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Investigating the Effects of Earthquakes on Tuzla Geothermal Field

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ABSTRACT

Tuzla Geothermal Field (TGF) is located at 80 km south of Çanakkale city and it is 5 km away from the Aegean Coast. History of the TGF dated back to 1960s and the earliest drilling activities are performed by General Directorate of Mineral Research and Exploration of Turkey (MTA) in 1980s. However, the field's energy production started at 2010. Geology of the area is mainly volcanic with rhyolite lava and pyroclastic deposits. Tuzla Geothermal field situated on the trans-tensional extensions of North Anatolian Fault Zone (NAFZ) and it is covered by NE-SW striking dextral fault and NW-SE striking normal faults. In Tuzla geothermal field there are 5 observation wells in which pressure data are recorded in every three minutes. Also, production and reinjection wells have well head recording instruments of temperature, pressure and flow rate data that reported in every 4 hours. Aim of this paper is to investigate and classify the effect of the earthquakes on geothermal source by matching the production – injection data as well as pressure response of the observation wells with Kandilli Observatory and Earthquake Research Institute's (KOERI) earthquake database. The classification is based on the earthquakes distance to the wells, depth and magnitude of the earthquake.

1. INTRODUCTION

Observation wells are used to investigate the field's response on operational changes so it's important to have enough number of observation wells spread through field. In Tuzla Geothermal Field there are five observation wells namely; T1, T7, T8, T11 and TA1 (Figure 1). Measurements are taken by sensors located at the well head at the wells T1, T11 and TA1 due to water level can reach to the well head and sensors were lowered beneath water table at the T7 and T8 wells and they have been recording pressure and temperature data since June 2016 and other three started at November 2016.

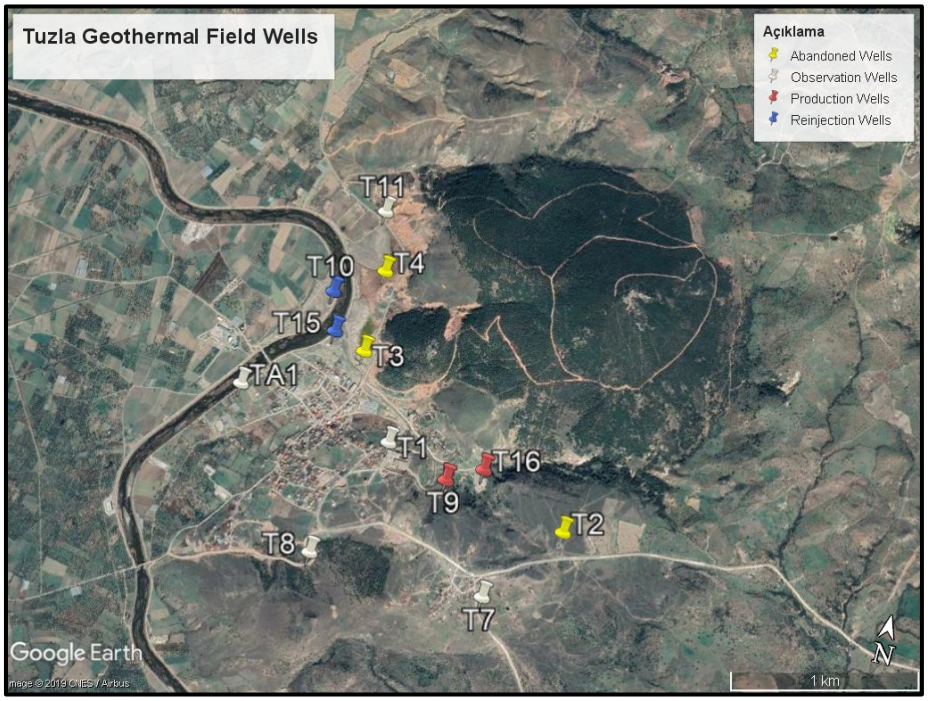

Figure 1: Tuzla Geothermal Field Well Locations

In Tuzla geothermal field, it is observed that observation wells can have responses to certain events. These events are; loss of power, production/reinjection well maintenance, power plant maintenance, change in flow rates in production/reinjection wells and etc. However, there are some changes that are not related to any operational event in the field. In order to explain the deviations in the observation data other events were checked. Some of these deviations are coinciding with neighboring power plants operational activities. However, majority of them remains unexplained. Further investigation shows that in March 2017 and April 2017 there were series of earthquakes in the region closer to the field. These earthquakes coinciding with unexpected data.

Since it is understood that earthquakes can affect pressure, it will raise some questions in the mind that which earthquakes and what are the properties of the earthquake affecting them.

2. METHODOLOGY

First of all, in order to understand the effects of earthquakes, it is required to find the earthquakes that occurred in the area. For this purpose, all the earthquakes that are recorded since January 2016 to June 2019 which are in Çanakkale province was sorted out from Kandilli Observatory and Earthquake Research Institute's (KOERI) earthquake database. Total of 4958 earthquakes sorted out with their attributes; location, depth, magnitude. All these earthquakes and their relative distances to the wells can be seen in Figure 2. As can be seen in the Figure 2, there is too much epicenters which were too far away from wells. To overcome this problem, wells pressure series were evaluated and unexpected changes in the pressure trend were recorded (Figure 3). In Figure 3, blue circles represent pressure records and black lines were operational activities. Notice that some of the changes that occur around day 400 cannot be explained with operational activities.

After that all earthquakes were searched and earthquakes that happened at least 2.5 hours before unexpected changes were indexed to form effecting earthquakes array. Depending on the wells responses 4958 earthquakes were sorted down to hundreds (Figure 4). In Figure 4 different markers represents earthquakes that are affecting different wells. Notice that some earthquakes are affecting more than one well.

