IMPLICATIONS OF SOLUTION-MINERAL EQUILIBRIA ON THE EXPLOITATION OF THE S-NEGROS GEOTHERMAL FIELD, PHILIPPINES

Oliver T. Jordan*
UNU Geothermal Training Programme
National Energy Authority
Grensasvegur 9, 108 Reykjavik
ICELAND

*Permanent Address:
Philippine National Oil Company (PNOC)
Energy Development Corporation (EDC)
Geothermal Division
PNOC Energy Companies Building
Merritt Road
Fort Bonifacio, Metro Manila
PHILIPPINES

ABSTRACT

Representative chemical data from production boreholes in the Southern Negros Geothermal Field, Philippines, were studied to assist in the evaluation of certain solute-mineral equilibria and the calibration and selection of the most applicable chemical geothermometer. Anhydrite and quartz are shown to be in equilibrium with the deep fluid, while calcite saturation seems to be governed by temperature and mixing with cooler fluid. A computer simulation of boiling and cooling processes suggests no potential calcite deposition, whereas problems of amorphous silica scaling could occur at a re-injection or production separation temperature of 150 °C and lower. Empirically derived relation of aqueous acid molecules and cation to proton ratios with temperatures, as obtained using chemical data in Iceland, fits well for the aqueous H_4SiO_4 and H_2CO_3 species in fluids of Southern Negros, but gives significant deviations for H_2S, H_2SO_4, and the cation to proton ratios. The deviations are attributed to the mechanisms of boiling and degassing, a different rock leaching property, and mixing with cold water. Calibration of various chemical geothermometers using measured temperatures at main production zone as reference, shows that the pressure sensitive silica geothermometer of Ragnarsdottir and Walther(1982) and the Na/K geothermometer of Arnorsson, et al. 1982 c) using computed activities of Na and K yield the least mean and standard deviations. Applying the Chloride-enthalpy mixing models of Fournier (1977), suggests cold meteoric water recharge from the northwest, picking up heat from the rock before mixing with the outflowing hydrothermal fluid within the vicinity of Sogongon and Nasuji. True reservoir temperatures are estimated to be at least 300 °C.

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1 INTRODUCTION

1.1 Scope and obejctive of work

The Philippines is one of the many countries presently engaged in an accelerated development programme to harness geothermal energy as an indigenous power source. The revised energy development strategy calls for an installed 1,774 MW of electricity at the end of 1985. Contributory to this ambitious plan is the availment of foreign expertise and assistance, as well as the foreign training of selected Filipinos in the leading countries engaged in geothermal exploration, development, and utilization. In line with this, the author was awarded a United Nations University Fellowship to attend the 1982 UNU Geothermal Training Programme held at the National Energy Authority in Reykjavik, Iceland. He attended the specialized course in the geochemistry of thermal fluids.

After a five week introductory lecture series covering the various scientific, engineering, and economic aspects in geothermal exploration and exploitation, the author received specialized training in the following topics: water and steam sampling from natural thermal manifestations and production boreholes (3 weeks); analytical methods and procedures (3 weeks); rock-fluid chemistry and chemical thermodynamics (2 weeks); computer compilation of analytical results (2 weeks); and computer approach to the interpretation of geothermal well discharges (2 weeks). This report represents a research project carried out during the last month of the training programme.

Chemical data from production boreholes in the Southern Negros geothermal field, Philippines, were studied to assist in their overall evaluation. Since the study of aquifer fluid chemistry involves lengthy and complex equations, calculations, and especially iterative procedures, a computer programme developed at the University of Iceland and the National Energy Authority, was used (Arnorsson, et al. 1982 a). This topic was selected to train the author in such a specialized field of studies commonly used both during the exploration and the exploitation stages in geothermal development.

1.2 Methods of collection and analysis

All analytical procedures were performed at the geochemical laboratories of PNOC-EDC Geothermal Division at Manila and Southern Negros. The following is a brief description of the methods used in water and steam sampling.

Figure 1 shows the typical discharge test assembly of production boreholes in the Southern Negros geothermal field. The two-phase fluid from the well head is by-passed to a horizontal discharge pipe and allowed to discharge to atmospheric pressure through a twin-tower cyclone silencer equipped with a rectangular weir and a trapezoidal cippoletti weir to measure water flow rate. Two sampling probes are located on the horizontal by-pass pipe consisting of either a 3/4" or 1/2" inside diameter nipple and a gate valve to control fluid flow during sampling. Generally, water samples were collected at atmospheric pressure and local boiling point (i.e. in the weirbox), and at the low pressure probe.

Water samples could not be collected at the high pressure point since it was experienced that steam carry over with the liquid phase could not be avoided, probably due to the proximity of this probe to the T-junction of the wellhead, where turbulent flow of both water and steam phases makes effective separation impossible. A weber cyclone separator was used to carry out the steam and water sampling under pressure. Sampling pressures ranged from 2-12 bars absolute. The difference between fluid pressure within the pipe and the sampling pressure were kept to a minimum to reduce the possibility of steam flashing.

Water sample treatment consists of acidification to pH 2-3 for the analysis of silica and the main cations and storing in polyethylene bottles;untreated samples were analysed for boron, chloride, and sulfate; water samples collected into air-tight

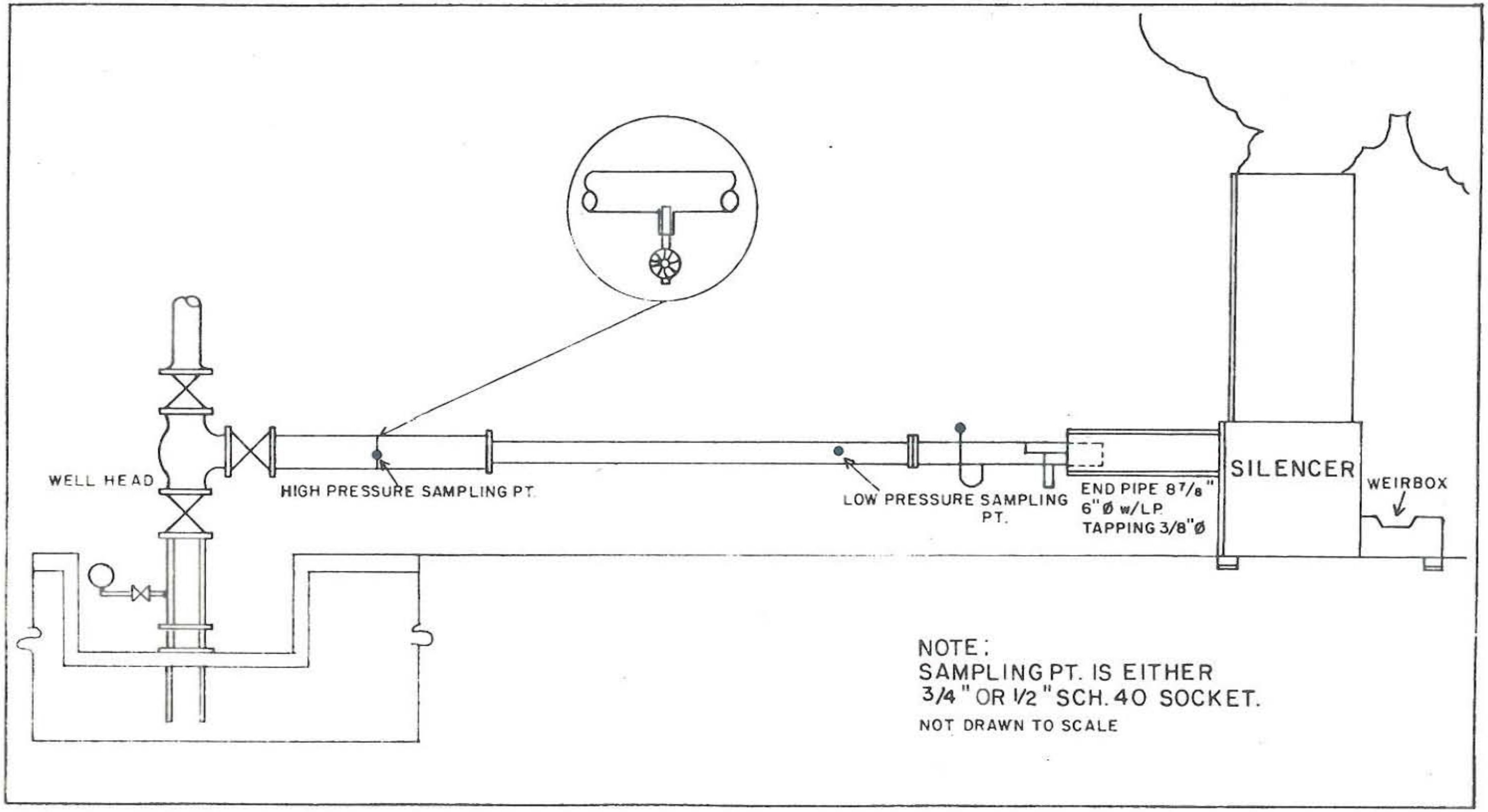

FIG 1. DISCHARGE TEST ASSEMBLY IN THE PALINPINON FIELD, SOUTHERN NEGROS

(modified from Baltazar, 1980)

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TABLE 1

Analytical methods for steam and water samples

	Element	Method
Steam phase	CO_2	Potentiometric titration from pH 8.25-3.80 using standard 0.1N hydrochloric acid.
	H_2S	Back titration with 0.01N sodium thiosulfate in acid solution(+2N sulfuric acid) after addition of 0.01N iodine solution
	NH_3	Specific ion sensitive electrode
	Cl	Mohr titration using 0.01N silver nitrate with potassium chromate-dichromate buffer indicator
Water phase	pH	Glass electrode
	Li	Atomic absorption spectrophotometry
	Na	Atomic absorption spectrophotometry
	K	Atomic absorption spectrophotometry
	Ca	Atomic absorption spectrophotometry
	Mg	Atomic absorption spectrophotometry
	Rb	Atomic absorption spectrophotometry
	Cs	Atomic absorption spectrophotometry
	Cl	Mohr titration using 0.1N silver nitrate standard solution with potassium chromate/dichromate buffer indicator
	SO_4	Ultra-violet spectrophotometry by liberation of chromate ions through pptn. of sulfate using barium chromate
	B	Potentiometric titration with 0.025N sodium hydroxide to pH 7.30 after addition of excess mannitol
	SiO_2	Ultra violet spectrophotometry through colorimetric reaction using ammonium molybdate
	CO_2	Double potentiometric titration from pH 8.25-3.80 using 0.02N hydrochloric acid
	H_2S	Same as for steam phase

glass bottles with a 6-8" long butyl rubber tubing equipped with aluminum clips (air free samples) were taken mainly for the analysis of pH, total sulfide, and total carbonate. Steam samples were collected both at the high and low pressure points, into evacuated 2-3 liters boro-silicate flasks containing a measured volume of 70 % sodium-hydroxide solution to bring the CO_2 and H_2S gases of the steam phase into solution. Separate untreated steam condensates were similarly collected into 3-liters evacuated flasks for ammonia analysis. All analytical procedures and methods used are summarized in Table 1. Relevant bore output data such as discharge enthalpies and total mass flow rates were also measured along with the time of sampling, using the critical lip pressure method developed by James (1962).

2 THE SOUTHERN NEGROS GEOTHERMAL FIELD

2.1 Introduction

2.1.1 Regional geological setting

The Southern Negros Geothermal Field (SNGF) covers almost one half of the peninsular arm of Negros Island, and encompasses a total reservation area of approximately 133,000 hectares (Fig. 2) The SNGF is situated within a localized graben that forms the Okoy river-valley, located in between the merging flanks of two dormant andesitic volcanoes, namely the Cuernos de Negros to the south, and mount Balinsasayao to the north. The whole field is dissected by a series of NNW trending right lateral faults, NE trending left late ral faults, and a system of step faults striking NW and NE. The first two fault patterns are believed to be sympathetic to the Philippine fault, while the third pattern could be due to a failure enhanced by local coupling stresses that could have been initiated by lateral movements along shear planes (Bagamasbad, 1979; Reyes and Tolentino, 1981).

The SNGF consists of two promising thermal areas, namely the Palinpinon field, located on the eastern section of the Okoy river valley, and the Baslay de Dauin area, situated within a ring plain southeast of the Cuernos volcano. The distribution of thermal springs and resistivity contours are shown in Fig. 3. These manifestations, in the form of numerous hot and warm springs, alteration patches, and steaming vents, are broadly contained within the two thermal areas, but are more numerous and intense along the 9 km length of the Okoy river, the southern tributaries of which drain the Northern flank of the large Plio-Pleiostocene composite volcano of Cuernos de Negros. Dipole-dipole and Schlumberger resistivity surveys with electrode spacings of AB/2 equals 250 and 500 m identified four distinct anomalies (5, 10, 20,and 50 ohm-meter), all

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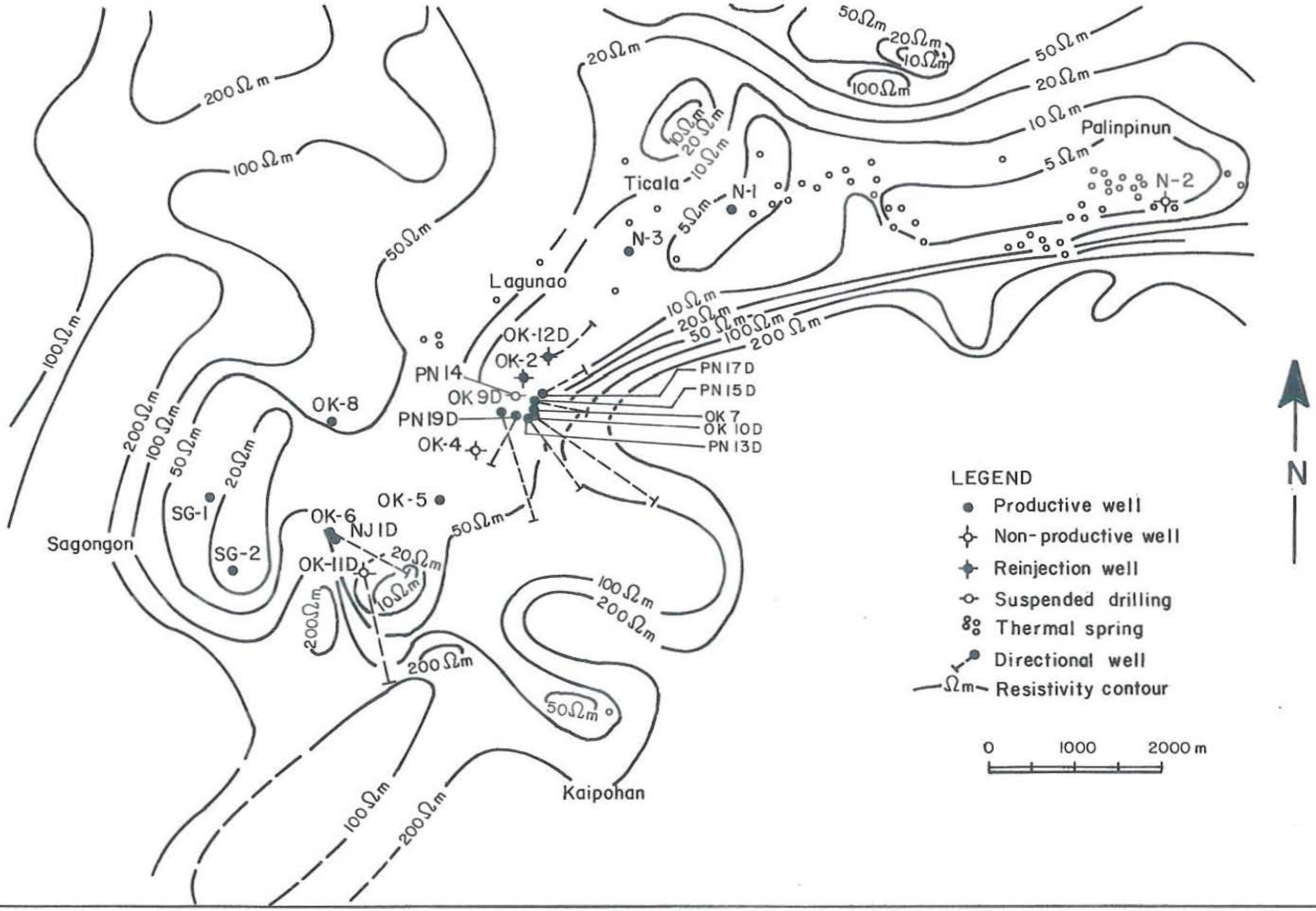
Figure 3 Map of Palinpinon field showing resistivity contours, distribution of thermal springs, and location of boreholes



converging towards the Cuernos volcano, suggesting that this may be the ultimate heat source of the field (KRTA, 1977).

2.1.2 Brief status of geothermal development.

The Palinpinon field has been given priority over Baslay de Dauin in exploration and production drilling due to the more impressive thermal areas and encouraging geological, geophysical, and geochemical results. In April, 1982 a total of 26 wells had been drilled (vertical and directional), while four others are currently being drilled. Due to the steep topography in Puhagan which severely limits the number of suitable sites for vertical wells, directional drilling has become common practice. Thus all targets can be reached from drillsites close to the location of the power station. These wells penetrate a series of intermediate volcanics and volcaniclastics before encountering a fossileferous sedimentary formation and/or a diorite-monzonite pluton (Reyes and Tolentino, 1981). Fig. 4 shows the main structures, the location of all wellheads, and the bottomholes of the directionally drilled producton wells that will be considered in this report.

2.2 Review of previous geochemical studies.

The chemistry of surface thermal manifestations and early exploration wells has been described by previous workers (Glover, 1975; Camales, 1979; Ruaya, 1980). Production borehole geochemistry studies were described by Jordan (1981 a,b,c) and Clemente (1982 a,b). A brief summary will be given of the general interpretations that have been made.

2.2.1 Geochemistry of surface thermal manifestations.

Figures 3 and 4 show the distribution of hot and warm springs of the SNGF. On the basis of their chemical composition, three distinct types have been identified:

1) Low lying, near neutral to slightly alkaline, high sodium chloride springs of Palinpinon and Cambucal.
2) Near neutral to acidic, high sulfate (up to 3,000 ppm) waters with significant chloride (780 ppm) of Tagbac-Magaso, Baslay and Nagpantaw at moderate elevations.
3) Acid, low chloride-high sulfate steam heated springs of Lagunao, Sogongon, and Kaipohan, at high elevations.

The first type is attributed to a direct leakage from the aquifer fluid, and hence, believed to reflect underground hydrothermal conditions. Chemical geothermometry and mixing models yield maximum and minimum subsurface temperatures of 279-173°C (KRTA, 1979).

The second type is believed to be associated with the hot chloride water but could have been diluted with near surface ground water. The neutral springs of this type could be formed when the hydrothermal fluids migrate upward via a formation of restricted permeability, where neutralization reactions between rock and fluid are enhanced by the slow flow rates, resulting in neutral emissions at the surface. The acid springs could be formed when steam separates from the water table of the hot chloride body and dilutes near surface ground water during upward flow.

The third type is evidently steam heated surface ground water and does not reflect deep condititons. The high sulfate and low pH could be quantitatively explained through the oxidation of hydrogen sulfide gas in the steam to sulfuric acid upon contact with oxygen containing meteoric water:

$$H_2S + 2O_2 = 2H^+ + SO_4^{--}$$

Glover (1975) concluded that the type of discharge could be controlled by elevation and permeability, and Barnett(1980) suggests a steam cap to be responsible for the steam heated springs.

2.2.2 Geochemistry of exploration and step-out wells.

Early exploration and step-out wells (N1 to N3, OK-2 to OK-5) intercepted higher saline fluids than the least diluted springs of Palinpinon and Cambucal, a consistent sodium chloride water containing variable concentrations of sulfate with a mineralization of about seven percent of total dissolved solids. The absolute chemical components vary slightly for each well and yet show relatively uniform ratios of non-reactive elements e.g. Cl/B, suggesting a single source of parent water undergoing varying degrees of mixing and dilution with cold ground water during ascent. An evidence for mixing is the linear relation between the absolute chloride content and quartz calculated temperatures (KRTA, 1977). Temperature dependent and reactive constituents e.g. Na, K, SiO_2 vary in direct proportion to the temperature of the deep water at any point, which is believed to range from 170°C to possibly 300°C. Wells N1 and N2 however, encountered problems with calcite deposition and output testing did not last long enough to allow any geochemical monitoring with time. Such deposition problems were correlated to the presence of abundant calcite that has crystallized in open fractures as reported from the petrological logs of cores that were cut between the major loss zones of N1. A similar problem was predicted for N3, (Glover, 1975, Barnett, 1980), but no indications of drastic decline in total mass flow rates have been observed. Consequently, no problems of calcite scaling have been encounterd in this well. The maximum measured temperatures for N1, N2, N3, OK-2 and OK-5 were 195°C, 163°C, 238°C, 247°C and 310°C, respectively. All geochemical data point to an easterly outflow of hot chloride water from west to east. Each well intercepted this flow regime and chemically calculated temperatures which were generally higher than measured values at conditions of stable flow, indicated that higher temperatures could exist towards the southwest. Preliminary isochemical plots of Obusan (1980) suggests a major upwelling zone within the vicinity of OK-5.

2.2.3 Geochemistry of production wells

Information on the subsurface chemistry of the area has been updated with the sucessful discharge of deep production wells. From 1980 to the first half of 1982, a total of 14 wells had undergone medium and long term discharge tests. These wells initially undergo a 1-2 month clearing discharge period, followed by a successive throttle series with the primary objective of examining variations in bore output characteristics in response to changes in wellhead pressures and end pipe diameters. Wells OK-5, PN13D, and OK-7 are currently utilized to drive the 3x1.5MW non-condensing turbines, which started operating in 1981 and 1982, while PN17D, PN15D, PN19D, NJ1D, and OK-8 are undergoing or have just completed their respective medium term discharge tests. OK-12D and OK-2 are used as reinjection wells. The boreholes in Southern Negros show slight two-phase conditions, except for SG1, OK-12D, PN13D, which appear to draw production from a single phase fluid. These wells have a discharge enthalpy ranging from 1050 to 1350 kJ/kg at wellhead pressures of 4-12 bars absolute; only OK-5 shows extreme two-phase conditions with an average discharge enthalpy of 1900 kj/Kg under fully opened conditions. Most wells encounter two major permeable zones at depth which is referred to as the main and secondary production zones (EDC-KRTA, 1982). Table 2 shows the physical measurements data of all production wells in S-Negros and Fig. 5 shows a cross section map of the SNGF showing these production zones.

Table 2.

Physical measurements, data and interpretations of production wells in S- Negros, showing production zones and measured temperatures

Well No.	Depth (m)	Loss zones (m)** main /secondary	Main Production *** zones(m)	Measured temperatures(°C) a	b	c	Power rating MWe
OK-7	2883	2600-2882/1500-1700	2600	268	318	318	12.5
OK-9D	2889	2400-2600/1600-1800	2400	306	332	291	6.4
OK-10D	3019	1500-1750/2900-3019	1600	226	270	259	6.8
OK-12D	2798	1400-1700/2000	2013	243	282	250	4.4
PN13D	2854	1600-1900/2000-2854	2000	236	317	268	4.6
PN15D	2807	1500-1600/2200-2806	1600	265	276	274	7.5
PN17D	3043	2000-2150/1600-1780	2100	281	290	245	4.5
OK-5	1975	1450-1550/1100-1200	1550	310	290	264	8.2
OK-6	2771	2300-2770/1340-1550	2550	254	285	285	10.1
OK-8	2982	2300-2400/1700-1900	2450	282	282	244	3.0
NJ1D	2848	*2050-2400/1325-1610	----	243	---	---	---
SG-1	2763	2550-2650/1550-1650	2650	278	277	277	5.5
SG-2	2945	2050-2150/1400-1600	1400	275	276	275	10.1

* Data available only from drilling logs

** Loss zones indicate zones of water losses deduced from pressure and temperature logs during completion testing of the well.

***Refers to the zone which dominates production at maximum discharge rate of the well; deduced from temperature and pressure logs at flowing conditions.

a Maximum measured well temp. before discharge

b Maximum measured well temp. after discharge

c Maximum measured temp. of main production zone in flowing conditions

The typical fluid chemistry is presented in Table 3. The wells are grouped on the basis of their respective locations, i.e. the Puhagan, Nasuji, and Sogongon areas.

Obtaining representative chemical data from a well is hindered by several factors. Fig. 6 shows the typical variations of chemically calculated subsurface temperatures, deep water enthalpy, chloride in total discharge, and the gas components (CO_2 and H_2S) in total flow with the normal duration of a discharge test of a well. Because of the large amount of fluids injected into the geothermal reservoir during drilling and completion tests, a well fluid is not representative until after approximately two months of full discharge. Another important factor to be taken into consideration is the mixing between aquifers. The existence of two production zones at a temperature difference of about 40-50°C both contributing to the total flow results in a mixed fluid at the surface sampling point.

