HYDROCHEMISTRY AND GEOTHERMOMETRY OF THE BAN PONG KUM, BAN SOP PONG AND BAN PA PAE GEOTHERMAL FIELDS, N-THAILAND.

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ABSTRACT

Most of the active geothermal fields in the world are located on plate boundaries. Although Thailand is not located on any plate boundary, it has extensive geothermal activity on a zone of rather high heat flow and geothermal gradient. Over 60 geothermal fields have been discovered which are scattered from the northern through to the southern part of Thailand. More than half are located in the northern part, like Ban Pong Kum (CM2), Ban Sop Pong (CR6), and Ban Pa Pae (CM4). The chemical data from these areas are studied to evaluate solute-mineral equilibria and for predicting subsurface temperatures using chemical geothermometry. In calculating aqueous species activities quartz equilibrium temperature was selected for reference. On the whole quartz-, CO2-, H2S-, CaH-, and HF temperatures are close to the mean temperature but H2SO4 temperature is systematically low and NaK temperature and MgK temperature show much scatter. Mineral equilibrium studies indicate that the reservoir fluid is saturated with respect to calcite, and undersaturated with respect to anhydrite and fluorite.

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1 INTRODUCTION

1.1 Scope of work

Utilization of geothermal energy has received increasing attention in Thailand during the last decade. This interest has been followed by exploration and preliminary study of some geothermal fields. Visiting scientists have taken great part in this developing exploration and national scientists have acquired know-how in this discipline.

The United Nations University (UNU) Geothermal Training Programme in Iceland aims to provide practical training and special courses in geothermal resources, including exploration, development and exploitation of geothermal system. The author was awarded an UNU Fellowship to attend this programme which is executed by the Geothermal Divisionof the National Energy Authority (NEA) and operated in cooperation with the University of Iceland. Supervisors and instructors come from these institutions as well as other individual specialized institutes. Each participant receives a practical training in his field of specialization.

Practical training in the chemistry of geothermal fluids provides some basic knowledge of the role of the thermal fluid chemistry in geothermal exploration. This includes water sampling, analysis of the major chemical components and interpretation of the results. Each participant deals with certain problems related to his speciality, sometimes he can bring data from his own country for interpretation. A final report is written at the end of the training programme.

The author brought some chemical data from three geothermal fields in northern Thailand for interpretation in the final report.

2 GEOLOGY AND THERMAL MANIFESTATIONS

2.1 Introduction

Thailand is not located on acrustal plate boundary. Yet, it has extensive geothermal activity on a zone of rather high heat flow and geothermal gradient (Thienprasert et al., 1978). Over 60 geothermal fields have been discovered which are scattered from the northern through to the southern part of Thailand (Fig. 1). More than half are located in the northern part, like Ban Pong Kum (CM2), Ban Sop Pong (CR6), and Ban Pa Pae (CM4) which are the subject of this report.

On a regional scale, hot springs of northern Thailand are related to the margins of a Cenozoic basin. This basin is generally bounded by faults which follow older tectonic patterns that were rejuvenated during Cenozoic times. This is indicated by faults affecting terraces of late Tertiary or Pleistocene age. Some hot springs occur near the margins of Mesozoic or older granite batholiths, or by major fault zones. A Tertiary igneous event has been postulated to explain the Tertiary age obtained by radiometric dating of the crystalline basement complex (Granite) west of Chiangmai basin (Ramingwong et al., 1984).

The CM2 geothermal field lies on an alluvial plain. There are several hot springs distributed over an area about 1 km. The thermal water ascends along faults bordering minor grabens and cutting through sedimentary sequences. Permeability is quite variable depending on the density of fractures in the older complexes. The flow rate is 12.6 1/s and maximum temperature 98°C.

The CR6 geothermal field is located on a small alluvial plain near the slope of a mountain. The hot springs are associated with a fault cutting Triassic granite covered by a thin sequence of Late Carboniferous volcanics. Permeability is provided by the tectonic fractures. The hot springs are distributed over an area of about 100 m². The water flow rate is 2.5 1/s and maximum temperature 98°C. The CM4 field is located in a small valley of the tributaries of Nam Mae Sae. The hot springs are distributed over an area 100 m² and are associated with a large fault cutting through a granitic body. The diameter of the two biggest pools are 3 and 4.5 m., respectively. The flow rate is about 22.7 l/s and the temperature is near the boiling point (90-99°C). Algae are abundant in someof the hot springs not directly discharging into the nearby stream. Deposits of silica and other precipitates, together with clay, occur as a coating on boulders bordering the hot pools (Balangue, 1984).

The thermal water of the CR6 and CM4 regions rises up through faults cutting granites or high grade metamorphic rocks. The hydrothermal systems are clearly related to deep circulation within major extensional faults in otherwise impermeable crystalline rocks. The high discharge temperatures and homogeneous composition indicate that mixing with cold meteoric water in the upflow is insignificant which in turn suggests either that the whole hydraulic circuit is restricted to some major faults or that the uprising hot water is insulated by self sealed fractures from shallower and colder aquifers possibly hosted within the crystalline rocks. (UNDP, 1984).

3 SAMPLING AND ANALYTICAL METHODS

3.1 Sampling methods

Water samples from three geothermal fields in northern Thailand, Ban Pong Kum (CM2), Ban Sop Pong (CR6), and Ban Pa Pae (CM4) are interpreted in this report. They were analysed at two laboratories, at the Department of Mineral Resources in Bangkok and the Department of Mineral Resources area 3 in Chiangmai.

The samples were collected into polyethylene bottles. Samples collected for analysing sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe) and manganese (Mn) were acidified by concentrated hydrochloric acid (HCl) to prevent some precipitation of the cations prior to analyses. pH, total dissolved solids (TDS), hydrogen sulphide (H₂S), sulphate (SO4), fluoride (F), chloride (Cl) and total carbonate (CO₃) were analysed from unacidified samples. The samples for silica (SiO₂) determination were diluted ten times to prevent polymerization.

3.2 Analytical methods

All chemical analyses were carried out in duplicate. The concentration of total carbonate (CO_3) , hydrogen sulphide (H_2S) and the pH of the water were analysed on the sampling day. The analytical methods and procedures are presented in Table 1 and the results of the analyses in Tables 2, 3 and 4.

At the UNU training course in Iceland, sampling was demonstrated and some analysis carried out. Some of the analytical procedures differ from the methods given in Table 1. The procedures presented at UNU for total carbonate (CO_3), hydrogen sulphide (H₂S), sulphate (SO₄), silica (SiO₂) and pH measurement may be particularly useful for geothermal waters. The details of the methods and analytical procedures are described in Appendix 1 (A-Q).

TABLE 1: Analytical methods

Components	Method
рH	Glass-electrode and pH-meter.
C02	Titration with 0.1N hydrochloric acid (HCl)
	using pH-meter to indicate end point.
H ₂ S	Back titration with 0.02N sodium thiosulphate
	(Na ₂ S ₂ O ₃) in acid solution by adding concen-
	trated hydrochloric acid (HCl) and excess $0.02N$
	iodine (I ₂).
Na	Atomic Absorption Spectrophotometer.
К	do
Ca	do
Mg	do
Mn	do
Cl	Chloride sensitive electrode and Mohr titration
	using 0.1N silver nitrate (AgNO3) solution.
F	Fluoride sensitive electrode.
Si02	Molybdenum blue method.
Fe	Phenanthroline method.
SO4	Gravimetric method involving precipitation with
	barium.
TDS	Evaporation and weighing.

4 CHEMICAL CHARACTERISTICS OF THE GEOTHERMAL WATERS

The water compositions in each geothermal field have their own characteristics depending on the residence time of the water, the rate of leaching of components from the rocks, the fluid flow into the system and the rate of formation of secondary minerals. Cooling due to boiling, conduction and dilution as well as degassing cause the chemistry of surface discharges to deviate from the composition of the thermal water in the reservoir. In the three geothermal fields which have been studied (see the data in Tables 2, 3, and4), the water has high carbonate as well as high hydrogen sulphide content and a pH generally between 8 to 9.5 (measured at 25°C). The main components are sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) and sulphate (SO4) which all follow the same pattern. The major cation is sodium (Na). Calcium (Ca), magnesium (Mg) and iron (Fe) occur in higher concentrations in cold water than in the thermal water.

Fluoride (F) and particularly the chloride (Cl) content is very low. The silica (SiO₂) concentrations are two times higher in the area CM4 than in the areas CM2 and CR6.

Arnorsson et al., (1983a) described that the low temperature geothermal areas in the Tertiary basalts in Iceland are very low in chloride (Cl) compared with water issuing from acid volcanic rocks. The fluoride (F) concentration follow the same trend i.e. they are low in basaltic rocks and high in acidic rocks.

5 DATA PROCESSING

The chemical data from the three geothermal fields, CM2, CR6, and CM4, were interpreted. The mean and standard deviation of chemical analyses taken both in May and June 1983 from the areas CM2 and CR6 were compared by statistical methods (Appendix 2) in order to see the correlation between water analyses during each one-month period. It was found that no significant deviation exists between the data taken in May and June, respectively. Therefore, the data from May only were chosen for further calculation and interpretation.

The computer programmes WATCH5 and WATCH3 (Arnorsson and Svavarsson, 1985 and Arnorsson et al., 1982) were used to interpret the chemical analyses of the geothermal water. The programme WATCH5 was used to calculate chemical geothermometry temperatures on the basis of the analyses. A choice of reference temperatures to be used in the programme is possible including those of equilibrium with quartz, chalcedony, or NaK-feldspar, or any arbitrary temperature such as the discharge temperature.

The programme WATCH3 computes the chemical composition of geothermal water and steam, aqueous speciation, some geothermometry temperatures, gas pressures, redox equilibria as well as the state of saturation with respect to selected minerals all based on a given chemical analysis of geothermal water at the surface (Svavarsson, 1981).

The WATCH3 programme is exclusively used for chemical analyses of water from boiling springs. If, on the other hand, the water is assumed not to have boiled before sampling, the programme is called WATCH2. The programme is run at a predetermined reference temperatures as the programme WATCH5.

When running the programme for these geothermal fields the quartz equilibrium temperature was used for reference. The waters of the CM4 geothermal field were assumed to have boiled but those of the other two areas not (Appendix 3). Degassing of the hot spring waters in the CM4 field was assumed to be 20% of maximum, i.e. equilibrium degassing.

6 GEOTHERMOMETRY INTERPRETATION

The chemical components dissolved in thermal fluids are valuable in understanding the characteristics of geothermal systems. An important task of geochemistry is to assess the state of equilibrium between solution and alteration minerals in geothermal reservoirs and subsequently to delineate processes affecting equilibrium conditions or departure from them. The phase rule is useful in describthe number of independent variables (degrees of ing freedom) needed of specify a chemical system at equilibrium. It is found that this number is equal to the number of external variables acting on the system. In the case of geothermal system these variables include temperature, pressure and mobile (incompatible) components. The only major mobile component in geothermal systems is chloride (Ellis and Mahon 1964, 1967). Pressure in the range geothermal systems (1-200 bars) occurring in is not expected to change the equilibrium conditions significantly as the change in partial molal volumes of minerals and solutes is not significant in this pressure range (Helgeson et al., 1978; Ellis and McFadden, 1972; Miller, 1982). Thus, the major element composition of geothermal systems at equilibrium for a given rock composition is controlled two variables, that is temperature and the mobile by component, chloride.

When predicting subsurface temperatures reactions in the modify the composition are assumed not to upflow significantly. Thus, in this respect the analyses of surface water are taken to be representative of the reservoir fluid. Mixing of the thermal water with cold water sometimes occurs which affects the composition of the water emerging at the surface and, therefore, the estimated subsurface temperatures. A number of geothermometers (Appendix 4) have been used to estimate subsurface temperatures, the most important are the quartz and chalcedony geothermometers (Fournier and Rowe, 1966; Mahon, 1966; Arnorsson, 1975; Fournier, 1977), the NaK-felspar geothermometer (Ellis, 1970; Truesdell, 1975; Arnorsson et 1983b), the NaKCa and NaKCaMg geothermometers al., (Fournier and Truesdell, 1973; Paces, 1975; Fournier and Potter II, 1979) and the NaLi-geothermometer (Fouillac and

Michard, 1981). Use of total water composition has recently been developed to facilitate geothermometry interpretation (Arnorsson and Svavarsson, 1985).

6.1 Solute geothermometers

For the evaluation of subsurface temperatures, as a rule, the concentration of a certain component is assumed to be equal to the activity of some aqueous species. The temperature functions in Table 5 (Arnorsson and Svavarsson, 1985), used in the WATCH5 computer programme are, however, based on activities or activity ratios of particular species. When deciding which cation ratios and neutral species concentrations to select as geothermometer, Arnorsson and Svavasrsson (1985) took temperature variations and minimum scatter of the data points to be of first priority.

In the previous section the data processing used to evaluate subsurface temperatures was outlined for the three geothermal fields CM2, CR6, and CM4. Subsurface temperatures estimated by the various solute geothermometers differ somewhat. The mean and standard deviation of individual geothermometry temperatures for each sample were compared by statistical methods (Appendix 2) in order to study their interrelation (Fig. 2).

In the CM2 and CR6 geothermal fields, the CO_2^- , H_2S^- , and HF-temperatures give similar results as shown by the relatively small scatter around the equal temperature curve (Fig. 2B, 2C, 2G). It is concluded, if the system attained equilibrium with guartz, that reactions with respect to these species were similar in the upflow as for quartz. The quartz and CaH temperatures (Fig. 2A, 2D) are slightly below the mean temperature which can be explained by increase in pH by reactions in the upflow and simultaneous ionization of some of the dissolved silica. The pH increase will also cause H2SO4-temperatures to be low, which is indeed the case (Fig. 2H). The NaK-temperatures tend to show large scatter and are above the curve. This is probably due to lack of equilibration, at least with respect to felspars. The MgK-temperatures also show a large scatter on both side of the curve. Magnesium concentrations are very variable in the waters which, I consider, to be due to leaching from the rock in the upflow thus causing erratic MgK-temperatures.

In the CM4 geothermal field, the quartz-, H2S-, CaH-, NaK-, and H₂SO4 temperatures are similar to the mean temperature when calculating aqueous speciation at the quartz equilibrium temperature (Fig. 2A, 2C, 2D, 2E). It is concluded, if equilibrium was attained with respect to quartz in the reservoir that reactions affecting the concentrations of the respective species in the upflow were insignificant. CO2-temperatures are high relative to the mean temperature (Fig. 2B) which may be explained by carbonate leaching in the upflow or that the anticipated degassing accompanying boiling was too high (20%). This is supported by the plot in Fig. 4B which indicates strong supersaturation at the quartz equilibrium temperature. The MgK-temperatures for the CM4 area are lower than the mean. The cause may be that magnesium is leached from the rock in the upflow. The HF-temperatures are not reliable as the temperature function used in the programme is probably invalid for the rocks in the CM4 area.

Evaluation of geochemical data by Arnorsson and Svavarsson, (1985) showed that:

- (1) The geothermometry results of hot springs in Iceland show the standard deviation in the range 50-100°C for mixed water.
- (2) The mixed waters tend to yield low H_{2S} , MgK⁻, and NaLi⁻temperatures but high NaK⁻temperatures.
- (3) Surface waters or other waters which have not equilibrated, or only for some components possess characteristics similar to the mixed waters.

The calculated geothermometry results for the CM2, CR6 and CM4 areas are given in Tables 8-10. The main results are as follows:

- (A) The standard deviation is in the range 20-40°C. Therefore, it is concluded that the thermal waters are unmixed except may be for sample no. CM4-C. This water possesses some of the typical characteristics of mixed waters. The mixing may have occurred with surface water.
- (B) The NaKCa⁻temperatures are always significantly lower than the NaK-temperature.
- (C) The average mean temperature for CM2, CR6, and CM4 areas are 148(b) $(138)(c)\circ c$, 148(b) $(142)(c)\circ c$, and 168(b) $(178)(d)\circ c$, respectively.

