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Evaluation of Dikili-Kaynarca Geothermal Field (NW Turkey)

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ABSTRACT

Dikili-Kaynarca geothermal field has been used since early 2000's by five different companies with the purpose of district heating, green house heating and thermal tourism. There are over 20 wells in the field with discharge temperatures ranging from 80 to 120 °C. Encouraging discharge temperature from the wells boosted the green house investments in the field. Heavy use of geothermal water resulted with decrease in both flow rates and discharge temperatures of the wells. A comprehensive well testing and water sampling campaign was carried out to determine the possible causes of those declines in the field. Chemical analyses revealed that Dikili-Kaynarca waters are Na+K – SO_4 type and meteoric in origin and a reservoir temperature range of 122-214 °C was estimated from geothermometry applications. Comparison of static and dynamic temperature measurements of two hottest wellbores within 9 years' time span indicated a temperature drop more than 10 °C. Two of three reinjection wellbores are very close to those production wellbores showing temperature decline. In addition, at least three production wellbores were found to have casing and cementing problems. All these observations indicated that current reinjection application and wellbore failures are the main causes of the decline in the productivity of the field.

1. INTRODUCTION

Dikili-Kaynarca field is one of the important geothermal fields of western Anatolia since it is a good example of direct use of geothermal energy (Figure 1). Along with its importance in being a good example for variety of use, the administration problems in management of the resource are remarkable. There are over 20 wells in the field and these wells owned by 5 different entities and used for 3 different purposes; namely, balneology, district heating, and green house heating (Figure 2). It is not so difficult to guess that every company/institution have different attitude and policy for usage. Along with variety in the type of utilization there exist big differences in the quality of the geothermal wells drilled by different companies. Although the reservoir unit is the highly permeable zones of volcanics and subsurface geology seems consistent, the variety in both the quality of the wells and differentiation in utilization of the wells resulted in a wide range of discharge temperatures in the field. This variety in discharge temperatures is accompanied by a temperature decrease in the field which is criticized as the reservoir cooling. This study aims to delineate the reasons for the temperature drop in the field by means of well tests comprising temperature, pressure and flow rate measurements. Together with the well tests, water chemistry and stable isotope analyses were conducted from 12 representative wells in the field. The water chemistry and stable isotope analyses results were used to investigate the source of the waters and estimation of the reservoir temperature.

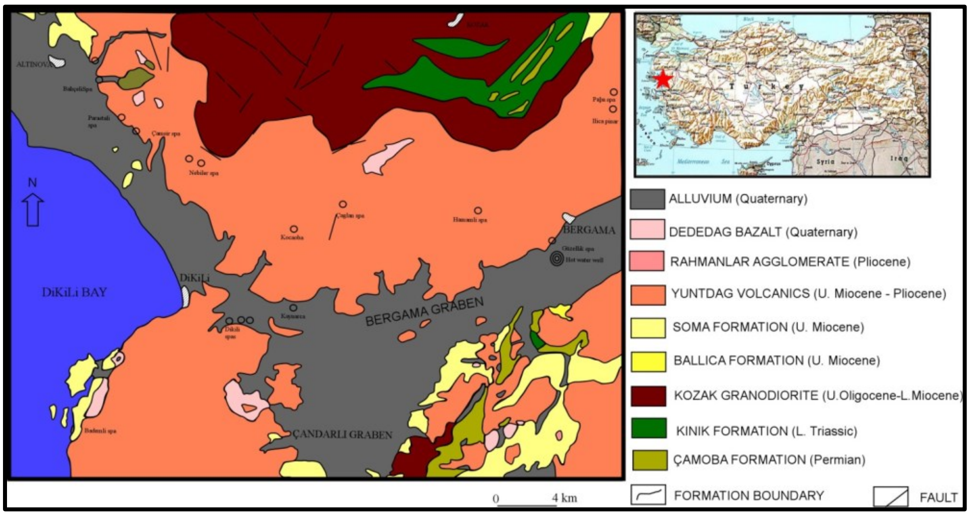

Figure 1: Geological map of the study area (Modified from MTA, 1986).

2. GEOLOGICAL SETTING

Dikili-Kaynarca geothermal field is located in western Anatolia. E-W trending horst-graben systems together with deep seated high angle normal faults enhance geothermal activity in western Anatolia where the study area is located (Bozkurt, 2003). Previous workers differentiated 8 different formations in the study area; namely, Çamoba Formation, Kınık Formation, Kozak Granodiorite, Ballıca Formation, Soma Formation, Yuntdağ Volcanics, Rahmanlar Volcanics and Dededağ Bazalt from old to young. Quaternary alluvium occurs unconformably over all the units (Figure 1 and Figure 3, MTA, 1978; 1986).

