PROCEEDINGS, 49th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 12-14, 2024
SGP-TR-227

Constructing the Sileri Area's Permeability Distribution Through Integrated Analysis of Surface Fault, Mechanical Zone, and PTS Trend

Iqbal Maratama, Rizkhy Ridoh Alamsyah, Siti Olivinia Yusra, Ezidin Reski, Randy Wijaya Atmaja

PT Geo Dipa Energi, Jl. Akses Tol Soroja, Blok Sumakamanah Parungserab, No.22, Parungserab, Soreang, Bandung

iqbal@geodipa.co.id

Keywords: Sileri, Java, geology structure, permeability, geothermal system

ABSTRACT

Structure Geology is a crucial parameter in constructing productive permeability in a geothermal system. Surface and subsurface structure correlation must be studied in greater comprehensive detail using robust data and analysis. PTS well data will give additional information about the permeability appearances in the well. Integrated structure and PTS trend analysis data are critical for defining potential permeability zones and being used as a baseline for next well targeting.

The intricate structure of the Dieng field, particularly the Sileri area, makes it challenging to learn about because of differences in surface and subsurface orientation, as well as deviations in in situ stress from borehole image data. The classification and characterization of structural elements, including fractures and faults, from surface mapping and borehole image data versus pressure-temperature spinner trend will be the primary objective of this paper. As a result of the correlation of structure characteristics and PTS trend, we will eventually be able to identify productive fracture zones that can produce optimal feed zones.

1. INTRODUCTION

Located on the Dieng Plateau in Central Java, Indonesia, the Dieng geothermal field stands as a testament to the region's unique geological characteristics and renewable energy potential. Nestled amidst the volcanic complex of the Dieng Plateau, this field boasts a diverse array of geothermal features owing to its location within the volcanic arc of the Sunda-Banda magmatic arc. The geology of the area is marked by a complex interplay of volcanic activity, with numerous fumaroles, and hot springs dotting the landscape, indicative of the underlying geothermal reservoirs.

With an estimated potential of over 400 megawatts of geothermal power, the Dieng geothermal field serves as a crucial resource in Indonesia's renewable energy portfolio. As of the most recent updates, the field is undergoing significant developments to harness its geothermal potential. Currently, the field hosts one operational power plant, with plans underway for the establishment of a second unit. This expansion underscores the ongoing efforts to capitalize on the abundant geothermal resources present in the area. To support these endeavors, extensive subsurface data from drilling campaigns are being utilized to assess and enhance the resource potential of the field, particularly in the context of powering the upcoming Unit 2 power plant. This concerted effort underscores the importance of integrating subsurface data with resource assessments to drive sustainable energy development in the region.

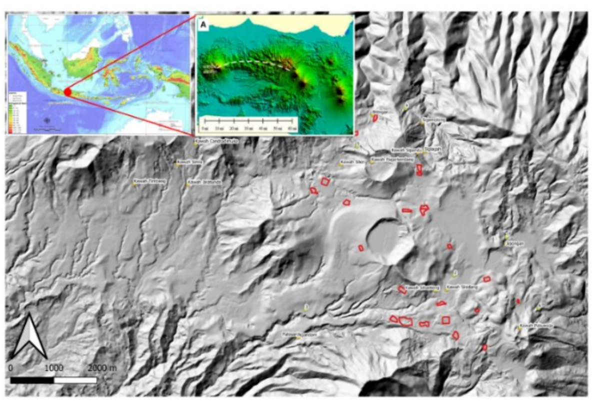

Figure 1: Location of Dieng Geothermal fields

2. METHODOLOGY AND DATA AVAILABILITY

In studying the structural framework of the Dieng Geothermal Field, the initial step involves gathering information from various geological surveys, satellite imagery, and existing literature to understand the broader tectonic context of the region. This includes identifying major fault systems, volcanic structures, and geological formations that influence the distribution of geothermal resources. Geological maps and remote sensing data are invaluable in delineating structural features such as fault lines, fractures, and volcanic vents that contribute to the overall structural framework of the area.

