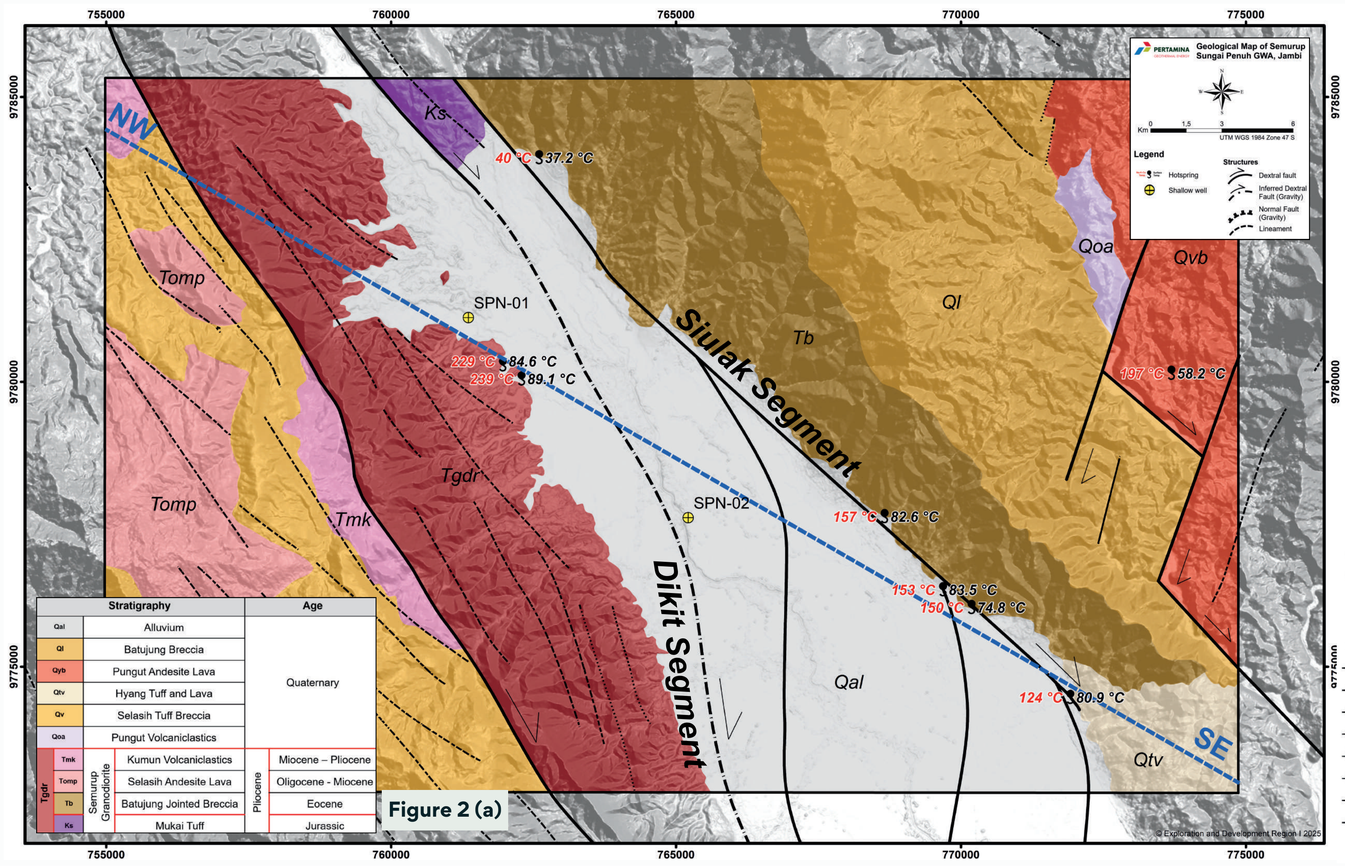
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CHARACTERIZATION OF PERMEABILITY ZONES THROUGH GEOMECHANICAL ANALYSIS AND ITS IMPLICATION TO THE SEMURUP GEOTHERMAL SYSTEM, INDONESIA

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INTRODUCTION

The Semurup Prospect, part of the Sungai Penuh Geothermal Working Area, is located in the Bukit Barisan Mountains within the Kerinci Depression, a tectonic lowland bounded by major segments of the NW -SE Sumatra Fault System (SFS). In addition, two chloride hot spring complexes and two shallow wells with favorable temperature gradients further reinforce the presence of a geothermal system in Semurup.

