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GEOCHEMICAL MONITORING OF THE ALUTO-LANGANO GEOTHERMAL FIELD, ETHIOPIA

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ABSTRACT

The Aluto-Langano pilot power plant is the first geothermal power plant producing electricity in the country. It has been operational since July 1998, and the commissioning work by Ethiopian Electric Power Corporation (EEPCO) was completed on June 16, 1999. The designed power output of the pilot power plant was 8.52 MWe (Gross) and 7.28 MWe (net). However, due to various problems, the power output is currently restricted to less than 2 MWe.

The Aluto-Langano geothermal power plant is the binary type, which consists of Geothermal combined cycle unit (GCCU) and Ormat energy converter (OEC). The pilot power plant is supplied with steam and brine from the four production wells (LA-3, LA-4, LA-6 and LA- 8) of around 2000-2500m depth. There is one re-injection well (LA-7), which is an original field exploration well.

Evaluation of change of concentrations of elements (e.g. chloride and silica) through time has demonstrated the absence of dilution or cooling effects in the deep wells of LA-3 and LA-6 due to invasion of cold water. The chemical data collected in the year 1999-2000 has indicated substantial increment of Cl, Si, Na, and K.

Evidence for the occurrence of stable thermal regime or slight heating of the upflow zone of the system (wells LA-3 and LA-6) has been documented by a comparison of chemical and gas geothermometric temperatures (Na-K-Ca = 355- 362°C ; CO2 = 337-347 °C) with the measured in hole temperatures (320-335 °C). The Na-K-Mg diagram is also supported this evidence where the recently collected discharge fluids (1999-2000) of wells LA-3 and LA-6 are found to be in full equilibrium with the reservoir rock at a temperature > 300°C. The discharge fluids collected during the year 1985-86 has fallen along the broad dilution/mixing line between the ground water and the deep reservoir fluid that is in equilibrium with the reservoir rock.

Evaluation of solution-mineral equilibria based on saturation indices has demonstrated the presence of likelihood of calcite and silica scaling problems in the productive wells of the Aluto-Langano geothermal field. Quartz could possibly precipitate within the boreholes, at the separator and in the brine transmission line of all four productive wells (LA-3, LA-4, LA-6 and LA-8). The scaling problem of calcite within the borehole, at the separator and in the brine transmission line is recognized only in well LA-4. There is a possibility of precipitation of amorphous silica in the brine transmission line of all four productive wells.

1. BACKGROUND

The Aluto-Langano geothermal field is located about 200 km south of Addis Ababa, close to the eastern margin of the Ethiopian Rift, and well inside the active axis of the rift, i.e. the Wonji Fault Belt (Fig.1). It is a high temperature (335ºC) water dominated gas rich geothermal field hosted by peralkaline rhyolitic lavas and ignimbrites as well as transitional to alkaline basalts.

In the Aluto-Langano geothermal field, eight deep exploratory wells were originally drilled to a maximum depth of 2500m, four of which are potentially productive. Exploratory wells identified an upflow zone (wells LA-3 and LA-6) with reservoir temperatures of 300-335°C and partial pressures of CO2 (6-13 bars). The zone of lateral outflow is characterized by more diluted waters with temperatures in the range of 150-270°C, local temperature inversion at the margins of the field and very high PCO2 (about 58 bars).

The Geological Survey of Ethiopia (GSE) handed over this geothermal field to the Ethiopian Electric Power Corporation (EEPCO) for development. The 1986 feasibility report was reviewed by Geothermal Energy New Zealand Limited (GENZL) in 1995. The turn Key contract for the construction of the pilot power plant was awarded to Ormat Industries of Israel on August 9, 1996.

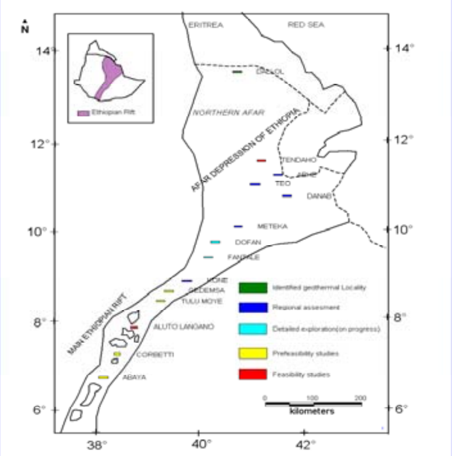

Fig.1 Location Map of the Geothermal Prospect Areas with in the Ethiopian Rift Valley

Figure 1 The Aluto-Langano Geothermal Pilot Power Plant Station

The Aluto-Langano pilot power plant is the first geothermal power plant producing electricity in the country. The designed power output of the pilot power plant was 8.52 MWe (Gross) and 7.28 MWe (net). However, due to various problems (e.g. heat exchanger tube leak) , the power output is currently restricted to < 2 MWe.