The geothermometry interpretation based on total water composition will aid distinguishing equilibriated waters from non-equilibriated and mixed waters and at the same time help substantiating or disproving the validity of the assumption made when applying geothermometers, namely that the water is in equilibrium with minerals at depth. The geothermometer involving Mg yield often temperature differing much from the other geothermeters. In many of the dilute Icelandic geothermal waters this metal occursin concentrations close to the detection limit (by AA) and this may, at least partly, be the cause of the difference.

Footnotes:

- b = The results do not include the NaKCA temperature.
- c = The results do not include the NaK and NaKCa temperatures.
- d = The results do not include the NaKCa and MgK temperatures.

6.2 Cation to proton ratios

As demonstrated by Arnorsson et al., (1983a), the ratios of all cations in geothermal water are fixed at a particular temperature, if an overall chemical equilibrium is attained with geothermal minerals. The correlation of the various major cations to hydrogen ion was arbitrarity selected. The functions in Table 6 describe the temperature dependence of

the major cation to proton ratios. Fig. 3 shows that the data points from areas CM2 and CR6 are slightly above the equilibrium curve at the quartz equilibrium temperature for the $\sqrt{Ca^+2/H^+}$, $\sqrt{Mg^+2/H^+}$ and Na^+/H^+ activity ratios. On the other hand, the same ratios show larger scatter and plot below the equilibium curve at the discharge temperature. The K+/H+ activity ratio also plots, with few exceptions, above the equilibrium curve both at quartz and discharge temperatures. It is concluded, if equilibrium with quartz was attained in the reservoir that equilibria involving cation/proton ratios in the reservoir have been disturbed partly in the upflow. It also appears that $\sqrt{Ca^+2/H^+}$ and √Mg⁺²/H⁺ activity ratios have changed more during cooling in the upflow than the Na+/H+ activity ratio. The main change apparently involves pH increase. The K+/H+ ratios depart from the equilibrium curve both at discharge and quartz equilibrium temperatures. The reason is most likely that the waters have not closely approached K-feldspar equilibrium in the reservoir.

In the CM4 geothermal field, the Na⁺/H⁺, K⁺/H⁺, $\sqrt{Ca^+/H^+}$ and $\sqrt{Mg^+2/H^+}$ activity ratios show a large scatter around the equilibrium curve at the quartz equilibrium temperature. At discharge temperatures they plot, on the other hand, always somewhat above the equilibrium curve. The variation of the ratios is probably affected by boiling and degassing in the upflow which causes the water pH increase.

6.3 Mineral solubilities

Fig. 4 shows the state of anhydrite, calcite, and fluorite saturation in the water from the CM2, CR6 and CM4 areas. The solubility product equations are given by Arnorsson et al., (1982) (Table 7). The waters are undersaturated with respect to anhydrite at both the quartz equilibrium temperature and discharge temperature. The degree of undersaturation increases when temperature decreases. The mobility of sulphate in the water may be controlled by the following reaction, Arnorsson et al., (1983a):

 $H_{2}S + 4H_{2}O = SO4^{--} + 2H^{+} + 4H_{2}$

The water from all the areas calculate to be calcite supersaturated, not only at the guratz equilibrium temperature but also at discharge temperature. The reason for the apparent calcite supersaturation may be that the pH of the water has increased from the time of collection to the time The degassing of the water in the CM4 area of analysis. may not be as extensive as assumed for the computer calculations. Water sample no. CM4-C calculates to be a little undersaturated at the quartz equilibrium temperature but saturated at the discharge temperature. It is concluded that re-equilibration has occurred in the upflow most likely by leaching of calcium from the rock. Near the surface degassing may cause conductively cooled calcite undersaturated water to become saturated.

The waters are fluorite undersaturated at the quartz equilibrium temperature but less so at discharge temperature.

7 DISCUSSION AND CONCLUSIONS

The relation between the solute geothermometry temperatures tend to be different for boiled unmixed waters and warm mixed waters. In warm mixed waters the NaK-temperatures are equal to or higher than the quartz temperatures but in boiled unmixed waters quartz temperatures tend to be higher than the NaK-temperatures. Leaching seems to govern the major cation distribution in mixed waters which cause the NaK-temperatures to be invalid as well as the NaKCatemperatures. Arnorsson et al., (1983a, 1983b) showed that each of the two cation ratios which constitute the NaKCa geothermometer (Na/K and $\sqrt{Ca/Na}$) are determined by water temperature alone. Application of this geothermometer, therefore, involves the addition of two temperature dependent ratios. For equilibrated gethermal waters, which have cooled by conduction in upflow zone, estimation of underground temperatures by the NaKCa-temperature is probably more conservative than estimation by the NaK geothermometer, as the ratio /Ca/Na appears to respond faster to cooling than the Na/K ratio. A disadvantage of the NaKCa geothermometer is that calcium may precipitate as calcite in significant amounts in upflow zones where boiling takes place. Such precipitation would yield high temperature estimates.

In low temperature fields the approximation to take analysed silica to represent H4SiO4 may not be satisfactory as the pH can be as high as 10. In high temperature fields the deep water pH tends to be near neutral but boiling and degassing in the upflow causes the water pH to increase and some silica ionization occurs. However, in every case, it is a good approximation, when temperatures exceed 200°C, to take analysed silica concentration to present undissociated silica (H4SiO4).

The concentrations of neutral aqueous species and cation to proton ratios are fixed at a particular temperature for a chemical system like a geothermal at equilibrium and with a fixed composition excluding, however, chloride which is mobile. The solubility of the equilibrating minerals determine individual species concentrations and ratios. This theoretical background is very useful for the prediction of deposition for certain minerals when the geothermal water cools.

In areas CM2, CR6, and CM4 most of the solute geothermometry temperatures show small scatter around the mean geothermometry temperature but a few fall slightly below the mean at the quartz equilibrium temperature. The cation to proton activity ratios fit well with the curve. Thus, it is concluded that these waters have equilibrated with quartz in the reservoir.

The mean subsurface temperatures for areas CM2, CR6 and CM4 are 148(b) $(138)(c)\circ c$, 148(b) $(142)(c)\circ c$ and 168(b) $(178)(d)\circ c$ standard deviations from the mean being only 6(b) $(6)(c)\circ c$, 4(b) $(5)(c)\circ c$ and 13(b) $(16)(d)\circ c$, respectively. The waters from areas CM2 and CR6 have similar subsurface temperatures.

All the waters are undersaturated with respect to anhydrite and fluorite but super saturated with respect to calcite.

The scatter of all data points varies for different activity ratios and concentrations. It is thought that boiling, precipitation and reactions with the rocks in the upflow zone are responsible.

The validity of the solute geothermometry results are affected by reaction in the upflow zone and departure from equilibrium in the reservoir. Evaluation of the water compositions in surface springs may be useful in visualizing scaling and environmental aspects that could accompany exploitation.

Footnotes

- b = The results do not include the NaKCa-temperature.
- c = The results do not include the NaK and NaKCa-temperatures.
- d = The results do not include the NaKCa and MGK-temperatures.

8 RECOMMENDATIONS

The following recommendations for further geochemical studies are considered valuable for assessing the characteristics of geothermal resources in Thailand. They are based on my work in Iceland, both interpretation in this report and other training.

(1) In order to obtain reliable data on pH, carbonate and hydrogen sulphide in water, samples should be collected into a gas sampling bulb and analysed on the day of collection. Details of sampling and analytical procedures are given in Appendix 1.

(2) The silica and sulphate should be analysed by the green silico-molybdate complex method and titration with barium perchlorate using thorin as indicator, respectively. These methods are rapid and have high accuracy (see Appendix 1).

(3) Additional elements like, lithium, rubidium, boron and aluminium should be analysed to improve interpretation.

(4) Gas samples, should be collected from the hot springs and analysed for components like, carbon dioxide, hydrogen sulphide, hydrogen, oxygen, nitrogen, argon and methane.

(5) Computer facilities should be made use of to evaluate subsurface temperatures and study mineral/solution equilibria from analyses of waters (see Appendix 3).

(6) It is desirable to select a prospective area for drilling of shallow wells. This would allow direct comparison of measured and geothermometry temperatures and facilitate geochemical interpretation in other areas.

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Fig. 3 Relationship between cation/proton activity ratios vs. reference temperature: Circles, triangles and squares represent hot spring areas CM2, CR6 and CM4 respectively. Open symbols indicate quartz reference temperature. Filled symbols correspond with discharge temperature.



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Fig. 4 State of anhydrite, calcite and fluorite saturation: Circles, triangles and squares represent hot spring areas CM2, CR6 and CM4 respectively. Open symbols indicate quartz reference temperature. Filled symbols correspond with discharge temperature.

										(a)		(b)			
Sample no	Temp (°C)	pH 25(°C)	SI02	Na	К	Ca	Mg	Fe	Mn	co2	SOų	H ₂ S	F	Cl	TDS
CM2A-1	78	8.6	98.4	112	10.0	3.94	0.03	e b	0.04	202.68	11.30	6.29	9.50	5.70	480
CM2A-2	75	8.0	91.1	108	10.8	7.63	0.10	-	0.09	187.53	0.10	9.64	8.93	5.10	450
CM2A-3	70	8.2	91.1	109	12.4	6.81	0.10	0.21	0.08	194.74	5.60	6.71	9.12	4.60	450
CM2A+4	64	8.0	92.8	109	12.4	6.06	0.10	0.08	0.09	183.92	1.90	11.32	9.12	3.30	460
CM2A-5	63	8.5	94.1	113	13.6	5.63	0.09	0.15	0.08	196.91	14.60	5.87	9.31	3.30	460
CM2A-6	69	8.1	94.1	108	13.2	6.00	0.08	-	0.05	188.25	4.30	9.64	8.93	3.30	460
CM2B-6	80	8.3	111.0	115	13.6	4.25	0.01	0.13	0.04	193.30	1.00	13.40	9.12	4.10	480
CM2B-7	65	8.3	106.0	106	14.8	3.94	0.01	0.19	0.05	181.76	9.30	10.50	8.93	5.10	460
CM2C-4	49	8.2	76.4	98.6	11.2	7.70	0.25	0.03	0.09	180.32	17.70	6.71	8.36	4.10	420
CM2C-6	63	8.2	76.4	100	11.2	8.13	0.62	0.08	0.24	179.60	11.50	7.55	8.55	3.30	420
CM2C-9	54	8.4	79.6	102	12.8	6.75	0.21	0.13	0.08	186.81	16.10	6.29	8.55	3.60	420
CM2C-10	56	8.5	85.6	106	11.2	7.20	0.13	0.08	0.05	181.76	11.90	5.03	8.93	3.60	450
CM2C-11	71	8.5	99.9	107	12.8	6.00	0.09	0.14	0.06	201.23	9.70	6.29	9.12	4.10	440
CM2C-12	77	8.1	91.1	109	12.8	7.88	0.14	0.13	0.05	187.53	4.70	10.90	8.93	3.80	420
CM2C-13	69	8.4	91.1	109	12.4	5.20	0.09	0.03	0.05	196.91	14.80	7.55	9.12	3.30	450
CM2C-14	61	8.2	81.1	101	12.4	7.50	0.02	0.06	0.05	186.09	15.80	7.55	8.74	4.10	420
CM2W*	27	7.1	21.2	36.4	8.8	7.38	1.60	1.60	0.38	90.88	6.20	0.84	1.69	3.80	180

TABLE 2: Chemical composition of thermal water from Ban Pong Kum hot spring area (CM2) northern Thailand. (concentration in ppm)

a = Total carbonate ; b = Total hydrogen sulphide

* = Non thermal water

										(a)		(b)			
Sample	Temp	pH	SI02	Na	K	Ca	Mg	Fe	Mn	CO2	SO4	H ₂ S	F	; C1	TDS
no.	(°C)	25(°C)													
****	****	****	******	** ** ** ** ** ** ** **			*****				****	****	*****		****
CR6A-1	92	8.9	109	90.9	8.40	3.22	0.02	0.08	0.04	146.42	6.20	9.22	11.0	5.90	420
CR6A-2	80	8.7	126	95.5	8.60	2.60	0.07	1.10	0.05	126.22	21.00	5.45	11.80	7.00	450
CR6A-3	86	8.9	132	91.4	8.92	1.91	0.02	0.13	-	148.58	6.80	8.80	11.00	5.10	420
CR6A-4	83	9.0	135	97.7	8.60	2.20	0.40	0.43	0.04	150.74	9.70	7.13	11.40	6.40	430
CR6A-5	81	9.1	136	96.8	9.00	1.82	0.02	0.13	0.01	152.19	11.50	6.29	11.20	5.70	450
CR6B-1	77	9.0	129	95.5	9.24	4.06	0.03	0.03	0.05	146.42	9.50	6.29	11.20	5.90	430
CR6B-2	80	7.9	126	89.5	8.20	4.13	0.05	0.10	0.01	133.43	5.60	10.10	10.60	6.40	430
CR6-S*	30	7.1	5.99	5.90	4.20	7.50	2.80	1.88	0.36	25.97	2.50	-	0.29	5.10	80

TABLE 3: Chemical composition of thermal water from Ban Sop Pong hot spring area (CR6) northern Thailand (concentration in ppm)

TABLE 4: Chemical composition of thermal water from Ban Pa Pae hot spring area (CM4) northern Thailand (concentration in ppm)

Sample no.	Temp (°C)	pH 25(°C)	SI02	Na	к	Ca	Mg	Fe	Mn	co2 ^(a)	soų	H ₂ s ^(b)	F	Cl	TDS
СМ4-А	99	9.5	272.80	82	5.6	2.3	~	0.08	-	119.70	10.00	8.8	11.50	1.0	425
CM4-B	94	9.6	256.70	81	5.6	1.7	-	0.05	-	122.70	15.00	4.0	12.00	1.0	425
CM4-C	94	8.9	243.90	81	5.6	2.3	-	0.08	-	124.15	10.00	2.4	12.00	1.0	430
CM4-D	98	9.7	272.80	81	5.6	1.8	-	0.10	-	121.15	13.00	3.2	12.00	1.0	415
CM4~E	97	9.5	240.70	83	5.6	2.2	-	0.10	-	119.70	11.00	2.8	12.00	1.0	435
CM4-F	90	9.3	228.90	79	5.4	6.9	-	0.10	-	110.73	16.00	2.4	11.00	1.0	425
CM4-G	78	9.2	231.00	81	6.5	2.1	-	0.25	-	116.67	10.00	3.2	11.00	1.0	430
CM4-S*	18	8.2	26.7	7.0	1.5	4.2	-	0.23	-	25.45	7.00	0.2	0.20	1.0	80
	-														

a = Total carbonate; b = Total hydrogen sulphide

= Stream water

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Geothermo- meter	log species/ratio	Temperature function, °K	Ma	σa	
Siloz	mHa SiOa	= -0.588 -0.00441.T -1515.21/T +1.3470.logT	9	7	
C02	mH2CO3	= -1.794 -0.00510.T -4469.63/T +4.1414.logT	10	9	
Has	mH2S	= -1.678 -0.00355 •T -5071.05/T +3.8889 • logT	10	11	
NaK	aNa +/aK+	= -0.692 +908/T	7	6	
NaRb	aNa+/aRb+	= +1.318 +1272/T	19	16	
Nali	aNa+/aLi+	= +0.161 + 1201/T	27	22	
CaH	a/Ca+2/all+	= +1.733 +0.01117.T +3890.51/T -3.9977.logT	9	7	
MaK	a, Mg+2/aK+	= -0.00396 •T +978.33/T	27	21	
HF	nuiF	= -5.262 -0.03511 •T -7964.11/T +12.1022 • logT	10	8	
H ₂ SO ₄	mH2S04	= -6.436 -0.03906 •T -13335.68/T +14.7958 • logT	8	7	

TABLE 5. Temperature functions for solute geothermometers.

