Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

The Geochemistry of the Deep Reservoir Wells in Kizildere (Denizli City) Geothermal Field (Turkey)

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Keywords: Geochemistry, Kizildere, Turkey

ABSTRACT

Kizildere Geothermal Field is the first discovered high enthalpy geothermal field that is used for electricity production in Turkey. Between 1968-2008 years, 25 wells geothermal wells were drilled by the government support at the field. At the end of 2008, after the privatization of Kizildere Geothermal Field, Zorlu Energy Group has drilled 19 new production and reinjection wells with the scope of 80 MWe new geothermal power plant investment between 2009-2012. The depths of these new wells change between 1551-2872 meters and mostly deeper than the previous wells in the field. Reservoir temperatures of the new production wells change between 220-245°C. The new 80 MWe power plant was put in to use at the last quarter of 2013 and total installed capacity of the field has reached to 95 MWe with the old power plant. The new production wells represent the deep reservoir and the electrical conductivity (EC) values at liquid phase change between 4600-5200 microS/cm at the west of the field while these values change between 3450-4110 microS/cm in the new reinjection wells at the east of the field. Silica values conform to reservoir temperatures and change between 469-732 mg/l in the deep reservoir, and between 115-402 mg/l in reinjection wells. $d^{18}O$ values of water phase change between -4,30 %o and -6,1%o and d D values change between -54%o and -59%o for production wells, while $d^{18}O$ values change between -8,05%o and -10,57%o , and d D between -59%o and -62%o for reinjection wells. In the new production wells, the dominant noncondensible gas is 98-99% CO_2 that show similarity with shallow wells while new wells have slightly higher proportion H_2S then shallow wells in the field.

1. INTRODUCTION

The first power production development performed at Kizildere (Denizli city) geothermal field in Turkey (Figure 1). After 1960's General Directorate of Mineral Research & Exploration (MTA) and United Nations started to joint project to understand the potential of the small part of the geothermal field. The first well was drilled in 1968 and was obtained 198 °C reservoir temperature in the field. Until 1984, when Kizildere-I 20 MWe gross capacity geothermal power plant (GPP) installed, 20 wells were drilled and characterized in Kizildere.

In 2008, Zorlu Energy Group acquired the Kizildere geothermal field. In the fall of 2008, the company began rehabilitation studies and some modifications and maintenance studies realize to increase Kizildere-I GPP capacity (Kindap et al, 2010). In 2009 the company started to new Kızıldere-II 80 MWe gross capacity power plant studies and 20 new deep wells were drilled, which depths reach to 2872 m in the field (Haklidir Tut & Kindap, 2013).

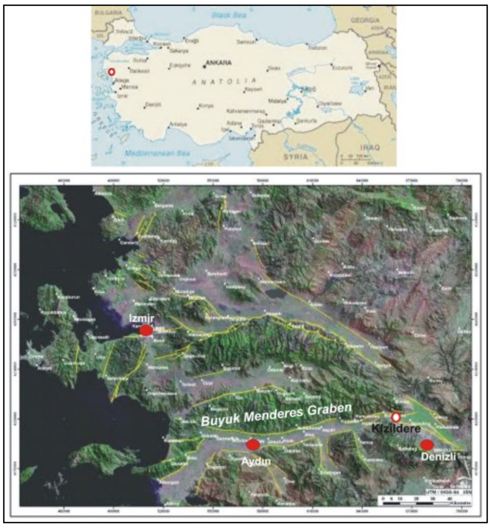

Figure 1: Kizildere Geothermal Field along Buyuk Menderes Graben

Kizildere-I GPP has 8 production wells (KD-14, KD-15, KD-16, KD-20, KD-21, KD-22, R-3, R-6) and Kizildere- II GPP has 9 production wells (KD-2A, KD-9A, KD-18A, KD-23B, KD-23D, R-1, R-1A, R-3A, R-5A) and there are 8 reinjection wells (KD-28A, KD-28B, KD-32A, KD-33A, KD-35, KD-38A, KD-38C, KT-1) in the field.

