# CHEPTER 6
# CONCLUSION

The objectives of this research are to use geochemistry and petrography data to determine the compositional variability of the organic matter, identify characteristics of maceral assemblages and assess petroleum generation potential of the source rock samples in the study area (Fang basin, Phisanulok basin, Suphanburi basin, Mae Sot basin, and comparative areas in Li and Na Hong coal fields).

## 6.1 Fang-MS well, Fang basin

Samples were analyzed deposited in a lake (low TS contents and high TOC/TS ratios) with moderate oxygen availability and may were influenced by brackish water. The organic matter is mainly composed of algal material (lamalginite, *Botryococcus*-type telalginite, fluorescing AOM, liptodetrinite). Huminite presents in subordinate amounts. This may occur disseminated in the lake facies or concentrated in coal seams associated with the lacustrine mudstone.

The organic matter can be classified as Type II and III kerogens base on HI and composition of organic matter. Partly oxidation of the algal material may have deteriorated the petroleum generation potential (low HI), resulting in Type III kerogen. The samples are fair to good petroleum source rock. An approximately 120 m thick unit (depth of 874.78-1,002.79 m) of Fang-MS well is the best petroleum source rock which has good source rock properties with TOC content > 1.5 wt%, $S_2$ value > 4 mg HC/g rock, HI values ranging from 291–428 mg HC/g TOC and EOM content > 0.2 wt%.

The source rocks have a potential for mixed oil/gas and oil generation. The drilled section is thermally immature with regard to oil generation (low PI, low Ts/(Ts+Tm) ratio, low $C_{29}$ (20S/(20S+20R)) ratios, CPI values higher than 1.0, homohopane (22S/(22S+22R)) ratio from 0.27 to 0.60, and $C_{29}$ ββ/( ββ+αα) ratio

around 0.35). The Fang-MS well has just drilled to the top of the oil window, which is located at a depth of about 1,100 m (VR ~0.7%$R_o$) (Foopatthanakamol *et al*., 2008).

**6.2 Na Hong basin**

Samples were analyzed deposited in a freshwater lake (low to high TS contents and high TOC/TS ratios) with low oxygen availability and were influenced by brackish water, which is commonly associated with coals and fluvial deposits or forest swamp environment (Sherwood *et al*., 1984; Cook and Sherwood, 1991; Ratanasthien *et al*., 1999; Petersen *et al*., 2006). TOC contents are high with majority having > 10 wt% TOC, and the organic matter is mainly composed of lamalginite, liptodetrinite, *Botryococcus*-type telalginite, resinite, fluorescing AOM, sporinite, exsudatinite and cutinite. Huminite present in high proportion (up to 28.9 %) and dominated by gelinite and dentrinite.

The organic matter can be classified as Types II and III kerogens base on HI and composition of organic metter. The samples have good to excellent source rock properties with HI values ranging from 174–414 mg HC/g TOC. The best petroleum source rocks is coaly mudstone which TOC content > 40 wt%, $S_1$ value > 3mg HC/g rock, $S_2$ value > 100 mg HC/g rock, HI values 274 to 414 mg HC/g TOC. The source rocks have a potential for mixed oil/gas and oil generation.

The sample is thermally immature with VR values ranging from 0.40-0.49%$R_o$ (low PI, low EOM/TOC ratio, low Ts/(Ts+Tm) ratio, low $C_{29}$ (20S/(20S+20R)) ratios, high CPI, low homohopane (22S/(22S+2R)) ratio, and low $C_{29}$ ββ/(ββ+αα) ratio).

**6.3 Ban Pa Kha subbasin, Li basin**

The samples were collected from interburden of coal mine in Ban Pa Kha subbasin, Li basin. The samples consist of mudstone, shale and oil shale. They were overall deposited in a freshwater lake (low TS contents and high TOC/TS ratios) with moderate oxygen availability and were influenced by brackish water, which is commonly associated with coals and fluvial deposits or forest swamp environment. TOC contents are high with majority having > 5 wt% TOC, and the organic matter is

mainly composed of lamalginite, *Botryococcus*-type telalginite, fluorescing AOM, liptodentrinite, sporinite and exsudatinite. Huminite proportion ranges from 6 to 9%.

The organic matter can be classified as Types I, II and III kerogen base on HI and composition of organic matter. The samples have good to excellent source rocks with HI values ranging from 308–679 mg HC/g TOC. The best petroleum source rocks of Ban Pa Kha is oil shale which TOC content > 25 wt%, $S_1$ value > 2 mg HC/ g rock, $S_2$ value > 100 mg HC/ g rock, HI value between 588 and 607 mg HC/ g TOC. The source rocks have a potential for mixed oil/gas and oil generation.

The sample is thermally immature with VR values ranging from 0.36-0.40%$R_o$ (low PI, low EOM/TOC ratio, low Ts/(Ts+Tm) ratio, low $C_{29}$ (20S/(20S+20R)) ratios, high CPI, low homohopane (22S/ (22S+2R)) ratio, and low $C_{29}$ ββ/(ββ+αα) ratio).