The criteria for selecting representative data from individual wells are thus a) a fully stabilized chemistry and b) a sample point where only the major production zone dominates bulk of the discharge, which, according to experience from temperature pressure logs at flowing conditions, occurs at throttled conditions. These criteria will also minimize the effects of excess enthalpies. All chemical data in Table 3 is taken under these conditions. The fluids are relatively neutral (pH 6-7) but contain high amounts of sodium, potassium, silica, and chloride. Significant amounts of the alkali metals are also present (Li, Rb, Cs), but magnesium, bicarbonate, and sulfate, though variable, are low. In the steam phase, carbon dioxide comprises more than 90% of the total non condensible gases, whereas hydrogen sulfide and ammonia comprises 2-4 %. Following is a summary of the interpretations about the reservoir fluid that have been made:

Table 3

Chemical composition of production well fluids at S-Negros field (all concentrations in parts per million)

Well No.	H KJ/Kg	SP bars abs	Steam	phase at SP		SP						Water phase at SP								
			CO_2	H_2S	NH_3	bars abs.	pH/25 C	Li	Na	K	Ca	Mg	Rb	Cs	Cl	SO_4	B	SiO_2	CO_2	H_2S
OK-7	1326	9.30	34.296	695.7	-	9.30	6.97	14.8	3161	724	118	0.13	4.22	3.00	5788	28.0	69.3	867	32.7	0.10
OK-9D	1286	4.52	21.599	493.5	26.0	4.52	7.43	12.4	2580	555	75.5	0.19	3.56	2.71	4308	34.7	52.0	734	43.6	-
OK-10D	1313	2.59	7079	165.8	17.0	2.59	6.69	14.0	3167	634	122	0.85	3.79	3.22	5424	51.5	76.1	717	2.6	-
OK-12D	1059	11.00	31.729	435.3	56.7	11.00	6.70	10.7	2352	457	76.0	0.36	2.53	2.10	4361	32.0	49.2	532	43.0	82.6
PN13D	1202	11.50	23.082	646.3	69.0	11.50	5.95	10.1	2472	551	58.3	0.38	3.17	2.33	4773	24.9	61.3	675	18.3	10.2
PN15D	1152	4.80	23.293	317.9	23.0	4.80	6.01	10.2	2800	497	63.1	0.26	2.70	2.31	4965	25.6	57.0	757	154	5.96
PN17D	1094	6.60	19.184	327.8	43.5	6.60	6.21	10.0	2965	421	68.6	0.42	2.41	2.16	4617	30.6	53.3	559	40.2	7.16
OK-5	1518	9.30	10.505	356.3	11.90	1.00	7.22	17.5	3347	820	35.1	0.04	5.31	3.58	5993	61.5	73.0	1073	68.5	9.88
OK-6	1263	11.10	12.738	204.4	9.59	11.10	6.60	11.6	2411	480	31.9	0.03	3.87	2.81	4436	32.5	52.0	726	6.60	-
OK-8	1269	7.62	11.480	199.5	-	1.00	7.85	14.3	2771	636	33.6	0.05	4.27	2.87	5262	36.1	64.4	864	6.98	6.49
NJ1D	1046	2.00	10.218	1109.0	-	1.00	5.20	6.88	1930	393	16.5	5.25	1.77	1.80	3489	155	46.9	600	2.54	2.39
SG-1	1147	6.90	9849	154.4	26.0	6.90	7.30	10.7	2250	457	34.4	0.06	2.97	2.15	4148	39.8	51.1	626	32.1	3.07
SG-2	1280	9.20	14.691	189.6	25.0	9.[illegible]	5.91	10.4	2139	452	21.4	0.06	2.99	2.07	3957	23.2	48.6	660	25.8	3.55

H measured discharge enthalpy (in Kj/Kg)

SP sampling pressure (in bars absolute)

CO_2 total carbonates (HCO_3^-, CO_3^{--}, H_2CO_3) reported as CO_2

H_2S total sulfides (H_2S, HS^-, S^{--})

--- analysis not available

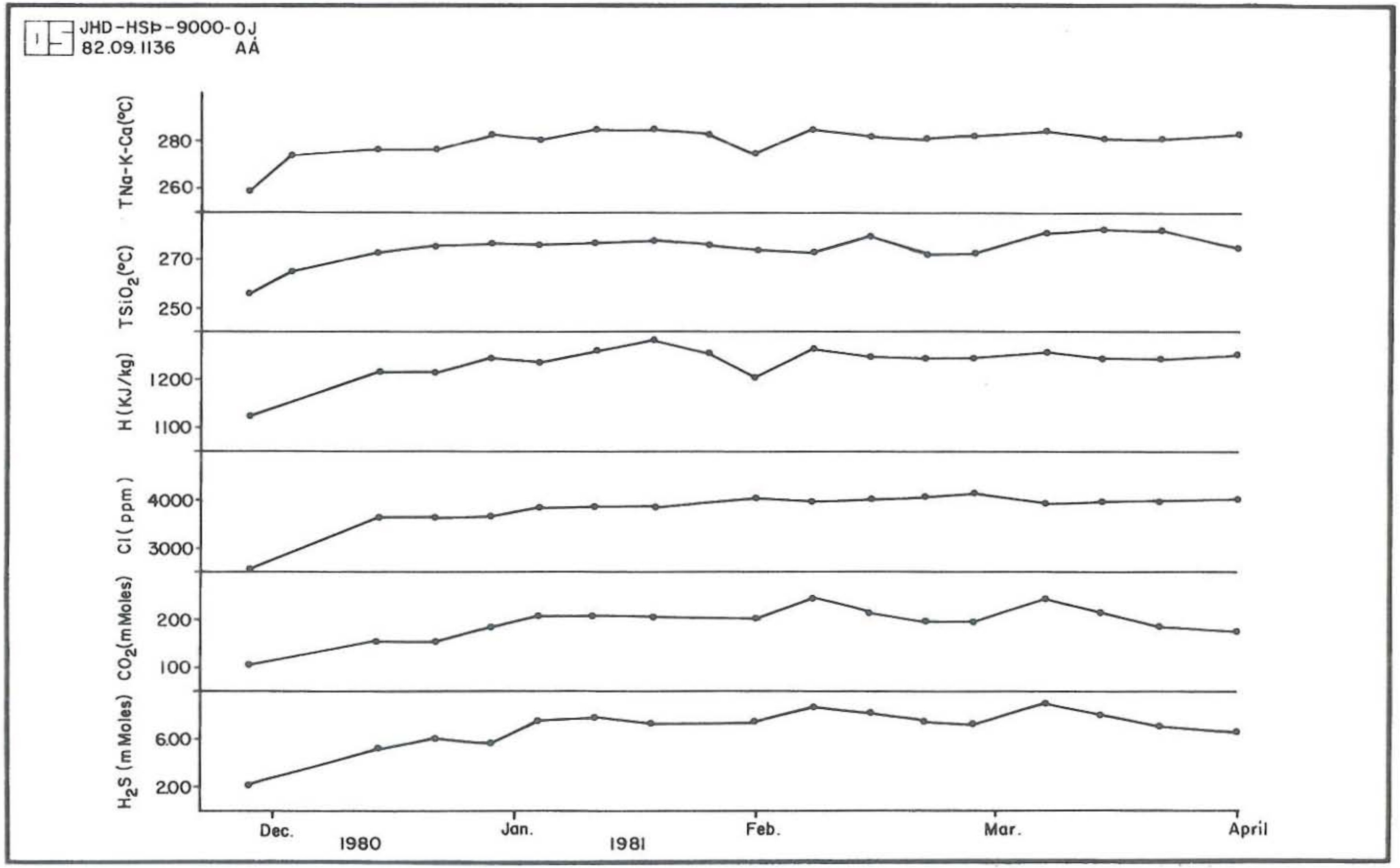


Figure 6 Typical variation with time of chemically calculated temperatures, deep water enthalpy, deep water chloride, and CO_2 and H_2S in total discharge of a production well (OK-9D).

1) Two production zones are deduced from the variation of total discharge chemistry in response to differing wellhead pressures, namely, a deep, highly saline fluid containing typically 3,900 ppm of chloride at a mean temperature of 280°C (T Na/K), and a less mineralized but gas rich fluid at shallower levels. variations with time and changing wellhead pressures are interpreted as an intermittent contribution from the upper feed zone (Jordan, 1981b,c, Clemente, 1982a,b). This also attributes to the wellhead pressure cycling that was noted in wells OK-5 and N3 (Camales 1979). This deduction is supported by fluid losses during completion testing and the temperature and pressure logs at flowing conditions, where at least two producing horizons are recognized. The top and bottom of these exploitable zones are believed to be at 300m bsl and 2600m bsl with mean temperatures of 230°C and 320°C respectively (KRTA 1981).

2) The Puhagan wells intercept the least diluted fluid, whereas the Nasuji and Sogongon fluid chemistry has been shown to be modified by dilution with cooler fluid, and oxidation with oxygen containing meteoric water. A common reservoir, however has been consistently indicated by the uniformity of alkali metal ratios, and the chloride to boron equivalence (Jordan, 1981,b,c).

3) The iso-chemical and isothermal contours (Harper and Clemente, 1982) suggest a narrow flow of thermal fluids to the northeast of Puhagan, where the contours close into the Okoy valley. This could be directly associated to a structural control of the Ticala fault which may confine the outflow in a narrow, northeasterly direction. A broad flow to the west through Nasuji and further into Sogongon is also evident, since the contours show a broader extension. This could be due to secondary permeability by thermal cracking, and not directly associated with faulting.

4) The main upflow zone which is postulated to lie beneath the Cuernos volcano, could probably be in temperatures of greater than 300°C. This was estimated by extrapolation of plots of deep chloride versus silica calculated temperatures (Harper and Clemente, 1982, Jordan, 1981 b,c).

3 SOLUTION-MINERAL EQUILIBRIA

3.1 Introduction

The study of solute/mineral equilibria has been shown to be one of the valuable aides in the overall geochemical evaluation of a geothermal system. This is based on the fact that fluid chemistry is primarily governed by the solubility of minerals, and thus an understanding of the thermodynamic factors which affect such equilibria is necessary for the proper interpretation of chemical data. The use of chemical geothermometers, and prediction of mineral scaling and deposition tendencies, for example, are shown to be very dependent on the saturation state that has been attained between rock and fluid.

Previous geochemical studies in the S-Negros Field, have mainly been focused on describing individual wells and field models. Only a limited attention has been given to a quantitative evaluation of the solute-mineral equilibria. It is the objective of this report to attempt such an evaluation investigation, and furthermore, to:

(1) evaluate the implications of solution mineral equilibria on the applicability and limitations of previous and current chemical geothermometers,
(2) anticipate mineral deposition tendencies, and,
(3) predict physical processes (dilution, conductive cooling, precipitation) across the geothermal field.

3.1.1 Applications of solute-mineral equilibria studies

Previous workers, (Fournier 1977; Ellis and Mahon, 1977; Arnorsson, et al. 1982b) have demonstrated that most high temperature geothermal waters attain an overall equilibrium between solutes and alteration minerals. It is known that chemical species is controlled by mineral solubility i.e. SiO_2 is controlled by the solubility of quartz and chalcedony, Na and K by sodium and potassium feldspars, calcium by calcite and calcium aluminum silicates, and sulfate by anhydrite and iron minerals. The state of saturation, however, is highly dependent on the physical processes which occur during the transport of the fluid from the reservoir to the surface. Intensive studies have shown (Arnorsson et al., 1982 b), that boiling, cooling, degassing, dilution with cooler fluid and the kinetics of water-rock interactions, are the major processes which cause some minerals to deviate from the original saturation state. First level boiling with maximum degassing, for example, has been shown to produce a supersatutated fluid with respect to calcite, and, progressive boiling and cooling to significantly lower temperatures yields amorphous silica saturated fluids, (Ellis and Mahon, 1977; Arnorsson, 1981). It is thus, highly desirable for the proper interpretation of chemical data, that such factors be taken into consideration.

The use of chemical geothermometers in predicting underground temperatures is based on the assumption that equilibrium between fluid and a particular mineral has been attained, and that re-equilibration during conductive cooling is insignificant. Many different chemical geothermometers have been used to estimate reservoir temperatures, among these are silica (Mahon, 1966), Na/K (White 1965; Ellis and Mahon, 1977; White, 1970; Truesdell, 1976a; Fournier, 1979a; Arnorsson et al. 1982 c) and Na-K-Ca (Fournier and Truesdell, 1973). They are based on the experimentally determined solubility of quartz and the variation of Na^+ and K^+ in natural geothermal waters as a function of temperature. The Na-K-Ca geothermometer was developed to deal with calcium rich waters that give anomalously high results when using the Na/K geothermometers, and is empirically calibrated.

It is important to consider the sensitivity of each chemical species (that is used as a temperature function), to physical and chemical changes accompanying the passage of fluid from the reservoir to the surface sampling point. The equilibria governing sodium and potassium feldspars are least affected by cooling, and the use of the ratios of sodium to potassium eliminates boiling and dilution effects, and hence, temperatures estimated from these geothermometers would tend to be higher than those of quartz. The quartz geothermometer, on the other hand, uses directly absolute concentrations of total silica, and would thus readily be affected by dilution. Furthermore, the equilibrium governing quartz and silica is more sensitive to conductive cooling and boiling and generally yields conservative values. Arnorsson et al.(1982 c) showed that the rate of quartz precipitation is positively related to water salinity. The rate of re-equilibration upon cooling between quartz, feldspar and solution is about the same for dilute solutions (1,000 ppm) for water temperatures of about 250°C (Namafjall, NE- Iceland Arnorsson, 1977). For waters of high salinity (13,000 ppm, Svartsengi SW-Iceland), conductive cooling by 10-20°C is fully detected by the quartz geothermometer, but not in the case of Na/K geothermometer.

The Na-K-Ca geothermometer is empirically calibrated involving the addititon of two temperature dependent ratios (Na^+/K^+ and Ca^{++}/Na^+). This geothermometer however,(unlike quartz and Na-K) is not in any way related to a specific mineral assemblage and the major reason why it works in some cases is that the free energy that is involved in the dissolution of a particular mineral and the formation of new ones are negligible so that no significant change in water composition is detectable. Furthermore, the work of Arnorsson et al.(1982 c) shows a larger scatter of data points for the ratio Ca^{++}/Na^+ than for Na^+/K^+ indicating that the scatter could be due to equilibrium with more than one mineral assemblage, whereas Na^+ and K^+ activities seem to be governed by equilibrium between low-albite and microline over the whole temperature range. This makes the Na-K-Ca geothermometer inferior to the Na/K geothermometer whatever calibration curve or beta value is used.

Temperature estimates of the Na-K-Ca geothermometer are more conservative than those of the Na-K geothermometer since large monovalent cations take a long time to equilibrate, whereas divalent, trivalent, and smaller ions re-equilibrate more rapidly. Hence, the Ca^{++}/Na^{+} would respond faster to cooling than the Na/K ratio. Another limitation to the application of the Na-K-Ca geothermometer is the precipitation of the calcium ion in significant amounts, especially in zones of intense boiling. This would then result in anomalously high calculated temperatures (Arnorsson et al.1982 c).

Gas geothermometers have also been used, (Ellis, 1979; D'Amore and Panichi, 1980) which involves the temperature dependence of gas-gas equilibria and the relative concentrations of CO_2, H_2S, H_2, and CH_4 in geothermal steam. The calibration is empirical and shown to be in a reasonable agreement with measured temperatures from nearby drillholes. However, re-equilibration between gases during upflow to the surface, has not been duly considered. The apparent discrepancy in temperature values obtained by various geothermometers thus often aid in identifying processes, such as:

a) dilution with cooler fluid,
b) conductive cooling,
c) precipitation and/or deposition along upflow zones accompanying boiling.

It is obvious that although several calibration curves are used in deriving temperature functions for chemical geothermometers, the most common practice in its use is three-fold, namely:

(1) Complexing between solutes is ignored and analytical concentrations are assumed to represent activities.
(2) Solubility measurements are mainly done at 25°C and just extrapolated to higher temperatues; effects of fluid pressure on mineral solubility is regarded insignificant, and,
(3) For gas geothermometers, effects of re-equilibration between various gases has been neglected.

The first case may be true for dilute solutions (<3,000 ppm chloride), but in most geothermal fields, where salinity is a significant factor, e.g. Reykjanes, Iceland (32,000 ppm Cl), Tongonan, Philippines (13,000- 18,000 ppm Cl), Salton Sea, California (33,000 ppm Cl), this assumption often gives misleading results. Arnorsson, et al. (1982 c) demonstrate that temperatures calculated for waters of high salinity and high sulfate from analytical sodium and potassium values, do indeed deviate more significantly from measured temperatures, than those from computed activities. In the second case, Ragnarsdottir and Walther (1982) demonstrated in their quartz solubility measurements at 250°C and 250, 500, and 1000 bars that pressure poses a significant effect on the silica concentrations especially at pressures above 500 bars. These experiments, together with previously reported quartz solubility measurements, yielded a "pressure sensitive silica geothermometer" that takes into account the effect of fluid pressure on the solubility of quartz. The temperature obtained from this geothermometer shows best agreement with measured temperatures in many different geothermal areas (e.g. in Iceland and Kenya) and as will be discussed in the preceding chapters, in S-Negros, Philippines.

Experience, however, shows that fluid pressure in geothermal wells does not reach as high as 350 bars and the main reason why this geothermometer seems to show best agreement with measured temperatures is that the solubility measurements are done at 250°C, which represents close to actual reservoir conditions, whereas the other quartz solubility measurements are done at 25°C and just extrapolated to higher temperatures.

For the gas geothermometers, Arnorsson et al.(1982 c) showed that gas-steam geothermometers are better than gas-reaction geothermometers since boiling and reaction with rock have less effect on the gas-steam ratios than on the gas-gas ratios. Furthermore, the previous gas geothermometers, which involve H_2, H_2S, and CH_4, are not known to be controlled by any mineral assemblages. The CO_2 gas geothermometer, proposed by Arnorsson et al.(1982 c), is believed to be controlled by the zoisite-epidote-phrenite-quartz-calcite assemblage and this assemblage has been found in many geothermal systems (Browne, 1978).

Arnorsson et al. (1982 b) demonstrated that the ratios of aNa^+/aH^+, aK^+/aH^+, $\sqrt{aCa^{++}}/aH^+$, $\sqrt{aMg^{++}}/aH^+$, and acid molecules e.g. H_2CO_3, H_2SO_4 , H_2S, HF, H_4SiO_4 are always fixed at a particular temperature, provided equilibrium has been obtained between rock and fluid. This known relation enabled the derivation of empirical equations which relate the ratios and concentrations of acid molecules to fluid temperatures. These temperature functions combined with other solubility curves of certain minerals (e.g. anhydrite, quartz, calcite, for this study) would aid in precise determinations of whether or not equilibrium has been attained between rock and fluid. This would furthermore check the reliability of the use of chemical geothermometers, and would help in evaluating what processes could be responsible for non-attainment of equilibrium, e.g. mixing, precipitation, etc.

An attempt to apply such an empirically derived relation will be made on the S-Negros field in this report. It is believed to be applicable to define water composition in other areas for two reasons:

(1) Free energies accompanying hydrothermal reactions are too small to be detected in water chemistry,

(2) Variations in alteration mineralogy at elevated temperatures are not significant in volcanic rocks ranging from basaltic to rhyolitic compositions, Browne (1978).

Mineral deposition, corrossion, and scaling can cause a major constraint in the exploitation of geothermal fields. The most common scales are calcite, aragonite, amorphous silica, and iron oxides. Depostion is directly associated with temperature dependent mineral/solute equilibria controlling water chemistry. Mineral deposition, as a rule, occurs when the fluid attains a supersaturated state with a particular mineral, which usually follows intensive boiling and cooling. Thus, an understanding of how particularly troublesome minerals deviate from equilibrium in response to physical changes is highly desirable in order to anticipate and controll scaling problems. As will be discussed in later sections, a computer simulation of cooling, boiling and degassing was used to follow mineral saturation states in response to the above mentioned processes.

3.1.2 Mineral saturation state of the deep fluid

Figures 7, 8 and 12a show the state of anhydrite, calcite, and quartz saturation of the deep water, with reference to the measured temperatures at the main production zone. The solublity values for each was calculated from the thermodynamic data of Helgeson (1969), and Helgeson et al. (1978), and the activities of the species from analytical values, using a computer programme described by Arnorsson et al.(1982 a). The saturation state of each mineral is expressed as:

$$\text{Log K anhydrite} = aCa^{++} * aSO_4^{--}$$
$$\text{Log K calcite} = aCa^{++} * aCO_3^{--}$$
$$\text{Log K quartz} = aH_4SiO_4$$

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Figure 7 State of anhydrite saturation of the deep water at measured temperatures.

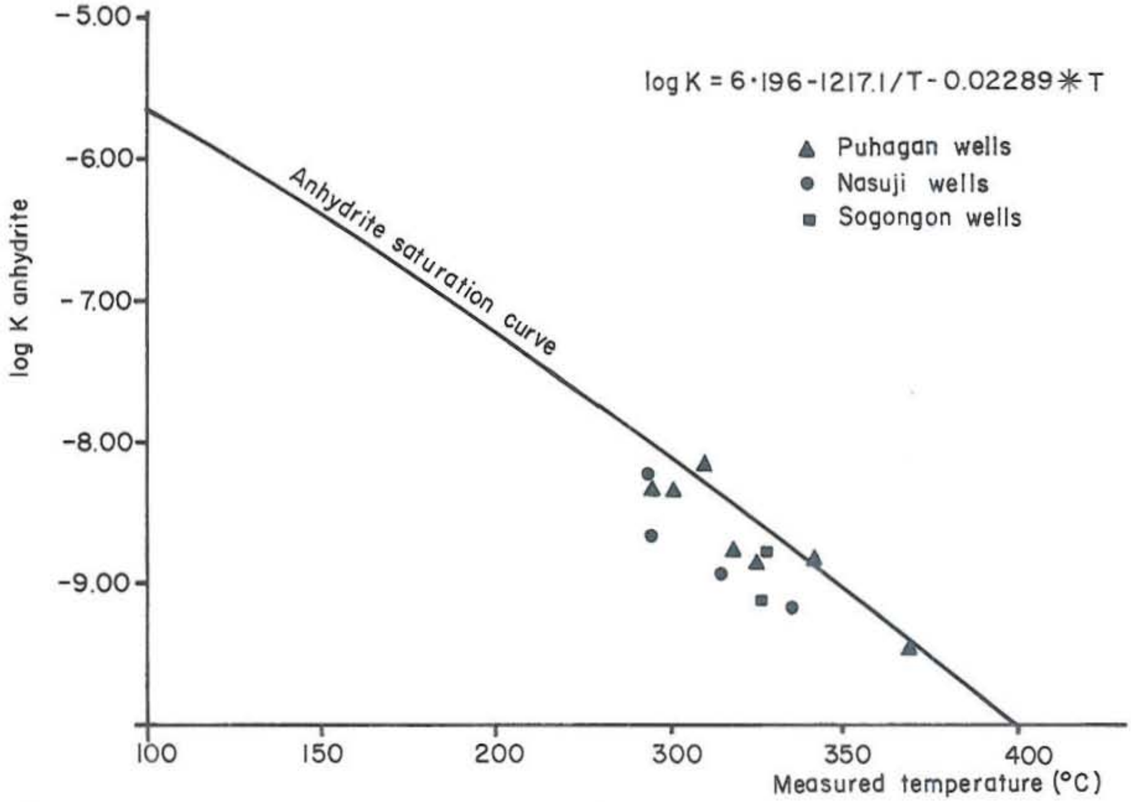
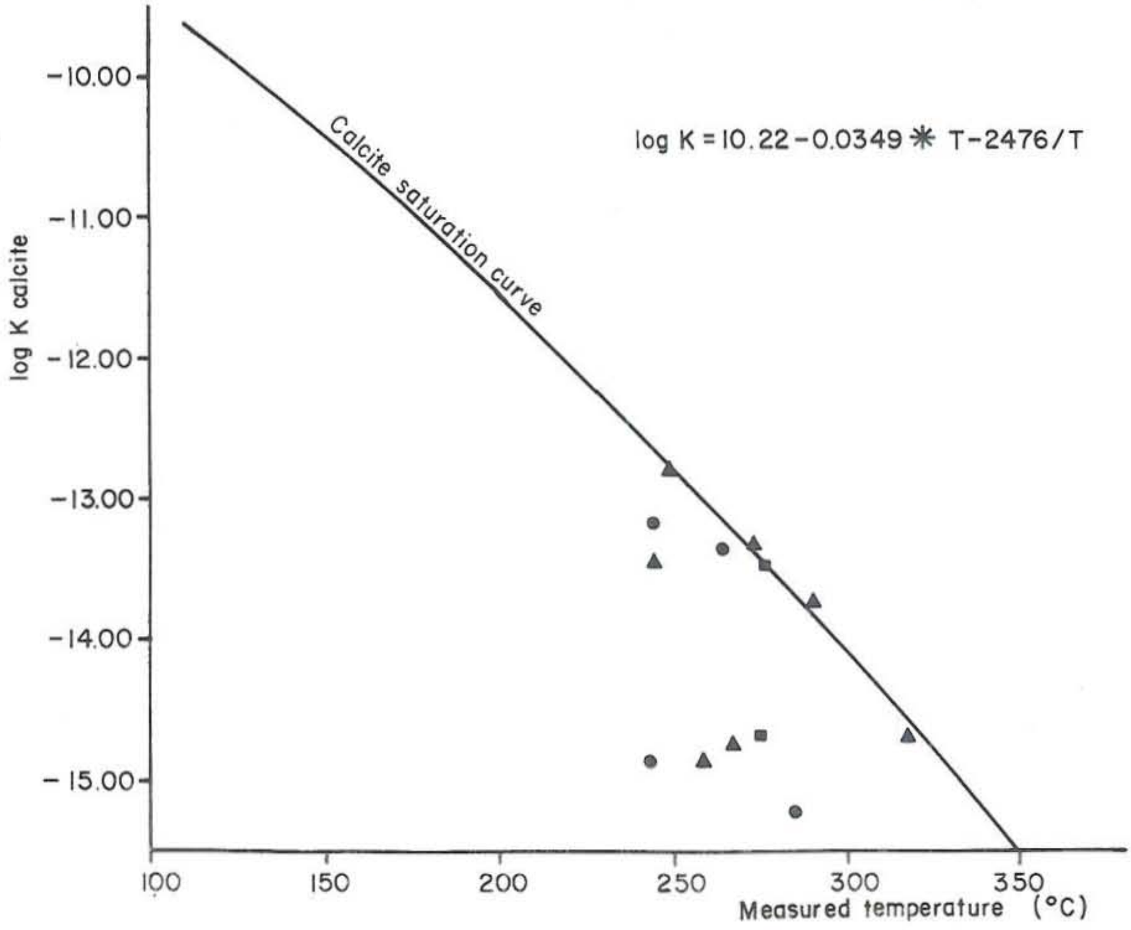


Figure 8 State of calcite saturation of the deep water at measured temperatures.



It is obvious from the figures that anhydrite and quartz saturation has been attained for most wells, only OK-6, OK-8, NJ1D and SG-2 shows slight undersaturation with respect to anhydrite. It is believed that the lower fluid salinity of these wells, caused probably by mixing and dilution, influences the controll of sulfate activity by the reaction, (Arnorsson et al.1982 a).

$$H_2S + 4H_2O = SO_4^{--} + 2H^+ + 4H_2$$

The equilibrium condition of anhydrite and quartz is not so sensitive to the reference temperature selected or at simulated runs for conditions of no excess enthalpies, since the calculated activities of aqueous H_4SiO_4, Ca^{++}, SO_4^{--} do not deviate significantly from the solubility curves.

The saturation state with calcite varies from well to well, but it generally seems to be disturbed by mixing with cooler fluid, which is more pronounced within the Nasuji-Sogongon areas. There most of the wells draw production from Calcite undersaturated fluids as shown in Fig. 8. This is supported by previous plots of aquifer chloride versus calculated silica temperatures where wells SG2, SG1 and OK-6 fall on the dilution line (Clemente 1981 a; Jordan 1981 b,c).