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^aMean and standard deviations of data points from the reported functions, respectively

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Table 6.	Equations	describing	the	temperature	dependence	٦o	cation/proton	ratios	and	uncharged	species
			cond	entrations in	geothermal di	rill I	hole discharges				

•	Y				Log species.	ion ratio
Species/ion ratio (moles/kg)		Temper	ature function		Mean deviation	S.D.
logH.SiO:	- 0.588	-0.004417	- 1515.21/T	+ 1.3470log T	0.06	0.05
logH;CO;	-1.794	-0.005107	- 4469.63/T	+4.1414logT	0.30	0.26
logH,S°	-1.678	-0.00355T	- 5071.05/T	+ 3.8889log T	0.36	0.33
logH,SO?	- 6.436	-0.03906T	- 13335.68/T	+ 14.7958logT	0.57	0.48
logHF°	- 5.262	-0.03511T	- 7964.11/T	+ 12.1022log7	0.32	0.28
logNa*/H*	2.694	+0.02023T	+4243.47/T	- 6.2069logT	0.14	0.12
logK*/H*	2.505	+0.01971T	+ 3325.71/T	- 5.7814logT	0.12	0.09
log√Ca ^{2*} /H*	1.733	+0.011177	+ 3890.51/T	- 3.9977logT	0.17	0.12
log√Mg ¹⁺ /H ⁺	1.816	+0.010787	+ 3727.48/T	- 4.1640logT	0.34	0.27
log√Fe2*/H*	- 4.696	-0.04273T	- 1011.46/7	+ 10.8032logT	0.18	0.17
logAl(OH);/OH-	- 3.407	-0.02364T	- 3417.36/T	+ 7.8426logT	0.21	0.12

TABLE 7: Equations describing the temperature dependence of mineral solubilities

MINERAL	REACTION	TEMPERATURE FUNCTION (*K)
401 ADULARIA ^C	$KAlSi_{3}O_{B} + BH_{2}O = K^{+} + Al(OH)_{4}^{-} + 3H_{4}SiO_{4}^{0}$	+38.85 -0.0458T -17260/T +1012722/T ²
402 LOW-ALBITE	$NaAlSi_{3}O_{8} + 8H_{2}O - Na^{+} + Al(OH)_{4}^{-} + 3H_{4}SIO_{4}^{+}$	+36.83 -0.0439T -16474/T +1004631/T ²
403 ANALCIME	NaALS1205 H20 + 5H20 - Na + AL (OH) + 2H45104	+34.08 -0.0407T -14577/T +970981/T ²
404 ANHYDRITE	$c_{aso_{4}} = c_{a}^{+2} + so_{4}^{-2}$	+6.20 -0.0229T -1217/T
405 CALCITE	$c_{a}c_{b} = c_{a}^{+2} + c_{b}^{-2}$	+10.22 -0.0349T -2476/T
406 CHALCEXXIV	S10, + 2H,0 - H,S10	+0.11 -1101/T
407 Mg-CHLORITE	$Mg_{a}Al_{2}Sl_{3}O_{10}(OH)_{B} + 10H_{2}O = 5Mg^{+2} + Al(OH)_{A}^{-} + 3H_{a}SlO_{4}^{0} + 8OH^{-}$	-1022.12 -0.3861T +9363/T +412.461ogT
408 FLUORITE	$CaF_{2} = Ca^{+2} + 2F^{-1}$	+66.54 -4318/T -25.471ogT
409 GOETHITE	FeOCH + H_0 + OH - Fe (OH)	-80.34 +0.099T +20290/T -2179296/T ²
410 LALMONTITE	$CaAl_{51}O_{7} + 4H_{2}O + 8H_{2}O = Ca^{+2} + 2Al(OH)_{4} + 4H_{4}SlO_{4}^{0}$	+65.95 -0.0828T -28358/T +1916098/T ²
411 MICROCLINE	$KAlsi_{1}O_{R} + 8H_{2}O = K^{+} + Al(OH)_{A}^{-} + 3H_{A}SiO_{A}^{0}$	+44.55 -0.0498T -19883/T +1214019/T ²
412 MAGNETITE	$Fe_{1}O_{4} + 4H_{2}O = 2Fe(OH)_{4}^{-} + Fe^{+2}$	-155.58 +0.1658T +35298/T -4258774/T ²
413 Ca-MONTMOR	$6Ca_{0.167}Al_{2.33}Si_{3.67}O_{10}(OH)_2 + 60H_2O + 12OH^{"}$ - $Ca^{+2} + 14Al(OH)_4^{-} + 22H_4SiO_4^{"}$	+30499.49 +3.5109T -1954295/T +125536640/T ² -10715.661ogT
414 K-MONTMORS	$3K_{0.33}AL_{2.33}SI_{3.67}O_{10}(CH)_{2} + 30H_{2}O + 6CH^{*}$ - K [*] + 7AL(CH)_{4} + 11H_{4}SIO_{4}^{*}	+15075.11 +1.7346T -967127/T +61985927/T ² -5294.72logT
415 Mg-MONTMOR.	$^{6Mg}_{0.167}$ $^{AL}_{2.33}$ $^{S1}_{3.67}$ $^{O}_{10}$ $^{(OH)}_{2}$ + $^{60H}_{2}$ O + 120H $^{''}_{4}$ + 22H $^{S10}_{4}$ $^{*}_{4}$ + 14A1 $^{(OH)}_{4}$ + 22H $^{S10}_{4}$	+30514.87 +3.5188T -1953843/T +125538830/T ² -10723.711agT
416 Na-MONTMOR	$3Na_{0.33}Al_{2.33}Si_{3.67}O_{10}(CH)_2 + 30H_2O + 6CH^-$ - Na ⁺ + 7AL(CH) ₄ ⁻ + 11H ₄ SiO ₄ ⁺	+15273.90 +1.7623T -978782/T +62805036/T ² -5366.181ogT
417 MUSCOVITE	$KAl_{3}Si_{3}O_{10}(OH)_{2} + 10H_{2}O + 2OH^{-} = K^{+} + 3Al(OH)_{4}^{-} + 3H_{4}SlO_{4}^{0}$	+6113.68 +0.6914T -394755/T +25226323/T ² -2144.771ogT
418 PREHNITE	$Ca_2Al_2Sl_3O_{10}(OH)_2 + 10H_2O = 2Ca^{+2} + 2Al(OH)_4^- + 2OH^- + 3H_4SlO_4^0$	+90.53 -0.1298T -36162/T +2511432/T ²
419 PYRRHOTITE	$8FeS + SO_4^{-2} + 22H_2O + 6OH^{-} = 8Fe(OH)_4^{-} + 9H_2S$	+3014.68 +1.2522T -103450/T -1284.861ogT
420 PYRITE	$8FeS_2 + 26H_2O + 10CH^{-} = 8Fe(OH)_4^{-} + SO_4^{-2} + 15H_2S$	+4523.89 +1.6002T -180405/T -1860.331ogr
421 QUARTZh	$Sio_2 + 2H_2O - H_4SiO_4^{\circ}$	+0.41 -1309/T (0-250°C); +0.12 -1164/T (180-300°C)
422 WAIRAKITE	$CaAl_{2}Si_{4}O_{12} \cdot 2H_{2}O + 10H_{2}O - Ca^{+2} + 2Al(OH)_{4}^{-} + 4H_{4}SiO_{4}^{0}$	+61.00 -0.0847T -25018/T +1801911/T ²
423 WOLLASTONITE	$Casio_3 + 2H^+ + H_2 O = Ca^{+2} + H_4 sio_4^\circ$	-222.85 -0.0337T +16258/T -671106/T ² +80.68logT
424 ZOISITE	$Ca_2Al_3Si_3O_{12}(OH) + 12H_2O = 2Ca^{+2} + 3Al(OH)_4^{-} + 3H_4SIO_4^{+} + OH^{-}$	+106.61 -0.1497T -40448/T +3028977/T ²
425 EPIDOTE	$Ca_2 FeAl_2Si_3O_{12}(CH) + 12H_2O = 2Ca^{+2} + Fe(CH)_4^{-}$ + 2Al(CH)_4 + 3H_SIO_4^{-} + CH	-27399.84 -3.8749T +1542767/T -92778364/T ² +9850.381ogT
426 MARCASITE ¹	$8FeS_2 + 26H_2O + 10OH^{-} = 8Fe(OH)_4^{-} + 5O_4^{-2} + 15H_2S$	+4467.61+1.5879T-169944/T -1838.45logT

AIF not otherwise specified data for minerals and aqueous species are from BELGESON et al. (1978) and HELGESON (1969). ^bData on Al(OR)⁷ and Fe(OR)⁷ are from ARNÓRSSON et al. (1963a) and GUNNLAUGSSON and ARNÓRSSON (1982) respectively. ^CThermodynamic data on adularia are from HELGESON (1969). ^dData on the enthalpy and entropy of calcium ion at 25°C are from ROBE et al. (1978). ^CARNÓRSSON et al. (1963b). Their empirical solubility function is very similar to the experimental solubility data of FOURNIER (1977). ^fNORDSTROM and JENNE (1977). ^GLANGMUIR (1971). ^hMOREY et al. (1962), KENNEDY (1950). ¹NAUMOV et al. (1971).

Location	Meas.	NaKCa	Qtz.	c02	H ₂ S	NaK	CaH	MgK	HF	H ₂ SO4	m̃(a)	_δ (a)
											(b) (c)	(b) (c)
CM2A-1	78	182	126	150	150	192	124	159	158	112	146(140)	25(19)
CM2A~2	75	181	123	155	162	202	124	132	164	88	144(135)	34(27)
CM2A+3	70	190	123	153	154	217	122	139	161	109	148(138)	33(20)
CM2A+4	64	191	124	155	165	217	127	139	165	105	150(140)	34(23)
CM2A-5	63	196	124	150	150	224	121	148	158	113	149(138)	35(18)
CM2A-6	69	195	125	154	161	225	126	147	163	109	151(141)	35(21)
CM2B+6	80	197	133	156	167	223	130	199	167	103	160(151)	39(31)
CM2B-7	65	206	131	154	162	242	130	205	165	115	163(151)	42(29)
CM2C+4	49	186	114	149	153	216	118	116	153	112	141(131)	35(20)
CM2C+6	63	185	114	149	155	214	117	97	154	109	139(128)	38(24)
CM2C+9	54	194	115	147	150	228	117	126	151	110	143(131)	38(18)
CM2C-10	56	184	119	147	147	208	116	130	153	110	141(132)	31(17)
CM2C-11	71	193	127	152	151	224	121	144	159	112	149(138)	35(18)
CM2C-12	77	190	123	154	163	220	122	133	162	109	148(138)	35(22)
CM2C-13	69	192	122	151	154	217	122	143	158	113	147(138)	33(18)
CM2C-14	61	191	121	152	156	225	120	126	159	115	147(136)	36(19)
m̃(a)		191	123	152	156	218	122	143	159	109	148(138)	
8(a)		6	5	3	6	11	4	27	5	6	6 (6)	

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TABLE 8: Geothermometry results for Ban Pong Kum hot spring area (CM2) northern Thailand

a = Mean and standard deviations of geothermometry results

b = The results do not include the NaKCa temperature

c = The results do not include the NaK and NaKCa temperatures

		QCZ	C02	H ₂ S	NaK	CaH	MgK	HF	H2SO4	M(a)	δ(a)
арарара	******	****	****	*******	арарарая	ARARAMAN A	*******	*******	********	*****	*****
										(b) (c)	(b) (c)
92	181	130	141	153	196	120	159	158	106	145(138)	28(20)
80	183	140	147	151	192	132	134	174	123	149(143)	23(17)
86	190	141	146	155	203	130	163	167	113	152(145)	27(19)
83	184	142	145	150	193	126	97	166	114	142(134)	30(23)
77	183	139	143	148	202	118	155	162	113	149(142)	27(19)
80	178	141	156	167	193	137	136	163	112	147(140)	28(19)
	184	139	146	153	197	127	144	185	120	154(149)	26(22)
	4	4	5	7	5	7	24	9	6	4 (5)	
988878	2 66 7 7 60	2 181 30 183 36 190 3 184 7 183 30 178 184 4	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

TABLE 9: Geothermometry results for Ban Sop Pong hot spring area (CR6) northern Thailand

TABLE 10: Geothermometry results for Ban Pa Pae hot spring area (CM4) northern Thailand

Location	Meas.	NaKCa	Qtz	co2	H ₂ S	NaK	CaH	MgK	_{HF} (e)	H ₂ SO4	M(a)	_δ (a)
******	*******	444444444	*********		16 66 68 66 64 64 64 64 64 64	44444444	*****	*******	********	****	(b) (d)	(b) (d)
CM4-A	99	167	189	191	187	170	178	106	-	152	168(179)	30(15)
СМ4-В	94	170	177	177	163	173	164	108	-	143	158(166)	25(13)
CM4-C	94	167	176	232	192	165	279	104	-	187	191(205)	55(43)
CM4-D	98	169	178	165	152	180	146	108	-	134	152(159)	26(18)
CM4-E	97	167	174	186	165	167	175	106	-	148	160(169)	27(13)
CM4-F	90	157	172	201	174	164	182	105	-	165	166(176)	30(14)
CM4-G	78	176	173	210	184	179	225	111	-	168	179(190)	36(23)
M ^(a)		168	177	195	174	171	193	107	-	157	168(178)	
8(a)		6	6	22	15	6	45	2	-	18	13 (16)	

a = Mean and standard deviations of geothermometry results; b = The results do not include the NaKCa temperature;

c = The results do not include the NaK and NaKCa temperatures; d = The results do not include the NaKCa and MgK temperatures;

e = The temperatures are not reliable.



APPENDIX I: Analytical methods

1. Recording of Samples.

One of the most important thing during collection of water samples is good recording. Analysis of water after careful collection procedure is of little use if noone knows where the samples were taken.

For the purpose of keeping good record of samples, it is suitable to use special form (see pages A-4 and 5. The upper part is for general information, such as number of sample, date of collection, the location of sample, reference to geographical map, and brief description of geological features. The temperature of the spring, and estimated or measured flow rate is also recorded. The lower part of the form is for recording all analytical measurements done during or shortly after collection. This part is used in connection to chapters C and D of this manual.

2. Collection Technique.

For the collection of thermal water from hot springs and drillholes with temperature lower than 100°C the following are required:

- 1. Polythene tubing 1/4", 5 m long.
- Polythene can, 0.5 1.0 liters.
- 3. Polythene funnel.
- 4. Maximum thermometer.
- 5. Stainless stoel cooling spiral to fit 1/4" tubing.
- 6. Bucket (10 liters).
- 7. Gas sampling bulb (250 ml).
- 8. Polythene bottles for storing the samples.

Various techniques have been developed to collect water from thermal springs, in order to minimize contamination from soil and rocks. Spring with high flow rates and/or wide basins are most easily sampled by scooping up the water with the can. If there is some slope where the water can flow, it is most convenient to use the funnel and the tubing (see lower part of fig. 1 and 2). In some cases, if the pooles are only a few centimeters deep the water can be sucked up using the gas sampling bulb.

The cooling spiral is only necessary for that part of the sample which is stored in the gas sampling bulb, later used for determination of pH, OO_2 , and H_2S (see fig. 2). The cooling spiral is made of stainless steel, but cooling spirals made of copper have been used. The latter is not suitable because the copper reacts with the hydrogen sulphide giving low concentration for sulphide during determination. It is desirable to cool the sample down to the storage temperature, where the analysis are done. If the sample is not cooled before it is stored in the gas sampling bulb, volume reduction caused by later cooling will produce low pressure in the bulb and cause degassing. During collection the temperature is measured using maximum thermometer and the water flow is measured or estimated.

