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Volcanology and Geothermal Research by Using Hydrothermal Alteration Processes of Well NWS-4 at Sabalan Volcano Geothermal Project, Iran

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ABSTRACT

The Mt. Sabalan Hypabbusal basement batholiths with monzogranite compenent have been replaced inside of Eocene volcanic rocks during Miocene-Pliocene. Due to this replacement other suitable geological and hydrological conditions, a geothermal reservoir has been formed around Mt. Sabalan. Based on resistivity surveys combined with other geological & geochemical data, the area at N-W Sabalan located 20 km to south of Meshkin shahr was selected for geothermal exploration drilling.

The well NWS-4 is one of the three exploration wells in this area. The result of studies show that an alteration system at NWS-4 has neutral pH & alteration zones consist of average argillic, phyllic & propylitic. In addition, by correlating extent temperature stability of alteration minerals for approximate well thermometry, the alteration temperature can be estimated to be 240 °C.

1. INTRODUCTION

Sabalan Hypabbusal basement batholith has been replaced by monzogranite composition during the Pyreneean phase of the Miocene-Pliocene period (GSI, 1999). As a result of this replacement as well as the geology and hydrology that developed in following phases, a geothermal reservoir has formed around Sabalan. Resistivity measurements combined with other geochemical and geological information determined that the region N–W of Sabalan and 20 km south of Meshkin shahr would be a good location for geothermal exploration drilling. The well NWS-4 is one of the exploration wells located 738694 E and 4239824 N UTM unit, and 2487 m above sea level. The main object of this article to consider the possibility of geothermal energy use focusing on hydrothermal mineral alteration.

2. METHODS

Exploration well drilling is an important phase in the search for geothermal energy. According to primary scientific studies from the place of these wells, they show the search for final phase and then well drilling shows the beginning main phase of searching, and primarily predication of producing water and steam has been confirmed or rebutted for capacity of these regions.

The first phase in geothermal well drilling is to review litho-geologic, tectonic, petrologic, and stratigraphic information, in order to guide planning of the well (Schuster, 1974). Since we need to have a preliminary model of the well and availability to site position of drilling rather to other geology factors in every time. Then we can compare the drilling data with preliminary predicated information.

In total, during drilling three sets of information can be collected: drill cuttings and cores, temperatures of mud slurry, and permeability based on the lost drilling fluids. The most important information in relation to the capacity of the region can be obtained of from different petrographic techniques that consist of:

- Temperatures deduced from hydrothermal mineralogy and fluid inclusions.
- Chemical quality of fluid or fluid sources by hydrothermal mineralogy (natural and acidic pH alteration collection) and fluid form inclusion such as CO2 volume, or existence of other gases and fluids.
- Permeability by texture & mineralogy and type of rocks.

The most important, least expensive, and the easiest way to get information during drilling is to compare preliminary information with drilling samples. The alteration condition and alteration of secondary minerals, is the most important factor, and temperatures in the region can be determined by studying alteration minerals. So, drilling samples were collected in 3 m intervals, and were studied in the geological laboratory; our methods include:

- Type of rock
- Primary or secondary texture
- Alteration intensity
- Alteration minerals such as main alteration, color characteristic, crystal size and sub alteration minerals (Razavi, 2000).
- Veins and mineral veins characterization.
- Sample comment from alteration and stratigraphic point of view.

3. GEOLOGY

The global tectonic encironment of the area is affected by some phenomenas such as subduction of the Arabian plate under the central Iranian plate. Also, tow thrust has made the Southern Caspian sea depression and tow thrust faults in the north of Iran and Caucasian range. Mt. Sabalan is a large quaternary stratovolcano in this area and Northwest of Iran.

The stratovolcana is created on a possible horst trending northeast–southwest and erupted possibly as recently as in the Holocene. The lava flows consist of trachyandesite, andesite, dacite, and pyroclastic deposits.

Hydrothermal alteration out-cropped in some parts indicating secondary alteration minerals as iron oxides, kaolinite, limonite, and clays.

4. STRATIGRAPHY

- Dizu : 0- 60 m

Equivalent with Qt1 and Qt2 in geological map of geological survey of Iran carried out by Amini (1998). Grain size is variable from sand to boulder. Deposits are unconsolidated and unaltered except for some rare extinct secondary alteration minerals. Grains have composition including: trachyandesite with plagioclase, hornblende and potassium feldespar; andesite with plagioclase and hornblende phenocrysts di grey groundmass.