In order to determine the deviation from the original equilibrium state of the fluid to cooling, boiling, and degassing, and to anticipate mineral deposition tendencies, a computer simulated approach was used. Figures 9 to 11 show the deviation curves for Log K values of quartz and amorphous silica, calcite, and anhydrite in response to a computer simulation of cooling, boiling, and degassing processes. An arbitrary choice of 9 boiling steps at conditions of maximum degassing and 7 cooling steps were taken to see their respective deviation from the equilibrium curve. The first four boiling steps are selected at close temperature intervals (2°C), since the

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Figure 9 State of quartz and amorphous silica saturation at boiling and cooling

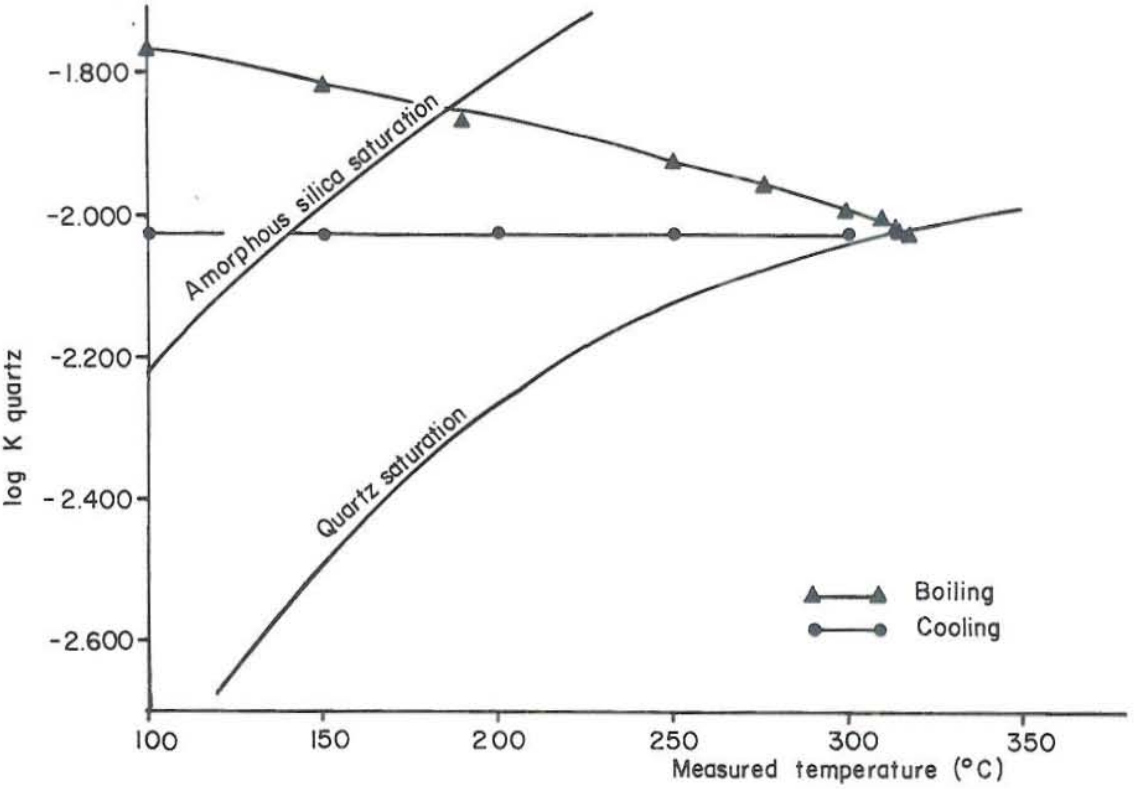

Figure 10 State of calcite saturation at boiling and cooling

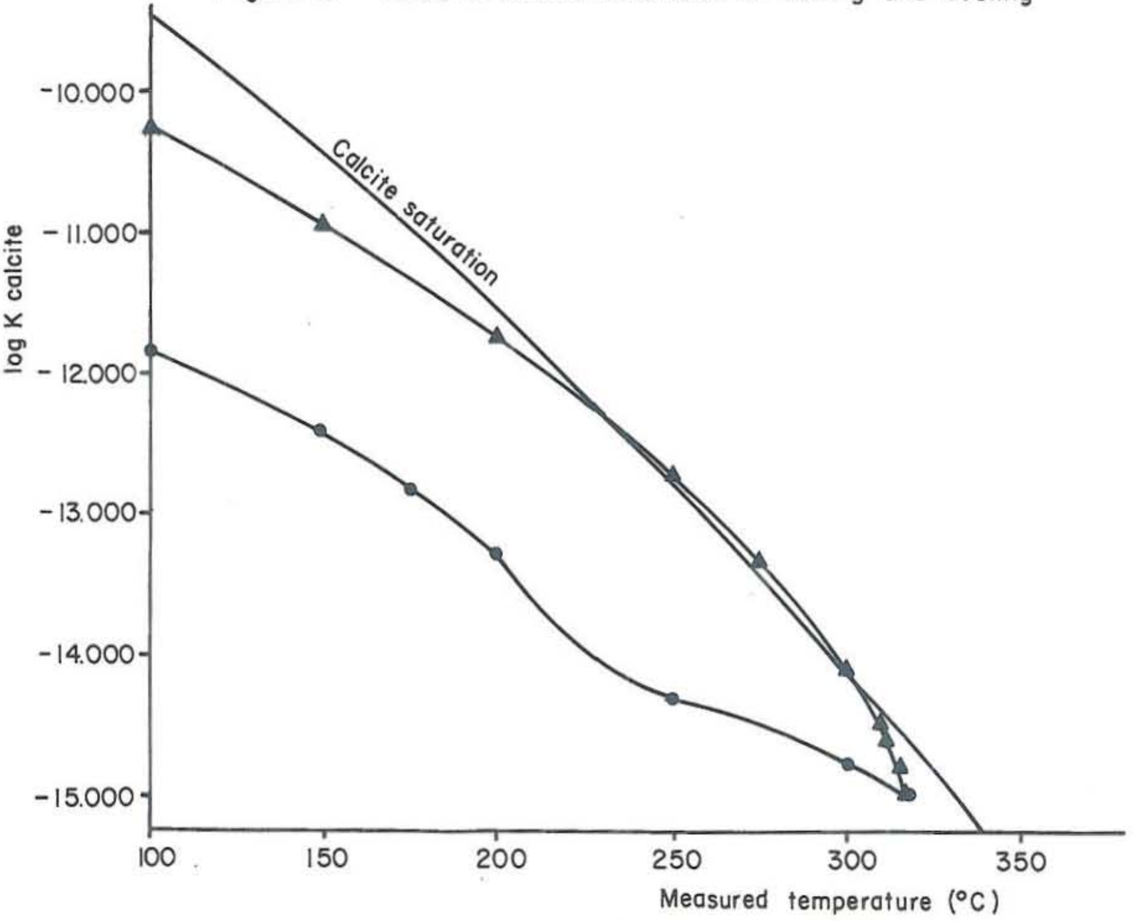

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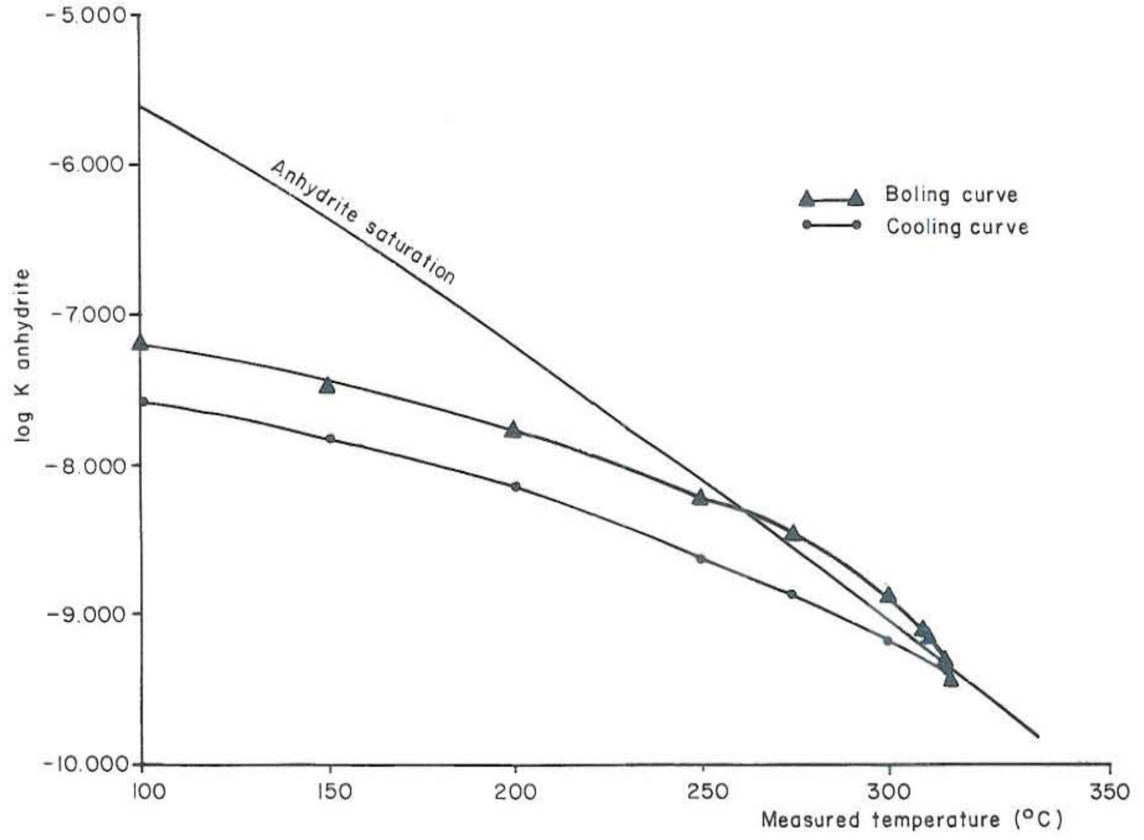
Figure 11 State of anhydrite saturation at boiling and cooling



most intense deviation from original saturation state usually occurs during the first few levels of boiling. The most representative well (OK-7) of the deep fluid was taken for this study since simulation runs from individual wells showed similar characteristic curves.

It is obvious from the figures for calcite and anhydrite that conductive cooling always yields undersaturated fluids in all the temperature range covered. The calcite and anhydrite curves indicate an approach to slight supersaturation during the first four steps of adiabatic boiling, attaining a maximum deviation from equilibrium after 43°C and 18°C adiabatic boiling for calcite and anhydrite, respectively. The rate of change decreases with progressive steam separation until undersaturation is attained. The slight approach to supersaturation with respect to calcite is not, however, regarded as an indication of potential scaling since log K values fall within the anticipated limit of experimental error.

In the case of silica, conductive cooling yields supersaturated fluids with respect to amorphous silica at about 140°C, whereas if waters cool adiabatically, amorphous silica saturation is reached at 186°C. Experience with re-injection of OK-7 waste water at 155°C for several months, however, showed no signs of serious amorphous silica scaling along the re-injection line. This would tend to indicate that other factors still control the extent of deposition apart from attaining supersaturation. Arnorsson (1981) suggests that the degree of degassing, changes in pH from steam loss, the type of flow (turbulent or laminar), and the possible separation of water and steam phases in the aquifer may control the temperature at which amorphous silica saturation is reached. These factors have not been thoroughly taken into consideration in deposition studies at S-Negros. It is anticipated that potential amorphous silica scaling would not occur until below 150°C.

3.1.3 Empirical relation between aqueous species and temperature.

As was discussed in the section 3.1.1, the attainment of an overall equilibrium between solutes and minerals enables an empirical relation to be derived between concentrations of acid molecules, cation to proton ratios, with temperatures in geothermal waters in Iceland. The selection of such components was arbitrary, i.e. some cation to proton ratios or acid molecule concentrations show better correlation than others. A good fit between aCa^{++}/aH^{+} and aMg^{++}/aH^{+} and temperature was for example noted, but no correlation found for Ca^{++}/Mg^{++} and temperatures.

This is partly attributed to the strong temperature dependence of the calculated hydrogen ion activity, which is caused by the variation with temperature of the dissociation constants of weak acids which control water pH. Table 4 summarizes the temperature functions obtained for the various acid molecules and cation to proton ratios.

An attempt was made to apply such empirically derived relation to the S- Negros field. Figures 12 and 13 show plots of log aqueous acid molecules and log cation to proton ratios. The refernce temperatures used are the measured temperatures at the main production zone. The best fit is noted for log H_4SiO_4 and log H_2CO_3. This indicates that the H_4SiO_4 and H_2CO_3 species govern the total silica and carbonate content of the fluids. The empirical relation for H_2S and H_2SO_4, though scattered, show a closer fit for the Puhagan than the Nasuji and Sogongon wells, which suggests that the Puhagan area is within a better proximity of the reservoir. Log H_2S and log H_2SO_4 show a larger deviation from equilibria and lower cation to proton ratios for most of the Nasuji and Sogongon wells. It is believed that the scatter of hydrogen sulfide could be due to the interim loss of this gas from the solution if much conductive cooling and oxidation occurs during the fluid flow from the reservoir to the surface.

Table 4

Equations for temperature dependence of log acid molecules and log cation to proton ratios(after Arnorsson et al.,1982 b)

Species/ion ratio	Temperature function	LogK deviation	
		mean	/standard
Log H_4SiO_4	-0.588-0.00441T-1515.21/T+1.3470logT	0.06	0.05
Log H_2CO_3	-1.794-0.00510T-4469.63/T+4.1414logT	0.30	0.26
Log H_2S	-1.678-0.00355T-5071.05/T+3.8889logT	0.36	0.33
Log H_2SO_4	-6.436-0.03906T-13335.68/T+14.7958logT	0.57	0.48
Log aNa^+/aH^+	2.694+0.02023T+4243.47/T-6.2069logT	0.14	0.12
Log aK^+/aH^+	2.505+0.01971T+3325.71/T-5.7814logT	0.12	0.09
Log aCa^{++}/ aH^+	1.733+0.01117T+3890.51/T-3.9977logT	0.17	0.12
Log aMg^{++} /aH^+	1.816+0.01078T+3727.48/T-4.1640logT	0.34	0.27

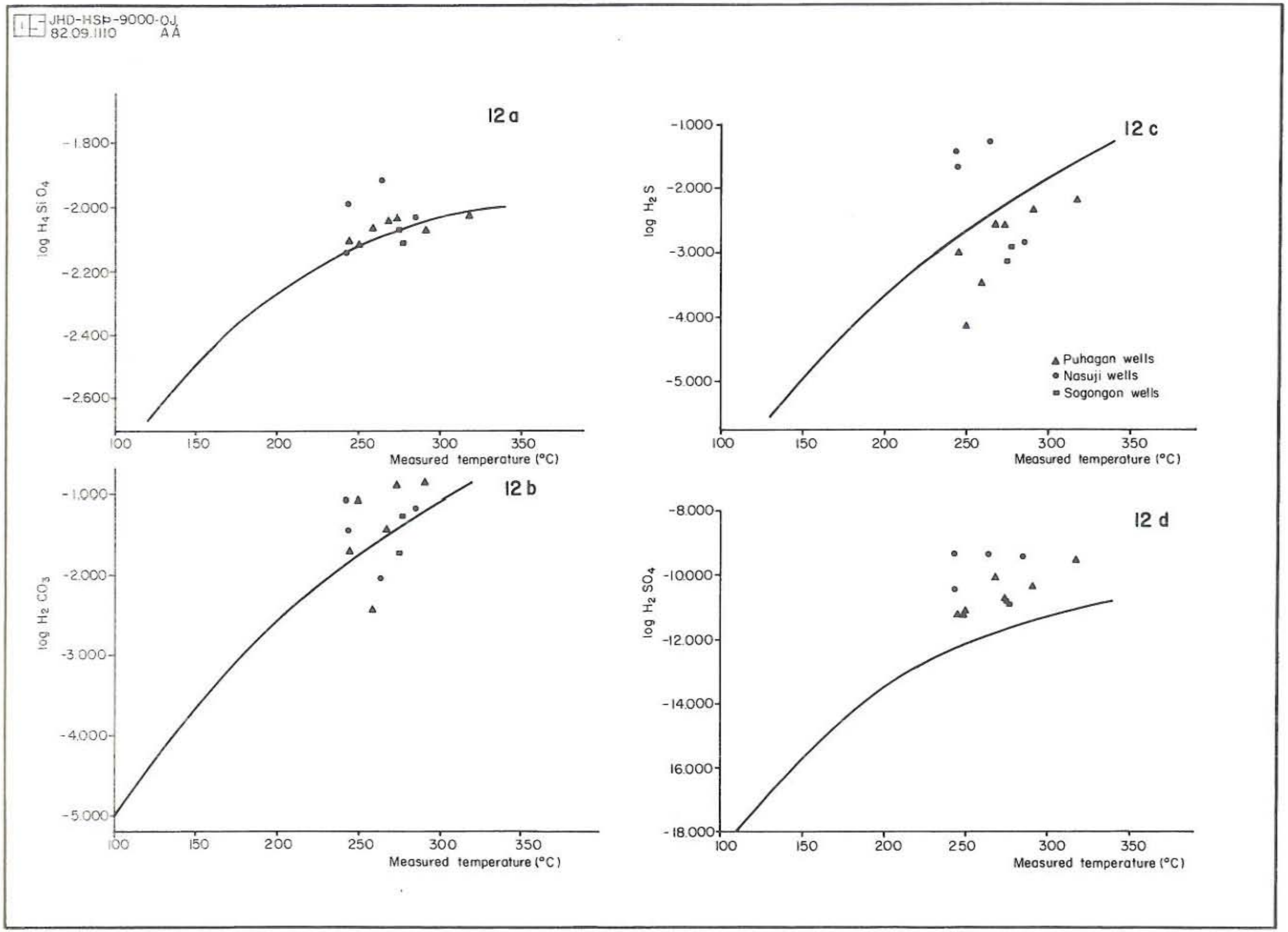


Figure 12 (a) Log H_4SiO_4 vs. measured temperatures (c) Log H_2S vs. measured temperatures
(b) Log H_2CO_3 vs. measured temperautres (d) Log H_2SO_4 vs. measured temperatures

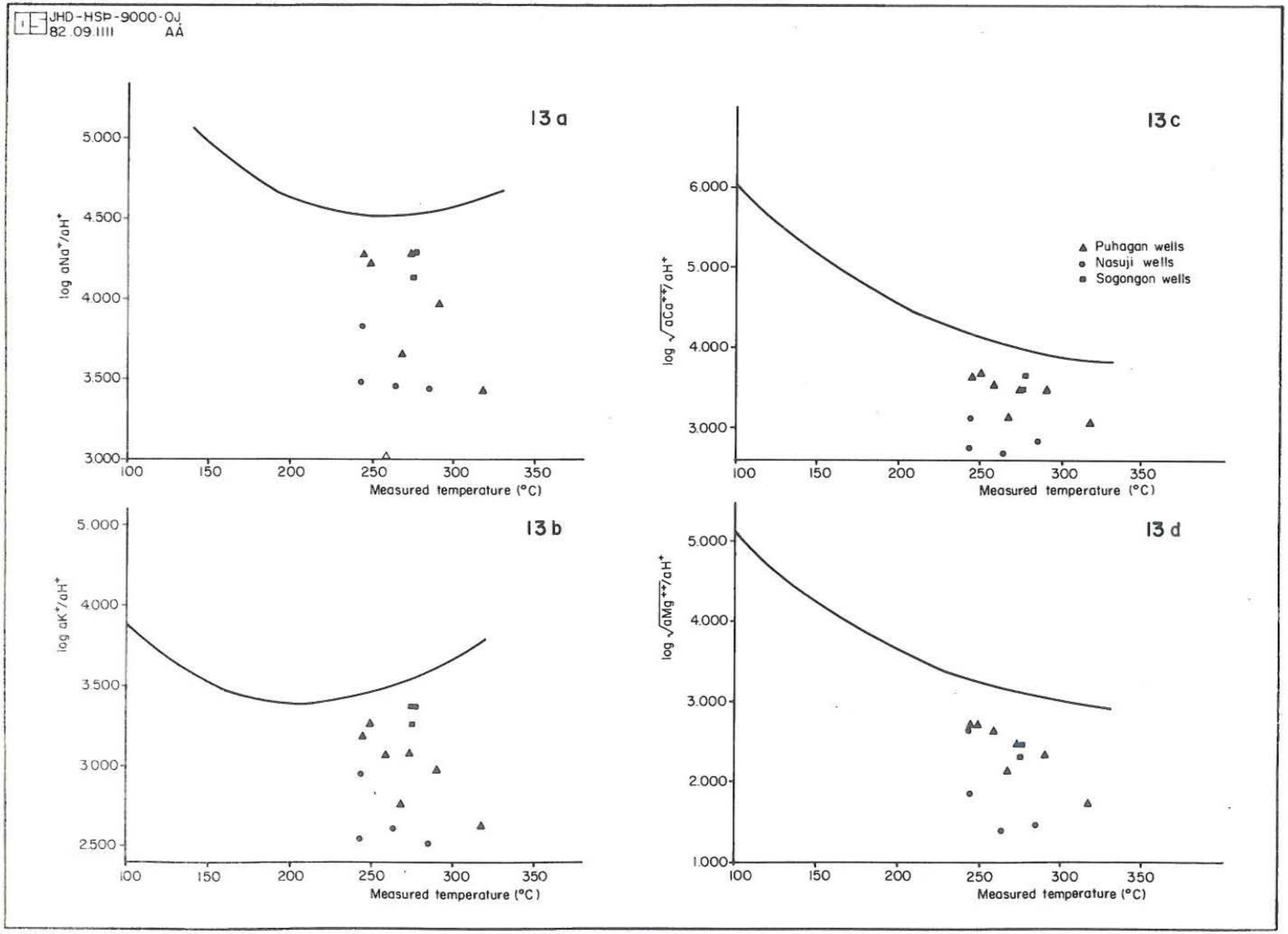


Figure 13 (a) Log aNa^+/aH^+ vs. measured temperatures (c) Log$\sqrt{aCa^{++}}/H^+$ vs. measured temperatures
(b) Log aK^+/aH^+ vs. measured temperatures (d) Log$\sqrt{aMg^{++}}/aH^+$vs. measured temperatures

The rather low cation/proton ratios could readily be attributed to the sensitivity of the hydrogen ion activities to boiling and degassing mechanisms which then have a large effect on the cation to proton ratios. Computer runs at Na-K reference temperatures and at conditions of no excess enthalpy do not in any way give a better fit with the calibration curves. This may indicate that significant mineral re-equilibration due to the presence of excess steam is not responsible for the low cation to proton ratio. It is, however, evident that no equilibrium has been attained between the fluid and the respective species and ratios. Two reasons are suggested:

(1) Figures 13a-13d indicates that to attain a better fit with the equilibrium curve would require more leaching of cations from the rock. Apparently, leaching rates are not sufficiently high.

(2) Dilution and mixing with cooler fluid could readily decrease cation concentrations and affect the H^+ concentrations. A mixing model is attempted in section 3.2.4..

3.2 Geothermometry

Table 5 shows the equations, temperature range, and source of the various chemical geothermometers that will be considered in this study. Table 6 shows chemically calculated and measured temperatures of the deep fluids of the production wells in S-Negros, and Table 7 shows the deviations of the calculated temperatures from measured values.

3.2.1 Quartz geothermometry

Since the pH of the separated waters are all below 8.5, the total silica as analyzed can be taken to represent the H_4SiO_4 fraction. This approximation, however, is not valid when the water pH approaches 9, since a significant

Table 5

Table showing equations of various chemical geothermometers used to compare with the measured temp. of main production zone at S-Negros (legend for Table 6)

Geothermometer	Range (°C)	Source
(1.) T(°C) $\frac{1309}{5.19 - \log SiO_2} - 273.15$	0 - 250	Fournier(1977), SiO_2 in mg/Kg of the deep water;assumes no steam loss
(2.) T(°C) $\frac{1164}{4.90 - \log SiO_2} - 273.15$	180 - 300	Arnorsson et al.(1982 c); SiO_2 in mg/Kg of the deep water; assumes no steam loss
(3.) T(°C) $771 + (336 + 0.017P) * \log mSi(OH)_4 * 2H_2O + 38.8(\log mSi(OH)_4 * 2H_2O)^2$	180 - 340	Ragnarsdottir and Walther(1982); SiO_2 in moles per liter at 1atm; P - fluid pressure in bars.
(4.) T(°C) $\frac{1647}{\log Na/K + B\log Ca/Na + 2.24} - 273.15$	4 - 340	Fournier-Truesdell(1973);B=1/3 for Ca/Na < 1 and T > 100°C; Na, K, Ca in moles per liter
(5.) T(°C) $\frac{1217}{\log Na/K + 1.483} - 273.15$	100 - 300	Fournier(1979); Na,K in mg/Kg
(6.) T(°C) $\frac{933}{\log Na/K + 0.993} - 273.15$	25 - 250	Arnorsson et al.(1982 c); Na,K in mg/Kg
(7.) T(°C) $\frac{1319}{1.699 - \log Na/K} - 273.15$	250 - 350	Arnorsson et al.(1982 c); Na,K in mg/Kg
(8.) Log Na/K $-1.782 - 2775.5/T + 558780/T2 - 0.00964T + 4.104\log T$	25 - 350	Arnorsson et al.(1982 c): Na,K in moles/Kg, T in °K
(9.) Log CO_2 $37.43 + 73192/T - 11829000/T2 + 0.18923T - 86.187\log T$	180 - 300	Arnorsson et al.(1982 c); CO_2 in moles/Kg steam at 1atm; T in °K

Table 6

* Chemically calculated and measured temperatures at the main production zone in S-Negros

Well No.	Temperatures(°C)									
	Meas.	Quartz		Na-K-Ca		Na/K				CO_2
		1)	2)	3)	4)	5)a	6)a	7)a	8)b	9)
OK-7	318	(264)	269	295	280	300	--	291	309	296
OK-9D	291	(252)	256	273	276	293	--	284	289	290
OK-10D	259	(256)	260	268	269	287	--	277	277	270
OK-12D	250	243	245	253	265	281	--	274	273	289
PN13D	268	(260)	265	272	281	297	--	288	289	286
PN15D	274	(262)	266	276	265	272	--	265	265	290
PN17D	245	244	247	253	249	249	234	--	238	284
OK-5	264	(288)	297	298	304	308	--	298	299	278
OK-6	285	(261)	266	279	279	284	--	276	279	276
OK-8	244	(273)	279	279	294	300	--	291	290	276
NJ1D	243	239	241	249	284	287	--	279	276	278
SG-1	277	246	248	263	278	286	--	278	280	271
SG-2	275	(254)	258	269	292	298	--	289	291	280

* For description of chemical geothermometers, see Table 5
a Na/K ratio from Na,K analyzed
b Na/K ratio from calculated Na^+,K^+ activities
Figures in brackets indicates extrapolated values

Table 7

Table showing mean and standard deviations of chemically calculated temperatures from measured temperatures at main production zones in S-Negros

Well No.	Quartz			Na-K-Ca	Na/K				CO_2
	1)	2)	3)	4)	5)a	6)a	7)a	8)b	9)
OK-7	-54	-49	-23	-38	-18	-	-27	-9	-22
OK-9D	-39	-35	-18	-15	+2	-	-7	-2	-1
OK-10D	-3	+1	+9	+10	+28	-	+18	+18	+11
OK-12D	-7	-5	+3	+15	+31	-	+24	+23	+39
PN13D	-8	-3	+4	+13	+29	-	+20	+21	+18
PN15D	-12	-8	+2	-9	-2	-	-9	-9	+16
PN17D	-1	+2	+8	+5	+4	-11	0	-7	+39
OK-5	+24	+33	+34	+40	+44	-	+34	+35	+14
OK-6	-24	-19	-6	-6	-1	-	-9	-6	-9
OK-8	+29	+35	+35	+50	+56	-	+47	+46	+32
NJ1D	-4	-2	+6	+41	+44	-	+36	+33	+35
SG-1	-31	-29	-14	+1	+9	-	+1	+3	-6
SG-2	-21	-17	-6	+15	+23	-	+14	+16	+5
Mean dev.(°C)	19.8	18.3	12.9	19.8	22.4	-	18.9	17.5	19.0
M(%)	7.31	6.69	4.72	7.21	8.09	-	6.90	6.46	7.01
σ(%)	5.63	5.78	4.10	5.90	6.73	-	5.30	5.11	5.06

\+ Sign refers to degrees C higher than measured temperatures
\- Sign refers to degrees C lower than measured temperatures
M mean percent deviation
σ standard deviation

fraction of the total silica exists as $H_3SiO_4^-$, which does not participate in the equilibria with quartz. The various quartz geothermometers (Fournier, 1977; Arnorsson et al., 1982 c) presented in Table 5 assumes no steam loss and are calculated from the deep water silica. The "pressure sensitive silica geothermometer" of Ragnarsdottir and Walther (1982) is calculated from silica concentrations at atmospheric pressure and from the fluid pressure at the depth of inflow. The silica concentrations at sampling pressures were recalculated to 1 atm assuming single stage adiabatic boiling.

The silica geothermometers of Fournier (1977) and Arnorsson et al. (1982 c) generally gives lower values than measured for most wells. This suggests silica being precipitated (probably within the liner and casing walls) at depth due to its relatively fast rate of re-equilibration which could be enhanced by fluid salinity, as readily shown in the high chloride wells OK-7 and OK-9D where the calculated silica geothermometers are lower than measured by 35°C to 45°C. Similarly the lower values of the geothermometers may indicate dilution with cooler fluid which was previously shown to be more pronounced in the Nasuji and Sogongon sector of the field. The quartz geothermometers, on the average, give 19°C lower than measured temperatures for wells SG-2, and SG-1.