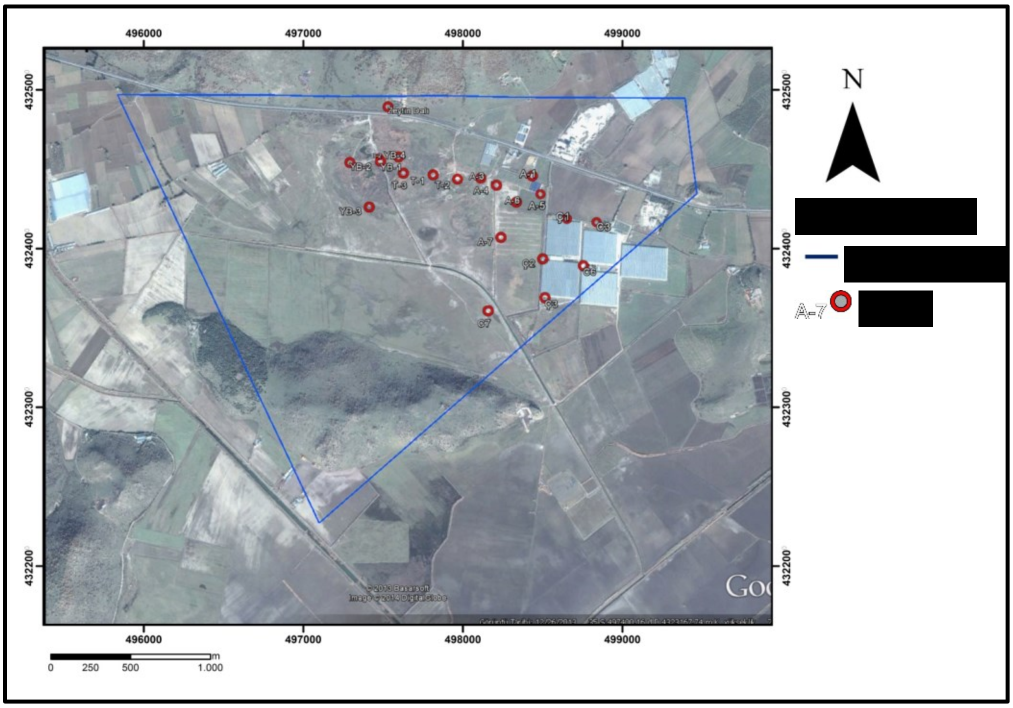

Figure 2: Google earth map showing the locations of the wells.

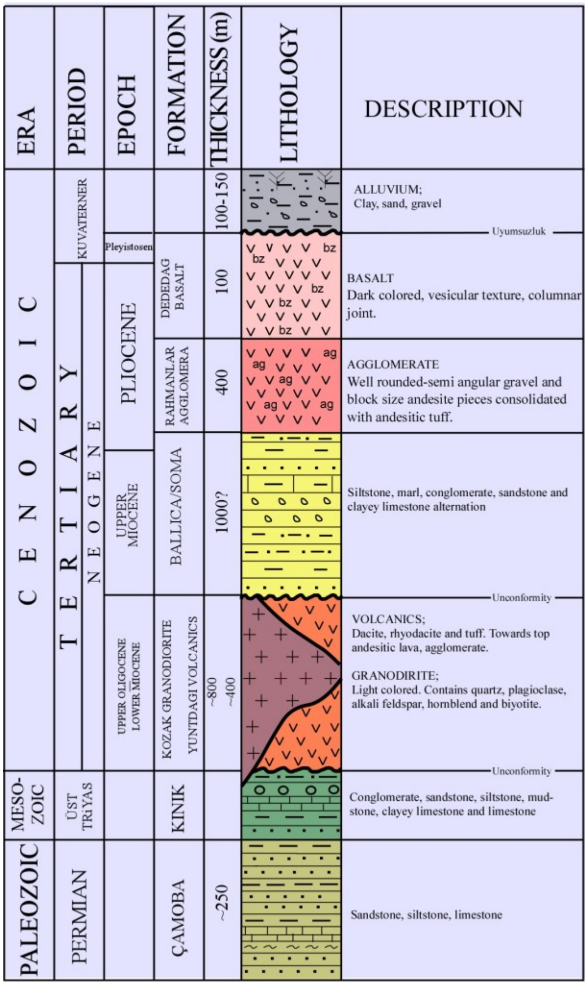

Figure 3: Generalized columnar section of the study area (MTA, 1986).

3. MATERIAL AND METHODS

The study was conducted in the time period of May - September 2013 when the heating season is ended and there was no fluid production from the field except one low flow rate wellbore with a wellhead temperature of 42 °C serving to a local spa. After letting the field to recover for a period of 2 months static temperature-pressure logs from 21 wells were taken and by August 14, 2013 the first wellbore, T1 was flow tested to record the dynamic pressure and temperature, to measure the flow rate and to collect the water samples. All 12 active wellbores of the field were flow tested one-by-one while 6 wellbores were used as observation points. Those observation wellbores were equipped with downhole pressure-temperature recorders and the response of the field to the production from different wellbores was recorded.

