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TECHNICAL SESSION POSTER AND PAPER

6\textsuperscript{TH} INTERNATIONAL GEOTHERMAL WORKSHOP 2017

“\textit{THE RISE OF GEOTHERMAL DEVELOPMENT IN INDONESIA}”

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THE GEOTHERMAL DIRECT USE UTILIZATION TO DEVELOP SUSTAINABLE SHORE ECONOMY IN PARANGTRITIS

Rizqi Mahfudz Prasetyo\textsuperscript{a}, Istifari Husna Rekinagara\textsuperscript{b}

\textsuperscript{a,b}Pembangunan Nasional “Veteran” University
SWK 104 Street (Lingkar Utara), Condong Catur, Yogyakarta
e-mail: rizqimp5@gmail.com, istifarirekinagara@gmail.com

ABSTRACT

The biggest geothermal potential in the world is owned by Indonesia. But, the utilization of geothermal as energy source is not optimal. Parangtritis, that is well-known from its beach tourism, has unique geothermal potential. This is proved with the appearance of geothermal manifestation as a hot spring, with measured 40\textdegree\text{C} - 53\textdegree\text{C}.

This paper discuss about the possible utilization of geothermal potential in Parangtritis. We uses multiple methodology, they are literature study, field observation, and interview to local residents.

Based on Hochestein (1990) classification, the potential geothermal system in Parangtritis classified as low enthalpy hydrothermal system. The geothermal utilizations suited to this area are direct use (tourism and industry). As the geothermal potential is located near to shore area, the potential industries to develop are shore industry, such as salt production, fish drying, saltwater desalination, and aquaculture. The current focused economy in Parangtritis are its tourism. But, this geothermal potential could ensure the sustainability of economic sector through shore industry.

Keywords
Direct use, geothermal, Parangtritis, shore, industry, sustainable
SMART GEO-ENERGY VILLAGE DEVELOPMENT BY USING CASCADE DIRECT USE OF GEOTHERMAL ENERGY IN BONJOL, WEST SUMATERA

Novrisal Prasetya\textsuperscript{a}, Defry Erwinsyah Umra Lubis\textsuperscript{b}, Dharmawan Raharjo\textsuperscript{c}, Nenny Miryani Saptadji\textsuperscript{d}, Heru Berian Pratama\textsuperscript{e}

\textsuperscript{a,b,c}Petroleum Engineering Study Programming, Institut Teknologi Bandung \\
\textsuperscript{d,e}Geothermal Engineering Study Programming, Institut Teknologi Bandung \\
Bandung, West Java, Indonesia \\
e-mail : novrisal.prasetya2796@gmail.com

ABSTRACT

West Sumatera is a province which has a huge geothermal potential - approximately 6% of Indonesia’s total geothermal potential which equals to 1,656 MWe. One of the significant reserves located in Bonjol subdistrict which accounts for more than 50 MWe. The energy from geothermal manifestation in Bonjol can be utilized prior to indirect development. Manifestation at the rate 3 kg/s and 87 °C will flow to cascading system consisting several applications, arranged in order from high to low temperature to efficiently use the excessive energy. The direct use application selected is based on the best potential commodities as well as temperature constraint of heat source.

The objective of this paper is to perform a conceptual design for the first cascade direct use of geothermal energy in Indonesia to establish Bonjol Smart Geo-Energy Village which will be transformed as the center of agricultural, stockbreeding, tourism as well as cultural site.

A comprehensive research was performed through remote survey area, evaluation featured product, analysis of heat loss and heat exchange in cascade system. From potential commodities, the three applications selected are cocoa drying and egg hatching incubation machine as well as new tourism site called “Terapi Panas Bumi”. The optimum temperature for cocoa drying is 62°C with the moisture content 7% which consumes 78 kW for one tones cocoa dried. Whereas, egg incubation system consists of two chamber with the same temperature 40°C for each room and relative humidity 55% and 80%. For the last stage, “Terapi Panas Bumi” works in temperature 37°C. Based on the result technical and economical aspect, it exhibits cascade direct use of geothermal energy is very recommended to develop.

Keywords

Cascade, Direct Use, Smart Geo-Energy Village, Bonjol
STUDY OF GEOTHERMAL UTILIZATION FOR CURING PROCESS IN LIGHTWEIGHT CONCRETE PRODUCTION IN PANGALENGAN, INDONESIA

Nur Muhamad Isnan Kurnia\textsuperscript{a}, Syarifudin\textsuperscript{b}, Mahdi Nurianto Ahmad\textsuperscript{c}

\textsuperscript{a,b}Department of Chemical Engineering, Institut Teknologi Bandung
\textsuperscript{c}Department of Petroleum Engineering, Institut Teknologi Bandung

Jalan Ganesha No. 10, Bandung, West Java, Indonesia

e-mail: \textsuperscript{a}isnanku@gmail.com, \textsuperscript{b}syarifudin1643@gmail.com, \textsuperscript{c}mahdisby@hotmail.com

ABSTRACT

Indonesia is the developing country that considered as one of the most populous countries in the world. Consequently, there are numerous building construction projects to meet the demand, particularly in big cities, that need building materials such as lightweight concrete. To produce such material, adequate steam is required in certain production step which is called as curing process. Until now the curing process in lightweight concrete production is using steam produced by boilers which use diesel oil as fuel. As the market price of diesel oil is increasing, the production cost of curing process is also getting higher. On the other hand, Indonesia has a lot of potential geothermal resources ranging from low to high enthalpy. One of them is geothermal resources in Wayang Windu – Pangalengan field which is near from big city that need great number of lightweight concretes. For this reason, a study was conducted to assess the possibility of utilizing Wayang Windu geothermal brine for curing process in lightweight concrete production especially curing process at Pangalengan. Analysis of this study includes the analysis of the energy balance, basic design process, and thermal equipment. By designing a specific and simple heat exchanger and using about 27 kg/s brine we can generate hot water which is sufficient to cure 840 m\textsuperscript{3} lightweight concrete per day.

Keywords

Direct use, Geothermal, Curing Process, Lightweight Concrete
STUDY OF GEOTHERMAL UTILIZATION FOR THERMOPHILIC OPERATION IN BIOGAS PRODUCTION IN PANGALENGAN, INDONESIA

Syarifudin\textsuperscript{a}, Nur Muhamad Isnan Kurnia\textsuperscript{b}, Mahdi Nurianto Ahmad\textsuperscript{c}

\textsuperscript{a,b}Department of Chemical Engineering, Institut Teknologi Bandung
\textsuperscript{c}Department of Petroleum Engineering, Institut Teknologi Bandung
Jalan Ganesha No. 10, Bandung, West Java, Indonesia
e-mail: \textsuperscript{a}syarifudin1643@gmail.com, \textsuperscript{b}isnanku@gmail.com, \textsuperscript{c}mahdisby@hotmail.com

ABSTRACT

World energy consumption is increasing year by year. Biomass is one of type renewable energy that considered as solution to tackle such challenge. Meanwhile, Indonesia has abundant resource of biomass, although nowadays it is not produced optimally. One of function of biomass is to produce biogas which need adequate temperature in particular step which is called as thermophilic operation to produce optimally. Until now the adequate temperature is achieved by introducing hot water that is warmed using Liquid Petroleum Gas (LPG) Combustion. Because LPG is needed, the production cost of biogas is high. On the other hand, Indonesia has a lot of potential geothermal resources ranging from low to high enthalpy. One of them is geothermal resources in Wayang Windu – Pangalengan which is a region known for dairy farms. Those dairy farms produce cow feces that are not used optimally. For this reason, a study was conducted to assess the possibility of utilizing Wayang Windu geothermal brine for thermophilic operation in biogas production in Pangalengan. Analysis of this study includes the analysis of the energy balance, thermal equipment, mass balance, and basic design process. By designing specific and simple heat exchanger in biodigester and using 5000 kg cow feces per day and 25000 kg/day brine we can produce 75 m\textsuperscript{3} biogas per hour.

Keywords

Direct use, Geothermal, Biogas Production, Thermophilic Operation
STUDY OF GEOTHERMAL UTILIZATION FOR TEA PASTEURIZATION IN READY TO DRINK TEA PRODUCTION IN PANGALENGAN, INDONESIA

Mahdi Nurianto Ahmad\textsuperscript{a}, Nur Muhamad Isnan Kurnia\textsuperscript{b}, Syarifudin\textsuperscript{c},

\textsuperscript{a}Department of Petroleum Engineering, Institut Teknologi Bandung, \textsuperscript{b,c}Department of Chemical Engineering, Institut Teknologi Bandung, Jalan Ganesha No. 10, Bandung, West Java, Indonesia
e-mail: \textsuperscript{a}mahdisby@hotmail.com, \textsuperscript{b}isnanku@gmail.com, \textsuperscript{c}syarifudin1643@gmail.com

ABSTRACT

Indonesia is considered as a country that has abundant geothermal resources ranging from low to high enthalpy and generally are located in mountainous areas with agricultural lands. One of them is geothermal resources in Wayang Windu, Pangalengan that has been exploited for generating electricity. The electricity plant uses flash steam technology, in which steam is used to generate electricity by directly driving a large turbine. Nowadays, 100 per cent of the brine is injected into injection wells located 14 km south of the plant. On the other hand, such power plant is surrounded by tea plantations. One of tea products is ready to drink tea which needs pasteurization process to produce it. Until now, the tea pasteurization process is still using steam produced by boilers which use diesel it as fuel. As the market price of diesel oil is increasing, the production cost of tea pasteurization is also getting higher. For this reason, a study was conducted to assess the possibility of utilizing Wayang Windu geothermal brine for tea pasteurization process in a tea industry at Pangalengan. Analysis of this study includes the analysis of the mass balance, energy balance, basic design process, operation unit, and thermal equipment. By designing a specific and simple heat exchanger and using about 75 kg/s geothermal brine, we can generate 329 kg/s hot water which is potential enough to pasteurize about 266 m\textsuperscript{3} ready-to-drink tea per hour.

Keywords

Direct use, Geothermal, Tea pasteurization, Ready to drink tea
A CRITICAL REVIEW OF DIRECT USE OF GEOTHERMAL ENERGY FOR ABSORPTION REFRIGERATION SYSTEM

Revandi Arya Guntara\textsuperscript{a}, Jooned Hendrarsakti\textsuperscript{b}

\textsuperscript{a,b} Faculty of Mechanical and Aerospace Engineering
\textsuperscript{b}Geothermal Study Program Institut Teknologi Bandung Jl Ganesha 10 Bandung, Indonesia aryaguntara@students.itb.ac.id

ABSTRACT

The objective of this paper is to present a comprehensive review in different regions around the world about direct use of geothermal energy in absorption refrigeration system. Absorption refrigeration system is one of an alternative cycle which has been used for refrigeration and air conditioning applications. Absorption refrigeration system becomes appealing when there is an inexpensive heat energy available, such as geothermal energy. A low-grade geothermal source with temperature less than 100\degree C can be used to supply heat to the generator of the absorption system.

Particularly, this review observes the recent research that aims to investigate the key parameters of the system such as cooling capacity produced at certain geothermal fluid temperature, the effect of operating conditions, and the effect of heat exchangers on the COP of absorption refrigeration system. Furthermore, this paper presents a thermodynamic analysis to investigate feasibility of using a low-enthalpy geothermal energy for cooling purposes in the absorption system.

It is concluded that increasing the temperature of the geothermal fluids entering the generator leads to increased COP of the system. Furthermore, it is obtained that the COP of the system increases with increasing in the generator and evaporator temperatures but decreases with increasing in the condenser and absorber temperatures. Also, the COP value with the SHE installed increases up to 43.4\% higher than that without the SHE. Meanwhile, the COP value increases only 5.4\% higher with increasing the RHE effectiveness. Eventually, based on the review and discussions that have been presented in this paper, it can be concluded that the direct use of geothermal energy for an absorption refrigeration system is an effective and sustainable approach to raise awareness about the importance of development on this system because of its economical and environmental friendly potential.

Keywords

Direct use, Geothermal energy, Absorption refrigeration system, COP
SLIM HOLE DRILLING AND TESTING STRATEGIES

Dennis L. Nielson\textsuperscript{a}, Sabodh K. Garg\textsuperscript{b}, Colin Goranson\textsuperscript{c}

\textsuperscript{a,b,c}DOSECC Exploration Services, LLC
Salt Lake City, Utah USA
dnielson@dosecc.com

ABSTRACT

The financial and geologic advantages of drilling slim holes instead of large production wells in the early stages of geothermal reservoir assessment has been understood for many years. However, the practice has not been fully embraced by geothermal developers. We believe that the reason for this is that there is a poor understanding of testing and reservoir analysis that can be conducted in slim holes. In addition to reservoir engineering information, coring through the cap rock and into the reservoir provides important data for designing subsequent production well drilling and completion. Core drilling requires significantly less mud volume than conventional rotary drilling, and it is typically not necessary to cure lost circulation zones (LCZ). LCZs should be tested by either production or injection methods as they are encountered. The testing methodologies are similar to those conducted on large-diameter wells; although produced and/or injected fluid volumes are much less. Pressure, temperature and spinner (PTS) surveys in slim holes under static conditions can used to characterize temperature and pressure distribution in the geothermal reservoir. In many cases it is possible to discharge slim holes and obtain fluid samples to delineate the geochemical properties of the reservoir fluid. Also in the latter case, drawdown and buildup data obtained using a downhole pressure tool can be employed to determine formation transmissivity and well properties. Even if it proves difficult to discharge a slim hole, an injection test can be performed to obtain formation transmissivity. Given the discharge (or injection) data from a slimhole, discharge properties of a large-diameter well can be inferred using wellbore modeling. Finally, slim hole data (pressure, temperature, transmissivity, fluid properties) together with reservoir simulation can help predict the ability of the geothermal reservoir to sustain power production.

Keywords

Coring, Reservoir Testing, Lost Circulation Zones, Pressure-Temperature-Spinner Surveys, Injection
OPTIMIZED PRACTICES AVOIDED STUCK PIPE ASSOCIATED WITH DRILLING PALEOSOL

Dimas Radityo Widianto\textsuperscript{a}, Joni Sofian\textsuperscript{b}, Matthew Kelley\textsuperscript{c}, Jim Hanson\textsuperscript{d}

\textsuperscript{a,b,c,d} PT. Halliburton Logging Services Indonesia (Project Management & Baroid)
Taman Tekno Blok D No.1 Sektor XI BSD City, Tangerang Selatan, Indonesia
Dimasradityo.widianto@halliburton.com

ABSTRACT

A project management team was selected to perform the developmental drilling campaign for the 330 MW Sarulla geothermal project in North Sumatra. The project consists of drilling 34 wells in two nearby fields: Namora I Langit and Silangkitang. Even with existing exploration well offset data in hand, severe drilling challenges, including drilling through unstable formations without mud returns, have caused many stuck pipe events.

Because it is common to drill with total losses through fractured volcanic formations, stuck pipe is always one of the main challenges encountered in drilling geothermal wells. In addition, unstable formations, known as paleosol, were encountered in every well in the Namora I Langit field. Paleosol formations are reddish brown clay-rich layers that often swell when exposed to water; consequently, sloughing and stuck pipe problems occur during drilling. Paleosol contains illite and smectite clay and are found near the geothermal resource depth.

The drilling team has gathered paleosol samples from the wells drilled, compiled operational lessons learned, and conducted a technical study of similar problematic formations in other geothermal fields. Further paleosol studies include performing X-ray diffraction (XRD) and linear swell meter (LSM) tests to learn more about the paleosol mineralogy and behavior, and to understand the suitable mud properties that should be used to minimize drilling risk. The results from the tests, along with the operational experience gained, were used to improve drilling techniques and fluid systems.

As a result, the project management drilling team has a better understanding of the paleosol formation behavior and has developed numerous procedures and strategies to drill through paleosol formations, including mud program improvements, drilling best practices, and cement stabilization plug techniques. The programs developed can significantly reduce stuck pipe incidents and reduce well costs; at least USD 500,000 has been saved from one well.

Keywords

Avoid Stuck Pipe, Paleosol, Clay, Drilling Best Practices, Swelling, Sloughing
COLLABORATIVE PROJECT MANAGEMENT CHANGES THE DELIVERY OF GEOTHERMAL WELLS

Matthew Kelley\textsuperscript{a}, Thomas Jenkins\textsuperscript{b}, Jose Villarreal\textsuperscript{c}, Shannon Slocum\textsuperscript{d}, Colton Thomas\textsuperscript{e}

\textsuperscript{a,b,c,d,e} Halliburton

matthew.kelley@halliburton.com

ABSTRACT

Geothermal drilling and completions are complex and challenging, even for experienced developers. Successful Indonesian geothermal resource development requires an experienced team with a range of skill sets, which many new investment companies entering the Indonesian market lack. A new, integrated, collaborative approach coordinates and manages up to 40 third-party subcontractors and the internal product lines within the organization. Advantages of this approach include efficient, cost-effective, and safe well delivery.

Immediate success in a new geothermal drilling campaign and avoiding a steep learning curve are difficult for most new investors in this market. The integrated approach to project management has enabled the development of relevant experience with the drilling of more than 30 wells for a current North Sumatra project. Outsourcing well completion and related tasks to a service company with this proven track record in geothermal resource development enables investor companies to drill exploration and development wells with only a small staff, reducing overhead costs. Investor companies can leverage the existing relationships and contracts for third-party geothermal well drilling and support services through the service company to expedite new projects and reduce costs by leveraging the service company purchasing power for well completion hardware. This process also increases efficiency and reduces non-productive time (NPT) through the use of a shared risk model among the wellsite contractor teams.

A team using this integrated approach was developed to provide many geothermal development functions, including contracting, purchasing, well engineering, wellsite supervision, civil works, well testing, support services (including water supply fabrication and operation, and waste management), and a health, safety, and environmental program. A prescribed well delivery process was developed to interface effectively with the small owners group.

The learning curve for this North Sumatra project was valuable to our organization and to the geothermal market. The integrated approach for the Indonesian geothermal development has provided NPT reductions, efficient completion times, and cost-effective solutions and support services.