2. BRIEF RESERVOIR GEOLOGY OF KIZILDERE GEOTHERMAL FIELD

In Kizildere geothermal area, the Paleozoic metamorphics are downthrown along a series of semi-parallel east-west trending normal faults with vertical throws of a few hundred meters at the edge of the Buyuk Menderes Graben to possibly thousands of meters in the center (Haizlip et al, 2013). These faults appear to be cut by northeast trending faults.

In the field three main reservoirs are determined. The shallow reservoir is a fractured in Mesozoic limestones, an intermediate depth reservoir in the uppermost Paleozoic carbonates and the third and deepest reservoir in fractures primarily in the brittle sections of the Menderes metamorphics. The sediments with higher clay content or metamorphics dominated by mica form impermeable cap rocks above and between the permeable reservoir zones hosted in more brittle formations (Haizlip et al 2013).

3. GEOCHEMISTRY OF DEEP RESERVOIR WELLS IN KIZILDERE

The heat source for Kizildere geothermal field is closely related to the high heat flow of extensional tectonic structure as the Buyuk Menderes Graben. Reservoir temperatures change such as; 200°C at 500 m depth and 240°C below -1200 m and the system is water dominated, deeply circulating along fractures within the high heat-flow Kizildere region. The flow rates of new wells change 200-450 tph in the production area.

The electrical conductivity (EC) values change between 4740-5500 microS/cm for production and nearly 5700 microS/cm reinjection wells and ph values range from 7 to 8.2 depending on sampling points after well heads and 9.5 before reinjection application in the field (Table 1). There is a sampling port before steam turbine and the steam condensate's ph is near 6 and EC value is 1325 microS/cm. Kizildere geothermal waters are characterized by Na-HCO3 (Haklidir et al, 2011). The brine chemistry in deep reservoir show similarity to intermediate reservoir chemistry except from silica values (Table 2, Figure 3a). The reservoir temperatures and silica values are show similarity, although sampling/analysis of silica is not easy, because of fast precipitation tendency of silica during sampling process in high temperature water systems. Among cations, calcium concentrations are quite different between production and reinjection wells because of reservoir temperatures in the field. In Table 2, the initial conditions of wells are represented as chemically, on the other hand, these results are taken from the first sampling periods during well completion tests in the field. During well tests, the scale inhibitor systems were not installed and it is thought that the calcium concentrations may be monitored lower than real results in the system. Concentrations of the some anions such as bicarbonate, sulphate in geothermal waters look different for production and reinjection wells (Figure 3b). Bicarbonate values depends on pH values and high pH values (over than 8.2) some of bicarbonate ions turn to carbonate ions in water, the case can be monitored in KD-38A reinjection well in the field.

Table 1: Electric conductivity and ph values of geothermal waters in geothermal wells during electricity production (T2: Steam turbine condensate)

Well ID	EC (micros/cm)	ph
KD-2A	5260	7,26
KD-9A	5030	7,1
KD-18A	5040	7,24
KD-23B	5320	7,02
KD-23D	5500	7,25
R-5A	4770	7,28
R-1*	5350	8,2
R-1A	4740	7,33
R-3A	5280	7
KD-38A	5690	9,5
KD-38C	5730	9,6
T-2	1325	6,09

Although gas composition is also same with the intermediate reservoir and the dominant gas is 98-99 % CO_2 and H_2S value is slightly higher at a few new deep wells (Haklidir et al, 2012) but the average noncondensible gas concentration (NCG) in the deep reservoir (0.03 kg NCG/kg brine) is quite high in the intermediate reservoir (0.015 kg NCG/kg) (Haizlip, et al, 2013) in Kizildere (Table 3).