The Aluto-Langano geothermal power plant is the binary type, which consists of two types of thermodynamic cooling cycles, (i) Geothermal combined cycle unit (GCCU) and (ii) Ormat energy converter (OEC). The pilot power plant was supposed to be supplied with steam and brine from the four production wells (LA-3, LA-4, LA-6 and LA- 8) of around 2000-2500m depth. There is one re-injection well (LA-7), which is an original field exploration well. The working fluid in the binary units is iso-pentane. Ambient air is the cooling media for the condenser in both units.

2. INTRODUCTION

2.1 Fluid chemistry

The hot spring waters, and the fluid from temperature gradient (TG) and deep wells of the Aluto-Langano geothermal field belong to an alkali-bicarbonate chloride water, with pH near neutral to slightly alkaline (Mekuria et al., 1987). The geothermal wells produce two phase fluid (water + steam) with a total flow rate of 10.4-25.6 Kg/sec. The deep wells in the upflow zone produce fluids of high enthalpy (1610-1650 kJ/kg) while the wells along the outflow zone produce fluids with a lower enthalpy (1000-1250 KJ/Kg). The geothermal fluids are characterized by a high gas content, with partial pressures of CO2 from 6-58 bar (Teklemariam, 1996).

2.2 Objective of the present work

The main objective of the present work is to perform geochemical monitoring of the deep wells in the Aluto-Langano geothermal field to evaluate and/or estimate various kinds of chemical and physical changes that are occurring as a result of exploitation and fluid depletion .

The assembled chemical and gas data from these productive wells and their interpretation would provide a means for constructing a conceptual model of the reservoir, that can be used for future assessment and management of the resource. The results of this work might also facilitate the understanding of other geothermal systems identified within the Ethiopian Rift, for which the exploration activities have not yet reached the same level of knowledge as that of the Aluto-Langano geothermal field e.g. Tendaho and Corbetti geothermal fields.

3. MATERIALS AND METHODS USED

The present geochemical study of discharge fluids from the productive wells of the Aluto-Langano geothermal field involve the following steps: (1) Field work; (2) Laboratory analysis; (3) Data processing and interpretation of results.

3.1 Field work

A total of fifteen water and three gas samples were collected from productive wells of LA-3 and LA-6 for chemical, gas and isotope determinations. Besides, water sample from the re-injection well, LA-7, was collected for chemical and isotope determination.

Physical measurements carried out at field site were mainly Well Head Pressure (WHP), Sampling Point Pressure (SPP), Sampling pressure (SP) and temperature, pH and conductivity of the sample. Chemical analysis performed at field laboratory were mainly determination of total carbonate (CO3 and HCO3), chloride and silica as well.

3.2. Chemical and gas analysis

Water samples, which were collected from the two deep geothermal wells (LA-3 and LA-6) of the Aluto-Langano geothermal field, were chemically analysed at the Central Geological Laboratory of the GSE (Tab. 1) . Gas samples from the deep wells of LA-3 and LA-6 were analysed for He, H2, N2 using the Gas Chromatogrph.

3.3 Data processing

Geochemical study based on computer data processing has been carried out using the chemical and gas data of the geothermal fluids from the productive wells of Aluto (LA-3, LA-4, LA-6 and

LA-8). The different methods applied for this study were application of various geochemical softwares such as WATCH (Arnorsson et.al., 1982) and SOLMINEQ 88 (Kharaka et al., 1989).

To have a better understanding of the deep conditions of the reservoir, already existing chemical and gas data from deep wells of the Aluto-Langano geothermal field (Mekuria et al., 1987; Gizaw, 1989; Teklemariam, 1996; Teklu and Gizaw, 1999) were used together with the present data for data processing and interpretation.

4. ANALYTICAL RESULTS

The presentation of the results is in the form of (1) Water chemistry ; (2) Output data; (3) Evaluation of water-rock equilibria by use of Na, K, and Mg content of geothermal fluids ; (4) Evaluation of chemical equilibria between alteration mineral assemblages and geothermal fluids based on saturation indices; and (5) Gas geochemistry .

4.1 Water chemistry

The chemical data of discharge fluid from the two high pressure wells (LA-3 and LA-6) of the Aluto-Langano geothermal field is given in Table 1. Representative data from the existing data-file (Mekuria et al., 1987; Gizaw, 1989; Teklu and Gizaw, 1999) were used together with the present data for data processing and interpretation (Tab. 2).