Keywords

Project Management, Drilling, Integrated Services, collaboration
DRILLING FLUID DENSITY MODELLING FOR PREDICTING EQUIVALENT STATIC DENSITY IN GEOTHERMAL WELL

Aris Wakhyudin\textsuperscript{a}, Deni Setiawan\textsuperscript{b}, Oscar Dwi Marjuwan\textsuperscript{c}

\textsuperscript{a}Institut Teknologi Bandung, Bandung, Indonesia, Jl. Ganesha No 10 Bandung
\textsuperscript{b}PT. Mitra Konsultansi Indonesia, Tangerang Selatan, Indonesia, Komplek Perkantoran Bidex CBD Tangerang Selatan
\textsuperscript{c}Institut Teknologi Bandung, Bandung, Indonesia, Jl. Ganesha No 10 Bandung
wakhyudin.aris@gmail.com

ABSTRACT

A geothermal well drilling has differences compared with oil and gas drilling especially for pressure and temperature profile. In this paper, a mathematical model of water base drilling fluid density in various pressure and temperature is presented for calculating equivalent static density (ESD) in a geothermal well. The ESD measurement is necessary to prevent liquid or gas kick in a static condition such as tripping in/out of drillstring and running casing. Previous experimental drilling fluid density measurement by McMordie (1982) was conducted using water based drilling fluid in 70 F – 400 F and 0 psig – 14000 psig to identify the effect of pressure and temperature on drilling fluid density. This data is cited to build a mathematical model using curve fitting and statistic software. Curve fitting on experimental data shows the cubical equation trend, hence the generated mathematical model is in cubical function too. The purposed model has a very small error (less than 0.34 \%) while Hoberock’s Model has 1.64 \% of error compared with McMordie laboratory data. To validate this model, an ESD result from a geothermal well in Hellisheidi, Iceland is compared with an ESD result of Hoberock’s (1982) model and an ESD calculation where it disregards the temperature and pressure effect using the same well-profile as an input. The geothermal well has been drilled up to 2700 m of depth with 254 °C of temperature and 190 bar of formation pressure. ESD calculation based on the developed mathematical model has a very small difference with ESD on Hoberock’s model about 20 kg/m\textsuperscript{3} in 1290 kg/m\textsuperscript{3} initial density of drilling fluid. On the contrary, ESD calculation which does not consider pressure and temperature effect has a large difference about 211 kg/m\textsuperscript{3}. This model is necessary for manage-pressure drilling (MPD) operation in field avoiding loss circulation and liquid/gas kick.

Keywords

Drilling fluid, Geothermal, Equivalent Static Density, High temperature, Mathematical model
ANALYSIS OF CONSTRUCTION CASING FAILURE IN GEOTHERMAL WELLS

Heriantoa, Masagus Mangku Gamab

a,b Petroleum Engineering Department, Faculty of Mineral Technology, Universitas Pembangunan Nasional “Veteran”, Yogyakarta Indonesia
e-mail: mangkugama@gmail.com

ABSTRACT

Geothermal energy is a renewable energy derived from interaction of heat emitted by heat source rocks of the fluid contained in the reservoir. Major problems that are usually encountered in geothermal drilling operations are total loss circulation, low penetration rate, high temperature damage of directional drilling tools and mud motors, breakdown of drilling foam structure at high temperatures, high drill string torque, total loss cement slurry and others (Zhang et al., 2012). Also, there are other problems encountered in geothermal well cementing are high temperature, high pressure, and corrosive fluid due to high concentration of minerals such as sulfate and bicarbonate and gas contents such as CO2 and H2S (Herianto et al., 2005).

The methodology used in this study is analyzing design of a hanging casing 7” on bottom of the hole after well is heated and cause of failure cementing casing 7”. The results analysis of construction casing failure concludes that as a result of cementing casing 9 5/8” from the depth of 1000 m up to surface with log CBL-VDL is obtained that 85% cementing result is bad, so the liner 7” was installed at top depth to surface and design hanging casing 7” should consider casing 7” elongation due to operating temperature and hoarding cutting from the bottom of the hole when heating-up. Therefore, design casing 7” from the bottom of the well supposed to be 15 m. From some of this analysis can be used as consideration in planning or design of casing 7” if encountered similar problems are like well X-13.

Keywords
cementing, casing, drilling, geothermal, thickening time
ABSTRACT

Generally, the formations found in the geothermal environment consist of both volcanic and pyroclastic rocks such as Andesite and Tuff which are typically hard and sometimes abrasive rocks. Roller cone Tungsten Carbide Insert (TCI) bits are the most common bits used in geothermal drilling as they are believed to be the most suitable bits to tackle volcanic rocks characteristics. Normally, reservoir sections should be drilled quickly to limit the effect of breakouts and swelling clays when total losses occur: this would require drilling a section ideally with one bit thus avoiding tripping for a bit change. This however is possible only sometimes since roller cone’s bits ‘life’ is limited by their reliability (maximum revolutions before the bearing seal fails).

The innovative Conical Diamond Element (CDE) bit was offered as the ‘solution’. This is a PDC-based bit leveraging the unique 3D geometry of CDE for superior impact and wear resistance. The concentrated point loading of CDE enables it to fracture high-compressive-strength rock efficiently. There is no bearing seal life constraint as CDE bit has no moving/rotating parts being a PDC bit.

The CDE bit was implemented in two sections, 12.25” and 9.875”. The results were excellent since both sections were drilled to TD in one run (respectively 660 and 799 m interval). ROP improvements were massive and had to be limited to 20-30 m/h due to hole cleaning concerns – Both bits in fact showed the capability to reach ROPs in excess of 50 m/hr. The average ROP (although ‘limited’) was in any case in excess of 20% higher compared to offset wells drilled with TCI bits bringing considerable savings to the operator. The CDE bits were pulled out of hole in very good and re-runnable conditions (1-1 and 0-0 cutters dull grade) thus completing a great success story.

Keywords
Volcanic and Pyroclastic rocks, Conical Diamond Element (CDE) Bit, ROP improvements, performance
THE FIRST “POINT THE BIT” ROTARY STEERABLE SYSTEM APPLICATION WORLDWIDE IN A GEOTHERMAL FIELD IN INDONESIA

Agus Ziyad Kurnia\textsuperscript{a}, Jiang Feng Bao\textsuperscript{b}, Bonar Noviasta\textsuperscript{c}, Donny Trias Ardianto\textsuperscript{d}, M.R. Yoan Mardiana\textsuperscript{e}, Stefano Scagliarini\textsuperscript{f}, Manuel Centeno Acuna\textsuperscript{g}, Geovannis Napitupulu\textsuperscript{h}

\textsuperscript{a,b,c,d,e,f,g,h} Schlumberger Suite 4201, Wisma Mulia, Jln. Jend. Gatot Subroto No 42, Jakarta, Indonesia

\textit{e-mail: AKurnia2@slb.com, FJiang@slb.com, BNoviasta@slb.com, DTArdianto@slb.com, MMardiana@slb.com, ssaglia@slb.com, MAcuna@slb.com, GNapitupulu@slb.com}

\begin{abstract}
In 2015, a Geothermal Operator started a drilling campaign in Indonesia. The wells are deviated and most of the directional work is generally performed in the intermediate hole section (17 ½”) using a mud motor. However this had some limitations, such as small RPM range available to clean the hole while rotating and the risk of getting stuck due to pack off especially in the presence of total losses while sliding (particularly for inclinations around 35 degrees and above) in formations of high heterogeneity encountered in the volcanic environment.

To overcome these drilling challenges, a Rotary Steerable System (RSS) has been utilized, specifically a RSS Xceed900. This is a “point the bit” system which ‘directs’ the bits in the wanted direction either thru bending a shaft or having a built in offset, as opposed to a “push the bit” system, which utilizes “pads” to allow steering – This is the first time a “point the bit” RSS have been used in a geothermal well worldwide.

To allow the successful deployment of this new technology in the geothermal arena, a thorough technical/commercial analysis and several simulation/re-iterations were performed, which include:

- Gyro and Magnetometer drilling modes due to the expected cross-magnetic interference from the formation.
- IDEAS (Integrated Dynamic Engineering Analysis System - Schlumberger proprietary software) simulations to ensure both directional and dogleg capabilities in the anticipated drilling conditions.
- Well plan optimization targeting a dogleg severity (DLS) below 3 deg/30m.
- Flow rate optimization during aerated drilling together with survey considerations (downlink).

The actual field results can be summarized as follow:

- Higher on bottom ROP (15%).
- Optimization of parameters for hole cleaning - RPM 100-140, flow rate 900-1100 gpm.
- Minimization of back reaming.
- Optimization of Hi-Vis pills usage.
\end{abstract}
• Smoother T&D trend (including micro dogleg avoidance).
• Implemented surveying strategy and QuikSurvey application.

The RSS Xceed900 showed several benefits that offset its higher cost compared to conventional mud motors in directional wells. This technology proved, in specific drilling challenges, to be a viable alternative to mud motors to improve both performance and hole cleaning.

Keywords

directional well, Rotary Steerable System (RSS), stuck pipe, Dog Leg Severity (DLS), Rate of Penetration (ROP), hole
INNOVATIVE CASING DRILLING TECHNOLOGY IMPROVED THE ABILITY TO SET THE CASING DEEPER THROUGH PROBLEMATIC ZONE IN INDONESIA GEOTHERMAL OPERATION

Budi Setiawan\textsuperscript{a}, Bonar Noviasta\textsuperscript{b}, Hanafi Muhamad Falhum\textsuperscript{c}

\textsuperscript{a}Pertamina Geothermal Energy
\textit{Menara Cakrawala 11\textsuperscript{th} Floor, Jakarta, Indonesia}
e-mail: budi.setiawan@pertamina.com
\textsuperscript{b,c}Schlumberger
\textit{Suite 4301, Wisma Mulia 43\textsuperscript{rd} Floor, Jakarta, Indonesia}
e-mail: BNoviasta@slb.com, HFalhum@slb.com

ABSTRACT

Well-A is one of the geothermal well in Field K, located in Jambi, Sumatera area. The pilot hole of 17.5-in. section was drilled to TD. However, a 13.375-in. casing running difficulty was experienced afterwards. A dedicated clean out BHA was run which unfortunately ended up with stuck pipe situation. The decision was taken to cement plug the pilot hole and to perform an open hole sidetrack. The difficulty in running the 13.375-in. casing is caused by collapsing formation from the borehole wall. With the commonly run casing/liner tie back system, there was no rotational capability when any obstruction is encountered while running the casing.

The 13.375-in. x 17.5-in. non-directional Casing Drilling technology is offered as an innovative solution. The main component of this technology is the drillable alloy casing bit, which drills on standard casing that is rotated at the surface. The casing bit is equipped with PDC cutters and nozzles with the same function as those in conventional PDC bit. The casing can be fully rotated while applying weight to cut through the obstruction.

The Casing Drilling system successfully set the 13.375-in. casing to 849.72 mMD, 320 m deeper than the initial point of casing running obstruction. The drilling/reaming capability of the casing bit helped cutting all the formation filling the pre-drilled hole. The cementing process was executed well, with a good integrity up to the surface (showed not only by a surface return when doing cement top job but also by a good CBL result). This Eliminated the requirement of having a casing/liner tie back system, which saved operating time and cost. The ability of casing to be set deeper sealed off the total loss zone, and as a result, the 12.25-in. section drilling could be executed without penetrating that problematic zone, which improved drilling efficiency.

Keywords

\textit{Casing Drilling, Drillable Alloy Casing Bit, Improved Drilling Efficiency}
AERATED DRILLING CUTTING TRANSPORT ANALYSIS IN GEOTHERMAL WELL

Aris Wakhyudin\textsuperscript{a}, Deni Setiawan\textsuperscript{b}, Oscar Dwi Marjuwan\textsuperscript{c}

\textsuperscript{a}Institut Teknologi Bandung, Bandung, Indonesia, Jl. Ganesha No 10 Bandung
\textsuperscript{b}PT. Mitra Konsultansi Indonesia, Tangerang Selatan, Indonesia, Komplek Perkantoran Bidex CBD Tangerang Selatan
\textsuperscript{c}Institut Teknologi Bandung, Bandung, Indonesia, Jl. Ganesha No 10 Bandung

wakhyudin.aris@gmail.com

ABSTRACT

Aerated drilling widely used for geothermal drilling especially when drilled into predicted production zone. Aerated drilling give better performance on preventing lost circulation problem, improving rate of penetration, and avoiding drilling fluid invasion to productive zone. While well is drilled, cutting is produced and should be carried to surface by drilling fluid. Hole problem, especially pipe sticking will occur while the cutting is not lifted properly to surface. The problem will affect on drilling schedule; non-productive time finally result more cost to be spent. Geothermal formation has different characteristic comparing oil and gas formation. Geothermal mainly has igneous rock while oil and gas mostly sedimentary rock. In same depth, formation pressure in geothermal well commonly lower than oil and gas well while formation temperature geothermal well is higher. While aerated drilling is applied in geothermal well, Igneous rock density has higher density than sedimentary rock and aerated drilling fluid is lighter than water based mud hence minimum velocity requirement to transport cutting is larger than in oil/gas well drilling. Temperature and pressure also has impact on drilling fluid (aerated) density. High temperature in geothermal well decrease drilling fluid density hence the effect of pressure and temperature also considered. In this paper, Aerated drilling cutting transport performance on geothermal well will be analysed due to different rock and drilling fluid density. Additionally, temperature and pressure effect on drilling fluid density also presented to merge.

Keywords

Aerated Drilling, Geothermal Well, Cutting Transport, Pressure, Temperature
MARKET OPPORTUNITIES FOR DIRECT USE OF GEOTHERMAL HEAT IN UGANDA

Faith Natukunda\textsuperscript{a}, Pall Valdimarsson\textsuperscript{b}

Pan African University Institute of Water and Energy Sciences (including Climate Change),
Tlemcen, Algeria.
faith.natukunda@yahoo.com
pvald.com, Reykjavik, Iceland

ABSTRACT

As a country, Uganda has a growing interest to diversify its energy mix from dependency on hydro power and traditional biomass. Prospects for the exploitation of the existing geothermal potential are therefore not only in power generation, but also direct use applications, although geothermal development is still in the preliminary stages. This study places emphasis on the range of opportunities for direct use of low temperature geothermal heat in Uganda. Because the transportation of heat over long distances is uneconomical; it is advisable to utilize the heat within a given radius of its source. In this study, the areas within such radii where geothermal activity is witnessed were assessed based on; fluid temperature, climate, population as well as main economic activities in order to better understand the market opportunities for the heat that will be extracted. Some of the more outstanding geothermal fields were studied; from which it was observed that out of the diversity of sectors for investment, agriculture based industries; agricultural drying and milk pasteurization, pose higher opportunities for success given the available sources of raw materials. It would however be important to carry out a detailed industry specific market analysis at the feasibility phase for a better understanding of the development of the selected industries for implementation.

Keywords

Fluid temperature, economic activity, direct use, market
MAKE-UP WELLS DRILLING COST IN CALCULATION IN
FINANCIAL MODEL FOR A GEOTHERMAL PROJECT

Fitri Oktaviani Purwaningsi\textsuperscript{a}, Ruly Husnie\textsuperscript{b}, Waldy Afuar\textsuperscript{c}, Gugun Abdurrahman\textsuperscript{d}

\textsuperscript{a}Geothermal Master Program Institut Teknologi Bandung, Bandung, Indonesia
\textsuperscript{b,c,d}PT Geo Dipa Energy, Jakarta, Indonesia
Feetre@gmail.com

ABSTRACT

After commissioning of a power plant, geothermal reservoir will encounter pressure decline, which will affect wells productivity. Therefore, further drilling is carried out to enhance steam production. Make-up wells are production wells drilled inside an already confirmed reservoir to maintain steam production in a certain level.

Based on Sanyal (2004), geothermal power cost consists of three components, those are capital cost, O&M cost and make-up drilling cost. The make-up drilling cost component is a major part of power cost which will give big influence in a whole economical value of the project.

The objective of this paper would be analyzing the make-up wells drilling cost component in financial modeling of a geothermal power project. The research will calculate make-up wells requirements, drilling costs as a function of time and how they influence the financial model and affect the power cost. The best scenario in determining make-up wells strategy in relation with the project financial model would be the result of this research.

Keywords

Make-up wells, decline rate, geothermal financial model
DEVELOPING A FRAMEWORK FOR ASSESSING THE IMPACT OF GEOThermal DEVELOPMENT PHASES ON ECOSYSTEM SERVICES

Jarot M. Semedi\textsuperscript{a*}, Louise Willemen\textsuperscript{b}, Triarko Nurlambang\textsuperscript{c}, Freek van der Meer\textsuperscript{d} Raldi H. Koestoer\textsuperscript{e}

\textsuperscript{a,b,d}Faculty of Geo-Information Science and Earth Observation, University of Twente
Enschede, The Netherlands
\textsuperscript{a,c,e}Sekolah Ilmu Lingkungan, Universitas Indonesia
Jakarta, Indonesia

*e-mail: j.m.semedi@utwente.nl; jarot.mulyo@ui.ac.id

ABSTRACT

The 2014 Indonesian National Energy Policy has set a target to provide national primary energy usage reached 2,500 kWh per capita in the year 2025 and reached 7,000 kWh in the year 2050. The National Energy Policy state that the development of energy should consider the balance of energy economic values, energy supply security, and the conservation of the environment. This has led to the prioritization of renewable energy sources. Geothermal energy a renewable energy source that produces low carbon emissions and is widely available in Indonesia due to the country’s location in the “volcanic arc”. The development of geothermal energy faces several problems related to its potential locations in Indonesia. The potential sites for geothermal energy are mostly located in the volcanic landscapes that have a high hazard risk and are often designated protected areas. Local community low knowledge of geothermal use also a challenge for geothermal development where sometimes strong local culture stand in the way. Each phase of geothermal energy development (exploration, construction, operation and maintenance, and decommissioning) will have an impact on the landscape and everyone living in it. Meanwhile, natural and other human-induced drivers will keep landscapes and environments changing. This conference paper addresses the development of an integrated assessment to spatially measure the impact of geothermal energy development phases on ecosystem services. Listing the effects on the ecosystem services induced by each geothermal development phases and estimating the spatial impact using Geographic Information System (GIS) will result in an overview on where and how much each geothermal development phase affects the ecosystem and how this information could be included to improve national spatial planning.

