Geothermal Heat Flow in Northern Indonesia

Rebecca Pitcock, Kirsten Nicholson, and Ahmed Benkhayal

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Heat flow is defined as the movement of heat from Earth's interior to its surface. Heat flow fluctuates among geographic locations as well as with time. This variability is the result of tectonic, volcanic, and other natural processes, making it a valuable tool in understanding a range of geologic topics.

This research aims to construct a geothermal map of the northernmost part of Indonesia with an emphasis on the Penyu/West Natuna Basin. Data contributing to these maps is from fifteen different basins, showing a wide range of geological and geothermal conditions. The Penyu/West Natuna Basin formed as one of three broken crests of the Malay Dome, a continental crust arch from a hot spot. Dividing the basin into two parts, a NW striking fault, Rumbia, formed as a response to differential transtensional and transpressional stress. Sources of such stress include the Indian Subplate collision with Asia, the westward drive of the Pacific Plate, the spreading of the South China Sea Basin, and the progression of the Indian Ocean-Australian Plate. This triple junction of the broken rift arms from the Malay Dome is still one of the highest heat flow areas of this region, making the Penyu/West Natuna Basin of high interest in oil and mineral exploration.

Geothermal mapping depicts the heat loss from the cooling of Earth's core and radioactive elements and its diffusion to the surface. The methodology for this was modeled after Dr. D. Blackwell's previously published work in North America (SMU Geothermal Laboratory). This method follows Fourier's Law of heat conduction which is calculated by multiplying a thermal conductivity by a local temperature gradient. Thermal conductivity is specific for each type of rock and is calculated based on the percentages of dominant lithologies in each well. The product of this equation is a heat flux vector. All data required for this calculation is found on the geophysical database of the South East Asia-Pacific region, donated by L. Bogue Hunt. Logs from this database provide physical, lithological, and paleontological characteristics, as well as seismological, structural and other detailed geological reports of several sites of exploration interest.

Data collected for this research is gathered and organized in an excel spreadsheet and includes: well name/number, well location with datum (e.g. longitude/latitude WGS84, easting/northing UTM zone 48N), basin name, operator, total vertical depth (in meters), bottom hole temperature (in centigrade), surface mean temperature, method of correction, geothermal gradient (calculated), heat flow measurement method (probe, interpolation, model, etc.) and thermal conductivity per unit (calculated).

This preliminary study, focused on Penyu/West Natuna Basin, covers an area of roughly 20,000 km^2. The analysis will be based on over 270 bottom hole temperatures and only wells extending deeper than 100 meters will be considered for BHT. Contouring and gridding will be completed

using ArcMap program. Contours are inferred in areas of tectonic interference. Due to this alteration, a geothermal map of this region is essential for not only petroleum exploration but also for mineral extraction and geothermal energy advancement.

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Abstract

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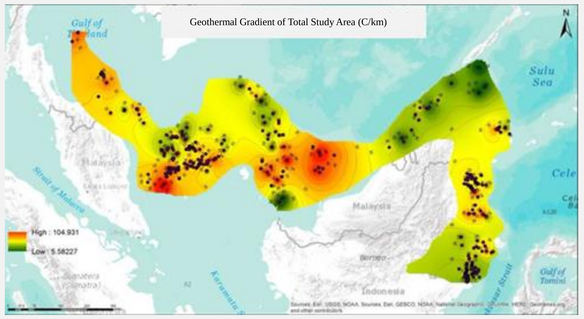
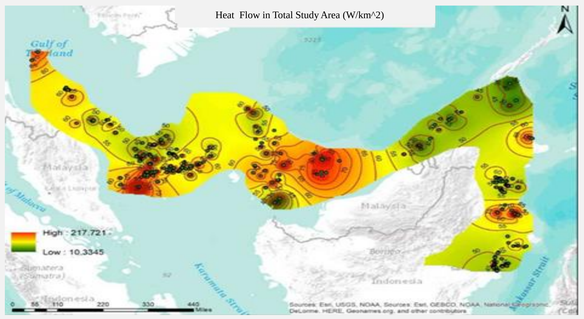
Total Study Area

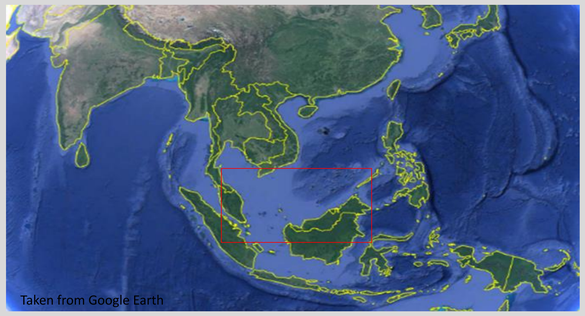


The total study area contained 359 practical wells. Values for geothermal gradient range from 5.58227 C/km to 104.931 C/km. Areas with significantly high geothermal gradient are located in the central portion of the map as well as in the western portion. Low geothermal areas are located in the northeast portion of the map, extending directly south. High geothermal gradient is correlated with deep wells that extend into basement rock. Wells are clustered and tend to be very similar in value with the rest of the cluster.