The next step entails correlating surface fault mapping with mechanical zones identified through detailed geological mapping and analysis of borehole images. Surface fault mapping provides essential information about the location and orientation of faults visible at the Earth's surface, while borehole imaging techniques offer insights into subsurface structures and mechanical properties of rock formations. By integrating these datasets, researchers can identify zones of enhanced permeability associated with fault networks and fracture systems, which are crucial for fluid flow and heat transfer in geothermal reservoirs.

The third step involves utilizing data from downhole measurements, including pressure, temperature, and spinner data obtained during completion operations of geothermal wells. These data provide crucial insights into reservoir conditions, such as fluid pressure gradients, temperature gradients, and flow rates. Analysis of pressure-temperature data helps characterize reservoir properties and identify potential flow pathways, while spinner data aids in delineating zones of fluid flow within the reservoir. Integration of these datasets with surface and subsurface geological data enhances the understanding of the geothermal system's behavior and facilitates reservoir management strategies.

Finally, constructing permeability distribution involves integrating all available data sets, including geological mapping, surface fault analysis, borehole imaging, and downhole measurements. This comprehensive approach allows researchers to delineate variations in permeability across the reservoir and identify high-permeability zones associated with fault networks, fractures, and other structural features. Understanding the permeability distribution is crucial for optimizing reservoir performance and designing efficient geothermal production and injection strategies. By employing a multidisciplinary methodology and leveraging diverse data sources, researchers can gain a comprehensive understanding of the structural framework and permeability distribution within the Dieng Geothermal Field, thereby enhancing its potential for sustainable energy production.

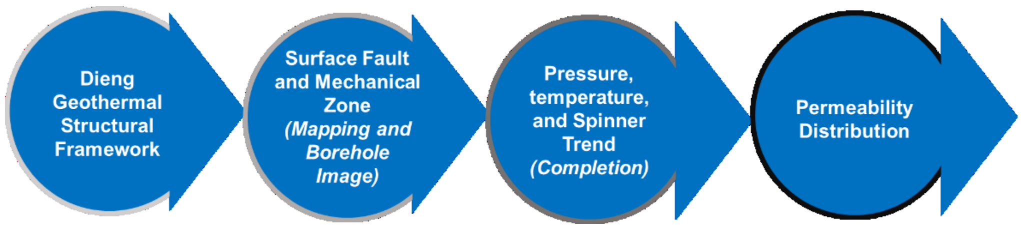

Figure 2: Flow Chart of Methodology and Data availability

3. TECTONIC SETTING

The Dieng Geothermal Field is situated within the complex tectonic setting of the Sunda Arc, a geologically active region characterized by subduction along the convergent boundary between the Australian Plate and the Eurasian Plate. This tectonic interaction has led to the formation of numerous volcanic arcs throughout Indonesia, including the Dieng Plateau where the geothermal field is located. The area is part of the larger volcanic complex known as the Dieng Volcanic Complex, which is composed of a series of stratovolcanoes and calderas.

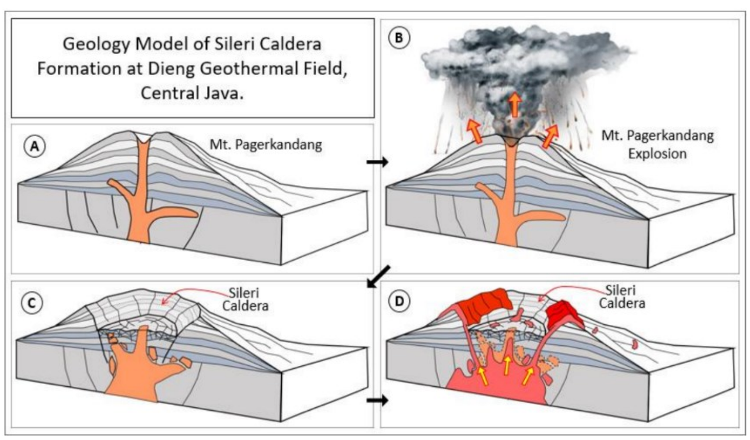

Figure 3: Geological Model of Sileri Caldera Formation at Dieng Geothermal Field, Central Java (Sumotarto)