Keywords
Geothermal development, integrated assessment, spatial planning, ecosystem services
INTEGRATION OF ENHANCED GEOTHERMAL SYSTEM AND CCS IN SARULLA GEOTHERMAL FIELD, NORTH SUMATERA, INDONESIA: CONTINUOUS LOOP OF CLEAN ENERGY OPPORTUNITY

Rinaldo Siagian\textsuperscript{a}, Muhammad Ali Akbar Velayati Salim\textsuperscript{b}, Rizke Nadya\textsuperscript{c}

\textsuperscript{a,h,c} Universitas Diponegro
Universitas Diponegro, Jalan Prof. Soedarto, Tembalang, Semarang, 50275, Jawa Tengah
e-mail: rinaldosiagian25@gmail.com, research.aliakbar@gmail.com, rizke.nadya@gmail.com

ABSTRACT
Indonesia is a country with the third largest geothermal potential with the numbers reaching up to 28543 MW, or approximately 40\% of the world's potential (US Energy Information Administration, 2015), but it is still only 1,189 MW that have been developed, one of the many factors that cause this is the lack of effective system of geothermal field production in Indonesia. This study intends to streamline the production of Sarulla geothermal field by injecting CO\textsubscript{2} in the selected field reservoir. The CO\textsubscript{2} gas could be obtained from PT Indonesia Asahan Aluminium and gas emissions resulting from any kind of production processes. Combining this method of Enhanced Geothermal System integrated with the use of CO\textsubscript{2} from Carbon Capture and Storage system in the production process system in this field could reduce CO\textsubscript{2} emissions by 1.3 million tons of CO\textsubscript{2} equivalent emissions per year, and would make this field as one of the geothermal fields with the most massive amount of production in Indonesia as well as a source of green energy capable of maintaining the stability of the CO\textsubscript{2} levels in the atmosphere.

Keywords
Sarulla field, CCS, EGS, reservoir, geothermal
WELL CALCULATION FOR CONSTRUCTION AND STEAM FIELD DEVELOPMENT OF GEOTHERMAL POWER PLANT

Endah Kurnia Setia Dewi, Cahaya Ningsih

Geophysical Engineering Department, Universitas Lampung
Bandar Lampung, Indonesia

e-mail: endahkurniasetadewi@gmail.com

ABSTRACT

Indonesia has a target to demand the electricity needs of 35000 MWe in 2025. One of these energy requirements utilizing geothermal power plant which is targeted to approximatively 7000 MWe capacities. The target must be balanced with the effectivity and accuracy in planning and developing geothermal projects, especially in the construction and field development plans. One of the stages in the construction planning and developing of the geothermal steam field is to estimate the well to make production wells, injection wells, substitution wells, make-up wells and separators will be affect to economy in a steam field development. Thus, it need to calculate estimation wells requirements to plan development. The calculation is using estimation of reservoir domination by ratio of brines are 70% for water and 30% for steam. The ratio of success is 80%. Geothermal working area is assumed 190 MWe capacities. Three units of power plan is needed to reach the production design of 190 MWe. The calculation is done by created a stage plan the unit 1 (1x55 MWe), the unit 2 (1x55 MWe), and the unit 3 (1x80 MWe). The unit 1 need five production wells, one substitution well, four injection wells and two unit separators. The unit 2 need well same as the unit 1. The unit 3 need seven production wells, two substitution wells, five injection wells and three unit separators. By using calculation, could determine make-up wells, for 30 years development plan need thirteen make-up wells on the steam field development.

Keywords

steam field development, wells construction, geothermal power plant

GENERAL
RISK MANAGEMENT OPTIONS ON THE GEOTHERMAL EXPLORATION ACTIVITY

Desy Caesary, Yovita Bhritya Adisresti

ABSTRACT

Lack of sufficient data due to technical and non-technical risks is commonly cited as significant constraint of geothermal development in Indonesia. The technical risks may include improper assessment of geothermal resource and drilling activity risk, whereas the non-technical risks may include force major, environment and social concerns. It is observed up until 2016, among 69 Geothermal Working Areas (WK) available in Indonesia, 9 WK are already in utilization stage, 8 WK are in exploitation stage, 15 WK are in exploration stage, and the rest of 37 WK are either in Geothermal License (IPB) issuance or tender preparation stage. Out of the 15 WK in exploration stage, only 4 WK have actually started exploration drilling activity. However, the remaining WK are in stagnant process, even, 5 WK have been revoked (1 WK was revoked after unsuccessful exploration well drilling) due to financial issue. This financial issue arises as a result of insufficient preliminary data, which causes the private holders to face difficulties in finding or lending funds from the bank. Typically reliable preliminary data is required by the bank to obtain better understanding of proposed project. Therefore, in this paper, risk management consisting of reduction measures (implementation of deep slim hole drilling and utilization of geochemical advanced analyzer), as well as risk mitigation measures (geothermal insurance application and risk allocation) are introduced, these measures are expected to reduce the exploration technical risk and to maintain sustainability of geothermal project.

Keywords

geothermal, geothermal exploration risk, risk reduction, risk mitigation
A REVIEW OF THE GEOTHERMAL RESOURCES OF SAUDI ARABIA

Aref Lashin\textsuperscript{a}, Abdulaziz Al Bassam\textsuperscript{b}, Emad Al-Homadhi\textsuperscript{c}, Nassir Al Arifi\textsuperscript{d}, Ali Al-Netaifi\textsuperscript{e}, Dornadula Chandrasekharan\textsuperscript{f}, Shafiqur Rehman\textsuperscript{g}

\textsuperscript{a,c,e,f}King Saud University, College of Engineering-Petroleum and Natural Gas Engineering Department, Riyadh 11421-Saudi Arabia
\textsuperscript{a}Benha University, Faculty of Science - Geology Department, P.O. Box 13518, Benha - Egypt
\textsuperscript{b,d}King Saud University, College of Science -Geology and Geophysics Department, P. O. Box 2455, Riyadh 11451 - Saudi Arabia
\textsuperscript{f}Department of Earth Sciences, Indian Institute of Technology Bombay, Mumbai, India 400076
\textsuperscript{b}Saudi Geological Survey Research Chair (SGSRS), King Saud University, Saudi Arabia
\textsuperscript{g}Center for Engineering Research, King Fahd University of Petroleum and Minerals, KFUPM BOX # 767, Dhahran – 31261, Saudi Arabia
arlashin@ksu.edu.sa
aref70@hotmail.com

ABSTRACT

Many geothermal resources are encountered in Saudi Arabia. Most of these resources are located along the western and south-western parts of the kingdom. These resources are classified into three types, i.e. low, medium and high potentiality. The low enthalpy resources (sedimentary aquifers) are located mainly in eastern and central parts of Saudi Arabia. It is represented by deep-seated sedimentary layers that are penetrated by deep oil wells where geothermal hot water comes to the surface with temperature up to 70 °C. The medium geothermal resources are represented by a number of hydrothermal and hot springs that are located along the western and southwestern coastal parts. The high enthalpy resources are represented by the basaltic lava fields or what is called "Harrats" that covers an area of approximately 80,000 km\textsuperscript{2}. The most interested of these Haratts is that of Khaybar where some fumaroles are observed. Another source of high geothermal potentiality is that of the pre- and post-orogenic granites that is located along the western Saudi Arabian shield and attains very high radioactive element content (U, Th and K). The estimated heat production of this granite varies from 15 to 134 \(\mu\text{W/m}^3\), with the highest value represented by Midian granites that is located NW of the shield (occupying an area of 375 km\textsuperscript{2}). This paper represents a review of the characteristics and potentially of geothermal resources of Saudi Arabia and the possible ways for its utilisations.

Keywords

geothermal resources, direct utilization, power generation, Harrats, Saudi Arabia
ASSESSMENT OF KAMOJANG GEOTHERMAL POWER PLANT
BASED ON HEAT AND MASS BALANCE ANALYSIS

Puspita Wahyuningsih

aInstitut Teknologi Bandung
Jl. Ganeca No. 10 Bandung, Jawa Barat, Indonesia
e-mail: wahyuningsih.puspita@gmail.com

ABSTRACT

Kamojang power plant is the first geothermal field utilization as a power generation in Indonesia. Unit 2 and Unit 3, which produce 55 MW of electricity each, have been operating since 1987.

Continuous monitoring and evaluation are needed in order to maintain the reliability of power production in this old geothermal power plant. It also acts as a measure of sustainability of the field. This work has a purpose to evaluate the power plant performance after 30 years of operation. An assessment based on heat and mass balance analysis is conducted to describe the recent power plant condition, to determine the heat losses, and to compare it to the design and commissioning situation. This research also acts as a preliminary study of the reservoir condition based on the power plant perspective.

Actual data of normal operation for one month are collected from the site. The analysis includes energy calculation in each stage of the process. The results show that the thermal efficiency of the overall power plant cycle has decreased by 1%. The power plant now consumes more steam than the first commissioning to generate the same amount of electricity. At present, Unit 2 uses 433 tons/hour of steam and Unit 3 consumes 425 tons/hour of steam while the commissioning only uses 392 tons/hour of steam. This number means that there are more heat losses in the plant now resulting a lower thermal efficiency. It also explains the quality of the steam where it is related to the reservoir condition.

Keywords

Geothermal power plant, heat and mass balance, power plant efficiency, geothermal energy utilization
AN EVALUATION OF ORC BOTTOMING UNITS FOR SINGLE FLASH GEOTHERMAL POWER PLANTS

Baran Kaypakoglu\textsuperscript{a}, Ugo Barbon\textsuperscript{b}

\textsuperscript{a,b}ELC-Electroconsult S.p.A.,
Jakarta, Indonesia Representative Office
baran.kaypakoglu@elc-electroconsult.com

ABSTRACT

As the geothermal industry continues growing, different power cycle combinations come into consideration for projects in Indonesia. A new option which has been brought into consideration lately is the Organic Rankine Cycle (ORC) bottoming units that can be used in conjunction with conventional single flash power plants. In this study we will evaluate the combination of the steam turbine with ORC bottoming units for geothermal fluid conditions similar to those found in Indonesia and study the results in terms of power production and efficiency. Taking into account also the investment cost and operation and maintenance in addition to the cycle efficiency, we will try to evaluate the feasibility of such systems for Indonesian resources.

Keywords

ORC, geothermal, bottoming, power, cycle, efficiency, carbon dioxide
A 63 MW HIGH EFFICIENCY STEAM TURBINE DESIGN CASE STUDY: KAMOJANG GEOTHERMAL POWER PLANT UNIT 4

Achmad Nawawi\textsuperscript{a}, Probo Nogoya Erawan Sastroredjo\textsuperscript{b}, Prihadi Setyo Darmanto\textsuperscript{c}

\textsuperscript{a,b,c}Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Bandung Jalan Cisitu Baru no. 37, Bandung, Jawa Barat nawa.amm@gmail.com

ABSTRACT

The rate of pressure declined in geothermal steam wellhead become a critical issue when the pressure no longer can fulfil turbine inlet pressure design requirements. As consequences, electricity generating from energy extraction unit (turbine) cannot be maintained. This study took place in Geothermal Field in Kamojang, Indonesia. Current Geothermal Power Plant in Kamojang unit 4 use a turbine with inlet pressure 11 bar to produce 63 MWe. Since there is no steam well with similar pressure, then the power generation in unit 4 will drop if there is no addition of steam supply. To maintain the turbine power generation, steam inlet pressure in unit 4 is lowered to 6.5 bar and new turbine design is needed. This study aims to design a steam turbine for Kamojang unit 4 at the turbine inlet pressure was 6.5 bar to produce 63 MWe. It was found that six stages of axial direction flow, double-flow type of impulse turbine, with 3000 rpm of rotational shaft speed, and steam outlet pressure 0.15 bar could provide electricity generation with internal efficiency was 74.97 %.

Keywords

Geothermal power plant, Wellhead pressure, Steam turbine design
PIPELINE MODELING WITH MONAZITE MINERAL TO PREVENT HEAT LOSS AND SCALING IN GEOTHERMAL WELL PRODUCTION: A STUDY CASE FIELD OF GEOTHERMAL DIENG

Nindyan Agna Ramadhan\textsuperscript{a}, Izza Hayyu Hanani\textsuperscript{b}, Ridwan Chandra\textsuperscript{c}, Zainun\textsuperscript{d}

\textsuperscript{a,b,c,d}Department of Geological Engineering, Diponegoro University  
Jalan Prof. Soedarto, S.H Tembalang-Semarang  
e-mail: nindyan.agna@gmail.com

ABSTRACT

Dieng Geothermal Field is one of geothermal areas in Dieng Plateau Geothermal Working Area (WKP) which owned by PT. Geo Dipa Energi. It has been estimated that this field has 350 MW (California Enegy, 1998). In this field, there are 8 production wells and 2 injection wells. The field has some problems like heatloss on steam distribution pipe until 4850 – 6000 Kwatt, the pressure drop is 0,69 – 1,41 bar/Km, and scaling precipitation rate in amount of 9.52 cm/year. Monazite (Pr, Nd, Ce, La) is REE (Rare Earth Element) carrier mineral which is radioactive and superconductor. This mineral has 2500 – 3000 °C of boiling point and melting point at 100-1500 °C. The focus of this research was to overcome indication of heatloss and scaling in production well. Methodology used in this research by conducting literature study case toward the problem of Dieng field production well and the utility of monazite mineral. The chemical reaction between Monazite and pipe can keep the temperature reduction in production well. This mineral is also able to prevent scaling due to drastic temperature reduction in production wells so that deposits on the well casing due to the decreasing temperature can be minimized. Monazite is one of the solutions for scaling and heat-loss problem to maximize this field geothermal potential and also it is a preventive way to overcome the maintenance costs in the production pipeline so it can be minimized.

Keywords

Heatloss, Pipeline Modelling, Monazite
DEVELOPMENT MODEL OF BRINE SILICA MANAGEMENT AT ONE OF WATER DOMINATED GEOTHERMAL POWER PLANT IN SUMATERA

Cukup Mulyana\textsuperscript{a}, Moch. Aril Indra Permana\textsuperscript{b}, Naufal Nandalarasyad\textsuperscript{c}, Aswad Hi Saad\textsuperscript{d}

\textsuperscript{a,b,c,d} Physics Department, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran
Jl. Raya Bandung-Sumedang Km 21, Jatinangor, Sumedang, Indonesia,
c.mulyana55@yahoo.com

ABSTRACT

Most of the brine from the single flash water dominated geothermal power plant in Indonesia is injected into the injection wells. The brine actually still have high temperature and high enthalpy that can be used to generate more electric power by double flash or binary cycle power plant. The main problem is because of the high salinity of the brine, if the double flash or binary cycle power plant is developed, the brine has the potential to deposit silica scaling in large quantities so it needs to be handled. In this paper, the management of silica scaling model is developed which will then be implemented by test rig simulation. Calculation shows in certain locations, after the brine is injected by acid inhibitor, the potential of silica scaling decreased rapidly (SSI $<1$) with the temperature minimum limit for multi-flash plant at $\approx 109^\circ$C. This temperature is important parameter for selecting parameter of flasher. If the brine is not injected by acid inhibitor, the time needed for silica scaling to reduce the pipe diameters until 25\% of its original diameter in the area before the separator is 3 years 9 months 25 days and in the area before the flasher is 1 year 3 months 27 days. These results can be used as an estimation of the production pipeline to be cleaned.

Keywords

Silica scaling, brine, single flash, acid injection
GEOTHERMAL WELL PRODUCTIVITY CHARACTERIZATION USING PTS FLOWING SURVEY: A CASE STUDY OF VAPOUR DOMINATED GEOTHERMAL FIELD IN WEST JAVA, INDONESIA

Iqbal Kurniawan\textsuperscript{a}, Mahdi Nurianto Ahmad\textsuperscript{b}, Muhammad Nizami\textsuperscript{c}

\textsuperscript{a}Petroleum Engineering Study Program, Institut Teknologi Bandung, Bandung, Indonesia
\textsuperscript{b}Petroleum Engineering Study Program, Institut Teknologi Bandung, Bandung, Indonesia
\textsuperscript{c}Petroleum Engineering Study Program, Institut Teknologi Bandung, Bandung, Indonesia

iqbalkurniawan123@yahoo.com

ABSTRACT

Mass and heat flow in geothermal well are essential values to be determined because it describes well potential and it is related to steam requirement to generate certain amount of electricity in accordance with the contract that has been made. Inability to fulfill the steam requirement surely results disadvantages for the buyer and company itself. Therefore, calculation of such well potential is important process in order to understand well production ability in geothermal reservoir. PTS survey is one of the most common measurements to determine well potential in geothermal industries. The measurement results are pressure and temperature profile with depth, and spinner frequency. Analysis of PTS data using common methodology could be used to determine various well characteristics, such as feedzone location, mass flowrate, and heat flow. From conducted data analysis, we obtained the mass flowrate of the well is 20 kg/s with average temperature of 230 °C so that the heat flow is about 56 MWth. Using specific steam consumption of 7.4 ton/Mwe.h gained from other field with high enthalpy reservoir in Indonesia, we can obtain well potential of 9.7 MWe.

Keywords

PTS survey, Well potential, Mass flow, Heat flow
A COMPARATIVE EXERGETIC ANALYSIS OF VARIOUS CONFIGURATIONS FOR ORC GEOTHERMAL POWER PLANTS

Saeid Mohammadzadeh Bina\textsuperscript{a}, Saeid Jalilinasrabady\textsuperscript{b}, Hikari Fujii\textsuperscript{c}

\textsuperscript{a,b,c}Graduate school of International Resource Sciences, Akita University
1-1 Tegata gakuen-machi, Akita 010-8502, Japan,
S.Mohammadzadeh66@gmail.com

ABSTRACT

The Organic Rankin Cycles (ORCs) are very common methods for electricity production of low to moderate geothermal resources. Installing Internal Heat Exchanger (IHE) after the turbine can increase the effectiveness of heat exchange process and consequently plant efficiency. The main objective of this study is to investigate and also compare the first and second laws of thermodynamic efficiencies for two different configurations of geothermal binary cycles including conventional ORC and ORC with Internal Heat Exchanger (IHE-ORC).

Thermodynamic models for both cycles were developed and a parametric study was conducted with respect to the maximum second law efficiency. Net power output per unit mass of the geofluid was set as objective function. Evaporator pressure, mass flowrate of geofluid, superheating degree of steam, the minimum pinch difference temperature in the evaporator and also condenser temperature were analyzed to obtain the optimal performance of the system. To investigate the effect of IHE in binary cycles, the exergy destruction rates for all components were determined. The results indicated that under optimized condition IHE-ORC had higher net power output (4859 kW vs. 5051 kW) and also had superior energy and exergy efficiencies (13.02%, 51.55% vs. 15.7%, 61.62%).