The water samples were taken into separate 100 ml polyethylene bottles. In every sampling location 100 ml water sample was taken for cations (filtered, acidified), 100 ml sample for anions (filtered), 100 ml water sample for stable isotopes. Water samples were kept cold and sent to the accredited laboratories immediately. Chemical analyses were done in Hacettepe University Water Chemistry and Environmental Tritium laboratory and stable isotope analyses were done in Hacettepe University International Karst Water Resources Application and Research Center (UKAM) stable isotope laboratory.

4. WATER CHEMISTRY

Although there are over 20 wells (active/inactive) present in Dikili-Kaynarca region, 12 representative wells were sampled for water chemistry and stable isotope analyses. Major ion concentrations are given in Table 1 and visualized in Figure 4 as a Schoeller diagram. As can be seen from Schoeller diagram the waters are alkali sulfate ($Na+K-SO_4$) type. Stable isotope analyses results reveal that Dikili-Kaynarca geothermal field waters are meteoric in origin (Table 1, Figure 5).

Cation and silica geothermometer results give temperature estimate ranges 122 -214°C and 217-337°C respectively (Table 1). Being on the safe side, cation geothermometers which indicate lower temperatures should be taken into consideration for future planning of the field.

Table 1. Major anions-cation concentrations, stable isotope ratios and geothermometer calculation results of the sampled waters. Sampling was conducted in 2013. Geothermometer results are in ˚C.

Sample No	A-3	A-4	A-5	A-6	C-3	C-7	Ç-1	Ç-2	T-1	T-2	YB-1	YB-2
Sampling Date	29.08	30.08	27.08	28.08	21.08	19.08	24.08	23.08	15.08	17.08	31.08	02.09
*Temp. (°C)	106	104	91	96	101	77	100	100	120	111	84	89
pH*	8.17	8.44	7.81	8.02	8.08	6.62	8.02	8.38	-	8.26	7.83	7.97
EC (µs/cm)	2450	2470	2460	2460	2300	2100	2450	2410	2570	2550	2600	2600
SiO_2 (mg/l)	820.68	761.13	927.18	999.33	566.44	443.91	640.88	668.37	676.38	683.25	635.15	746.24
HCO_3 (mg/l)	502.52	490.9	551.9	482.19	412.48	447.33	447.33	453.14	395.05	406.67	563.52	502.52
Cl (mg/l)	59.32	56.63	60.63	56.99	57.09	49.73	60.99	84.5	55.66	59.64	57.8	64.97
SO_4 (mg/l)	793.89	779.91	750.78	751.23	731.29	639.54	793.55	763.32	796.84	804.36	797.04	799.71
Na (mg/l)	530.88	534.79	477.56	507.5	480.18	405.29	521.27	535.71	536.18	543.95	573.72	558.7
K (mg/l)	37.79	38.03	31.7	36.04	35.03	30.86	34.8	39.01	33.41	37.28	39.49	43.8
Ca (mg/l)	96.92	93.29	105.42	79.91	81.75	76.71	66.59	84.62	104.78	86.45	80.62	64.71
Mg (mg/l)	11.72	8.51	12.59	7.33	5.79	14.29	5.93	7.28	6.07	5.82	5.39	5.17
$\delta^{18}O$	-5.97	-6.07	-6.14	-5.94	-6.24	-6.05	-5.36	-5.47	-6.14	-5.7	-6.59	-6.52
δD	-39.73	-40.12	-39.95	-38.91	-41.47	-42.35	-38.27	-37.78	-41.48	-40.8	-42.79	-42.24
Estimated Reservoir Temperature from Geothermometers (°C)												
Quartz Fournier (1977)	302	293.9	315.7	324.5	264	241.7	276.1	280.3	281.6	282.6	275.2	291.8
Q-max. steam loss Fournier (1977)	263.6	257.4	273.8	280.2	234.7	217.4	244	247.2	248.1	248.9	243.3	255.9
Chalcedony Fournier (1977)	308	297.5	325.9	337.4	259.7	232.1	274.8	280.2	281.7	283.1	273.7	294.8
Chalcedony Arnorsson et al. (1983)	284	275	299.2	309	242.4	218.3	255.6	260.2	261.5	262.6	254.6	272.7
Truesdell (1976)	153.7	153.6	147.3	153.4	155.9	160	147.8	155.8	141.7	150.2	150.6	162.8