The "pressure sensitive silica geothermometer" of Ragnarsdottir and Walther (1982) yields the least average deviations from the measured values (12.9°C). The average deviations of the quartz geothermometers of Fournier (1977) and Arnorsson et al. (1982 c) are 19.8°C and 18.3°C, respectively.

3.2.2 Cation geothermometry

Tables 6 and 7 show that the Na/K geothermometer, on the average, yields temperatures which are higher than measured. The Na-K-Ca geothermometer gives slightly lower temperatures than the Na-K which can be attributed to the fact that the function Ca/Na is more sensitive to cooling than the Na-K ratio. The above trend could also imply that higher temperatures could still exist, probably greater than 300°C.

The calibration curves of Arnorsson et al. (1982 c) for the Na-K geothermometer are based on low albite-microline data from Helgeson (1969) and calibrated empirically using analytical values for Na^+ and K^+ on one hand and computed activities on the other. When applied to the S-Negros data the calibration curves show a temperature difference of more than 2°C for almost half of the samples, particularly in the more saline Puhagan fluids. The high salinity and high temperature of the fluid could cause the analytical ratios of Na/K to deviate significantly from the Na^+/K^+ activity ratio due to the higher degree of complexing of sodium to form NaCl species. The use of the Na^+/K^+ activity ratio, which cancels out the complexing process, is regarded the most reliable geothermometer to estimate subsurface temperatures in the S-Negros geothermal field. Well NJ1D, which shows exceptionally high sulfate (155 ppm) is the only Nasuji well whose Na/K temperature as calculated from analytical concentrations and computed activities differ by as much as 5°C. The high sulfate content of the fluid could give higher stability to the KSO_4^-complex relative to $NaSO_4^-$, which yields high temperatures when analytical concentrations are used instead of activities, (Arnorsson et al.1982 c).

Arnorsson et al.(1982 c) empirically calibrated the Na/K geothermometer using the computed activities of Na^+ and K^+ and showed this geothermometer to have the least deviation among cation geothermometers. The significant differences between the Na-K temperatures from quartz temperatures supports the concept of precipitation of quartz in saline fluids and dilution with cooler fluid for less saline waters.

3.2.3 CO_2 geothermometry

Arnorsson et al. (1982 c) proposed an empirical CO_2 geothermometer based on data from deep drillholes in Iceland, which is applicable in the temperature range 180-300°C. The lower limit is set by the effect of the salinity of the parent water on the CO_2 concentrations in the steam, while the upper limit is set by the mobility of the gas at higher temperatures.

CO_2 concentrations in steam at sampling pressure was recalculated to 1 atmosphere assuming adiabatic boiling in one stage. Tables 6 and 7 show that the calculated temperatures gave generally higher values than measured by about 19°C which provides evidence for higher temperatures elsewhere, as was also concluded for the Na/K geothermometers.

3.2.4 Chloride-enthalpy mixing models

The following factors which have been described earlier might be explained by mixing: a) the discrepancies between the quartz and the Na/K geothermometers, b) non-attainment of overall equilibrium between certain species and cation to proton ratios, and c) linear relationship between silica and chloride.

The chloride-enthalpy mixing model was utilized to test the hypothesis that cold meteoric water recharge from the northwest is the diluting component of the discharges in the Sogongon and some Nasuji wells, and to estimate the temperature of the hot water component. Fig. 14 shows the chloride concentrations plotted against the deep water enthalpy. The deep water enthalpy was taken from the silica calculated temperatures of Ragnarsdottir and Walther (1982), which gave the least deviation from measured values. Deep water chloride values were calculated from analytical results at sampling pressure to the measured

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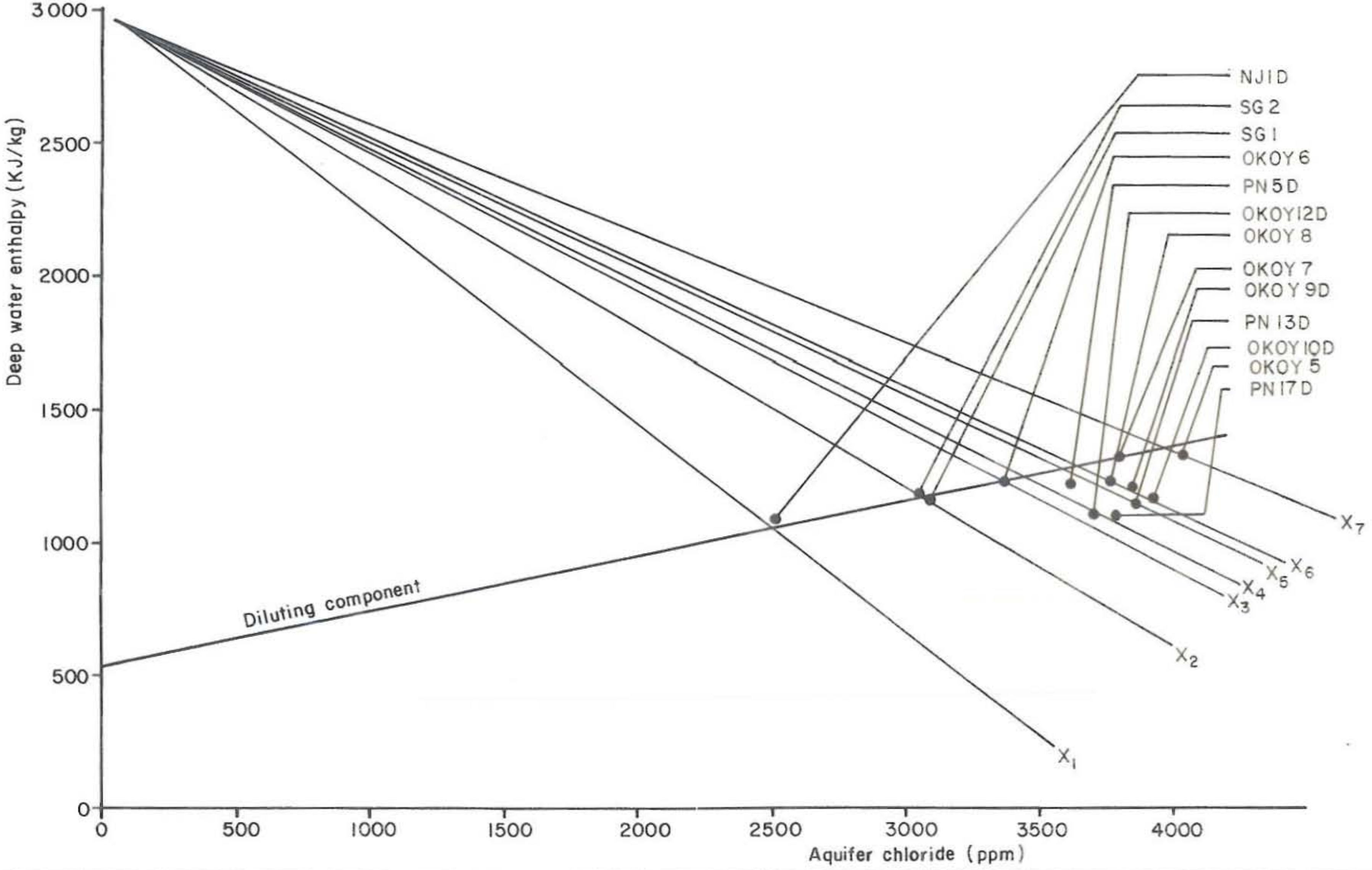
Figure 14 Deep water enthalpy – aquifer chloride plot



temperatures at the main production zones, after appropriate corrections for excess enthalpies had been made.

Following the procedure described by Fournier (1977), assuming minimal heat gain or loss after mixing, extrapolation of the best fit line (dilution line) yields maximum and minimum temperatures of the hot water component to be 310-300°C. This is slightly lower than the maximum measured bottomhole temperatures of some wells (318°C OK-7, 322°C OK-9D, 317°C PN-13D, 310°C OK-5) and reveals that the hottest wells are still withdrawing from a mixed fluid, but with a significantly lower fraction of the cooling component. Fig. 14 indicates that the diluting component has a negligible chloride content (indicative of meteoric water) yet has an enthalpy of 520 KJ/Kg which corresponds to a liquid water saturation temperature of 120°C. This suggests either a) cold meteoric water picking up heat from the rock before mixing with the hydrothermal fluid, or b) Steam heated ground water rich in carbonate and sulfate. From the absolute sulfate, carbonate, and pH of the discharges of SG-1, SG-2, OK-6, NJ1D, however, cause a) is more likely.

The slightly lower enthalpy yet relatively high chloride of contents of wells OK-8, PN-13D, PN17D, OK-10D,and OK-12D are indicative of conductive cooling. Points designated as X1-X7 would represent variations in enthalpy and chloride contents of the liquid water fraction during progressive steam separation. The use of the above mixing model is believed to give more reliable temperatures that the silica-enthalpy plot since the temperature of the hot water component is close to 300°C (Fournier, 1977).

3.3 Isochemical and isothermal contours

In order to visualize the pattern of temperature distribution, to predict further areas for drilling priorities, and to determine the extent of the reservoir, selected chemical geothermometers and species were plotted across the field and compared with the isothermal contours at 1000m depth. The isothermal contours were deduced from the estimated stable rock temperatures which were taken after a careful examination and selection of all downhole temperature logs, (Catigtig and Amistoso, 1981). Figures 15-17 show plots of iso T aNa^+/aK^+, iso T $Si(OH)_4*2H_2O$, and iso-chloride. Figure 18 shows the isothermal plots at 1000m depth.

The isochemical contours, more or less, shows a series of broad concentric rings towards the north and west, but exhibit a definite sharpening and distortion within the vicinity of the Puhagan wells. This sharpening trend seems to be dirctly associated with the Ticala fault (Harper and Clemente, 1982), which confines the flow in a narrow northeasterly direction.

The inherent low temperature and low permeability of well OK-11D results in a similar narrow contour stretch between the bottomholes of OK-5,and OK-9D, and further indicates that the flow from an upwelling fluid is initially restricted within these areas, but then broadens outwards to the west into Nasuji, and progressively into Sogongon. The present author, however, suggests that indications of a broad flow within this vicinity cannot be presented with reasonable certainty. Connection of contour lines between the widely spaced wells (OK-6 to SG-1 and 2, to OK-8) must be treated with extreme caution. It is evident from the plots that an outflow zone is located near wells SG-1, SG-2, and OK-12D. In this area differnces in absolute chemistry from the rest of the wells indicate the flow regime to be slow and indulgent in continued water-rock reaction during conductive cooling and/or dilution with cooler fluid.

The difference in absolute values between T $Si(OH)_4 2H_2O$ and T aNa^+/K^+ is significant in the Sogongon wells(32-33°C) and some Nasuji wells, (OK-6 13°C, NJ1D 35°C), indicative of

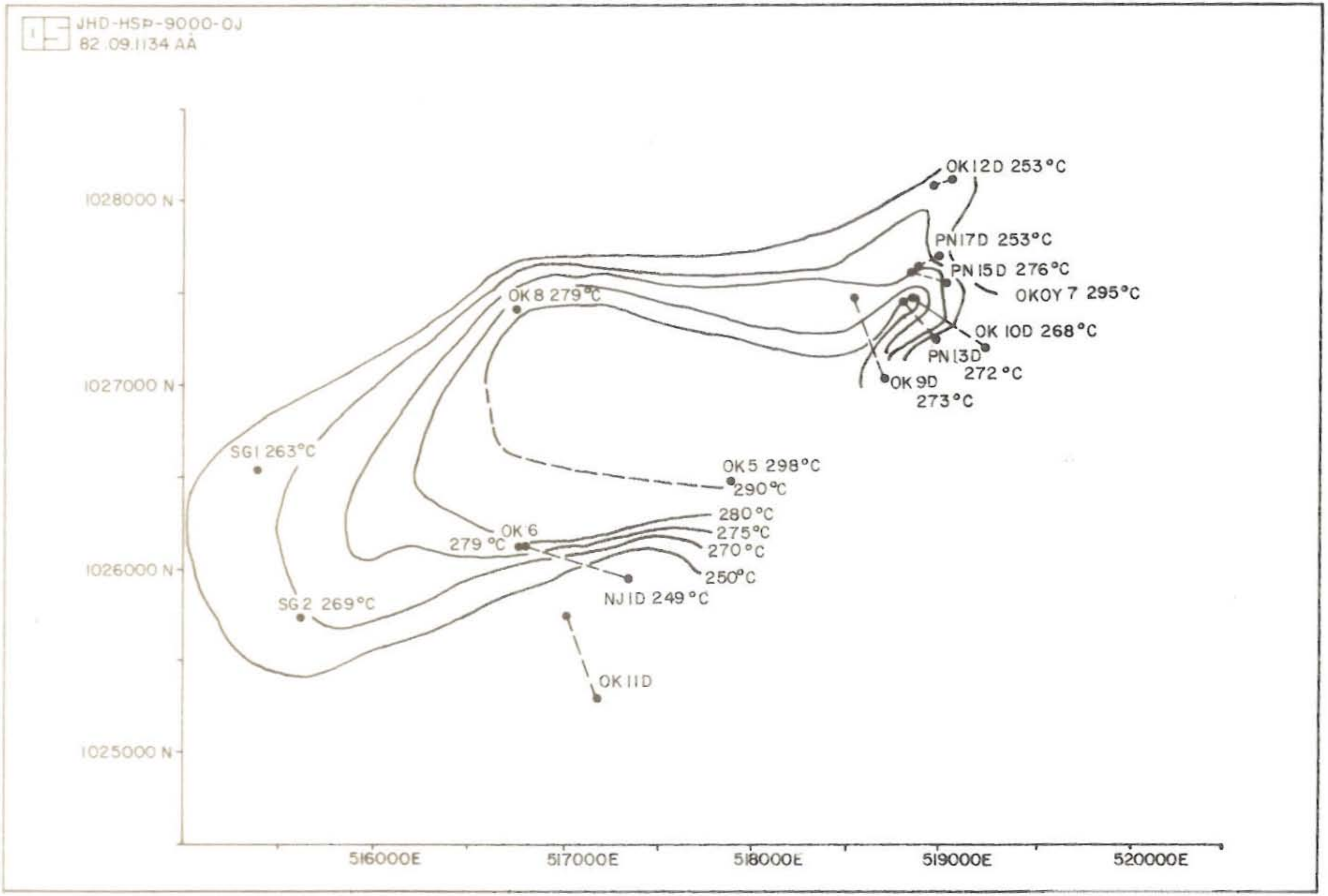


Figure 15. Iso $T_{Si(OH)_4 \cdot 2H_2O}$ map of the Palinpinon field.

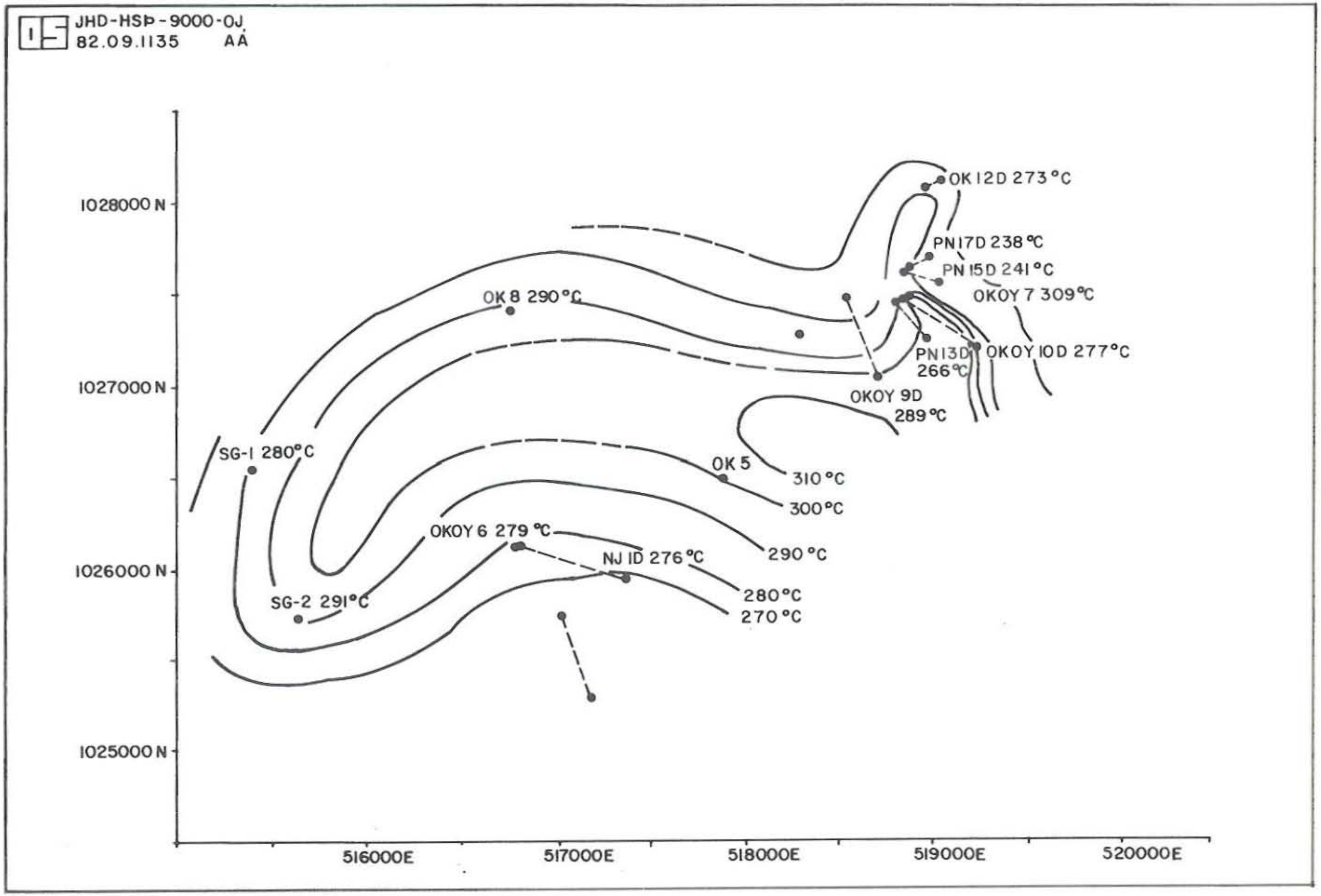


Figure 16. Iso T_{aNa^+/aK^+} map of the Palinpinon field.

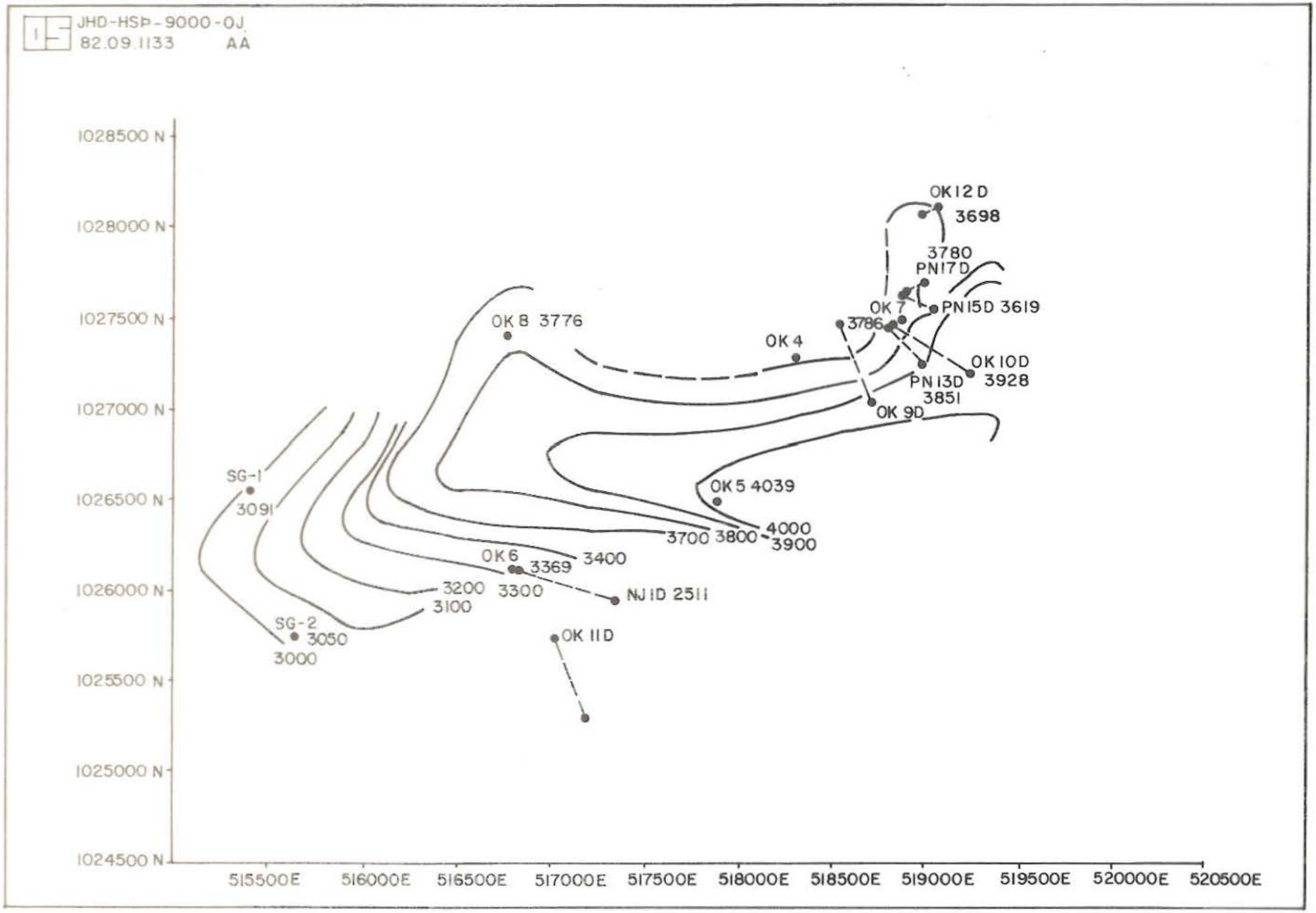


Figure 17. Iso chloride map of the Palinpinon field.

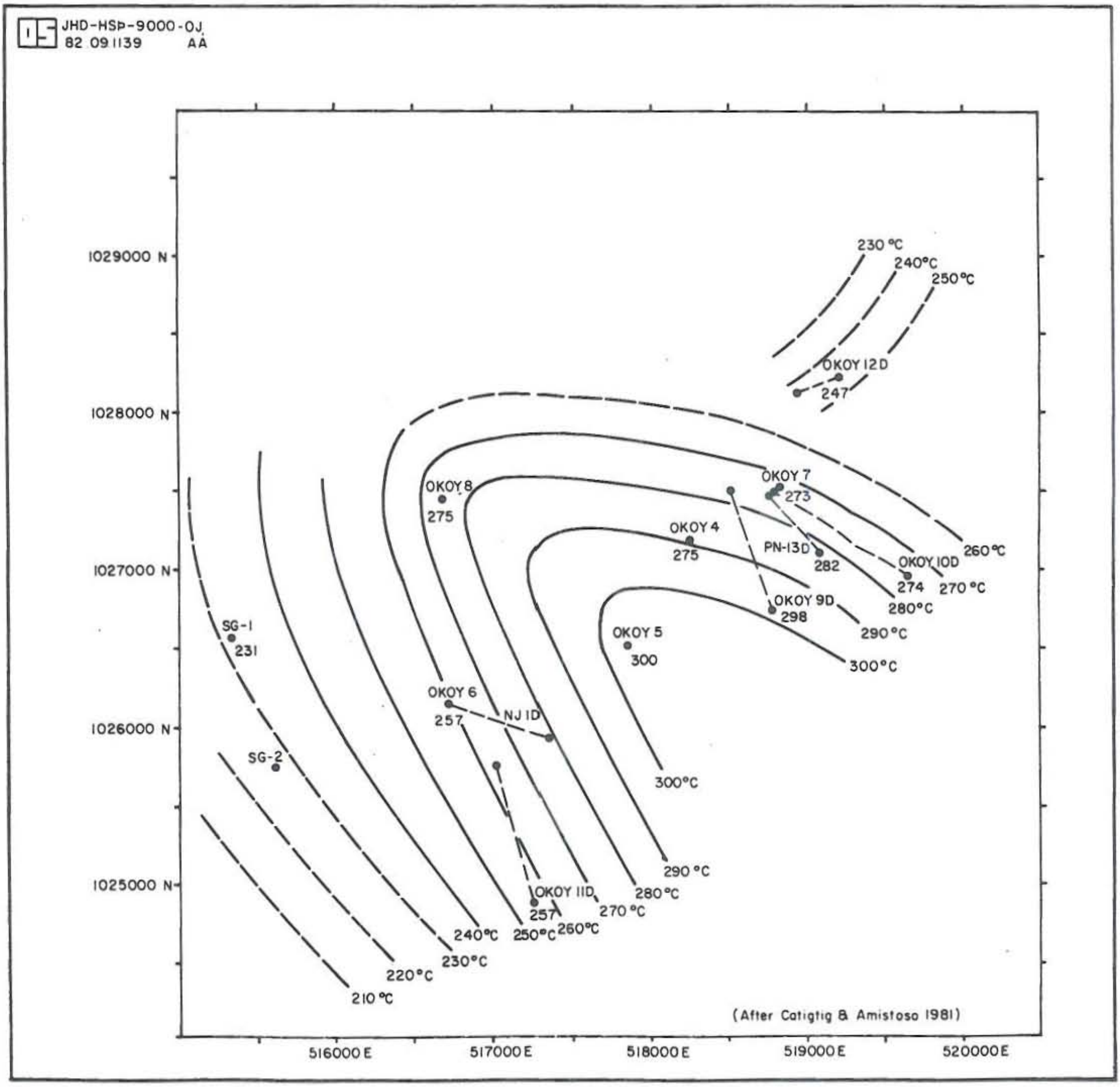


Figure 18 Isotherms at 1000m bmsl of the Palinpinon field.

mixing. This is readily supported by the iso chloride contours (Fig. 17) which show a definite dilution trend, increasing in magnitude from east to west. The absolute deep water chloride values of wells SG-1 and 2, OK-6 and NJ1D are lower (3000-3360 ppm), than the Puhagan wells (3400-3950 ppm). All contours point to the Cuernos volcano as the ultimate heat source of the field, beneath which the upwelling zone is postulated to be at temperatures of over 300°C.

3.4 CONCLUSIONS

a) The complex and iterative calculations involved in the interpretation of the chemical data from the production wells in SNGF made the use of a computer programme necessary.

b) Anhydrite and quartz are shown to be in equilibrium with the deep water for most wells. Calcite saturation, however, appears to be controlled by temperature and affected by mixing with cooler fluid. Potential calcite deposition is not likely to occur, but amorphous silica scaling could be a problem below 150°C reinjection or production separation temperature.

c) The empirically derived relation between aqueous species and temperature, Arnorsson et al.(1982 b) compares well for the silica and bicarbonate species; but the low cation to proton ratios could be due to a different rock leaching property and the effects of dilution with extranneous fluids.

d) For S-Negros fluids, the "pressure sensitive silica geothermometer" of Ragnarsdottir and Walther (1982), and the Na-K geothermometer of Arnorsson et al. (1982 c) using the computed activities of Na^+ and K^+, yield the least deviation from measured values of the various geothermometers tested.

e) Chloride - enthalpy mixing models suggest that cold meteoric water recharge from the northwest picks up heat from the rock before mixing with an outflowing hydrothermal fluid, which explains its high enthalpy yet almost zero chloride content. True reservoir temperatures are estimated to be at least 300 °C.