Keywords

Geothermal, Organic Rankine cycle, Thermodynamic analysis, Exergy, Optimization, Efficiency
PROBABILISTIC APPROACH : BACKPRESSURE TURBINE FOR GEOTHERMAL VAPOR-DOMINATED SYSTEM

Angga Alfandi Ahmad, Fransiscus Xaverius Guwowijoyo, Heru Berian Pratama

Geothermal Engineering Study Program, Institut Teknologi Bandung
Gedung Energi Lt. 2, Jl. Ganesha 10 Bandung, Indonesia
Email : anggaalfandi@gmail.com, guwowijoyo@gmail.com, hb.pratama@gmail.com

ABSTRACT

Geothermal business nowadays needs to be accelerated in a way that profit can be obtained as soon as reasonable possible. One of the many ways to do this is by using one of geothermal wellhead generating unit (GWGU), called backpressure turbine. Backpressure turbine can be used in producing electricity as soon as there is productive or rather small-scale productive well existed after finished drilling. In a vapor dominated system, steam fraction in the wellhead capable to produce electricity based on each well productivity immediately. The advantage for using vapor dominated system is reduce brine disposal in the wellhead so it will be a cost benefit in operation. The design and calculation for backpressure turbine will use probabilistic approach with Monte Carlo simulation. The parameter that will be evaluated in sensitivity would be steam flow rate, turbine inlet pressure, and turbine exhaust pressure/atmospheric pressure. The result are probability for P10, P50, and P90 of gross power output which are 1.78 MWe, 2.22 MWe and 2.66 MWe respectively. Whereas the P10, P50, and P90 of SSC are 4.67 kg/s/MWe, 5.19 kg/s/MWe and 5.78 kg/s/MWe respectively.

Keywords

Wellhead generating unit, backpressure turbine, probabilistic approach, Monte Carlo simulation
GEOTHERMAL RESERVOIR SIMULATION IN HOT SEDIMENTARY AQUIFER SYSTEM USING FEFLOW®

Hardi Nur Hidayat\textsuperscript{a}, Maximilian Gala Permana\textsuperscript{b}

\textsuperscript{a,b}Department of Geothermal Engineering Institute of Petroleum Engineering, TU Clausthal Clausthal-Zellerfeld, Germany
e-mail: hardi.nur.hidayat@tu-clausthal.de maximillian.gala.permana@tu-clausthal.de

ABSTRACT

The report presents the results of Hot Sedimentary Aquifer Simulation. Hot sedimentary aquifer (HSA) is a conduction-dominated hydrothermal play type utilizing deep aquifer, which is heated by near normal heat flow. One of the examples of HSA is Bavarian Molasse Basin in South Germany. This system typically uses doublet wells: an injection and production well.

This study’s objective is to generate a transient HSA model using FEFLOW software package. The simulation was run for 3650 days of simulation time. The technical feasibility and performance are analyzed in regards to the extracted energy from this concept. Several parameters are compared to determine the model performance.

The workflow of HSA modelling in FEFLOW is presented in order to clarify the modelling process; therefore, readers can follow the process for comparison. Parameters such as reservoir characteristics, temperature information and well information are defined. Several assumptions are also defined to simplify the simulation process.

The main results of the simulation are heat period budget or total extracted heat energy, and heat rate budget or heat production rate. After 10 years of simulation time, the base model generated almost 15.5 GWh with heat production rate at 171 kW, which declined exponentially at 2.303 \times 10^{-5} \text{ kW/day}. Qualitative approaches for sensitivity analysis are conducted by using five parameters in which assigned lower and higher value scenarios. Results of the simulation are compared to each scenario and demonstrate intriguing outcomes.

Keywords

Reservoir, geothermal, doublet well, hot sedimentary aquifer, simulation, modelling, feflow
STUDY OF SUSTAINABLE PRODUCTION IN TWO-PHASE LIQUID DOMINATED WITH STEAM CAP UNDERLYING BRINE RESERVOIR BY NUMERICAL SIMULATION

Heru Berian Pratama\textsuperscript{a}, Nenny Miryani Saptadji\textsuperscript{b}

\textsuperscript{a,b}Geothermal Engineering Study Program, Institut Teknologi Bandung, Indonesia
Jalan Ganesa 10, Bandung, Indonesia
hb.pratama@gmail.com

ABSTRACT

The main issue in the management of the two-phase liquid-dominated geothermal field is rapid decline pressure in the reservoir so that the supply of steam to the power plant cannot be fulfilled. To understanding that, modelling and numerical simulation used reservoir simulators. The model is developed on liquid-dominated geothermal fields are assessed in various scenarios of production strategies (focusing only steam cap, brine reservoir and a combination) and injection strategies (deep and shallow injection, centered and dispersed injection), with the calculation using separated steam cycle method. The simulation results of the model for sustainable production are production 25% from steam cap + 75% from brine reservoir, dispersed and deep reinjection with make-up wells from steam cap results 9 make-up well number. The implementation of production-injection strategy needs to be planned right from the beginning of exploitation so that the strategy can adapt to changes in reservoir characteristics.

Keywords

Reservoir liquid-dominated, Steam cap, Sustainable Production
A NEW GEOTHERMAL MODELLING WORKFLOW USING LEAPFROG AND TOUGH2

John O'Sullivan\textsuperscript{a}, Rosalind Archer\textsuperscript{b}, Mike O’Sullivan\textsuperscript{c}, Thomas Krom\textsuperscript{d}, Brennan Williams\textsuperscript{e}

\textsuperscript{a,b,c}Department of Engineering Science, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
\textsuperscript{d,e}ARANZ Geo Limited, PO Box 42002, Christchurch 8140, New Zealand
e-mail: jp.osullivan@auckland.ac.nz

ABSTRACT

Modelling software provides essential tools for the development and management of geothermal systems. Geological modelling software is important for understanding geothermal systems, developing consistent conceptual models and presenting meaningful information about their behaviour. Reservoir modelling software is used to support a wide range of activities including power production predictions, makeup well scheduling, well testing and resource assessment. Both geological models and reservoir models evolve throughout the lifecycle of a geothermal project and they provide the most added value when they are consistent and well maintained.

ARANZ Geo Limited and the Geothermal Institute at the University of Auckland have jointly developed a new geothermal modelling workflow using the 3D geological modelling software Leapfrog\textsuperscript{®} and the industry standard reservoir modelling software TOUGH2. The new workflow ensures consistency between geological models and reservoir models and provides tools for automatically generating reservoir model parameters. This not only allows reservoir modelling to begin at the early stages of a project but also streamlines the process of using new field data to update the conceptual model and transferring those changes to the reservoir model. Leapfrog’s powerful 3D visualisation tools are also used to make high quality presentations of both field data and reservoir modelling results.

Keywords

Leapfrog, TOUGH2, Geothermal Modelling Workflow
PROBABILISTIC APPROACH OF RESOURCE ASSESSMENT IN KERINCI GEOTHERMAL FIELD USING NUMERICAL SIMULATION COUPLING WITH MONTE CARLO SIMULATION

Iki Hidayat\textsuperscript{a}, Sutopo\textsuperscript{b}, Heru Berian Pratama\textsuperscript{c}

\textsuperscript{a,b} Petroleum Engineering Study Program, Institut Teknologi Bandung, Bandung, Indonesia, \textsuperscript{b,c} Geothermal Engineering Study Program, Institut Teknologi Bandung, Bandung, Indonesia

Jl. Ganeca No. 10, Bandung 40132

e-mail: ikihidayah@gmail.com

ABSTRACT

The Kerinci geothermal field is a one phase liquid reservoir system in the Kerinci District, western part of Jambi Province. In this field, there are geothermal prospects that identified by the heat source up flow inside a National Park area. Kerinci field was planned to develop 1×55 MWe by Pertamina Geothermal Energy. To define reservoir characterization, the numerical simulation of Kerinci field is developed by using TOUGH2 software with information from conceptual model. The pressure and temperature profile well data of KRC-B1 are validated with simulation data to reach natural state condition. The result of the validation is suitable matching. Based on natural state simulation, the resource assessment of Kerinci geothermal field is estimated by using Monte Carlo simulation with the result P10-P50-P90 are 49.4 MW, 64.3 MW and 82.4 MW respectively. This paper is the first study of resource assessment that has been estimated successfully in Kerinci Geothermal Field using numerical simulation coupling with Monte carlo simulation.

Keywords

Kerinci, numerical simulation, resource assessment, monte carlo
RE-INJECTION SYSTEM TO AVOID DECREASING TEMPERATURE OF GEOTHERMAL SYSTEM AFFECT FACILITIES PRODUCTION PROBLEMS, STUDY CASE : SALAK MOUNTAIN

Michi Oktaviana\textsuperscript{a}, Fandy Fahreza\textsuperscript{b}

\textsuperscript{a,b}Geological Engineering Diponegoro University Semarang, Central Java, Indonesia
e-mail: michioktaviana@gmail.com

ABSTRACT

Salak Mountain has a high potential of geothermal energy, the type of geothermal system is a liquid-dominated with low to moderate non-condensable gas content and the reservoir has moderate to high temperature (240\textdegree{} C - 312\textdegree{} C). Recently geothermal fluid production of Awibengkok field at Salak Mountain reach 60 MWe, however derating production occur almost 2 MWe. This derating production could be affected by several factor one of them is decreasing temperature. Decreasing temperature cause new problems appearance on geothermal fluid production facilities, scaling is one of the major problems.

Scaling affect blockage on production facilities cause decreasing production, in this case the scaling material came from steam-carried particles. This problem on geothermal system consequences technical problems on production facilities and natural shifting of geothermal system. Decreasing temperature it’s due to technical problems origin by re-injection system failure. Therefore required proper handling of re-injection system concern to the location of re-injection wells and the amount of re-injected fluid. The precisely re-injection system in order to maintain existing either preventing extinguish geothermal system.

Keywords

Decreasing Temperature, Scaling, Derating, Re-injection System, Salak Mountain
APPLICATION OF EXPERIMENTAL DESIGN IN GEOTHERMAL RESOURCES ASSESSMENT OF CIWIDEY-PATUHA, WEST JAVA, INDONESIA

Ali Ashat\textsuperscript{a}, Heru Berian Pratama\textsuperscript{b}

\textsuperscript{a,\textsuperscript{b}}Geothermal Engineering Study Program, Institut Teknologi Bandung, Indonesia
Jalan Ganesa 10, Bandung, Indonesia
hb.pratama@gmail.com

ABSTRACT

The successful Ciwidey-Patuha geothermal field size assessment required integration data analysis of all aspects to determined optimum capacity to be installed. Resources assessment involve significant uncertainty of subsurface information and multiple development scenarios from these field. Therefore, this paper applied the application of experimental design approach to the geothermal numerical simulation of Ciwidey-Patuha to generate probabilistic resource assessment result. This process assesses the impact of evaluated parameters affecting resources and interacting between these parameters. This methodology have been successfully estimated the maximum resources with polynomial function covering the entire range of possible values of important reservoir parameters.

Keywords

Ciwidey-Patuha, Experimental Design, Resources Assessment
COUPLING FLOW-GEOMECHANICAL MODEL FOR STIMULATION OF FRACTURED GEOTHERMAL FIELDS

Francesco Pizzocolo\textsuperscript{a}, Peter Fokker\textsuperscript{b}

ABSTRACT

Geothermal energy, with its combination of very low CO\textsubscript{2} emission rates and the possibility of providing electricity, has the potential of being a key factor in the global greenhouse gas emission reduction. Some geothermal systems, however, require stimulation to achieve economic production. To simulate the effectiveness of stimulation techniques, a synergy between dynamic flow simulators and geomechanical models is crucial. Especially in volcanic environments. Such systems are characterized by a high fracture density, fluids are generally stored in the pores of the rock mass, but the fracture network, rather than the connectivity of the pores, provides the conduits for fluids and heat to flow through the reservoir. Injecting fluid alters the stress field in the area. If the induced extra pressure is larger than the rock strength, it propagates tensile fractures in the rock, enhancing the conductivity and permeability. For smaller pressures, the reduction of the effective stress might cause hydro-shearing of existing fractures. Moreover, injecting fluid colder than the in situ temperature will generate thermal stresses, with similar effect on the fractures. To tackle all those aspects, we linked numerical simulators and analytical solutions to connect the evolving fluid properties and temperature with the changes in the stress field for the future.
CHARACTERISTIC OF NON-VOLCANIC GEOTHERMAL SYSTEM IN SOUTH BANGKA REGENCY, BANGKA BELITUNG ISLANDS

Riska Nuraffifah\textsuperscript{a}, Hiskia Ulinuha A\textsuperscript{b}, Nur Anesi\textsuperscript{c}, Siswandi\textsuperscript{d}, Dedi Kusnadi\textsuperscript{e}

\textsuperscript{a,b,c,d}Geological Engineering, Jenderal Soedirman University, Purwokerto, Indonesia, Jln. HR.Boenyamin No 708 Banyumas-Central Java
\textsuperscript{e}Center of Geological Resources, Bandung, Indonesia, Jln Soekarno Hatta 444 Bandung – West Java
hiskia.annisa@gmail.com

ABSTRACT

The research area is located on Gudang District, South Bangka Regency. Geomorphology of this area consists of intrusion hill and peneplain. This condition is controlled by the variety of lithologies i.e. sandstone, granite intrusion, and alluvial deposits. Northwest-Southeast trending normal fault as structure geology controlled the geological setting. This study has found two manifestations including the hot springs. Both of these manifestations are chloride-type (Cl) water. Based on analysis of stable isotope δD and δ\textsuperscript{18}O, it showed that the geothermal fluid was derived from meteoric water. Soil chemical anomalies are surrounding manifestations that can be determined according to several soil parameters including the distribution of temperature anomalies, pit, pH, CO\textsubscript{2} and Hg contents. As a result, geothermal system in this area could be classified as burial or sedimentary basin system. Heat was transferred from heat source to reservoir which is sandstone Tanjung Genting Formation. It has a range temperature of 137 – 157 °C measured by Na – K geothermometer at 20-60 meters depth. The heat source came from pressure and sediment load. This temperature were able to rise the degree of subsurface temperature (geothermal gradient). Geothermal fluid rose to the surface through fracture such normal fault, and turns as geothermal manifestations.

Keywords

Bangka Island, granite, non-volcanic geothermal system, burial system, geochemistry
ELEVATED MERCURY CONTENT FROM GEOTHERMAL SOURCES IN WAE SANO AREA, MANGGARAI BARAT REGENCY, NUSA TENGGARA TIMUR PROVINCE, INDONESIA

Fajar Rizki Widiatmoko\textsuperscript{a}, Mochamad Nur Hadi\textsuperscript{b}, Dedi Kusnadi\textsuperscript{b}, Yo-Ho Chang\textsuperscript{a}

\textsuperscript{a} Department of Natural Resources and Environmental Studies, National Dong Hwa University, Hualien, Taiwan
\textsuperscript{b} Pusat Sumber Daya Geologi, Kementerian Energi dan Sumber Daya Mineral, Bandung, Indonesia
e-mail: widiatkogeo@gmail.com

ABSTRACT

Manggarai Barat regency, western Flores Island, Indonesia is experiencing tourism and industrial growth in recent years. According to the electricity production and supply statistic of this regency, there are 38,498 houses living without electricity. To solve this problem the regency has to upgrade the electrical service to meet the basic needs of residents. The electricity generations by diesel and thermal electricity generation were compared and tried to find a sustainable energy source. In this regency there is a Wae Sano inactive volcano, but it still actively produces hot springs and surrounding rocks have been altered by hydrothermal alteration. This may have potential to produce steam energy for electricity generation purpose. This area also has been declared feasible to generate power about 26MW. At preliminary stage of finding geothermal source is to understand the general geological setting by literature review, image interpretation, and regional Bouguer anomaly study. Soil sampled within 1-2 meters depth around the potential geothermal areas were also analyzed mercury levels. Mercury is known that it easily evaporates when temperature is increasing. If there is a geothermal source, mercury will evaporate because of geothermal activity, but mercury will be trapped into top soil horizons where are cooler. The results shown number of elevated mercury concentrations sites have been found in two groups of soil samples. The E area (the southeastern Wae Sano Lake) has had depression structures, hot springs and altered rocks. The W area (the western Wae Sano Lake) has eroded hydrothermal altered rock. Consider to the DEM and Bouguer anomaly map, the W area might have the same structure as those of the E area, but the altered rocks of the W area were older than those of the E area. The W area was categorized as a paleo hot springs with lower temperature. As a conclusion, the E area was the prioritized area for future geothermal power plant site.

Keywords

Soil geochemistry, hot springs alteration, digital elevation model (DEM)
GEOLOGY AND GEOCHEMISTRY OF GEOTHERMAL WATER ON THE NON VOLCANIC GEOTHERMAL SYSTEM IN SOUTHERN KUNINGAN, WEST JAVA

Bela Agung Pratama\textsuperscript{a}, Sachrul Iswahyudi\textsuperscript{a}, Indra Yanastyapricena\textsuperscript{b}, Sofia Salsabila\textsuperscript{a}, Atikah Nurina Sari\textsuperscript{a}, M. Rifky Ghifari\textsuperscript{c}, Fauzan Rachmad\textsuperscript{c}

\textsuperscript{a}University of Jenderal Soedirman
\textsuperscript{b}dr.Bumi Research Group (dRBG)
\textsuperscript{c}SM-IAGI UNSOED

Jl. Mayjen Sungkono KM 8
e-mail: bela.tama@gmail.com

ABSTRACT

The research area is located in the Subang Subdistrict, Cipakem Subdistrict, Ciniru Subdistrict, and surroundings in Kuningan regency, West Java. This study was conducted to determine geology and geochemistry condition of geothermal water in this area. Several methods were used in this study comprising observation, detailed geological mapping and geochemical analysis of geothermal water. Morphology in research area was interpreted into structural hills. Lithologies in the study area are mudstone unit, sandstone unit, basalt intrusion and andesite breccia unit. Developing structure in the study area are anticline fold, reverse fault, left slip fault and right slip fault. Three geothermal manifestations in the study area are hot springs that exist in the study area are BAP-HS 1 (62\degree C), BAP-HS 2 (41\degree C), and BAP-KL 3 (51\degree C). Based on geochemical analysis of geothermal water, research area obtained two types of water: chloride water and dilute chloride-bicarbonate water. Geothermal water in research area comes from one reservoir. Temperature reservoir in research area is 151\degree C-163\degree C and the depth of geothermal reservoir in research area is 190-270 m in the subsurface. Geothermal system at the research area is included into water dominated system at the low relief system with the cycle and storage system. Heat source on this geothermal system is derived from geological structure and imposition of sedimentary rocks. Left slip fault structure is being a way out for geothermal water to surface area as manifestation and both reservoir and cap rock are sandstone that altered into clay mineral. Based on Heat loss calculation, geothermal potential in research area is 29.055 kW and speculative resource is 290.55 kWe.