Tonani (1980)	159	158.9	152.3	158.8	161.4	165.6	152.8	161.2	146.4	155.3	155.7	168.6
Arnorsson et al. (1983)	175.3	175.2	168.8	175.1	177.6	181.7	169.3	177.4	163.2	171.8	172.2	184.5
Fournier (1979)	189.5	189.4	184.2	189.3	191.4	194.7	184.6	191.2	179.5	186.6	186.9	197
Nieva and Nieva (1987)	176.9	176.8	171.7	176.7	178.7	182	172.1	178.6	167.2	174.1	174.4	184.2
Giggenbach (1988)	206.6	206.5	201.6	206.4	208.3	211.4	202	208.2	197.2	203.8	204.2	213.6
Fournier & Truesdell (1973)	133	134.5	121.7	135.9	133.2	127.1	140.1	138.5	125.7	136.1	141.5	152.8

*on site measurements

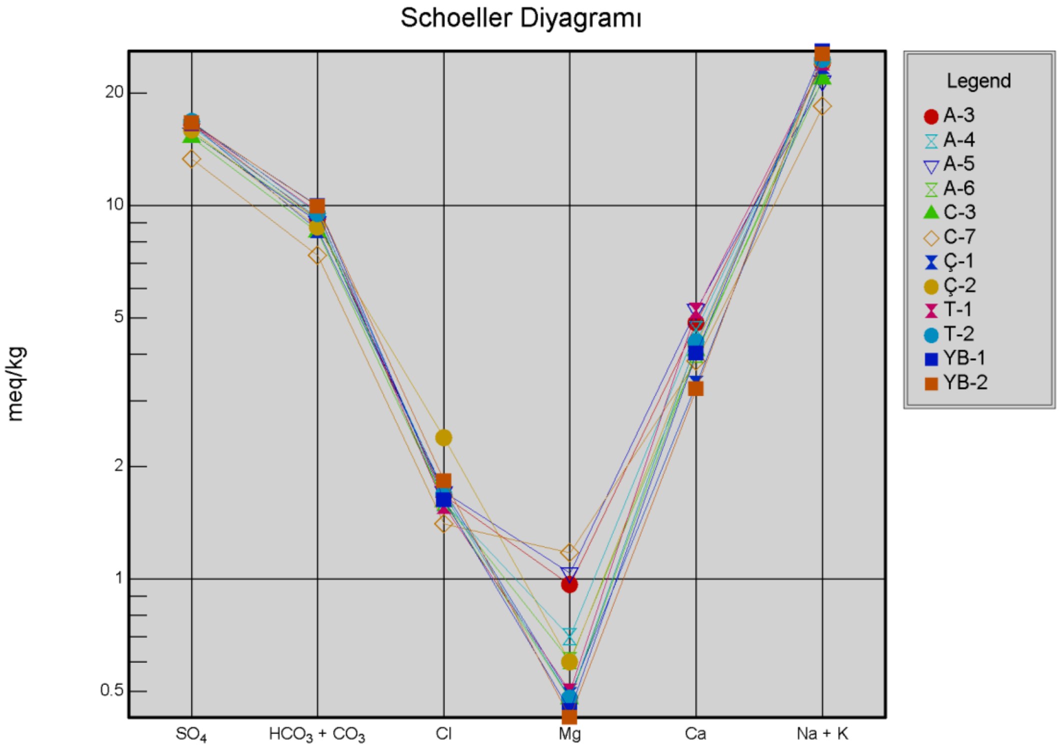

Figure 4: Schoeller diagram.

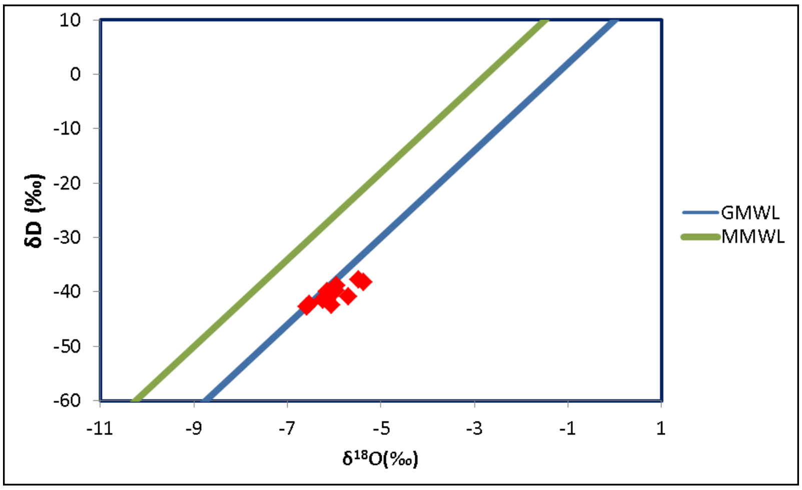

Figure 5: δ18O versus δD graph of the Dikili-Kaynarca field. [MMWL: Mediterranean Meteoric Water Line (IAEA, 1981); GMWL: Global Meteoric Water Line (Craig, 1961).