The geology of the Dieng Geothermal Field is shaped by this tectonic setting, with volcanic activity playing a significant role in the formation of its geothermal resources. The presence of magma chambers beneath the surface provides a continuous heat source, heating groundwater and creating the conditions necessary for the formation of geothermal reservoirs. Additionally, the tectonic processes associated with subduction contribute to the fracturing and faulting of the crust, creating pathways for the circulation of fluids and enhancing the permeability of the reservoir rocks. This complex interplay of tectonic forces has endowed the Dieng Geothermal Field with its unique geological characteristics, making it a prime location for the extraction of renewable energy resources.

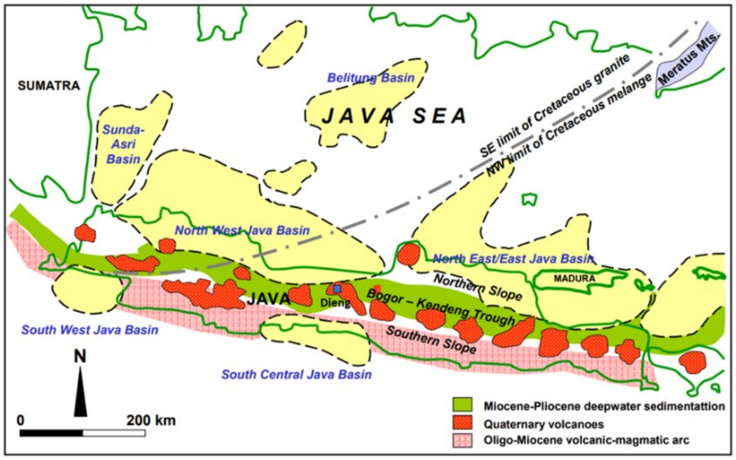

Figure 4: Present-day tectonic setting of Java Island showing the tectonic provinces, Quaternary volcanoes and sedimentary basin outlines. Miocene-Pliocene deepwater sedimentation area and Oligo-Miocene volcanic-magmatic arcs are indicated for reference. (Satyana, 2005)

2.2 Dieng Geothermal Structural Framework

The structural framework of the Dieng Geothermal Field, viewed from a geological perspective, is deeply influenced by the tectonic processes associated with the subduction zone located to the south of Java Island. Subduction occurs where one tectonic plate is forced beneath another, leading to intense geological activity including volcanic eruptions and the formation of structural features such as faults and fractures. In the case of Dieng, this subduction zone plays a pivotal role in shaping the structural landscape of the region.

One prominent structural orientation within the Dieng Geothermal Field is characterized by a north-south alignment of open faults. These faults, resulting from the tectonic stresses associated with the subduction zone, create pathways for the movement of fluids within the Earth's crust. The presence of these faults facilitates the circulation of geothermal fluids, which is crucial for the development of a viable geothermal reservoir.

Another significant structural orientation in the area is aligned along a west-east axis, correlating with the broader subduction process occurring to the south of Java. This structural alignment is indicative of the broader tectonic forces at play, which exert considerable influence on the distribution of geological features and the overall structural framework of the Dieng region. Additionally, the circular structure observed in the Dieng area corresponds to the volcanic activity that has shaped the landscape over time. This circular structure is a manifestation of the volcanic calderas and related volcanic features that characterize the Dieng Volcanic Complex, highlighting the intricate relationship between volcanism and the structural framework of the geothermal field. Overall, the structural framework of the Dieng Geothermal Field reflects the complex interplay of tectonic processes, including subduction-related deformation, faulting, and volcanic activity, which collectively shape the geological characteristics of the region and influence its geothermal potential.