Keywords

Geochemical of Geothermal water, geology, geothermal system, heat loss, Kuningan, Non-volcanic system
CL/B RATIO OF GEOTHERMAL FLUID AROUND SLAMET VOLCANO, JAWA TENGAH, INDONESIA

Agung Harijoko\textsuperscript{a}, Saefudin Juhri\textsuperscript{b}

\textsuperscript{a,b}Department of Geological Engineering, Faculty of Engineering, Universitas Gadjah Mada Jl. Grafika No. 2, Kompleks Kampus Fakultas Teknik UGM, Yogyakarta
e-mail: aharijoko@ugm.ac.id

ABSTRACT

Geothermal manifestations occurred in four areas surrounding Slamet Volcano, such as Guci, Baturraden, Paguyangan, and Bantarkawung. These areas are located of about 7.5 km, 8 km, 25 km and 33 km from the summit of Slamet volcano, respectively. We analyzed the chemical composition of cold and hot water in order to understand the genesis and hydrological the relationship of the hot springs. The plot on $\text{HCO}_3$-$\text{Cl}$-$\text{SO}_4$ ternary diagram classified the hot water into four water types i.e. chloride-bicarbonate water (Bantarkawung), chloride water (Paguyangan), sulfate-chloride water (Baturraden), and bicarbonate water (Guci). The Cl/B ratio values indicate that the southern part of the Slamet volcano (Baturraden) hot springs have high Cl/B ratio compared to that of the northern hot springs (Guci area). While the hot springs in the western part (Paguyangan and Bantarkawung) are classified into high and low Cl/B ratio. This indicates that the hot springs in Paguyangan and Bantarkawung are the outflow of Baturraden and Guci.

Keywords

Slamet volcano, geothermal, Baturraden, Guci, chloride, boron
A MINERAL ANALYSIS WORKFLOW FOR DRILL CUTTINGS AT THE WELLSITE: APPLICATIONS TO GEOTHERMAL RESOURCE EXPLORATION, APPRAISAL AND DEVELOPMENT

Joseph Hamilton\textsuperscript{a}, Sigrid Hillier\textsuperscript{b}, Carmen Harris\textsuperscript{c}

\textsuperscript{a,b,c}Ana-min
Perth, Western Australia
e-mail: joseph.hamilton@ana-min.com

ABSTRACT

Development of a workflow for mineral analysis at the well site has been developed from a comprehensive laboratory work flow for predrill analysis of legacy samples. It uses benchtop Fourier Transform Infrared spectrometry (FTIR) analysis of individual minerals sampled by handpicking and / or with a scalpel, in amounts as small as a few milligrams. Identification of scale minerals and key minerals indicative of the conditions of hydrothermal alteration is made from their FTIR spectra. Where legacy samples are available, the workflow comprises use of other methods of mineral analysis (X ray diffraction, thin section petrography, fluid inclusion geothermometry, scanning electron microscopy/ energy dispersive spectrometry) in addition to bench top FTIR analysis. Some comparison of the advantages and disadvantages of some of the methods available are provided. To date, projects have been laboratory based but the well site work flow is now available for geothermal resource application.

Keywords

Minerals, Fourier Transform Infrared Spectroscopy, Hydrothermal Alteration, Scaling
A NEW IDEA: THE POSSIBILITES OF OFFSHORE GEOTHERMAL SYSTEM IN INDONESIA MARINE VOLCANOES

Teguh Rahat PRABOWO, Fithriyani FAUZIYYAH, Suryantini, Sutikno BRONTO

\textit{a} Master Student of Geothermal Technology Magister Program, ITB, Bandung, Indonesia, teguhprabowo_23@yahoo.com
\textit{b} Master Student of Hydrogeology Magister Program, ITB, Bandung, Indonesia
\textit{c} Lecturer of Geothermal Technology Magister Program, ITB, Bandung, Indonesia
\textit{d} Pusat Survei Geologi, Ministry of Energy and Mineral Resource, Bandung, Indonesia

ABSTRACT

High temperature geothermal systems in Indonesia are commonly associated with volcanic systems. It is believed that volcanoes are acting as the heat source for a geothermal system. Right now, most of the operating geothermal fields in the world are associating with volcanic settings which known as the conventional geothermal system. Meanwhile, more than 200 volcanoes located from Sumatra Island to the eastern part of Indonesia. Volcanoes forming vents or fractures which enable magma, fractured rocks, and volcanic gases released to the surface. Volcanoes are created in active tectonic zone such as collision zone and MOR (mid oceanic ridge). The later is the one which formed the marine volcanoes on the sea floor.

The advances of today’s technology in geothermal energy has created many ideas regarding a new kind of geothermal system, including the ideas of developing the utilization of marine volcanoes. These marine volcanoes are predicted to be hotter than the land system due to the shorter distance to the magma chamber thus making it a great potential for heat source, although there are still some issues to be dealt with. Seamounts like NEC, Banua Wuhu, and Kawio Barat in Indonesia are good spots to be studied. Some of the methods used for exploration and exploitation are basically the same with on-land geothermal but with more improvements and more advanced technology. Methods such as remote sensing using NOAA images, sonar, and MAPR are commonly used, eventhough these would be more accurate with more detailed techniques. This has become the challenge for all geothermal scientists to overcome for a better study result.

Keywords

\textit{Offshore Geothermal, Seamounts, NOAA, Remote Sensing, Indonesia Sea}
ABSTRACT

Cimanggu warm springs are located on Cimanggu Village, West Bandung District, West Java. It is one of several surface manifestations around Mt. Tangkuban Perahu. The warm springs occur about 20 kilometers on west direction from Lembang. Normalized Different Vegetation Index is one of remote sensing methods which purpose to calculate ratio between near infrared band and red band from vegetation. The method can be used in preliminary stage of geothermal exploration to detect active thermal manifestation surface. This method is used for inspecting vegetation anomaly and determine NDVI threshold surface as initial reference which is proved in geothermal prospect area. The data which is acquired from landsite 8 satellite imagery calibrated using atmospheric correction. Based on NDVI analysis and ground checking validation. We determine the NDVI threshold value which is equivalent to 0.17.

Keywords

Cimanggu, NDVI, Geothermal System, Surface Manifestations
REASSESSMENT OF GEOTHERMAL SYSTEM ON THE SOUTHERN SLOPE OF THE BUYAN-BRATAN CALDERA, BALI, INDONESIA

Sachihiro Taguchi a, Koki Okamura b, Eiki Arita c, Ryuichi Itoi d, Agung Harijoko e, I Wayan Warmada f, Koichiro Watanabe g

aDepartment of Earth System Science, Faculty of Science, Fukuoka University, Fukuoka, Japan, e-mail: staguchi@fukuoka-u.ac.jp
b,c,d,gDepartment of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Fukuoka, Japan
fDepartment of Geological Engineering, Faculty of Engineering, Gadjah Mada University, Yogyakarta, Indonesia

ABSTRACT

Hot springs from the southern flanks of Buyan-Bratan caldera, Bali shows systematic changes of geochemical characteristics. All are grouped into HCO$_3$ type of water. However, from higher to lower elevation, Cl contents of the hot springs increase, and SO$_4$ decreases in contrast. Although the chemical characteristics of hot springs located higher (Angseri) and lower (Yeh Panes) elevations are different, isotopic data suggest the source of meteoric water is derived from the almost the same elevation.

Helium isotope of bubbling gases from hot springs show a mixing of air and magmatic gas with $^{3}$He/$^{4}$He of 10x10$^{-6}$, indicating direct ascending of geothermal fluid ascends from the beneath of the hot springs on the southern flanks of the Buyan-Bratan caldera, not from the central part of caldera.

Keywords

Geothermal, steam field, power plant, Rajabasa
STUDY OF GEOTHERMAL RESERVOIR ROCKS BASE ON PHYSICAL PROPERTIES OF ARJUNO-WELIRANG, EAST JAVA

Almira Mahsa\textsuperscript{a}, Nuha Malihati\textsuperscript{b}, Indah Purwaningtyas\textsuperscript{c}, Adib Banuboro\textsuperscript{d}, Jobit Parapat\textsuperscript{e}

\textsuperscript{a,b,c,d,e} Geophysical Engineering Dept, Sepuluh Nopember Institute of Technology, Surabaya Indonesia, Almiramahsa9@gmail.com

ABSTRACT

Physical properties of rock are very important parameters for modeling of geophysical responses or evaluation of geophysical data. Density and porosity are common of physical rock properties parameters that can be utilized to describing the condition in the subsurface area. The study was conducted in a complex Arjuno-Welirang volcano. Arjuno-Welirang geothermal prospect area is situated in ring of fire Indonesia and located in Kab. Mojokerto, Kab. Malang, Kab. Pasuruan and Kota Batu, East Java. Arjuno-Welirang volcano is a part of B/C volcano type. On this areas, Systematic rock sampling were used to characterize geothermal rock properties. Rock sample has been collected on geothermal area of Arjuno-Welirang. After collect the samples, by using numerous methods in the laboratory such as saturation weight and Archie’s law we can determine density and porosity. From the rock samples, can be obtained 11 data of saturated density, dry density, normal density and porosity spread along Tretes-Singosari, Lawang-Arjuno side, Karangploso-BatuPujon, Batu-Cangar, Cangar-Pacet, Tretes-Welirang summit-Cangar and Tretes-Arjuno summit-Lawang. From the result, we can know the rock characterization of the volcano. The collected information can represent a useful base to evaluate changes of the system, also induced by volcanic activity or geothermal exploitation.

Keywords

Geothermal, Rock Properties, Density, Porosity
GEOTHERMAL POTENTIAL ANALYSIS BY INTEGRATION GEOLOGY, GEOCHEMICAL, AND GEOPHYSICAL DATA OF “TG14” GEOTHERMAL FIELD, SUMATERA

Aziz Fajar Setiawan\textsuperscript{a}, Evi Muharoroh\textsuperscript{b}

\textsuperscript{a,b}University of Lampung
Bandar Lampung, Indonesia
e-mail: azizfajar11@gmail.com

ABSTRACT

Indonesia is one of many countries that have the large potential of geothermal energy in the world. This research is purposed to analyze the potential energy of “TG14” Geothermal Field in Sumatera. This study uses the integration of geology, geochemical and geophysical data to analysis the geothermal potential energy generated by "TG14" geothermal field in Sumatera. Geological conditions of the area were analyzed from lineament extraction of ASTER GDEM imagery. The physical and chemical parameters determined by using geophysical and geochemical data. Geothermal potential energy determined using volumetric method calculation. The regional lineament analysis result shows some lineaments in the research area. The minor and major lineaments analyzed by using rose diagram which result the trend is North East-South West (NE-SW) and it prescribed as the deformations from the Sumatra Fault System. From the geochemical data observed by using geothermometer, the temperature reservoir reached >160\degree C. While the result from forward modeling gravity data shows that the width and the thickness of the reservoir is 5 km\textsuperscript{2} and 1 km. Based on the observed data, the potential of geothermal energy on research area is known 42.74MW.

Keywords

Geothermal, Energy Estimated, Geological, Geochemical, Geophysical
CONCEPTUAL MODEL OF “EM-AFS” GEOTHERMAL PROSPECT BASED ON GEOLOGICAL, GEOCHEMICAL, AND GEOPHYSICAL DATA

Evi Muharoroh\textsuperscript{a}, Aziz Fajar Setiawan\textsuperscript{b}

\textsuperscript{a,b}University of Lampung
Bandar Lampung, Indonesia
e-mail: evimuharoroh96@gmail.com

ABSTRACT

Determining a conceptual model of the geothermal system which is compiled from geological, geochemical, and geophysical data is an essential element to be employed in geothermal reservoir analysis. In this paper, identification of geological conditions in research area were used remote sensing methods on ASTER and DEM imagery with defoliant technique (PCA) to determine geological structure, and the type of hydrothermal alteration. Geochemical data is used to determine the manifestation fluid type and the reservoir temperature. Manifestation fluid type was known by plotting fluid composition on ternary diagram Cl-HCO\textsubscript{3}-SO\textsubscript{4}, while the temperature in the reservoir known by plotting on ternary diagram Na-K-Mg, then calculate using geothermometer. Geophysical data were used to determine the geothermal system geometry i.e. reservoir depth, reservoir thickness, reservoir area, and the bedrock type. Based on the results of geological studies, the geothermal prospect is controlled by fault and structural lineament which has NE-SW trend and alteration minerals dominated by Alunite-kaolinite. These characteristic shown interaction between rock with acidic water that characterize the geothermal presence. Analysis result of geochemical data on two manifestations BR and BL indicates that the manifestation fluid type is acid and the reservoir temperature around of > 160°C. The temperature is calculated on the basis geothermometer Na-K and ternary diagram Na-K-Mg. Finally, based on the resistivity modeling of geophysical data, it is found that geothermal reservoir area is around 5 km\textsuperscript{2}. In addition, based on 2D modeling of gravity data, it is known that reservoir thickness is 0.5 km and the bedrock type is andesitic which has density 2.54 gr/cc and the cap rock is clay cap.

Keywords

Conceptual Model, Geological, Geochemical, Geophysical
ABSTRACT

Indonesia faces increased electricity demand by 10% or 6 GW every year. Geothermal energy is an alternative energy that is able to donate electric energy in Indonesia. Ungaran Mount in Central Java is one of the areas that has Geothermal potential with the emergence of hot springs in the vicinity of Ungaran Mount. Analysis by the method of Geology, Geophysics (Gravity Method), and Geothermal Fluid Geochemistry (Geothermometer) to support the development Geothermal energy in Ungaran Mount.

Geology of Ungaran Mount dominated by volcanic rocks, which are composed of volcanic rock Kaligesik Formation (Qpk), volcanic rock Gajah Mugkur Formation (Qhg), and lava Sumbing Formation (QLS). Gravity anomalies in Ungaran and the surrounding area is dominated by volcanic rocks distribution of rocks that has orientation East-West, with the density values in the range of 130-210 mGal (regional anomalies) and 70-100 mGal (local anomalies). The geological structure has orientation North-South. The geological structure is suspected as a factor of their appearance Gonoharjo hot springs in the area where the location of the geochemical data measurements conducted in the Gonoharjo area. Types of geothermal fluid is a mixture of chloride water with bicarbonate. Temperature reservoir in the area Gonoharjo range about ± 207 ° C. The range of estimated reserves in Ungaran ± 1367 MW

Keywords

Geology, Gravity, Ungaran Mount, Geothermal
FAULT FRACTURE DENSITY ANALYSIS FOR NON-VOLCANIC GEOTHERMAL POTENTIAL TO DETERMINE RECHARGE AREA; A CASE STUDY IN LORE LINDU AREA, CENTRAL SULAWESI

Raden Dikky Surya R\textsuperscript{a}, Oki Kurniawan\textsuperscript{b}, Gatra Wargaliyasa\textsuperscript{c}

\textsuperscript{a,b} Faculty of Geological Engineering, Universitas Padjajaran, Bandung, Indonesia
\textsuperscript{c} Department of Geological Engineering, Institut Teknologi Bandung, Bandung, Indonesia
Komplek Manglayang Regency Blok J-1 No. 18 Bandung
suryadikky@gmail.com

ABSTRACT

Sulawesi has 76 potential locations for geothermal fields with 3.229 Mwe potential value. However, nothing of these non-volcanic geothermal fields in Sulawesi have been developed to be a power plant. Lore Lindu area is one of the non-volcanic geothermal field that is interesting to be a research object. The primary data in this research consist of lineament delineation from SRTM, topography data, and geological structure such as joint and slicken side. In this research, several methods were used consist of Fault Fracture Density (FFD), slope analysis, and fieldwork method. FFD method has been used for early study in geothermal exploration. This method gives us information about high density fracture zone. Slope analysis method is purposed to determine the catchment area. Fieldwork method gives us information about geological structure and geothermal manifestation. As a result of these analysis there are 3 recharge zone that can be determined in this research area which located in Rahmat District Area, Kadidia District Area around Kadidia Fault, and the area around Koalarawa hot spring. The recharge zone generally located in hill area with high slope value which morphology was influenced by geological structure.

Keywords

Non-volcanic geothermal, fault fracture density (FFD), recharge zone, Lore Lindu, Central Sulawesi
ERUPTIVE HISTORY OF THE POST-CALDERA VOLCANOES OF BUYAN-BRATAN CALDERA, NORTH BALI, INDONESIA

Mitsuru Okuno\textsuperscript{a}, Agung Harijoko\textsuperscript{b}, I Wayan Warmada\textsuperscript{c}, Koichiro Watanabe\textsuperscript{d}, Toshio Nakamura\textsuperscript{e}, Sachihiro Taguchi\textsuperscript{f}, Tetsuo Kobayashi\textsuperscript{g}

\textsuperscript{a,f}Department of Earth System Science, Faculty of Science, Fukuoka University, Fukuoka, Japan  
\textsuperscript{b,c}Department of Geological Engineering, Gadjah Mada University, Yogyakarta, Indonesia  
\textsuperscript{d}Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Fukuoka, Japan  
\textsuperscript{e}Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan  
\textsuperscript{g}Graduate School of Science and Engineering, Kagoshima University, Kagoshima, Japan  
e-mail: okuno@fukuoka-u.ac.jp

ABSTRACT

We conducted field survey to establish tephra stratigraphy of the post-caldera volcanoes (Lesung, Tapak, Sengayang, Pohen and Adeng) of Buyan-Bratan caldera in Bali Island, Indonesia. Tapak volcano has three craters aligned from north to south. Lava effused from the central crater flows down to the northwest and separated the Tamblingan and Buyan lakes. This lava also covers the tip of the lava flow from Lesung volcano. Therefore, this is a product of the latest eruption in the post-caldera volcanoes. Lesung volcano also has two craters, and specific gully developing on a pyroclastic cone from north to western slope. Lava from the south crater flows down to the western flank beyond the caldera rim. Another lava distributed in the east from the south also surrounds Sengayang volcano. Adeng volcano is surrounded by lava and/or debris avalanche deposits from Pohen volcano. Based on the topographic relationships, Sengayang volcano is the oldest in the post-caldera volcanoes, and then Adeng, Pohen, Lesung, and Tapak volcanoes have been formed up to the present. Coarse-grained scoria-falls around this area are intercalated with two foreign tephras, the Samalas AD 1257 tephra from Lombok Island and the Penelokan tephra (ca. 5.5 kBP) from Batur caldera. The source of these scoria-falls is estimated to be Tapak or Lesung volcanoes. It implies that at least two volcanoes erupted in the Holocene period.