The chemical data given in Table 2 are plotted in the Cl-HCO3-SO4 triangular plot (Fig. 2) . The data plotted on the triangular diagram are representative of the reservoir fluids. The discharge fluids from wells LA-3 and LA-6, collected at different times, belong to the alkali-bicarbonate chloride type. Here, the waters are characterized by higher bicarbonate concentrations, indicating the absence of important dilution and/or cooling effects in the productive wells of LA-3 and LA-6.

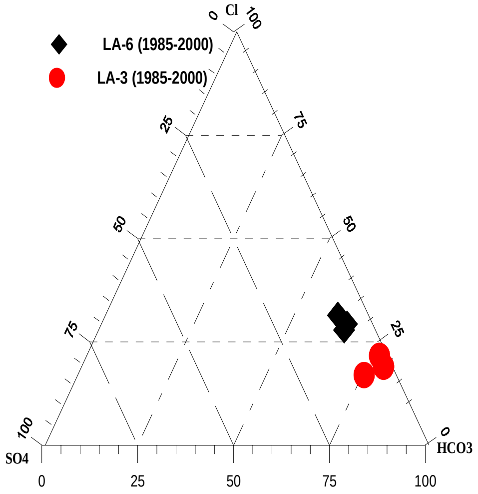

FIGURE 2: A plot of Cl-HCO3-SO4.

In order to evaluate the change of concentrations of certain elements (Si, Cl, Na, K) through time, chemical data collected at different times were plotted on Figures 3 and 4 for the wells LA-3 and LA-6, respectively. The chemical data collected from 1987-1999 do not show significant variation of concentration of the elements considered through time. However, substantial increment of the concentration of the elements is observed in the year 1999-2000 (Figs. 3 and 4) .

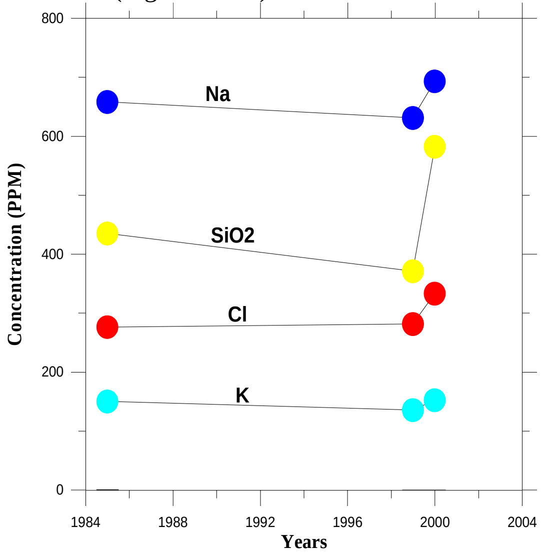

FIGURE 3: A Plot of concentration vs time (well LA-3).

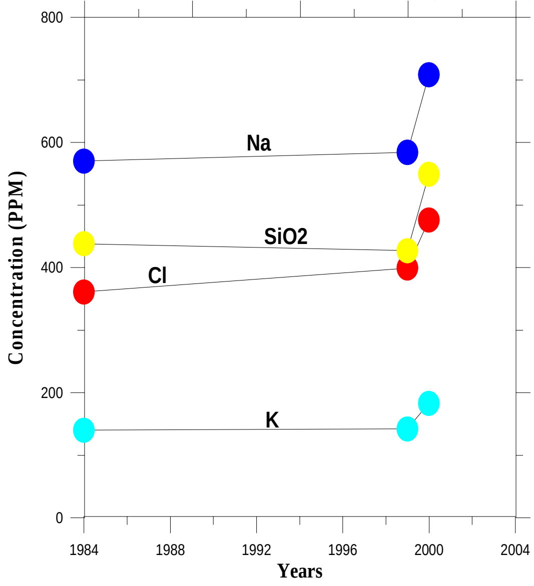

FIGURE 4: A Plot of concentration vs time (well LA-6)

4.2 Output data

The output data of WATCH and SOLMINEQ88 computer programs include: Partial pressure of gases, Chemical geothermometers, pH of the fluid at various temperature, and Saturation indices of the minerals and activities of aqueous ions.

(a) Partial pressure of Carbon dioxide:

The presence of a large amount of carbonates in the reservoir fluid is observed. This is indicated by the presence of high PCO2 values as computed using both WATCH and SOLMINEQ88 programs. The reservoir fluid PCO2 vary from 35 to 60 bars for the productive wells of the Aluto-Langano geothermal field.