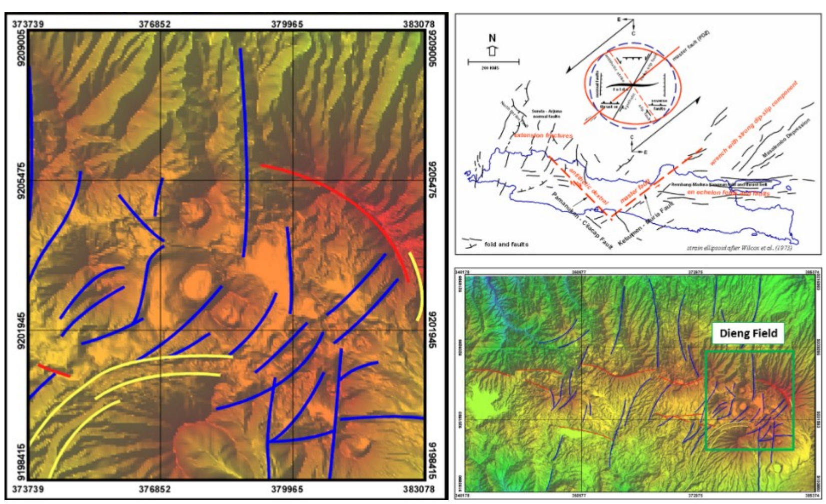

Figure 5: Dieng Geothermal Structural Framework and Structural analysis using strain ellipsoid kinematics. (Satyana,2007)

4. STRUCTURE GEOLOGY

4.1 Surface Structure

The surface fault network within the Dieng geothermal field reveals a complex interplay of tectonic forces, indicative of the region's dynamic geological setting. Extensive mapping efforts have unveiled a predominant West-East fault trend, which is primarily controlled by the north-south tensional tectonic regime prevalent in the area. This fault trend underscores the influence of regional tectonic stresses on the development of surface fractures within the field. Moreover, some of the North-West and West-East extensional fractures have evolved into normal faults, highlighting the active extensional processes shaping the landscape. Additionally, volcanic faults exhibiting a west-east trend further contribute to the intricate fault network, reflecting the significant impact of volcanic activity on the structural evolution of the area.

Furthermore, detailed mapping data has identified shear fractures with Northeast-Southwest and Northwest-Southeast trends, indicative of complex shear deformation within the field. These shear fractures, along with the extensional fractures exhibiting North-South and West-East trends, underscore the multi-directional stress regime prevalent in the region. The presence of such diverse fault orientations highlights the complex interplay of various tectonic forces shaping the structural framework of the Dieng geothermal field. Understanding the spatial distribution and characteristics of these surface faults is crucial for assessing seismic hazards and their implications for geothermal exploration and development activities within the field.

