International Journal of GEOMATE, Nov, 2022, Vol.23, Issue 99, pp.48-55
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2022.99.3581
Geotechnique, Construction Materials and Environment

SWELLING SHALE ZONE PREDICTION USING THE RELATIONSHIP OF CLAY MINERAL AND SHALE VOLUME OF FANG BASIN, THAILAND

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*Corresponding Author, Received: 26 June 2022, Revised: 15 Sept. 2022, Accepted: 10 Oct. 2022

ABSTRACT: Stuck pipe of the drilling string by shale swelling is one of the problems for petroleum drilling wells, especially in the Fang oil field, Thailand. The research objectives are to study the shale volume using gamma ray log, and the variation of clay mineral and elemental composition of drill cuttings of FA-SS-35-04 well to identify minerals and predict the swelling shale zone. The FA-SS-35-04 well is in the San Sai oil field, Fang Basin. The lithology of the basin can be divided into two formations including Mae Fang formation (~450-2,600 ft) and Mae Sod formation (~2,600-9,200 ft) based on drill cutting. 39 samples in Mae Sod formation are analyzed using gamma ray log data, X-ray diffraction, and X-Ray fluorescence. The gamma-ray value shows a high content of shale volume in clay layers. The results of clay mineral consist of 18.0-82.2% quartz (avg. 51.26%), 5.1-37.7% kaolinite (avg. 17.68%,), 1.8-17.7% illite (avg. 9.97%), 0-2.0% chlorite (avg. 0.99%), 0-46.6% calcite (avg. 6.83%), 3.9-17.5% feldspar (avg. 9.27%), and 0.6-8.9% montmorillonite (avg. 3.99%). The montmorillonite in all units of Mae Sod formation impacts directly shale swelling according to the increased depth, Al2O3, Fe2O3, and MgO contents. The lower zone (unit C) of this formation (especially 7,110-9,150 ft) represents the highest montmorillonite content which can affect shale swelling. Based on this shale swelling zone study, it can lead to forewarning and select the appropriate method to reduce and prevent the risk of stuck drill string or logging tools or formation caving problems during drilling operations in Fang basin.

Keywords: Clay Mineral, Shale Swelling, Shale volume, Montmorillonite, Fang Basin.

1. INTRODUCTION

Fang basin oil field is a tertiary basin located about 150 kilometers northwest of Chiang Mai province, Thailand and it is the first field that has been developed in Thailand [1]. The location of the Fang basin is shown in Fig. 1 [2,3].

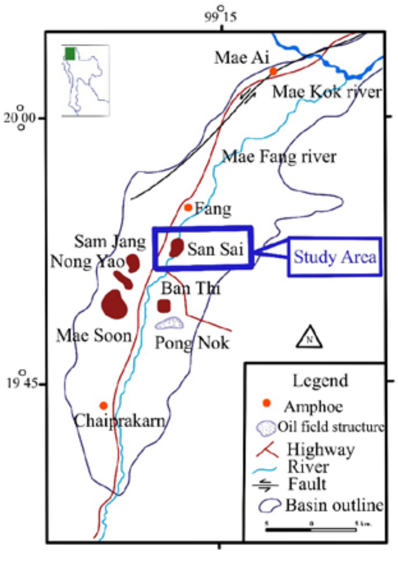


Fig 1. Fang Basin area (modified after Latt and Giao, (2012); Pitumwong (2011) [2,3].

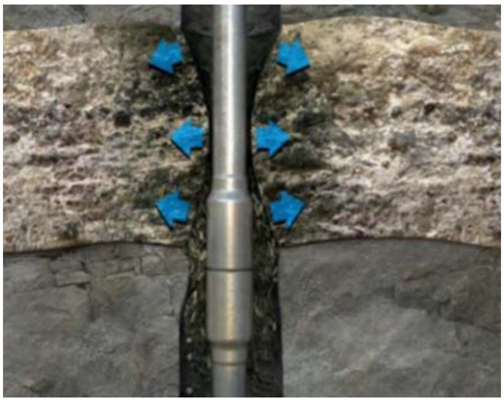
Fang basin can be divided into two units consisting of Mae Fang and Mae Sod Formation.

The Mae Fang Formation (Pleistocene to Recent in age), 2,500 feet thick, is composed mainly of clay, coarse- to very coarse-grained sandstones, gravel and carbonized woods which were deposited in a fluvial environment. It overlies unconformably with the Mae Sod Formation. [4].

