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THE USAGE OF PETROGRAPHY IN GEOTHERMAL EXPLORATION

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ABSTRACT

Geothermal is an alternative energy that has a high temperature and in certain temperature and preassure the surrounding rocks become alterated, in this alteration zone usually the type and characteristic of geothermal system can be decided. Therefore in order to know further about the geothermal system a certain tool is needed to investigate the alteration rocks. Petrography is a branch of petrology that studies the characteristics of rocks in a microscopic scale. Due to the microscopic scale, this method can describe provenance, zone of alteration, mineral assemblages, and characteristics of rocks more specific and detailed than macroscopic scale. In petrography there are many techniques that can be used based on the purposes of doing the petrographic analysis such as thin section preparation, X-Ray Diffraction, Scanning Electron Microscope, GPAC and etc; to make a better result and a higher accuracy data these techniques can be combine together.
In geothermal exploration, the petrographic analysis plays an important role in determining the potential resources. A petrographic analysis can be use in many ways like describing core samples from an exploration well, using a scanning electron microscope to characterize the fracture surfaces from microstructures or doing X-ray diffraction to identify exact mineral assemblages of a rock, and thin section to confirm the alteration minerals and type of rocks.

Keywords : geothermal, petrographical analysis, potential resources.

INTRODUCTION

Geothermal is an alternative energy that usually occurs in the area that has high temperature and certain preassure. A geothermal system requires heat, permeability, and water. The heat from the Earth's core continuously flow outward and heating nearby rock and water. When water is heated by the earth's heat, hot water or steam can be trapped in permeable and porous rocks under a layer of impermeable rock and a geothermal reservoir can be formed. This hot water can manifest itself on the surface as hot springs or fumaroles, but most of it stays deep underground, trapped in cracks and porous rock. These hot water that trapped make a certain reaction with the surrounding minerals and create a new ones.
Due to the production of each reactions will not be the same, these can indicate the condition of the geothermal reservoir. To know further about these reactions, we need a certain tool to investigate it. The exact tool to use is petrographical analysis.
That is why the writers make these paper to inform that the petrographical analysis is important in geothermal especially in exploration.

PETROGRAPHICAL ANALYSIS

Basic Theory

Petrology is a branch of geological study, the main object is to examine the characteristics of rocks whether it is igneous rocks, sedimentary rocks, or metamorphic rocks. The role of petrology is very essential in geology, this was because of the primary materials that form the earth's crusts are rocks.
In the investigation of the microscopic scale, the petrography is more useful than petrology. Although petrography is a branch of petrology but it's looked like their have their own study objects.
Petrography has a better result in describing provenance, zone of alteration, mineral assemblages, and characteristics of rocks. In describing provenance by doing petrographical analysis we can see the microscopic scale of rock textures and the shale distribution, this help us to examine the characteristics of rocks more details than in macroscopic scale. The same way also works in zone of alteration and mineral assemblages.
Due to the characteristic of geothermal, the petrographical analysis is focused in describing the zone of alteration. Where the theory are :

Rock alteration

Rock alteration simply means changing the mineralogy of rock. It happens when the primary minerals are replaced or react with the secondary minerals because of the changes in the prevailing conditions subjected to the rock. These changes could

be changes in temperature, pressure, or chemical conditions or any combination of these. (Lagat, 2010)

Hydrothermal alteration

Hydrothermal alteration simply means a change in the mineralogy as a result of interaction with hot water fluids, the fluids carry metals in solution, either from a nearby igneous source, or from leaching out some nearby rocks. Besides metals, the fluids also compose of variable materials like gases, salts (brines fluid), water, silica, chlorite, or etc. (Lagat, 2010)

Sampling

Cuttings from geothermal wells are normally sampled after every 2m interval, but if the sample was too little and unrepresentative, up to 4m depth interval is sampled. Preliminary analysis of the cuttings and coring are normally done at the rig site by use of a binocular microscope and specimen samples which are representative of all rock units penetrated are selected for further analysis.

The problem with cuttings generally, is that the rock chippings in some samples are fine, usually smaller than the crystals hence bringing about the difficulty in identifying some lithologic units conclusively. Another problem is when cutting chips derived from a specific depth may have fallen from a shallow level due to cave-ins resulting to mixing cuttings. If this problem occurred, geosweeps can be use, geosweeps are some kind of tools to carried out where mixing of cutting is suspected. (Lagat, 2010)

Minerals characteristic

Fachrudin (2010) suggest that usually in hydrothermal deposits, there will always kind of minerals like quartz, feldspars, muscovite, chlorite, epidote, hornblende, tourmaline, barite, calcite, dolomite, casiterite, ilmenite, fluorite, chalcopyrite, bornite, pyragyrite, pyrite, etc. while in the fumaroles and the hot springs deposits are quartz (chalcedony), opal, zeolite, gypsum, alunite, hematite, magnetite, halite, sulfur, etc.