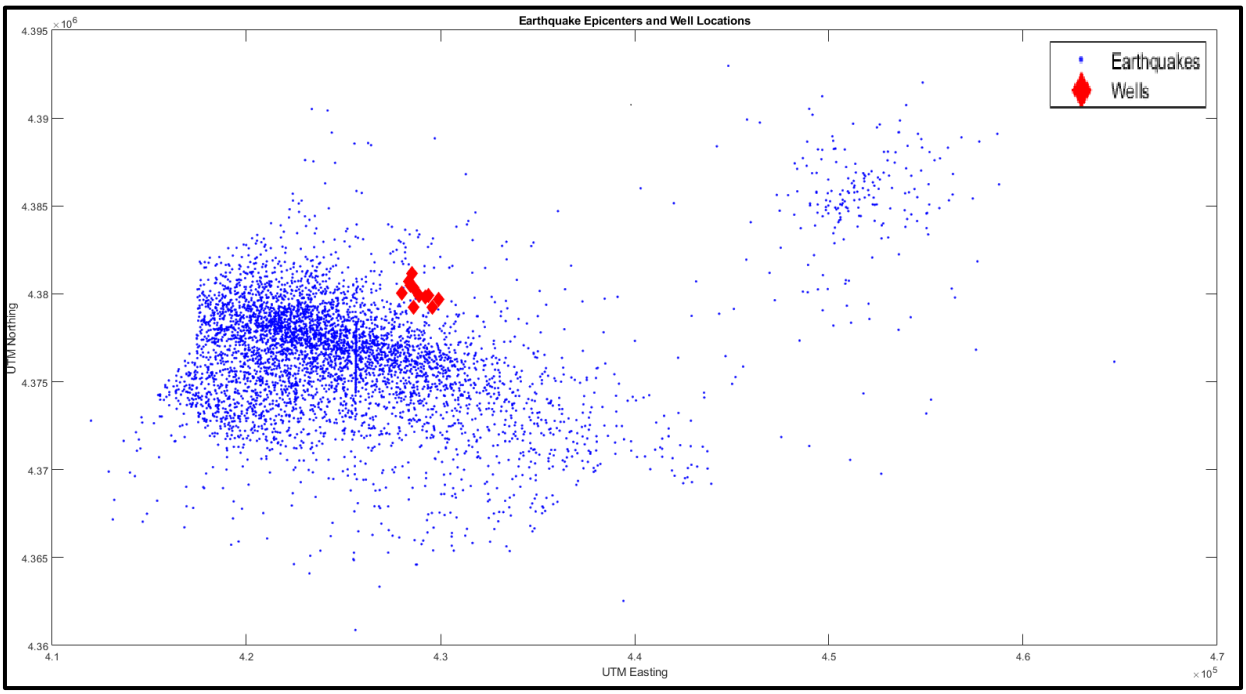

Figure 2: Earthquake Epicenters and Well Locations

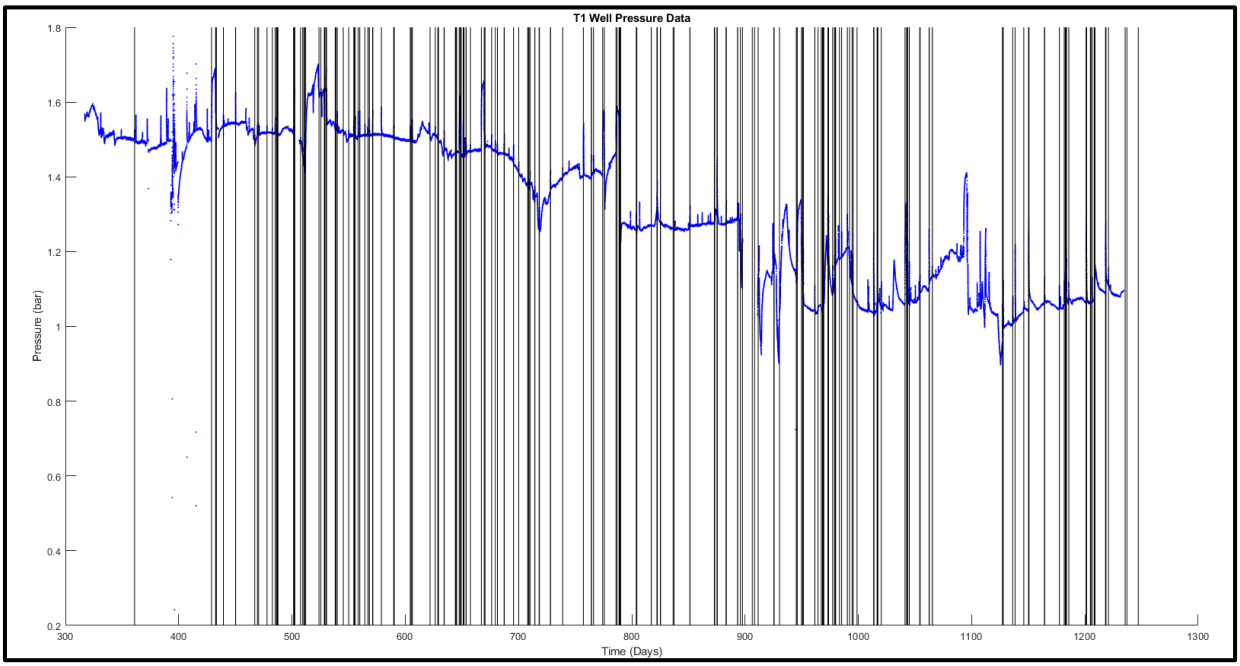

Figure 3: Pressure Record for Well T1 (blue circles = pressure records, black lines = operational activities)