(b) Chemical geothermometer:

Reservoir temperatures were calculated using the present data and the data presented by Teklu and Gizaw (1999). The Na-K-Ca geothermometer gave a good estimate of the reservoir temperatures (350-360°C) which are close to the measured in-hole temperatures of the wells LA-3 (320°C) and LA-6 (335°C).

The reservoir rock is in equilibrium with calcium bearing phases as there is a consistency of the computed temperatures, using the geothermometer, with the measured in-hole temperatures.

In the case of wells LA-4 (233°C) and LA-8 (282°C), the closest computed temperatures to the measured in-hole temperatures are found to be 230°C (Na/K) and 287°C (Na-K-Ca), respectively.

4.3 Evaluation of water-rock equilibria by use of Na, K and Mg content of geothermal fluids

Evaluation of the Na, K, Mg geothermometer was carried out by the use of triangular diagram provided by Giggenbach (1988). The chemical data obtained from the present work and previous studies (Mekuria et al., 1987; Teklu and Gizaw, 1999) were plotted in such a diagram (Fig.5). The plot reveals that the earlier chemical data (1985-86) from the deep wells of LA-3 and LA-6 fall along the dilution line indicating that the discharge fluids are in partial equilibrium condition with the reservoir rock. They are found to be the result of mixing between the shallow ground (immature water) and the deep reservoir fluid, which is in equilibrium with the reservoir rock.

On the other hand, the present data and the data collected by Teklu and Gizaw (1999) were plotted at the equilibrium line (Fig. 5) indicating that these fluids are found to be in full equilibrium with the reservoir rock at a temperature greater than 300°C. This temperature range is in a good agreement with the in-hole measured temperature (320-335°C) and also with the temperature computed by using Na-K-Ca correction geothermometers of (350-360°C).

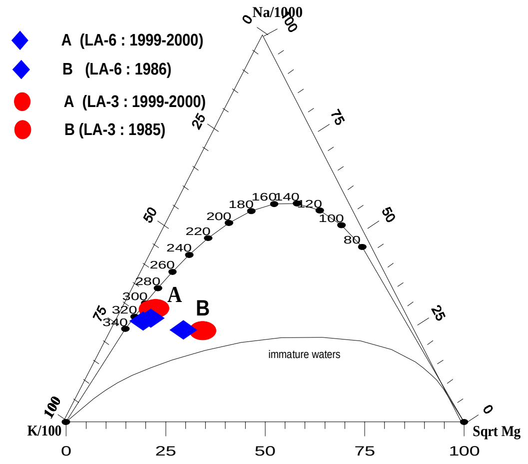

FIGURE 5: Na-K-Mg diagram (Giggenbach, 1988).

4.4 Evaluation of chemical equilibria between alteration mineral assemblages and reservoir fluids based on saturation indices

Figs. 6, 7, 8, 9 and 10 depict a plot of Saturation index vs temperature for wells LA-3, LA-4, LA-6, LA-8 and LA-7 (re-injection well). The value of saturation indices for each mineral were computed using both WATCH and SOLMINEQ-88 computer programs . Only the authigenic minerals that are assumed to create scaling problems (Calcite, amorphous silica and quartz) are considered here.

The discharge fluid of well LA-3 is oversaturated with quartz at a temperature < 290°C whereas the fluid is found to be undersaturated with respect to calcite and amorphous silica throughout the temperature range (Fig. 6). In the case of well LA-6, the discharge fluid is oversaturated with quartz (< 285°C) and amorphous silica at a temperature < 175°C (Fig. 7). Calcite is found to be undersaturated throughout the temperature range (150-350°C).

On the other hand, in well LA-4, the discharge fluid is found to be oversaturated with respect to calcite and quartz at a temperature < 210°C. Amorphous silica is understurated with respect to the fluid throughout the temperature range (Fig. 8). In the case of well LA-8, the discharge fluid is oversaturated with respect to quartz at a temperature < 233°C. Calcite is found to be near saturation at a temperature of about 250 °C (Fig. 9). In the case of the reinjection well, well LA-7, quartz and amorphous silica are oversaturated throughout the temperature range and at a temperature of < 200°C and <100°C, respectively. Calcite is undersaturated at a temperature of < 190 °C (Fig. 10). At higher temperatures, most of the discharge fluids of the productive wells seem to be undersaturated with respect to silica (quartz and amorphous silica) whereas they are oversaturated at a lower temperature. The super-saturation condition of calcite is mostly observed in well LA-4, which might be due to the high PCO2 condition (reaches to about 60 bar) in the reservoir fluid.