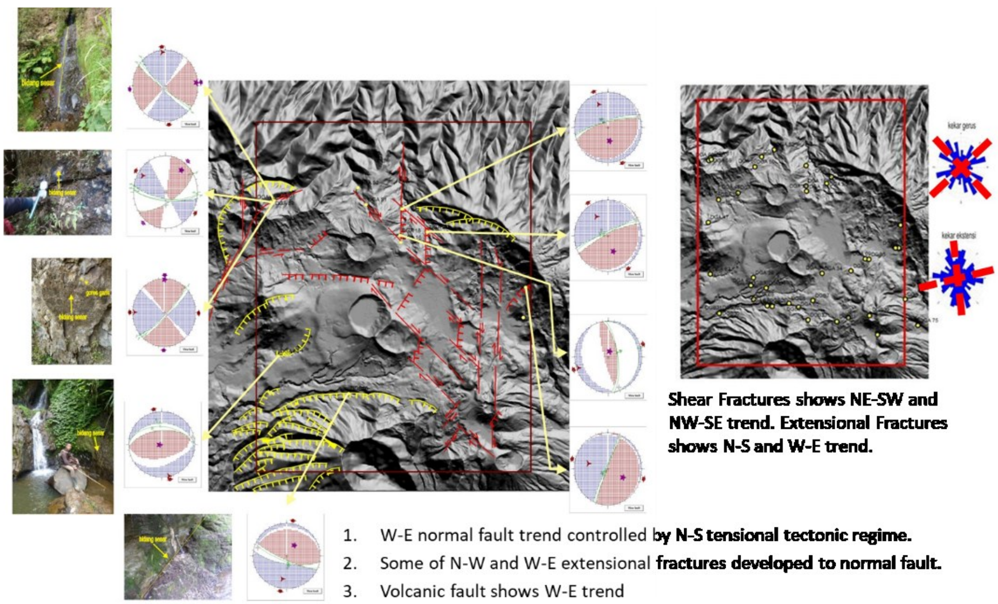

Figure 6: Detail structural geological mapping with structure trend in base field data

4.2 Mechanical Zone

In the context of a Dieng geothermal well, the mechanical zone refers to a distinct geological feature characterized by the clustering of fractures identified from borehole image data. Unlike conventional analyses that consider the strike and dip of fractures, the mechanical zone focuses on the density of fractures irrespective of their orientation. This approach provides valuable insights into the structural integrity and mechanical behavior of the subsurface formations encountered during drilling operations. The borehole image data typically encompass various types of fractures, including resistive fractures, conductive fractures, and partial fractures, each offering unique information about the subsurface structure geology.

Through comprehensive analysis of the borehole image data, researchers have identified five distinct clustering areas within the mechanical zone, each exhibiting a similar major orientation of fractures aligned predominantly in a north-south direction. This consistent orientation suggests a regional structural control influencing the distribution of fractures within the mechanical zone. Moreover, these mechanical zones exhibit a correlation with the depth of feed zones encountered in the well. This correlation implies that the mechanical zones, delineated based on density fracture data, are closely associated with zones where feed zone occurs, underscoring their significance in understanding fluid flow dynamics and reservoir behavior.

The integration of mechanical zone analysis with feed zone correlation enhances the understanding of subsurface reservoir characteristics and aids in optimizing well completion and stimulation strategies. By delineating zones of heightened fracture density and correlating them with areas of feed zone, engineers can effectively design wellbore configurations and hydraulic fracturing treatments to maximize reservoir connectivity and productivity. This holistic approach to mechanical zone characterization not only improves reservoir management practices but also contributes to the sustainable development of geothermal resources in the Dieng field.