Mae Sod Formation (Middle Tertiary) is composed of brown to gray shale, yellowish mudstone generally interbedded with sand and sandstone with a series of channels of sand paleo-delta and fluvial sand [5].

One of the problems when drilling through shale formation in the Fang basin is a stuck drilling string caused by the swelling of shale [6,7]. Shales dominated by smectite (montmorillonite) minerals are highly reactive with aqueous fluids, causing swelling [8].

Generally, all the clay mineral types listed adsorb water, but smectites (montmorillonite) assimilate more into their structure than the other classes, in part due to their expanding lattice [9]. So, the variation of montmorillonite content is the main effect of this swell due to its clumping properties



and water adsorbent to molecule structure (Fig. 2 and Fig. 3).

Fig 2. Stuck pipe in borehole [6].

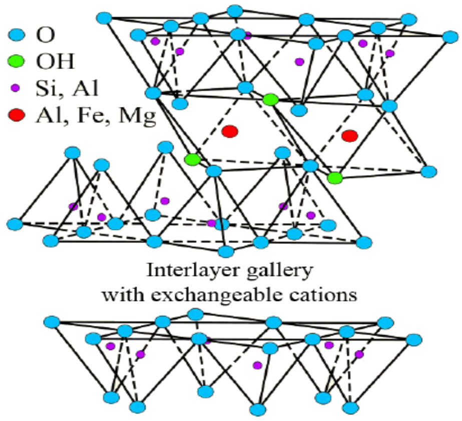


Fig 3. The structure of Montmorillonite clay [7].

From the previous study of shale swelling in Fang basin from FA-MS-61-95 well in Mae Soon oil field, the pipe stuck while the drilling operation occurred from the effect of shale swelling zone, whereas represented slightly increased montmorillonite content (4.92 to 6.77%) [10]. Moreover, the mineral composition study from FA-PK-60-09 well [11], Fang oil field, Fang basin (Fig. 1) represents the montmorillonite and illite tend to affect shale swelling [11]. Therefore, the objective of this research is to study the shale volume using gamma ray log and the variation of clay mineral and elemental composition of drill cuttings from FA-SS-35-04 well to identify minerals variation and predict swelling shale zone.

2. MATERIALS AND METHODOLOGY

2.1 Geological Background

FA-SS-35-04 well is in the San Sai oil field at latitude 19°52’ 35’’ N and longitude 99° 12’ 12’’ E. This well was drilled into the San Sai oil reservoir and the lithology to be drilled consists of Mae Fang formation and Mae Sod formation. The stratigraphy of FA-SS-35-04 well [12] is shown in Fig. 4

2.1.1 Mae Fang Formation

The sediment compositions of the Mae Fang formation are mainly sand, gravel, and clay. The sand is generally light gray to dark gray, coarse to very coarse-grained with some granules, and moderately sorted. The gravel is light gray to gray, with some coarse- to very coarse-grained and poorly sorted, sand. The clay is generally gray.

2.1.2 Mae Sod Formation

The main lithology of the Mae Sod formation is shale, mudstone, siltstone, and sandstone with some coal layers interbedded. The Mae Sod formation consists of 3 sub-units including sub-unit A, B, and C. There are 2 parts of sub-unit A as the upper part and the lower part. The upper part consists interbedded of shale and sandstone with clay dominant. Shale is characterized by gray to dark gray and brown color, whereas sandstone is generally light gray to gray color and is medium- to very coarse-grained and mostly well sorted. The upper part is interpreted to be the marginal lacustrine facies. The lower part of sub-unit A composes of thick dark gray, black, and brown shale with fine-grain sandstone intercalation and there are some coal layers interbedded. It represents the shallow to deep lacustrine facies.

Sub-unit B consists of extremely thick dark-gray shale, fine-grained sandstone, and coal. This lithological succession is interpreted to be deposited in low-energy conditions of freshwater paleo-lake. The products that accumulate in this environment are sedimentary rocks of lacustrine facies.

Sub-unit C consists of the lower part of sandstone and a coal bed interbedded with black shale and the upper part of approximately 200 ft thickness of coal beds and some sandstone. The sandstone of the upper part of sub-unit C is generally red and gray, fine to very coarse-grained with some layers of very clean sand. It represents marginal lacustrine facies.