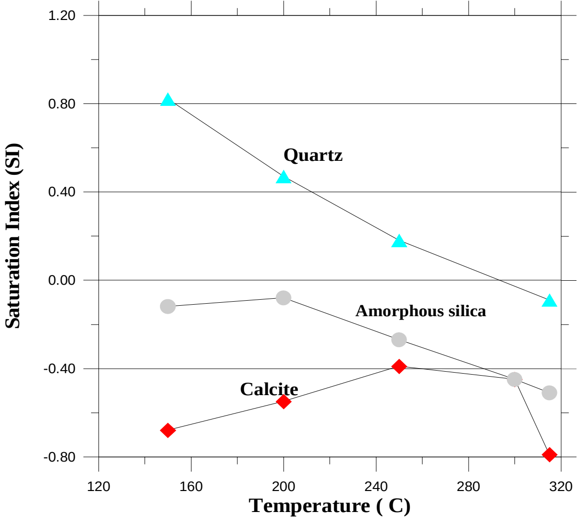

FIGURE 6: A plot of SI vs temperature (well LA-3)

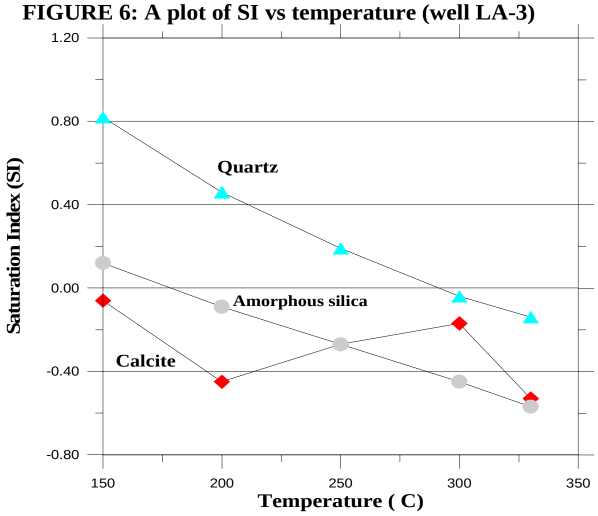

FIGURE 7: A plot of SI Vs temperature (well LA-6)

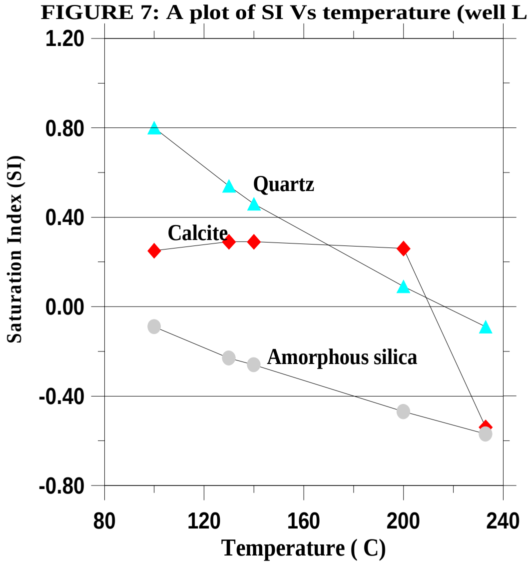

FIGURE 8: A plot of SI vs temperature (well LA-4)

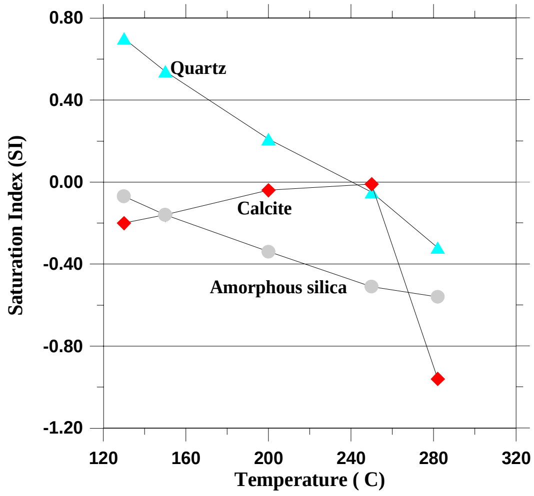

FIGURE 9: A plot of SI vs temperature (well LA-8)

