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Microstructural Analysis of Calcium Carbonate Scaling in Geothermal Wells of Menderes Massive

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ABSTRACT

Calcium carbonate scales are collected from two wells of Kizildere Geothermal Energy Field which is located in the most productive geothermal region of Turkey. Location of the two wells are at the two extremes of the field. Samples are taken from inside the well from the inner walls of the master valve and from the inner walls of the separator. Samples were first cut with a diamond saw to expose the layers of deposits and were analyzed by XRD (X-Ray Diffraction), SEM-EDS(Scanning Electron Microscope, Energy Dispersive Spectrometry). Some layers were observed to be darker than the others. Slices were cut further to analyze dark and light colored layers. Electron microscopy analysis revealed the mineral morphology and the distribution of elemental composition. Most of the samples consisted of aragonite mineral while the master valve of the well R1 contained calcite. Separator of R1 consisted cheifly of aragonite with minor amounts of quartz and some little calcite. There was considerable amount of strontium in almost all samples.

1. INTRODUCTION

First studies on the Kizildere Geothermal Field which is located between Aydin and Denizli in the western end of the Buyuk Menderes Graben were conducted in 1965 by Mineral Exploration Directorate (MTA). 1968 marked the first drilling of the well (KD-1) followed by several others after quite successful experiences.

So far 25 deep wells have been drilled 10 of which are used for energy generation, one for injection leaving the rest for observation.

Energy generation was initiated at Kizildere Geothermal Field in 1984 with an installed capacity of 20.4 MW_e for the electric power plant but average power generation per annum was only 9-11 MW_e until recently. Electric power generation is compromised by the ever growing calcium carbonate scale that reduces the well inner diameter (ENEL 1989).

Scaling is a serious issue in the electric power generation. It causes production losses not only because the usable well diameter is reduced but also because of the cleanup costs. Additional losses in productivity occur in due to scaling of surface transport lines and the separator.

At the moment there are a total of nine wells with a total production of 1000tons/hour of fluid. Because wells KD-14 and KD-20 are injected with inhibitors they do not suffer too much from production losses. The remaining wells, however, experience losses in production due to scaling.

In this study, samples of scales are collected from two wells that are situated at two extreme ends of the geothermal field. Chemical composition, mineral structure and morphologies were investigated.

1.1. Scaling

Calcium carbonate scaling is observed in Kizildere Geothermal Field either in the form of calcite or in the form of aragonite. One or both can form in aqueous solutions depending on conditions of temperature and pressure and ionic concentrations [Tassew 2001].

Calcite solubility depends on the partial pressure of carbondioxide. When the latter decreases, CO_2 quickly transforms into the vapor phase and the pH value of the fluid increases. Fluid becomes oversaturated and calcium carbonate precipitates via reaction 1.

2HCO3(solution) +Ca+(soluition) = CO2(g)+H2O(fluid) +CaCO3(solid) (1)

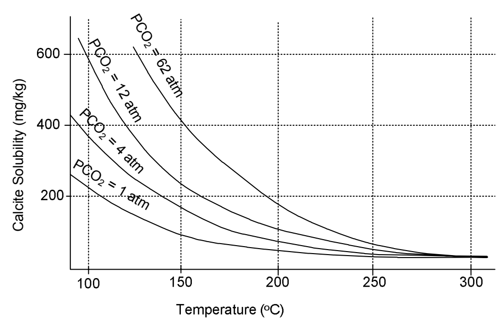

Figure 1: Calcite solubility [Nicholson 1993]

1.2. Depth and morphology of scaling in wells

Scales were measured by the Geophysics Log Team of MTA Center by taking caliper logs in order to determine scale geometry, depth and thickness (Figure 2). Same type of geometry was identified in other wells of the same field. Scaling in the well starts at locations were boiling takes place. Measurements indicated that scaling began around 500-600m. In addition, scale thicknesses have been monitored by annual go devil measurements prior to scale cleanups. In a previous study by Dunya, it was found that caliper measurements were in good agreement with go devil measurements [Dunya 2003].