**6.4 Mae Sot basin**

The samples were collected from outcrop and consist of oil shales. The oil shales are very dark gray to dark gray. They were overall deposited in a freshwater lake (low TS contents and high TOC/TS ratios) with low oxygen availability. The TOC contents are high with majority having > 20 wt% TOC, and the organic matter is mainly composed of lamalginite, fluorescing AOM, *Botryococcus*-type telalginite and liptodentrinite. Huminite may be present in subordinate amounts.

The organic matter can be classified as Types I and II kerogens base on HI and composition of organic metter. The samples are good to excellent source rock properties with HI values ranging from 679–831 mg HC/g TOC. The best petroleum source rocks of Mae Sot is oil shale in the upper part which TOC content > 25 wt%, $S_1$ value > 3 mg HC/ g rock, $S_2$ value > 150 mg HC/ g rock, HI value 679 to 771 mg HC/ g TOC. The source rocks have a potential for oil generation.

The sample is thermally immature with VR values ranging from 0.35-0.37%$R_o$ (low PI, low Ts/(Ts+Tm) ratio, low $C_{29}$ (20S/(20S+20R)) ratios, high CPI, low homohopane (22S/(22S+2R)) ratio, and low $C_{29}$ ββ/(ββ+αα) ratio).

**6.5 Phitsanulok basin**

The samples were collected from Yom, Pratu Tao, Chum Seang and Lan Krabu Formation between depths of 900 and 3,070 m. of P-SK well in 50 m interval.

Yom Formation is dominated by sandstone, claystone and siltstone. Pratu Tao Formation is dominated by sandstone and claystone. Chum Saeng Formation is dominated by mudstone and shale. Lan Krabu Formation is dominated by mudstone, siltstone and sandstone.

The samples from P-SK well were overall deposited in a lake (low TS contents and high TOC/TS ratios) with moderate oxygen availability and were influenced by brackish water. TOC contents are moderate with majority having > 1 wt% TOC, and the organic matter is mainly composed of exsudatinite, fluorescing amorphous organic matter, liptodetrinite, laminated lamalginite, *Botryococcus* type telalginite, resinite and sporinite. Huminite proportion ranges from 5 to 9%.

The organic matter can be classified as Type II and III kerogens base on HI and composition of organic matter. The samples are poor to good petroleum source rock. Yom and Pratu Tao Formations are poor to fair source rock. The best petroleum source rock of P-SK well is depths between 1,900 and 2,200 m which is Chum Saeng formation and depths between 2,600 and 2,800 m which is Lan Krabu formation. TOC content higher than 2 wt%, $S_1$ value higher than 2 mg HC/g rock, $S_2$ value higher than 10 mg HC/ g rock, HI value 324 to 523 mg HC/ g TOC and EOM content is higher than 0.2 wt%. The source rocks have a potential for mixed oil/gas and oil generation.

The drilled section is early thermal mature to mature with regards to oil generation with VR values ranging from 0.40-0.66%$R_o$ (majority was PI higher than 0.1, Ts/(Ts+Tm) ratio ranging 0.31-0.36, high $C_{29}$ (20S/(20S+20R)) ratios, CPI around 1.0, high Homohopane (22S/(22S+2R)) ratio, and $C_{29}$ ββ/(ββ+αα) ratio around 0.3). The P-SK well has onset of efficient oil expulsion, which is located at a depth of about 3,000 m (VR ~0.70%$R_o$).

**6.6 Suphanburi basin**

The samples were collected from Units A to D between depths of 1,000 to 2,840 m of SP1 well at 15 m interval. Unit D is dominated by thick non-calcareous mudstone interbedded with thin sandstone and calcareous mudstone. Unit C is dominated by mudstone interbedded with sandstone and thick mudstone. Unit B is

dominated by mudstone interbeded with thin sandstone. Unit A is dominated by thick sandstones interbedded with mudstone and siltstone.

In SP2 well, samples were collected from Unit A to D between depths of 1,000 to 2,095 m in 5 to 10 m interval. Unit D is dominated by mudstone interbedded with thin sandstone and calcareous mudstone. Unit C is dominated by mudstone with marlstone. Unit B is dominated by mudstone interbedded with sandstone and siltstone. Unit A is dominated by mudstone interbeded with sandstone.

The samples from SP1 and SP2 well were overall deposited in a lake (low TS contents and high TOC/TS ratios) with moderate oxygen availability and were highly influenced by brackish water which is indicated as marine transgressed. TOC contents are moderate with majority having > 1 wt% TOC, and the organic matter is mainly composed of laminated lamalginite, liptodetrinite, fluorescing amorphous organic matter, exsudatinite, *Botryococcus* type telalginite, resinite and sporinie in SP1 well, while laminated lamalginite, liptodetrinite, *Botryococcus* type telalginite, fluorescing amorphous organic matter, exsudatinite, resinite, sporinite and cutinite. Huminite proportion ranges from 6 to 15%.