Keywords

Buyan-Bratan caldera, eruptive history, post-caldera volcano, 14C dates, geomorphology
THE OCCURRENCES OF HOT SPRING MANIFESTATIONS IN POHON BATU AREA, WEST CERAM

Airiza Rahman Hakim\textsuperscript{a}, Windi Anarta Draniswari\textsuperscript{b}, Dede Iim Setiawan\textsuperscript{c}

\textsuperscript{a}Universitas Padjajaran, Bandung, Indonesia
\textsuperscript{b}Institut Teknologi Bandung, Bandung, Indonesia
\textsuperscript{c}Pusat Sumber Daya Geologi, Bandung, Indonesia
airizarahmanhakim@gmail.com

ABSTRACT

Pohon Batu area is located in West Ceram and belongs to Tehoru metamorphic complex. It’s an interesting study area because the occurrences of the hot spring manifestations are not related to the volcanic system. The purpose of this research is to identify the characteristic of geothermal manifestations in this area using surface geological and structural data combined with geochemical analysis. Tectonics, crust characteristic (lithology), and surface structural figure, could affect the occurrence of geothermal manifestations in this area.

Eight hot springs were identified in this area. The geochemical analysis shows that the hot springs have dilute-chloride type water from single reservoir. By using Na/K geothermometer calculation, it could be determined that the geothermal reservoir of the study area has temperature around 190°C and depth of 582 km. Structural analysis shows that the hot spring manifestations are controlled by sinistral-fault in the northern part of Pohon Batu area and the outflow is affected by dynamically maintained fractures system.

Keywords

Geochemistry, structure, Pohon Batu, hot spring
STUDY OF ROCK MICROSTRUCTURE BASED ON SEM-EDX AND XRD CHARACTERIZATION TO EVALUATE ARJUNO-WELIRANG GEOTHERMAL POTENTIAL

Husnia Nur Annisa\textsuperscript{a}, Almira Mahsa\textsuperscript{b}, Silvia Veronica\textsuperscript{c}, Nuha Malihati\textsuperscript{d}, Karim Rahman Hartono\textsuperscript{e}

\textsuperscript{a,b,c,d,e}Geophysical Engineering, Institut Teknologi Sepuluh Nopember
Jl. Raya ITS, Keputih, Sukolilo, Keputih, Sukolilo, Kota SBY, East Java
\textit{e-mail: husnia.nia.annisa@gmail.com}

ABSTRACT

The x-ray diffractometer is used to qualitatively or quantitatively identify individual minerals. While sem-edx used for the surface analytical techniques. Samples are selected from eleven lithologic units around arjuno-welirang volcanoes. The purpose of this study is to determine how the state morphology, crystal structure and the percentage of the mineral content of the samples using x-ray characterization diffraction (xrd) and scanning electron microscope-energy dispersive x-ray spectroscopy (sem-edx). Arjuno-welirang geothermal prospect area is situated in ring of fire indonesia and located in kab. Mojokerto, kab. Malang, kab. Pasuruan and kota batu, east java. Geologically, the prospect area is dominated by quartenary volcanic rocks, both lava and phyroclastic. The samples obtained from arjuno-welirang volcanoes by digging to a depth of 1-1.5 m as many as eleven points. The method used in this research is the method of powder. Eleven samples were crushed and sifted in the sieve of 200 mesh. Characterization of the eleven samples were done with the technique of x-ray diffraction (xrd) and scanning electron microscope- energy dispersive x-ray spectroscopy (sem-edx). Based on sem-edx test, the morphology of the eleven samples is generally shaped slab or blob defects and sizes. While the result of xrd test, mineral contents in the samples are dominated by albite, anorthite, and kyanite mineral that showed geothermal potential.

\textbf{Keywords}

Geothermal, SEM-EDX, XRD
GEOTHERMAL SYSTEM BOUNDARY AT THE NORTHERN EDGE OF PATUHA GEOTHERMAL FIELD BASED ON INTEGRATED STUDY OF VOLCANOSTRATIGRAPHY, GEOLOGICAL FIELD MAPPING AND COOL SPRINGS CONTAMINATION BY THERMAL FLUIDS

Cindyta Rachmawati\textsuperscript{a}, Suryantini\textsuperscript{b}, Mirzam Abdurrahman\textsuperscript{c}

\textsuperscript{a}Geology Engineering Study Program, Faculty of Earth Sciences and Technology, Institut Teknologi Bandung, Indonesia  
\textsuperscript{b}Geothermal Technology Study Program, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Indonesia  
\textsuperscript{c}Jl Ganesha 10 Bandung 40132  
e-mail: rcindyta@gmail.com

ABSTRACT

Patuha Geothermal System is a volcanic hydrothermal system. In this type of system, the boundary of the system is often determined by low resistivity (10 ohm.m) anomaly from Magnetotelluric (MT) or DC-Resistivity survey. On the contrary, during geothermal exploration, the system boundary often need to be determined as early as possible even prior of resistivity data available. Thus, a method that use early stage survey data must be developed properly to reduce the uncertainty of the geothermal area extent delineation at the time the geophysical data unavailable.

Geological field mapping, volcanostratigraphy analysis and fluid chemistry of thermal water and cold water are the data available at the early stage of exploration. This study integrates this data to delineate the geothermal system boundary. The geological mapping and volcanostratigraphy are constructed to limit the extent of thermal and cold springs. It results that springs in the study area are controlled hydrologically by topography of Patuha Volcanic Crown (complex) or so called PVC, the current geothermal field and Masigit Volcanic Crown (complex) or so called MVC, the dormant volcano not associated with active geothermal system.

Some of the cold springs at PVC are contaminated by subsurface steam heated outflow while others are not contaminated. The contaminated cold springs have several characteristics such as higher water temperature than ambient temperature at the time it was measured, higher total dissolved solid (TDS), and lower pH. The soluble elements analysis support the early contamination indication by showing higher cation and anion, and positive oxygen shifting of stable isotope of these cool springs. Where as the uncontaminated spring shows similar characteristic with cool springs occur at MVC.

The boundary of the system is delineated by an arbitrary line drawn between distal thermal springs from the upflow or contaminated cool springs with the cool uncontaminated springs.
This boundary is more or less in agreement with low resistivity boundary derived from MT and DC resistivity survey. The area defined as part of geothermal area from this method is also validate with drilling data that give high temperature gradient. It suggests that the method use in this study is applicable and reliable.

Keywords

Patuha, geology, volcanostratigraphy, geothermal, springs, water chemistry
LITHOLOGY VARIATION AND HYDROTHERMAL ALTERATION OF WELL AN-1 TELOMOYO GEOTHERMAL SYSTEM

Yoga Aribowo\textsuperscript{a}, Anindya Estian\textsuperscript{dari}\textsuperscript{b}

\textsuperscript{a,b}Diponegoro University, Semarang, Indonesia, yogaribowo@gmail.com

ABSTRACT

Telomoyo Volcano located about 35 km southern of Semarang, is a product of Quarternary volcanism. The occurrence of surface manifestations such as warm spring and altered ground around Candi Umbul, Pakis Dadu, Banyubiru, Sepakung, Kendal Duwur, and Keningar indicated that it associated with thermal activity. Several geoscience researches had been conducted. One of the studies is the shallow drilling project to get information about the variation of vertical lithology, thermal gradient, and hydrothermal alteration related to physicochemical processes in particular section.

The methods used in the study are megascopic analysis of drilling core sample, petrographic, X-Ray Diffractometer (XRD), ASD, and Scanning Electron Microscope (SEM) analysis of rock sample from well DIP-1 and DIP-2 with depth about 700m.

Lithology variation at the study area consist of colluvial, andesite lava – basaltic andesite, tuff, andesite breccia and tuff breccia. Hydrothermal mineral observed are clay minerals (kaolinite, smectite, alunite, dan illite), calcite, chlorite, gypsum, pyrite, sericite, and anhydrite. The mineral association of the upper part indicate the acid condition and medium-low temperature, and the mineral association of the lower part indicate medium-high temperature and acid-neutral condition.

Keywords

Shallow drilling, alteration, lithology variation, acid-neutral
PRELIMINARY STUDY OF THE NON-VOLCANIC GEOTHERMAL POTENTIAL AS TRANSITION FROM PETROLEUM TO GEOTHERMAL EXPLORATION AT CIPARI AREA, CENTRAL JAVA

Kiddy Nahli\textsuperscript{a}, Vicco Oryzavica\textsuperscript{b}, Daniel Radityo\textsuperscript{c}

\textsuperscript{a,b,c}\textit{Master Student of Geological Engineering, Institut Teknologi Bandung, Bandung, Indonesia, kiddynahli@gmail.com}

\textsuperscript{a,b,c}\textit{FNRG Indonesia, Bandung, Indonesia}

ABSTRACT

Oil and gas exploration at Cipari area hasn’t found any success because of unknown factor. Cipari area has a hotspring manifestation which may indicate geothermal potential. So, we suggest to change oil and gas exploration into geothermal exploration.

Cipari is a non-volcanic area and has several uniquenesses such as oilseep and hotspring manifestation in narrow area. To identify the possibility of moving to geothermal exploration, this study uses FFD (Fault and Fracture Density) method from SRTM and topography data. The parameters that affect density value are intensity, density, and dimensionless intensity. These data will be combined with morphology data to delineated catchment area and recharge area. Data from the literature related to regional geology and geochemistry of the hotspring manifestations have been used as reference in this study.

This research describes the application of FFD method as a preliminary study and its potential that applied in area that dominated by sedimentary rocks and volcanoclastic rocks.

Keywords

\textit{Cipari, Hotspring manifestation, Fault and Fracture Density, Structure Geology, Geothermal Exploration}
BASIC OVERVIEW TOWARDS THE ASSESSMENT OF LANDSLIDE AND SUBSIDENCE RISKS ALONG A GEOTHERMAL PIPELINE NETWORK

Astisiasari\textsuperscript{a}, Cees Van Westen\textsuperscript{b}, Victor Jetten\textsuperscript{c}, Freek van der Meer\textsuperscript{d}, Dyah Rahmawati Hizbaron\textsuperscript{e}

\textsuperscript{a,b,c,d} Faculty of Geo-Information Science and Earth Observation, University of Twente, Enschede, the Netherlands
\textsuperscript{e} Faculty of Geography and Environmental Science, University of Gadjah Mada (UGM), Yogyakarta, Indonesia
\textsuperscript{e}-mail: a.astisiasari@utwente.nl

ABSTRACT

An operating geothermal power plant consists of installation units that work systematically in a network. The pipeline network connects various engineering structures, e.g. well pads, separator, scrubber, and power station, in the process of transferring geothermal fluids to generate electricity. Besides, a pipeline infrastructure also delivers the brine back to earth, through the injection well-pads.

Despite of its important functions, a geothermal pipeline may bear a threat to its vicinity through a pipeline failure. The pipeline can be impacted by perilous events like landslides, earthquakes, and subsidence. The pipeline failure itself may relate to physical deterioration over time, e.g. due to corrosion and fatigue.

The geothermal reservoirs are usually located in mountainous areas that are associated with steep slopes, complex geology, and weathered soil. Geothermal areas record a noteworthy number of disasters, especially due to landslide and subsidence. Therefore, a proper multi-risk assessment along the geothermal pipeline is required, particularly for these two types of hazard. This is also to mention that the impact on human fatality and injury is not presently discussed here.

This paper aims to give a basic overview on the existing approaches for the assessment of multi-risk assessment along geothermal pipelines. It delivers basic principles on the analysis of risks and its contributing variables, in order to model the loss consequences. By considering the loss consequences, as well as the alternatives for mitigation measures, the environmental safety in geothermal working area could be enforced.

Keywords

landslide, subsidence, geothermal, pipelines, disaster, risk, assessment
PERMEABILITY ZONE ANALYSIS BASED ON ELECTRICAL BOREHOLE IMAGE LOG, A CASE STUDY OF VERTICAL FAULT AT AN TRANSTENSIONAL STRUCTURE PATTERN GEOTHERMAL FIELD MUARA LABOH, WEST SUMATERA

Friska Agustin\textsuperscript{a}, Benyamin Sapiie\textsuperscript{b}, Chalid Idham Abdullah\textsuperscript{c}, Dayinta Adi Dyaksa\textsuperscript{d}, Mauliate Agustinus\textsuperscript{e}

\textsuperscript{a, b, c}Geology Engineering Study Program, Faculty of Earth Sciences and Technology, Institut Teknologi Bandung
\textsuperscript{d, e}PT Supreme Energy, Menara Sentraya, 23rd Floor, Kebayoran Baru, Jakarta, Indonesia Friska.agustin08@gmail.com

ABSTRACT

Vertical faults have two mechanical components; dilatational and translational force. These components are controlled by environment heterogeneities thus it influences the spatial distribution of deformation structures. The environment heterogeneities include how rock mechanical properties can vary over time and how it alters deformation processes and resultant structures. This study is aimed to assess fracture characteristic which most likely correspond with either stress that obtained while drilling program being executed or fault as a result of tectonic.

Muara Laboh geothermal prospect area located in a step-over transtensional structural play between Suliti and Siulak Segment of Great Sumatera Fault (GSF). The identified zones were used as basis for geological field investigation, based on visual interpretation of based on the data review consider fractures observed in delineation lineament from LiDAR and macroscopic scale electric logs image. Geological structures in the area show structural pattern that controlled by oblique divergent strike-slip fault caused by right lateral movement of Sumatera Fault. Dilation zone between the two segments and form groups of relatively vertical normal faults negative flower structure with two trend, which is Northwest-Southeast and North-South trend. The result of structures from drilling intensity fractures and faults in damage zones observed in the area of study is found to decrease with distance according well logging. Fault constant is the fracture density at unit distance 1 meter from the fault, it ranges from 10-30 fractures/meters in damage zones. Therefore, geology structure mechanism in study area indicates to the regional tectonic mechanism. The pattern of these geological structures is associated with the occurrence of surface manifestations that might indicate permeability zones existence as conduit of geothermal fluid from subsurface to surface area.

Keywords
Muara Laboh, Great Sumatera Fault, fracture, vertical fault, borehole-image log, and geothermal
GEOTHERMAL HEAT LOSS CALCULATION: AN ANDROID MOBILE APPLICATION IN GEOTHERMAL EXPLORATION

Allen Haryanto\textsuperscript{a}, Rizki T. Hutami\textsuperscript{b}, Qodri S. Ramadhan\textsuperscript{c}, Dimas T. Maulana\textsuperscript{d}

\textsuperscript{a,b,c,d}Geothermal Master Degree Program, Institut Teknologi Bandung (ITB) \textsuperscript{c}Indonesia Geothermal Center of Excellence (IGCoE) Jl. Ganesha No. 10, Bandung, West Java 
e-mail: Allenharyanto45@gmail.com

ABSTRACT

The rapid development of technologies attend to complete projects easier, more efficient and even digitally, using a mobile phone. Currently mobile applications have been developed to support human activities in various fields and the field of geothermal exploration is no exception. Geoscientists are now able to directly perform a total natural heat loss calculation at any moment after conducting a surface manifestation survey of geothermal field. This could be done with mobile applications for instance Geothermal Heat Loss Calculation (GEO-HLC); an android application in the geothermal studies. GEO-HLC is equipped with the calculation of total natural heat loss in every manifestation as well as location plotting using GPS system. Normally, natural heat loss calculations needed to be done with the help of computers and therefore could not be performed during field surveys. GEO-HLC is created using android software studio with Java Coding. The formula of natural heat loss calculations used in this application are based on conductive and convective heat transfer. Several tests are conducted using a case study: Tangkuban Perahu prospect area to validate GEO-HLC application. These tests are performed by comparing the calculation results between GEO-HLC and X-Steam Excel Program on a computer. The result indicates that both of GEO-HLC and X-Steam Excel calculations are similar. It can be concluded that GEO-HLC is proven to perform natural heat loss calculations as well as to provide data recording and accurate location tracking in real time. This application is able to facilitate the work of geoscientists in the near future.

Keywords

Geothermal exploration, heat loss calculation, android application
REMOTE SENSING STUDY TO DETERMINE GEOTHERMAL WORKING AREA USING OPTIC AND SYNTHETIC APERTURE RADAR SATELLITE PRODUCTS IN MERANGIN, JAMBI, INDONESIA

Indra Agoes Nugroho, Beta Kurniawahidayati, Reza Syahputra Mulyana

Geothermal Master Degree Program, Bandung Institute of Technology
10th Ganeca Street, Bandung City, West Java, Indonesia
E-mail: indraanugroho@live.com

ABSTRACT

Remote sensing is one of the methods that used in geothermal preliminary exploration. This method can be used to map the geological structures, manifestation and predict the geothermal potential working area. The results from remote sensing were used as guidance for the next step exploration. Remote sensing is the easiest method to obtain surface information without direct contact to the object.

The research took a place in District Merangin, Jambi Province. The area selected due to Merangin has some volcanoes, they are Mount Sumbing, Hulunilo and Masurai which can be a good heat source. Moreover, surface geothermal manifestation in the shape of hot spring and hot pools were found in Graho Nyabu, west area of Merangin, and predicted have a relationship with the developed structures, either major structure, Great Sumatra Fault, or local structures.

The methods that used for this research are volcanostratigraphy analysis to get information about volcano condition and heat source, lineament extraction and Line Fracture Density (LFD) analysis to find the geological structures and permeable zone, and Normalized Difference Vegetation Index (NDVI) analysis to create vegetation stress that can be resemblance as surface geothermal manifestation. These analysis using image that obtained by optic satellite, Landsat 8 OLI-TIRS, and Synthetic Aperture Radar (SAR) satellite, ALOS PALSAR Level 1.1. Each data must be calibrated and corrected before can be used for analysis.

Geothermal working area is predicted using combination of all the results from remote sensing methods. Predicted potential geothermal working area found in the west of research area, in Graho Nyabu. This location is predicted has a high permeable zone, has a heat source that can be found beneath Mount Sumbing and has local structure that can take a role as system boundary or permeable zone.