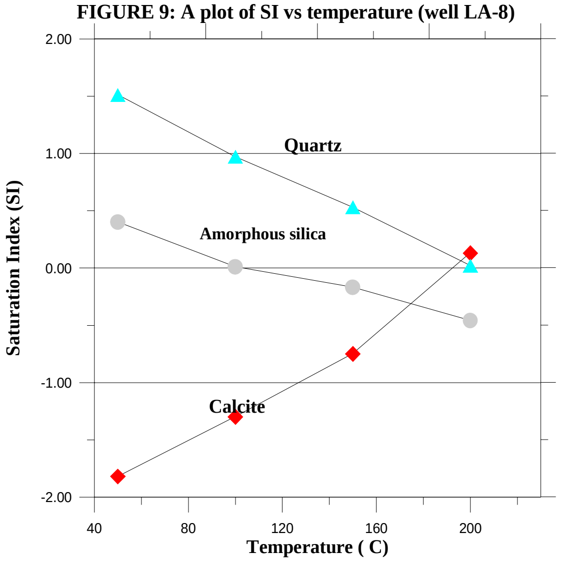

FIGURE 10: A plot of SI vs temperature (well LA-7)

5. DISCUSSION

The concentration of elements in geothermal water are dependent on temperature. Mixing of geothermal water and colder water often causes deviation from equilibrium. Changes in the chemical composition of geothermal water caused by inflow of cold water may precede temperature and chemical changes. The results of chemical changes may be a source of potential corrosion and scaling. Data obtained from chemical monitoring of fluids may, therefore, give warning in time for preventive actions.

Based on this approach, discussion of the results has taken place by focussing on the production characteristics of geothermal fields such as cooling, scaling and environmental problems.

5.1 Absence of Cooling Effects in the Reservoir

Elements which have been proved to be valuable in chemical monitoring of exploited geothermal fields are mainly chloride (Cl), Silica (Si), Magnesium (Mg), Hydrogen sulfide (H2S), Fluoride (F), and dissolved oxygen (Axellsson and Gunnlaugsson, 2000). These elements are controlled by equilibrium with few minerals, and are usually first to show changes.

For this purpose, determination of reservoir Silica and Chloride concentrations are probably the most important. A fall in the reservoir chloride probably indicates dilution of the reservoir fluids and, if coupled with a drop in silica temperatures, could signal cause for alarm. As it is shown in figures 3 and 4 , an increment of concentration of reservoir silica, Chloride, sodium and potassium is observed through a period of time from 1984 to 2000. This indicates the absence of dilution of the reservoir fluid, and hence no cooling effects in the reservoir. The good health of the reservoir (e.g absence of dilution/cooling) in these wells is also detected by using the Na-K-Mg triangular diagram (Fig.5) of Giggenbach (1988), where recently collected discharge fluids (1999-2000 A) have fallen at the full equilibrium line with the reservoir rock at a temperature of more than 300°C. On the other hand, discharge fluids collected in 1985-1986 fall along the dilution line between the surface groundwater and the deep reservoir fluid (Fig. 5). The good condition of the reservoir of wells LA-3 and LA-6 is also supported by the presence of high computed reservoir temperatures using chemical (Na-K-Ca=350-360°C) and gas (CO2) geothermometers (337-347°C). These computed temperatures using both chemical and gas geothermometers are found to be slightly higher than the in-hole measured temperature of the wells LA-3 (320 °C) and LA-6 (335 °C). This could possibly indicate the heating up of the upflow zone of the system. This is also in good agreement with the results obtained from fluid inclusion study (Teklemariam, 2000) that has indicated the occurrence of heating condition within the center of the field (wells LA-3 and LA-6).

5.2 Likelihood of Scaling Problems

Knowledge of the physical and chemical conditions causing mineral deposition from geothermal water allows an evaluation of the magnitude of the scaling problems and may help in visualizing how they could be overcome.

Based on this approach, the present study has given emphasis on monitoring of the likelihood of calcite and silica (amorphous silica and quartz) scaling problems. The emphasis was mainly based on the comparison of the water chemical composition with the solubility of the minerals. Such data enables to predict scaling. It is worth noting that this limited study could not and does not provide guidance about the rate of deposition of these minerals.

Reservoir fluids of wells LA-3 and LA-6 are found to be oversaturated with respect to quartz at a temperature < 280-290º C (Figs. 6 and 7). This might indicate that there could be a possibilty of scaling probelm of quartz within the borehole, separator , and also in the brine transmission line. In both wells of LA-3 and LA-6, calcite would not create scaling problems within the formation as well as within the boreholes.

In well LA-4, Calcite and quartz are found to be oversaturated with respect to the reservoir fluid at temperature of about < 210°C (Fig.8). This could indicate the possibility of precipitation of both calcite and quartz within the borehole, at the separator and also in the brine transmission line. The oversaturation condition of calcite is mostly observed in this well which is due to the high partial pressure of carbondioxide in the reservoir.