The organic matter can be classified as Type II and III kerogens base on HI and composition of organic matter. The samples range non source rock to good petroleum source rock. Units A and D are no potential to fair petroleum source rocks. The best petroleum source rock of SP1 well from depths between 1,950 and 2,250 m which is Unit B, have TOC content higher than 2 wt%, $S_2$ value higher than 5 mg HC/ g rock, HI value 247 to 390 mg HC/ g TOC and EOM content higher than 0.2 wt%. The best petroleum source rock of SP2 from depths between 1,200 and 1,250 m which is unit C and depths between 1,450 and 1,650 m which is unit B, TOC content higher than 2 wt%, $S_1$ value 0.17 to 1.17 mg HC/g rock, $S_2$ value higher than 10 mg HC/ g rock, HI value 446 to 675 mg HC/ g TOC and EOM content higher than 0.2 wt%. The source rocks have a potential for mixed oil/gas and oil generation.

For SP1 well, the drilled section is thermal maturity with regard to oil generation with VR values ranging from 0.59-1.35%$R_o$ (below depth of 1,750 m, PI higher than 0.1, Ts/(Ts+Tm) ratio ranging 0.26-0.74, $C_{29}$ (20S/(20S+20R)) ratio ranging 0.16-0.51, CPI around 1.0, homohopane (22S/(22S+2R)) ratio ranging 0.30-

0.60, and $C_{29}$ ββ/(ββ+αα) ratio ranging 0.30-0.55). The SP1 well has onset of efficient oil expulsion, which is located at a depth of about 1,800 to 2,500 m (VR ~0.70%$R_o$).

For SP2 well, the drilled section is early thermal mature with regards to oil generation with VR values ranging from 0.45 to 0.72%$R_o$ (below depth of 1,800 m, PI higher than 0.1, Ts/ (Ts+Tm) ratio ranging 0.13 to 0.44, low $C_{29}$ (20S/(20S+20R)) ratio, high CPI, homohopane (22S/(22S+2R)) ratio ranging 0.27 to 0.56, and low $C_{29}$ ββ/(ββ+αα) ratio). The SP2 well has just drilled to the top of the oil window (VR ~0.70%$R_o$).

In summary, the samples of all basins were deposited in freshwater lakes with low oxygen availability for Na Hong and Mae Sot basin and moderate oxygen availability for Fang-MS well (Fang basin), Ban Pa Kha (Li basin), P-SK well (Phitsanulok basin) and SP1 and SP2 wells (Suphanburi basin). The Na Hong and Li basins are commonly associated with coals and fluvial or forest swamp environments. The overall TOC contents vary from low to high values.

Outcrop sample from Na Hong basin have the highest TOC value which is up to 50 wt% in coaly mudstone and majority having > 10 wt%. The samples from drill well, SP2 samples have the highest value, ~ 6 wt %, and majority having > 1 wt%. The organic matter is dominated by liptinite group (up to 65 vol %). The organic matter consists mainly of lamalginite, liptodetrinite, fluorescing AOM, *Botryococcus*-type telalginite, exsudatinite, resinite, sporinite and cutinite. Huminite present in high proportion (up to 28.9 %) and dominated by gelinite and dentrinite in Na Hong samples and another basin, huminite may be present in subordinate amounts. The organic matter of Mae Sot samples and some sample of Ban Pa Kha can be classified Type I kerogen and the organic matter of Fang-MS, Na Hong, some of samples of Ban Pa Kha, P-SK, SP1and SP2 samples can be classified as Type II and III kreogens.

The samples of Fang-MS are fair to good source rock properties. The samples of P-SK are poor to good source and the samples of SP1 and SP2 are no source rock to good source. The samples of Na Hong, Ban Pha Kha and Mae Sot basin are excellent source rock. An approximately 120 m thick unit of Fang-MS well is the best petroleum source rock which has good source rock properties and have a potential for mixed oil/gas and oil generation. An approximately 300 m thick unit (Chum Saeng

Formation) of P-SK well is the best petroleum source rock and have a potential for mixed oil/gas and oil generation An approximately 100 m thick unit (Unit B) of SP1 well and 200 m thick unit (Unit C) of SP2 well are the best petroleum source rock and have a potential for mixed oil/gas and oil generation The source rocks of Na Hong and Ban Pa Kha have a potential for mixed oil/gas and oil generation but the source rocks of Mae sot have a potential for oil generation.

The samples of Na Hong, Ban Pa Kha and Mae Sot basins are thermally immature. The samples of Fang-MS well are thermally immature with regard to oil generation. The Fang-MS well has just drilled to the top of the oil window, which is located at a depth of about 1100 m (VR ~0.7%$R_o$). The samples of P-SK well are early thermal maturity to maturity with regard to oil generation. The P-SK well has onset of efficient oil expulsion, which is located at a depth of about 3,000 m (VR ~0.55%$R_o$). The samples of SP1 and SP2 wells are thermal maturity with regard to oil generation. The SP1 well has onset of efficient oil expulsion, which is located at a depth of about 1,800 to 2,500 m (VR ~0.76%$R_o$). The SP2 well has just drilled to the top of the oil window (VR ~0.65%$R_o$). From Pr/$n$$C_{17}$ versus Ph/$n$$C_{18}$ plot indicated as Na Hong samples are the lowest maturity and samples of Unit B of SP1 well are the highest maturity.