4.0 RECOMMENDATIONS

The following are recommendations for further geochemical studies based upon the results which have emerged during the evaluation of the chemical data presented in this report:

(a) A representative sample from each well should be analyzed for iron, aluminum, and flouride. Most of the minerals found in SNGF contain these elements and analysis of these elements therefore would allow more solute/mineral equilibria studies.

(b) To facilitate and speed up studies of mineral deposition and scaling, a computer programme such as that developed in Iceland should be utilized. This is highly relevant considering the accelerated discharge testing of wells and especially for the programmed reinjection wells in SNGF.

(c) The use of gas geothermometers should be given equal attention to that of the quartz and the cation geothermometers. This could much aid in predicting subsurface temperatures and in identifying flow processes in the field, especially in areas where intense steaming grounds are located, e.g. Kaipohan and Baslay de Dauin.

(d) Variations of chemistry with time, especially for wells on long term discharge tests, should be examined carefully to detect the response of the reservoir to exploitation. This may be detectable only after years of continous discharge.

(e) A revision of certain aspects in sampling procedures and analytical methods are still necessary. For more details of this recommendation, see manual on methods of collection and analysis of geothermal fluids by the Virkir Consulting Group Ltd.

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ORKUSTOFNUN   JHD                GEOCHEMISTRY OF WELL SONGON-1
1982-11-12  OLIVER
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%%%%%%%%%%811214%%%%  SOGONGON-1                                    S.NEGROS,PHILIPPINES  SOGONGON

PROGRAM WATCH1.

WATER SAMPLE (PPM)           STEAM SAMPLE

PH/DEG.C          7.30/25.0  GAS (VOL.%)                    REFERENCE TEMP.      DEGREES C    277.0 (MEASURED)
SIO2          626.00         CO2               0.00
NA           2250.00         H2S               0.00         SAMPLING PRESSURE    BARS ABS.      6.9
K             457.00         H2                0.00         DISCHARGE ENTHALPY    MJOUL/KG    1.222 (MEASURED)
CA             34.40         O2                0.00         DISCHARGE              KG/SEC.    35.8
MG              0.060        CH4               0.00
CO2            32.10         N2                0.00         MEASURED TEMPERATURE DEGREES C      0.0
SO4            39.80                                        RESISTIVITY/TEMP.   OHMM/DEG.C      0.0/ 0.0
H2S             3.07                                        EH/TEMP.             MV/DEG.C     0.000/ 0.0
CL           4148.00
F               0.00         LITERS GAS PER KG
DISS.SOLIDS     0.00         CONDENSATE/DEG.C  5.23/25.0      MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL              0.0000                                           DEGREES C/METERS        DEPTH (METERS)
B              51.1000
FE              0.0000       CONDENSATE (PPM)                         0.0       0.0            0.0
NH3             0.0000       PH/DEG.C          0.00/ 0.0              0.0       0.0            0.0
                             CO2               0.00                   0.0       0.0            0.0
                             H2S               0.00                   0.0       0.0            0.0
                             NA                0.00                   0.0       0.0            0.0
                                                                      0.0       0.0            0.0
                                                                      0.0       0.0            0.0
                                                                      0.0       0.0            0.0
                             CONDENSATE WITH NAOH (PPM)               0.0       0.0            0.0
                             CO2            9848.70                   0.0       0.0            0.0
                             H2S             154.40                   0.0       0.0            0.0

IONIC STRENGTH =  0.11594     IONIC BALANCE :   CATIONS (MOL.EQ.)0.11101650
                                                ANIONS  (MOL.EQ.)0.11839960
                                                DIFFERENCE    (%)     -6.44

DEEP WATER (PPM)                                      DEEP STEAM (PPM)          GAS PRESSURES (BARS ABS.)

SIO2       466.63         CO2        2305.96          CO2       195879.34       CO2        0.492E+01
NA        1677.05         H2S          40.53          H2S         1043.08       H2S        0.338E-01
K          340.61         H2            0.00          H2             0.00       H2         0.000E+00
CA          25.64         O2            0.00          O2             0.00       O2         0.000E+00
MG           0.045        CH4           0.00          CH4            0.00       CH4        0.000E+00
SO4         29.66         N2            0.00          N2             0.00       N2         0.000E+00
CL        3091.47         NH3           0.00          NH3            0.00       NH3        0.000E+00
F            0.00                                                             H2O        0.613E+02
DISS.S.      0.00                                                             TOTAL      0.663E+02
AL           0.0000
B           38.0841                                   H2O (%)                0.12
FE           0.0000                                   BOILING PORTION        0.25

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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APPENDIX I

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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.698      KSO4-       0.639      FE++         0.179      FECL+        0.609
OH-         0.598      F-          0.598      FE+++        0.040      AL+++        0.040
H3SIO4-     0.609      CL-         0.585      FEOH+        0.631      ALOH++       0.167
H2SIO4--    0.167      NA+         0.609      FE(OH)3-     0.631      AL(OH)2+     0.639
H2BO3-      0.572      K+          0.585      FE(OH)4--    0.159      AL(OH)4-     0.621
HCO3-       0.609      CA++        0.179      FEOH++       0.159      ALSO4+       0.621
CO3--       0.148      MG++        0.219      FE(OH)2+     0.639      AL(SO4)2-    0.621
HS-         0.598      CAHCO3+     0.651      FE(OH)4-     0.639      ALF++        0.167
S--         0.159      MGHCO3+     0.609      FESO4+       0.631      ALF2+        0.639
HSO4-       0.621      CAOH+       0.651      FECL++       0.159      ALF4-        0.621
SO4--       0.138      MGOH+       0.660      FECL2+       0.631      ALF5--       0.148
NASO4-      0.639      NH4+        0.572      FECL4-       0.609      ALF6---      0.014

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.00   -5.690       MG++        0.04   -5.790       FE(OH)3       0.00   0.000
OH-           0.13   -5.100       NACL      398.81   -2.166       FE(OH)4-      0.00   0.000
H4SIO4      745.95   -2.110       KCL        34.14   -3.339       FECL+         0.00   0.000
H3SIO4-       0.31   -5.487       NASO4-      6.65   -4.253       FECL2         0.00   0.000
H2SIO4--      0.00  -10.902       KSO4-       8.72   -4.190       FECL++        0.00   0.000
NAH3SIO4      0.19   -5.786       CASO4       2.96   -4.662       FECL2+        0.00   0.000
H3BO3       217.70   -2.453       MGSO4       0.02   -6.895       FECL3         0.00   0.000
H2BO3-        0.12   -5.688       CACO3       0.02   -6.627       FECL4-        0.00   0.000
H2CO3      3215.52   -1.285       MGCO3       0.00  -10.488       FESO4         0.00   0.000
HCO3-        27.05   -3.353       CAHCO3+    11.58   -3.941       FESO4+        0.00   0.000
CO3--         0.00   -8.552       MGHCO3+     0.00   -7.597       AL+++         0.00   0.000
H2S          39.92   -2.931       CAOH+       0.02   -6.440       ALOH++        0.00   0.000
HS-           0.59   -4.751       MGOH+       0.00   -7.190       AL(OH)2+      0.00   0.000
S--           0.00  -13.289       NH4OH       0.00    0.000       AL(OH)3       0.00   0.000
H2SO4         0.00  -10.950       NH4+        0.00    0.000       AL(OH)4-      0.00   0.000
HSO4-         3.03   -4.506       FE++        0.00    0.000       ALSO4+        0.00   0.000
SO4--        13.01   -3.868       FE+++       0.00    0.000       AL(SO4)2-     0.00   0.000
HF            0.00    0.000       FEOH+       0.00    0.000       ALF++         0.00   0.000
F-            0.00    0.000       FE(OH)2     0.00    0.000       ALF2+         0.00   0.000
CL-        2833.31   -1.097       FE(OH)3-    0.00    0.000       ALF3          0.00   0.000
NA+        1518.83   -1.180       FE(OH)4--   0.00    0.000       ALF4-         0.00   0.000
K+          320.18   -2.087       FE(OH)++    0.00    0.000       ALF5--        0.00   0.000
CA++         20.15   -3.299       FE(OH)2+    0.00    0.000       ALF6---       0.00   0.000

IONIC STRENGTH =  0.07866       IONIC BALANCE :   CATIONS (MOL.EQ.)0.07537772
                                                  ANIONS  (MOL.EQ.)0.08066924
                                                  DIFFERENCE    (%)      -6.78

CHEMICAL GEOTHERMOMETERS DEGREES C                1000/T DEGREES KELVIN =  1.82

QUARTZ      246.3
CHALCEDONY  999.9
NAK         288.3

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.486    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                TEOR.     CALC.                     TEOR.     CALC.                      TEOR.     CALC.
ADULARIA       -14.374   99.999     ALBITE LOW     -13.947   99.999     ANALCIME       -11.599   99.999
ANHYDRITE       -8.611   -8.774     CALCITE        -13.481  -13.426     CHALCEDONY      -1.891   -2.110
MG-CHLORITE    -87.175   99.999     FLUORITE       -11.109   99.999     GOETHITE         3.805   99.999
LAUMONTITE    -24.818    99.999     MICROCLINE     -14.977   99.999     MAGNETITE      -14.275   99.999
CA-MONTMOR.   -72.578    99.999     K-MONTMOR.     -33.814   99.999     MG-MONTMOR.    -74.086   99.999
NA-MONTMOR.   -34.099    99.999     MUSCOVITE      -17.842   99.999     PREHNITE       -38.313   99.999
PYRRHOTITE     -5.596    99.999     PYRITE         -21.879   99.999     QUARTZ          -1.996   -2.110
WAIRAKITE     -25.119    99.999     WOLLASTONITE     7.047    5.225     ZOISITE        -39.262   99.999
EPIDOTE       -39.107    99.999     MARCASITE       -5.949   99.999
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ORKUSTOFNUN   JHD               GEOCHEMISTRY OF WELL SOGONGON-2
1982-11-12  OLIVER
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%%%%%%%%%%820118%%%%  SOGONGON-2                                 S.NEGROS,PHILIPPINES  SOGONGON

PROGRAM WATCH1.

WATER SAMPLE (PPM)          STEAM SAMPLE

PH/DEG.C        5.91/25.0  GAS (VOL.%)                    REFERENCE TEMP.      DEGREES C    275.0 (MEASURED)
SIO2          660.00       CO2            0.00
NA           2139.00       H2S            0.00            SAMPLING PRESSURE    BARS ABS.      9.2
K             482.00       H2             0.00            DISCHARGE ENTHALPY    MJOUL/KG    1.280 (MEASURED)
CA             21.40       O2             0.00            DISCHARGE              KG/SEC.     14.9
MG              0.060      CH4            0.00
CO2            25.80       N2             0.00            MEASURED TEMPERATURE DEGREES C      0.0
SO4            23.20                                      RESISTIVITY/TEMP.   OHMM/DEG.C      0.0/ 0.0
H2S             3.58                                      EH/TEMP.             MV/DEG.C    0.000/ 0.0
CL           3957.00
F               0.00       LITERS GAS PER KG
DISS.SOLIDS     0.00       CONDENSATE/DEG.C  7.97/25.0      MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL              0.0000                                         DEGREES C/METERS        DEPTH (METERS)
B              48.6000
FE              0.0000     CONDENSATE (PPM)                      0.0       0.0               0.0
NH3             0.0000     PH/DEG.C          0.00/ 0.0           0.0       0.0               0.0
                           CO2               0.00                0.0       0.0               0.0
                           H2S               0.00                0.0       0.0               0.0
                           NA                0.00                0.0       0.0               0.0
                                                                 0.0       0.0               0.0
                                                                 0.0       0.0               0.0
                                                                 0.0       0.0               0.0
                           CONDENSATE WITH NAOH (PPM)            0.0       0.0               0.0
                           CO2           14690.90                0.0       0.0               0.0
                           H2S             189.60                0.0       0.0               0.0

IONIC STRENGTH =  0.10991      IONIC BALANCE :  CATIONS (MOL.EQ.)0.10623719
                                                ANIONS  (MOL.EQ.)0.11206885
                                                DIFFERENCE    (%)     -5.34

DEEP WATER (PPM)                                   DEEP STEAM (PPM)         GAS PRESSURES (BARS ABS.)

SIO2        508.89      CO2        786.80          CO2        70179.68      CO2       0.171E+01
NA         1649.14      H2S         24.29          H2S          657.35      H2S       0.207E-01
K           371.60      H2           0.00          H2             0.00      H2        0.000E+00
CA           16.50      O2           0.00          O2             0.00      O2        0.000E+00
MG            0.046     CH4          0.00          CH4            0.00      CH4       0.000E+00
SO4          17.89      N2           0.00          N2             0.00      N2        0.000E+00
CL         3050.53      NH3          0.00          NH3            0.00      NH3       0.000E+00
F             0.00                                                          H2O       0.595E+02
DISS.S.       0.00                                                          TOTAL     0.612E+02
AL            0.0000
B            37.4664                               H2O (%)               4.47
FE            0.0000                               BOILING PORTION       0.23

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.702       KSO4-       0.643       FE++        0.183       FECL+       0.614
OH-         0.602       F-          0.602       FE+++       0.041       AL+++       0.041
H3SIO4-     0.614       CL-         0.590       FEOH+       0.635       ALOH++      0.171
H2SIO4--    0.171       NA+         0.614       FE(OH)3-    0.635       AL(OH)2+    0.643
H2BO3-      0.576       K+          0.590       FE(OH)4--   0.163       AL(OH)4-    0.625
HCO3-       0.614       CA++        0.183       FEOH++      0.163       ALSO4+      0.625
CO3--       0.152       MG++        0.223       FE(OH)2+    0.643       AL(SO4)2-   0.625
HS-         0.602       CAHCO3+     0.654       FE(OH)4-    0.643       ALF++       0.171
S--         0.163       MGHCO3+     0.614       FESO4+      0.635       ALF2+       0.643
HSO4-       0.625       CAOH+       0.654       FECL++      0.163       ALF4-       0.625
SO4--       0.142       MGOH+       0.663       FECL2+      0.635       ALF5--      0.152
NASO4-      0.643       NH4+        0.576       FECL4-      0.614       ALF6---     0.014

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.00   -5.526       MG++         0.04   -5.753        FE(OH)3       0.00    0.000
OH-           0.09   -5.269       NACL       370.25   -2.198        FE(OH)4-      0.00    0.000
H4SIO4      813.66   -2.072       KCL         35.80   -3.319        FECL+         0.00    0.000
H3SIO4-       0.24   -5.600       NASO4-       3.83   -4.492        FECL2         0.00    0.000
H2SIO4--      0.00  -11.169       KSO4-        5.43   -4.396        FECL++        0.00    0.000
NAH3SIO4      0.15   -5.902       CASO4        1.31   -5.016        FECL2+        0.00    0.000
H3BO3       214.21   -2.460       MGSO4        0.01   -7.081        FECL3         0.00    0.000
H2BO3-        0.08   -5.857       CACO3        0.00   -7.523        FECL4-        0.00    0.000
H2CO3      1100.87   -1.751       MGCO3        0.00  -11.216        FESO4         0.00    0.000
HCO3-         6.66   -3.962       CAHCO3+      2.14   -4.675        FESO4+        0.00    0.000
CO3--         0.00   -9.310       MGHCO3+      0.00   -8.172        AL+++         0.00    0.000
H2S          24.02   -3.152       CAOH+        0.01   -6.734        ALOH++        0.00    0.000
HS-           0.25   -5.114       MGOH+        0.00   -7.346        AL(OH)2+      0.00    0.000
S--           0.00  -13.834       NH4OH        0.00    0.000        AL(OH)3       0.00    0.000
H2SO4         0.00  -10.886       NH4+         0.00    0.000        AL(OH)4-      0.00    0.000
HSO4-         2.44   -4.599       FE++         0.00    0.000        ALSO4+        0.00    0.000
SO4--         7.59   -4.103       FE+++        0.00    0.000        AL(SO4)2-     0.00    0.000
HF            0.00    0.000       FEOH+        0.00    0.000        ALF++         0.00    0.000
F-            0.00    0.000       FE(OH)2      0.00    0.000        ALF2+         0.00    0.000
CL-        2808.91   -1.101       FE(OH)3-     0.00    0.000        ALF3          0.00    0.000
NA+        1502.71   -1.185       FE(OH)4--    0.00    0.000        ALF4-         0.00    0.000
K+          351.25   -2.047       FE(OH)++     0.00    0.000        ALF5--        0.00    0.000
CA++         15.26   -3.419       FE(OH)2+     0.00    0.000        ALF6---       0.00    0.000

IONIC STRENGTH =  0.07779      IONIC BALANCE :   CATIONS (MOL.EQ.)0.07513352
                                                 ANIONS  (MOL.EQ.)0.07951997
                                                 DIFFERENCE    (%)      -5.67

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.82

QUARTZ       257.8
CHALCEDONY   999.9
NAK          304.1

OXIDATION POTENTIAL (VOLTS) :     EH H2S= -0.462    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
               TEOR.     CALC.                      TEOR.     CALC.                     TEOR.     CALC.
ADULARIA      -14.373   99.999      ALBITE LOW     -13.944   99.999      ANALCIME      -11.591   99.999
ANHYDRITE      -8.573   -9.108      CALCITE        -13.427  -14.284      CHALCEDONY     -1.899   -2.072
MG-CHLORITE   -86.993   99.999      FLUORITE       -11.097   99.999      GOETHITE        3.689   99.999
LAUMONTITE    -24.794   99.999      MICROCLINE     -14.980   99.999      MAGNETITE     -14.476   99.999
CA-MONTMOR.   -72.578   99.999      K-MONTMOR.     -33.824   99.999      MG-MONTMOR.   -74.086   99.999
NA-MONTMOR.   -34.108   99.999      MUSCOVITE      -17.841   99.999      PREHNITE      -38.232   99.999
PYRRHOTITE     -6.754   99.999      PYRITE         -23.333   99.999      QUARTZ         -2.004   -2.072
WAIRAKITE     -25.072   99.999      WOLLASTONITE     7.078    4.823      ZOISITE       -39.157   99.999
EPIDOTE       -38.947   99.999      MARCASITE       -7.344   99.999
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ORKUSTOFNUN   JHD               GEOCHEMISTRY OF WELL OKOY-5
1982-11-12  OLIVER
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%%%%%%%%%%820307%%%%  OKOY-5                                      S.NEGROS,PHILIPPINES  BALAS-BALAS

PROGRAM WATCH3.               TEMPERATURE FIXING STEAM LOSS   100.0 DEGREES C

WATER SAMPLE (PPM)            STEAM SAMPLE

PH/DEG.C          7.22/25.0   GAS (VOL.%)                    REFERENCE TEMP.     DEGREES C    264.0 (ARBITRARY)
SIO2           1073.00        CO2
NA             3347.00        H2S                            SAMPLING PRESSURE   BARS ABS.
K               820.00        H2                             DISCHARGE ENTHALPY   MJOUL/KG
CA               35.10        O2                             DISCHARGE             KG/SEC.     29.0
MG                0.040       CH4
CO2              68.50        N2                             MEASURED TEMPERATURE DEGREES C     0.0
SO4              61.50                                       RESISTIVITY/TEMP.   OHMM/DEG.C     0.0/ 0.0
H2S               9.88                                       EH/TEMP.              MV/DEG.C   0.000/ 0.0
CL             5993.00
F                 0.00        LITERS GAS PER KG
DISS.SOLIDS       0.00        CONDENSATE/DEG.C                  MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL                0.0000                                           DEGREES C/METERS        DEPTH (METERS)
B                73.0000
FE                0.0000      CONDENSATE (PPM)                        0.0       0.0              0.0
NH3               0.0000      PH/DEG.C                                0.0       0.0              0.0
                              CO2                                     0.0       0.0              0.0
                              H2S                                     0.0       0.0              0.0
                              NA                                      0.0       0.0              0.0
                                                                      0.0       0.0              0.0
                                                                      0.0       0.0              0.0
                                                                      0.0       0.0              0.0
                              CONDENSATE WITH NAOH (PPM)              0.0       0.0              0.0
                              CO2                                     0.0       0.0              0.0
                              H2S                                     0.0       0.0              0.0

IONIC STRENGTH =  0.17111      IONIC BALANCE :   CATIONS (MOL.EQ.)0.16779573
                                                 ANIONS  (MOL.EQ.)0.17154194
                                                 DIFFERENCE    (%)     -2.21

DEEP WATER (PPM)                                     DEEP STEAM (PPM)             GAS PRESSURES (BARS ABS.)

SIO2        723.34       CO2        27568.29         CO2            0.00          CO2        0.641E+02
NA         2256.11       H2S         1867.72         H2S            0.00          H2S        0.171E+01
K           552.71       H2             0.00         H2             0.00          H2         0.000E+00
CA           23.66       O2             0.00         O2             0.00          O2         0.000E+00
MG            0.027      CH4            0.00         CH4            0.00          CH4        0.000E+00
SO4          41.45       N2             0.00         N2             0.00          N2         0.000E+00
CL         4039.36       NH3            0.00         NH3            0.00          NH3        0.000E+00
F             0.00                                                                H2O        0.501E+02
DISS.S.       0.00                                                                TOTAL      0.116E+03
AL            0.0000
B            49.2025                                 H2O (%)                 0.00
FE            0.0000                                 BOILING PORTION         0.00

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+           0.691      KSO4-         0.626       FE++          0.169       FECL+         0.593
OH-          0.580      F-            0.580       FE+++         0.037       AL+++         0.037
H3SIO4-      0.593      CL-           0.566       FEOH+         0.617       ALOH++        0.156
H2SIO4--     0.156      NA+           0.593       FE(OH)3-      0.617       AL(OH)2+      0.626
H2BO3-       0.551      K+            0.566       FE(OH)4--     0.148       AL(OH)4-      0.606
HCO3-        0.593      CA++          0.169       FEOH++        0.148       ALSO4+        0.606
CO3--        0.137      MG++          0.211       FE(OH)2+      0.626       AL(SO4)2-     0.606
HS-          0.580      CAHCO3+       0.639       FE(OH)4-      0.626       ALF++         0.156
S--          0.148      MGHCO3+       0.593       FESO4+        0.617       ALF2+         0.626
HSO4-        0.606      CAOH+         0.639       FECL++        0.148       ALF4-         0.606
SO4--        0.126      MGOH+         0.649       FECL2+        0.617       ALF5--        0.137
NASO4-       0.626      NH4+          0.551       FECL4-        0.593       ALF6---       0.011

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.02   -4.732         MG++        0.02   -5.991        FE(OH)3       0.00    0.000
OH-           0.01   -6.056         NACL      445.01   -2.118        FE(OH)4-      0.00    0.000
H4SIO4     1156.94   -1.920         KCL        50.00   -3.174        FECL+         0.00    0.000
H3SIO4-       0.07   -6.138         NASO4-      6.76   -4.246        FECL2         0.00    0.000
H2SIO4--      0.00  -12.381         KSO4-       9.00   -4.176        FECL++        0.00    0.000
NAH3SIO4      0.05   -6.350         CASO4       1.62   -4.925        FECL2+        0.00    0.000
H3BO3       281.40   -2.342         MGSO4       0.01   -7.221        FECL3         0.00    0.000
H2BO3-        0.02   -6.480         CACO3       0.00   -7.488        FECL4-        0.00    0.000
H2CO3     38793.44   -0.204         MGCO3       0.00  -11.402        FESO4         0.00    0.000
HCO3-        52.90   -3.062         CAHCO3+    14.62   -3.840        FESO4+        0.00    0.000
CO3--         0.00   -9.045         MGHCO3+     0.00   -7.599        AL+++         0.00    0.000
H2S        1863.09   -1.262         CAOH+       0.00   -7.589        ALOH++        0.00    0.000
HS-           4.49   -3.867         MGOH+       0.00   -8.582        AL(OH)2+      0.00    0.000
S--           0.00  -13.411         NH4OH       0.00    0.000        AL(OH)3       0.00    0.000
H2SO4         0.00   -9.358         NH4+        0.00    0.000        AL(OH)4-      0.00    0.000
HSO4-        15.73   -3.790         FE++        0.00    0.000        ALSO4+        0.00    0.000
SO4--        12.89   -3.872         FE+++       0.00    0.000        AL(SO4)2-     0.00    0.000
HF            0.00    0.000         FEOH+       0.00    0.000        ALF++         0.00    0.000
F-            0.00    0.000         FE(OH)2     0.00    0.000        ALF2+         0.00    0.000
CL-        3745.64   -0.976         FE(OH)3-    0.00    0.000        ALF3          0.00    0.000
NA+        2079.73   -1.044         FE(OH)4--   0.00    0.000        ALF4-         0.00    0.000
K+          523.88   -1.873         FE(OH)++    0.00    0.000        ALF5--        0.00    0.000
CA++         17.38   -3.363         FE(OH)2+    0.00    0.000        ALF6---       0.00    0.000

IONIC STRENGTH =  0.10647      IONIC BALANCE :   CATIONS (MOL.EQ.)0.10487515
                                                 ANIONS  (MOL.EQ.)0.10693281
                                                 DIFFERENCE    (%)     -1.94

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.86

QUARTZ       297.6
CHALCEDONY   999.9
NAK          314.9

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.367    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                TEOR.    CALC.                     TEOR.    CALC.                     TEOR.    CALC.
ADULARIA      -14.374   99.999    ALBITE LOW     -13.938   99.999    ANALCIME       -11.554   99.999
ANHYDRITE      -8.366   -8.906    CALCITE        -13.136  -14.042    CHALCEDONY      -1.940   -1.920
MG-CHLORITE   -86.028   99.999    FLUORITE       -11.034   99.999    GOETHITE         3.058   99.999
LAUMONTITE    -24.679   99.999    MICROCLINE     -15.008   99.999    MAGNETITE      -15.567   99.999
CA-MONTMOR.   -72.582   99.999    K-MONTMOR.     -33.888   99.999    MG-MONTMOR.    -74.090   99.999
NA-MONTMOR.   -34.169   99.999    MUSCOVITE      -17.837   99.999    PREHNITE       -37.810   99.999
PYRRHOTITE    -13.082   99.999    PYRITE         -31.297   99.999    QUARTZ          -2.047   -1.920
WAIRAKITE     -24.827   99.999    WOLLASTONITE     7.253    3.411    ZOISITE        -38.605   99.999
EPIDOTE       -38.184   99.999    MARCASITE      -14.975   99.999
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ORKUSTOFNUN   JHD              GEOCHEMISTRY OF WELL OKOY-6
1982-11-12  OLIVER
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%%%%%%%%%%810823%%%%  OKOY-6                                  S.NEGROS,PHILIPPINES  NASUJI

PROGRAM WATCH1.

WATER SAMPLE (PPM)           STEAM SAMPLE

PH/DEG.C         6.60/25.0   GAS (VOL.%)                  REFERENCE TEMP.     DEGREES C    285.0 (MEASURED)
SIO2           725.60        CO2              0.00
NA            2411.00        H2S              0.00        SAMPLING PRESSURE   BARS ABS.     11.1
K              480.00        H2               0.00        DISCHARGE ENTHALPY   MJOUL/KG    1.263 (MEASURED)
CA              31.90        O2               0.00        DISCHARGE             KG/SEC.     13.2
MG              0.030        CH4              0.00
CO2              6.60        N2               0.00        MEASURED TEMPERATURE DEGREES C     0.0
SO4             32.50                                     RESISTIVITY/TEMP.  OHMM/DEG.C      0.0/ 0.0
H2S              0.00                                     EH/TEMP.             MV/DEG.C    0.000/ 0.0
CL            4436.00
F                0.00        LITERS GAS PER KG
DISS.SOLIDS      0.00        CONDENSATE/DEG.C 0.00/ 0.0     MEASURED DOWNHOLE TEMP.   FLUID INFLOW
AL             0.0000                                          DEGREES C/METERS      DEPTH (METERS)
B             52.0000
FE             0.0000        CONDENSATE (PPM)                     0.0       0.0            0.0
NH3            0.0000        PH/DEG.C         0.00/ 0.0           0.0       0.0            0.0
                             CO2              0.00                0.0       0.0            0.0
                             H2S              0.00                0.0       0.0            0.0
                             NA               0.00                0.0       0.0            0.0
                                                                  0.0       0.0            0.0
                                                                  0.0       0.0            0.0
                                                                  0.0       0.0            0.0
                             CONDENSATE WITH NAOH (PPM)           0.0       0.0            0.0
                             CO2          12738.00                0.0       0.0            0.0
                             H2S            204.40                0.0       0.0            0.0

IONIC STRENGTH =  0.12317     IONIC BALANCE :  CATIONS (MOL.EQ.)0.11848436
                                               ANIONS  (MOL.EQ.)0.12564923
                                               DIFFERENCE    (%)     -5.87

DEEP WATER (PPM)                                    DEEP STEAM (PPM)          GAS PRESSURES (BARS ABS.)