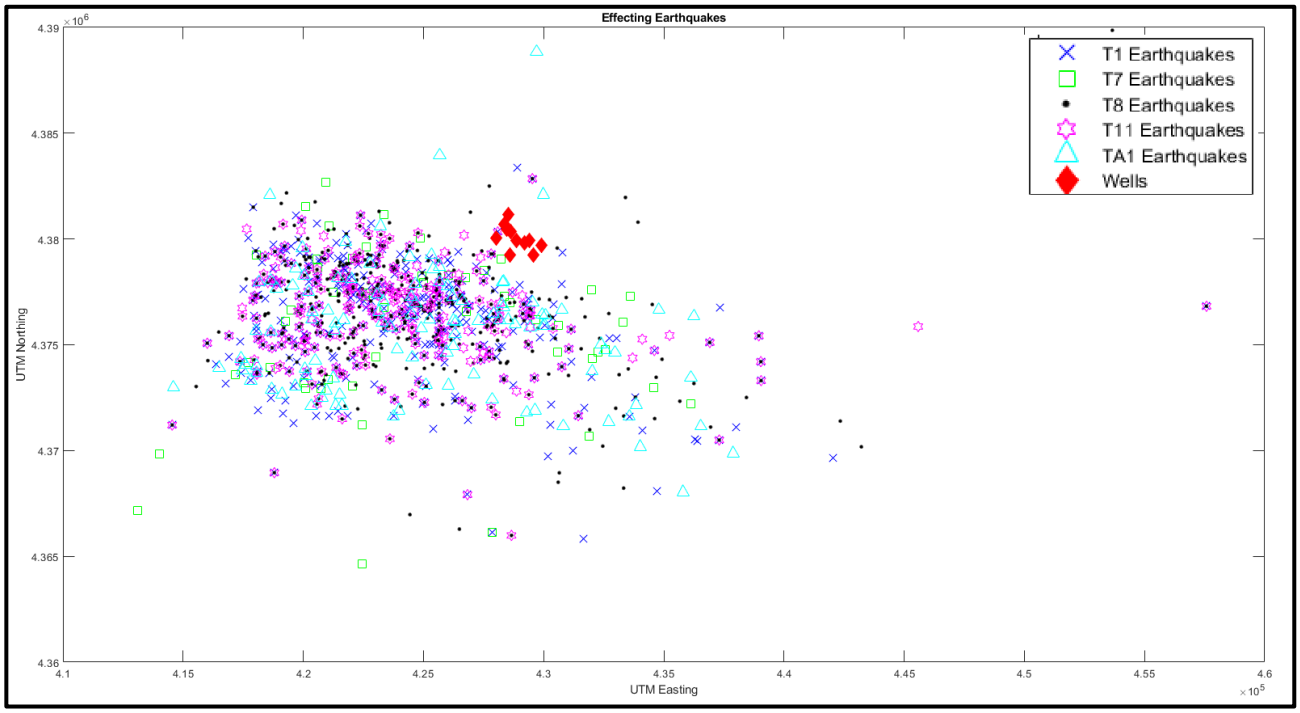

Figure 4: Effecting Earthquakes

3. RESULTS AND DISCUSSION

Total of 897 unique earthquakes (18% of total) were found to be affecting the observation wells. After narrowing down the earthquakes, classification procedure starts. In the classification, first epicenters distance to the well heads were found. Figures 5 to 9 shows distances of epicenters to different earthquakes. Colored circles are for estimating the distance to the well. It can easily be observed that most of the earthquakes were located Southwest of the wells. Most of these earthquakes were associated with Tuzla Fault which corresponds to the activation of the fault. (Bulut et al. 2018).

Following the distance classification, magnitude and depth classifications were made. Analysis of all earthquakes show that most of the earthquakes have magnitudes of 2 in richter scale and it ranges from 0.88 to 5.6 (Figure 10). Four magnitude categories were defined according to Richter scale and can be seen in Table 1. Figure 11 shows histogram for magnitudes with comparison to each well.

Same as magnitude, most of the earthquakes have occurred in 5km depth but it varies from 1 to 31km (Figure 12). Depth classification and the number of earthquakes corresponds to that class can be seen in Table 2. Figure 13 shows histogram for depths with comparison of each well.

Apart from histograms, bubble maps for magnitudes and depths for each wells effecting earthquakes can be seen in Figures 14 to 23.