GEOLOGICAL SETTING

The oldest unit is the Jurassic Mukai Tuff (Ks), unconformably overlain by Tertiary volcanic rocks: Jointed Batujung Breccia (Tb), Selasih Andesite Lava (Tomp), and Kumun Volcaniclastics (Tmk). These units are displaced by the SFS and intruded by the Semurup Granodiorite (Tgdr), which aligns with the NW–SE SFS trend. Petrography shows deformation textures, indicating strong structural overprinting. Furthermore, granodiorite-granite intrusions along the SFS commonly act as geothermal heat sources. Overlying these are Quaternary volcanic units: Pungut Volcanics (Qoa), Selasih Tuff Breccia (Qv), Hyang Tuff and Lava (Qtv), Pungut Andesite Lava (Qyb), and Batujung Breccia (Ql). The youngest unit is alluvium (Qal), forming the main basin fill.

METHODS

FAULT-SLIP POTENTIAL

Slip Tendency
(Morris et al., 1996)

permeability maintenance $T_s = \frac{\tau}{\sigma_n}$

Dilation Tendency
(Ferril et al., 1999)

permeability generation $T_d = \frac{\sigma_1 - \sigma_n}{\sigma_1 - \sigma_3}$

Slip tendency reflects shear failure, while dilation tendency reflects tensile failure. Comparing both allows identification of **hybrid failure** modes or faults or faults with optimal slip–dilation behavior.

STRESS-STRAIN TRANSFER

Modeling focused on **three key parameters:** Coulomb shear stress (CSS) change, dilation change, and normal stress change. Elevated CSS and dilation, combined with reduced normal stress, indicate zones where permeability is generated, enhanced, or preserved.

likelihood of slip → **Dilation**
volumetric expansion → **CSS**
perpendicular stress → **Normal Stress**

PARAMETERS

Stress Polygon

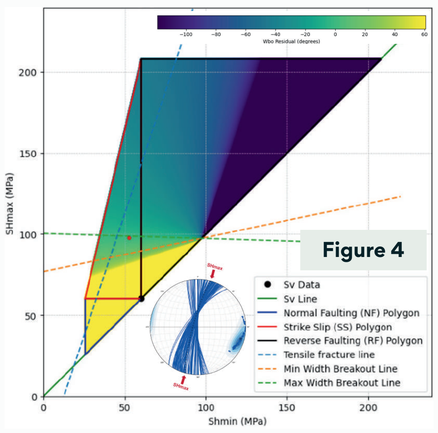
Vertical depth	2270 m (PGE, 2017)
Friction coefficient	0.79 (Okumura et al., 2015)
Initial tensile strength	0 Pa
Initial wellbore breakout width	0°
Vertical stress	60.3 MPa (Altered lava ρ = 2.71 g/cc (Pereira et al., 2024)
UCS	125 MPa (Pereira et al., 2024)
Hydrostatic pressure	15 MPa (PGE, 2017)
Mud pressure	15.1 MPa (PGE, 2017)
Minimum wellbore breakout width	39.99° (PGE, 2017)
Maximum wellbore breakout width	62.00° (PGE, 2017)

Stress-Strain Transfer and Fault Slip Potential

Tectonic regime	strike-slip
SHmax magnitude (2270 m depth)	97.8 MPa
SHmin magnitude (2270 m depth)	52.8 MPa
Sv magnitude (2270 m depth)	60.3 MPa
SHmax azimuth	N 5° E
Shmin azimuth	N 95° E
Sv azimuth	vertical
Pore fluid pressure (2270 m depth)	15.1 MPa
Young's Modulus	47.81 GPa (Heap et al., 2020)
Poisson's Ratio	0.25 (Heap et al., 2020)
Friction coefficient	0.79 (Okumura et al., 2015)
Cohesive strength	0 (Siler et al., 2018)

RESULTS

STRESS POLYGON



Tectonic Regime	Shmax Azimuth	Stress Magintude (MPa)		
		Shmax	Sv	Shmin
Strike-slip	N 5° E	97.8	60.3	52.8

FAULT SLIP POTENTIAL

Slip Tendency

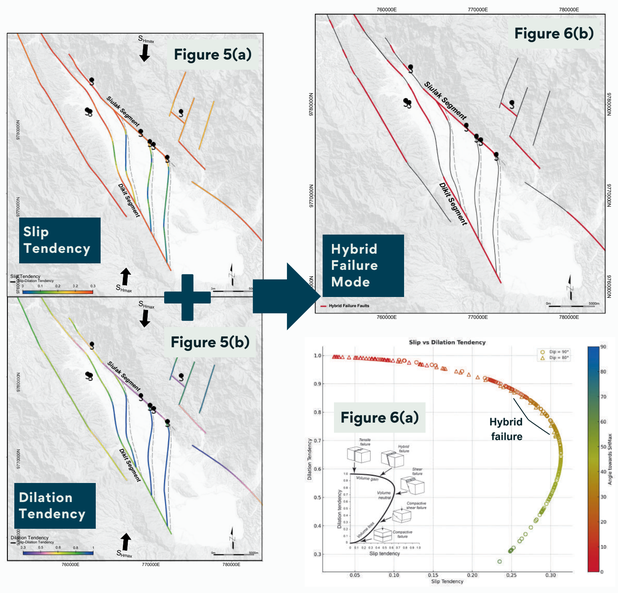
fault segments oriented at an angle of **35°-45° to the SHmax** direction exhibit the highest slip.