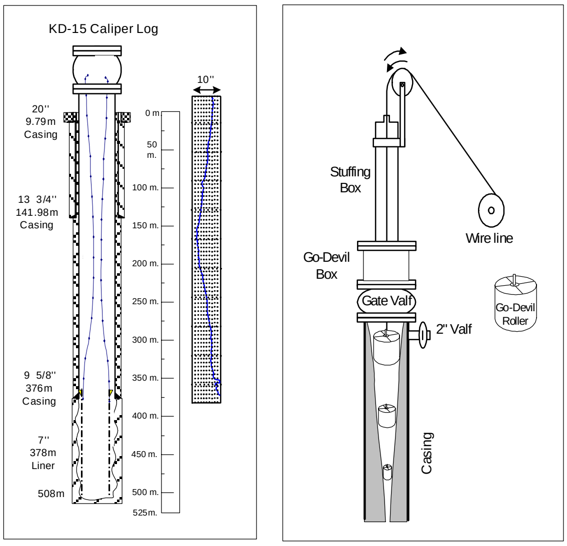

Figure 2: Profile for well KD15.

2. EXPERIMENTAL

Samples were collected from Kizildere Geothermal Field from two wells on two extreme locations (Figures 3-4). Codes and descriptions of samples and their locations are given in Table 1. Photographs of polished cross sections from chunks of samples are given in Figures 5 to 9.

Table 1. Codes and descriptions of samples and their locations.

Code	Description	Well No.
R1 MVI	R1 well, Master Valve Interior	R1
R1 IS	R1 well, Inside the Separator	R1
R1 HP	R1 well, Horizontal Pipe Interior	R1
KD15 MVI	KD15 well, Master Valve Interior	KD15
KD15 IS	KD15 well, Inside the Separator	KD15

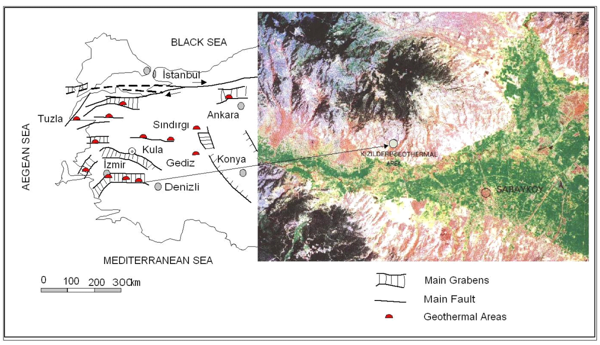

Figure 3: Kizildere Geothermal Field

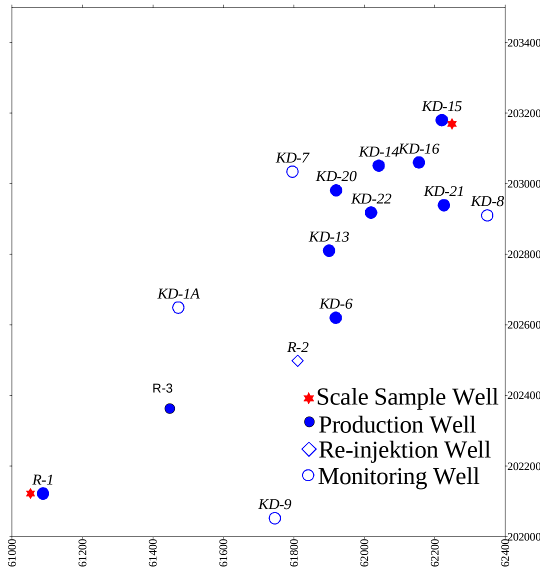

Figure 4: Kizildere Geothermal Field

Figure 5: Cross section from chunk of R1 MVI sample.

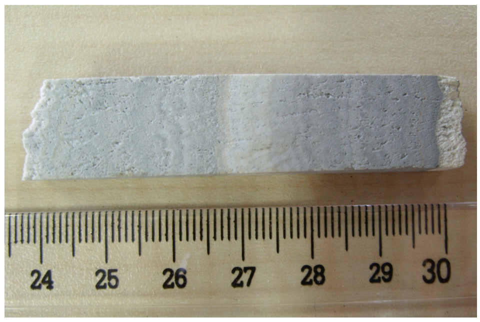

Figure 6: Cross section from chunk of R1 IS sample.