Keywords
Geothermal, Remote Sensing, Geothermal Working Area, Jambi
TOPOGRAPHIC MAP ANALYSIS TO DETERMINE ARJUNO-WELIRANG VOLCANO STRATIGRAPHY AND IMPLICATION FOR GEOTHERMAL EXPLORATION

Lestari Apriani\textsuperscript{a}, Reza Syahputra Mulyana\textsuperscript{b}, Citra Aulian Chalik\textsuperscript{c}, Indra Agoes Nugroho\textsuperscript{d}

\textsuperscript{a,b,c,d}Magister Program of Geothermal Engineering, Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Indonesia
Email: aprianilestari04@gmail.com

ABSTRACT

Volcano-stratigraphy study is used to support the geothermal exploration preliminary survey. The study is important to delineate the center of volcano eruption which shows potential area of geothermal heat source.

The purpose of Volcano-stratigraphy study is going to divide the characteristics of volcanic eruption product that compose the volcano body. The volcanostratigraphy units consist of hummock for one eruption center, a crown that consists of some hummocks, a brigade that consists of some crowns, and an arc that consists of some brigades and super brigades. The analysis of Arjuno-Welirang volcanostratigraphy identification is based on topographic map of Malang sheet with 1:100,000 scale and 1:50,000 scale, and geological map.

Regarding to the delineation of ridge and river, we determine four crowns and six hummocks. The crowns consist of Arjuno-Welirang, Kawi, Tengger, Penanggungan. and the hummocks comprise of Ringgit, Arjuno, Welirang, Kembar III, Kembar II, and Kembar I .

Based on topographic map interpretation and wohletz method analysis, The result of this study shows that Arjuno-Welirang prospect area has good geothermal resource potential.

Keywords

Volcano stratigraphy, Geothermal Potential, Arjuno-Welirang
DETERMINING VOLCANIC MATERIAL DISTRIBUTION, GEOLOGICAL STRUCTURE, AND SURFACE MANIFESTATION USING OPTICAL AND SAR REMOTE SENSING IN PAPANDAYAN GEOTHERMAL FIELD

Beta Kurniawahidayati\textsuperscript{a}, Indra Agoes Nugroho\textsuperscript{b}, Reza Syahputra Mulyana\textsuperscript{c}

\textsuperscript{a,b,c}Geothermal Master Degree Program, Bandung Institute of Technology
10\textsuperscript{th} Ganeca Street, Bandung City, West Java, Indonesia
e-mail: betakurnia@gmail.com

ABSTRACT

Mount Papandayan is A-type volcano which is located at Garut District, West Java. Discoveries of hot springs and solfatar are evidence of geothermal system existence below the surface in this area. Those thermal surface manifestations are existed because the presence of heat source and high permeability zone caused by local geological structure. Location of heat source and high permeability zone can be expected with remote sensing approach. Volcanostratigraphic analysis of Papandayan was done to determine the location of potential heat source from recognizing the eruption center and its product distribution. Lineament of ridges and valleys study, combined with vegetation stress indication using Normalized Difference Vegetation Index (NDVI) method and its association with thermal surface manifestation, reflected high permeability zone below which potential to be geothermal reservoir. The data that used in this research were Landsat-8 OLI/TIRS for volcanostratigraphic study and Alos Palsar 1.1 for geological structure analysis. Those data were processed using remote sensing software i.e. ENVI, SNAP, ArcGis, and Rockwork. According to lineament study, major lineament directions in research area are Northwest – Southeast and Northeast – Southwest. Those directions associated with major fault that occurred in the caldera area of Mount Papandayan. According to NDVI study, thermal anomaly area located in the center of caldera and some areas around it. Due to the result of lineament study and NDVI can be concluded that high permeability zone of Mount Papandayan concentrated at the peak of Papandayan. There is another permeable zone at south western side of Papandayan but does not show any thermal activity indication on the surface.

Keywords

Remote sensing, geothermal, volcanostratigraphy, NDVI, lineament study, papandayan
IDENTIFICATION OF GEOTHERMAL POTENTIAL AT MT. CIREMAI BASED ON FFD METHOD

Hasbi Fikru Syabia, Rifqi Alfadhillah Sentosab, Stephenc, Agil Gemilang Ramadhand, Boy Yoseph CSSSAe

a,b,c,d,e Department of Geological Engineering
University of Padjadjaran
Jl. Raya Bandung Sumedang Km. 21, Hegarmanah, Jatinangor, Sumedang 45363 – Indonesia.
hasbifikru@gmail.com

ABSTRACT

West Java is a province in Indonesia which has a number of volcanoes. One of those volcanoes is Mt. Ciremai, located administratively at Kuningan and Majalengka District, and is known for its significant geothermal potential in Java Island.

This research aims to assume geothermal potentials at Mt. Ciremai using Fault and Fracture Density (FFD) method, which is correlated to the geochemistry of geothermal surface manifestations around the mountain. This FFD method is using SRTM data to delineation lineaments, which are assumed associated with fractures and faults in researched area. These faults and fractures were assumed as the paths for reservoir fluids to reach the surface as geothermal manifestations.

Based on this FFD method, it is known that area with high-density of lineaments is located on Mt. Kromong at the northern side of Mt. Ciremai, in southern of Mt. Ciremai, and western of Mt. Ciremai. Geothermometer shows that the reservoir temperature at the northern side of Mt. Ciremai is about 192.6-209 oC, whereas the southern side of Mt. Ciremai is about 164.2-182.7 oC. However, only in the north Mt. Ciremai which has manifestations of Sulfate and Cl water that can be interpreted as upflow or outflow zone. Geothermal potential of Mt. Ciremai is located around Mt. Kromong bounded by manifestations KR-7 as upflow zone, manifestation KR-1 as outflow zone and highest density.

Keywords

Geothermal, FFD, Mt. Ciremai, Surface Manifestation
PRELIMINARY STUDY OF SONGA-WAYAUHA GEOTHERMAL PROSPECT AREA USING VOLCANOSTRATIGRAPHY AND REMOTE SENSING ANALYSIS

Ribka ASOKAWATY\textsuperscript{a}, Indra A. NOEGROHO\textsuperscript{b}, Joshua SATRIANA\textsuperscript{c}, Muhammad HAFIDZ\textsuperscript{d}

\textsuperscript{a,b,c,d} Master of Geothermal Engineering, Institut Teknologi Bandung
Jln. Ganesha no. 10, Bandung, West Java, Indonesia
ribkaasokawaty1410@students.itb.ac.id

ABSTRACT

Songa-Wayauha geothermal prospect area is located on Bacan Island, Northern Mollucas Province. Geothermal systems in this area associated with several quartenary volcanoes, such as Mt. Pele-pele, Mt. Lansa, and Mt. Bibinoi. Based on literature study, some surface manifestations such as hot springs and alteration occurred within this area. The active manifestations indicate that Songa-Wayauha area has potential geothermal resource. This study objective is to evaluate Songa-Wayauha geothermal system on preliminary study stage. We use volcanostratigraphy and remote sensing analysis to delineate geothermal system area boundary. The result of this study showed that Songa-Wayauha prospect area has several heat source potentials (Pele-pele Hummock, Lansa Hummock, Songa Hummock, and Bibinoi Hummock), controlled by geological structure, and had several places as the recharge and discharge area which are very fulfilling as a geothermal system.

Keywords

Geothermal, geology, Eastern Indonesia, Mollucas, Songa-Wayauha, Volcanostatigraphy, FFD, remote sensing
REVIEW OF SUBDUCTION AND ITS ASSOCIATION WITH GEOTHERMAL SYSTEM IN SUMATERA-JAVA

Ayuta Fauzia Ladiba\textsuperscript{a}, Lia Putriyana\textsuperscript{b}, Betseba br. Sibarani\textsuperscript{c}, Hari Soekarno\textsuperscript{d}

\textsuperscript{a,b,d} Research and Development Center of Electricity, New and Renewable Energy, and Energy Conservation, Ministry of Energy and Mineral Resources

\textsuperscript{c} Geothermal Master Study Program, Institut Teknologi Bandung

Jl. Ciledug Raya Kav.109, Kebayoran Lama, Jakarta Selatan, 12230
ayuta.fauzia@esdm.go.id

ABSTRACT

Java and Sumatera have the largest geothermal resources in Indonesia, in which mostly are spatially associated with volcanoes of subduction zones. However, those volcanoes are not distributed in a regular pattern due to the difference of subduction position. Subduction position in Java is relatively more perpendicular to the trench than in Sumatera. In addition, Java has a concentration of large productive geothermal field with vapor dominated system in the western part of Java, which may be caused by the various subduction dip along the island. In order to understand the relationship between the subduction process and geothermal system in the subduction zone volcanoes, we examined several kinematic parameters of subduction that potentially relevant to the formation of geothermal system in overriding plate such as slab dip, subduction rate, and direction of subduction. Data and information regarding tectonic setting of Sumatera and Java and productive geothermal field in Sumatera and Java have been collected and evaluated. In conclusion, there are three condition that caused the geothermal fluid to be more likely being in vapor phase, which are: the subduction is in an orthogonal position, the slab dip is high, and rate of subduction is high. Although there are plenty researches of subduction zone volcanoes, only a few of them present information about its formation and implication to the geothermal system. The result of this study may be used as reference in exploration of geothermal field in mutual geologic environment.

Keywords

subduction zone, slab dip, volcanic arc, vapor phase
VOLCANOSTRATIGRAPHY APPROACH IN GEOTHERMAL EXPLORATION ON ANJASMORO VOLCANIC COMPLEX, EAST JAVA, INDONESIA

Yuniar Zhafira ABDILLAH\textsuperscript{a}, Immanuel Lumban GAOL\textsuperscript{b}, Teguh Rahat PRABOWO\textsuperscript{c}, Fithriyani FAUZIYYAH\textsuperscript{d}

\textsuperscript{a,b,c}Master Student of Geothermal Technology Magister Program, ITB, Bandung, Indonesia
\textsuperscript{d}Master Student of Hydrogeology Magister Program, ITB, Bandung, Indonesia
yuniar.zhafira@gmail.com

ABSTRACT

Vulcanostratigraphy acted as one of the important methods in geothermal exploration since most of Indonesia geothermal systems are associated with volcanic system, thus called volcanic-hydrothermal system. This method helped to understand the characteristic and the classification of volcanoes and the relationship with the geothermal potential. There are over 100 volcanoes located on Sumatra, Java, and eastern part of Indonesia. Volcanostratigraphy used in the early stage of geothermal exploration. Together along with geology, geophysics, remote sensing, and geochemistry it can predict the geothermal potential of an area.

The stratigraphy of Anjasmoro Volcano is used to identify the geothermal potential in the area, especially in Songgoriti. Anjasmoro Volcano is identified using topographic map and regional geological map of Kediri sheet and Malang sheet of 1:100,000 and 1:50,000 scale. The schematic flowchart for volcano evaluation is used to identify the geothermal potential associated with volcanic system (Wohletz, 1992). Geology, geochemistry, and geophysics research has been done in this area and are used together with volcanostratigraphy and NDVI analysis to estimate the geothermal potential in this area. It is predicted that Anjasmoro Volcano Complex, especially around Mt. Kawi and Mt. Butak are presumed to have adequate potential and deserve further investigation.

Keywords

Anjasmoro Volcano, Songgoriti, Geothermal, Volcanostratigraphy, NDVI
IDENTIFICATION NATURAL FRACTURES AND IN SITU STRESS AT THE RANTAU DEDAP GEOTHERMAL FIELD

Andika Artyanto⁸, Benyamin Sapiie⁹, Chalid Idham Abdullah⁸, Ridwan Permana Sidik⁹

⁸,⁹ Bandung Institute of Technology, Ganesha 10, Bandung, Indonesia, Email ID
⁸ PT Supreme Energy, Menara Sentraya, 23rd Floor, Kebayoran Baru, Jakarta, Indonesia
andika.artyanto@gmail.com

ABSTRACT

Rantau Dedap Area is a geothermal field which located in Great Sumatra Fault (GSF). Borehole image image are data depiction of conditions the borehole with the appearance of the response of the properties in the borehole. Rantau Dedap has several well that possess borehole imaging data, in example RD-1, RD-2, and RD-3 well.

The natural fractures are the result of responses to stress were working on a rock. Conductive fractures and partial fractures have been identified in Rantau Geothermal Field. Both of them are permeability controlling factor in research area. Natural fracture are strongly clustered with true strike trending the first dominant direction is N170°E – N180°E (N-S), the second dominant direction is N60°E – N70°E (NE-SW) and the third dominant direction is N310°E – N320°E (NW-SE), while the true dip dominant is 80°–90°.

Based on breakout analysis, maximum horizontal stress orientation is identified in N162°E – N204°E (N-S) and N242°E (NE-SW). Its constantly similar with regional stress which affected by GSF. Several parameters have been identified and analyzed are $S_{H\text{max}}$, $S_{H\text{min}}$, and $S_y$. From these data we conclude that Rantau Dedap Geothermal Field is affected by strike-slip regime. The determination of in situ stress and natural fractures to know the pattern of spread of reservoir permeability at geothermal field.

Keywords

Rantau Dedap, Borehole Image, Natural Fractures, In situ stress, Breakout
GEOTHERMAL SYSTEM AND POTENTIAL OF SOUTHEAST SULAWESI REGION FOR DEVELOPMENT OF FUTURE ALTERNATIVE ENERGY

Ariel Afrandi Tatawu\textsuperscript{a}, Rydo Faisal Arisandy\textsuperscript{b}, Juventus Karo Sekali Naibobe\textsuperscript{c}, Michel Ostias Jene\textsuperscript{d}

\textsuperscript{a,b,c,d}Geological Engineering, Faculty of Mineral Technology – Institut Sains & Teknologi AKPRIND Yogyakarta, juventnaibobe@gmail.com

ABSTRACT

According to a survey that has been carried out that there are 217 geothermal prospects, namely along the volcanic ranging from Sumatra to Sulawesi in the region that formerly was an active Indonesia volcanic as a pathway to Miocene epoch. Sulawesi region identified had been fulfilled main condition for the formation of geothermal system that there are a large heat source, a reservoir to accumulate heat, and covering layer to seal heat accumulation (cap rock). Thermal gradient and gravity as geophysics data being the source to create a tentative modelling leads to gain an early estimation of geothermal potential. Former sub-surface geological research shows that geothermal system in this region known geologically associated with non-volcanic system. It’s considered that the presence of geothermal system beneath influenced by the combined effect of geological structure pattern and the residual heat from the magmatic. Nevertheless it remains predicted has favorable geothermal potential to be developed as an alternative energy for the future.

Keywords

Geothermal systems, non-volcanic, potential energy, Southeast Sulawesi
SUBSURFACE SEISMIC AND ANISOTROPY STRUCTURE
REVEALED BY USING DELAY TIME AND SHEAR WAVE SPLITTING
TOMOGRAPHY IN “KHP” GEOTHERMAL FIELD

Kadek Hendrawan Palgunadi\textsuperscript{a}, Andri Dian Nugraha\textsuperscript{b}, M. Rachmat Sule\textsuperscript{c}, Riskiray Ryannugroho\textsuperscript{d}, Philippe Jousset\textsuperscript{e}, Kemal Erbas\textsuperscript{f}, Yosep Kusnadi\textsuperscript{g}

\textsuperscript{a,d}Geophysical Engineering, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung
\textsuperscript{b}Global Geophysics Research Group, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung
\textsuperscript{c}Exploration and Engineering Seismology Research Group, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung
\textsuperscript{e,f}Helmholtz GFZ Postdam, German
\textsuperscript{g}PT Star Energy Geothermal, Indonesia
Email: hendrawan.palgunadi@gmail.com

ABSTRACT

The developments of micro-seismic analysis are widely used to depict the subsurface condition, one of them analyzes the fracture or crack as well as structure within the geothermal reservoir. The structures provide porosity for fluid storage and permeability for fluid movement, which is significant for the next geothermal development. Knowing the correspond area beneath the geothermal field, that provide well porosity or permeability, is a must. Therefore, the objective of this study is to depict the subsurface seismic and anisotropy structures using delay time tomography and shear-wave splitting tomography approach with comprehensive data, in order to conduct an appropriate interpretation. Structure and polarization direction are obtained from anisotropy parameter as well as seismic velocity parameter. In this study, we used micro-earthquake data of 1,067 events and recorded using 15 stations during almost a-year. The delay time tomography produced seismic velocities structure (V\textsubscript{p}, V\textsubscript{s} and V\textsubscript{p}/V\textsubscript{s} ratio), to delineate reservoir structure based on physical property of rock. Next, the corresponding S-wave velocity is used as an initial model to create a shear-wave splitting tomography. Analyzing the shear-wave splitting parameter, we used a rotation of S-wave components. The two horizontal components are rotated from azimuth of 0° to 180° with 1° increment by using cross-correlation between the two components. The time window of shear-wave splitting is obtained using short-time Fourier transform analysis (STFT). The reservoir characteristics revealed by both delay time tomography and shear-wave splitting tomography. The northern reservoir is lied at a higher elevation than the southern part and the steam zone lies above the water zone. The prominent feature leads between the two reservoirs, the reservoirs are separated by a high anisotropy
followed by low Vp/Vs ratio. Our interpretation is these features may be related to discharging area with a high degree of alteration.

**Keywords**

*shear-wave splitting, tomography, geothermal*
ZONE OF RESERVOIR GUCI CENTRAL JAVA GEOTHERMAL FIELD
BASED ON MAGNETOTELLURIC AND GEOCHEMISTRY METHODS

Dedi Yuliansyah\textsuperscript{a}, Ahmad Zaenudin\textsuperscript{b}, Rustadi\textsuperscript{c}, Eddy Z. Gaffar\textsuperscript{d}, Nanda H. Maulida\textsuperscript{e}

\textsuperscript{a,b}Geophysical Engineering University Of Lampung, Bandar Lampung 35141
\textsuperscript{c,d}Research Center for Geotechnology LIPI, Bandung 40135
\textsuperscript{e}Geothermal Master Program ITB, Bandung
Dedi.yuliansyah17@gmail.com

ABSTRACT

This research uses magnetotelluric and geochemistry methods to identify reservoir zones, estimated reservoir temperature and fluid type of geothermal Guci field. Magnetotelluric data is processed through various processes to get a 2D model, that are Fourier transform, robust processing, smoothing curves and inversion. Geochemistry data manifestation of Guci’s hot water plotted into triangular diagram (Cl-SO\textsubscript{4}-HCO\textsubscript{3}, Na-K-Mg and Cl-Li-B), while the estimated reservoir temperature using water geothermometer.