Some minerals that usually occurs in geothermal field are :

Adularia, it occurs as replacement of plagioclase or primary K-feldpars and is occasionallydeposited in veins as well as forming incrustations in fissured rocks. The psudomorphs of adularia are made up of numerous overlapping crystals of rhombic section.

Actinolite, is green to grayish green in colour, forms radiating fibers or circular crystals and also massive to granular aggregates in the groundmass and has a moderate birefringeance. This mineral is formed as a replacement of ferromagnesian minerals in association with epidote and chlorite.

Chalcedony is a quartz that partly transformed, usually it was colourless, white, or bluish – grey cryptocystalline chalcedony lines vesicles and coat fractures and veins. At high temperature, chalcedony in vesicles is seen transforming or is completely into quatz but the chalcedonic outline is still preserved.

Chlorite, it shows a wide distribution and a big variability in colours, forms and textures. In the volcanic sequences, chlorite appears in small intergranular patches whereas at the deepest level, chlorite is idiomorphic, forming radial aggregates in veinlets and vugs in association with quartz, calcite, epidote, amphibole and pyrite. Within veins, chlorite occurs as microsphere enclosed within epidote, but it may also replace primary pyroxene and the matrix.

Epidote, it usually shows a systematic textural development with increasing depth and filling fractures,vesicles, and replacing primary plagioclase and pyroxene and in most cases forms mineral association with mainly quartz, chlorite, and sometimes calcite.

Fluorite, it usually dark brown, pink to reddish orange in colour and occurs in veins that associate with calcite and quartz. It forms a typical cubic and to a lesser extent the octahedrons as well as combinations of these two and other rarer isometric habits.

Pyrite, usually occurs as euhedral cubic crystals with brassy yellow luster in reflected light. It usually deposited in fractures, vesicles, and veins.

Quatz, is colourless to white in colour and occurs in anhedral to subhedral crystals. It is identified both as open space (vesicle) fillings and vein filling mineral.

<u>Methods</u>

There are many methods that can be used in petrographical analysis, they are :

a. Thin Section
   Thin sections used for petrological and mineralogical observations are made in different sizes and using different techniques for curing, polishing and staining. Thin sections also known as a laboratory preparation. In optical mineralogy and petrology, a thin section (or petrographic thin section) is a laboratory preparation of a rock, mineral, soil, pottery, bones, or even metal sample for use with a polarizing petrographic microscope, electron microscope and electron microprobe.
   (Shelley, 1985)
b. XRD
   Is a method used for determining the atomic molecular structure of acrystal, in which the crystalline atoms cause a beam of X-Rays to diffract into many specific directions. In an X-Ray diffraction measurement, a crystal is mounted on goniometer and gradually rotated while being bombarded with X-rays,

producing a diffraction pattern of regularly spaced spots known as reflections. (Westgren, 1925)

c. SEM

Scanning Electron Microscope (SEM) uses a focused beam of high energy electrons to generate a variety if signals at the surface of solid specimens. The signals that derive from electron – sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. (Egerton, 2005)

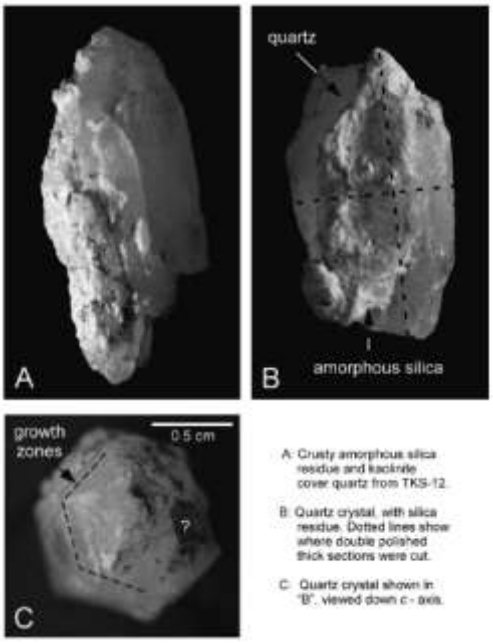

Figure 1: Photograph of quartz crystals collected from the Paeora Fault Scrap, G.Bignall et al/ geothermics 33 (2004) 615 - 635

d. GPAC

This analysis technique allows for the development of petrophysical properties on cutting and percussion sidewall cores where these measeurements cannot be accurately made. This analaysis significantly enhances the overeall information from these type of rock samples. When integrated with thin section and XRD analysis, improved understanding of reservoir potential is achieved.

