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Project Title: Heat flow map of SE Asia including Papua New Guinea, Indonesia, Malaysia and the Philippines.

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As anticipated, the project has initially focused Indonesia. In 2014, Indonesia ranked 21st globally in oil production, with most of the oil produced in Sumatra. The region has been subjected to intense tectonic activity. Due to the tectonic complexity of the region, petroleum generation is often difficult to understand and predict. The current heat flow maps of the region are old and based on limited data. Hence, the generation of a new heat flow map of the region will allow researchers to better predict petroleum generation, which in turn can be used to identify new targets and potentially expand petroleum resources in the region.

The Southern East Asian region has undergone a several of serious environmental hazards. Due to the complex geologic history and active tectonics, the region (specifically Sunda Arc Basins) is considered one of the best natural resources of geothermal heat and petroleum in the world. Among all Sunda arc basins, the Central Sumatra Basin (CSB) is the most prolific hydrocarbon basin in the region. Due to advances in drilling technology (particularly in horizontal drilling and hydraulic fracturing), organic-rich shale formations have recently become an economical source of energy. Additionally, the Pematang Formation (Pematang Group), in the Central Sumatra Basin (CSB), is known as the sole of source rock for the tens of billions of barrels of oil. The Pematang Formation in the study area shows low geothermal gradient values that reach up to 18 °C/km at the Paleogene Graben. On the other hand, the northeast area represents a high geothermal gradient value (123 °C/km), and this is most likely due to the thinning of layers. Additionally, the level of maturity varies from 6.5 to 9.6 with formation temperature ranging from 57 to 127 °C. Due to the lack of uranium log data and the drawbacks of using the reduction reduced major axis (RMA) regression line, the Passey's ΔlogR method is the primary applicable method to the study area. The hydrocarbon potential of Pematang Formation is considered to be good to excellent with a range of TOC 1.12 to 17 W%, and there is a significant increase in TOC values from north to southeast. By and large, the aquatic impedance (AI) values prove the ability of Passey's ΔlogR method in estimating the potential Pematang Formation quality in the absence of core data.

In contrast to the CSB, the Bali Basin is a frontier basin located behind the mid-Sunda Arc. Hydrocarbon production declines in the Bali Basin and does not increase throughout the remainder of the eastern Sunda Arc. The Bali Basin has minimal production to date; but has only a limited exploration history. Source rock maturity could be affected by back arc subduction along the Lombok Thrust Zone. For this reason, the Bali Basin model was created in conjunction with a heat flow analysis. Bali Basin wells were found to have an average Q value of 76.0 and an average bottom hole temperature of 59.4 °C. This analysis was expanded to include a comprehensive heat flow map of the Southeast Pacific Region. Thermal gradients were calculated from total depths and bottom hole temperatures recorded from 857 wells across Indonesia and Malaysia, in combination with thermal conductivity values corresponding to bottom hole lithologies, in order to calculate the Q value of each well.

While depths to the sourcing interval in the Bali Basin are shallow, they are similar to source depths in producing wells found in the Northeast Java Basin. Additionally, the depositional and tectonic chronology of the Bali Basin supports the generation and entrapment of hydrocarbons. This data, in combination with quality source rock, porous reservoirs, and a laterally extensive sealing formation, shape promising hydrocarbon prospectivity for the Bali Basin, but this potential is not realized. Significant thrusting north and south of the basin may have uplifted the source formation from the oil window during the early stages of hydrocarbon generation, evidenced by shallow formation depths and low heat flow. The presence of gas discoveries, particularly those of the Pagerungan field, could be a result of kerogen type, rather than thermal maturity. Alternatively, fault reactivation during the current compressional regime could have facilitated the escape of previously trapped hydrocarbons. In this case, hydrocarbon plays could very well exist further from the source of deformation and closer to areas of higher heat flow, toward the center of the basin.

To date this PRF grant has supported three graduate (MSc) and three undergraduate students. With students as the primary authors and presenters, we have submitted 5 conference abstracts, attended three conferences, and there is one manuscript in preparation. We hope to have two manuscripts submitted by the end of 2019.

Of the students participating in the research, two of the undergraduate students have finished their degrees and one of them has continued on to an MSc program. The third undergraduate student is continuing to work on the project in 2018/19. One of the graduate students completed their thesis and is now working in petroleum exploration. The other two graduate students will defend their theses within the next 6 weeks and both plan to pursue PhD degrees. One of the PhD students will continue to work on this project with plans to expand the results beyond petroleum, to include the areas of understanding tectonic risks and geothermal energy.