3. Treatment of Samples.

It must be garanteed during collection of samples, that the concentration of the elements does not change until the analyses are carried cut. The following components often changes during storage: pH, carbonate, hydrogen sulphide, calcium, magnesium, sulphate, nitrate and silica. This can be prevented in the following way:

1. Carbonate, sulphide and pH.

Carbonate and sulphide degasses during storage and change the pH. To prevent this, part of the sample is cooled and stored in the gas sampling bulb. This is determined within 36 hours, usually the same evening.

2. Sulphate.

If the concentration of the hydrogen sulphide is high, the sulphide can oxidize to sulphate. To be able to determine sulphate after storage, the sulphide must be precipitated using $\text{Zn}(\text{CH}_3\text{COO})_2$ solution (20.88 g/l). Two ml of the solution is added to 100 ml of the sample and stored in polythene bottle.

3. Calcium and nitrate.

is high. To prevent this, part of the sample is acidified. water during storage, specially if the carbonate content age. Oxidation may be prevented by freezing the sample. Amonium and nitrite may oxidize to nitrate during stor-Calcium and magnesium sometimes precipitates from the One ml conc. HCl is added to 100 ml of sample and then stored in polythene bottle.

4. Silica.

which simplifies analysis. If this is left, the polymerized If the silica content is above 100 ppm, it will polimerize. silica can be disintergrated by boiling in dilute alkaline This can be prevented by dilution of the sample if the silica content is expected to be higher than 100 ppm, solution.

expected to change during storage. For determination The concentration of other major components are not of these elements, 500 ml of sample is stored in a polythene bottle.

Sumary of Collection:

1. One gas sampling bulb, cooled to 20-30 °C.

500 ml sample untreated, in polytheme bottle.
 100 ml sample + 1 ml conc. HCl to polytheme bottle.
 100 ml sample + 2 ml Zn(Gi₃C00)₂ to polytheme bottle.

CONSULTING GROUP LTD. A NUT REAL

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YEAR WONTH COUNTRY

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Determination of pH and carbonate.

Total carbonate is determined by titration with o.1 N HCl from pH 8.2 to 3.8 at 20°C but pH is measured using pH meter.

The following equipment and reagents are required for this determination:

1) portable pH-meter

2) pH electrode

3) saturated KCl solution

4) three small beakers for pH buffers

5) 150 ml beaker for sample

6) 50 ml and 100 ml volumetric flasks

7) themometer

8) 25 ml burette calibrated at 0.1 ml interval,

burette stand and clamp or 2.5 ml micro syringe

9) 1 ml and 5 ml pipettes

10) 0.1 N HCl solution (e.g. titrisol 0.1 N HCl, Merck 9973)

11) Approx. 0.1 N NaCH solution. Dissolve 4 g NaCH in

1 liter of distilled water

12) pH buffers. Phosphate buffer 6.88, borax buffer 9.22 and acetate buffer 4.62

13) distilled water

Procedure:

1) Fill the electrode with KCl solution if necessary.

2) Rinse the electrode with distilled water.

- 3) Adjust the pH-meter to the 6.88 pH-buffer.
- 4) Measure the 9.22 and 4.62 buffers and rinse the electrode between measurements with distilled water.
- 5) Measure 100 ml (50 ml) of sample using the volumetric flask. and put into the 150 ml beaker.

6) Determine the pH and the temperature.

7) Adjust the pH carefully to correct 8.2 value using 0.1 N HCl if the pH is higher than 8.2 but using

0.1 N NaOH if the pH is lower than 8.2. 8) Titrate from pH 8.2 to pH 3.8 using 0.1 N HCL.

9) Record the amount HCl required. 10) Rinse the electrode with distilled water and go to no. 5. Titrate each sample in duplicate. 13) ppm co2 = (mlHC1 · N · 44000) - (6.93 +1.182 ppmH2S + 0.0088 ppm Si 0.")

The procedure in part 1 - 4 are only made once every time measurements are carried cut and are valid for all samples measured at the same time. The measurement of three pH buffers makes it possible to correct for deviation from theoretical behaviour of the electrode. Two methods can be used for these corrections. One involves plotting measured values of the pHbuffers against right values of the buffers and then use the best fit line for correcting the pH of the samples. The other method is to use two buffers (6.88 and 9.22) and calculate correct pH using:

pH sample_corr.= 6.88 + (9.22-6.88) (pH sample_meas.-6.88) buffer 9.22_meas.-6.88

The values of the pil-buffers varies with temperature. The values 4.62, 6.88 and 9.22 are at 20°C. If the temperature is different the values have to be corrected according to table 1.

TABLE 1.

Changes in pH values of buffers with different temperature.

°C	Phosphate	Borax
	Buffer	Buffer
0	6.984	9.464
5	6.951	9.395
10	6.923	9.332
15	6.900	9.276
20	6:381	9.225
25	6.865	9.180
30	6.853	9.139
35	6.844	9.102
38	6.840	9.081
40	6.838	9.068
45	6.834	9.038
50	6.833	9.011
45 50	6.834 6.833	9.038

°C	Phosphate Buffer	Borax Buffer
55	6.834	8,985
60	6.836	8.962
70	6.845	8.921
80	6.859	8.885
90	6.877	8.850
95	6.886	8.833

If the electrode is far off right values for the buffers, the starting and the end point of the titration must be corrected. The new values can be calculated using the same equation as for pH correction. In table 2 the starting and end points have been calculated for few values of the pH buffer 9.22.

TABLE 2

Values of starting and end point for CO₂titration. The pH meter is adjusted to the 6.88 buffer, and the buffer 9.22 is measured.

I. Measured value of buffer 9.22 .

II. pH at the starting of CO2 titration.

III. pH at the end of CO, titration.

I	II	III	I	II	III
8.7	7.91	4.48	9.24	8.21	3.77
8.75	7.93	4.42	9.26	8.22	3.75
8.80	7.96	4.35	9.28	8.23	3.72
8.85	7.99	4.29	9.30	8.25	3.69
8.90	8.01	4.22	9.32	8.26	3.67
8.95	8.04	4.16	9.34	8.27	3.64
9.00	8.08	4.09	9.36	8.28	3.62
9.02	8.09	4.06	9.38	8.29	3.59
9.04	8.10	4.04	9.40	8.30	3.56
9.06	8.11	4.01	9.50	8.36	3.43
9.08	8.12	3.98	9.55	8.39	3.37
9.10	8.13	3.96	9.60	8.41	3.30
9.12	8.14	3.93	9.70	8.47	3.17
9.14	8.15	3.91	9.80	8.53	3.04
9.16	8.17	3.88	9.90	8.58	2.90
9.18	8.18	3.85	10.00	8.64	2.77
9.20	8.19	3.83		10000000	
. 9.22	8.20	3.80			

Determination of H₂S by dithizone

Hydrogen sulphide is determined by titration with $\mathrm{Hg}\left(\mathrm{GH}_3\mathrm{COO}\right)_2$ solution.

Equipment and reagents necessary for the field measurement of hydrogen sulphide are:

- 10 ml burette calibrated at 0.05 ml intervals, burette stand and clamp or 1 ml micro syringe.
- 2) 50 ml Erlenmayer flask.
- 3) 1.0 ml, 5.0 ml and 10 ml pipettes.
- 4) 5.0 ml or 10 ml measuring cylinder.
- 5) Glass rod
- 6) Acetone
- 5 N NaCH solution. Dissolve 200 g NaCH in 1 liter distilled water.
- 8) Solid dithizone.
- 9) 0.001 M Hg(CH₃COO)₂ solution freshly prepared. Dissolve 0.3187 g Hg(CH₃COO)₂ in 1 liter distilled water.

Procedure:

 Measure 5 ml 5N NaCH and 5 ml acetone into 50 ml Erlermayar flask.

 Add 1.0 - 10 ml of sample and distilled water to the flask. The amount of sample depends on the H₂S concentration. The total amount sample + distilled water should be 10 ml.

- 3) Add small grain of solid dithizone.
- 4) Titrate with 0.001 M Hg(CH3C00), to red endpoint.
- Record volume of sample and amount of Hg(CH₃C00)₂ needed.

6) ppm H₂S =
$$\frac{\text{mL Hg}(CH_3C00)_2 \cdot 34}{\text{mL sample}}$$

During the titration, black precipitate of HgS forms. The end point is decided when the colour changes from yellow

colour of the dithizone in alkaline solution to the red colour of the Hg-dithizonate. If the concentration of $\mathrm{H_2^S}$ is high the sample becomes yellowish brown and even black during titration. This is caused by the HgS precipitate and makes the endpoint uncertain. In the case of high concentration of $\mathrm{H_2^S}$ it is better to reduce the volume of the sample.

Spectrophotometric Determination of Silica

This method is based on the reaction of silica with molybdate ions at pH of 1.2 - 1.5. A green silicomolybdate complex is formed which is determined by spectrophotometry. If the concentration of silica in thermal water is higher than 100 ppm. the silica polymerizes and if the polymerized silica will not react with molybdate in the cold. Treatment with alkall converts it all to the jonic state.

As described under sample collection it is dosirable to dilute samples containing more than 100 ppm SiO_2 sufficiently to bring the final silica concentration below 100 ppm. When this is done, later analysis should follow the procedure described for samples containing less than 100 ppm SiO_2 . Dilution below 100 ppm is necessary for saline waters. The silica in excess of this concentration will precipitate upon storage for one week or less.

The adopted procedure covers the concentration range of 20-500 ppm. Higher concentrations can be determined by taking smaller aliquot. No interference will occur from elements present in the thermal waters. Only colour or turbidity of the sample will interfere. High concentrations of hydrogen sulphide may reduce the silicomolybdate complex to molybdenum blue. This can be prevented by oxidising of the sulphide with jodine.

The main disadvantage of this method is the unstability of colour of the solution. This necessitates that samples and standards need to be prepared at the same time and that absorbance must be read between 10 and 60 minutes after developing the colour. Average difference between duplicate samplus should be 3t or less over the whole concentration range.

Procedure

Sam	ple containing more than	Sam	ples containing less t	than	100
100	ppm sio ₂	bpm	sio ₂ .		
3	Pipette 5 ml sample into	3	Pipette 5 ml sample 1	Into	50
	platinum crucible or teflon		volumetric flash		
	beaker				
(a)	Add 0.5 ml of IN NaOH solution				
(q)	Add 5 ml distilled water and				
	heat on a steam bath for 10				
	minutes. Take care that				
	there is no significant loss				
	of volume by evaporation				
()	When cold transfer the				
	solution to a 50 ml volu-				
	metric flask				
P	Add 0.5 ml of IN HCL				

If the sample contains high concentration of hydrogen sulphide follow step 2-3 otherwise go to step 4.

- Add iodine solution dropwise until the solution in the volumetric flask becomes yellow or yellow brown
- Destroy the yellow or yellow brown colour by adding sodium thiosulphate dropwise
- 4) Add 2 ml of anmonium molybdate solution
 5) Add 1 ml of 6N hydrochloric acid and ⁶¹¹
- 5) Add 1 ml of 6N hydrochloric acid and fill to the mark. Mix and leave for 15 minutes
- 6) Read the absorption at 410 millimicron within 60 minutes.

Reagents

- 1) Sodium hydroxide, analytical roagent grade
- 2) IN sodium hydroxide (NaON). Dissolve 40 g of the reagent in distilled water and dilute to 1 litre. This solution is required only for digesting samples containing more than 100 ppm SiO₂.
- 3) Hydrochloric acid, sp. gr. 1. 18 or 1.19, analytical reagent grade.

님

- 4) IN hydrochloric acid (HCI) solution. Mix 40 ml of the concentrated acid with 400 ml of distilled water. This solution is needed to neutralize samples after digestion with NaOH - solution.
- 5) EN hydrochloric acid (HCL) solution. Mix 240 ml of the concentrated acid with 200 nl of distilled water.
- 6) Ammonium molybdate solution, 10%. Dissolve 20 grof the reagent in water and dilute to 200 ml.
- 7) Potassium iodide (XI), analytical reagent grade.
- 8) Iodine resublimed (I_2) , analytical reagent grade.
- 9) Iodine solution, approx. 0.1 N. Dissolve 2.5 g KI in 5 to 10 ml distilled water, add 1.77 g I_2 and dilute to 100 ml with distilled water.
- 10) Sodium thiosulphate, analytical reagent grade.
- II) Sodium thicsubhate approx. 0.05N. Dissolve 1.2409 g of the reagant in 100 mL distilled water.
- 12) Standard silica solution 100 ppm. The solution can be obtained from manufacturers of chemicals. If not available, solution of this strength can be propared as follows: Fune 0.2 g of pure silica with 3g of sodium carbonate in a platinum crucible. Dissolve in water and make to 200 ml. Store in polythone bottle. It is convenient to standardise the solution by gravimotric analysis.

Standards

From the 1000 mg/l SiO₂ solution prepare standard solutions containing 20,50,100,150,200 ppm SiO₂. Proceed as described in stage 4 - 7 of the procedure.

Small quantities of sulphate can be determined by titration with barium perchlorate, using thorin as indicator. The titration is carried out in 80 % alcohol in the pH range 2.5 to 4.0. Before the titration the cations are removed by passing the sample through an ion exchange column. Phosphate makes the methode inaccurate but it is usually absent or in very low concentreatio in thermal waters.

Reagents.

- 1. Cation exchanger (Ionenaustaucher I, Merk Art. 4765)
- 2. 2- propanol, analytical reagent grade.
- 3. Perchloric acid, sp.gr. 1.67, Analytical reagent grade.
- 4. Barium perchlorate, analytical reagent grade.
- 5. Absolute ethyl alcohol , analytical reagent grade.
- Barium perchlorate, 0.005 M. Dissolve 2.0 g barium perchlorate trihydrate (1.63 g barium perchlorate water free) in 200 ml.of distilled water and add 300 ml of ethyl alcohol. Adjust the pH to about 3.5 with perchloric acid. Standardize against sulphate standard.
- 7. Sodium sulphate, analytical reagent grade.
- Sulphate standard, 1000 ppm SO₄. Dissolve 1.4796 g of Na₂SO₄ in 1000 ml of distilled water.
- 9. Thorin, analytical reagent grade.
- Thorin, 0.2 %. Dissolve 0.2 g of the reagent in 100 ml of distilled water.

Apparatus

- 25 ml byrette with ionic exchanger. The bottom of the byrette is stopped with glass wool (or cutton wool). About 15 ml of the ionic exchanger is placed in the byrette.
- 2. 10 ml byrette, subdivided at 0.02 ml for barium perchlorate.
- 3. Magnetic stirrer.
- 4. Porcelain evaporating dishes.

Procedure.

 Fill the ionic exchange byrette with the sample and pass it through the column. Fill the byrette again and pass the sample through. Fill the byrette for the third time and let the sample pass dropwise to the 0 mark. Dispose the efluent.

- Pass 10 ml of sample (or less imount if the concentration of SO₄ is high) dropwise through the ionic exchange column to the porcelein evoporating dish.
- 3. Add 40 ml propanol (ratio: sample/propanol 1/4)
- 4. Add 3 drops of thorin indicator.
- Titrate with barium perchlorate using magnetic stirrer until first change from yellow to pink colour appears.
- 6. Calculations.

$$ppm SO_4 = \frac{m1 Ba(C1O_4) \cdot N}{m1 sample} \cdot 96062$$

Reference.

Fritz, J.S. and Yamamura, S.S. 1955. Rapid microtitration of sulphate. Analytical chemistry, vol. 27, no. 9, pp 1461-1464.

APPENDIX II: Basic statistical equations for two variables

These equations calculate the means and standard deviations derived from a set of ungrouped data points $\{(x_1, y_1), 1 = 1, 2, ..., n\}$, or grouped data points $\{(x_1, y_1, f_1), 1 = 1, 2, ..., n\}$. f_1 denotes the frequency of repetition of (x_1, y_1) .