SIO2       551.23         CO2       2972.49         CO2     213048.64         CO2       0.603E+01
NA        1831.46         H2S         48.73         H2S       1059.15         H2S       0.387E-01
K          364.60         H2           0.00         H2           0.00         H2        0.000E+00
CA          24.23         O2           0.00         O2           0.00         O2        0.000E+00
MG          0.023         CH4          0.00         CH4          0.00         CH4       0.000E+00
SO4         24.69         N2           0.00         N2           0.00         N2        0.000E+00
CL        3369.41         NH3          0.00         NH3          0.00         NH3       0.000E+00
F            0.00                                                             H2O       0.692E+02
DISS.S.      0.00                                                             TOTAL     0.752E+02
AL         0.0000
B         39.4969                                   H2O (%)               0.05
FE         0.0000                                   BOILING PORTION       0.24

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+         0.685     KSO4-       0.622      FE++         0.162      FECL+        0.591
OH-        0.578     F-          0.578      FE+++        0.033      AL+++        0.033
H3SIO4-    0.591     CL-         0.565      FEOH+        0.613      ALOH++       0.150
H2SIO4--   0.150     NA+         0.591      FE(OH)3-     0.613      AL(OH)2+     0.622
H2BO3-     0.551     K+          0.565      FE(OH)4--    0.142      AL(OH)4-     0.602
HCO3-      0.591     CA++        0.162      FEOH++       0.142      ALSO4+       0.602
CO3--      0.132     MG++        0.201      FE(OH)2+     0.622      AL(SO4)2-    0.602
HS-        0.578     CAHCO3+     0.634      FE(OH)4-     0.622      ALF++        0.150
S--        0.142     MGHCO3+     0.591      FESO4+       0.613      ALF2+        0.622
HSO4-      0.602     CAOH+       0.634      FECL++       0.142      ALF4-        0.602
SO4--      0.122     MGOH+       0.644      FECL2+       0.613      ALF5--       0.132
NASO4-     0.622     NH4+        0.551      FECL4-       0.591      ALF6---      0.010

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.02   -4.827        MG++          0.02   -6.045        FE(OH)3      0.00   0.000
OH-           0.02   -5.951        NACL        563.27   -2.016        FE(OH)4-     0.00   0.000
H4SIO4      881.68   -2.038        KCL          44.60   -3.223        FECL+        0.00   0.000
H3SIO4-       0.04   -6.335        NASO4-        3.13   -4.580        FECL2        0.00   0.000
H2SIO4--      0.00  -12.653        KSO4-         4.61   -4.467        FECL++       0.00   0.000
NAH3SIO4      0.03   -6.618        CASO4         1.46   -4.970        FECL2+       0.00   0.000
H3BO3       225.89   -2.437        MGSO4         0.00   -7.550        FECL3        0.00   0.000
H2BO3-        0.02   -6.543        CACO3         0.00   -8.267        FECL4-       0.00   0.000
H2CO3      4184.33   -1.171        MGCO3         0.00  -12.481        FESO4        0.00   0.000
HCO3-         3.97   -4.187        CAHCO3+       1.99   -4.705        FESO4+       0.00   0.000
CO3--         0.00  -10.307        MGHCO3+       0.00   -8.676        AL+++        0.00   0.000
H2S          48.65   -2.845        CAOH+         0.00   -7.217        ALOH++       0.00   0.000
HS-           0.08   -5.618        MGOH+         0.00   -8.197        AL(OH)2+     0.00   0.000
S--           0.00  -14.946        NH4OH         0.00    0.000        AL(OH)3      0.00   0.000
H2SO4         0.00   -9.453        NH4+          0.00    0.000        AL(OH)4-     0.00   0.000
HSO4-        12.14   -3.903        FE++          0.00    0.000        ALSO4+       0.00   0.000
SO4--         5.83   -4.217        FE+++         0.00    0.000        AL(SO4)2-    0.00   0.000
HF            0.00    0.000        FEOH+         0.00    0.000        ALF++        0.00   0.000
F-            0.00    0.000        FE(OH)2       0.00    0.000        ALF2+        0.00   0.000
CL-        3006.53   -1.072        FE(OH)3-      0.00    0.000        ALF3         0.00   0.000
NA+        1609.26   -1.155        FE(OH)4--     0.00    0.000        ALF4-        0.00   0.000
K+          339.88   -2.061        FE(OH)++      0.00    0.000        ALF5--       0.00   0.000
CA++         23.01   -3.241        FE(OH)2+      0.00    0.000        ALF6---      0.00   0.000

IONIC STRENGTH =  0.08307       IONIC BALANCE :   CATIONS (MOL.EQ.)0.07986062
                                                  ANIONS  (MOL.EQ.)0.08500110
                                                  DIFFERENCE    (%)     -6.24

CHEMICAL GEOTHERMOMETERS DEGREES C                1000/T DEGREES KELVIN =  1.79

QUARTZ      266.4
CHALCEDONY  999.9
NAK         288.0

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.382    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                TEOR.    CALC.                       TEOR.    CALC.                        TEOR.    CALC.
ADULARIA      -14.386   99.999     ALBITE LOW      -13.963   99.999     ANALCIME        -11.637   99.999
ANHYDRITE      -8.762   -9.164     CALCITE         -13.696  -15.220     CHALCEDONY       -1.863   -2.038
MG-CHLORITE   -87.922   99.999     FLUORITE        -11.156   99.999     GOETHITE          4.274   99.999
LAUMONTITE    -24.921   99.999     MICROCLINE      -14.972   99.999     MAGNETITE       -13.468   99.999
CA-MONTMOR.   -72.564   99.999     K-MONTMOR.      -33.766   99.999     MG-MONTMOR.     -74.072   99.999
NA-MONTMOR.   -34.051   99.999     MUSCOVITE       -17.845   99.999     PREHNITE        -38.645   99.999
PYRRHOTITE     -0.939   99.999     PYRITE          -16.041   99.999     QUARTZ           -1.965   -2.038
WAIRAKITE     -25.314   99.999     WOLLASTONITE      6.922    3.584     ZOISITE         -39.690   99.999
EPIDOTE       -39.816   99.999     MARCASITE        -0.345   99.999
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ORKUSTOFNUN   JHD              GEOCHEMISTRY OF WELL OKOY-7
1982-11-12  OLIVER
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%%%%%%%%%%800915%%%%  OKOY-7                                      S.NEGROS,PHILIPPINES  PUHAGAN

PROGRAM WATCH1.

WATER SAMPLE (PPM)             STEAM SAMPLE

PH/DEG.C            6.97/25.0  GAS (VOL.%)                  REFERENCE TEMP.      DEGREES C    318.0 (MEASURED)
SIO2           867.00          CO2            0.00
NA            3161.00          H2S            0.00          SAMPLING PRESSURE    BARS ABS.      9.3
K              724.00          H2             0.00          DISCHARGE ENTHALPY    MJOUL/KG    1.448 (CALCULATED)
CA             118.00          O2             0.00          DISCHARGE              KG/SEC.    29.5
MG               0.130         CH4            0.00
CO2             32.70          N2             0.00          MEASURED TEMPERATURE DEGREES C      0.0
SO4             28.00                                       RESISTIVITY/TEMP.   OHMM/DEG.C      0.0/ 0.0
H2S              0.10                                       EH/TEMP.              MV/DEG.C    0.000/ 0.0
CL            5788.00
F                0.00          LITERS GAS PER KG
DISS.SOLIDS      0.00          CONDENSATE/DEG.C 18.20/25.0    MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL               0.0000                                          DEGREES C/METERS       DEPTH (METERS)
B               69.3000
FE               0.0000        CONDENSATE (PPM)                    0.0       0.0             0.0
NH3              0.0000        PH/DEG.C        0.00/ 0.0           0.0       0.0             0.0
                               CO2             0.00                0.0       0.0             0.0
                               H2S             0.00                0.0       0.0             0.0
                               NA              0.00                0.0       0.0             0.0
                                                                   0.0       0.0             0.0
                                                                   0.0       0.0             0.0
                                                                   0.0       0.0             0.0
                               CONDENSATE WITH NAOH (PPM)          0.0       0.0             0.0
                               CO2          34296.00               0.0       0.0             0.0
                               H2S            695.70               0.0       0.0             0.0

IONIC STRENGTH =  0.16599      IONIC BALANCE :   CATIONS (MOL.EQ.)0.16148533
                                                 ANIONS  (MOL.EQ.)0.16411228
                                                 DIFFERENCE    (%)     -1.61

DEEP WATER (PPM)                                    DEEP STEAM (PPM)           GAS PRESSURES (BARS ABS.)

SIO2        567.29       CO2       11879.01         CO2            0.00        CO2       0.182E+02
NA         2068.10       H2S         240.60         H2S            0.00        H2S       0.143E+00
K           473.66       H2            0.00         H2             0.00        H2        0.000E+00
CA           77.20       O2            0.00         O2             0.00        O2        0.000E+00
MG            0.085      CH4           0.00         CH4            0.00        CH4       0.000E+00
SO4          18.32       N2            0.00         N2             0.00        N2        0.000E+00
CL         3786.52       NH3           0.00         NH3            0.00        NH3       0.000E+00
F             0.00                                                             H2O       0.110E+03
DISS.S.       0.00                                                             TOTAL     0.128E+03
AL            0.0000
B            45.3358                                H2O (%)               0.00
FE            0.0000                                BOILING PORTION       0.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.630     KSO4-       0.559      FE++        0.107      FECL+       0.524
OH-         0.510     F-          0.510      FE+++       0.016      AL+++       0.016
H3SIO4-     0.524     CL-         0.495      FEOH+       0.549      ALOH++      0.098
H2SIO4--    0.098     NA+         0.524      FE(OH)3-    0.549      AL(OH)2+    0.559
H2BO3-      0.480     K+          0.495      FE(OH)4--   0.091      AL(OH)4-    0.537
HCO3-       0.524     CA++        0.107      FEOH++      0.091      ALSO4+      0.537
CO3--       0.083     MG++        0.141      FE(OH)2+    0.559      AL(SO4)2-   0.537
HS-         0.510     CAHCO3+     0.572      FE(OH)4-    0.559      ALF++       0.098
S--         0.091     MGHCO3+     0.524      FESO4+      0.549      ALF2+       0.559
HSO4-       0.537     CAOH+       0.572      FECL++      0.091      ALF4-       0.537
SO4--       0.075     MGOH+       0.583      FECL2+      0.549      ALF5--      0.083
NASO4-      0.559     NH4+        0.480      FECL4-      0.524      ALF6---     0.004

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.01   -4.915      MG++          0.08   -5.472      FE(OH)3     0.00   0.000
OH-           0.02   -5.899      NACL       1557.53   -1.574      FE(OH)4-    0.00   0.000
H4SIO4      907.39   -2.025      KCL         119.51   -2.795      FECL+       0.00   0.000
H3SIO4-       0.03   -6.510      NASO4-        1.22   -4.989      FECL2       0.00   0.000
H2SIO4--      0.00  -12.934      KSO4-         5.14   -4.420      FECL++      0.00   0.000
NAH3SIO4      0.02   -6.866      CASO4         1.72   -4.899      FECL2+      0.00   0.000
H3BO3       259.28   -2.377      MGSO4         0.00   -7.554      FECL3       0.00   0.000
H2BO3-        0.02   -6.442      CACO3         0.00   -7.355      FECL4-      0.00   0.000
H2CO3     16725.57   -0.569      MGCO3         0.00  -11.659      FESO4       0.00   0.000
HCO3-         8.31   -3.866      CAHCO3+      14.47   -3.844      FESO4+      0.00   0.000
CO3--         0.00  -10.163      MGHCO3+       0.00   -7.729      AL+++       0.00   0.000
H2S         240.41   -2.152      CAOH+         0.01   -6.593      ALOH++      0.00   0.000
HS-           0.19   -5.247      MGOH+         0.00   -7.095      AL(OH)2+    0.00   0.000
S--           0.00  -14.202      NH4OH         0.00    0.000      AL(OH)3     0.00   0.000
H2SO4         0.00   -9.507      NH4+          0.00    0.000      AL(OH)4-    0.00   0.000
HSO4-        10.10   -3.983      FE++          0.00    0.000      ALSO4+      0.00   0.000
SO4--         2.47   -4.589      FE+++         0.00    0.000      AL(SO4)2-   0.00   0.000
HF            0.00    0.000      FEOH+         0.00    0.000      ALF++       0.00   0.000
F-            0.00    0.000      FE(OH)2       0.00    0.000      ALF2+       0.00   0.000
CL-        2784.88   -1.105      FE(OH)3-      0.00    0.000      ALF3        0.00   0.000
NA+        1455.14   -1.199      FE(OH)4--     0.00    0.000      ALF4-       0.00   0.000
K+          409.50   -1.980      FE(OH)++      0.00    0.000      ALF5--      0.00   0.000
CA++         70.95   -2.752      FE(OH)2+      0.00    0.000      ALF6---     0.00   0.000

IONIC STRENGTH =  0.07990      IONIC BALANCE :   CATIONS (MOL.EQ.)0.07745818
                                                 ANIONS  (MOL.EQ.)0.07875313
                                                 DIFFERENCE    (%)     -1.66

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.69

QUARTZ      269.5
CHALCEDONY  999.9
NAK         331.9

OXIDATION POTENTIAL (VOLTS) :     EH H2S= -0.443    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
               TEOR.    CALC.                       TEOR.    CALC.                       TEOR.    CALC.
ADULARIA     -14.524   99.999     ALBITE LOW      -14.114   99.999     ANALCIME        -11.860   99.999
ANHYDRITE     -9.396   -9.433     CALCITE         -14.600  -14.964     CHALCEDONY       -1.752   -2.025
MG-CHLORITE  -91.310   99.999     FLUORITE        -11.360   99.999     GOETHITE          6.271   99.999
LAUMONTITE   -25.485   99.999     MICROCLINE      -15.050   99.999     MAGNETITE       -10.043   99.999
CA-MONTMOR.  -72.299   99.999     K-MONTMOR.      -33.478   99.999     MG-MONTMOR.     -73.793   99.999
NA-MONTMOR.  -33.750   99.999     MUSCOVITE       -17.840   99.999     PREHNITE        -40.187   99.999
PYRRHOTITE    18.677   99.999     PYRITE            8.400   99.999     QUARTZ           -1.849   -2.025
WAIRAKITE    -26.235   99.999     WOLLASTONITE      6.431    4.083     ZOISITE         -41.640   99.999
EPIDOTE      -43.932   99.999     MARCASITE        23.189   99.999
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ORKUSTOFNUN   JHD             GEOCHEMISTRY OF WELL OKOY-8
1982-11-12  OLIVER
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%%%%%%%%%%820422%%%%  OKOY-8                              S.NEGROS,PHILIPPINES  NASUJI

PROGRAM WATCH3.             TEMPERATURE FIXING STEAM LOSS   100.0 DEGREES C

WATER SAMPLE (PPM)          STEAM SAMPLE

PH/DEG.C          7.85/25.0 GAS (VOL.%)               REFERENCE TEMP.      DEGREES C    244.0 (ARBITRARY)
SIO2             864.00     CO2
NA              2771.00     H2S                       SAMPLING PRESSURE    BARS ABS.
K                636.00     H2                        DISCHARGE ENTHALPY   MJOUL/KG
CA                33.60     O2                        DISCHARGE              KG/SEC.    32.6
MG                 0.050    CH4
CO2                6.98     N2                        MEASURED TEMPERATURE DEGREES C     0.0
SO4               36.10                               RESISTIVITY/TEMP.   OHMM/DEG.C     0.0/ 0.0
H2S                6.48                               EH/TEMP.              MV/DEG.C   0.000/ 0.0
CL              5262.00
F                  0.00     LITERS GAS PER KG
DISS.SOLIDS        0.00     CONDENSATE/DEG.C            MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL                 0.0000                                  DEGREES C/METERS        DEPTH (METERS)
B                 64.4000
FE                 0.0000   CONDENSATE (PPM)                 0.0       0.0             0.0
NH3                0.0000   PH/DEG.C                         0.0       0.0             0.0
                            CO2                              0.0       0.0             0.0
                            H2S                              0.0       0.0             0.0
                            NA                               0.0       0.0             0.0
                                                             0.0       0.0             0.0
                                                             0.0       0.0             0.0
                                                             0.0       0.0             0.0
                            CONDENSATE WITH NAOH (PPM)       0.0       0.0             0.0
                            CO2                              0.0       0.0             0.0
                            H2S                              0.0       0.0             0.0

IONIC STRENGTH =  0.14498     IONIC BALANCE :   CATIONS (MOL.EQ.)0.13799763
                                                ANIONS  (MOL.EQ.)0.14961219
                                                DIFFERENCE    (%)     -8.08

DEEP WATER (PPM)                                  DEEP STEAM (PPM)          GAS PRESSURES (BARS ABS.)

SIO2       620.16        CO2        1672.52       CO2          0.00         CO2       0.440E+01
NA        1988.78        H2S         757.91       H2S          0.00         H2S       0.792E+00
K          456.44        H2            0.00       H2           0.00         H2        0.000E+00
CA          24.12        O2            0.00       O2           0.00         O2        0.000E+00
MG           0.036       CH4           0.00       CH4          0.00         CH4       0.000E+00
SO4         25.91        N2            0.00       N2           0.00         N2        0.000E+00
CL        3776.28        NH3           0.00       NH3          0.00         NH3       0.000E+00
F            0.00                                                           H2O       0.359E+02
DISS.S.      0.00                                                           TOTAL     0.411E+02
AL           0.0000
B           46.2164                               H2O (%)               0.00
FE           0.0000                               BOILING PORTION       0.00

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.712     KSO4-        0.653     FE++         0.200     FECL+        0.623
OH-         0.611     F-           0.611     FE+++        0.050     AL+++        0.050
H3SIO4-     0.623     CL-          0.598     FEOH+        0.645     ALOH++       0.187
H2SIO4--    0.187     NA+          0.623     FE(OH)3-     0.645     AL(OH)2+     0.653
H2BO3-      0.584     K+           0.598     FE(OH)4--    0.177     AL(OH)4-     0.634
HCO3-       0.623     CA++         0.200     FEOH++       0.177     ALSO4+       0.634
CO3--       0.166     MG++         0.243     FE(OH)2+     0.653     AL(SO4)2-    0.634
HS-         0.611     CAHCO3+      0.665     FE(OH)4-     0.653     ALF++        0.187
S--         0.177     MGHCO3+      0.623     FESO4+       0.645     ALF2+        0.653
HSO4-       0.634     CAOH+        0.665     FECL++       0.177     ALF4-        0.634
SO4--       0.154     MGOH+        0.674     FECL2+       0.645     ALF5--       0.166
NASO4-      0.653     NH4+         0.584     FECL4-       0.623     ALF6---      0.018

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)      0.01   -5.119      MG++          0.03   -5.861       FE(OH)3       0.00   0.000
OH-            0.03   -5.733      NACL        256.65   -2.357       FE(OH)4-      0.00   0.000
H4SIO4       991.70   -1.986      KCL          29.03   -3.410       FECL+         0.00   0.000
H3SIO4-        0.19   -5.699      NASO4-        5.52   -4.334       FECL2         0.00   0.000
H2SIO4--       0.00  -11.449      KSO4-         3.75   -4.371       FECL++        0.00   0.000
NAH3SIO4       0.13   -5.949      CASO4         1.84   -4.870       FECL2+        0.00   0.000
H3BO3        264.29   -2.369      MGSO4         0.01   -7.063       FECL3         0.00   0.000
H2BO3-         0.05   -6.092      CACO3         0.00   -7.669       FECL4-        0.00   0.000
H2CO3       2342.25   -1.423      MGCO3         0.00  -11.456       FESO4         0.00   0.000
HCO3-         12.61   -3.685      CAHCO3+       3.69   -4.437       FESO4+        0.00   0.000
CO3--          0.00   -9.123      MGHCO3+       0.00   -8.146       AL+++         0.00   0.000
H2S          750.65   -1.657      CAOH+         0.00   -7.235       ALOH++        0.00   0.000
HS-            7.05   -3.672      MGOH+         0.00   -8.365       AL(OH)2+      0.00   0.000
S--            0.00  -12.992      NH4OH         0.00    0.000       AL(OH)3       0.00   0.000
H2SO4          0.00  -10.492      NH4+          0.00    0.000       AL(OH)4-      0.00   0.000
HSO4-          3.52   -4.440      FE++          0.00    0.000       ALSO4+        0.00   0.000
SO4--         12.58   -3.883      FE+++         0.00    0.000       AL(SO4)2-     0.00   0.000
HF             0.00    0.000      FEOH+         0.00    0.000       ALF++         0.00   0.000
F-             0.00    0.000      FE(OH)2       0.00    0.000       ALF2+         0.00   0.000
CL-         3606.79   -0.992      FE(OH)3-      0.00    0.000       ALF3          0.00   0.000
NA+         1886.72   -1.086      FE(OH)4--     0.00    0.000       ALF4-         0.00   0.000
K+           439.55   -1.949      FE(OH)++      0.00    0.000       ALF5--        0.00   0.000
CA++          22.11   -3.258      FE(OH)2+      0.00    0.000       ALF6---       0.00   0.000

IONIC STRENGTH =  0.09912      IONIC BALANCE :   CATIONS (MOL.EQ.)0.09445145
                                                 ANIONS  (MOL.EQ.)0.10242935
                                                 DIFFERENCE    (%)      -8.10

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.93

QUARTZ      279.4
CHALCEDONY  999.9
NAK         303.5

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.390    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
               TEOR.    CALC.                      TEOR.    CALC.                     TEOR.    CALC.
ADULARIA     -14.424   99.999    ALBITE LOW      -13.972   99.999    ANALCIME       -11.525   99.999
ANHYDRITE     -7.996   -8.652    CALCITE         -12.616  -13.860    CHALCEDONY      -2.019   -1.986
MG-CHLORITE  -84.428   99.999    FLUORITE        -10.925   99.999    GOETHITE         1.944   99.999
LAUMONTITE   -24.541   99.999    MICROCLINE      -15.112   99.999    MAGNETITE      -17.506   99.999
CA-MONTMOR.  -72.617   99.999    K-MONTMOR.      -34.020   99.999    MG-MONTMOR.    -74.115   99.999
NA-MONTMOR.  -34.295   99.999    MUSCOVITE       -17.850   99.999    PREHNITE       -37.131   99.999
PYRRHOTITE   -24.401   99.999    PYRITE          -45.633   99.999    QUARTZ          -2.131   -1.986
WAIRAKITE    -24.442   99.999    WOLLASTONITE      7.585    4.294    ZOISITE        -37.695   99.999
EPIDOTE      -37.289   99.999    MARCASITE       -28.672   99.999
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ORKUSTOFNUN   JHD            GEOCHEMISTRY OF WELL OKOY-9D
1982-11-12  OLIVER
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%%%%%%%%%%%810313%%%%%  OKOY-9D                                S.NEGROS,PHILIPPINES  PUHAGAN

PROGRAM WATCH1.

WATER SAMPLE (PPM)          STEAM SAMPLE

PH/DEG.C        7.43/25.0   GAS (VOL.%)                  REFERENCE TEMP.      DEGREES C    291.0 (MEASURED)
SIO2            734.00      CO2              0.00
NA             2580.00      H2S              0.00        SAMPLING PRESSURE    BARS ABS.     4.5
K               555.00      H2               0.00        DISCHARGE ENTHALPY    MJOUL/KG    1.296 (MEASURED)
CA               75.50      O2               0.00        DISCHARGE              KG/SEC.     12.8
MG                0.190     CH4              0.00
CO2              43.60      N2               0.00        MEASURED TEMPERATURE DEGREES C     0.0
SO4              34.70                                   RESISTIVITY/TEMP.   OHMM/DEG.C     0.0/ 0.0
H2S               0.00                                   EH/TEMP.              MV/DEG.C    0.000/ 0.0
CL             4308.00
F                 0.00      LITERS GAS PER KG
DISS.SOLIDS       0.00      CONDENSATE/DEG.C 11.50/25.0     MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL                0.0000                                       DEGREES C/METERS        DEPTH (METERS)
B                52.0000
FE                0.0000    CONDENSATE (PPM)                     0.0       0.0             0.0
NH3               0.0000    PH/DEG.C         0.00/ 0.0           0.0       0.0             0.0
                            CO2              0.00                0.0       0.0             0.0
                            H2S              0.00                0.0       0.0             0.0
                            NA               0.00                0.0       0.0             0.0
                                                                 0.0       0.0             0.0
                                                                 0.0       0.0             0.0
                                                                 0.0       0.0             0.0
                            CONDENSATE WITH NAOH (PPM)           0.0       0.0             0.0
                            CO2          21599.00                0.0       0.0             0.0
                            H2S            493.50                0.0       0.0             0.0

IONIC STRENGTH =  0.12865      IONIC BALANCE :   CATIONS (MOL.EQ.)0.12987454
                                                 ANIONS  (MOL.EQ.)0.12300957
                                                 DIFFERENCE    (%)      5.43

DEEP WATER (PPM)                                   DEEP STEAM (PPM)           GAS PRESSURES (BARS ABS.)