5. WELL TESTS

Among 21 wellbores drilled in the field 12 of them are being used as producers, 3 as re-injectors and 4 both producers and re-injectors (Figure 6). Remaining two are abandoned wellbores because of the technical failures. Except K-1 and Zeytin Dalı, all wellbores were tested for their static pressure and temperature profiles after mid-July of 2013 almost 2.5 months later ceasing the fluid production from the field in May 2013. Interpretation of static temperatures resulted with areal temperature distribution of the field at different depths with 20 m intervals (Figure 7). Although the field seems to have two separate sections in terms of temperature at the first 80 m it becomes unified at a depth of 100 m with a temperature over 100 °C. The main reason of the separation in terms of temperature is thought to be the cold water re-injection from well T-3.

One other important result from static measurements obtained from well T-1. The highest temperature of the field was recorded from this wellbore and it is still is the hottest wellbore in the field. But, its static temperature comparison at different dates indicates that there exists a decrease in bottom-hole temperature (more than 10 °C) of the wellbore temperature (Figure 8-a). The temperature decrease in T-1 is more obvious from dynamic temperature recordings taken within about 10 years interval. The initial dynamic temperature recording was 130 °C in 2004 but decreased to 120 °C in 2013. The reason for this decline in temperature in T-1 is attributed to the cold water injection from well T-3 which is very close to T-1.

All producers of the field were put on production for dynamic tests one by one and the response of the field for fluid production was studied through pressure recordings from 6 observation wells (Figure 6). Figure 9 presents the change in down-hole pressure as response to fluid production from different wellbores. A pressure-temperature recorded was set to a fixed depth in T-3 and the down-hole pressure and temperature were recorded at every one minute. It is obvious from Figure 9 that the production from T-1 is the most effective one on T-3 among all producers which indicates a strong communication between T-1 and T-3. This is another strong indication that the cold water injection from T-3 has a negative effect on the productivity of the field.

One important result for the production-injection applications was obtained from dynamic test of well A-6. This wellbore is alternatingly used as producer or injector. It was drilled to a depth of 430 m and cased and cemented at 120 m. A dynamic test of this wellbore should result with a profile that, any fluid entry into the wellbore must be deeper than 120 m. The dynamic temperature profile of well A-6 (Figure 10), on the other hand shows a strong hot water entry at a depth of 90 m causing an increase in the flowing fluid temperature form 92 °C to 96 °C. There exist also fluid entry points at even shallower depths. Cooling at the depth of 30 m is the result of air injection to stimulate the wellbore for fluid production since the wellbore is not an artesian well. Metal particles were recovered from this wellbore in the casing of pressure-temperature sensor (Figure 11). Those metal particles are believed to be from corroded casing. As the integrity of the casing is lost water started to enter into the wellbore at the levels shallower than the casing landing depth. The reason of casing failure is thought to be the fatigue caused by frequent temperature change because of alternating production-injection application as well as air-oxygen entrance into the wellbore during water injection which may accelerate the corrosion.