Means

 $\bar{\mathbf{x}} = \frac{1}{n} \sum_{i=1}^{n} \mathbf{x}_{i} \qquad \bar{\mathbf{y}} = \frac{1}{n} \sum_{i=1}^{n} \mathbf{y}_{i}$

Standard deviations

$$h_x = \sqrt{\frac{2x_1 - h_x}{n-1}}$$

/ 2 -2

$$Sy = \sqrt{\frac{\Sigma y_1^2 - n\bar{y}^2}{n^{-1}}}$$

Note n is a positive integer and n > 1

APPENDIX III: Computer print out of WATCH3 and WATCH5

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520210	11300830	1000915								
QUARTZ	125.7	CHALCED	AND	102.1	NAK	195.3				
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NaL1	Y+744	124	2	VSU	n*ACT	ŧ	0.801	PUCTH	0*711	
520210	02300830	5160002								
QUART2	123.2	CHALCED	UNI	\$9,4	NAK	205.3				
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URLI	1.111	671 UP1	2	VSU	C')??!	ż	104*0	4057H	68*0	
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Si02	98.0	C02 153	19 19	H2S Mak	154.5	NaK ur	217.0	NaRb	6466	
THPU		77T UP1	2	VIEL	P-LOT	z	A*101	LACTU	L+141	
520210	4300830	516004								
QUARTZ	124.2	CHALCED	UNY	100.4	NAK	219.7				
S102	5*66	C02 155	5	H2S	165.0	NaK	217.0	NaRb	9.99.9	
NaLI	6.999	CaH 127	•	MsK	139.0	1	165.5	H2504	105.0	
520210	5300830	2160005								
QUARTZ	123.7	CHALCED	UNY	100.0	NAK	226.8				
Si02	0.99	CD2 150	2	H2S	150.0	NaK	224.5	NaRb	6.949.9	
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Nati	999.9	CaH 126	0	Yek	147.5	노	163.5	H2504	109.5	
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NaLi	6.992	CaH 130.		EX.	5.991	生	367.5	H2SD4	103.0	
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0114817	A.071	CHAF CSDR	AM	0.7.0	NAK	6.540				
S102	106.0	C02 154.		S	162.5	XIX	242.5	NaRth	649.9	
NaLi	6.999	CaH 130.	0	Nel Nel	205.5	늊	165.0	H2504	115.5	
520230	13068302	160009								
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NaLi	6.999	CaH 118.		X	116.5	1	153.0	H2SD4	112.5	
5202304	3008305	160010								
DUARTZ	113.9	CHAL CEDO	IN	89.7	NAK	217.3				
Si02	89.0	C02 149.	H O	3	0.25	NaK	214.5	NaRb	999.9	
NaLi	6*666	CaH 117.	¥2	eK.	\$7.5	খ	154.0	H2504	109.5	

5.011 999.9 999.9 999.9 5.211 999.9 999.9 9-99.9 999.9 MaRb H2SOA NaRb H2504 NaRb H2SDA MaRb H2SD4 NaRb H2SD4 NaRb H2504 KaRb H2SD4 NaRb H2S04 WaRb HZS04 151.5 208.5 224.5 220.5 217.5 222.5 196.0 192.5 203.5 MAK 230.2 150.5 NaK 126.0 HF 211.9 Nak HF 226.8 NaK HF 223.2 Nak HF 220.3 NaK HF 227.9 NaK HE 199.3 HaK HF 155.5 北武 南 206.8 NaK HF NAK 147.0 130.0 NAK 151.5 144.5 163.5 NAK 154.5 143.5 NAK 156.0 NAK NK 159.5 NAK 151.0 漢 155.0 91.3 H2S MaK 94.9 H2S Maik 103.3 H2S Melk 99.2 H2S MeK 98.5 HZS MsK 97.2 H2S Nek 106.4 H25 MsK 116.6 H2S MaK 118.1 H25 MeK CHALCEDONY 02 147.5 al 116.0 QUARTZ 115.4 CHALCEDONY S102 90.5 CO2 147.5 Mali 999.9 CaH 117.0 CHALCEDONY D2 151.0 aH 122.5 152.0 154.0 CHALCEDONY GUARTZ 121.0 CHALCEDONY SiO2 96.0 CO2 152.0 Nali 999.9 Cah 120.5 GUARTZ 129.9 CHALCEDOHY Si02 105.0 CO2 141.5 Nati 999.9 CaH 120.0 JUARTZ 139.6 CHALCEDONY SIO2 115.5 CO2 147.5 Nali 999.9 Cah 132.0 CHALCEDONY 146.5 CHALCEDONY GUARTZ 122.3 CHALCE S102 97.5 C02 15 Nali 999.9 Cah 12 GUARTZ 123.0 CHALC S102 98.0 CD2 1 NaLi 999.9 CaH 1 GHARTZ 126.9 CHAL SIO2 102.0 CD2 NaL1 999.9 CaH Cert Her 52023103008305160012 52023113008345160013 52023123008305160014 52023133098395160015 52023143008305160016 66061013008305160001 QUARTZ 141.0 CHAI SiO2 117.0 CD2 Nati 999.9 CaH 66061023008305160002 66061033008305160003 GUARTZ 118.9 SID2 94.0 (Mali 999.9 (

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999.9

NaRb H2SD4

200.0

203.2 NaK HF

NAK 146.5 165.0

118.2 K2S MsK

CHALCEDONY 02 142.5 1 aH 125.5 1

Si02 117.0 C02 NaLi 999.9 CaH 66062013008305160006

52023093008305160011

QUARTZ 141.1

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NaRb H2S04

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COT Carl

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CHAL CEDONY 145.0

PROGRAM WATCHS																							÷	
SCIFACE INSTITUTE unu thailand 1985-38-14 chem. BEOTHERMOMETRY TENPERATURES IN DEG.C		2404TATATATATATATATATATATATATATATATATATAT	SIHCOR > 2.0	GAS STAUBILITY MILLIPLYING FACTOR : 0,20	GUARTZ 199.5 CHALCEDRHY 140.2 MAK 172.4 ITERATIONS WHILE DECIDING "TEMPERATURE" MORE THAN 1001 SiO2 145.0 CD2 191.0 H2S 187.5 Mak 170.0 Marb 999.9 Mali 999.9 CaH 178.0 Mar 106.0 HF 999.9 H2504 122.5	54041023008101250002 MaTCHA	GAS SOLUBILITY MULTIPLYING FACTOR : 0.20	GUMATZ 176.7 CHALCEBORY 155.5 MAK 175.9 SUG2 157.5 CD2 177.0 H25 163.5 MAK 173.5 MARb 999.9 Mali 999.9 Can 164.0 Mak 108.0 HF 223.5 H2504 143.5	54041033008101250003 WATCH6	GAS SOLUBILITY MULTIFLYING FACTOR : 0.20	QUARTZ 176.2 CHALCEDNY 155.0 MAK 166.6 ITERATONS WHLE DECIDINS 'TERPERATURS' MORE THAN 1001 SiO2 157.0 CO2 232.0 H2S 197.0 MAK 165.0 MARb 999.9 Wali 999.9 Cah 279.5 Mak 104.5 HF 999.9 H2504 187.5	54041043008101253004 VATCH6	GAS SOLUBILITY MULTIPLYING FACTOR : 0.20	QUMRTZ 178.3 CHMLCEDONY 157.2 MMK 182.9 SiO2 159.5 CO2 165.5 H25 152.0 Mak 180.0 Maro 999.9 Mali 999.9 Cah 146.5 Mgk 108.5 HF 200.0 H2504 134.5	54041053008101230005 BATCH6	GAS SOLUBILITY HULTIPLYING FACTOR : 0.20	QUARTZ 174.0 CHALCEDARY 152.6 MAK 169.1 5102 154.0 CD2 184.5 H25 165.0 MAK 167.0 Marb 999.9 Mali 999.9 Cam 175.5 Mak 106.0 MF 261.5 H25D4 148.5	54041063008101250006 WATCH6	GAS SOLUBILITY MALTIPLYING FACTOR : 0.20	BUARTZ 172.0 CHALCEDONY 150.5 * MAK 166.5 ITERATIONS WHLE BECIDING TENETRANION TAAN 1001 SIO2 152.0 CD2 201.0 H25 174.0 Mak 164.5 Marb 999.9 Mali 999.9 Cah 182.5 Mak 105.0 HF 959.9 H2504 165.5	54041073008101250007 MAICH6	64S SOLUBILITY MULTIPLYING FACTOR : 0.20	ULBARTZ 172.7 CHALCEDONY 151.3 HAK 182.4 ITERATONS WHLE DECIDING TEDPERATURE" MORE THAN 1001 Sidz 152.5 CH2 210.5 H2S 184.5 MAK 179.5 MARD 999.9 Mali 999.9 Cah 225.5 Mak 111.0 HF 999.9 H2SOA 168.5	
	999.9			6.999.9	120.5																			
	5 NaRb 5 H2SO			5 NaRb	D HZ20																			
6.	202.		ļ	.193.	182.																			
NAK 205	S HE			NAN 170	± ?																			
5.9	K 155			167 167	N 136																			
DONY 11	3.5 HS			11 INU	1.0 Ma																			
CHALCE	H 11	1007		LINHLLEI 124 134	1																			
38.9	4.5 C	08305160		7.0 6																				
QUARTZ 1	Si02 11 Malli 99	660620230		Si02 11	Val 1																			

ACTIVITY C	DEFFICIENTS	IN DEEP WAT	EK EK					
ŧ	0.912	-KSD4-	0*905	H	+	579.0	FECL+	0.902
-10	106*0	1	106.0		ŧ	0.437	AL++	0.437
	20410	-70	0.879	2 1	CH+	.904	ALOH++	1/9*0
	1/010	THU I	70/10	21		404.1	RL(UN)2+	506.0
HZBUS-	RAR*0	Lott	0.475	2 2	+(HD)	1.669	AL.(0H)4-	0.903
	1111	TION	707 0	2 1		1001	THURSDAY	201.0
HS-	0.901	CAHEN	4.00.904	2 8	17 (UN) 4-7 (UN)	505.0	AL (SIM) 2-	£06*0
J.	0.669	MGHC03	+ 0.902		S04+	1.904	ALF24	0.905
HS04-	205*0	CAOH+	0.906	F	Ct+	0.669	ALF4-	0*903
S04	0.662	HOSE	0.907		0.24	1.904	ALFS-	0.665
NASU4-	0.905	1414	0.898	R	-+10	1.902	1156	0.400
CHENICAL CO	I STNENDER	N DEEP WATER	(PPM AND LOG)	(JUE)				8
HH (ACT.)	00*0	-7.888	H6++	0.02	-6.023	FE(CH)3	0.00	0.000
岩	. E0.2	-3.923	NACL.	10.0	-6.638	FE(0H)4-	0.00	0,000
H4SI04	138.55	-2.841	KCL	0.00	-8.349	FECLA	0.00	0,000
H3SI04-	17.75	-3.729	NAS04-	0.27	-5.644	FECL2	0.00	0.000
H2SI04	0.02	-6.642	KS04-	0.08	-6.240	FEOLH	0.00	0.000
NAH3SI04	1.12	-5.023	CASD4	0.20	-5.825	FELL24	0.00	0.000
H3803	00*0	0000*0	HGS04	0.01	-6.992	FECL3	0,00	000*0
H2B03-	0.00	0.000	CAC03	1.59	-4.798	FECL4-	0.00	0*000
2003	11.31	-3*739	HECO3	10.0	-7.220	FES04	0*00	0.000
HUU5-	101007	105.2	CAHCU3+	2.65	182.1-	FES04+	0.00	0.000
	201	COC++-	TOM.UST	10.0	001.1-	8L +++	00.0	0000
57H	8710	480*0	CAUNT	10.0	-0.019	ALOH++	00*0	0000
-64	2000	20/102	MUMT NUM	00*0	CC2*/-	AL (UH) Z+	00*0	0.000
		07011		20.0	000*0	ALCOM13	00.0	0000
HICON	- 00.0	101.8	144	00*0	0000	AL(UH) 4-	00*00	0.000
	10 01	OCCUP.	1111	00.0	000.0	RL5841	00.00	0000
- Loo	Vo v	04/10		00.0	000*0	RL(50472-	00"0	0000
	0 50	DATE /	FCURT	00.0	0.000	ALT T	0.00	0.000
1	07 1	TOPIC D	7(10)34	00*0	0000		00.0	0000
TVA	CZ 111	211 0	-C(00)3-	00.00	000*0	HL73	0.0	0000
	7/1111	203 2	LC/UD/4		000*0		00.0	000*6
CAH	2,18	4.264	FE (GH)24	0.00	0.000	ALF 3	00.0	0.000
		10141	17/00/51				60*0	000*0
IONIC STREM	GTH = 0.00	S71 10N	ITC BALANCE !	CATIONS	(MBL.ER.)0.	00525219		
				DIFFEREN	CHULLER. JO.	-9.53		
CHEMICAL 150	DIHERHUHETE	RS DEGREES C		1000/T D	EGREES KELV	IN = 2,48		
GUARTZ	129.5							
CHALCEDONY	99.9							
NAK	187.7							
OXIDATION PL	DTENTIAL (V	OLTS) :	EH H2S= -0.48	7 EH C	H4= 99.949	EH H2= 99.9	S9 EH W	13= 99.999
TOG SOLUBIL.	LLY PRODUCT	S OF MINERAL	S IN DEEP WATE	~				
	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-16.212	666*65	ALBITE LON	-15,565	666*66	ANALCINE	-12.52	665*66
ANHYDR1 IE	-6.043	-8,560	CALCITE	-9,981	-9.178	CHALCEDONY	-2,625	-2.841
RG-CHLORITE	106.97-	666*66	FLUORITE	-10.531	-11.128	BOETHLIE	-3,530	665*66
LAUNDNIIE	-26,000	666.66	NJCROCLINE.	-17.395	66.999	MAGNETITE	-27.427	666*66
LA-MUNIAUK.	-79 tot	99, 999	K-BUNINUK.	-38.494	666.66	PIG-RONTHUR	-80.918	99.999
PV09UDTTE	aco 70-	00 000	PUPULIC	175 201	000 000	PREMNIE.	10,005-	444.44
MAIRAKITE	-24.124	665'66	WOLL ASTONITE	9.985	8.499	201STIF	110.2-	162.3-
EPIDOTE	-41,266	665*66	MARCASITE	-104.136	666'66	111010707	PELOD.	111111