2.2 Methodology

The methodology of this research can be divided into log interpretation and quantification of clay minerals. As part of log interpretation, the volumes of shale are calculated by the Gamma-ray (GR) log of the FA-SS-35-04 well. Thirty-nine drilling cutting samples from 2,600 to 9,200 ft depth of FA-SS-35-04 well emphasis on Mae Sod formation were analyzed using cutting sample petrographic analysis, X-ray powder diffraction (XRD), and X-ray fluorescence (XRF) in the Suranaree University of Technology for the quantification of clay mineral and elementary composition analysis of all tested samples.

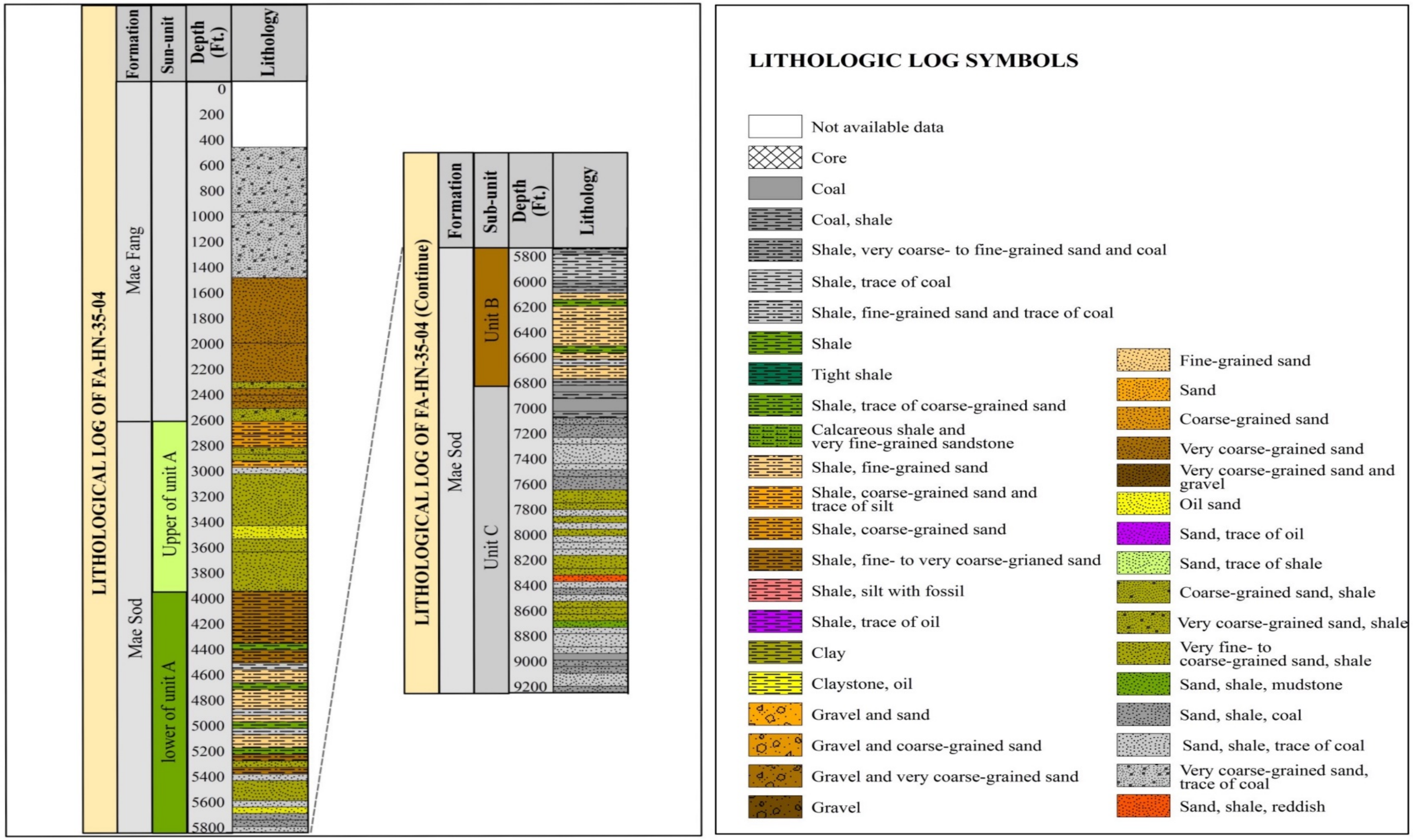


Fig 4. Lithological log of FA-SS-35-04 well [12].