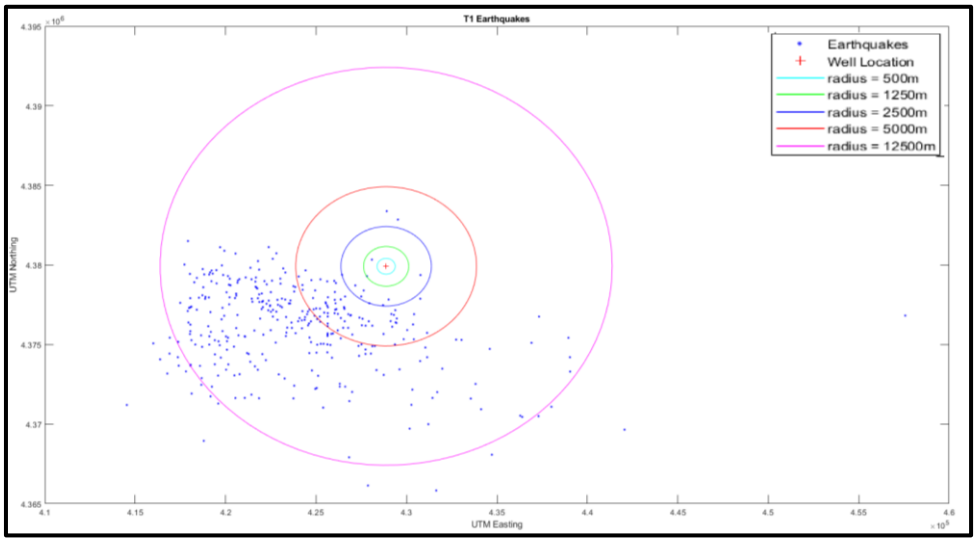

Figure 5: Earthquakes affecting T1 well

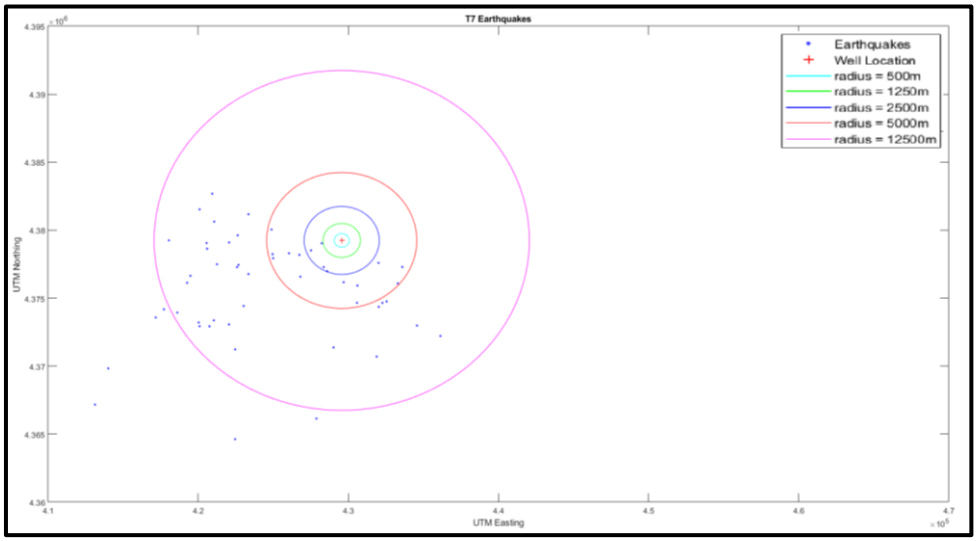

Figure 6: Earthquakes affecting T7 well

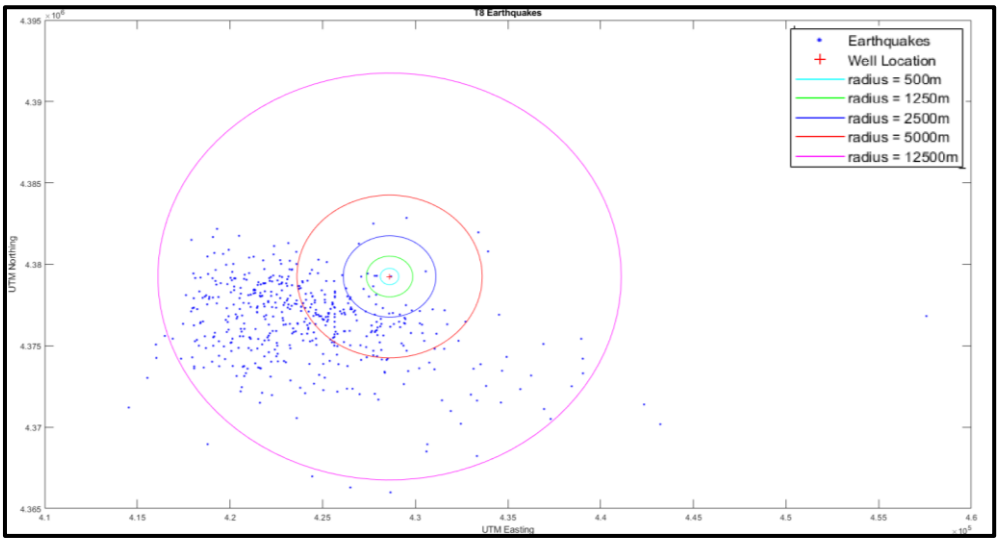

Figure 7: Earthquakes affecting T8 well

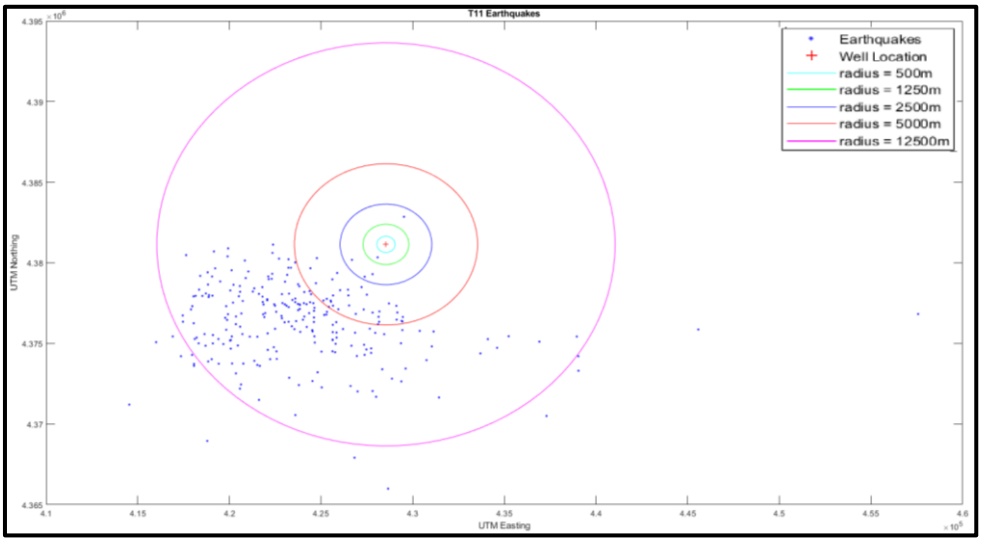

Figure 8: Earthquakes affecting T11 well

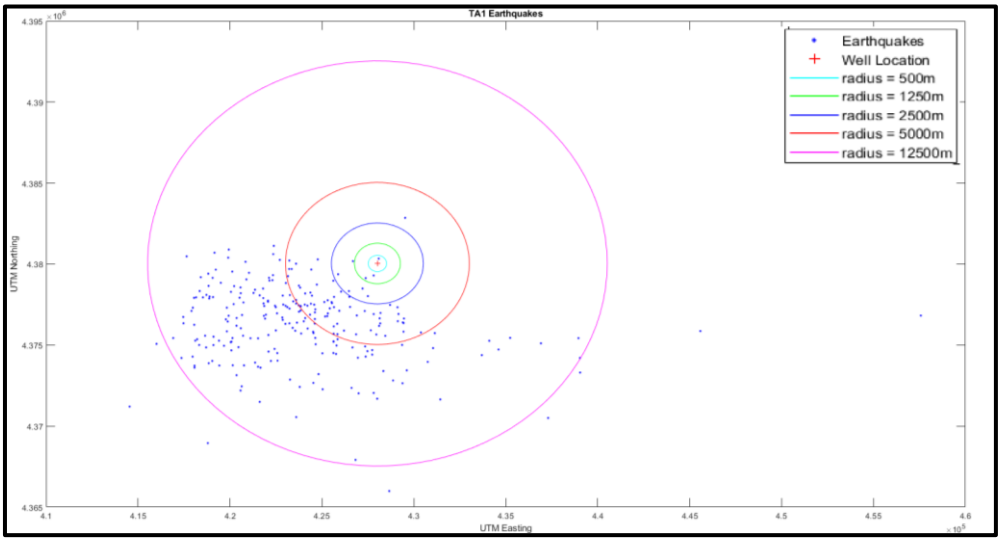

Figure 9: Earthquakes affecting TA1 well

Table 1: Classification Categories for Magnitudes

Magnitude Categories		
Category Name	**Range**	**Number of Occurence**
Not Felt	0 - 3	4671
Minor	3 - 4	254
Light	4 -5	28
Moderate	5 - 6	5

Table 2: Classification Categories for Depths

Depth Categories		
Category Name	**Range (km)**	**Number of Occurence**
Very Shallow	0 - 4	343
Shallow	4 - 8	2471
Slightly Shallow	8 - 12	1205
Slightly Deep	12 - 16	673
Moderately Deep	16 - 20	174
Deep	20 - 24	56
Very Deep	24 - 28	26