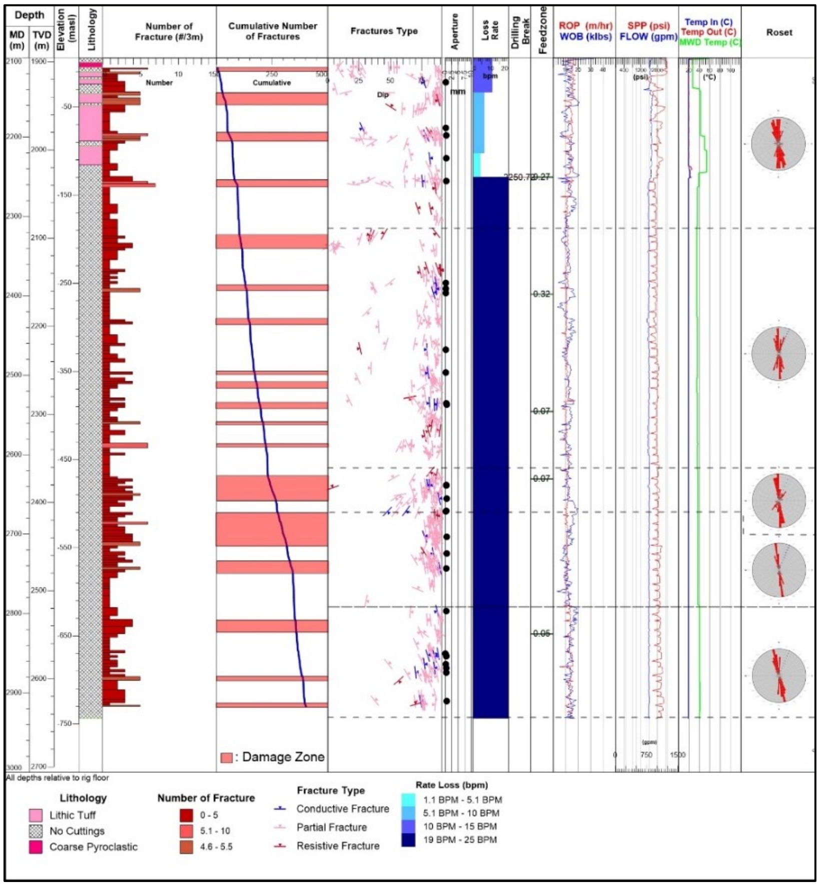

Figure 7: Mechanical zone and fracture orientation from borehole image data

5. COMPLETION

5.1 PTS Trend

Completion test normally conduct after drilling well was completed. The analysis obtained to observe the characteristic of the reservoir during injection amount of water. It will identify feed zone location, its contribution, pressure and temperature during injection. In some case, it also helps to indicate the steam cap area.

Figure (8) shows PTS injection result in one of production well in Dieng. Based on interpretation of spinner, pressure and temperature data, the feed zone located below 100 mASL. From the analysis, there is observed the major feed zone located around -200 mASL. Furthermore, correlations between these trends and depth measurements of total loss circulation and partial loss circulation reveal important patterns related to fracturing within the wellbore. Specifically, areas of total or partial loss circulation indicate zones of increased permeability and potential fracture networks, which play a significant role in reservoir connectivity and fluid flow. Therefore, integrating these pressure, temperature, spinner, and loss circulation data in the drilling summary provides a comprehensive understanding of the subsurface geology and aids in optimizing reservoir development strategies for efficient geothermal energy production.