-Valazir : 60 – 383m

This formation is equivalent with Qpad in Amini geological map and consists of Andesite, porphyritic dacite that underlies the Dizu formation. Lithology consists of consolidated rocks as andesite flow, trachyandesite and volcanic breccia with porphyritic texture. Samples from this well in Valazir formation is totally altered to clay, silica, pyrite, calcite and minimal amounts of chlorite. Primary lithology is not to clear and volcanic altered is the term that uses for it.

-Epa 383-1840m

Composed of microlitic porphyritic andesite, most of the rocks have hardly any epidote due to contact with hypabbysals. The top of the formation is rich in iron oxide.

- Hypabbysal rocks: 1840 – 2625 m

Fine-grained, altered, diorite with secondary calcite, epidote, actinolite, and chlorite.

5. DISCUSSION

Since the prediction of alteration temperatures was one of our most important goals during drilling, diagnostic minerals were analyzed via microscope to approximate geothermometry of the well. Then, a list of hydrothermal minerals and temperature limits of their endurance were selected and used for approximate geothermometry of the well (Kingstone Morison, 1998) (figure 1 in appendix.).

Because of their abundance, mineral characteristics and microscopic analysis led to easy differentiation, that can be divided to many clay zones .These zones give a total of approximate of well temperature (figure 2 in appendix).

6. TYPE OF ALTERATION ZONES

In this part, we followed the result yielded from hydrothermal solution effects on rocks as reported by Meyer & Hemly (1997). The base of this categorization are metasomatic processes that alkalis and hydrogen activity have an important role. Although chemical composition of the hydrothermal solution, temperature, EH, pH, and alteration mineral composition are main controllers of it. In this division, alteration is separated as a one of many minerals with base point, every part knows a zone. Therefore collection of hydrothermal minerals (opaque and non opaque) can be used to determine hydrothermal water composition. So by the collection of these alteration minerals, we can determine the acidic ratio of hydrothermal fluids. The alteration on the base of acidic can be divided to natural pH and acidic alteration. Each mineral has a separate limit temperature and watery compound (Elis & Mohan, 1977). The perfect alteration zone in NWS-4 has been cited to crystal abundance form, alteration intensity, and specifically to alteration mineral formation in veins.

Review of mineralization process showed that weathering, deterioration, diagenesis, hydrothermal, and contact metamorphism were a many of the factors that had a role in producing secondary minerals in NWS-4. The hydrothermal conditions have a dominant role in the process.

By looking at the minerals in each alteration zone we can see three alteration zones in NWS-4. From groung-level to 80 m depth no minerals are observed except hematite, which was produced by weathering. We assumed the depths between 80–680 m to be an argillic zone because of the existence of quartz, smectite, calcite, pyrite and less altered to non-altered feldspar. Depths between 680–1,200 m are a sericitic alteration zone because of the existence of chlorite, clay minerals (probably illite), pyrite, and in some depths chalcopyrite and white muscowite. Depths below 1,200 m are known as a propylitic alteration zone since it's volume increased and there is a lot of crystalline epidote. There is not any sign of drilling samples because of total loss of circulation (TLC) between 1,598-2,030 m. But, the samples studied below 2030 m indicate a propylitic zone because of a lesser amount of biotite and ferromagnetic and secondary ferromagnetic minerals (probably magnetite). In addition, alteration minerals are best correlated with flowline temperature (figure 3 in appendix.).

7. CONCLUSION

In total the studies have been done from up to down show that the geothermal system in NWS-4 is neutral pH with three medium argillic, sericitic and prophylitic alteration zones. By comparing the limit temperature endurance of alteration minerals we can approximate geothermometry of the well,which is estimated at 240 ℃̇.

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APPENDIX:

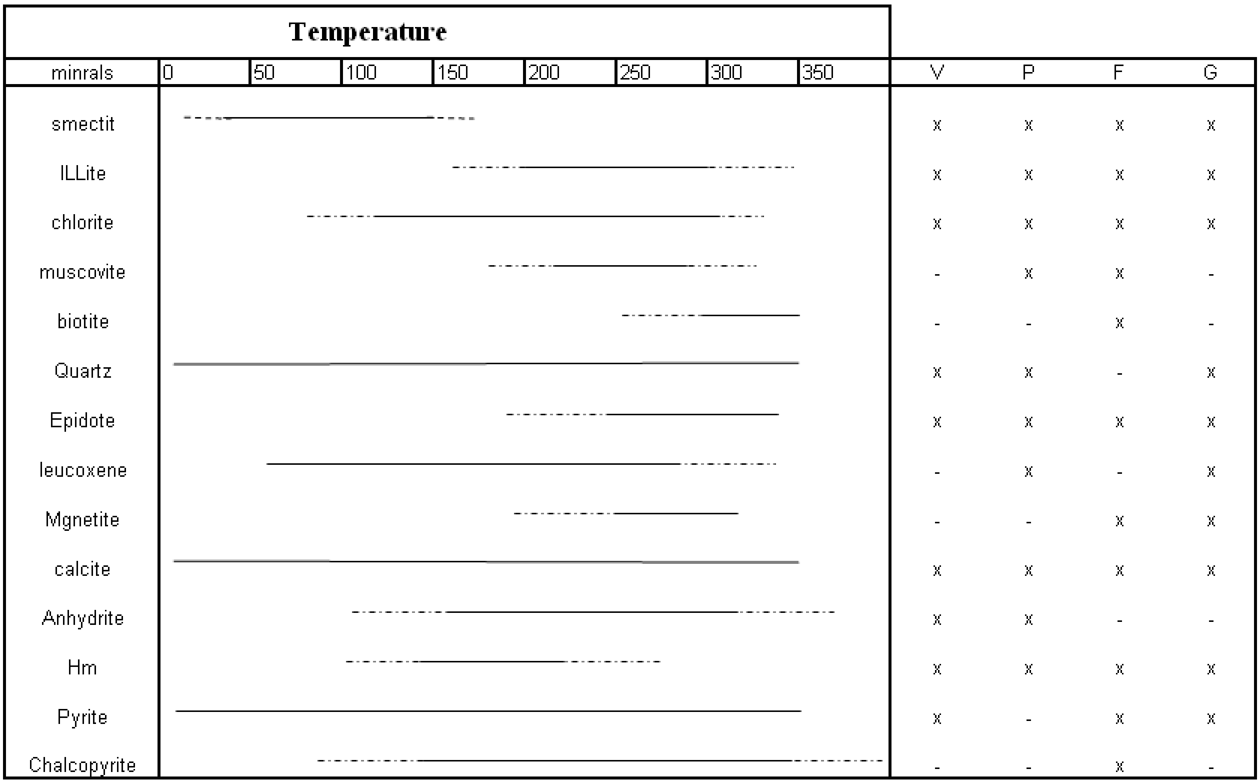

Figure 1: The thermal stability limit for hydrothermal minerals in NWS-4. V, P, F, G are the minerals formed in veins, replaced in feldspars, replaced in Ferro magnesium and replaced in context, respectively.

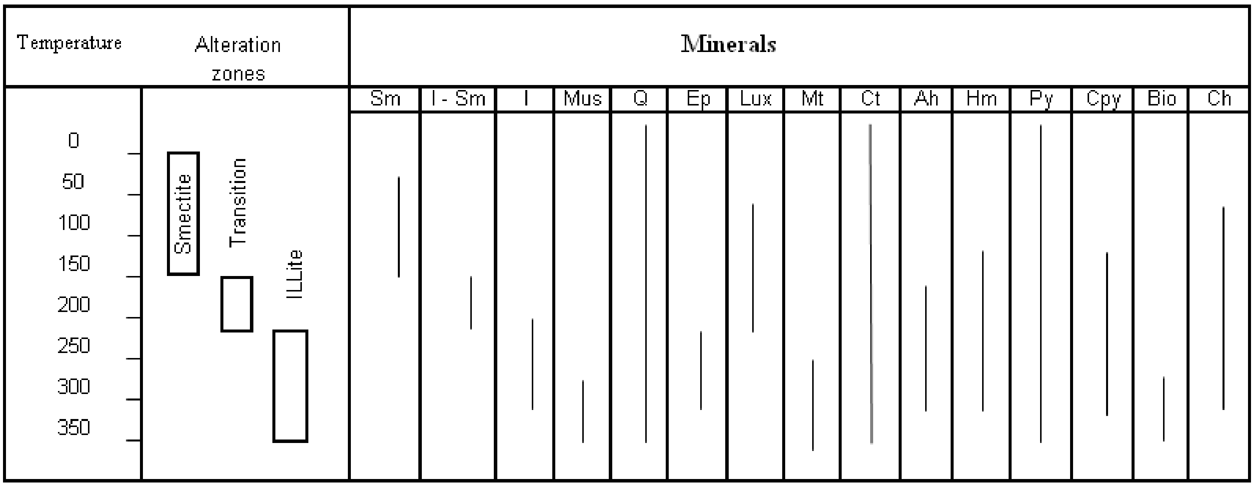

Figure 2: The types of clay alteration zones in NWS-4.