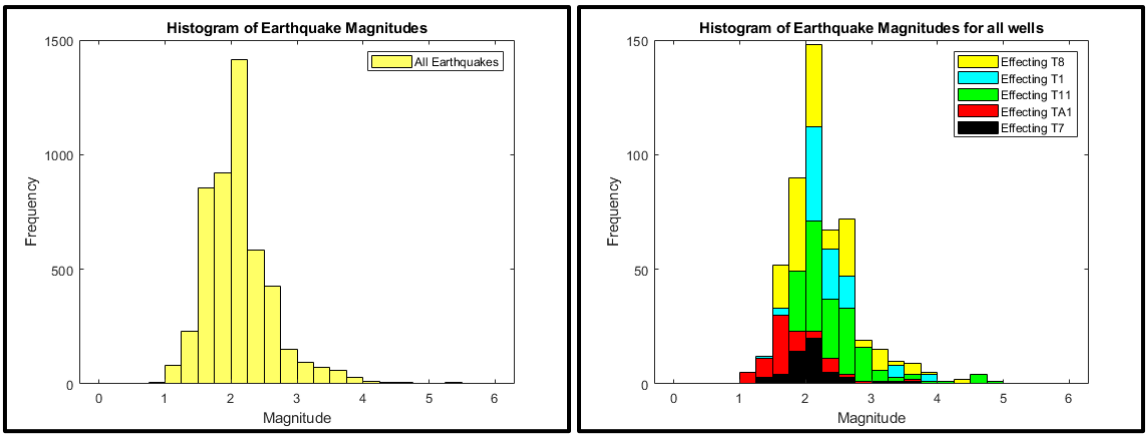

Figure 10: Magnitude Histogram for all Earthquakes and Wells

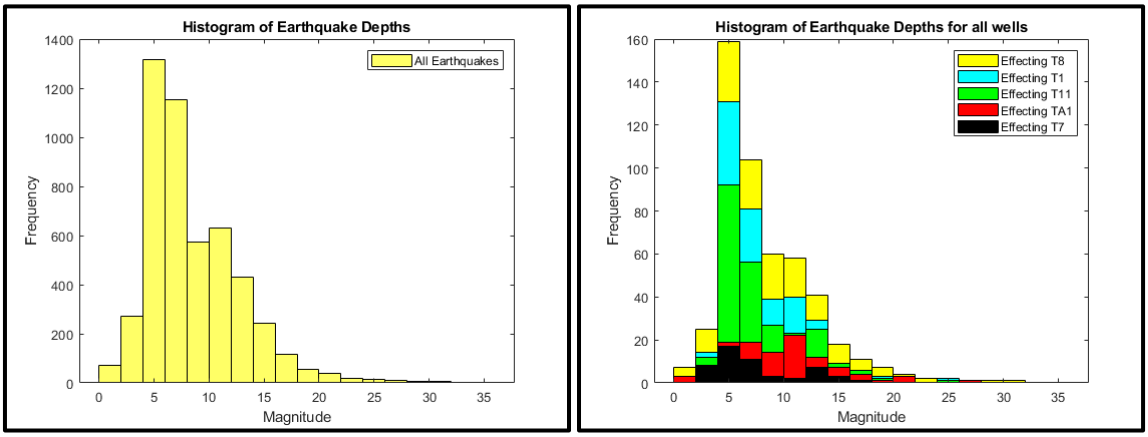

Figure 11: Depth Histogram for all Earthquakes and Wells

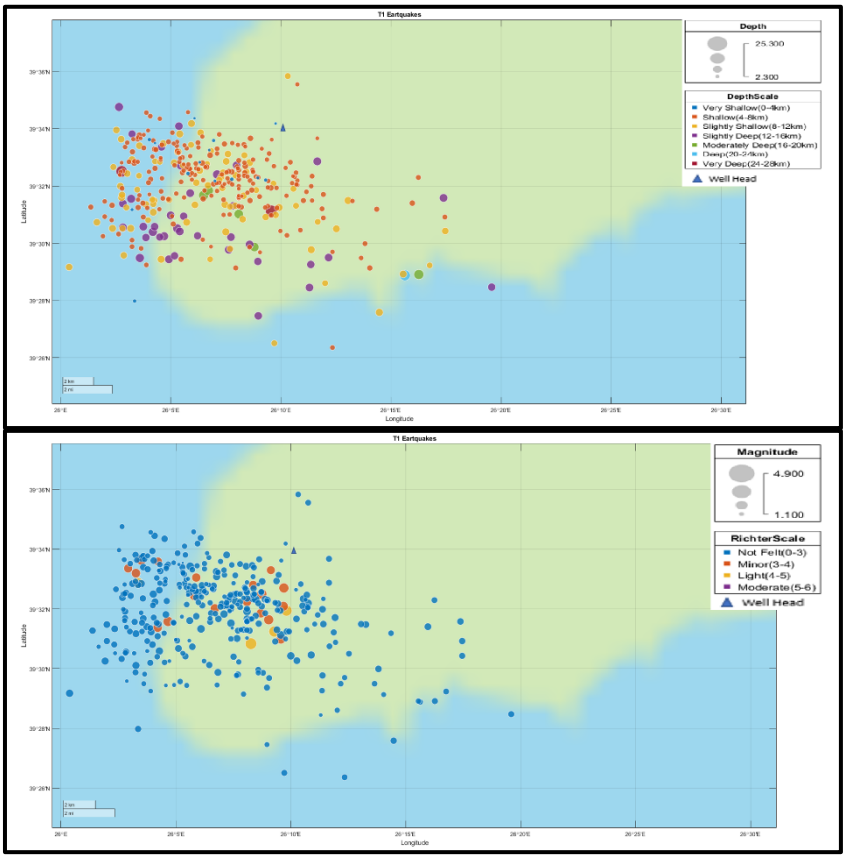

Figure 12: T1 Well Earthquakes Bubble map for Depth and Magnitude

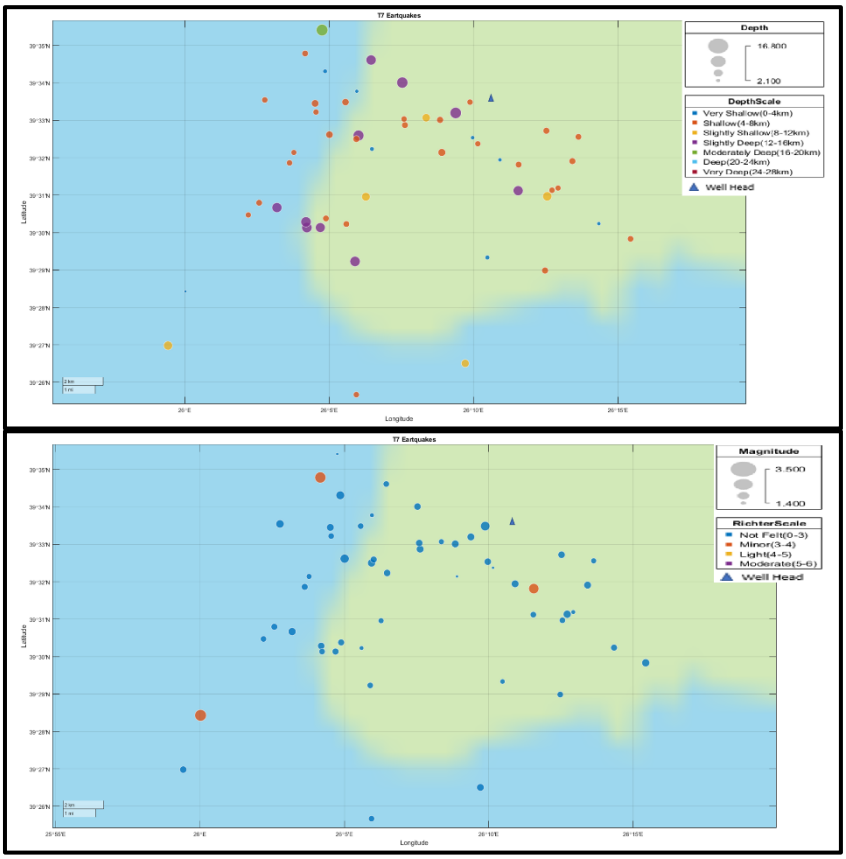

Figure 13: T7 Well Earthquakes Bubble map for Depth and Magnitude