2.2.1 Shale volume

One of the clay quantificational predictions is shale volume calculation using a method of measuring naturally occurring gamma ray radiation to characterize the rock of sediment in a borehole. The shale volume is calculated using the linear method [13] as the following Eq. (1).

Vsh = (GRlog – GRmin) / (GRmax - GRmin) (1)

Where, the GRlog = gamma-ray of the interesting zone, GRmin = minimum value of gamma-ray log, and GRmax = maximum value of the gamma-ray log.

2.2.2 Swelling shale

Clay minerals are composed of particles with small crystals, and they can be classified into different groups based on crystalline structure. Due to improper sorting in sedimentary environments, most sandstone reservoirs are containing clay minerals.

Shale can be usually divided into effective and non-effective shales. Effective shale, that rock referred to in the literature as shale is usually predominately the multilayer clays such as smectites (montmorillonite, bentonite, etc.) and illite. This shale has significant CEC (Cation exchange capacities) but, the non-effective shale, kaolinites, and chlorites have essentially very low CEC. Shale is the main problem in oil and gas drilling well. One problem is shale swelling, the effect of absorbing water from clay minerals such as montmorillonite causes stuck pipe and interpret logging [14] and the effect of shale can also result in erroneous values of water saturation and porosity as calculated from logs, especially effective shale. Therefore, the analyzed XRD for mineral composition and XRF techniques were used to analyze elemental composition to identify the quantity and types of clay minerals for all tested samples.

3. RESULTS AND DISCUSSION

The results from the FA-SS-35-04 well analysis to study shale volume, a rock-forming mineral of shale, and element association including upper and lower parts of sub-unit A, sub-unit B, and sub-unit C are presented in Table 1.

3.1 Shale volume

Based on Eq. (1) calculation, the shale volume of all samples varies from 0.42 to 8.75% for 2,820 to 9,150 feet depth (Fig. 5). The upper unit A has 16.80 to 80.28% of shale volume and the high shale volume values are at depth 3,150 and 3180 ft. The shale volume of lower unit A is 17.5 to 87.5% and the high shale volume values are at depths of 4,020, 4,140, 4,170, and 4,360 ft. The shale volume of unit B is between 2.08 and 50.0%, the high shale volume value is at depth of 6,700 ft. Unit C has 0.42 to 6.67% of shale volume and a high shale volume value at depth of 7,110 ft.

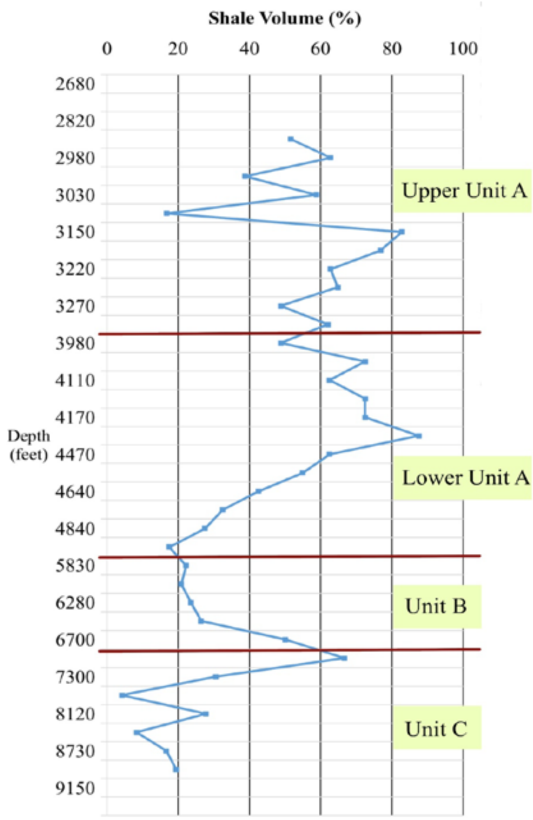


Fig 5. Shale volume of Mae Sod Formation of FA-SS-35-04 well.

3.2 Mineral and elemental composition

The composition of minerals from XRD and elements from XRF are shown in Table 1, Fig. 6, and Fig. 7, respectively. The study is focused on clay minerals, especially montmorillonite which causes shale swelling [7,12]. The result of elements of FA-SS-35-04 well of Fang basin deposit is given in Table 1 including Na_2O, MgO, Al_2O_3, Si_2O, K_2O, CaO, Cr_2O_3, MnO_2, Fe_2O_3, NiO, TiO_2, ZrO_2, and PbO. The Al_2O_3, Fe_2O_3, and MgO contents affect montmorillonite which relates to the shale swelling zone (Fig. 6).