Table 2: The initial chemical compositions of geothermal waters for production and reinjection wells (analysed by MTA, between 2010-2012)

Well ID	Unit	Sampling Date	WHP (barg)	ph (20-22 °C)	K	Na	Ca	Mg	Li	Fe	Bt	SiO2*	NH4+	CO3 2-	HCO3-	Cl-	SO4 2-	F -	Br -	As	PO4	Hg
KD-23B	mg/l	05.01.2011	11,9	6,9	228	1304	1,33	<1	4,3	0,08	22,3	697	8,3	<10	2515	110	653	20,6	0,6	0,91		<0,005
KD-23D	mg/l	17.01.2010	13,9	6,7	209	1295	1,08	<1	4,1	0,05	24,1	503	11,3	<10	2487	104	591	18,2	0,9	0,98	<0,1	<0,005
KD-18A	mg/l	05.06.2011	12,5	7	220	1165	1,45	<1	3,8	<0,05	21	552	10,3	<10	2577	115	638	19,2	0,8	1,26	0,3	<0,005
KD-2A	mg/l	16.09.2010	24	7,6	204	1305	1,96	<1	4,5	0,05	25,9	682	5,6	<10	2624	115	588	21	0,7	1		<0,005
KD-9A	mg/l	08.12.2010	13,5	6,7	184	1158	1,36	<1	3,5	<0,05	23,9	520	8,4	<10	2379	92,9	524	17,7	0,6	0,8		<0,005
R-1A	mg/l	15.03.2011	13,6	6,7	183	1135	1,3	<1	3,5	0,05	20,5	601	9,5	<10	2420	107	620	18	0,5	1,3		<0,005
R3A	mg/l	29.10.2011	10	7,2	347	1278	4,41	<1	4,5	<0,05	31	732	6,7	<10	2990	122	623	26	0,7	0,07	0,4	<0,005
R-5A	mg/l	16.02.2011	13,2	6,8	165	1147	1,19	<1	3,2	<0,05	22,3	469	8,2	<10	2338	101	572	21	0,5	0,73	0,7	<0,005
KD38A	mg/l	17.03.2011	2	8,2	107	1001	1	1,23	2,8	0,07	17	402	6,4	138	1729	92,9	577	18	0,5	0,6	0,54	<0,005
KD38C	mg/l	09.03.2011	7,6	6,3	111	800	24,7	4,91	2,4	0,3	7,5	364	6,7	<10	1573	90	497	6,4	0,4	0,42	0,4	<0,005
KD28A	mg/l	07.04.2011	5,8	6,8	140	977	46,1	9,12	2	0,5	9,31	229	7,1	<10	2049	94,4	574	7,9	0,5	0,7	0,3	<0,005
KD-27A	mg/l	13.11.2010	14,2	7,3	175	1086	1,37	1,39	3,6	<0,05	18	315	7,7	<10	2204	77,1	472	14,3	0,5	1,02		<0,005
KD25A	mg/l	20.05.2010	10,2	6,75	142	1100	3,66	1,06	3,9	<0,05	18	578	10	<10	2267	95,7	597	14	0,5	0,7		<0,005
Kar	mg/l	01.03.2012	1,5	7,5	130	859	4,37	9,23	1,5	0,09	5	115	4,7	<10	1903	85,8	458	2,1	0,3	0,7	<0,1	<0,005
KD-35	mg/l	28.02.2012	8,9	6,6	96,8	836	39,1	9,29	2,2	0,2	6,6	115	8,1	<10	1637	118	559	3,4	0,5	0,27	<0,1	<0,005
KD33	mg/l	01.07.2011	3,5	7	104	555	131	15,4	1,3	0,2	5,6	302	7,2	<10	1432	65,6	515	4,5	0,3	0,28	<0,1	<0,005
KD-32A	mg/l	29.07.2011	1,1	7,2	70,5	466	226	35	1,1	0,3	4,7	250	7,2	<10	1362	60,9	629	5,2	0,4	0,11	<0,1	<0,005

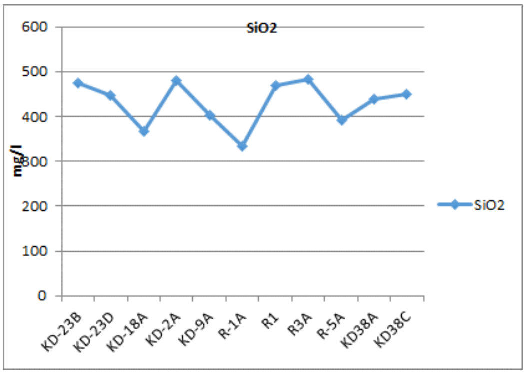

Figure 3a: Silica concentrations variations in production and reinjection wells in Kizildere