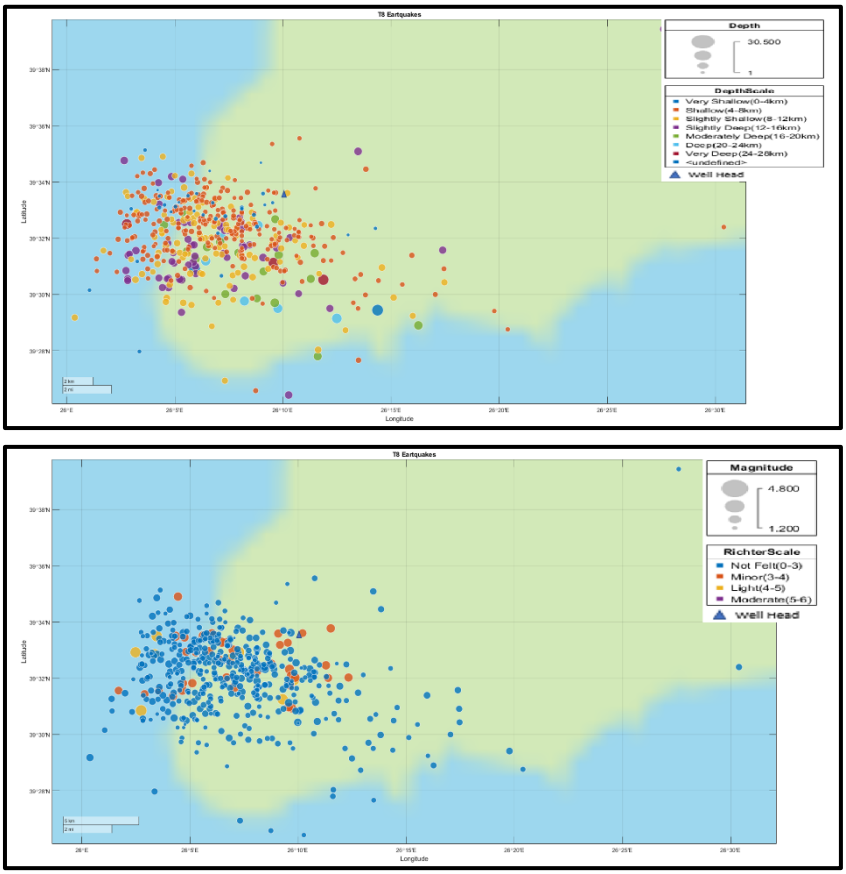

Figure 14: T8 Well Earthquakes Bubble map for Depth and Magnitude

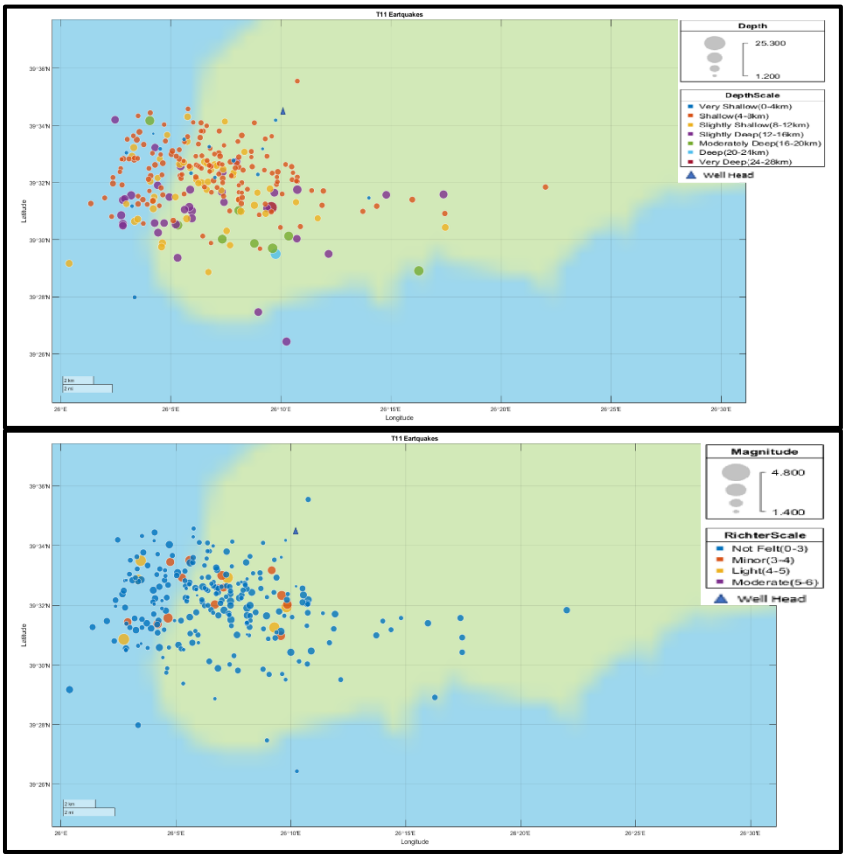

Figure 15: T11 Well Earthquakes Bubble map for Depth and Magnitude

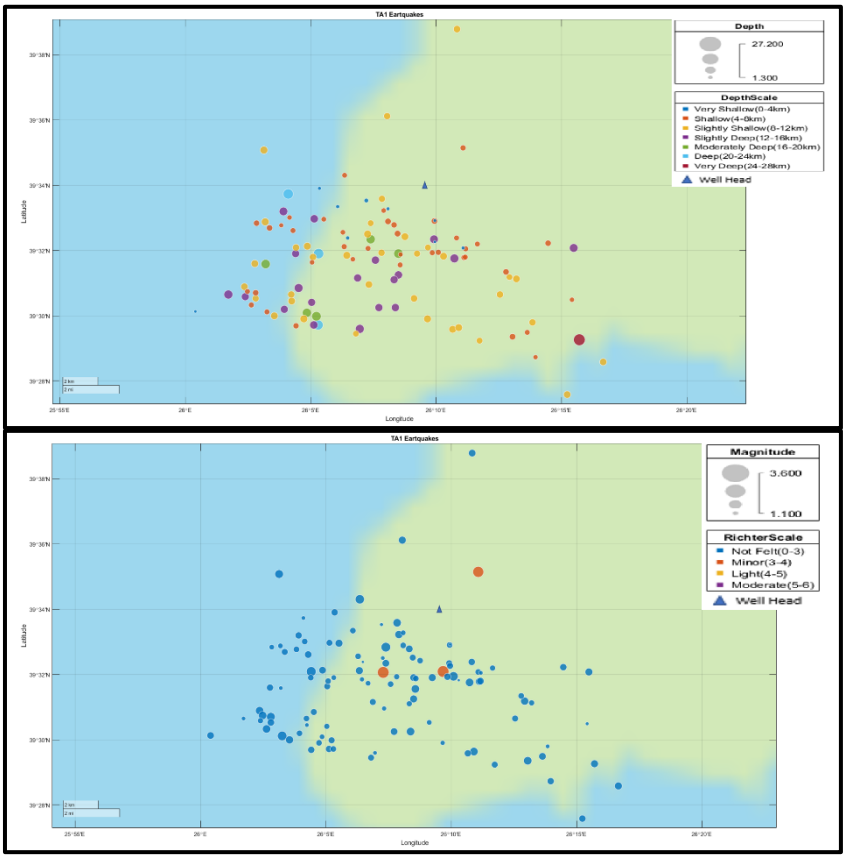

Figure 16: TA1 Well Earthquakes Bubble map for Depth and Magnitude

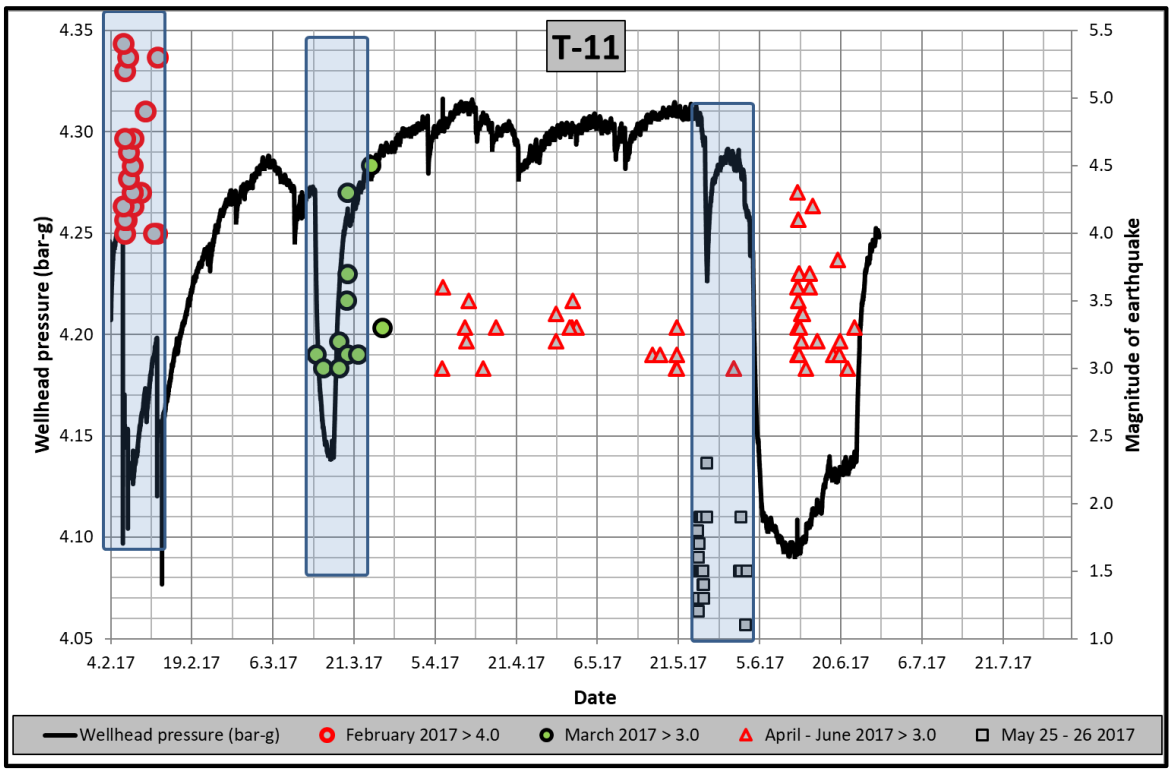

Figure 17: Magnitude of Pressure Change Related with Earthquakes(T11 Well)