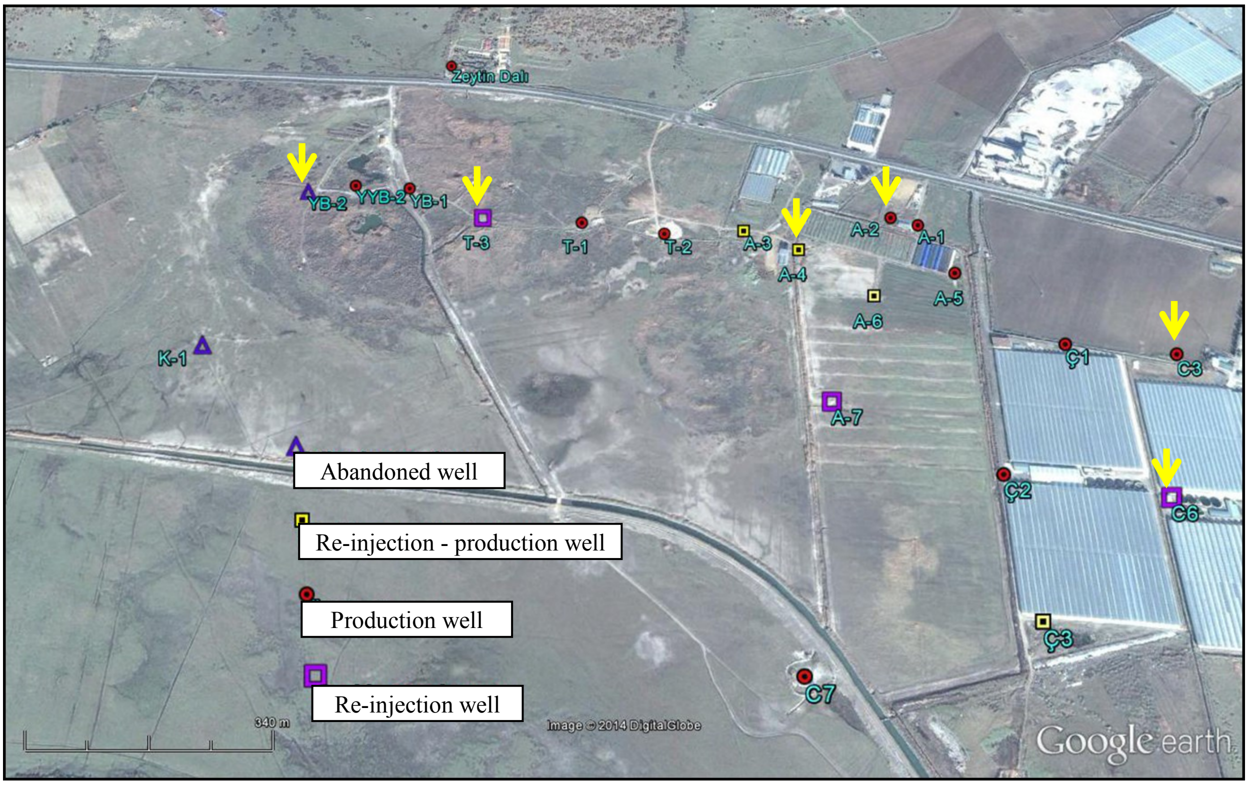

Figure 6: Location of Dikili geothermal field wells (yellow arrows indicate the observation wells during interference test).

6. CONCLUSIONS

The following conclusions are drawn from this study:

- Most of the wells in the area (either production or reinjection) are improperly designed and old enough to allow water circulation behind the casing. The cooling of the reservoir is caused mostly by misuse of the wells
- Waters are Na+K – SO_4 type and meteoric in origin.
- Reservoir temperature estimates reveal a temperature between 122 and 214 °C.
- Not only reinjection but also the production wells are not in a good condition which causes waste of energy and cooling.

All these observations indicated that current reinjection application and wellbore failures are the main causes of the decline in the productivity of the field.