SIO2        501.10        CO2         6509.85      CO2       406004.66        CO2        0.126E+02
NA         1761.21        H2S          154.26      H2S         2911.42        H2S        0.116E+00
K           378.85        H2             0.00      H2             0.00        H2         0.000E+00
CA           51.54        O2             0.00      O2             0.00        O2         0.000E+00
MG            0.130       CH4            0.00      CH4            0.00        CH4        0.000E+00
SO4          23.69        N2             0.00      N2             0.00        N2         0.000E+00
CL         2940.56        NH3            0.00      NH3            0.00        NH3        0.000E+00
F             0.00                                                            H2O        0.755E+02
DISS.S.       0.00                                                            TOTAL      0.882E+02
AL            0.0000
B            35.4940                               H2O (%)              0.10
FE            0.0000                               BOILING PORTION      0.32

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.681      KSO4-       0.620       FE++         0.159      FECL+       0.589
OH-         0.576      F-          0.576       FE+++        0.032      AL+++       0.032
H3SIO4-     0.589      CL-         0.563       FEOH+        0.611      ALOH++      0.147
H2SIO4--    0.147      NA+         0.589       FE(OH)3-     0.611      AL(OH)2+    0.620
H2BO3-      0.550      K+          0.563       FE(OH)4--    0.140      AL(OH)4-    0.600
HCO3-       0.589      CA++        0.159       FEOH++       0.140      ALSO4+      0.600
CO3--       0.130      MG++        0.197       FE(OH)2+     0.620      AL(SO4)2-   0.600
HS-         0.576      CAHCO3+     0.631       FE(OH)4-     0.620      ALF++       0.147
S--         0.140      MGHCO3+     0.589       FESO4+       0.611      ALF2+       0.620
HSO4-       0.600      CAOH+       0.631       FECL++       0.140      ALF4-       0.600
SO4--       0.120      MGOH+       0.641       FECL2+       0.611      ALF5--      0.130
NASO4-      0.620      NH4+        0.550       FECL4-       0.589      ALF6---     0.010

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)      0.00   -5.374      MG++         0.12   -5.310       FE(OH)3       0.00    0.000
OH-            0.07   -5.408      NACL       577.80   -2.005       FE(OH)4-      0.00    0.000
H4SIO4       801.37   -2.079      KCL         46.81   -3.202       FECL+         0.00    0.000
H3SIO4-        0.12   -5.882      NASO4-       4.07   -4.466       FECL2         0.00    0.000
H2SIO4--       0.00  -11.704      KSO4-        7.24   -4.271       FECL++        0.00    0.000
NAH3SIO4       0.08   -6.177      CASO4        3.62   -4.575       FECL2+        0.00    0.000
H3BO3        202.96   -2.484      MGSO4        0.02   -6.697       FECL3         0.00    0.000
H2BO3-         0.05   -6.060      CACO3        0.02   -6.625       FECL4-        0.00    0.000
H2CO3       9133.78   -0.832      MGCO3        0.00  -10.385       FESO4         0.00    0.000
HCO3-         25.81   -3.374      CAHCO3+     24.90   -3.608       FESO4+        0.00    0.000
CO3--          0.00   -9.014      MGHCO3+      0.01   -7.098       AL+++         0.00    0.000
H2S          153.50   -2.346      CAOH+        0.02   -6.386       ALOH++        0.00    0.000
HS-            0.74   -4.650      MGOH+        0.01   -6.816       AL(OH)2+      0.00    0.000
S--            0.00  -13.397      NH4OH        0.00    0.000       AL(OH)3       0.00    0.000
H2SO4          0.00  -10.324      NH4+         0.00    0.000       AL(OH)4-      0.00    0.000
HSO4-          5.38   -4.256      FE++         0.00    0.000       ALSO4+        0.00    0.000
SO4--          7.36   -4.116      FE+++        0.00    0.000       AL(SO4)2-     0.00    0.000
HF             0.00    0.000      FEOH+        0.00    0.000       ALF++         0.00    0.000
F-             0.00    0.000      FE(OH)2      0.00    0.000       ALF2+         0.00    0.000
CL-         2567.81   -1.140      FE(OH)3-     0.00    0.000       ALF3          0.00    0.000
NA+         1533.11   -1.176      FE(OH)4--    0.00    0.000       ALF4-         0.00    0.000
K+           352.20   -2.045      FE(OH)++     0.00    0.000       ALF5--        0.00    0.000
CA++          40.57   -2.995      FE(OH)2+     0.00    0.000       ALF6---       0.00    0.000

IONIC STRENGTH =  0.07660      IONIC BALANCE :   CATIONS (MOL.EQ.)0.07797492
                                                 ANIONS  (MOL.EQ.)0.07303931
                                                 DIFFERENCE    (%)        6.54

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.77

QUARTZ      256.2
CHALCEDONY  999.9
NAK         300.8

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.470    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
               TEOR.    CALC.                      TEOR.    CALC.                       TEOR.    CALC.
ADULARIA     -14.401   99.999     ALBITE LOW     -13.981   99.999     ANALCIME        -11.669   99.999
ANHYDRITE     -8.876   -8.830     CALCITE        -13.858  -13.694     CHALCEDONY       -1.842   -2.079
MG-CHLORITE  -88.501   99.999     FLUORITE       -11.192   99.999     GOETHITE          4.629   99.999
LAUMONTITE   -25.008   99.999     MICROCLINE     -14.974   99.999     MAGNETITE       -12.857   99.999
CA-MONTMOR.  -72.549   99.999     K-MONTMOR.     -63.728   99.999     MG-MONTMOR.     -74.053   99.999
NA-MONTMOR.  -34.010   99.999     MUSCOVITE      -17.848   99.999     PREHNITE        -38.906   99.999
PYRRHOTITE     2.578   99.999     PYRITE         -11.641   99.999     QUARTZ           -1.943   -2.079
WAIRAKITE    -25.468   99.999     WOLLASTONITE     6.831    4.876     ZOISITE         -40.023   99.999
EPIDOTE      -40.420   99.999     MARCASITE        3.883   99.999
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ORKUSTOFNUN   JHD               GEOCHEMISTRY OF WELL OKOY-10D
1982-11-12 OLIVER
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%%%%%%%%%%810530%%%%  OKOY-10D                                          S.NEGROS,PHILIPPINES  PUHAGAN

PROGRAM WATCH1.

WATER SAMPLE (PPM)            STEAM SAMPLE

PH/DEG.C          6.69/25.0   GAS (VOL.%)                  REFERENCE TEMP.      DEGREES C    259.0 (MEASURED)
SIO2            717.00        CO2               0.00
NA             3167.00        H2S               0.00        SAMPLING PRESSURE    BARS ABS.      2.6
K               634.00        H2                0.00        DISCHARGE ENTHALPY    MJOUL/KG    1.313 (MEASURED)
CA              122.00        O2                0.00        DISCHARGE              KG/SEC.     50.3
MG               0.850        CH4               0.00
CO2               2.60        N2                0.00        MEASURED TEMPERATURE DEGREES C      0.0
SO4              51.50                                      RESISTIVITY/TEMP.   OHMM/DEG.C      0.0/ 0.0
H2S               0.00                                      EH/TEMP.              MV/DEG.C    0.000/ 0.0
CL             5424.00
F                 0.00        LITERS GAS PER KG
DISS.SOLIDS       0.00        CONDENSATE/DEG.C  3.76/25.0      MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL              0.0000                                            DEGREES C/METERS       DEPTH (METERS)
B              76.1000
FE              0.0000        CONDENSATE (PPM)                       0.0       0.0             0.0
NH3             0.0000        PH/DEG.C          0.00/ 0.0            0.0       0.0             0.0
                              CO2               0.00                 0.0       0.0             0.0
                              H2S               0.00                 0.0       0.0             0.0
                              NA                0.00                 0.0       0.0             0.0
                                                                     0.0       0.0             0.0
                                                                     0.0       0.0             0.0
                                                                     0.0       0.0             0.0
                              CONDENSATE WITH NAOH (PPM)             0.0       0.0             0.0
                              CO2           7079.00                  0.0       0.0             0.0
                              H2S             165.80                 0.0       0.0             0.0

IONIC STRENGTH =  0.16024      IONIC BALANCE :   CATIONS (MOL.EQ.)0.15971066
                                                 ANIONS  (MOL.EQ.)0.15369166
                                                 DIFFERENCE    (%)      3.84

DEEP WATER (PPM)                                      DEEP STEAM (PPM)           GAS PRESSURES (BARS ABS.)

SIO2        519.39         CO2         168.06         CO2       21418.91         CO2       0.405E+00
NA         2293.94         H2S          11.32         H2S         442.03         H2S       0.108E-01
K           459.20         H2            0.00         H2            0.00         H2        0.000E+00
CA           88.37         O2            0.00         O2            0.00         O2        0.000E+00
MG           0.616         CH4           0.00         CH4           0.00         CH4       0.000E+00
SO4          37.30         N2            0.00         N2            0.00         N2        0.000E+00
CL         3928.42         NH3           0.00         NH3           0.00         NH3       0.000E+00
F             0.00                                                               H2O       0.462E+02
DISS.S.       0.00                                                               TOTAL     0.466E+02
AL          0.0000
B          55.1162                                    H2O (%)               11.07
FE          0.0000                                    BOILING PORTION        0.28

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.694      KSO4-        0.630      FE++         0.174      FECL+        0.597
OH-         0.584      F-           0.584      FE+++        0.039      AL+++        0.039
H3SIO4-     0.597      CL-          0.570      FEOH+        0.621      ALOH++       0.161
H2SIO4--    0.161      NA+          0.597      FE(OH)3-     0.621      AL(OH)2+     0.630
H2BO3-      0.555      K+           0.570      FE(OH)4--    0.152      AL(OH)4-     0.609
HCO3-       0.597      CA++         0.174      FEOH++       0.152      ALSO4+       0.609
CO3--       0.141      MG++         0.216      FE(OH)2+     0.630      AL(SO4)2-    0.609
HS-         0.584      CAHCO3+      0.642      FE(OH)4-     0.630      ALF++        0.161
S--         0.152      MGHCO3+      0.597      FESO4+       0.621      ALF2+        0.630
HSO4-       0.609      CAOH+        0.642      FECL++       0.152      ALF4-        0.609
SO4--       0.130      MGOH+        0.652      FECL2+       0.621      ALF5--       0.141
NASO4-      0.630      NH4+         0.555      FECL4-       0.597      ALF6---      0.012

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.01   -5.271       MG++        0.57   -4.628        FE(OH)3       0.00    0.000
OH-           0.05   -5.528       NACL      393.55   -2.172        FE(OH)4-      0.00    0.000
H4SIO4      830.50   -2.063       KCL        36.98   -3.305        FECL+         0.00    0.000
H3SIO4-       0.19   -5.709       NASO4-      7.67   -4.191        FECL2         0.00    0.000
H2SIO4--      0.00  -11.380       KSO4-       7.90   -4.233        FECL++        0.00    0.000
NAH3SIO4      0.14   -5.913       CASO4       8.61   -4.199        FECL2+        0.00    0.000
H3BO3       315.17   -2.293       MGSO4       0.19   -5.801        FECL3         0.00    0.000
H2BO3-        0.08   -5.882       CACO3       0.00   -7.905        FECL4-        0.00    0.000
H2CO3       234.63   -2.422       MGCO3       0.00  -11.119        FESO4         0.00    0.000
HCO3-         1.26   -4.686       CAHCO3+     1.60   -4.800        FESO4+        0.00    0.000
CO3--         0.00  -10.084       MGHCO3+     0.00   -7.879        AL+++         0.00    0.000
H2S          11.21   -3.483       CAOH+       0.02   -6.397        ALOH++        0.00    0.000
HS-           0.11   -5.494       MGOH+       0.01   -6.760        AL(OH)2+      0.00    0.000
S--           0.00  -14.534       NH4OH       0.00    0.000        AL(OH)3       0.00    0.000
H2SO4         0.00  -10.469       NH4+        0.00    0.000        AL(OH)4-      0.00    0.000
HSO4-         4.46   -4.337       FE++        0.00    0.000        ALSO4+        0.00    0.000
SO4--        14.85   -3.811       FE+++       0.00    0.000        AL(SO4)2-     0.00    0.000
HF            0.00    0.000       FEOH+       0.00    0.000        ALF++         0.00    0.000
F-            0.00    0.000       FE(OH)2     0.00    0.000        ALF2+         0.00    0.000
CL-        3672.10   -0.985       FE(OH)3-    0.00    0.000        ALF3          0.00    0.000
NA+        2137.61   -1.032       FE(OH)4--   0.00    0.000        ALF4-         0.00    0.000
K+          437.52   -1.951       FE(OH)++    0.00    0.000        ALF5--        0.00    0.000
CA++         85.18   -2.673       FE(OH)2+    0.00    0.000        ALF6---       0.00    0.000

IONIC STRENGTH =  0.10851      IONIC BALANCE :   CATIONS (MOL.EQ.)0.10848394
                                                 ANIONS  (MOL.EQ.)0.10392465
                                                 DIFFERENCE    (%)       4.29

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.88

QUARTZ       259.9
CHALCEDONY   999.9
NAK          283.1

OXIDATION POTENTIAL (VOLTS) :     EH H2S= -0.403    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                TEOR.    CALC.                      TEOR.    CALC.                       TEOR.    CALC.
ADULARIA       -14.381   99.999    ALBITE LOW      -13.941   99.999    ANALCIME         -11.542   99.999
ANHYDRITE       -8.273   -8.129    CALCITE         -13.005  -14.367    CHALCEDONY        -1.959   -2.063
MG-CHLORITE    -85.609   99.999    FLUORITE        -11.006   99.999    GOETHITE           2.776   99.999
LAUMONTITE     -24.635   99.999    MICROCLINE      -15.028   99.999    MAGNETITE        -16.058   99.999
CA-MONTMOR.    -72.386   99.999    K-MONTMOR.      -33.916   99.999    MG-MONTMOR.      -74.090   99.999
NA-MONTMOR.    -34.197   99.999    MUSCOVITE       -17.838   99.999    PREHNITE         -37.629   99.999
PYRRHOTITE     -15.934   99.999    PYRITE          -34.898   99.999    QUARTZ            -2.067   -2.063
WAIRAKITE      -24.723   99.999    WOLLASTONITE      7.335    5.046    ZOISITE          -38.365   99.999
EPIDOTE        -37.900   99.999    MARCASITE       -18.420   99.999
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ORKUSTOFNUN   JHD          GEOCHEMISTRY OF WELL OKOY-12D
1982-11-12  OLIVER
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%%%%%%%%%%810912%%%%  OKOY-12D                                S.NEGROS,PHILIPPINES  PUHAGAN

PROGRAM WATCH1.

WATER SAMPLE (PPM)          STEAM SAMPLE

PH/DEG.C         6.70/25.0  GAS (VOL.%)                 REFERENCE TEMP.      DEGREES C    250.0 (MEASURED)
SIO2           532.00       CO2           0.00
NA            2352.00       H2S           0.00          SAMPLING PRESSURE    BARS ABS.     11.0
K              457.00       H2            0.00          DISCHARGE ENTHALPY    MJOUL/KG     1.089 (MEASURED)
CA              76.00       O2            0.00          DISCHARGE              KG/SEC.     16.8
MG               0.360      CH4           0.00
CO2             43.00       N2            0.00          MEASURED TEMPERATURE DEGREES C      0.0
SO4             32.00                                   RESISTIVITY/TEMP.  OHMM/DEG.C      0.0/ 0.0
H2S             82.60                                   EH/TEMP.              MV/DEG.C    0.000/ 0.0
CL            4361.00
F                0.00       LITERS GAS PER KG
DISS.SOLIDS      0.00       CONDENSATE/DEG.C 16.90/25.0    MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL               0.0000                                      DEGREES C/METERS        DEPTH (METERS)
B               49.2000
FE               0.0000     CONDENSATE (PPM)                    0.0       0.0            0.0
NH3              0.0000     PH/DEG.C          0.00/ 0.0         0.0       0.0            0.0
                            CO2               0.00              0.0       0.0            0.0
                            H2S               0.00              0.0       0.0            0.0
                            NA                0.00              0.0       0.0            0.0
                                                                0.0       0.0            0.0
                                                                0.0       0.0            0.0
                                                                0.0       0.0            0.0
                            CONDENSATE WITH NAOH (PPM)          0.0       0.0            0.0
                            CO2           31728.90              0.0       0.0            0.0
                            H2S             435.30              0.0       0.0            0.0

IONIC STRENGTH =  0.12351     IONIC BALANCE :   CATIONS (MOL.EQ.)0.11755587
                                                ANIONS  (MOL.EQ.)0.12505311
                                                DIFFERENCE    (%)      -6.18

DEEP WATER (PPM)                                   DEEP STEAM (PPM)          GAS PRESSURES (BARS ABS.)

SIO2      451.20        CO2        3441.02         CO2      532191.44        CO2       0.866E+01
NA       1994.63        H2S         121.17         H2S        5742.93        H2S       0.121E+00
K         387.54        H2            0.00         H2            0.00        H2        0.000E+00
CA         64.45        O2            0.00         O2            0.00        O2        0.000E+00
MG          0.305       CH4           0.00         CH4           0.00        CH4       0.000E+00
SO4        27.14        N2            0.00         N2            0.00        N2        0.000E+00
CL       3698.06        NH3           0.00         NH3           0.00        NH3       0.000E+00
F           0.00                                                             H2O       0.398E+02
DISS.S.     0.00                                                             TOTAL     0.486E+02
AL          0.0000
B          41.7204                                 H2O (%)                0.28
FE          0.0000                                 BOILING PORTION        0.15

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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 ACTIVITY COEFFICIENTS IN DEEP WATER
 H+          0.707       KS04-        0.648       FE++         0.193       FECL+        0.617
 OH-         0.605       F-           0.605       FE+++        0.047       AL+++        0.047
 H3SI04-     0.617       CL-          0.592       FEOH+        0.639       ALOH++       0.180
 H2SI04--    0.180       NA+          0.617       FE(OH)3-     0.639       AL(OH)2+     0.648
 H2B03-      0.578       K+           0.592       FE(OH)4--    0.171       AL(OH)4-     0.629
 HC03-       0.617       CA++         0.193       FEOH++       0.171       ALS04+       0.629
 C03--       0.160       MG++         0.236       FE(OH)2+     0.648       AL(S04)2-    0.629
 HS-         0.605       CAHC03+      0.659       FE(OH)4-     0.648       ALF++        0.180
 S--         0.171       MGHC03+      0.617       FES04+       0.639       ALF2+        0.648
 HS04-       0.629       CAOH+        0.659       FECL++       0.171       ALF4-        0.629
 S04--       0.149       MGOH+        0.668       FECL2+       0.639       ALF5--       0.160
 NAS04-      0.648       NH4+         0.578       FECL4-       0.617       ALF6---      0.016

 CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
 H+ (ACT.)     0.00   -5.523      MG++         0.28   -4.943        FE(OH)3        0.00    0.000
 OH-           0.08   -5.310      NACL       281.43   -2.317        FE(OH)4-       0.00    0.000
 H4SI04      721.23   -2.125      KCL         26.61   -3.447        FECL+          0.00    0.000
 H3SI04-       0.32   -5.469      NAS04-       6.08   -4.292        FECL2          0.00    0.000
 H2SI04--      0.00  -10.850      KS04-        5.62   -4.381        FECL++         0.00    0.000
 NAH3SI04      0.23   -5.717      CAS04        4.47   -4.483        FECL2+         0.00    0.000
 H3B03       238.52   -2.414      MGS04        0.09   -6.118        FECL3          0.00    0.000
 H2B03-        0.11   -5.744      CAC03        0.06   -6.256        FECL4-         0.00    0.000
 H2C03      4769.28   -1.114      MGC03        0.00   -9.493        FES04          0.00    0.000
 HC03-        56.15   -3.036      CAHC03+     38.37   -3.421        FES04+         0.00    0.000
 C03--         0.00   -8.122      MGHC03+      0.02   -6.558        AL+++          0.00    0.000
 H2S         118.64   -2.458      CAOH+        0.02   -6.446        ALOH++         0.00    0.000
 HS-           2.45   -4.130      MGOH+        0.00   -6.950        AL(OH)2+       0.00    0.000
 S--           0.00  -13.002      NH4OH        0.00    0.000        AL(OH)3        0.00    0.000
 H2S04         0.00  -11.162      NH4+         0.00    0.000        AL(OH)4-       0.00    0.000
 HS04-         1.77   -4.738      FE++         0.00    0.000        ALS04+         0.00    0.000
 S04--        13.26   -3.860      FE+++        0.00    0.000        AL(S04)2-      0.00    0.000
 HF            0.00    0.000      FEOH+        0.00    0.000        ALF++          0.00    0.000
 F-            0.00    0.000      FE(OH)2      0.00    0.000        ALF2+          0.00    0.000
 CL-        3514.69   -1.004      FE(OH)3-     0.00    0.000        ALF3           0.00    0.000
 NA+        1882.69   -1.087      FE(OH)4--    0.00    0.000        ALF4-          0.00    0.000
 K+          371.96   -2.022      FE(OH)++     0.00    0.000        ALF5--         0.00    0.000
 CA++         47.89   -2.923      FE(OH)2+     0.00    0.000        ALF6---        0.00    0.000

 IONIC STRENGTH =  0.09866     IONIC BALANCE :   CATIONS (MOL.EQ.)0.09419770
                                                 ANIONS  (MOL.EQ.)0.10042552
                                                 DIFFERENCE    (%)     -6.40

 CHEMICAL GEOTHERMOMETERS DEGREES C              1000/T DEGREES KELVIN =  1.91

 QUARTZ       243.3
 CHALCEDONY   999.9
 NAK          278.7

 OXIDATION POTENTIAL (VOLTS) :     EH H2S= -0.439    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

 LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                  TEOR.    CALC.                       TEOR.    CALC.                       TEOR.    CALC.
 ADULARIA       -14.402   99.999     ALBITE LOW      -13.956   99.999     ANALCIME        -11.528   99.999
 ANHYDRITE       -8.106   -8.325     CALCITE         -12.771  -12.555     CHALCEDONY       -1.995   -2.125
 MG-CHLORITE    -84.886   99.999     FLUORITE        -10.957   99.999     GOETHITE          2.273   99.999
 LAUMONTITE     -24.572   99.999     MICROCLINE      -15.073   99.999     MAGNETITE       -16.930   99.999
 CA-MONTMOR.    -72.600   99.999     K-MONTMOR.      -33.975   99.999     MG-MONTMOR.     -74.098   99.999
 NA-MONTMOR.    -34.252   99.999     MUSCOVITE       -17.843   99.999     PREHNITE        -37.322   99.999
 PYRRHOTITE     -21.030   99.999     PYRITE          -41.351   99.999     QUARTZ           -2.105   -2.125
 WAIRAKITE      -24.549   99.999     WOLLASTONITE      7.484    5.285     ZOISITE         -37.954   99.999
 EPIDOTE        -37.492   99.999     MARCASITE       -24.586   99.999
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ORKUSTOFNUN   JHD                GEOCHEMISTRY OF WELL NJ-1D
1982-11-12  OLIVER
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%%%%%%%%%%820427%%%%  NASUJI-1D                                         S.NEGROS,PHILIPPINES  NASUJI

PROGRAM WATCH3.               TEMPERATURE FIXING STEAM LOSS   100.0 DEGREES C

WATER SAMPLE (PPM)            STEAM SAMPLE

PH/DEG.C          5.20/25.0   GAS (VOL.%)                  REFERENCE TEMP.      DEGREES C    243.0 (ARBITRARY)
SIO2            600.00        CO2
NA             1930.00        H2S                          SAMPLING PRESSURE    BARS ABS.
K               393.00        H2                           DISCHARGE ENTHALPY    MJOUL/KG
CA               16.80        O2                           DISCHARGE              KG/SEC.      0.0
MG                5.250       CH4
CO2               2.54        N2                           MEASURED TEMPERATURE DEGREES C      0.0
SO4             155.00                                     RESISTIVITY/TEMP.   OHMM/DEG.C      0.0/ 0.0
H2S               2.39                                     EH/TEMP.              MV/DEG.C    0.000/ 0.0
CL             3489.00
F                 0.00        LITERS GAS PER KG
DISS.SOLIDS       0.00        CONDENSATE/DEG.C                MEASURED DOWNHOLE TEMP.   FLUID INFLOW
AL                0.0000                                         DEGREES C/METERS      DEPTH (METERS)
B                46.9000
FE                0.0000      CONDENSATE (PPM)                      0.0       0.0             0.0
NH3               0.0000      PH/DEG.C                              0.0       0.0             0.0
                              CO2                                   0.0       0.0             0.0
                              H2S                                   0.0       0.0             0.0
                              NA                                    0.0       0.0             0.0
                                                                    0.0       0.0             0.0
                                                                    0.0       0.0             0.0
                                                                    0.0       0.0             0.0
                              CONDENSATE WITH NAOH (PPM)            0.0       0.0             0.0
                              CO2                                   0.0       0.0             0.0
                              H2S                                   0.0       0.0             0.0

IONIC STRENGTH =  0.10023      IONIC BALANCE :   CATIONS (MOL.EQ.)0.09498397
                                                 ANIONS  (MOL.EQ.)0.10125270
                                                 DIFFERENCE    (%)      -6.39

PH LOWER THAN 4.00

DEEP WATER (PPM)                                     DEEP STEAM (PPM)          GAS PRESSURES (BARS ABS.)

SIO2       431.94         CO2       3727.97          CO2          0.00         CO2        0.987E+01
NA        1389.30         H2S       1220.27          H2S          0.00         H2S        0.129E+01
K          282.88         H2           0.00          H2           0.00         H2         0.000E+00
CA          12.09         O2           0.00          O2           0.00         O2         0.000E+00
MG           3.779        CH4          0.00          CH4          0.00         CH4        0.000E+00
SO4        111.57         N2           0.00          N2           0.00         N2         0.000E+00
CL        2511.32         NH3          0.00          NH3          0.00         NH3        0.000E+00
F            0.00                                                              H2O        0.353E+02
DISS.S.      0.00                                                              TOTAL      0.464E+02
AL           0.0000
B           33.7576                                  H2O (%)                0.00
FE           0.0000                                  BOILING PORTION        0.00

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.736      KSO4-        0.686      FE++         0.239      FECL+        0.662
OH-         0.652      F-           0.652      FE+++        0.066      AL+++        0.066
H3SIO4-     0.662      CL-          0.641      FEOH+        0.680      ALOH++       0.226
H2SIO4--    0.226      NA+          0.662      FE(OH)3-     0.680      AL(OH)2+     0.686
H2BO3-      0.630      K+           0.641      FE(OH)4--    0.217      AL(OH)4-     0.671
HCO3-       0.662      CA++         0.239      FEOH++       0.217      ALSO4+       0.671
CO3--       0.206      MG++         0.279      FE(OH)2+     0.686      AL(SO4)2-    0.671
HS-         0.652      CAHCO3+      0.696      FE(OH)4-     0.686      ALF++        0.226
S--         0.217      MGHCO3+      0.662      FESO4+       0.680      ALF2+        0.686
HSO4-       0.671      CAOH+        0.696      FECL++       0.217      ALF4-        0.671
SO4--       0.195      MGOH+        0.703      FECL2+       0.680      ALF5--       0.206
NASO4-      0.686      NH4+         0.630      FECL4-       0.662      ALF6---      0.029

PH LOWER THAN 4.00

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.01   -4.902         MG++         2.77   -3.944         FE(OH)3      0.00   0.000
OH-           0.02   -5.982         NACL       135.56   -2.635         FE(OH)4-     0.00   0.000
H4SIO4      690.82   -2.143         KCL         13.52   -3.741         FECL+        0.00   0.000
H3SIO4-       0.08   -6.093         NASO4-      19.41   -3.788         FECL2        0.00   0.000
H2SIO4--      0.00  -12.110         KSO4-       17.70   -3.883         FECL++       0.00   0.000
NAH3SIO4      0.04   -6.444         CASO4        4.71   -4.461         FECL2+       0.00   0.000
H3BO3       193.06   -2.506         MGSO4        4.88   -4.392         FECL3        0.00   0.000
H2BO3-        0.02   -6.476         CACO3        0.00   -8.031         FECL4-       0.00   0.000
H2CO3      5236.00   -1.074         MGCO3        0.00   -9.555         FESO4        0.00   0.000
HCO3-        16.52   -3.568         CAHCO3+      2.52   -4.603         FESO4+       0.00   0.000
CO3--         0.00   -9.280         MGHCO3+      0.07   -6.057         AL+++        0.00   0.000
H2S        1213.43   -1.448         CAOH+        0.00   -7.763         ALOH++       0.00   0.000
HS-           6.63   -3.698         MGOH+        0.01   -6.640         AL(OH)2+     0.00   0.000
S--           0.00  -13.300         NH4OH        0.00    0.000         AL(OH)3      0.00   0.000
H2SO4         0.00   -9.380         NH4+         0.00    0.000         AL(OH)4-     0.00   0.000
HSO4-        26.51   -3.564         FE++         0.00    0.000         ALSO4+       0.00   0.000
SO4--        49.88   -3.285         FE+++        0.00    0.000         AL(SO4)2-    0.00   0.000
HF            0.00    0.000         FEOH+        0.00    0.000         ALF++        0.00   0.000
F-            0.00    0.000         FE(OH)2      0.00    0.000         ALF2+        0.00   0.000
CL-        2422.67   -1.165         FE(OH)3-     0.00    0.000         ALF3         0.00   0.000
NA+        1332.21   -1.237         FE(OH)4--    0.00    0.000         ALF4-        0.00   0.000
K+          270.67   -2.160         FE(OH)++     0.00    0.000         ALF5--       0.00   0.000
CA++          9.71   -3.616         FE(OH)2+     0.00    0.000         ALF6---      0.00   0.000

IONIC STRENGTH =  0.06861      IONIC BALANCE :   CATIONS (MOL.EQ.)0.06560814
                                                 ANIONS  (MOL.EQ.)0.06985241
                                                 DIFFERENCE    (%)      -6.27

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.94

QUARTZ      239.5
CHALCEDONY  999.9
NAK         284.3

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.355    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                TEOR.    CALC.                        TEOR.    CALC.                       TEOR.    CALC.
ADULARIA      -14.428   99.999      ALBITE LOW      -13.975   99.999      ANALCIME       -11.524   99.999
ANHYDRITE      -7.978   -8.233      CALCITE         -12.591  -14.204      CHALCEDONY      -2.023   -2.143
MG-CHLORITE   -84.354   99.999      FLUORITE        -10.920   99.999      GOETHITE         1.889   99.999
LAUMONTITE    -24.536   99.999      MICROCLINE      -15.119   99.999      MAGNETITE      -17.601   99.999
CA-MONTMOR.   -72.623   99.999      K-MONTMOR.      -34.027   99.999      MG-MONTMOR.    -74.117   99.999
NA-MONTMOR.   -34.300   99.999      MUSCOVITE       -17.852   99.999      PREHNITE       -37.100   99.999
PYRRHOTITE    -24.961   99.999      PYRITE          -46.345   99.999      QUARTZ          -2.135   -2.143
WAIRAKITE     -24.425   99.999      WOLLASTONITE      7.602    3.422      ZOISITE        -37.653   99.999
EPIDOTE       -77.240   99.999      MARCASITE       -28.751   99.999
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ORKUSTOFNUN   JHD             GEOCHEMISTRY OF WELL PN-13D
1982-11-12  OLIVER
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%%%%%%%%%%820127%%%%  PUHAGAN-13D                                         S.NEGROS,PHILIPPINES  PUHAGAN

PROGRAM WATCH1.