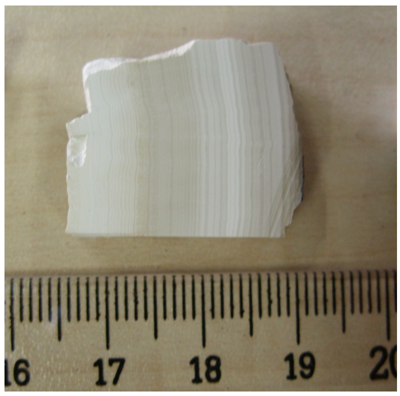

Figure 7: Cross section from chunk of R1 HP sample.

Figure 8: Cross section from chunk of KD15 MVI sample.

Figure 9: Cross section from chunk of KD15 IS sample.

3. RESULTS AND DISCUSSION

Samples in Figures 5-7 had clear marks of light and dark colored layers indicating the potential presence of iron at certain intervals. The reservior which feeds the well R1 consists largely of mica schists containing iron. Slices of samples were cut from regions of light color and layers of dark color. These samples were crushed in a mortar and pestle and analyzed using XRD. The sliced samples shown in Figures 5-9 were observed in an SEM. EDS analyses were also performed to see if there was any immedietly recognisabe variations in chemistry as a function of location in the sample. Results are summarized in Figures 10-14 and Table 2. Presence of iron could not be detected in any of the samples.

Table 2. XRD, SEM-EDS and other data on the samples.

Code	Observed phases and the XRD peak intensities	WHP (bars)	T, °C	Q (Flow rate, tons/h)
R1 MVI	C	30	218	165
R1 IS	A + Little Q + Very Little C	6.5	168	135 tons water + 30 tons vapor
R1 HP	A	15	170	100
KD15 MVI	A + Very Little C	13	180	130
KD15 IS	A	4.7	147	115 tons water + 15 tons vapor

C: Calcite, A: Aragonite, Q:Quartz, Little: Weak peak intensity

XRD charts for all samples are not given for the sake of brevity. Figure 10 shows the XRD chart for R1 MVI sample which consisted of calcite an SEM image of which is shown in Figure 15. The KD15 MVI sample as shown in Figure 13 composed largely of aragonite. Production pressure of R1 well was 30 bars (WHP) and the temperature was 218°C. KD15 well, however, had lower pressure (Table 2). A similar observation was made by Giese et.al. [Giese 1998].

As far as the samples taken from inside the separators are concerned, R1 IS sample, as shown in Figure 11, contained only aragonite in the light colored layers and aragonite and minor amounts of quartz and calcite in the darker layers. R1 HP sample, as shown in Figure 12, contained only aragonite in the light and dark colored layers. KD15 IS sample had only aragonite in the XRD chart. Iron was not detected in the SEM-EDS analysis so its composition was lower than the detection limit of roughly 1%. Strontium was detected in such proportions of roughly 1 part strontium per 4 parts of calcium by weight.

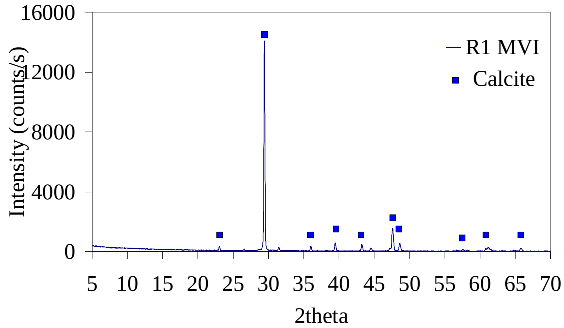

Figure 10: R1 MVI sample XRD diagram (CuKα radiation)

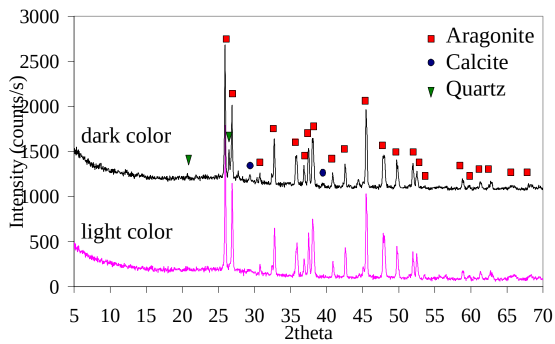

Figure 11: R1 IS sample XRD diagram (CuKα radiation)