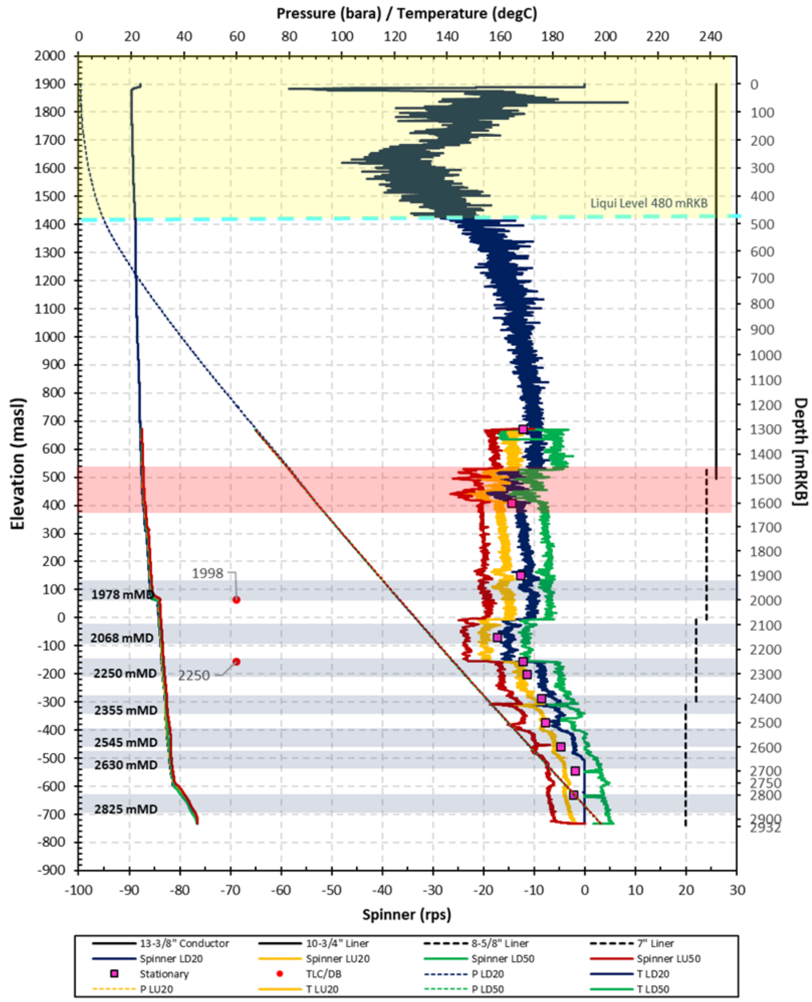

Figure 8: Pressure, Temperature, and Spinner Trend while Completion

6. PERMEABILITY DISTRIBUTION

The correlation between the mechanical zone and pressure, temperature, spinner trend data within the Dieng geothermal well provides crucial insights into the reservoir dynamics and fluid circulation pathways. Through rigorous analysis, it has been observed that the mechanical zone, characterized by clustered fractures from borehole image data, exhibits a strong correlation with pressure, temperature, and spinner trends. This correlation underscores the pivotal role of fractures within the mechanical zone in facilitating the circulation of geothermal fluids through the wellbore. The presence of fractures within the mechanical zone not only serves as conduits for fluid flow but also plays a significant role in creating productive feed zones where fluid influx occurs, thus influencing the overall reservoir productivity.

Furthermore, the correlation between the mechanical zone and pressure, temperature, and spinner trend data is further supported by high-temperature measurements exceeding 300 degrees Celsius within the well. This elevated temperature profile is indicative of the presence of high-temperature geothermal fluids circulating through the fractured reservoir formations. The combined analysis of mechanical zone characteristics and downhole data provides valuable insights into the spatial distribution of fractures and their impact on reservoir behavior.