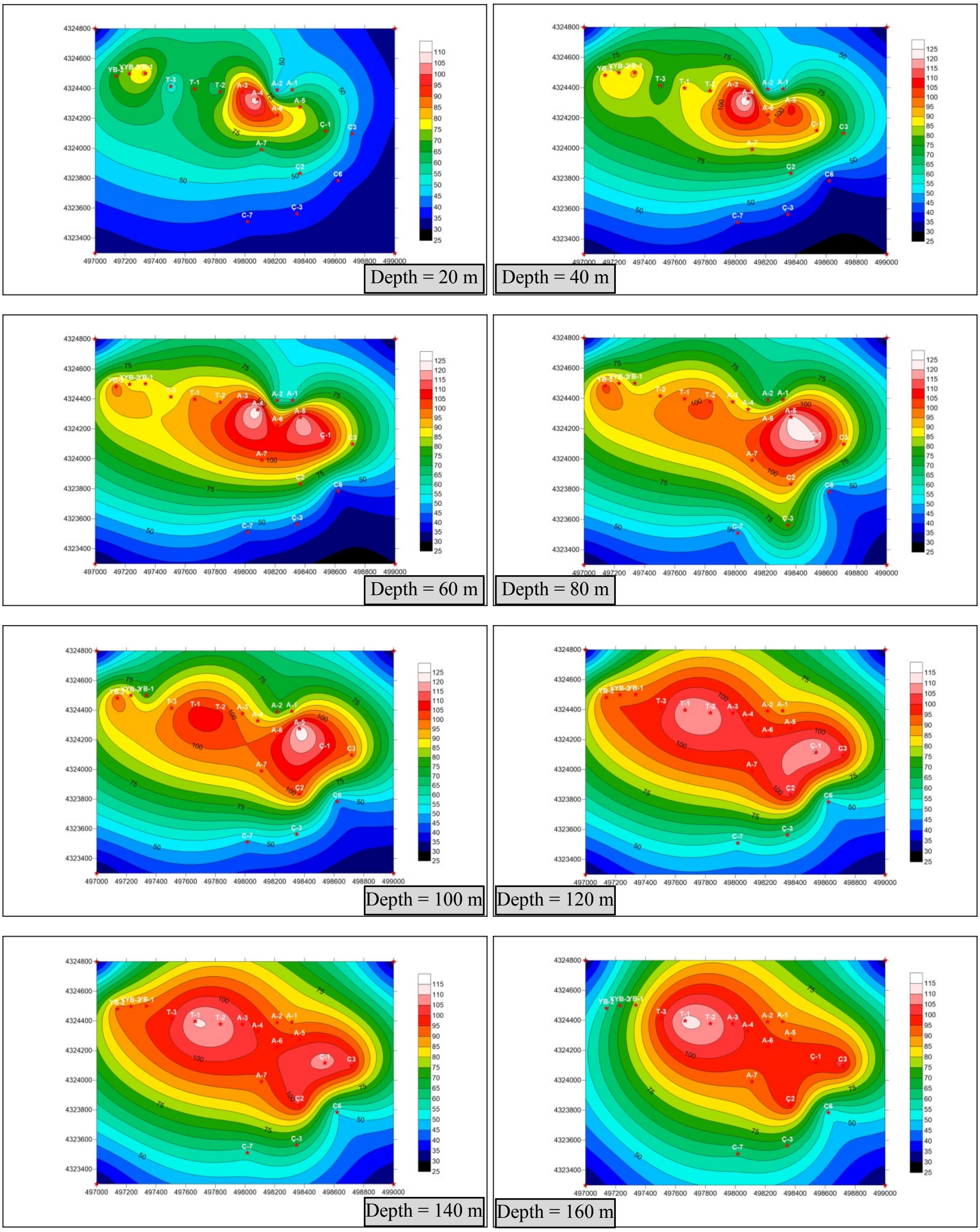

Figure 7: Temperature contour maps derived from static temperature profiles.

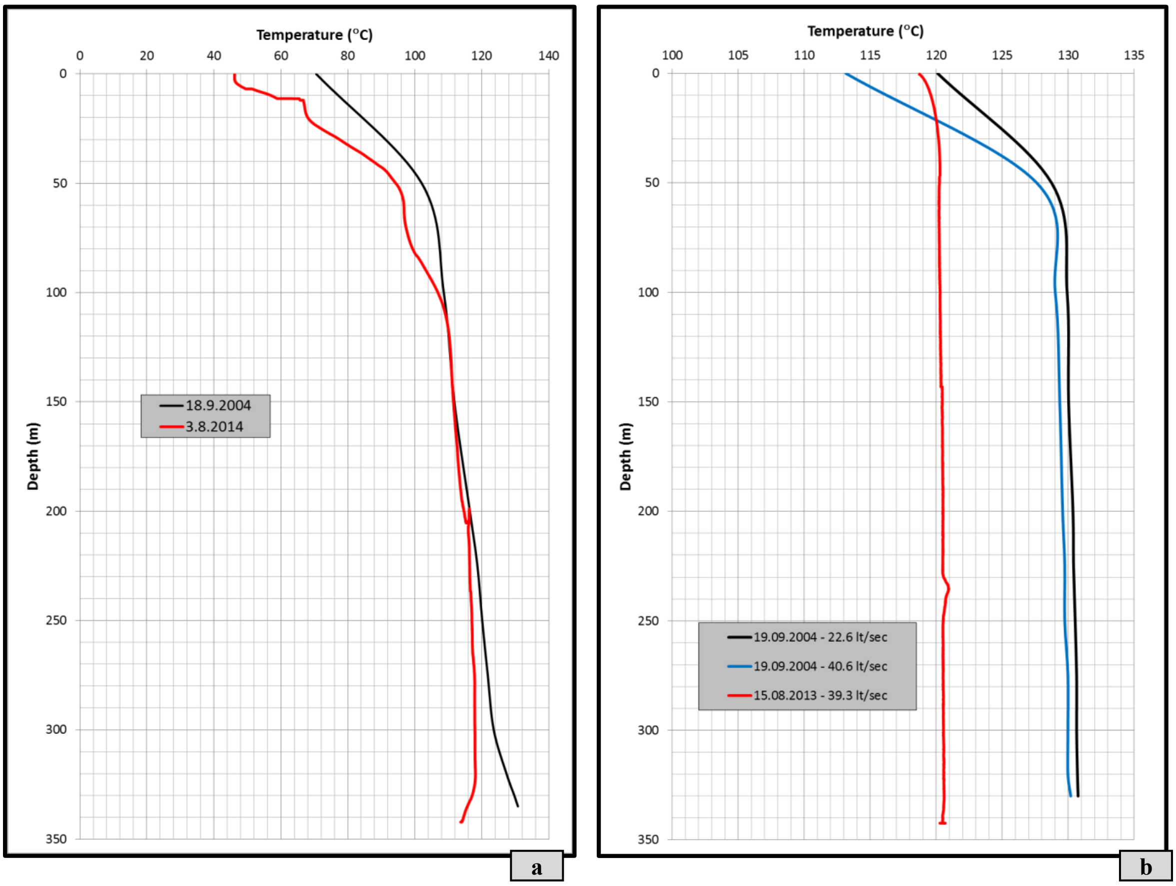

Figure 8: Temperature profiles for T-1, a) Static, b) Dynamic.