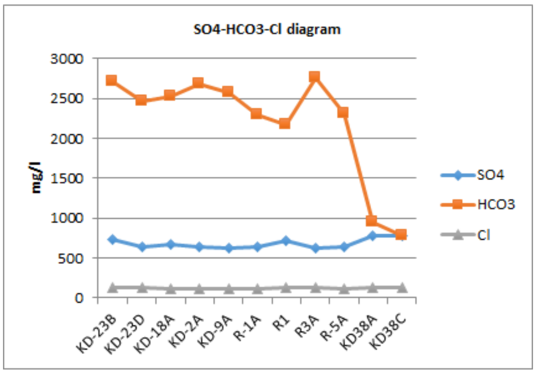

Figure 3b: Major anions concentrations of geothermal waters in deep wells in Kizildere

Table 3. NCG compositions in intermediate and deep reservoir in Kizildere geothermal field (Haizlip et al 2013)

	Reservoir gas/H2O*	CO2	H2S	NH3	Ar	N2	CH4	H2	He	O2
	(kg/kg)	Measured (dry mole fraction)								
Kiz Deep	**0.030**	98.7%	0.021%		0.01%	0.67%	0.56%	0.025%	0.00003%	0.013%
Kiz Intermediate	**0.015**	98.6%	0.005%		0.003%	0.81%	0.42%	0.003%	0.0002%	0.013%

In Kizildere stable isotope compositions are also quite different for production and reinjection areas. $d^{18}O$ values of geothermal waters change between -4,30 ‰ and -6,1‰ and d D values change between -54‰ and -59‰ for production wells, while $d^{18}O$ values change between -8,05‰ and -10,57‰ , and d D between -59‰ and -62‰ for reinjection wells (Figure 4). These are also initial values and it is thought that they will be important during production period in the field in future.

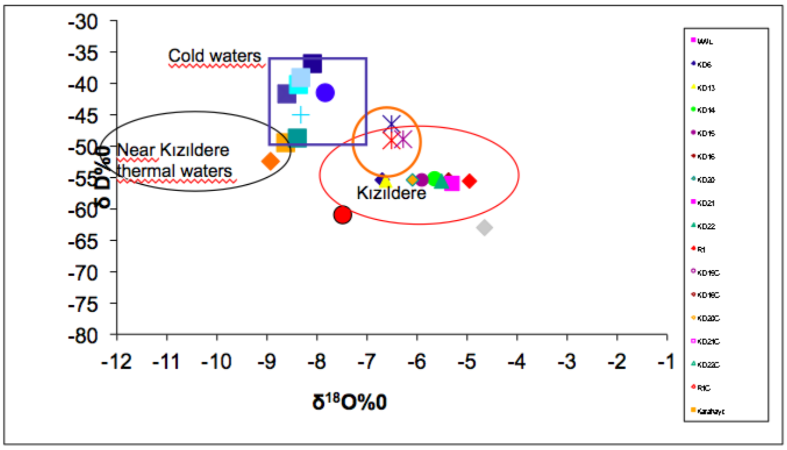

Figure 4: d18O%0 &dD %0 compositions of Kizildere new wells and surrounding low temperature systems (such as Pamukkale, Karahayıt geothermal fields; Haklidir et al, 2012)

CONCLUSION

In October 2013, Kizildere new 80 MWe_{gross} (60 MWe triple flash and 10x2 MWe binary units) capacity put into use in Denizli city in Turkey. For this new power plant 20 new deep wells have drilled with production and reinjection purposes in the license area. With old 15 MWe_{net} capacity, the total capacity of geothermal power has reached to 95 MWe in the field. With new wells, the working well numbers have reached to 30 in the field that most of them were drilled in deep reservoir in the system.

Kizildere geothermal system has multi reservoirs and it is characterized by intermediate and deep that are mainly distinguished by temperature and NCG concentrations. Kizildere is one of the high ncg and water dominated geothermal systems in Turkey and maximum temperature has been recorded as 245°C in the deep reservoir. The dominant gas is CO_2 in the system and it causes big amount calcium carbonate scale potential in boreholes in deep reservoirs.

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