ORNUISTOFNUN	R		thailand					
1985-09-10	chea.							
520210130083	02160001 BAH	HOM	S ION ANPHOE DOI S	AKET		5	ANGUAT CHIANG	IN
PROSRAM WATC	Н2,							
WATER SAMPLE	(PPN)		STEAK SAKPLE					
PH/DEG.C	8*60/25	0	GAS (VOL.Z)	_	REFERENCE TEMP.	DEGREES	C 0.0 (C	(210
201S	98.40		C02					
NA NA	112.00		SZH		SAHPLING PRESSI	RE BARS AB	*	
*	10.00		H2	30.3	DISCHARGE ENTHA	LPT AJOUL	E E	
5 5	44.5		70	-	UISCHARGE	NU/SE		
503	0,030		5		Service Tranco	CLOSED DELEV	-	
	201202		71		DEASUREJU LENYER	HUNE DEGREES	r /8.0	
50R	00.14				FULTERP.	PU/DEC	.r a.non/ a.	
2	5.70						-	
! L	9.50		LITERS GAS PER KG					
DISS.SOLIDS	480.00		CONDENSATE/DEG.C		KEASURED DOW	NHOLE TEMP.	FLUTD INFLOM	
ÅL	0,0000				DEGREES C	/NETERS	DEPTH (METERS	0
	0.0000							
FE	0,000		CONDENSATE (PPH)		0.0	0.0	0.0	
EHN	0.000		PH/DEG.C		0*0	0.0	0.0	
			C02		0.0	0.0	0.0	
			H2S		0.0	0.0	0*0	
			NA		0.0	0.0	0.0	
					0.0	0.0	0.0	
					0.0	0.0	0.0	
					0.0	0.0	0.0	
			CONDENSATE WITH N	(NAA) HO	0.0	0.0	0.0	
			200		0.0	0.0	0.0	
			SZH		0.0	0.0	0.0	
IONIC STRENGT	H = 0.00587		IDNIC BALANCE :	CATIONS (HOL	ER.)0.00530354	-		
				ANTONS (HOL	.EQ.)0.00583083	-		
				DIFFERENCE	(1)	-		
DEEP VATER (F	(HJ			LS 4330	(RPM) ME3	GAS PRES	SSURES (BARS A	35.)
,102	14.41	202	202.68	C02	0.00	C02	0.227E-01	
NA I	12.00	SCH	92.14	SCH	0.00	SCH	A. 3795-03	
×	10.00	£	0*0	Ŧ	0.00	÷	0.000F100	
CA	3.94	20	0*00	20	0.00	10	0.000F100	
DH	0:030	CHA	00'0	CHA	0.00	CHA	0.000E400	
504	11.30	N2	0*00	24	0.00	NZ	0.000E100	
5	5.70	EHN	0*00	EHN	0.00	EHN	0.000E100	
ła.,	9.50					H20	0.266E401	
DISS.S. 4	80.00					TOTAL	0.268E101	
AL 0	0000							
m 1	0000			(Z) 02H		0.00		
2	1000			RALLAN	NULL INV	0*00		

