Basin Thermal Evolution of the Phitsanulok Basin, Thailand

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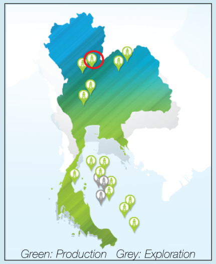
PTTEP

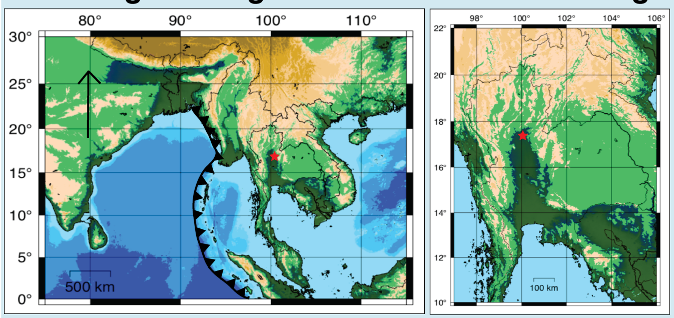
1.Introduction



Modified from www.pttep.com/en/Home.aspx

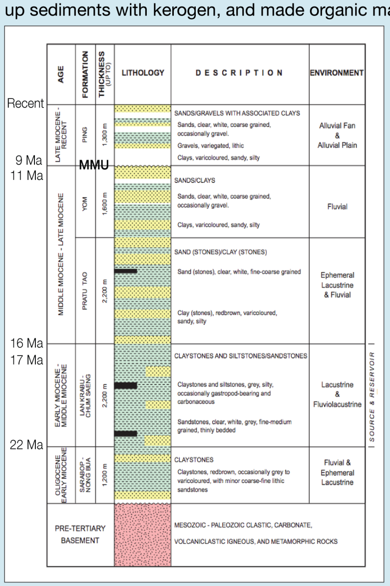
Phitsanulok Basin is the largest onshore continental rift basin (4,000 sq km) in Thailand generating ~31,000 barrels per day (PTTEP, 2019). It is important to study this basin since some source rocks and reservoir rocks are not fully exploited. This research models thermal history of the basin by utilizing stratigraphy and surface heat flow data, and is constrained by vitrinite reflectance. Tectonic contexts are also taken into account for all models. Thermal models give us an insight into how and when petroleum was formed and stored within the basin.

2. Geologic Background and Tectonic Setting



Location of Thailand and Phitsanulok Basin (marked with a red star)

- Northward collision between India and Eurasia: ~56 Ma
  - oblique subduction of India underneath Eurasia west of Myanmar
- Phitsanulok Basin was opened up in a W-E direction in ~23 Ma
- This continental rifting process created accommodation space in the basin, heated up sediments with kerogen, and made organic matters matured to form oil and gas.



Petroleum generated was trapped in reservoir rocks by either stratigraphic trap or structural trap.

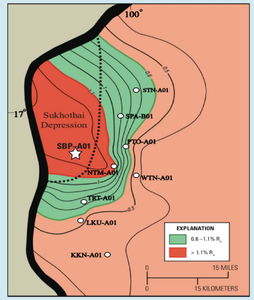
Two formations of interest are Lan Krabu and Chum Saeng Formations, since they contain kerogen and are heated up enough for hydrocarbon maturation.

- Lan Krabu Formation (LK)
  - Type III kerogen (gas-prone)
  - Fluvio-lacustrine claystones
- Chum Saeng Formation (CS)
  - Type I kerogen (oil-prone)
  - Lacustrine shale

Pratu Tao (PTO), Yom, and Ping Formations do have organic materials but they are not heated up enough for hydrocarbon maturation.

Figure on the left shows the stratigraphic column of the Phitsanulok Basin (Modified from Knox and Wakefield (1983) and C&C Reservoirs (2009))

3. Methods



Locations of nine wells and vitrinite reflectance map of the basin (Modified from USGS, 2014)

The thermal history of nine wells in the basin is assessed based on their stratigraphy and cnstrained by vitrinite reflectance data provided in Pinyo (2010).

The TQTec and FTage codes produce burial history, thermal history, and production history by incorporating burial and erosion/uplift events along with thermal parameters such as thermal conductivities and surface heat flow, and vitrinite reflectance (%R0).

Two main models
(i) Constant heat flow model
(ii) Variable heat flow model
(depends on geologic history)

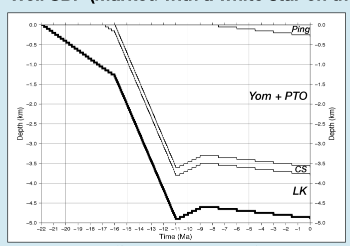
The best-fit models are the ones that fit present-day surface heat flow and observed vitrinite reflectance

4. Results

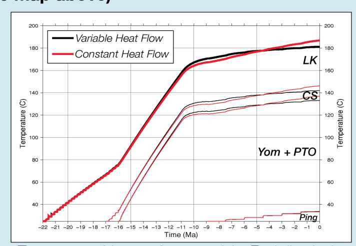
Continental rifting, which increased thermal input from asthenosphere, is hypothesized to be between 16 Ma and 11 Ma based on rapid subsidence in this period. The variable heat flow model is designed to represent this heat flow change. On average, this model fits the vitrinite reflectance data of nine wells better than the constant heat flow model. The heat flow values through time are shown in the table below.

