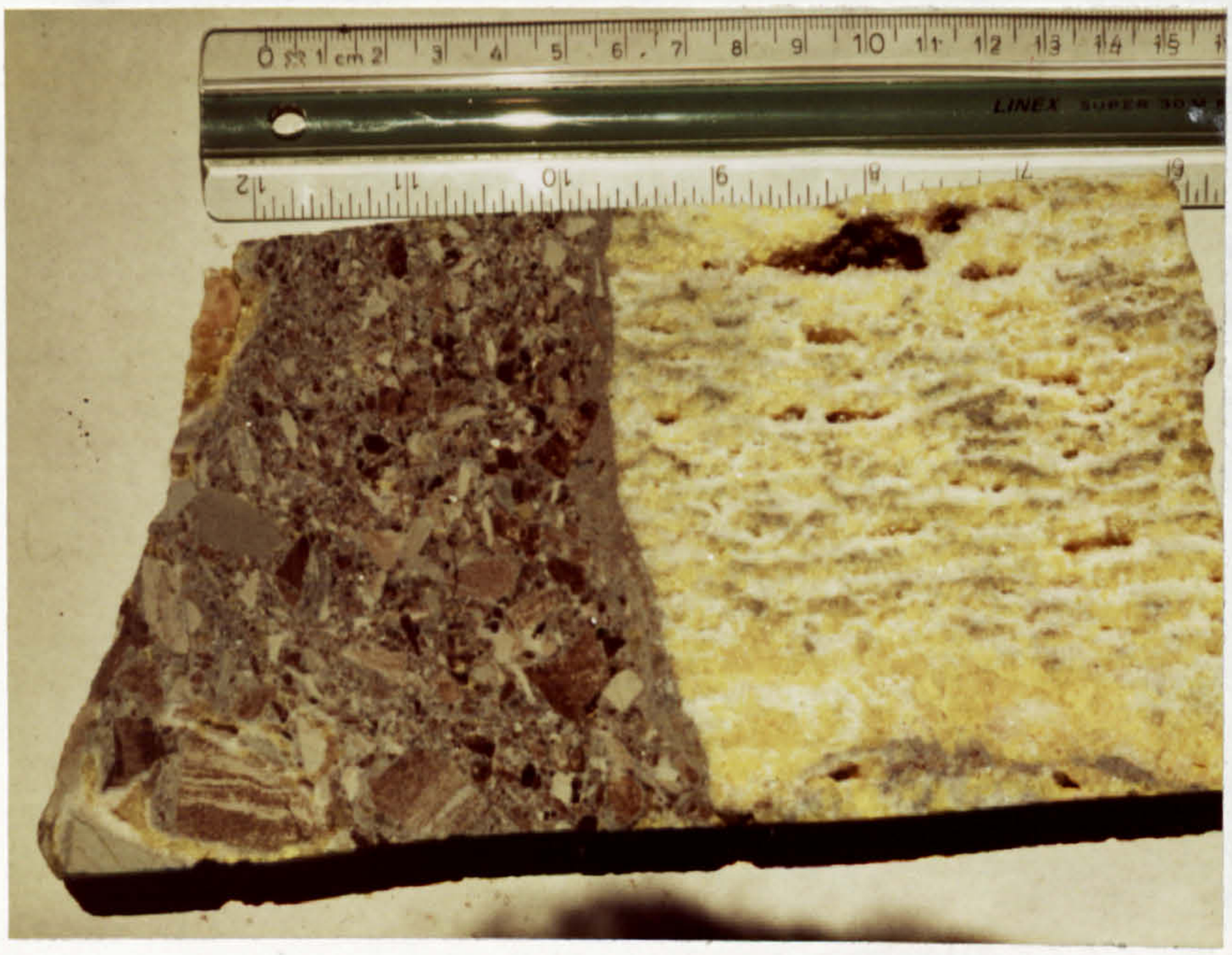

Plate 15: Core sample from the Productive Series of Mishraq sulphur structure showing a "Fault Breccia" across a ribbon-type sulphur deposit.