In the case of well LA-8 (Fig. 9) quartz is found to be oversaturated with respect to the reservoir fluid at a temperature < 233°C. Calcite is near saturation at a temperature of about 250°C while amorphous silica is found to be undersaturated with respect to the reservoir fluid throughout the temperature range. This reveals that there could possibly be scaling problem of quartz within the borehole, at the separator and in the brine transmission line.

The re-injection temperature of the waste water is about 80°C . In the reinjection well (Fig. 10) amorphous silica and quartz are found to be oversaturated at a temperature of about <100°C and <200°C, respectively. This shows that there is a possibility of precipitation of these minerals in the waste water transmission line and also in the re-injection well.

6. CONCLUSIONS

The conclusion is mainly based on the assembled chemical and gas data from the productive wells of Aluto. The conclusions include:

(i) Evaluation of change of concentrations of elements (e.g. chloride and silica) through time has demonstrated the absence of dilution or cooling effects in the deep wells of LA-3 and LA-6 due to invasion of cold water. The chemical data collected in the year 1999-2000 has indicated substantial increment of Cl, Si, Na, and K. Their increment of concentration in the reservoir fluid might indicate the occurrence of boiling within the Aluto-Langano geothermal system.

(ii) Evidence for the occurrence of stable thermal regime or slight heating of the upflow zone of the system (wells LA-3 and LA-6) has been documented by a comparison of chemical and gas geothermometric temperatures (Na-K-Ca = 355-362°C ; CO2 = 337-347 °C) with the measured in hole temperatures (320-335 °C). The Na-K-Mg diagram is also supported this evidence where the recently collected discharge fluids (1999-2000) of wells LA-3 and LA-6 are found to be in full equilibrium with the reservoir rock at a temperature > 300°C. The discharge fluids collected during the year 1985-86 has fallen along the broad dilution/mixing line between the ground water and the deep reservoir fluid that is in equilibrium with the reservoir rock.

(iii) Evaluation of solution-mineral equilibria based on saturation indices has demonstrated the likelihood of calcite and silica scaling problems in the productive wells of the Aluto-Langano geothermal field. Quartz could possibly precipitate within the boreholes, at the separator and in the brine transmission line of all four productive wells (LA-3, LA-4, LA-6 and LA-8). The scaling problem of calcite within the borehole, at the separator and in the brine transmission line is recognized only in well LA-4. There is a possibility of precipitation of amorphous silica in the brine transmission line of all four productive wells.

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TABLE 1: Chemical data for the deep wells of LA-3 and LA-6, Aluto-Langano geothermal field. Concentration in PPM. Conductivity=µs/cm-sec. SW= Separated water; WB= Weir box; RW= Re-injection well

Feature	Cond.	pH	Na	Ca	Mg	K	CO3	HCO3	Cl	SO4	F	NO3	HBO2	SiO2
LA-3 (SW)	4918	9.15	1070	0.1	<0.1	235	194	1642	514	26	74.6	19.64	25.53	899
LA-6 (SW)	5760	8.99	1170	0.1	<0.1	303	151	1423	787	177	75.2	26.47	49	907
LA-3 (SW)	4563	9.3	1000	0.1	<0.1	228	242	1464	514	23	73.6	20.87	25.21	974
LA-6 (SW)	5456	9.04	1110	0.1	<0.1	290	190	1314	791	158	73.6	22.15	48.06	936
LA-3 (SW)	4636	9.07	1010	0.2	<0.1	228	244	1458	493	19	76.8	19.94	25.84	997
LA-6 (SW)	5467	8.89	1150	0.1	<0.1	290	142	1365	783	162	76.4	24.37	48.54	912
LA-6 (SW)	5530	9.03	1140	0.2	<0.1	285	21	1282	801	180	74.3	26.58	48.38	916
LA-3 (SW)	4531	8.97	990	0.1	<0.1	220	162	1509	486	21	73.2	19.94	26.63	982
LA-3 (SW)	4584	9.16	1040	<0.1	<0.1	228	252	1393	510	19	72.2	24.37	26	984
LA-6 (SW)	5593	9.03	1150	0.2	<0.1	290	174	1354	794	163	74.7	24.37	48.69	934
LA-6(WB)	6487	9.76	1340	0.2	<0.1	340	625	748	900	207	90.2	20.82	55.94	1048
LA-3(WB)	5288	9.14	1170	0.1	<0.1	255	284	1543	553	25	83.3	12.4	31.36	993
LA-6(SW)	5726	9.03	1200	0.1	<0.1	305	198	1437	808	191	78.5	17.72	50.74	960
LA-6(WB)	6591	9.75	1400	0.1	<0.1	350	656	786	936	205	88.5	19.94	57.52	1107
LA-7 (RW)	4007	7.64	760	0.1	<0.1	203	-	1180	539	108	50.5	22.15	34.98	465