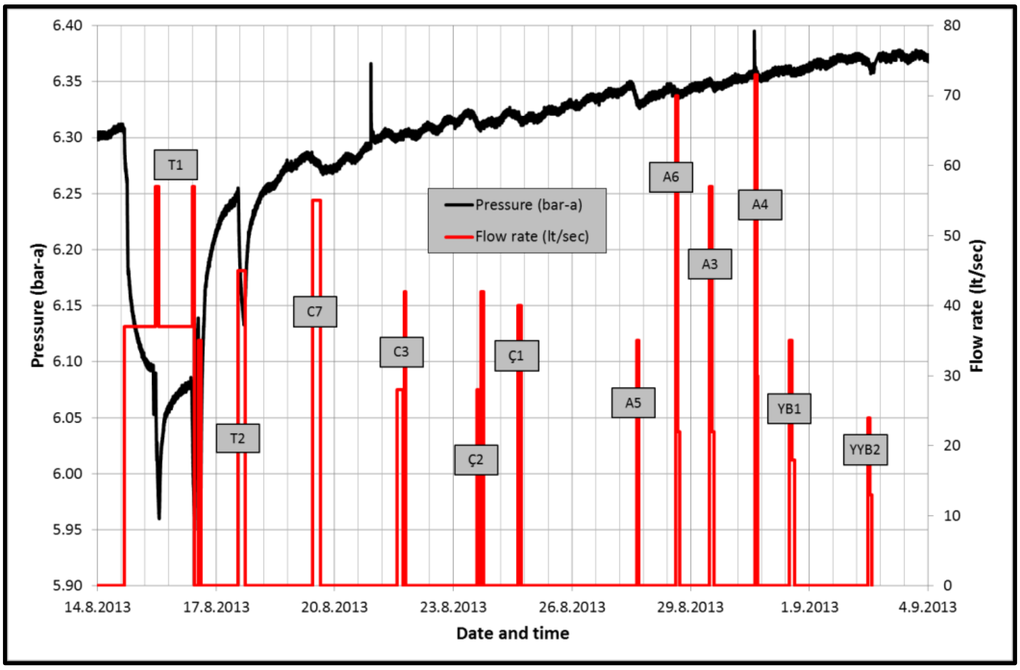

Figure 9: Change in down-hole pressure of T-3 as response to fluid production from different wellbores.

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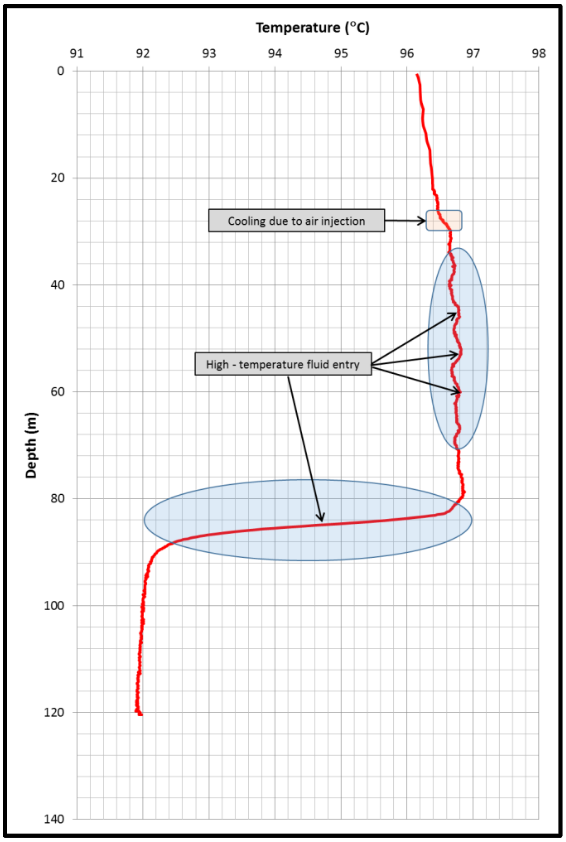

Figure 10: Dynamic temperature profile of well A-6.

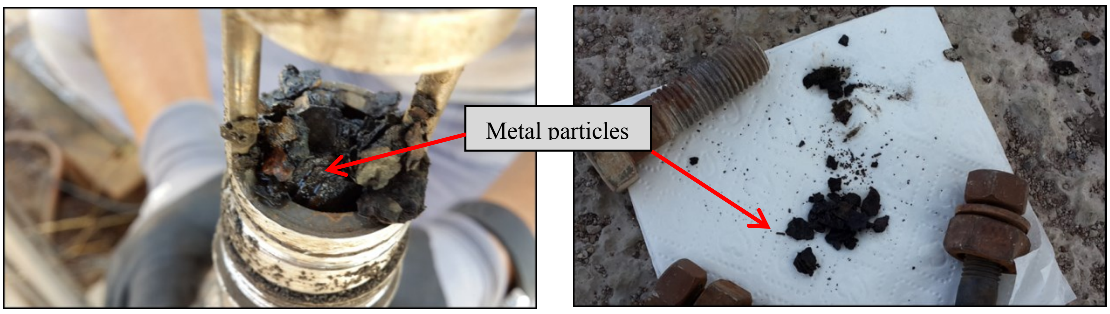

Figure 11: Metal particles recovered from well A-6 during dynamic test.