Time	Basal Heat Flow Value (mWm^2)
22 Ma	85-90
16 Ma	90-100
11 Ma	80-90
9 Ma	60-70
0 Ma (Now)	60-70

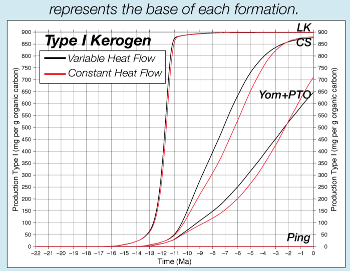
Model sample (Variable heat flow model)
Well SBP (marked with a white star on the map above)



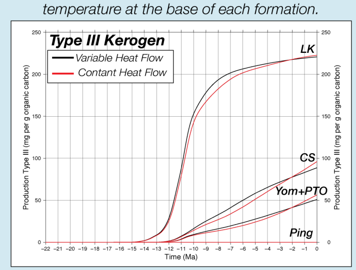
Burial History (Same in both models). Each line represents the base of each formation.



Temperature history of two models. Each line is the temperature at the base of each formation.



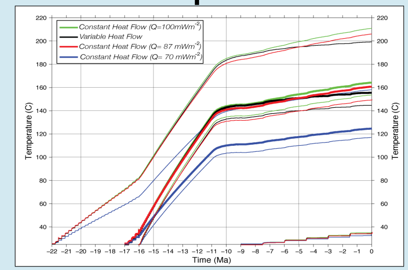
(Oil-prone) Type I kerogen production curves for two different models. Only CS Formation has Type I kerogen and oil generation began at ~13 Ma and completed at ~1Ma

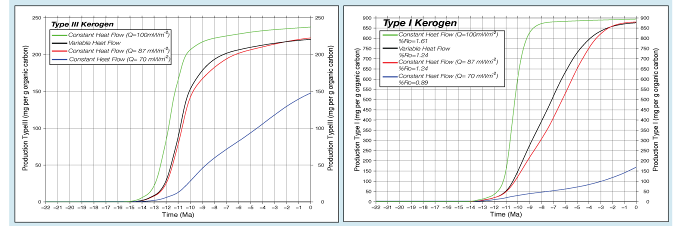


(Gas-prone) Type III kerogen production curves for two different models. Only LK Formation has Type III kerogren and petroleum (gas) generation began at ~14Ma and completed at ~4Ma

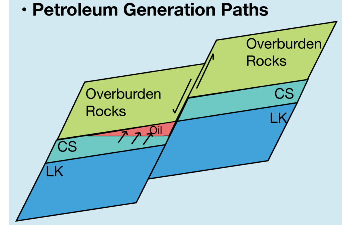
Observed Vitrinite Reflectance of Chum Saeng (CS) Fm.: 1.23
Modeled Vitrinite Reflectance of Chum Saeng (CS) Fm.: 1.24

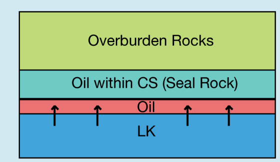
5. Discussion and Implications





- **Model Differences**
  - Constant heat flow model underestimates the vitrinite reflectance values
  - The variable heat flow model predicts that the petroleum maturation is approximately 0.5-2 Ma faster than what the constant heat flow model predicts.
  - Since the basin itself is only ~22 Ma, this difference in petroleum maturation timing from two models is significant.
- **Heat Flow effect or Other effects?**
  - Since the variable heat flow model fits all vitrinite data (within 0.07) in the basin, it can be implied that these differences in vitrinite reflectance across the basin are not caused by the difference in heat flow.
  - Explanation: More accommodation space in the Sukhothai Depression
- **Petroleum Generation Paths**





Structural Trap: Normal Fault
- Source Rock: CS
- Reservoir Rock: CS
- Time of generation: 13 Ma-Now
- Normal faults were created before 13 Ma, so petroleum is still trapped.

Stratigrahic Trap
- Source Rock: LK
- Seal Rock: CS
- Reservoir Rock: LK
- Time of generation: 14Ma

6. Acknowledgement

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7. References

C&C Reservoirs (2009). Field Evaluation Report, Sirikit Field, Phitsanulok Basin, Thailand

Knox, G., & Wakefield, L. L. (1983). An introduction to the geology of the Phitsanulok basin: Proceedings of Conference on Geology and Mineral Resources of Thailand. Bangkok, Thailand.

Pinyo, K. (2010). Petroleum System of the Chum Saeng Formation, Phitsanulok Basin, Thailand (Doctoral dissertation, Colorado School of Mines. Arthur Lakes Library).

USGS Phitsanulok Basin Assessment Team. (2014). Geology and Assessment of Unconventional Oil and Gas Resources of the Phitsanulok Basin, Thailand.