This analysis involves the use of backscatter imaging techniques using a scanning electron microscope on ultra polished billets. It is a unique approach that allows for a study of the pore system at much higher levels of magnification than can be obtained from performing this analysis on thin section. Analysis requires BSI on ultra polished billet and SEM photomicrograph on fresh surface. (GPAC,2013)

e. Etc.

PETROGRAPHY USAGE IN GEOTHERMAL EXPLORATION

As we know that the use of petrography analysis plays an important roles to investigate the potential resources. Due to the microscopic scale, we can describe the zone of alteration more specific and detail than the macroscopic scale.

According to the study that has been held by Greg Bignall, 2004 in Te Kopia, the petrography gave a massive contribution to his study. The methodology that he used was SEM – CL imaging of surface quartz which the results are SEM – CL imaging indicates that Te Kopia quartz crystals have had a complex history (e.g. Fig.2). Most of the quartz crystals have a low intensity luminescence core (CL-dark) which is inferred to have grown under stable physic-chemical conditions within Te Kopia geothermal reservoir.

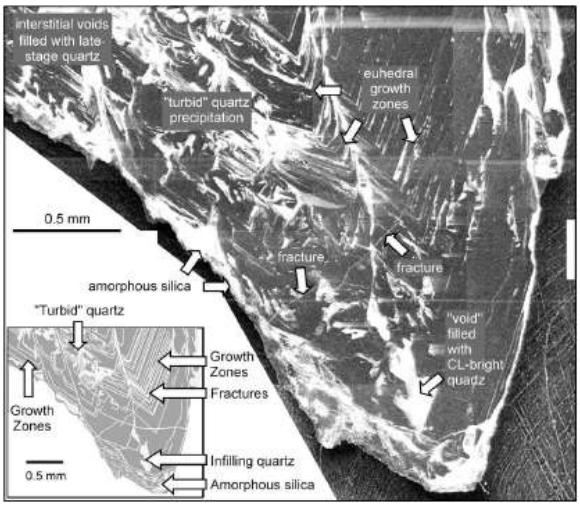

Figure 2: A SEM – CL mosaic of quartz crystal from G.Bignall et al / geothermics 33 (2004) 615 - 635

This study is held to support his data in Fluid inclusion microthermometry of Te Kopia quartz. In this study he informed that most fluid inclusions are liquid-rich, although co-existing liquid and vapour inclusions were identified. The majority of fluid inclusions are primary (some have negative crystal form) and occur in well-defined growth zones, while some secondary fluid inclusions occur in healed fractures. By plotting fluid inclusions data on a boiling point for deptch curve for pure water, it is inferred that initial crystal growth occurred at least

350m below the water table, in a 215±10°C liquid reservoir.

Besides the study of Greg Bignall, petrography also plays an important role in the study that have been held by John Lagat, 2010 in Olkaria domes. From his study we can infer that we can describe the zone of alteration from the minerals assemblages.

Table 1 Grade potential resources according to the zone of alteration

Zone	Minerals	Temp.	Grade potential
Propylitic	Chlorite Epidote Actinolite Tremolite	High	Good
Potassic	Biotite K-Feldspar Adularia	High	Very Good
Albitic	Albite Sodic plagioclase	High	Good
Silicification	Quartz Chalcedony	High	Good
Silication	Silicate minerals + Quartz	High	Good
Argilic	Clay minerals	Low	Bad
Zeolitic	Zeolite minerals	Moderate	Bad

From the table above, the potassic zone is the best indicator of good reservoir, because not only that it shows a high temperature but it also shows that the area have a good permeability.

CONCLUSIONS

The petrography have been given a massive contribution to some geothermal study, which have been seen in the geothermal area in Te Kopia and Olkaria domes, the main role of petrography is shown in it method that help to describing the zone of alteration and other characteristic of geothermal reservoir.

Using petrographical analysis in the exploration of geothermal will give higher accuration data, and if the exploration bring a positive data the investors will not be hesitate to invest in geothermal energy. And this will help to improve the progress of geothermal energy.

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