Upper unit A: the clay mineral compositions are 37.41 to 82.20 % of quartz (avg. 63.99%), 5.05 to 31.27% of kaolinite (avg. 4.52%), 1.75 to 13.05% of illite (avg. 7.04%), 0 to 1.58% of chlorite (avg. 0.63%), 0 to 0.21% of calcite (avg. 0.02%), 7.62 to 17.49% of feldspar (avg. 11.75%), and 0.59 to 4.16% of montmorillonite (avg. 2.02%). The montmorillonite content is highest at 3,180 ft. The

Table 1 Result of study including shale volume, X-ray diffraction analysis, and X-Ray fluorescence from FA-SS-35-04 well.

NO.	Unit	Depth (ft.)	Gamma Ray log		X-Ray Diffraction (XRD) (%)							X-Ray Fluorescense (XRF) (%)												
			API	Shale volume(%)	Quartz	Kaolinite	Illite	Chlorite	Calcite	Felspar	Mont	Na2O	MgO	Al2O3	SiO2	K2O	CaO	Cr2O3	MnO2	Fe2O3	NiO	TiO2	ZrO2	PbO
1	Upper of unit A	2680	-	-	63.265	17.525	6.655	0.960	0.000	9.030	2.385	4.956	2.379	14.534	64.272	1.802	0.948	0.069	0.350	10.079	0.004	0.594	0.007	0.019
2		2790	-	-	65.845	16.455	6.335	0.915	0.000	8.415	2.040	3.360	1.074	11.056	77.677	2.487	0.427	0.083	0.078	3.402	0.000	0.344	0.003	0.011
3		2820	-	-	82.510	4.795	2.485	0.225	0.010	9.480	0.515	3.865	1.116	10.668	77.907	2.265	0.364	0.074	0.053	3.328	0.001	0.319	0.001	0.010
4		2950	212	0.516	53.940	19.570	10.380	0.780	0.000	12.300	3.030	3.469	0.998	8.741	79.461	2.296	0.281	0.086	0.067	3.098	0.000	0.211	0.001	0.009
5		2980	240	0.628	68.420	8.510	5.870	0.170	0.000	16.030	1.000	4.913	1.962	16.706	68.096	2.635	0.308	0.079	0.097	4.566	0.006	0.613	0.003	0.019
6		3000	180	0.388	68.740	9.610	6.400	0.360	0.000	13.910	0.980	3.112	1.030	7.910	82.244	1.341	0.734	0.145	0.073	3.213	0.000	0.240	0.000	0.007
7		3030	230	0.588	70.760	8.320	4.770	0.230	0.000	14.960	0.960	4.519	2.436	19.928	64.485	1.930	0.441	0.048	0.076	5.165	0.007	0.935	0.011	0.018
8		3080	125	0.168	47.380	20.760	11.080	0.930	0.000	17.490	2.360	4.945	1.379	9.400	78.332	1.282	1.262	0.077	0.064	2.907	0.000	0.315	0.001	0.008
9		3150	290	0.828	75.220	6.530	6.260	0.000	0.000	9.480	2.510	5.389	1.482	12.108	73.972	2.106	0.371	0.088	0.115	3.988	0.001	0.370	0.000	0.011
10		3180	275	0.768	37.410	31.270	13.050	1.580	0.000	12.520	4.160	5.119	1.552	12.376	74.056	1.947	0.229	0.082	0.103	4.080	0.001	0.440	0.004	0.011
11		3220	240	0.628	77.440	8.190	3.560	0.300	0.210	9.450	0.850	4.945	1.379	9.400	78.332	1.282	1.262	0.077	0.064	2.907	0.000	0.315	0.001	0.008
12		3240	245	0.648	68.480	10.680	5.540	0.550	0.050	13.500	1.200	5.389	1.482	12.108	73.972	2.106	0.371	0.088	0.115	3.988	0.001	0.370	0.000	0.011
13		3270	205	0.488	64.540	12.760	7.260	0.490	0.020	13.310	1.620	5.119	1.552	12.376	74.056	1.947	0.229	0.082	0.103	4.080	0.001	0.440	0.004	0.011