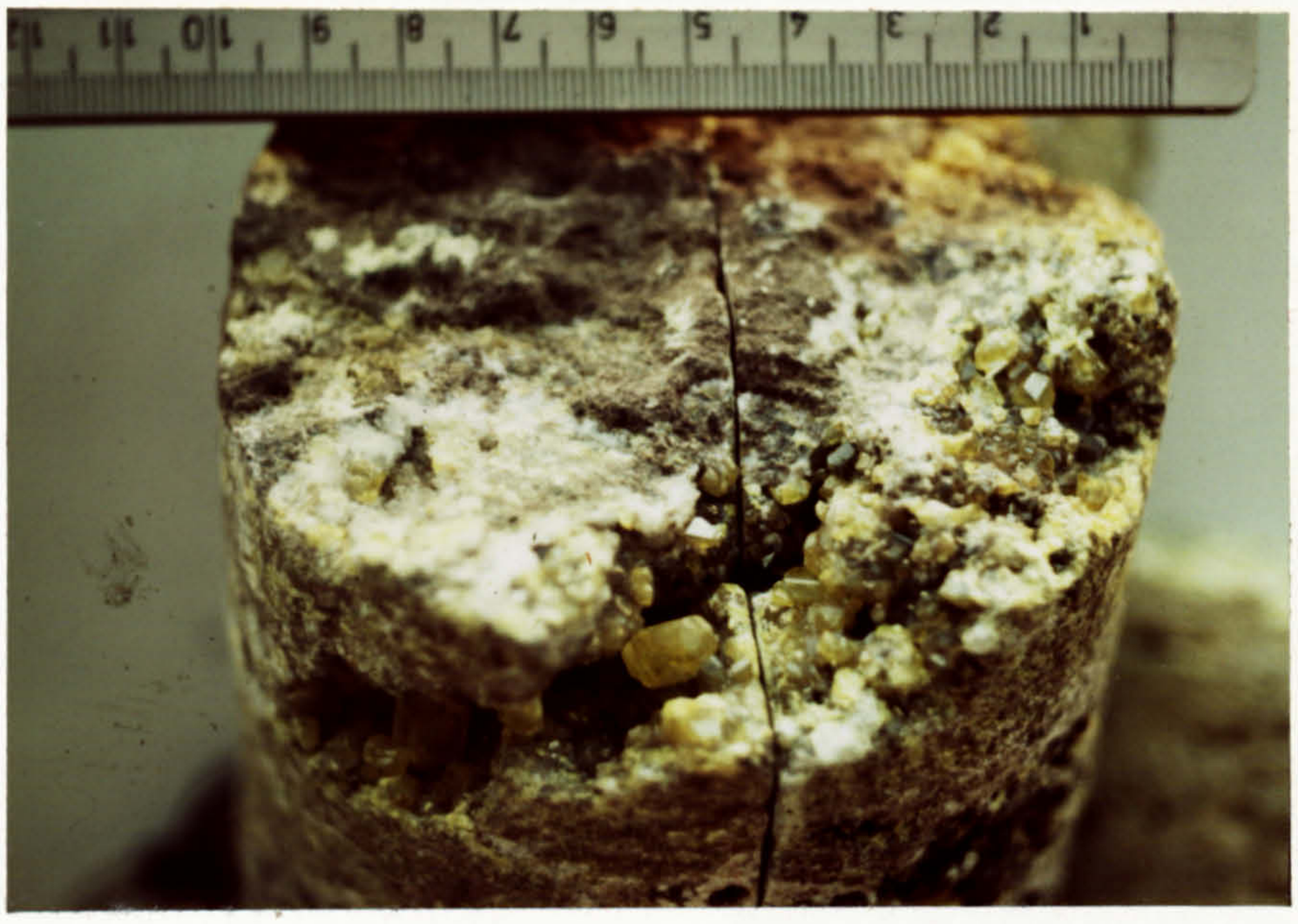

Plate 16: Core sample from the Productive Series of Mishraq sulphur structure showing the deposition of native sulphur in the cavernous limestone

Plate 17: Core sample from the Productive Series of Mishraq sulphur structure showing the alteration of gypsum to sulphur and calcite.