Dilation Tendency

fault segments oriented **parallel to sub-parallel to the SHmax** direction exhibit the highest dilation.

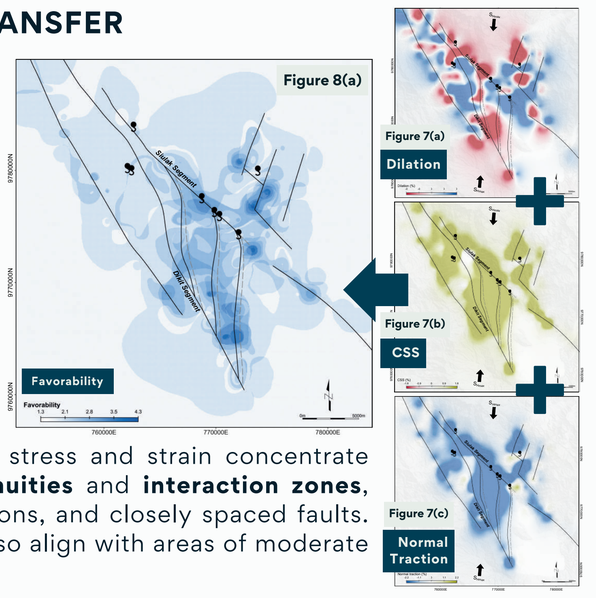
Hybrid Failure

segments oriented 29°-55° relative to SHmax (optimum slip-dilation)



STRESS-STRAIN TRANSFER

The analysis results reveal a disperse distribution pattern of dilation and compression zones. On the other hand, the CSS and normal stress change analyses yield identical results, with zones of increased CSS corresponding to zones of reduced normal stress.



This analysis shows that stress and strain concentrate mainly in **fault discontinuities** and **interaction zones**, such as bends, intersections, and closely spaced faults. Surface manifestations also align with areas of moderate to high favorability.

DISCUSSION

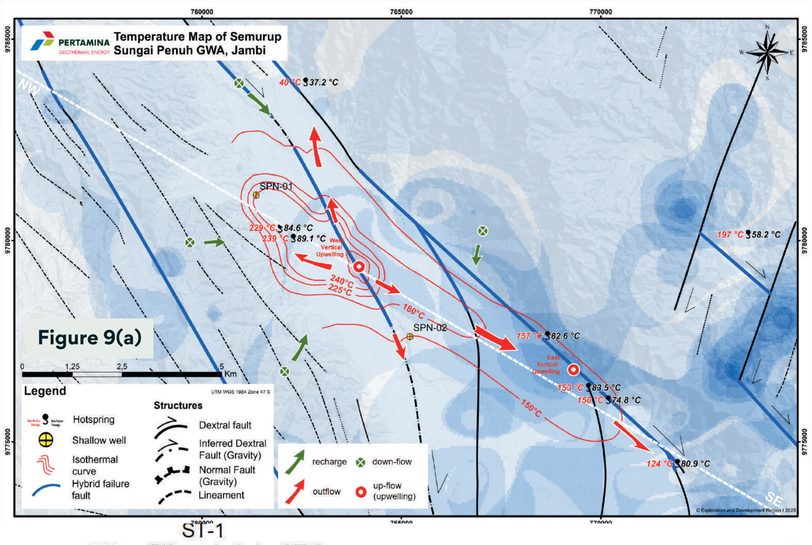
Analogous Field **Dixie Valley, Basin and Range, USA**, is considered the analogous for Semurup Prospect. The field is characterized permeability that is primarily controlled by **damage zones** along extensional faults, as well as by **fracturing within Tertiary and pre-Tertiary rock units.**

Permeability Geomechanical analysis results reveals that the permeability in this prospect is mainly controlled by the **NW-SE faults** with **hybrid failure mode** and the surrounding permeable fractures. Fractured tertiary rocks (basement) is also interpreted as the primary permeability in the system.

Hydrology **Vertical upwelling** in the Siulak and Dikit segments, outflowing along the NW – SE faults and lateral (primary) permeability mainly to SE. **Recharge in the higher elevation** area and permeable faults and fractures.

Clay Cap The **alluvium (Qal)** is interpreted to act as the **caprock** of the Semurup geothermal system.

Heat Source Deep **dike intrusions** along the NW-SE Faults.



CONCLUSION

- The **geomechanical analyses** have proven effective in characterizing permeable fault segments and zones.
- These results have provided valuable insights for developing the conceptual model of the Semurup Prospect, specifically regarding **permeability controls** and **hydrogeological behavior**.

KEY REFERENCES

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