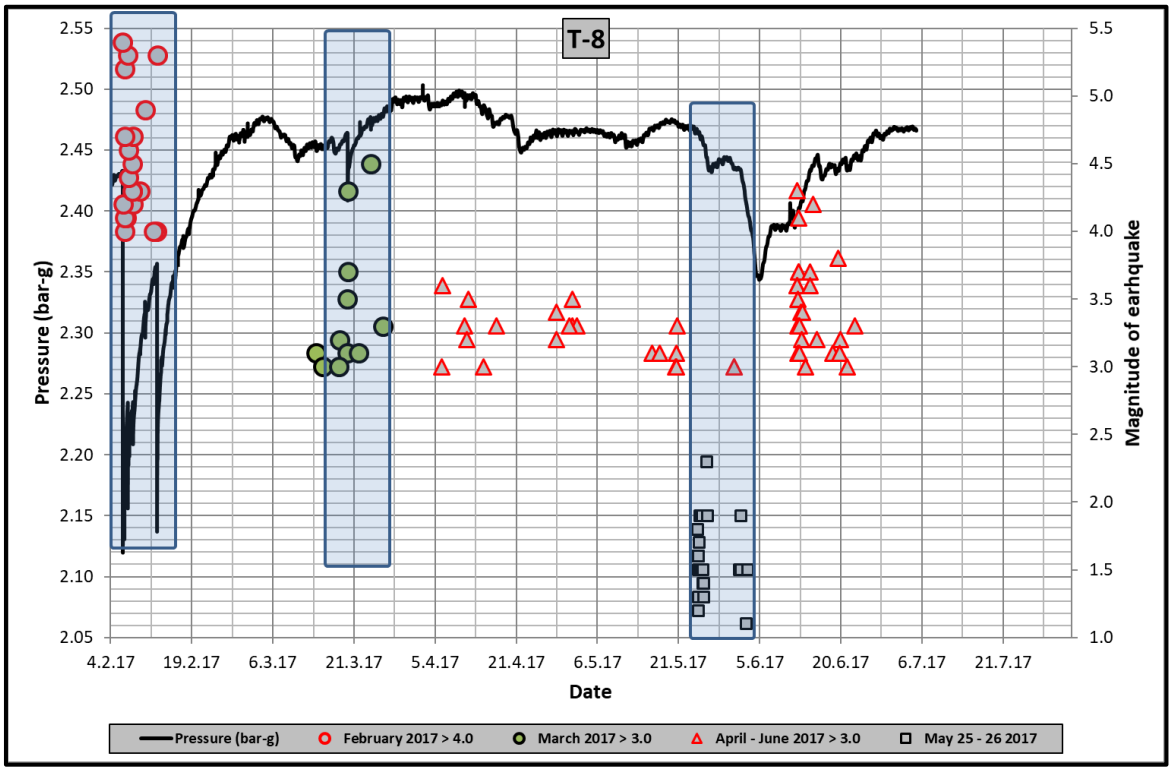

Figure 18: Magnitude of Pressure Change Related with Earthquakes (T8 Well)

4. CONCLUSIONS

(1) Earthquakes can affect pressure recordings in the wells near vicinity and their effect can reach over 15km's in surface. (2) Earthquakes with greater magnitude have an undeniable impact on pressure readings, it is also important that wells with strong hydraulic connection can affect easier than the others such as well T-7. (3) Earthquakes can cause more than 0.3 bar pressure difference in wells which corresponds approximately 4m of water level change (Figure 17 and 18). (4) More research is needed to identify which earthquake property has the major effect on the reservoir pressure; magnitude, distance, or depth.

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