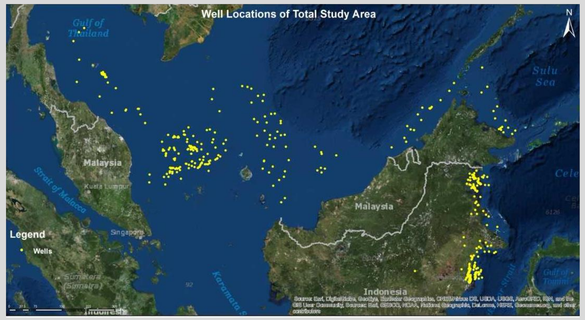


Calculated values for heat flow in the total study area range from 10.3345 W/km^2 to 217.721 W/km^2. Spatial distribution of heat flow mimics the distribution of geothermal gradient with high heat flow located in the central portion of this map. Low values of heat flow are found in the northeast and develop into higher heat flow regions with southern migration. Regions with the highest heat flow values have the deepest wells and as a result more basement rock to increase thermal conductivity.

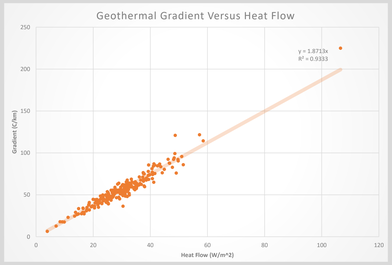
World Map With Study Area Outlined



Map of Total Study Area with Well Locations

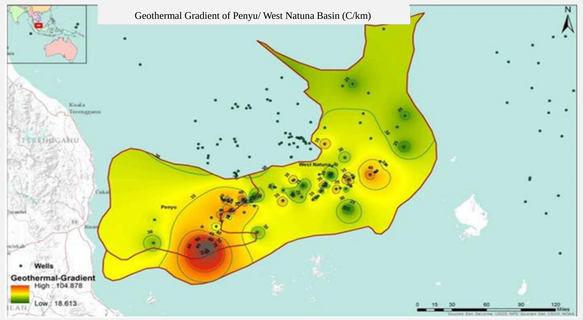


Relationship of Geothermal Gradient and Heat Flow

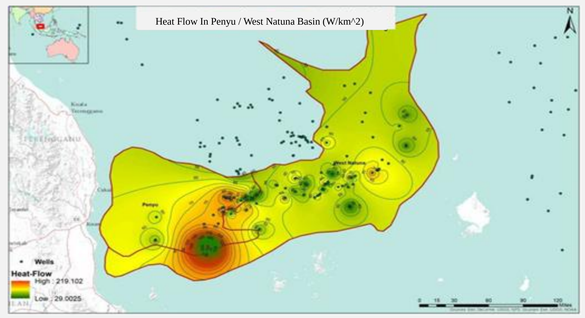


Funded by a Petroleum Research Fund grant, American Chemical Society, to K. Nicholson

Penyu/West Natuna Basin



The Penyu/West Natuna Basins contained 88 viable wells. Values for geothermal gradient range from 18.613 C/km to 104.878 C/km. High geothermal gradient is concentrated in the south-central portion of the map. From this region, moderate to low geothermal gradient values radiate, with the lowest values being in the northeast portion. The area of high geothermal gradient corresponds to the southernmost region of high geothermal gradient on the map showing the total study area. Wells with the greatest depths are found in regions of high geothermal gradients.



Heat flow values for Penyu/West Natuna Basins range from 29.0025 W/km^2 to 219.102 W/km^2. Heat flow spatial distribution follows the same trend as geothermal gradient with high values concentrated in the south-central portion of the map. Moderate heat flow values envelop the high heat flow region, and continue to disperse outward. Lowest heat flow values are located in the northeast region of the map. The high heat flow region corresponds with the southernmost high heat flow region in the map representing total study area.