Based on geochemistry data, hot water include bicarbonate water (HCO\textsubscript{3}) conditions are immature water, and in outflow area. Water is predicted coming from the reservoir and has been mixed with meteoric water. Reservoir temperature is about 280 °C, based on geothermometer water. Based on geochemistry data, reservoir depth is about 1900 m. Based on the magnetotelluric method, reservoir is indicated by the distribution of resistivity values of 10-60 Ωm at 0-2000 m depth, relatively more shallow in the Southeast. Reservoir thickness is about 1000 m, it is to be on the Kumbang Formation. Clay cap has varying depth from 0-2500 m. The heat source was probably derived from G. Mingkrik which is the youngest activity of Mount Slamet.

Tentative model of geothermal Guci is made based on geology, magnetotelluric and geochemistry data to describe geothermal systems of Guci. Geothermal of Guci is generally controlled by Northwest-Southeast fault and Northeast-Southwest fault. Reservoir is at a depth with thick clay cap.

Keywords

Fluid type, outflow, resistivity, clay cap, reservoir
TOP RESEVOIR DETERMINATION BASED ON RESISTIVITY RESPONSE USING BOSTICK AND OCCAM AUDIO MAGNETOTELLURIC INVERSION IN BATANGTORU, SOUTH TAPANULI, NORTH SUMATERA

MD Deni Setia Gunawan\textsuperscript{a}, Fahriansyah\textsuperscript{b}, Fandi Budi Stiyawan\textsuperscript{c}, Fajar Alpine\textsuperscript{d}

\textsuperscript{a,b,c,d} Geophysical Engineering Department, Faculty of Mineral Technology, UPN “Veteran” Yogyakarta

Jalan SWK 104 (Lingkar Utara) Condongcatur 55283
e-mail: mddenisetia@gmail.com

ABSTRACT

Geothermal energy is a prospective alternative energy that would be used for generating electricity for people’s need. Indonesian territory is very strategic because it is located along the Indo-Australia plate, Eurasia plate, and Pacific plate. The tectonic setting between three tectonic plates that have given an important role for the resources of geothermal energy in Indonesia. South Tapanuli has the potential of geothermal prospect. These areas are the heat source from Mount Lubukraya and Mount Sibualbuali.

The purpose of Geophysical survey is to classify rocks based on a value of true resistivity and determine the top reservoir on a geothermal system using Audio Magnetotelluric (AMT) method in the Batangtoru, South Tapanuli, North Sumatera. As principle, the AMT method will measure the ratio between of electric field and magnetic field. Advanced data processing methods for Audio Magnetotelluric inversion of 1-dimensional and 2-dimensional using software Mappros and WinGlink. Static shift correction using an averaging static shift method. As the results of the correction process is carried out using 1D and 2D Bostick and Occam inversion.

An interpretation according qualitatively and quantitatively is retrieved on the obtained data in the processing of AMT method at the geothermal field of Batangtoru. Resistivity values >10 - 44 Ohm.m is sandstone is the part of reservoir rocks, the clay cap (<10 Ohm.m) is tuff alteration, and overburden layers (>44 Ohm.m). Low resistivity value on the clay cap caused form argillitic alteration within it illite, smectite, and kaolinite mineral. The reservoir rocks spread on BT_015 station until BT_001 station with varying depths. Estimated on the shallow reservoir top research area under BT_011 station at a depth of 600 meters from surface.

Keywords

Audio Magnetotelluric, Clay Cap, Inversion, Resistivity, Top Reservoir
MODE AND ORIENTATION COMPARISON OF MAGNETOTELLURIC DATA INVERSION FOR STRUCTURES IDENTIFICATION IN VOLCANIC AREA: A STUDY CASE-MT. TANGKUBAN PARAHU

*Nur Rochman Muhammad, Imam Gazali, Firman Syaifuddin, Sugeng Triyono

a,b Department of Geophysical Engineering Institut Teknologi Sepuluh Nopember Surabaya, Indonesia

c,d Laboratory of Petrophysics, Department of Geophysical Engineering Institut Teknologi Sepuluh Nopember Surabaya, Indonesia

3) PT. Tangkuban Parahu Geothermal Power, Indonesia

*Kampus ITS Sukolilo, Surabaya 60111

*e-mail: nur13@mhs.geofisika.its.ac.id

ABSTRACT

This study has been carried out inversion on the MT data of Tangkuban Parahu mountain areas with varying; orientation of inversion, dimensional of inversion, a Determinant mode of tensor impedance. Dimensional inversion of these data is 1,5 D and 2D with Occam’s algorithm. Then we do a comparative analysis of each variation inversion in terms of their respective advantages when used in the interpretation of geological structures either lateral interpretation and vertical interpretation, it has influence caused by structural control on some variation of inversion. Of each cross section of the inversion results can be seen that Transverse Electric mode is more sensitive to the measurements along the strike of conductor, which means it’s better to interpret the structure of the fault line and lateral distribution of the type of rock formation. For a Transverse Magnetic mode is more effective characterize resistivity values in vertical direction, this mean the TM mode is superior when used to characterize the layering rocks based on the value of resistivity. For Determinant mode has the advantage on both vertical and horizontal resolution as the determinant mode have two characters in the TE and TM modes. For orientation variation was known that 1,5D and 2D inversion is better to characterize the resistivity-cross section in the direction away from the crater. Then best results used for interpretation, indicate volcanic rocks distribution with resistivity values > 30 Ωm. Caps rock is located below the volcanic rock with resistivity values between 20-30 Ωm for the South prospect area, and for the North prospect area obtained between 2-30 Ωm. The reservoir in North Tangkuban Parahu is on high temperature areas brine areas condition with resistivity value < 2 Ωm, while at the Southern part predicted as high-temperature chlorite areas with resistivity value < 20 Ωm.

Keywords

Determinant, Magnetotelluric, Transverse Electric, Transverse Magnetic
ENHANCEMENT OF SUBSURFACE GEOLOGIC STRUCTURE MODEL BASED ON GRAVITY, MAGNETOTELLURIC, AND WELL DATA IN KAMOJANG GEOTHERMAL FIELD

Muhammad Yustin Kamah\textsuperscript{a}, Adilla Armando\textsuperscript{b}, Dinda Larasati Rahmani\textsuperscript{c}, Shabrina Paramitha\textsuperscript{d}

\textsuperscript{a,b,c,d}Upstream Technology Center, PT Pertamina (Persero), Jakarta
e-mail: yustinkamah@pertamina.com

ABSTRACT

Geophysical methods such as gravity and magnetotelluric methods commonly used in conventional and unconventional energy exploration, notably for exploring geothermal prospect. They used to identify the subsurface geology structures which is estimated as a path of fluid flow. This study was conducted in Kamojang Geothermal Field with the aim of highlighting the volcanic lineament in West Java, precisely in Guntur-Papandayan chain and located in the southern end, where there are three geothermal systems. Kendang Fault has predominant direction NE-SW, identified by magnetotelluric techniques and gravity data processing techniques. Magnetotelluric techniques such as impedance tensor and inverse modeling are required to know major orientation. Gravity techniques such as spectral analysis, derivative solutions, and Euler deconvolution indicate the typical and geometry of anomaly. Furthermore, the result from those methods will be compared to geology information and some section of well data, which is sufficiently suitable. This research is very useful to trace out another potential development area.

Keywords

Gravity and magnetotelluric method, magnetotelluric attributes, gravity techniques, well data
WEAK ZONES DELINEATION USING SINGLE COMPONENT ELECTROMAGNETICS AND SEISMICITY METHODS IN GEOTHERMAL INTEREST AREA

Kevin Gardo Bangkit Ekaristi\textsuperscript{a}, Aditya Aries Furkhan\textsuperscript{b}, Agra Adipta\textsuperscript{c}

\textsuperscript{a,b,c}Geophysical Engineering Department, Faculty of Mineral Technology, Universitas Pembangunan Nasional “Veteran” Yogyakarta
SWK 104 Street, Condongcatur, Depok Sub-district, Sleman Regency, Special District of Yogyakarta 55283
e-mail: kevin.gardo@gmail.com

ABSTRACT

Recent geological discoveries revealed that Karangsambung has a complex tectonic framework associated with the evolution of Java Island - Indonesia, in which led further geological and geophysical research specified in this region. Another geological interest has arisen such geothermal manifestation emerged in form of hot spring in Krakal, a village located southern of Karangsambung. Locally Krakal hot spring settled at the top of claystone unit member of Panosogan formation without in addition of geothermal minerals alteration that generally occurs on geothermal manifestation area. Prior to the lack of geological data, geologists tend to construct preliminary interpretation which is less representative to the current manifestation findings. An earlier hypothesis states that the regional structures may control the local weak zones which later became a geothermal interest zone. The geophysical preliminary survey was conducted in order to delineate subsurface structures and mineralization boundaries indication. The research involves two geophysical methods which are electromagnetic and seismicity methods. The electromagnetic methods consist of Very Low Frequency (VLF) & Conductivity-Meter Direct (CMD) to determine potential shallow structural and mineralization boundaries and seismicity method practices Microseismic to determine structure controlled weak zones. The electromagnetic analysis indicates the existence of an anomalous closure spreads in east-west direction while the seismicity analysis indicates the subsurface structure which later is interpreted as a structural fault with the identical direction as the electromagnetic analysis. According to the VLF and CMD model, the anomalous closure is characterized by high-current density zones and high-conductivity zones. Due the weak zones are looser than the compacted zones, thus electrical current is able to move easily through the weak zones. While according to the amplification map, the anomalous closure is characterized by high-amplified zones. In geothermal interest area, fluids move through the weak zones which later creates a small tremor and amplifies throughout the weak zones.

Keywords

Karangsambung, Hot spring, Fault, Electromagnetic, Microseismic
THE APPLICATION OF SECOND VERTICAL DERIVATIVES (SVD) TO COMPLETE BOUGEUR ANOMALY DATA FOR INTERPRETING GEOLOGY STRUCTURES. CASE STUDY: GEOTHERMAL AREA “X”

Riki Irfan\textsuperscript{a}, Safiul Primasatya\textsuperscript{b}, Wonsa Aditya\textsuperscript{c}, Sigit Wahono\textsuperscript{d}, Hery Ferdiansyah\textsuperscript{e}

\textsuperscript{a,b,c,d,e}Universitas Indonesia.
Jalan Salemba Raya No. 4. 3\textsuperscript{rd} Floor of Gedung FMIFA UI Jakarta Pusat Indonesia
e-mail: rikiirfan@yahoo.com; safiul_ta05@yahoo.com

ABSTRACT

The paper will discuss case study of the application of second vertical derivatives (SVD) method to help analyze main geological structure and as well as identify the density boundary at geothermal area “X”. Area “X” is located in Sumatera Island which controlled by major strike slip fault and a graben area. The Complete Bougeur Anomaly (CBA) data was used to produce SVD gravity map. The 2 dimensional forward modeling then conducted based on the residual gravity anomaly to image the subsurface condition. There are 3 interpreted structures including F1, F2 and F3 faults as the result of this study. Those interpreted subsurface structures are having good correlation with some major geological structures resulted from field geological mapping as real check reference. The result of this study lead to conclusion that Second Vertical Derivatives applied to CBA data and 2D forward modeling of the residual gravity anomaly were proven to provide better understanding and as well as convincing as one of very simple approach on interpreting the subsurface geology structure at geothermal area “X”.

Keywords

Geothermal, Gravity, Second Vertical Derivatives, Structure
APPLICATION OF MT AND CSAMT FOR GEOTHERMAL EXPLORATION IN INDONESIA

Hendra Grandis\textsuperscript{a}, Prihadi Sumintadireja\textsuperscript{b}

\textsuperscript{a}Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung
\textsuperscript{b}Faculty of Earth Science and Technology, Institut Teknologi Bandung
Jalan Ganesha 10 Bandung 40132, Indonesia
e-mail: grandis@itb.ac.id

ABSTRACT

Magnetotelluric (MT) and Controlled-Source Audio-frequency Magnetotelluric (CSAMT) methods are well recognized geophysical methods in geothermal exploration. Both methods can be used to infer resistivity structure related to the temperature regime of the subsurface, especially to map altered zone as cap-rock and possibly the reservoir underneath. In Indonesia, CSAMT was considered superior to MT due to its successful application in some geothermal prospects sometimes in the past. This point of view influenced policy and decision making in adopting CSAMT, and thus disregarding MT, for geothermal exploration programs in a certain period. The paper describes the basic concept as well as practical aspects of both MT and CSAMT in order to underline their similarities and differences especially with respect to their application for geothermal exploration. We used synthetic data associated with simple models and also real field data to exemplify pitfalls that may generate misleading interpretation of CSAMT data. We expect that geothermal exploration program employing MT or CSAMT will be based on correct and well-founded scientific knowledge related to the specific target of the survey.

Keywords

Magnetotellurics, MT, CSAMT, pseudo-section, resistivity, cap-rock
IDENTIFICATION OF POTENTIAL GEOTHERMAL WITH GRAVITY METHODS USING SATELLITE DATA IN BLAWAN, IJEN VOLCANO, EAST JAVA

Anggi Kristanto\textsuperscript{a}, Novita Awal Ristanti\textsuperscript{b}, Indri Dwi Yuliandari\textsuperscript{c}

\textsuperscript{a,b,c}Department Physics University of Brawijaya Malang

e-mail: anggikristanto17@gmail.com

ABSTRACT

Mount Ijen is a mountain located in Banyuwangi, East Java. This mountain is a volcano that classified as having geothermal potential. One area of research that we select an area of the Blawan, Situbondo is an area adjacent to Mount Ijen is located at coordinates 8°02’48.99”S 114°10’32.98’’E. The method in this study using gravity utilizing their various densities that exist below the surface of the Earth. Based on the contour map CBA (Complete Bouguer Anomaly), obtained the density anomaly is indicated by the difference in density value in research area. The value of the density difference in the area ranges between 20-155 mGal showed by regional map. Geothermal potential is characterized by a striking difference in density between the region and other regions, are shown in a residual contour map with a range value of -20-14 mGal on the south and north regions Blawan. This is evidenced by their manifestations in the form of hot springs in the area Blawan. On gravity modeling with Grav2DC showed the area low density with value 26.00 g/cm\textsuperscript{3}.

Keywords

Geothermal, Gravity Method, Blawan
3D VP AND VP/VS RATIO SEISMIC STRUCTURE AROUND “ECS” GEOTHERMAL FIELD DERIVED FROM TRAVEL TIME TOMOGRAPHY

Eric Candra Simanjuntak\textsuperscript{a}, Andri Dian Nugraha\textsuperscript{b}, M. Rachmat Sule\textsuperscript{c}, Riskiray Ryannugroho\textsuperscript{d}, Philippe Jousset\textsuperscript{e}, Kemal Erbas\textsuperscript{f}, Yosep Kusnadi\textsuperscript{g}

\textsuperscript{a,d}Geophysical Engineering, Faculty of Mining and Petroleum Engineering, Institute Technology of Bandung, Indonesia, simanjuntak.ericandra@gmail.com
\textsuperscript{b}Global Geophysics Research Group, Faculty of Mining and Petroleum Engineering, Institute Technology of Bandung, Indonesia
\textsuperscript{c}Exploration and Engineering Seismology Research Group, Faculty of Mining and Petroleum Engineering, Institute Technology of Bandung, Indonesia,
\textsuperscript{e,f}Helmholtz GFZ Postdam, Germany
\textsuperscript{g}PT Star Energy Geothermal, Indonesia

**ABSTRACT**

Seismic tomography is one of the main techniques to determine subsurface seismic velocities structure in the geothermal exploration area. In this study, we conducted travel time tomography to determine 3D seismic velocities (Vp and Vp/Vs ratio) around geothermal area. We used P- and S-wave arrival times of 361 selected microearthquake events in “ECS” geothermal area for time period of January to October 2013. The SIMULPS12 technique has been applied to calculate Vp and Vp/Vs ratio structure with hypocenter location improvement. The resolution model of tomographic inversion was evaluated by applying checkerboard test resolution model. The main results show fairly clearly high Vp/Vs ratio area with low velocities anomalies around production well area which are may be associated with steam zone of reservoir associated with pressure decrease and the drying of argillaceous mineral (illite). This effects were probably resulted from the removal of reservoir fluids by production. The results of tomographic inversion in this study will provide new physical properties information of the geothermal reservoir.

**Keywords**

Geothermal, microearthquake, tomography, Vp, Vp/Vs
GRAVITY MODEL AND FRACTAL DIMENSION OF UNGARAN GEOTHERMAL AREA

Syaiful Alam\textsuperscript{a}, Zunarto Saputra\textsuperscript{b}

\textsuperscript{a}Universitas Padjadjaran
\textsuperscript{b}Institut Teknologi Bandung

Faculty of Geological Engineering, Bandung, Indonesia

Corresponding author: syaifulalam61@gmail.com

ABSTRACT

Ungaran Volcano is known as an undeveloped geothermal field, located at Central Java. Fumarole, hot spring, acidic mud pool and hydrothermal alteration constitute the southern part of Ungaran Mountain, Gedongsongo. Better understanding of geothermal system is the most important in exploration. The second vertical derivative of gravity data revealed the geothermal manifestation is surrounded by normal fault. The structural system of geothermal area has its regularity and randomness within principle of self-similarity. This natural system could be realized by fractal geometry of bouguer anomaly and drainage pattern. The two variables, bouguer anomaly and drainage pattern, are negatively related as bouguer decreases while drainage pattern increases in fractal dimension (D).

A quantified drainage pattern geometry as function of lithology and structure is approached by box counting algorithm. In the other hand, a quantified fractal bouguer dimension is equivalent to the representative of deep and shallow anomaly. The Gedongsongo geothermal manifestation is characterized by lower bouguer fractal dimension, 1.1-1.2 D, and higher drainage pattern dimension, 1.7-1.8 D. No significant change between regional and residual anomaly of gravity data indicate the deeper anomaly has strong influence to the shallower anomaly due to its inherent correlation of fractal dimension. Fractal dimension is able to predict its irregularity behavior natural system.

Keywords

Fractal Dimension, Gravity Model, Drainage Pattern, Geothermal System