TABLE 2: Representative previous and present chemical data. Concentration in PPM. SW= Separated water; WB= Weir Box; RW= Re-injection well; WHP = Well head Pressure (Bar guage); SPP = Sampling point pressure(Bar guage) ; SP= Sampling pressure (Bar guage) ; ST= Sampling temperature (ºC). (-) = not determined. SP for WB= 1 atm

Date	Well	WHP	SPP	SP	ST	pH	Na	K	Ca	Mg	CO3	HCO3	Cl	SO4	F	NO3	HBO2	SiO2
4/4/00	LA-3 (SW)	-	5.6	6	-	9.2	1070	235	0.1	<0.1	194	1642	514	26	74.6	19.6	25.53	899
10/4/00	LA-3 (SW)	6.4	5.6	6.1	73	9.1	1010	228	0.2	<0.1	244	1458	493	19	76.8	19.9	25.84	997
9/3/99	LA-3 (SW)	6.5	5	3.5	40	8.8	1020	218	0.2	<0.1	137	1681	454	33	64.9	0.4	28.06	599
16/3/99	LA-3 (SW)	5.8	4.6	4.5	35	8.4	940	208	0.1	<0.1	18	1729	471	61	62	5.8	26.2	572
9/11/92	LA-3 (SW)	-	-	-	-	8.9	1010	225	0.9	<0.1	-	1696	483	85	69.4	11.2	25.3	1091
25/11/90	LA-3 (SW)	"	"	1.7	"	9.0	1040	217	2	0.1	-	-	550	13	72	-	28	1055
29/4/85	LA-3 (SW)	"	"	3	"	9.1	1100	250	3	0.75	198	1696	462	202	68	"	25	728
20/4/00	LA-3 (WB)	"	-	1	"	9.1	1170	255	0.1	<0.1	284	1543	553	25	83.3	12.4	31.36	993
23/2/99	LA-3 (WB)	"	"	"	"	10	1240	296	0.1	<0.1	695	904	592	82	68	16.3	38.9	706
16/3/99	LA-3 (WB)	"	"	"	"	9.7	1170	255	0.1	<0.1	732	728	619	77	73.9	20.8	31.4	888
29/4/85	LA-3 (WB)	"	"	"	"	9.4	1200	275	3	0.5	420	1635	540	45	78	-	20	813
5/4/00	LA-6 (SW)	6.8	6.2	6.2	80	8.9	1170	303	0.1	<0.1	151	1423	787	177	75.2	26.4	49	907
13/4/00	LA-6 (SW)	7.5	7	6.9	81	9.0	1140	285	0.2	<0.1	211	1282	801	180	74.3	26.6	48.38	916
21/3/99	LA-6 (SW)	18	8.5	7.2	31	8.1	960	233	0.1	<0.1	-	1498	656	128	43.6	31	19.4	701
10/11/92	LA-6 (SW)	-	-	-	-	8.6	1140	291	1	0.3	"	1696	725	200	73.2	14	48.2	941
11/1190	LA-6 (SW)	"	"	5.4	"	8.6	1240	296	2	0.1	"	-	845	180	77	-	45	1002
3/10/84	LA-6 (SW)	"	"	4.5	"	8.8	975	240	4	0.3	120	1305	617	161	50	"	28	749
20/4/00	LA-6 (WB)	"	"	1	"	9.8	1340	340	0.2	<0.1	625	748	900	207	90.2	20.8	55.94	1048
25/4/00	LA-6 (WB)	"	"	“	"	9.8	1400	350	0.1	<0.1	656	786	936	205	88.5	19.9	57.52	1107
21/3/99	LA-6 (WB)	"	"	"	"	9	1150	278	0.1	<0.1	203	1438	900	169	51.4	9.3	49.5	605
22/2/86	LA-6 (WB)	"	"	"	"	8.1	1475	400	1	0.5	-	2275	957	205	82	-	90	1142
25/4/00	LA-7 (RW)	"	"	"	"	7.6	760	203	0.1	<0.1	“	1180	539	108	50.5	22.2	34.98	465
1/3/99	LA-7 (RW)	"	"	"	"	9.7	1440	170	0.6	<0.1	574	874	1010	209	32.8	2.2	43.11	465