WATER SAMPLE (PPM)            STEAM SAMPLE

PH/DEG.C          5.95/25.0   GAS (VOL.%)                   REFERENCE TEMP.      DEGREES C   268.0 (MEASURED)
SIO2            675.00        CO2               0.00
NA             2472.00        H2S               0.00        SAMPLING PRESSURE    BARS ABS.    11.5
K               551.00        H2                0.00        DISCHARGE ENTHALPY    MJOUL/KG   1.202 (MEASURED)
CA               58.30        O2                0.00        DISCHARGE              KG/SEC.    14.1
MG               0.380        CH4               0.00
CO2              18.30        N2                0.00        MEASURED TEMPERATURE DEGREES C     0.0
SO4              24.90                                      RESISTIVITY/TEMP.   OHMM/DEG.C     0.0/ 0.0
H2S              10.20                                      EH/TEMP.              MV/DEG.C   0.000/ 0.0
CL             4773.00
F                 0.00        LITERS GAS PER KG
DISS.SOLIDS       0.00        CONDENSATE/DEG.C 13.00/25.0     MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL              0.0000                                           DEGREES C/METERS      DEPTH (METERS)
B              61.3000
FE              0.0000        CONDENSATE (PPM)                       0.0       0.0             0.0
NH3             0.0000        PH/DEG.C          0.00/ 0.0            0.0       0.0             0.0
                              CO2               0.00                 0.0       0.0             0.0
                              H2S               0.00                 0.0       0.0             0.0
                              NA                0.00                 0.0       0.0             0.0
                                                                     0.0       0.0             0.0
                                                                     0.0       0.0             0.0
                                                                     0.0       0.0             0.0
                              CONDENSATE WITH NAOH (PPM)             0.0       0.0             0.0
                              CO2           23081.90                 0.0       0.0             0.0
                              H2S             646.30                 0.0       0.0             0.0

IONIC STRENGTH =  0.13136     IONIC BALANCE :  CATIONS (MOL.EQ.)0.12428541
                                               ANIONS  (MOL.EQ.)0.13502967
                                               DIFFERENCE    (%)     -8.29

DEEP WATER (PPM)                                      DEEP STEAM (PPM)           GAS PRESSURES (BARS ABS.)

SIO2        544.67         CO2        1704.92         CO2       178562.48        CO2        0.390E+01
NA         1994.52         H2S          92.14         H2S         2944.96        H2S        0.830E-01
K           444.55         H2            0.00         H2             0.00        H2         0.000E+00
CA           47.04         O2            0.00         O2             0.00        O2         0.000E+00
MG           0.307         CH4           0.00         CH4            0.00        CH4        0.000E+00
SO4          20.09         N2            0.00         N2             0.00        N2         0.000E+00
CL         3850.75         NH3           0.00         NH3            0.00        NH3        0.000E+00
F             0.00                                                               H2O        0.533E+02
DISS.S.       0.00                                                               TOTAL      0.573E+02
AL          0.0000
B          49.4550                                    H2O (%)                1.75
FE          0.0000                                    BOILING PORTION        0.19

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.692      KS04-        0.629      FE++         0.172      FECL+       0.597
OH-         0.584      F-           0.584      FE+++        0.038      AL+++       0.038
H3SI04-     0.597      CL-          0.571      FEOH+        0.621      ALOH++      0.159
H2SI04--    0.159      NA+          0.597      FE(OH)3-     0.621      AL(OH)2+    0.629
H2B03-      0.556      K+           0.571      FE(OH)4--    0.150      AL(OH)4-    0.609
HC03-       0.597      CA++         0.172      FEOH++       0.150      ALS04+      0.609
C03--       0.140      MG++         0.213      FE(OH)2+     0.629      AL(S04)2-   0.609
HS-         0.584      CAHC03+      0.642      FE(OH)4-     0.629      ALF++       0.159
S--         0.150      MGHC03+      0.597      FES04+       0.621      ALF2+       0.629
HS04-       0.609      CAOH+        0.642      FECL++       0.150      ALF4-       0.609
S04--       0.129      MGOH+        0.651      FECL2+       0.621      ALF5--      0.140
NAS04-      0.629      NH4+         0.556      FECL4-       0.597      ALF6---     0.012

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.01   -4.979       MG++         0.29   -4.917       FE(OH)3       0.00   0.000
OH-           0.03   -5.808       NACL       427.67   -2.136       FE(OH)4-      0.00   0.000
H4SI04      871.11   -2.043       KCL         42.87   -3.240       FECL+         0.00   0.000
H3SI04-       0.08   -6.049       NAS04-       3.43   -4.541       FECL2         0.00   0.000
H2SI04--      0.00  -12.083       KS04-        4.38   -4.490       FECL++        0.00   0.000
NAH3SI04      0.06   -6.304       CAS04        2.52   -4.733       FECL2+        0.00   0.000
H3B03       282.83   -2.340       MGS04        0.05   -6.387       FECL3         0.00   0.000
H2B03-        0.03   -6.247       CAC03        0.00   -7.807       FECL4-        0.00   0.000
H2C03      2395.35   -1.413       MGC03        0.00  -11.083       FES04         0.00   0.000
HC03-         5.13   -4.075       CAHC03+      3.97   -4.406       FES04+        0.00   0.000
C03--         0.00   -9.863       MGHC03+      0.00   -7.512       AL+++         0.00   0.000
H2S          91.78   -2.570       CAOH+        0.01   -6.893       ALOH++        0.00   0.000
HS-           0.35   -4.980       MGOH+        0.00   -7.191       AL(OH)2+      0.00   0.000
S--           0.00  -14.260       NH4OH        0.00    0.000       AL(OH)3       0.00   0.000
H2S04         0.00  -10.029       NH4+         0.00    0.000       AL(OH)4-      0.00   0.000
HS04-         5.59   -4.239       FE++         0.00    0.000       ALS04+        0.00   0.000
S04--         6.86   -4.146       FE+++        0.00    0.000       AL(S04)2-     0.00   0.000
HF            0.00    0.000       FEOH+        0.00    0.000       ALF++         0.00   0.000
F-            0.00    0.000       FE(OH)2      0.00    0.000       ALF2+         0.00   0.000
CL-        3570.94   -0.997       FE(OH)3-     0.00    0.000       ALF3          0.00   0.000
NA+        1825.60   -1.100       FE(OH)4--    0.00    0.000       ALF4-         0.00   0.000
K+          420.80   -1.968       FE(OH)++     0.00    0.000       ALF5--        0.00   0.000
CA++         44.72   -2.952       FE(OH)2+     0.00    0.000       ALF6---       0.00   0.000

IONIC STRENGTH =  0.09792      IONIC BALANCE :   CATIONS (MOL.EQ.)0.09246597
                                                 ANIONS  (MOL.EQ.)0.10097204
                                                 DIFFERENCE    (%)      -8.79

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.85

QUARTZ      265.1
CHALCEDONY  999.9
NAK         301.1

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.390    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                 TEOR.    CALC.                        TEOR.    CALC.                        TEOR.    CALC.
ADULARIA       -14.371   99.999      ALBITE LOW      -13.938   99.999      ANALCIME        -11.566   99.999
ANHYDRITE       -8.441   -8.754      CALCITE         -13.242  -14.436      CHALCEDONY       -1.925   -2.043
MG-CHLORITE    -86.372   99.999      FLUORITE        -11.057   99.999      GOETHITE          3.286   99.999
LAUMONTITE     -24.717   99.999      MICROCLINE      -14.996   99.999      MAGNETITE       -15.172   99.999
CA-MONTMOR.    -72.580   99.999      K-MONTMOR.      -33.864   99.999      MG-MONTMOR.     -74.086   99.999
NA-MONTMOR.    -34.146   99.999      MUSCOVITE       -17.838   99.999      PREHNITE        -37.960   99.999
PYRRHOTITE     -10.789   99.999      PYRITE          -28.408   99.999      QUARTZ           -2.031   -2.043
WAIRAKITE      -24.913   99.999      WOLLASTONITE      7.189    4.197      ZOISITE         -38.801   99.999
EPIDOTE        -38.439   99.999      MARCASITE       -12.208   99.999
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ORKUSTOFNUN   JHD             GEOCHEMISTRY OF WELL PN-15D
1982-11-12  OLIVER
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%%%%%%%%%%820211%%%%  PUHAGAN-15D                                   S.NEGROS,PHILIPPINES  PUHAGAN

PROGRAM WATCH1.

WATER SAMPLE (PPM)          STEAM SAMPLE

PH/DEG.C          6.01/25.0  GAS (VOL.%)                   REFERENCE TEMP.       DEGREES C    274.0 (MEASURED)
SIO2              757.00     CO2              0.00
NA               2800.00     H2S              0.00         SAMPLING PRESSURE     BARS ABS.     4.8
K                 497.00     H2               0.00         DISCHARGE ENTHALPY    MJOUL/KG     1.206 (MEASURED)
CA                 63.10     O2               0.00         DISCHARGE               KG/SEC.     78.7
MG                 0.260     CH4              0.00
CO2               154.00     N2               0.00         MEASURED TEMPERATURE DEGREES C      0.0
SO4                25.60                                   RESISTIVITY/TEMP.   OHMM/DEG.C      0.0/ 0.0
H2S                 5.96                                   EH/TEMP.              MV/DEG.C    0.000/ 0.0
CL               4965.00
F                   0.00     LITERS GAS PER KG
DISS.SOLIDS         0.00     CONDENSATE/DEG.C 12.20/25.0     MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL                0.0000                                       DEGREES C/METERS        DEPTH (METERS)
B                57.0000
FE                0.0000     CONDENSATE (PPM)                       0.0       0.0            0.0
NH3               0.0000     PH/DEG.C         0.00/ 0.0             0.0       0.0            0.0
                             CO2              0.00                  0.0       0.0            0.0
                             H2S              0.00                  0.0       0.0            0.0
                             NA               0.00                  0.0       0.0            0.0
                                                                    0.0       0.0            0.0
                                                                    0.0       0.0            0.0
                                                                    0.0       0.0            0.0
                             CONDENSATE WITH NAOH (PPM)             0.0       0.0            0.0
                             CO2          23293.10                  0.0       0.0            0.0
                             H2S            317.90                  0.0       0.0            0.0

IONIC STRENGTH =  0.14127     IONIC BALANCE :   CATIONS (MOL.EQ.)0.13736156
                                                ANIONS  (MOL.EQ.)0.14154568
                                                DIFFERENCE    (%)     -3.00

DEEP WATER (PPM)                                    DEEP STEAM (PPM)         GAS PRESSURES (BARS ABS.)

SIO2       551.90        CO2        5942.73         CO2     541211.75        CO2        0.130E+02
NA        2041.19        H2S          88.51         H2S       2451.36        H2S        0.759E-01
K          362.29        H2            0.00         H2           0.00        H2         0.000E+00
CA          46.00        O2            0.00         O2           0.00        O2         0.000E+00
MG          0.190        CH4           0.00         CH4          0.00        CH4        0.000E+00
SO4         18.66        N2            0.00         N2           0.00        N2         0.000E+00
CL        3619.17        NH3           0.00         NH3          0.00        NH3        0.000E+00
F            0.00                                                            H2O        0.586E+02
DISS.S.      0.00                                                            TOTAL      0.716E+02
AL         0.0000
B         41.5490                                   H2O (%)              0.09
FE         0.0000                                   BOILING PORTION      0.27

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.692     KSO4-       0.628      FE++        0.168      FECL+       0.596
OH-         0.583     F-          0.583      FE+++       0.036      AL+++       0.036
H3SIO4-     0.596     CL-         0.570      FEOH+       0.620      ALOH++      0.155
H2SIO4--    0.155     NA+         0.596      FE(OH)3-    0.620      AL(OH)2+    0.628
H2BO3-      0.555     K+          0.570      FE(OH)4--   0.147      AL(OH)4-    0.608
HCO3-       0.596     CA++        0.168      FEOH++      0.147      ALSO4+      0.608
CO3--       0.137     MG++        0.209      FE(OH)2+    0.628      AL(SO4)2-   0.608
HS-         0.583     CAHCO3+     0.641      FE(OH)4-    0.628      ALF++       0.155
S--         0.147     MGHCO3+     0.596      FESO4+      0.620      ALF2+       0.628
HSO4-       0.608     CAOH+       0.641      FECL++      0.147      ALF4-       0.608
SO4--       0.126     MGOH+       0.650      FECL2+      0.620      ALF5--      0.137
NASO4-      0.628     NH4+        0.555      FECL4-      0.596      ALF6---     0.011

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.00   -5.398     MG++          0.18   -5.140      FE(OH)3       0.00   0.000
OH-           0.07   -5.384     NACL        486.54   -2.080      FE(OH)4-      0.00   0.000
H4SIO4      882.49   -2.037     KCL          37.28   -3.301      FECL+         0.00   0.000
H3SIO4-       0.20   -5.672     NASO4-        4.10   -4.463      FECL2         0.00   0.000
H2SIO4--      0.00  -11.331     KSO4-         4.51   -4.477      FECL++        0.00   0.000
NAH3SIO4      0.14   -5.911     CASO4         2.39   -4.755      FECL2+        0.00   0.000
H3BO3       237.57   -2.415     MGSO4         0.03   -6.554      FECL3         0.00   0.000
H2BO3-        0.07   -5.921     CACO3         0.03   -6.574      FECL4-        0.00   0.000
H2CO3      8319.67   -0.872     MGCO3         0.00   -9.999      FESO4         0.00   0.000
HCO3-        39.66   -3.187     CAHCO3+      26.06   -3.589      FESO4+        0.00   0.000
CO3--         0.00   -8.617     MGHCO3+       0.01   -6.820      AL+++         0.00   0.000
H2S          87.75   -2.589     CAOH+         0.02   -6.539      ALOH++        0.00   0.000
HS-           0.73   -4.653     MGOH+         0.01   -6.899      AL(OH)2+      0.00   0.000
S--           0.00  -13.476     NH4OH         0.00    0.000      AL(OH)3       0.00   0.000
H2SO4         0.00  -10.703     NH4+          0.00    0.000      AL(OH)4-      0.00   0.000
HSO4-         2.88   -4.527     FE++          0.00    0.000      ALSO4+        0.00   0.000
SO4--         7.58   -4.103     FE+++         0.00    0.000      AL(SO4)2-     0.00   0.000
HF            0.00    0.000     FEOH+         0.00    0.000      ALF++         0.00   0.000
F-            0.00    0.000     FE(OH)2       0.00    0.000      ALF2+         0.00   0.000
CL-        3306.31   -1.030     FE(OH)3-      0.00    0.000      ALF3          0.00   0.000
NA+        1848.97   -1.095     FE(OH)4--     0.00    0.000      ALF4-         0.00   0.000
K+          341.44   -2.059     FE(OH)++      0.00    0.000      ALF5--        0.00   0.000
CA++         34.94   -3.060     FE(OH)2+      0.00    0.000      ALF6---       0.00   0.000

IONIC STRENGTH =  0.09360      IONIC BALANCE :   CATIONS (MOL.EQ.)0.09117395
                                                 ANIONS  (MOL.EQ.)0.09410425
                                                 DIFFERENCE    (%)     -3.16

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.83

QUARTZ       266.5
CHALCEDONY   999.9
NAK          268.6

OXIDATION POTENTIAL (VOLTS) :      EH H2S= -0.452    EH CH4= 99.999    EH H2= 99.999    EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
               TEOR.    CALC.                      TEOR.    CALC.                      TEOR.    CALC.
ADULARIA     -14.372   99.999    ALBITE LOW      -13.943   99.999    ANALCIME        -11.587   99.999
ANHYDRITE     -8.554   -8.837    CALCITE         -13.401  -13.316    CHALCEDONY       -1.902   -2.037
MG-CHLORITE  -86.903   99.999    FLUORITE        -11.091   99.999    GOETHITE          3.631   99.999
LAUMONTITE   -24.782   99.999    MICROCLINE      -14.982   99.999    MAGNETITE       -14.576   99.999
CA-MONTMOR.  -72.580   99.999    K-MONTMOR.      -33.830   99.999    MG-MONTMOR.     -74.084   99.999
NA-MONTMOR.  -34.115   99.999    MUSCOVITE       -17.840   99.999    PREHNITE        -38.193   99.999
PYRRHOTITE    -7.333   99.999    PYRITE          -24.060   99.999    QUARTZ           -2.007   -2.037
WAIRAKITE    -25.049   99.999    WOLLASTONITE      7.094    4.924    ZOISITE         -39.106   99.999
EPIDOTE      -38.871   99.999    MARCASITE        -8.041   99.999
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ORKUSTOFNUN   JHD               GEOCHEMISTRY OF WELL PN-17D
1982-11-12  OLIVER
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%%%%%%%%%%820131%%%%  PUHAGAN-17D                                   S.NEGROS,PHILIPPINES  PUHAGAN

PROGRAM WATCH1.

WATER SAMPLE (PPM)            STEAM SAMPLE

PH/DEG.C         6.21/25.0    GAS (VOL.%)                  REFERENCE TEMP.      DEGREES C    245.0 (MEASURED)
SIO2            559.00        CO2              0.00
NA             2965.00        H2S              0.00        SAMPLING PRESSURE    BARS ABS.       6.6
K               421.00        H2               0.00        DISCHARGE ENTHALPY     MJOUL/KG   1.094 (MEASURED)
CA               68.60        O2               0.00        DISCHARGE               KG/SEC.    33.4
MG               0.420        CH4              0.00
CO2              40.20        N2               0.00        MEASURED TEMPERATURE DEGREES C      0.0
SO4              30.60                                     RESISTIVITY/TEMP.    OHMM/DEG.C      0.0/ 0.0
H2S               7.16                                     EH/TEMP.               MV/DEG.C   0.000/ 0.0
CL             4617.00
F                 0.00        LITERS GAS PER KG
DISS.SOLIDS       0.00        CONDENSATE/DEG.C 10.40/25.0     MEASURED DOWNHOLE TEMP.    FLUID INFLOW
AL              0.0000                                            DEGREES C/METERS      DEPTH (METERS)
B              53.3000
FE              0.0000        CONDENSATE (PPM)                      0.0       0.0             0.0
NH3             0.0000        PH/DEG.C         0.00/ 0.0            0.0       0.0             0.0
                              CO2              0.00                 0.0       0.0             0.0
                              H2S              0.00                 0.0       0.0             0.0
                              NA               0.00                 0.0       0.0             0.0
                                                                    0.0       0.0             0.0
                                                                    0.0       0.0             0.0
                                                                    0.0       0.0             0.0
                              CONDENSATE WITH NAOH (PPM)            0.0       0.0             0.0
                              CO2          19184.00                 0.0       0.0             0.0
                              H2S            327.80                 0.0       0.0             0.0

IONIC STRENGTH =  0.13896     IONIC BALANCE :   CATIONS (MOL.EQ.)0.14288795
                                                ANIONS  (MOL.EQ.)0.13101509
                                                DIFFERENCE    (%)      8.67

DEEP WATER (PPM)                                     DEEP STEAM (PPM)           GAS PRESSURES (BARS ABS.)

SIO2        457.71        CO2         874.01         CO2      151280.00         CO2       0.226E+01
NA         2427.52        H2S          34.86         H2S        1852.17         H2S       0.358E-01
K           344.67        H2            0.00         H2            0.00         H2        0.000E+00
CA           56.16        O2            0.00         O2            0.00         O2        0.000E+00
MG           0.344        CH4           0.00         CH4           0.00         CH4       0.000E+00
SO4          25.05        N2            0.00         N2            0.00         N2        0.000E+00
CL         3779.73        NH3           0.00         NH3           0.00         NH3       0.000E+00
F             0.00                                                              H2O       0.365E+02
DISS.S.       0.00                                                              TOTAL     0.388E+02
AL          0.0000
B          43.6340                                   H2O (%)                1.96
FE          0.0000                                   BOILING PORTION        0.18

GAS SOLUBILITY MULTIPLYING FACTOR :  1.00
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ACTIVITY COEFFICIENTS IN DEEP WATER
H+          0.706      KSO4-       0.645       FE++        0.191       FECL+       0.613
OH-         0.601      F-          0.601       FE+++       0.047       AL+++       0.047
H3SIO4-     0.613      CL-         0.587       FEOH+       0.636       ALOH++      0.177
H2SIO4--    0.177      NA+         0.613       FE(OH)3-    0.636       AL(OH)2+    0.645
H2BO3-      0.573      K+          0.587       FE(OH)4--   0.168       AL(OH)4-    0.625
HCO3-       0.613      CA++        0.191       FEOH++      0.168       ALSO4+      0.625
CO3--       0.157      MG++        0.234       FE(OH)2+    0.645       AL(SO4)2-   0.625
HS-         0.601      CAHCO3+     0.656       FE(OH)4-    0.645       ALF++       0.177
S--         0.168      MGHCO3+     0.613       FESO4+      0.636       ALF2+       0.645
HSO4-       0.625      CAOH+       0.656       FECL++      0.168       ALF4-       0.625
SO4--       0.145      MGOH+       0.666       FECL2+      0.636       ALF5--      0.157
NASO4-      0.645      NH4+        0.573       FECL4-      0.613       ALF6---     0.016

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)
H+ (ACT.)     0.00   -5.499      MG++         0.32   -4.880        FE(OH)3       0.00   0.000
OH-           0.08   -5.343      NACL       307.64   -2.279        FE(OH)4-      0.00   0.000
H4SIO4      731.58   -2.119      KCL         21.44   -3.541        FECL+         0.00   0.000
H3SIO4-       0.34   -5.451      NASO4-       6.43   -4.267        FECL2         0.00   0.000
H2SIO4--      0.00  -10.813      KSO4-        4.17   -4.511        FECL++        0.00   0.000
NAH3SIO4      0.28   -5.626      CASO4        3.90   -4.543        FECL2+        0.00   0.000
H3BO3       249.46   -2.394      MGSO4        0.09   -6.117        FECL3         0.00   0.000
H2BO3-        0.11   -5.731      CACO3        0.01   -6.858        FECL4-        0.00   0.000
H2CO3      1209.94   -1.710      MGCO3        0.00  -10.028        FESO4         0.00   0.000
HCO3-        15.46   -3.596      CAHCO3+     10.12   -4.000        FESO4+        0.00   0.000
CO3--         0.00   -8.647      MGHCO3+      0.01   -7.086        AL+++         0.00   0.000
H2S          34.07   -3.000      CAOH+        0.02   -6.497        ALOH++        0.00   0.000
HS-           0.76   -4.638      MGOH+        0.00   -6.997        AL(OH)2+      0.00   0.000
S--           0.00  -13.557      NH4OH        0.00    0.000        AL(OH)3       0.00   0.000
H2SO4         0.00  -11.255      NH4+         0.00    0.000        AL(OH)4-      0.00   0.000
HSO4-         1.46   -4.823      FE++         0.00    0.000        ALSO4+        0.00   0.000
SO4--        12.63   -3.881      FE+++        0.00    0.000        AL(SO4)2-     0.00   0.000
HF            0.00    0.000      FEOH+        0.00    0.000        ALF++         0.00   0.000
F-            0.00    0.000      FE(OH)2      0.00    0.000        ALF2+         0.00   0.000
CL-        3582.92   -0.995      FE(OH)3-     0.00    0.000        ALF3          0.00   0.000
NA+        2305.20   -0.999      FE(OH)4--    0.00    0.000        ALF4-         0.00   0.000
K+          332.22   -2.071      FE(OH)++     0.00    0.000        ALF5--        0.00   0.000
CA++         50.99   -2.895      FE(OH)2+     0.00    0.000        ALF6---       0.00   0.000

IONIC STRENGTH =  0.10795      IONIC BALANCE :   CATIONS (MOL.EQ.)0.11143742
                                                 ANIONS  (MOL.EQ.)0.10161908
                                                 DIFFERENCE    (%)       9.22

CHEMICAL GEOTHERMOMETERS DEGREES C               1000/T DEGREES KELVIN =  1.93

QUARTZ       244.5
CHALCEDONY   999.9
NAK          236.5

OXIDATION POTENTIAL (VOLTS) :     EH H2S= -0.423   EH CH4= 99.999   EH H2= 99.999   EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER
                TEOR.    CALC.                     TEOR.    CALC.                        TEOR.    CALC.
ADULARIA      -14.420   99.999    ALBITE LOW     -13.969   99.999     ANALCIME       -11.525   99.999
ANHYDRITE      -8.014   -8.334    CALCITE        -12.642  -13.067     CHALCEDONY      -2.015   -2.119
MG-CHLORITE   -84.503   99.999    FLUORITE       -10.931   99.999     GOETHITE         1.998   99.999
LAUMONTITE   -24.545   99.999    MICROCLINE     -15.105   99.999     MAGNETITE      -17.410   99.999
CA-MONTMOR.   -72.613   99.999    K-MONTMOR.     -34.012   99.999     MG-MONTMOR.    -74.113   99.999
NA-MONTMOR.   -34.286   99.999    MUSCOVITE      -17.848   99.999     PREHNITE       -37.162   99.999
PYRRHOTITE    -23.841   99.999    PYRITE         -44.921   99.999     QUARTZ          -2.126   -2.119
WAIRAKITE     -24.459   99.999    WOLLASTONITE     7.568    5.265     ZOISITE        -37.737   99.999
EPIDOTE       -37.318   99.999    MARCASITE      -27.993   99.999
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