4. CONCLUSIONS

Calcium carbonate scaling was observed in all wells of Kilizdere Geothermal Field at varying levels of severity. XRD analyses of samples of chunks collected from wells R1 and KD15 showed that calcite deposited in the well with the higher pressure and temperature while aragonite formed in all other areas of wells where pressure was lower. Periodically repeating darker and lighter layers indicated that darker layers were composed mainly of aragonite and some quartz and calcite. Iron was not detected in the SEM-EDS analysis so its concentration was lower than the detection limit of roughly 1%.

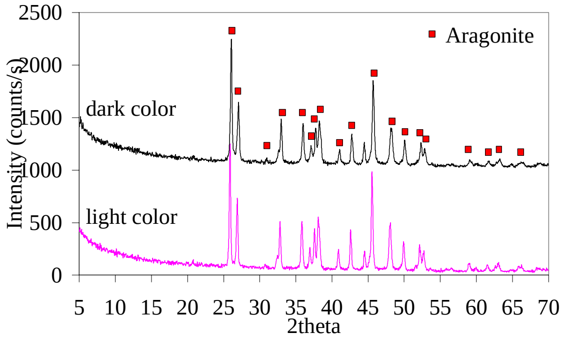

Figure 12: R1 HP sample XRD diagram (CuKα radiation)

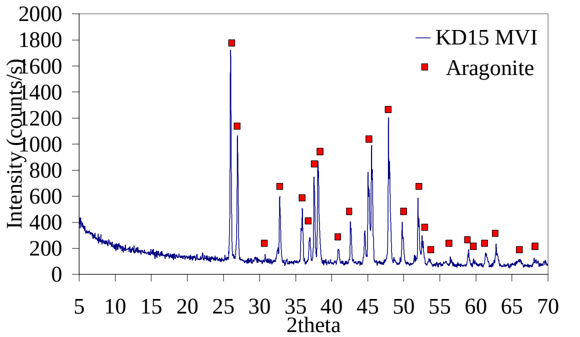

Figure 13: KD15 MVI sample XRD diagram (CuKα radiation)

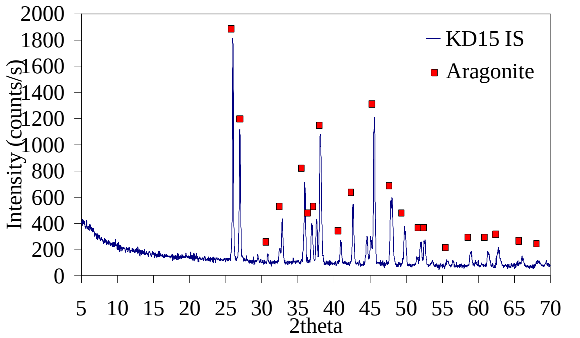

Figure 14: KD15 IS sample XRD diagram (CuKα radiation)

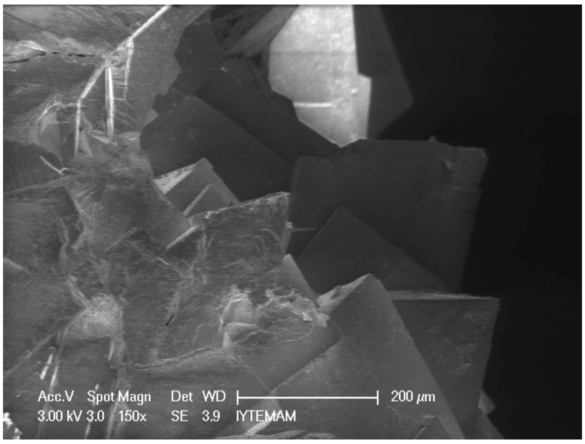

Figure 15: SEM image of calcite scale observed in sample R1 MVI.

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