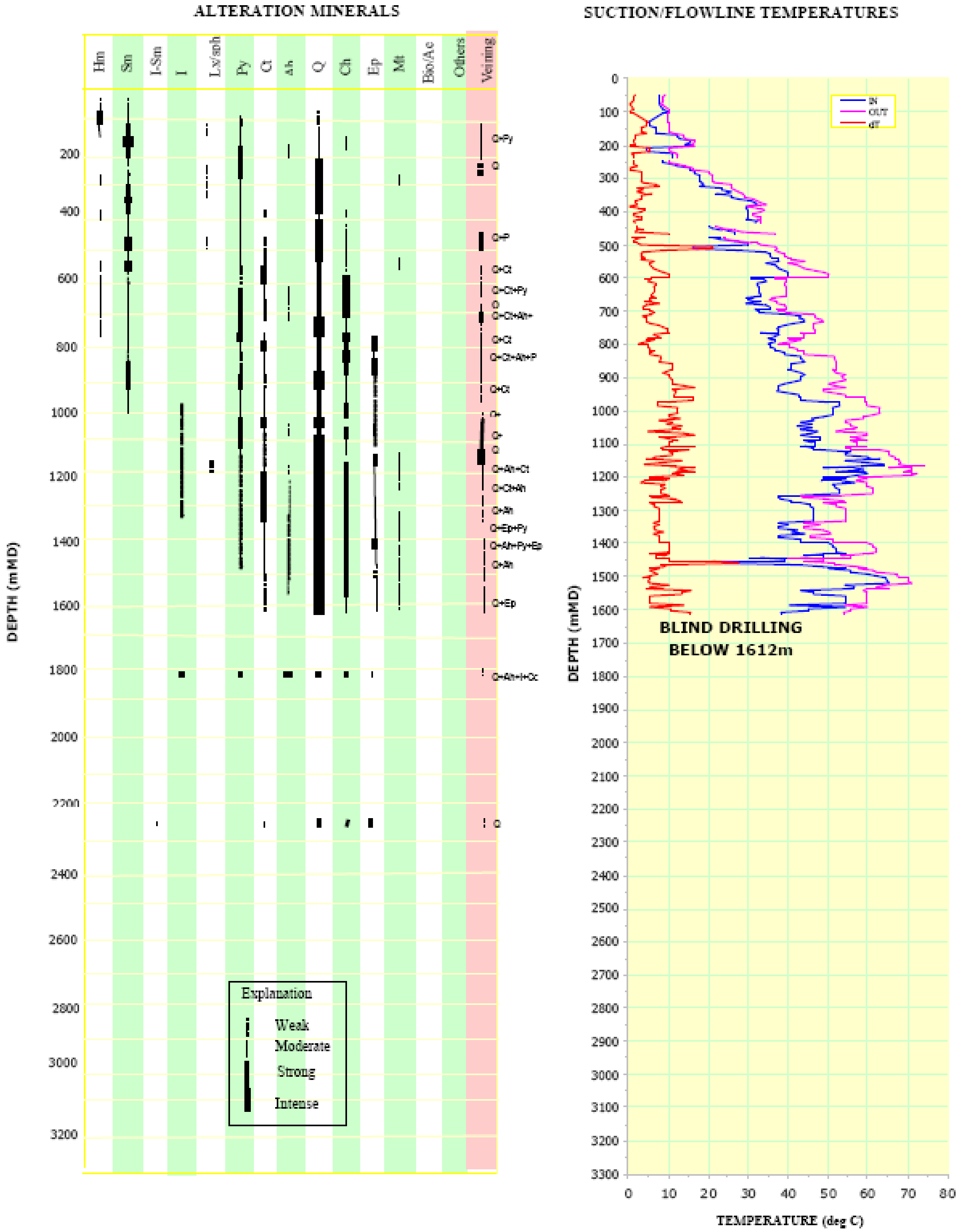

Figure 3: Distribution of alteration minerals in NWS-4 in relation with flow line temperature.