Image: Description of the second s					1				
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	#	814.0	KSD4-	0.912	28	± 1	269.0	FECL +	0.90
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	HISTOA-	0.909	ż	0.907			0.911	AL DIALA	57.0
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	H25104	0.492	HAH	0.909	: ::	-2(HU)	0.911	TCURUI IT	0.0
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	-TURCH	0.906	17	0.907	1 1	-FUNU	0.400	AL FOUNDAL	10 0
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	HCD1-	0.909	Catt	0.495	2 8	- THU	0.490	ALCOLD	10 0
Inc. 0.001 Contrast 0.011 Effection 0.011 ALT-1 0.010 SGH- 0.013 FEX1+ 0.010 ALT-1 0.011 ALT-1 0.010 SGH- 0.012 BHH 0.013 FEX1+ 0.000 ALT-1 0.010 SGH- 0.121 FEX1+ 0.000 ALT-1 0.000 ALT-1 0.000 BH- 0.121 FEX1+ 0.000 ALT-1 0.000 ALT-1 0.000 BH- 0.12 -5.871 FEX1+ 0.600 -5.017 ALT-1 0.01 -7.238 BEXID- 0.011 -5.871 FEX1+ 0.01 -5.871 FEX1+ 0.00 -6.01 -	-203	0.687	HGH+	0.705	1	+C(HU)	0.912	ALCONTO-	10.0
e^- 0.400 Encircit 0.400 Excite 0.401 2.55	HS-	0.908	CAHCU3+	0.913		-CH014-	0.912	AL FH	0.69
	Ŀ	0.690	MGHC03+	0.909	Ē	504+	0.911	ALF24	0.91
S0H- 0.481 MBHH 0.791 EEX12- 0.911 ALTS 0.667 REELL 0.312 MBH 0.703 FEX1+ 0.709 ALTS 0.667 REELL 2.00 -3.580 MGH 0.02 -4.513 FE(1013 0.01 -5.524 RESIDA 2.00 -3.680 MGH 0.01 -5.537 FE(123 0.00 -5.524 RESIDA 0.03 -6.613 FEX1+ 0.00 -5.524 MEH 0.00 -5.524 RESIDA 0.03 -6.613 FEX1+ 0.00 -5.524 FEX1+ 0.00 -5.524 RESIDA 0.00 -0.600 -6.614 FEX1+ 0.00 -5.524 FEX1+ 0.00 -5.544 <td< td=""><td>H504-</td><td>0.910</td><td>CAUHH</td><td>0.913</td><td>E</td><td>11</td><td>0.690</td><td>ALF4-</td><td>0.91</td></td<>	H504-	0.910	CAUHH	0.913	E	11	0.690	ALF4-	0.91
M630+ 0,12 MH 0,90 FELA+ 0,909 ALF6- 0,430 CHELICAL CONFORMERS IN REF. MAILER MICL 0,00 -5,430 RE(1) 0,00 -5,230 RE(1) 0,22 -6,010 -7,235 RESIDH- 2,70 -5,430 RE(1) 0,00 -5,430 RE(1) 0,00 -7,235 RESIDH- 2,345 -5,500 MCL 0,00 -5,537 FECL1 0,00 -2,732 RESIDH- 0,33 -4,531 RESUD 0,31 -5,573 FECL1 0,00 -2,732 RESIDH- 0,33 -4,451 RESUD 0,31 -5,573 FECL1 0,00 -2,732 RESIDH- 0,33 -4,451 0,01 -2,733 RE(1) 0,01 -2,733 RE(1) 0,00 -2,733 RE(1) 0,00 <td>-+0S</td> <td>0.684</td> <td>HIGHH</td> <td>0.914</td> <td>FEI</td> <td>124</td> <td>0.911</td> <td>ALFS</td> <td>0.68</td>	-+0S	0.684	HIGHH	0.914	FEI	124	0.911	ALFS	0.68
CHERTICAL CONFONENTS IN REET WATER (FPN AND LOG MOLE) O.02 -3.418 FE(10) -3.23 FE(11) -0.23 -3.24 S.3.4 S.3.4<	-+056M	0.912	AH4+	0.706	FE	-+12	0.909	ALF6	54.0
He (acri.) 0.00 -7.564 MEH 0.02 -6.185 FE (BH) 0.01 -7.259 HSIOH- 23.46 -3.408 MEL 0.01 -6.434 FE (BH) 0.01 -7.254 HSIOH- 23.45 -3.408 MSIOH- 0.13 -5.557 FE (12) 0.00 -0.01 -7.212 HSION- 23.45 -3.408 MSIOH- 0.11 -5.697 FE (12) 0.00 -5.721 HSION 0.00 0.00 0.000 MSIOH 0.01 -5.721 Structure 0.01 -5.721 HSION 0.01 -5.735 FE (11) 0.00 -5.721 Structure 0.00 -5.721 HSION 0.01 -5.735 FE (11) 0.00 -5.721 Structure 0.00 -5.721 Structure -5.721 Structure 0.00 -5.721 Structure -5.721 Structure -5.721 Structure -5.721 Structure -5.721 Structure -5.721 Stru	CHENICAL CI	OMPONENTS 1	IN DEEP WATER	(PPM AND LOG H	OLE)				
Het- 2.70 -3.60 MCL 0.01 -6.464 FECHH- 0.12 -6.017 MESIOH- 2.44 -2.208 MCL 0.01 -6.454 FECH+ 0.01 -5.57 FECH+ 0.01 -5.51 MESIOH- 0.03 -6.68 MSIH- 0.11 -6.68 FECH+ 0.01 -5.53 FECH+ 0.01 -5.51 FECH+ 0.01 -5.51 FECH+ 0.00 -5.51 SCH+ 0.00 -5.51 MCH+ 0.00 -5.51 MCH+ <th< td=""><td>HH (ACT.)</td><td>0.00</td><td>-7.966</td><td>H0H</td><td>0.02</td><td>-6.185</td><td>FE(DH)3</td><td>0.01</td><td>-7.25</td></th<>	HH (ACT.)	0.00	-7.966	H0H	0.02	-6.185	FE(DH)3	0.01	-7.25
MKELOM 195-41 -2.200 MCL 0.00 -6.373 FEL1 0.00 -0.00 -1.213 MKSELOM 1.123 -4.983 KSM 0.11 -5.957 FEL1 0.00 -2.313 MKSELOM 1.123 -4.983 KSM 0.11 -5.957 FEL1 0.00 -2.313 MKSELOM 1.123 -4.983 KSM 0.01 -5.334 FEL1 0.00 -5.314 MKSELOM 1.123 -4.983 KSM 0.01 -7.411 FES04 0.00 -37.413 MKDB 7.33 -5.751 KMMH 0.00 -7.411 FES04 0.00 -37.413 MKDB 6.00 -1.335 KMMH 0.00 -5.373 MLBH 0.00 -37.413 MKDB 6.00 -1.315 KMMH 0.00 -37.413 MLBH -0.00 -37.413 MLBH -37.413 MLBH -37.413 MLBH -37.413 MLBH -37.413 MLBH -3	-13	2.70	-3.800	NACL	0.01	-6.684	FE(DH)4-	0.12	10.4-
RESTON- 0.03 -0.403 RESU- 0.13 -5.557 FEL1 0.00 -7.213 RMSIGN 0.03 -6.431 RSN+ 0.01 -7.335 FEL1+ 0.00 -5.234 RMSIGN 0.00 0.00 -6.431 RSN+ 0.01 -7.335 FEL1+ 0.00 -7.373 RMSIGN 0.00 -1.403 RSN+ 0.01 -7.355 FEL1+ 0.00 -7.373 RND- 0.30 0.400 -1.403 RSN+ 0.01 -7.355 FEL1+ 0.00 -27.738 RND- 0.30 -7.411 FED1+ 0.40 -7.411 FED1+ 0.40 -27.739 RND- 0.30 -1.325 RSN+ 0.00 -7.355 RLN+ 0.40 -27.739 RND- 0.41 0.40 -7.355 RLN+ 0.40 -27.730 RND- 0.41 0.40 -7.355 RLN+ 0.40 -27.730 RND- 0.41 <t< td=""><td>H4S104</td><td>149.64</td><td>-2,808</td><td>XCL</td><td>0.00</td><td>-8.374</td><td>FECI +</td><td>0.00</td><td>-10.42</td></t<>	H4S104	149.64	-2,808	XCL	0.00	-8.374	FECI +	0.00	-10.42
RKS104- 0.45 -6.451 KS04- 0.451 -5.234 FECLH 0.00 -7.232 RMOSTOR 1.23 -4.980 0.01 -7.533 FELL3 0.00 -23.435 RED01- 0.00 0.000 CK013 1.1.5 -4.466 FELL4- 0.00 -23.435 RED01- 1.23 -3.528 MGRC31 1.3 -4.466 FELL4- 0.00 -23.435 RED1- 1.23 -3.528 MGRC31 1.3 -4.521 RU131 0.00 -23.435 RED3- 0.00 -1.273 RU141 0.00 -5.531 RU131 0.00 -5.537 RED4- 0.00 -1.00 7.335 RU1313 0.00 -5.537 RE304 0.01 -5.531 RU141 0.00 -5.537 RU1312- 0.00 -5.537 RE44 0.00 -7.437 RU141 0.00 -5.537 RU1312- 0.00 -5.537 RU1312- 0.00 -5.537	-HOISEH	23.45	-3.608	NASD4-	0.13	-5.957	FEC12	0.00	-22.17
MMGSTGM 1.23 -4,983 GASIM 0.11 -6,006 FEL12 0.00 -27,135 REDG3 0.00 0.000 RGM 0.01 -5,355 FEL12 0.00 -72,753 REDG3 0.00 0.000 RGM 1.35 -5,328 RGM 0.00 -72,753 REDG3 0.35 -5,328 RGM 1.13 -4,327 RED 0.00 -73,473 RED 92,41 2,535 RGM 0.00 -7,335 RLM 0.00 -73,473 RED 0.00 -13,535 RGM 0.00 -7,335 RLM 0.00 -53,474 0.00 -53,474 0.00 -53,474 0.00 -53,474 1.01 -53,543 RLM 0.00 -53,444 1.01 -53,543 RLM 0.00 -50,00 0.00 0.00 -000 -53,444 1.01 0.00 -53,444 1.01 1.01 1.14,54 1.14,54 1.14,54 1.14,54 1.14,54 1.	H2S104	0.03	-6.451	KS04-	10.0	-6.534	FECLH	0.00	-25.21
READ 0.00 0.00 READ 0.00 CCUID 1.35 -4.88 FEL1 0.00 -27.729 REDD- 0.00 0.000 0.000 -4.88 FEL1 0.00 -27.73 REDD- 1.33 -4.88 FED1 0.00 -7.411 FES04 0.00 -7.433 REDD- 1.33 -4.88 FED1 0.00 -7.411 FES04 0.00 -7.733 REDD- 1.33 -4.88 FED1 0.00 -7.411 FES04 0.00 -7.733 REDD- 0.00 -1.321 RMH 0.00 -0.00 -0.00 -0.00 S1 -3.535 FE11 0.00 -3.533 REDH 0.00 -0.00 <td< td=""><td>MAH3SIOA</td><td>1.23</td><td>-4.983</td><td>CASO4</td><td>0.11</td><td>-6.086</td><td>FECL24</td><td>0.00</td><td>-28.43</td></td<>	MAH3SIOA	1.23	-4.983	CASO4	0.11	-6.086	FECL24	0.00	-28.43
XIDD3 0.00 0.000 CAG03 1.36 -4.486 FECL4- 0.00 -37.72 ZDD3 1.22 -4.456 RMCD3 1.00 -7.411 FESD4 0.00 -37.32 CD3- 1.232 -4.456 RMCD3 1.00 -7.412 FESD4 0.00 -3.738 RES 0.35 -4.565 RMMCD3 0.00 -7.412 FESD4 0.00 -3.738 SF -4.555 RMM 0.00 -7.412 RES04 0.00 -3.738 SF -4.555 RMM 0.00 -7.413 RMM 0.00 -3.600 SF -4.601 REHH 0.00 -3.738 REHH 0.00 -3.600 REM1 0.00 -0.00 0.00	H3B03	0.00	0*00	HGSD4	10.0	-7.353	FECL3	0.00	-32.78
Z003 7,33 -3,928 M603 0.00 -7,411 FEBH 0.00 -9,398 C003- 1,32 -4,520 CM0H1 0.00 -7,433 ALHH 0.00 -0.00 <td>H2B03-</td> <td>00*0</td> <td>0.000</td> <td>CACD3</td> <td>1.36</td> <td>-4.868</td> <td>FECL4-</td> <td>0.00</td> <td>-37.72</td>	H2B03-	00*0	0.000	CACD3	1.36	-4.868	FECL4-	0.00	-37.72
HCD3- 172-49 -2.501 CAMCD3+ 1.89 -4.729 FES04+ 0.00 -2.3429 HCD3- 1.32 -4.356 MEMCD1+ 0.00 -7.335 MLHH 0.00 -0.00 0.00	2003	7.33	-3.928	MGCD3	0.00	-7.411	FES04	0.00	-9.39
CIC3	HCD3-	192.49	-2.501	CAHC034	1.89	-4.729	FES044	0.00	-23.42
RE 0.35 -4.786 CAMH 0.02 -6.521 MCHH 0.00 <	200	1.32	-4.656	MGHCD.34	00.0	-7.573	ALTT	0.00	0.00
Bit Bit -3.555 MGINH 0.00 -7.355 MGINH 0.00 -0.00 0.0	H2S	0.35	-4.986	CADHI	0.02	-4.521	ALCH++	0.00	0.00
S=- 0.00 -11.251 MH4H 0.00 0.000 AL (EH)13 0.00 0.000 <t< td=""><td>-92</td><td>19*8</td><td>-3.5H5</td><td>HODH+</td><td>0.00</td><td>-7.355</td><td>AL ((GI)2+</td><td>00*0</td><td>0.40</td></t<>	-92	19*8	-3.5H5	HODH+	0.00	-7.355	AL ((GI)2+	00*0	0.40
RZ504 0.00 -18.401 MH+ 0.00 0.00 AL (16H) 1- 0.00	Ŀ	00"0	12.11-	NH40H	0.00	0.000	AL.(CH1)3	0.00	0.00
HIGH- 0.00 -8.221 FEH 0.00 -7.4501 ALSUH 0.00 0.000 FF 10.00 -7.277 FE(H) 0.00 -7.451 ALSUH 0.00 0.000 FF 11.00 -7.277 FE(H) -0.00 -7.531 ALF3 0.00 0.000 CL- 5.89 -3.779 FE(H) -0.00 -17.199 ALF3 0.00 0.000 CL- 5.89 -3.779 FE(H) -0.00 -17.111 ALF3 0.00 0.000 CL- 5.89 -3.779 FE(H) -0.00 -11.021 ALF4 0.00 0.000 CL- 5.89 -3.779 FE(H) -0.00 -11.021 ALF4 0.00 0.000 CL- 5.89 -3.779 FE(H) -0.00 -11.021 ALF4 0.00 0.000 CL- 5.89 -3.779 FE(H) -0.00 -11.021 ALF5 -0.00 0.000 CH 2.37 -1.669 FE(H) -0.00 -11.021 ALF5 -0.00 0.000 CH 2.317 DALCEDITION CONTRENS DEGREES C 1000/1 DEINEES KEL/IN = 2.46 CH 13.7 DALCEDITION POTENTIAL (VALTS) 1 CH 25.97 979 CH 2.317 CH 10.42 CH 10.42 CH 2.44 99.999 CH ALCEDITION CONTENT CONTRENS DEGREES C 100.047331 CH 2.44 99.999 CH ALCEDITION CONTENT CONTRENS DEGREES C 2.20 CH 2.44 99.999 ANALCITIE -12.43 99.999 CH CH 2.44 99.999 ANALCITIE -12.44 99.999 ANALCITIE -3.359 -2.22 CH 2.44 99.999 ANALCITIE -12.49 99.999 ANALCITIE -2.460 200 CH 2.44 99.999 ANALCITIE -2.500 99.999 ANALCITIE -3.359 -2.22 CH 2.44 99.999 ANALCITIE -2.500 99.999 ANALCITIE -2.500 99.999 ANALCITIE -2.500 79.999 CH 2.44 99.999 ANALCITIE -2.500 99.999 ANALCITIE -2.500 79.999 ANALCITIE -2.500 79.999 ANALCITIE -2.500 70.900 79.999 ANALCITIE -2.500 79.9999 ANAL	H2504	00*0	105-81-	++FR	00*0	0.000	AL(0H)4-	0.00	0.00
SUH 5,73 -4.206 FEHH 0.00 -24.375 RLFH 0.00 -0.00 0.000 -0.00 0.000 <th< td=""><td>-+20H-</td><td>0.00</td><td>-8.821</td><td>FE++</td><td>0.00</td><td>-7.601</td><td>AL:S04+</td><td>0.00</td><td>0.00</td></th<>	-+20H-	0.00	-8.821	FE++	0.00	-7.601	AL:S04+	0.00	0.00
FF 0.00 -7.077 FE(H) 0.02 -6.5537 M.F.H 0.00	++OS	5.93	-4.206	FEHH	- 00"0	24.845	AL(504)2-	0.00	0.00
F- 11.00 -5.237 FE(0H)2 0.01 -6.954 ALF2+ 0.00	#	00.0	-7.077	FEOH4	0.02	-6.537	ALFH	0.00	0.00
CL- 5.89 -3.779 FE(0H)3- 0.00 -8.533 ALF3 0.00 0.00 0.00 RH 90.43 -2.404 FE(0H)3+ 0.00 -11.021 ALF3 0.00 0.00 0.00 0.00 RH 8.37 -3.668 FE(0H)3+ 0.00 -11.021 ALF4- 0.00 0.00 0.00 RH 8.39 -3.668 FE(0H)2+ 0.00 -11.021 ALF5 0.00 0.00 0.000 RH 8.39 -3.668 FE(0H)2+ 0.00 -11.021 ALF5 0.00 0.00 0.000 RH B.37 CATIONS (FBLACE I CATIONS (FBLACE) 10.00/71 SLEPCO 0.00 0.00 0.00 0.00 RHCIA I TATA VIRALESING I RULA 2.46 I RULA 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	4	11.00	-3.237	FE(DH)2	10.0	-6.954	ALF24	00*0	0.00
MH 90.45 -2.404 FE(0H)4- 0.00 -1.239 FE(0H)4+ 0.00 -1.467 FE(0H)4+ 0.00 -1.00 0.0	-	5.89	-3,779	FE(0H)3-	00.0	-8.533	ALF3	0.00	0.00
Rt 8.39 -5.469 FE (BH)+1 0.00 -17.111 ALS 0.00 0.00 0.000 CH+1 1.48 -4.328 FE (BH)2+ 0.00 -11.021 ALS 0.00 0.000 0.000 CH+1 1.48 -4.328 FE (BH)2+ 0.00 -11.021 ALS 0.00 0.000 0.000 CH+1 1.48 -4.328 FE (BH)2+ 0.00 -10.00 0.000 0.000 0.000 CH+1 1.48 -4.328 FE (BH)2+ 0.00 10.00 10.00 7.11 ALS 0.00 0.000 0.000 CH+1 0.0043 IDM/FEEKNE (21) -10.00473531 DIFFEEKNE (21) -10.00 9.000	NA+	90.63	-2,404	FE(OH) 4	- 00*0	12.990	ALF4-	0.00	0.00
Ch++ 1.88 -1.228 FE(UH)2+ 0.00 -1.021 Alf 0.00 0.00 0.000 IDNIC STRENGTH 0.00464 IDNIC BALANCE (ZATIONS (MUL.EP.)0.00473331 0.00 0.000 0.000 DIFFERENCE (ZATIONS (MUL.EP.)0.00473331 DIFFERENCE (Z) -10.30 0.000 0.000 DIARTZ 133.7 ANILONS (MUL.EP.)0.00473331 DIFFERENCE (Z) -10.30 0.000 0.000 DARTZ 133.7 ANILONS (MUL.EP.)0.00471 (BEINEES KEL/JIN = 2.46 DIFFERENCE (Z) -10.30 DIFFERENCE (Z) -10.30 DARTZ 133.7 ANILONS (MUL.EP.) EN ACC 1000/1 (BEINEES KEL/JIN = 2.46 DIF DIFFERENCE (Z) -10.30 DIF DI	t	8.39	-3+669	FE (0H) ++	- 00.0	111.11	ALFS	0.00	0.00(
IDNUC STRENGTM 0.00464 IDNUC BALANCE CATIONS (MUL.ED.,00.0073531 DIFFERENCE (1) -10.30 -10.30 DIATI 133.7 -10.30 -10.30 DIATI 133.7 -10.30 -10.30 DIALCDUM 1000/T BEINERS NELVIM 2.46 DIALCDUM 1000/T BEINERS NELVIM 2.46 DIALCDUM 1000/T BEINERS NELVIM 2.46 DIALOUR 1000/T BEINERS NELVIM 2.46 DIALOUR 1000/T BEINERS NELVIM 2.46 DIALOUR 110.41 2.46 DIALOUR 110.41 2.44 DIALOUR 110.41 2.44 DIALOUR 110.41 2.44 DIALOUR 1110 2.44 DIALOUR 12.43 9.99 <tdd< td=""><td>115</td><td>1.88</td><td>-1.128</td><td>FE(UN)2+</td><td>- 00*0</td><td>11.021</td><td>ALF6</td><td>0.00</td><td>0.00</td></tdd<>	115	1.88	-1.128	FE(UN)2+	- 00*0	11.021	ALF6	0.00	0.00
ANICINS (HILL.EU.)0.00473531 DIFFEKENC: (2) -10.30 DIFFEKENC: (2) -10.30 DIARTIZ 133.7 BURKT: 133.7 BURLEDMY POTENTIAL (VRLTS) : EM HZS = -0.506 BUR.BURLETT PRODUCTS OF MINERALS IN BEEP WAITS EM HZ = 99.999 BUR.BURLETT PRODUCTS OF MINERALS IN BEEP WAITS FEOR. BUR.ART -16.009 97.999 BUR.ART -16.009 97.999 BUR.ART -11.044 97.999 BUR.ART -10.050 97.999 BUR.ART -10.046 97.999 BUR.ART -10.046 97.999 BUR.ART -10.046 97.999 BUR.ART -10.046 97.999 BUR.ART	IONIC STREN	0°0 = H19	0464 IONI	IC BALANCE :	CALTONS	(HUL.ED.)0	.00427143		
DIFFERENCE (1) -10.30 DIGHICAL REDIRERMONCERS DEGREES C 1000/1 DEGREES KELVIN = 2.46 DARTZ 133.7 DARTZ 143.7 DARTZ 133.7 DARTZ 133.7 DARTZ 133.7 DARTZ 144.97,979 DARTZ DARTZ					ANEONS	(HIL.ET.)0	15257400.		
DIGHLICAL REDINERMONETERS DEGREES C 1000/1 DEGREES KELVIN = 2.46 DARTZ 133.7 DARTZ 144.9 99.999 DARTZ FLH					DIFFEREN	(Z) 30	-10.30		
BURKIZ 133.7 BURKIZ 133.7 BALGEDMY 104.2 BAL 191.4 GG SOLUBILITY FEOR CAL TECR CALC TECR CALC BG-CALLINE -10.099 BG-CALLINE -10.044 BG-CALLINE -10.044 BG-CALLINE -10.0555 BG-CALLINE -10.044 BG-CALLINE -10.044 BG-CALLINE -10.0555 BG-CALLINE -10.0555 BG-CALLINE -10.044 BG-CALLINE -10.044 BG-CALLINE -10.044 BG-CALLINE -10.0555 BG-CALLINE -10.044 BG-CALLINE -10.044 BG-CALLINE -10.357	CHEMICAL BE	DTHERHORET	ERS DEGRECS C		1000/1 0	EINEES KEL	VIN = 2.46		
District CEDENT 104.2 CMLCEDENT 104.2 District 104.2 99.499 EN HIZ= 99.999 EN HIZ= 99.999 EN HIZ= 99.999 DISTRICT PRODUCTS OF NINERALS IN DEEP WATER TEOR. CALC. TEOR. CALC. DISTRICT - 66.099 99.999 EN HIZ= 99.999 EN HIZ= 99.999 EN HIZ= 99.99 DISTRICT FORDUCTS OF NINERALS IN DEEP WATER TEOR. CALC. TEOR. CALC. ANALCHATA -16.099 99.999 ANALCHIK -23.539 -27.2 ANALCHATA -56.009 99.999 ANALCHIK -23.539 -27.2 ANALON -55.864 99.999 MALCHIK -10.434 99.999 99.999 ANALON -55.864 99.9999 MALCHIK -10.445 99.4999 99.999 99.999 AMMENTITE -55.864 99.9999 PALON -23.539 -22.2 ANALON -38.556 CALCITE -19.535 -11.044 600THITE -3.539 -2.2.2 AMMENTITE -55.864 99.9999 99.9999 99.9999	314kT7	111.7							
KIBATION POTENTIAL (VUR.TS) : EN HZS = -0.506 EN EH = 99.999 EN HZS = 99.99 EN HZS = 99.99 .06 SOLUBILITY PRODUCTS OF HIMERALS IN DEEP WAITER TEOR. CALC. TEOR. CALC. .08 SOLUBILITY PRODUCTS OF HIMERALS IN DEEP WAITER TEOR. CALC. TEOR. CALC. .010LARIA -16.090 99.999 ANALCIHE -12.433 99.999 ANALCIHE -12.433 99.999 ANALCIHE -12.433 99.999 ANALCIHE -12.433 99.999 ANALCIHE -12.434 99.999 49.999 ANALCIHE -12.433 99.999 49.999 ANALCIHE -12.436 -2.354 -2.35 -2.3.491 99.999 99.9	CHALCEDONY MAX	104.2							
.06 SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER .06 SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER .06 SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER .010LARIA -16.079 97.979 MAITE LON .15.454 99.999 ANALCINE -12.443 99.99 MNYORVIE -6.107 98.555 CALCITY -10.065 -2.556 -2.53 GG-CALURIFE -5.107 99.999 ANALCINE -12.443 99.999 ANALCINE -2.536 -2.53 ANYORVIE -5.107 99.999 FLONIT -10.5555 -11.044 606/HUTE -3.259 -2.2.2 ANMUTINE -55.864 99.999 MCMOTINE -3.2.075 99.999 MGANETIE -25.697 -99.399 199.499 ANMUNILE -55.844 99.999 MCMOTINE -10.5.279 199.399<	NTRATTON PI	UTENTTAL O	una tes .	IN NOS SCH PL	2 13	11- 00 000	tu un- 00 0	CU CU	10-100
.06 SOLUBRLIFT PRODUCTS OF NIMERALS IN DEEP WATER .01 SOLUBRIA TEUR. CALC. TEUR. CALC. TEUR. CALC. TEUR. CALC. TEUR. CALC. NURLARIA -16.009 99.999 ANALCINE -12.443 99.999 MNTURVIE -6.10.009 98.556 CALCINE -10.004 GLACK -23.559 -23.539 GG-CALURVIE -79.904 99.9999 NALORINE -21.243 99.999 ANALCINE -23.559 -22.5 AMMENTINE -55.804 99.9999 NALORINE -3.539 -23.53 -23.549 -23.549 -23					5		*24 -70 H3		
IEUM CALC. IEUM CALC. <t< td=""><td>OG SOLUBIL.</td><td>ILY PRODUC</td><td>IS OF HINERALS</td><td>IN DEEP WATER</td><td></td><td></td><td></td><td></td><td></td></t<>	OG SOLUBIL.	ILY PRODUC	IS OF HINERALS	IN DEEP WATER					
UNUCLURIA -10.000 77.779 ALGITE LOM -13.474 97.979 AGALCINE -12.434 97.3 MMYTORITE -6.107 95.955 CALUETE -10.654 -9.305 CHALCEDAY -2.596 -2.8 G-CALUETE -6.107 95.999 FLUGNETE -10.655 -11.044 GBETHIE -3.239 -2.2 AMMANTIE -75.864 99.999 MICHOLLINE -10.535 -11.044 GBETHIE -75.097 99.3 AMMANTIE -75.864 99.999 MICHOLLINE -10.539 97.979 MARKETTE -25.097 99.3 AMMANTIE -75.864 99.999 MICHOLLINE -17.249 99.999 MARKETTE -27.097 99.3 AMMANTIE -25.864 99.999 MICHOLLINE -17.249 99.999 MARKETTE -25.097 99.3 AMMANTIE -25.864 99.999 MICHOLLINE -19.259 99.399 AGARETTE -25.097 99.3 AMMANTIE -25.864 99.999 MICHOLLINE -19.259 99.399 AGARETTE -25.097 99.3 AMMANTIE -25.864 99.999 MICHOLLINE -19.259 99.399 AGARETTE -25.097 99.3 AMMANTIE -25.915 -55.915 PIRTE -12.2793 -89.207 GUARTE -25.608 -2.6 AMMANTIE -24.067 99.999 WICHOLLINE 1.22.793 -89.207 GUARTE -25.608 -2.6 AMMANTE -24.067 99.999 WICHOLLINE 1.22.930 -89.207 GUARTE -25.608 -2.6 AMMANTE -24.067 99.999 WICHOLLINE 1.22.930 -89.207 GUARTE -25.608 -2.6	1.404 110	TEOR.	CALC.		TEOR.	CALC.		TEO	R. CA
MARCHRENE -6.107 -8.656 GALCITE -10.064 -9.305 CHALEDHY -2.596 -2.28 Ge-SALURIFE -79.904 99.999 FLUORITE -10.535 -11.044 GUETHLFE -3.539 -2.22 ALHWATTIE -25.864 99.999 FLUORILINE -10.535 -11.044 GUETHLFE -3.539 -2.22 AHMANTAR -78.790 99.999 K-MUNIDAR -38.079 99.999 RE-MUNITAR -00.779 99.19 Re-MUNIDAR -78.799 K-MUNIDAR -38.079 99.999 RE-MUNITAR -00.779 99.197 TRENDITIE -28.915 -65.915 PYRITE -127.930 -89.207 GUARTZ -2.608 -2.6 PYREMOTITE -24.067 99.999 WULASTUNITE -127.297 98.458 ZOISITE -35.414 99.19	BULANIA	-16.090	39.999	ALBITE LOW	-12.454	666.999	ANALCIME	-12.4	43 66
PER-CALLURILE -79,399 FLUINELE -10,535 -11,044 BUEINHIE -5,539 -2,23 AUMUNTIE -23,584 99,999 HLONGLINE -12,249 99,999 MG-MUNTIE -23,097 -19,8 A-MUNTUR, -73,999 HLONGLINE -33,079 99,999 MG-MUNTIRE -23,997 -19,8 H-MONTINGK -33,138 99,999 HULSCUVIE -12,534 99,999 FRENNTRE -53,990 99,5 YREMOTIFE -82,915 -65,915 PYRITE -122,730 -89,207 GUARTZ -2,808 -2,8 YREMOTIFE -82,915 -65,915 PYRITE -122,730 -89,207 GUARTZ -2,808 -2,8 ALRANTE -24,067 99,999 HULASTUNTE -122,730 -89,207 GUARTZ -2,808 -2,8 ALRANTE -24,067 99,999 HULASTUNTE -0,9,207 GUARTZ -2,808 -2,8	NHYDRITE	-6.107	-8.856	CALCITE	-10.064	-9.305	CHALCEDON	-2'2	96 -2.
AMMONITIE -23:864 99:999 MICMOLLINE -17.249 99:999 MG-MONETIE -27.607 -19.8 2-MUNTMUR38:9799 FK-MUNLMR28:20.29 99:999 MG-MUNTMR00.279 99:5 A-MUNTMUR38:39:999 FK-MUNLMR19.5.30 99:999 PK-201 A-MUNLTIE -82.915 -55.915 PYRITE -122.920 -89.207 GUARTZ -2.808 -2.8 PYRAMOTTIE -82.915 -55.915 PYRITE -122.920 -89.207 GUARTZ -2.808 -2.8 A-MUNLMELTE -24.667 99.999 WULLMARTBUTTE 9.876 8.458 ZOISITE -35.414 99.9	6-CHLURITE	-79.904	99.999	FLUORITE	-10.535	-11.044	GOETHITE	-3.5	26 -5'
24-жОНТИНИК78.790 99.999 К-КОНТИИК38.029 99.999 МС-КОНТИКК00.279 99.9 М-КОНТИСК28.138 99.999 МСКЛОЧТЕ -19.554 99.999 РЕКЕМИТЕ -35.990 99.3 МАКИНТИС -82.915 -65.915 РИКИТЕ -127.920 -89.200 ВОКТЕ -35.414 99.5 МАТАКТЕ -24.067 99.999 ИОДАКТИТЕ -127.920 -89.200 ВОКТЕ -35.414 99.5	AUNONTITE	-25.864	666*66	MICKOCLINE	-17.249	666"66	MAGNETITE	-27.0	97 -19.
M-ROWIFICK -38.138 99.999 MISCOVIE -19.554 99.999 FREBWIE -35.990 99.5 YRGHATIE -82.915 -65.915 PYRITE -122.920 -89.200 004RTZ -22.808 -2.4 MIBAKIE -24.067 99.999 WOLLASTONIE -122.920 -89.288 ZOISIE -35.414 99.5	A-HONTHOR.	-78. 990	666.66	K-MONTHOR.	-38.029	66°.669	BRINDE-BR		64 61
MIRAMITE -22,015 -65.915 PYRITE -122.920 -89.207 0UARTZ -2.608 -2.6 MIRAMITE -24.667 99.999 UGLASTOWITE -123.414 99.2 	M-KONTHOK.	-38.138	665.969	MUSCOVI TE	-19.534	666.66	PREHNITE	-32'6	50 99.
MARGALIC "24:UO/ 77:777 NULLASIUNLIL 7:0/0 0:000 LULALIC "30:414 77:7	YROHOTTE	CI4-28-	-65.915	PYRITE	-122.939	-89.207	QUANTZ	-2-B	·2- 80
	BIKANIIC	100162-	77.477	NULL AS IUM IL	0/2"L	ALOS OF	TUTCH	L-100-	14 11