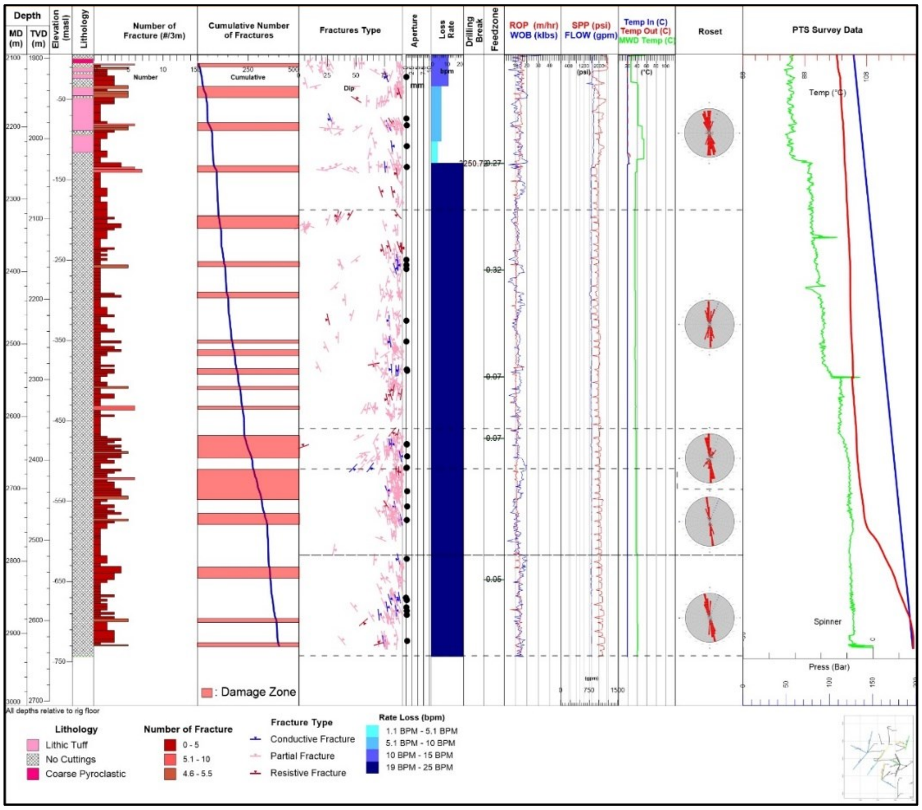

Figure 9: Correlation of Mechanical Zone and PTS Trend

7. CONCLUSION

The comprehensive analysis presented in this paper sheds light on the intricate relationship between permeability distribution, surface data, borehole image data, and downhole measurements within the Dieng geothermal field. Through meticulous examination, it was revealed that the major orientations of faults and fractures identified from surface data correspond closely with those observed in borehole image data, emphasizing the structural control on permeability distribution within the reservoir. This correlation highlights the importance of integrating multiple data sources to accurately characterize subsurface fracture networks and their influence on fluid flow pathways.

Moreover, the study demonstrates a strong correlation between mechanical zones identified from borehole image data and pressure, temperature, spinner trend (PTS) data. The mechanical zones, characterized by clustered fractures, exhibit a consistent major orientation and align closely with the depth of feed zones encountered in the well. This correlation underscores the pivotal role of fractures within the mechanical zones in facilitating fluid circulation and enhancing reservoir productivity. The integration of mechanical zone analysis with PTS data provides valuable insights into reservoir behavior and aids in optimizing well placement and stimulation strategies for efficient geothermal energy extraction.

Overall, the findings of this study underscore the significance of understanding permeability distribution and its controlling factors in reservoir characterization and development. By elucidating the correlation between surface data, borehole image data, mechanical zones, and downhole measurements, this research contributes to a better understanding of fluid flow dynamics and reservoir performance in the Dieng geothermal field. These insights are essential for informed decision-making and effective management of geothermal resources, ultimately contributing to sustainable energy production and utilization. To grow and develop guarantee that the correlation between fracture data and feed zone from that research, a production test, PTS flow, and TFT need to be performed.

REFERENCES

Dieng Subsurface Team.: Dieng Well Prognosis and Resources Risk & Uncertainty Mitigation Plan, SPDEP Phase 3, Internal Report of Geodipa (2021).

Harijoko, Agung, et al.: Long-Term Volcanic Evolution Surrounding Dieng Geothermal Area, Indonesia, Proceedings World Geothermal Congress, (2010)

Layman, B Erik., Irzarwadi Agus., and Samsudin Warsa.: The Dieng Geothermal Resource, Central Java, Indonesia, Geothermal Resources Council Transactions, (2002), Vol. 26.

LKFT UGM.: Detailed Structural Mapping Lapangan Panas Bumi Dieng, Internal Report, (2013) Satyana, Awang H.: Central Java, Indonesia-A "Terra Incognita" In Petroleum Exploration: New Considerations on The Tectonic Evolution and Petroleum, Proceedings, Thirty-First Annual Convention and Exhibition, Indonesia Petroleum Association, (2007).

Satyana, Awang Harun.: Oligo-Miocene Carbonates Of Java, Indonesia: Tectonic-Volcanic Setting And Petroleum Implications, Proceedings, Thirty-First Annual Convention and Exhibition, Indonesia Petroleum Association, (2005).

Sumotarto, Untung., Hendrasto, Fajar., et al: Geological Model of Sileri Crater at Dieng Geothermal Field, Central Java, Proceedings, PIT IAGI.