ORKUSTOFNUN 1985-09-10 0	JHD chen.		thailand					
6605101300830	1000915t	SOP	PONG, ANPHOE WIANG	PA PAD		CHAN	GMAT CHIANCRAL	
PROGRAM WATCH	. 2							
WATER SAMPLE	(PPN)		STEAN SAMPLE					
PH/DEG.C	8.90/25.	0	GAS (VOL.Z)	REI	EKENCE TEMP.	DEGREES C	(Z10) 0'0	
S102	109.00		C02					
NA	90.90		H2S	SAI	APLING PRESSURE	BAKS ABS.		
ж	8.40		民	10	SCHARGE ENTRALPY	A MANUL/KG		
51	3.22		20	DI	SCHAKGE	KG/SEC.	0.0	
5	0*050			ME	SCHOOL TENDEOATH	DE DECOLLE P	0.09	
	74-047		22		CONCUTATION AND A CONCUMULATION	THINK DECORES &	0 0 0 0	
SU4	07*9			EN.	TEND.	UNTRA DEB. C	0.000/0.0	
	2.90			2				
; u	11.60		I TTERS RAS PER KG					
MISS. SDI TIS	420.00		CONDENSATE/DEG.C		MEASURED DOUMED	RE TEMP.	FLUID INFI DW	
AL	0.0000				DEGREES C/HE	TERS D	EPTH (METERS)	
1	0.0000							
H	0.0800		CONDENSATE (PPH)		0.0	0.0	0.0	
EHM	0,0000		PHVDEG.C		0.0	0.0	0.0	
			C02		0.0	0.0	0.0	
			SCH		0.0	0*0	0.0	
			MA		0.0	0.0	0.0	
					0.0	0.0	0.0	
					0*0	0.0	0.0	
					0*0	0.0	0.0	
			CONDENSAFE WITH HE	(HAA) HO	0.0	0.0	0.0	
			C02		0.0	0.0	0.0	
			H/2S		0.0	0.0	0.0	
IONIC STRENGT	H = 0.00481		TONIC BALANCE :	CATIONS (NOL.)	R. 10.00430734			
				ANIONS (NOL.)	1889/10.00.001/6881			
				DIFFERENCE	(1) -10.17			
BEEP WATER (P	(Mde			DEEP SIE	(NPP) M	GAS PRESS	URES (BARS ABS.)	
102	10.90	C02	146.42	C02	0.00	C02	0.150E-01	
No.	00.00	DCH	6.22	SCH	0.00	SCH	5.475F-03	
E	8.40	-	0.00	R	0.00	H2	0.0000100	
5	3.22	20	0.00	20	0.00	20	0.000E400	
SH	0*020	동	0.00	CH4	0.00	CH4	0.000E100	
\$04	6.20	H2	0.00	CH	0*00	N2	0013000*0	
5	5.90	SHK	0.00	EHN	0.00	EHN	0.0005400	
-	11,00					H20	0.3016401	
biss.s. 4	20.00					TOTAL.	0.302E+01	
AL 0	* 0000							
m 1	0000			H20 (I)	0	00.		
FE 0	0080*			SHICING P	ORTION	.00		

ACTIVITY COE	FFICCENTS	IN DEEP WAI	TER						
ŧ	0.910	K504-	0.903	HHH		0.670	ECL+	0.90	
-+0	0.900	Li	004*0	LT21		874-0	A DIG 1	2240	0 0
H35104-	104.0	-17	0:077	una l	-210	EUG C	TCANUT IN	00.0	
	/0010	THE	102*0			5770	-F(HU) N	0.00	2.0
H2BU3-	0.898	LALL CALL	0.470	FERN		597	at Shat	0.90	
	CYY	115	0.681	FECO	H)24	503	A. (S04) 2-	0.90	
-5#	0.900	CAHCO	34 0.905	FE(0	H)+-	0.903	HLFH	0.66	-
J.	0.665	MGHCOC	54 0.901	FESD	4+	0.903	ALF24	0.90	m
HS04-	0.902	CACHH	0*905	FECL	+	0.665	-4-I	0.00	2
+0S	0.659	HGOH	0*905	FECL	24	0.903	LF5-	0.66	N
NASD4-	0*903	NH4+	0.898	FECL	+	106.0	N.F.6	0.39	9
CHENICAL CON	POWENTS IN	I DEEP VATE	CEPH AND LOG HO	E)		1			
TOTAL TO	0000	1 174	MC11	0.0A -	UEY'S	FECHOIS	0.01	-4.98	-
DUL-	10 1	676 L	NACT	- 00.0	2.452	FF(DH)4-	E1.0	-5.96	. 10
-un	150.40	BLT C	KLI	- 00.0	501.0	FECL+	0,00	-12.76	
LOTOLD	11 15	050 2	-TUSW	- 52.0	5.674	FEC1 2	0.00	-22.21	00
	0.00	1.451	KS04-	0.06	657.9	FECLH	0.00	-25.96	0
ANTUTATION NON	0.57	5.317	CASDA	0.16 -	5.935	FECL24	0.00	-29.95	0
TRATE	0.00	0.000	MGSDA	0.06 -	£12.6	FECL3	0.00	-34.79	10
H2B03-	0.00	0.000	CAC03	0.36 -	5.450	FECL4-	00'0	0.00	
2003	90.38	-2.834	MGCD3	- 00.0	7.304	FES04	00'0	-11.21	5
HCD3-	211.50	-2,460	CAHC034	2.47 -	4.613	FES04+	0.00	-23.21	2
C03	0.15	-5,589	MGHC034	0.02 -	6.548	AL+++	0.00	0.00	0
SCH	2.78	4.088	CADHE	- 10.0	£82.8	ALOH1 +	0.00	0.00	
-SH	9.04	-3.563	ROOK	- 10.0	6.565	AL (UH) 24	00'0	0.00	0
J	0.00 -1	1.443	NH40H	0.00	0.000	AL (DH)3	0.00	0.00	0
ADSCH.	0.00	5.766	MH4+	0.00	0,000	AL (0H) 4-	0.00	0.00	0
ncus-	10.0	CLC. L.	1111	0.00	9.572	AL 5044	0.00	0.00	
	10.5	1.001	1111	0.00 -2	S. Rek	AI (S04)2-	0.00	0.00	0
		5.05A	EEN44	0.00	502.8	AL 544	0.00	0.0	
2 4	9.58	1.797	FF (0H)2	- 00.0	8.455	AUF24	0,00	0.00	0
	0.87	007.1	FF(DN)3-	0.00	9.484	ALF3	0.00	0.0	0
Not	VB. TO	105.0-	FE(DR) 4	0.00	4.288	ALF4-	0,00	0.00	0
K+	4.66	-3.924	FE(OH)++	0.00 -1	7.670	ALF5	00'0	0.0	0
Catt	0./5	4.729	FE(0H)2+	0.00 -1	0.954	ALF 6	00.00	0.0	0
IONIC STRENG	STH = 0.00	1 E040	DNIC BALANCE :	CATIONS (HOL.ER.)0	+17215714			
				ANIONS (POL.EQ. JOH	.00468445			
				DIFFERENCE	(2) ¥	-38*95			
CHENTER OF	THERMORE IS	PRS BEGREFS	2	1000/1 DE	GREES KEL	VIN = 2,18			
CHARTZ	186.5								
CHALCEDONY	159.0								
NAK	161.9								
OXIDATION P	DTENTIAL (1	AULTS) :	EH H25= -0.542	EH C	4= 99,999	EH H2= 99.	999 EH	NH3= 91	666*
I no chilibri	TY PROMIC	TC OF AINER	ALS IN DEEP VALEN						
רתם מתרחמעד	TERD.	Cal C.		TEOR.	CALC.		TE	GR.	ALC.
ACHI ARTA	-14.950	666.999	ALBITE LON	-14.435	666.999	ANALCIME	-11-	746 9	666*
ANHYDRITE	-6.972	-9.167	CALCITE	-11.206	-10.671	CHALCE DON	Y -2.	286	438
K6-IMLIRITE	-81.072	99.999	FLUORITE	-10.666	-11.590	GOETHI FE	7	- 210	+66*
LAUMONTITE	-24.736	66.999	MICROCLINE	-15.853	666.999	MAGNETITE	-3	743 -2	.763
CA-HONTHOR.	-73.920	666.999	K-HONTHOR.	-35.058	666*66	UK1802-92	R75.	332 9	666*
NA-HONTHOR.	-35.271	66.999	HUSCOVITE	-18.231	666.999	PREHNITE	-	918	456
PYRRHOT I TE	-55*703	-56.512	PYRITE	\$21.68-	-/3.509	UNRN 12	17.		438
MAIRAKITE	-23.832	99.999	MULLASIUM IE	CVV 27-	14041	SITCINT		1 000	1111
EPIDOTE	-37.736	44.44	THNIASLIL	740-10-	LACICI-				

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APPENDIX IV: Chemical geothermometers

			Range (°C)	Source
Chalcedony				
(1)	<i>t</i> °C =	$\frac{1112}{4.91 - \log SiO_2} - 273.15$	25 - 180	(1)
(2)*	<i>t</i> °C =	$\frac{1264}{5.31 - \log SiO_2} - 273.15$	100 - 180	(1)
Ouartz			<u> </u>	
(3)	$t^{\circ}C =$	$\frac{1309}{5.19 - \log SiO_2} - 273.15$	0 - 250	(2)
(4)	<i>t</i> °C =	$\frac{1164}{4.90 - \log SiO_2} - 273.15$	180 - 300	(1)
(5)*	$t^{\circ}C =$	$\frac{1522}{5.75 - \log SiO_2} - 273.15$	100 - 250	(2)
(6)*	t°C =	1498 - 273.15 5.70 - logSiO ₂	180 - 300	(1)
Na – K (low a	lbite/K – f	eidspar)		
(7)	ℓ°C =	$\frac{933}{0.993 + \log Na/K} - 273.15$	25 - 250	(1)
(8)	$t^{\circ}C =$	$\frac{1319}{1.699 + \log Na/K} = 273.15$	250 - 350	(1)
Na – K – Ca				
(9)	$t^{\circ}C =$	<u>1647</u> 2.24 + logNa/K + β†log√Ca/Na	- 273.15 4 - 340	(3)
Na – Li				
(10)‡	t°C =	$\frac{1000}{\log Na/Li - 0.14} - 273.15$	20 - 340	(4)
(11)§	t°C =	$\frac{1195}{\log Na/Li - 0.39} - 273.15$	20 - 340	(4)

Recommended equations for chemical seathermomet

Concentrations are in ppm except for the Na-K-Ca geothermometer where they are in mols/l. *After adiabatic steam loss to 100°C.

 $^{\dagger\beta} = 4/3$ for $\sqrt{Ca/Na} > 1$ and $t < 100^{\circ}C$; $\beta = 1/3$ for $\sqrt{Ca/Na} < 1$ or $t_{*\beta} > 100^{\circ}C$. ‡ For waters of low to moderate salinity. $^{\$}$ For marine waters and brines. It may be that the latter Na - Li equation is also appropriate for waters in basaltic rocks.

(1) Arnorsson et al. (1983b); (2) Fournier (1977); (3) Fournier and Truesdell (1973); and (4) Fouillac and Michard (1981).