14		3930	238	0.620	54.075	20.755	10.810	1.075	0.000	10.040	3.255	4.952	2.144	15.184	65.155	1.829	0.354	0.051	0.471	9.111	0.005	0.707	0.005	0.019
15		3980	205	0.488	60.375	17.265	7.550	0.750	0.000	11.600	2.440	5.040	2.396	14.522	66.494	1.981	0.336	0.037	0.505	7.985	0.004	0.675	0.008	0.017
16	Lower of unit A	4020	220	0.725	62.110	16.460	6.665	0.985	0.000	11.025	2.750	5.102	2.201	13.231	64.628	1.839	0.290	0.259	0.745	11.221	0.005	0.636	0.008	0.022
17		4110	200	0.625	47.310	26.420	9.830	1.215	0.000	11.105	4.115	4.703	2.571	16.780	62.457	2.119	0.317	0.042	0.641	9.416	0.007	0.910	0.007	0.030
18		4140	220	0.725	55.485	21.665	8.705	1.220	0.000	9.170	3.745	4.912	2.555	14.458	62.963	1.818	0.295	0.060	0.598	11.513	0.005	0.784	0.006	0.032
19		4170	220	0.725	51.600	24.640	9.235	1.340	0.000	8.570	4.610	3.145	2.506	14.978	62.130	1.922	0.339	0.055	0.530	13.237	0.010	0.882	0.009	0.036
20		4360	250	0.875	41.405	32.005	10.665	1.955	0.000	8.125	5.835	4.348	2.860	16.286	53.852	1.874	0.636	0.340	0.932	18.155	0.015	0.958	0.006	0.043
21		4470	200	0.625	28.380	37.050	14.500	1.895	0.000	10.270	7.905	4.158	3.008	19.403	54.669	2.388	0.630	0.039	0.401	13.934	0.019	1.300	0.011	0.042
22		4500	185	0.550	28.970	32.000	14.360	2.105	5.075	10.395	7.095	4.077	3.325	17.867	52.038	2.364	3.529	0.037	0.462	14.984	0.017	1.250	0.008	0.041
23		4640	160	0.425	43.420	21.685	11.370	1.585	10.670	6.450	4.830	4.528	2.831	13.699	55.589	1.803	6.477	0.039	0.475	13.507	0.010	1.012	0.003	0.026
24		4740	140	0.325	35.495	16.550	17.580	1.645	19.395	4.560	4.765	7.800	2.950	12.558	46.004	1.535	11.192	0.034	0.909	16.170	0.010	0.843	0.000	0.027
25		4840	130	0.275	39.605	15.558	14.578	0.700	19.825	5.050	4.220	7.257	2.594	11.857	51.381	1.631	11.257	0.039	0.642	12.320	0.011	0.986	0.002	0.024
26		4940	110	0.175	33.080	12.705	12.940	0.550	33.110	4.050	3.565	6.203	2.180	11.017	46.536	1.572	18.894	0.335	0.502	12.059	0.013	0.959	0.005	0.013
27	Unit B	5830	120	0.222	20.215	15.725	10.965	0.525	45.290	4.300	2.970	2.213	2.247	11.706	35.445	1.602	25.472	0.042	0.415	19.729	0.015	1.097	0.004	0.012
28		6160	115	0.208	17.825	11.940	13.370	0.410	45.820	5.485	5.155	6.340	2.938	11.202	33.490	1.547	24.264	0.041	0.383	18.715	0.016	1.052	0.004	0.007
29		6280	125	0.236	22.975	12.190	9.115	0.575	46.450	4.715	3.985	5.849	2.694	13.837	47.770	1.211	20.746	0.037	0.155	6.871	0.012	0.807	0.004	0.007
30		6450	135	0.264	39.950	10.130	12.690	0.480	27.225	4.500	5.025	6.462	2.977	13.261	56.767	1.128	11.151	0.030	0.287	7.264	0.005	0.656	0.001	0.013
31		6700	220	0.500	40.650	17.885	15.950	0.505	8.835	7.610	8.560	4.454	2.949	17.310	59.126	1.484	4.326	0.029	0.212	9.314	0.007	0.770	0.003	0.015
32	Unit C	7110	280	0.667	29.170	33.200	14.600	1.350	0.420	13.160	8.100	4.025	2.854	23.031	57.489	2.317	0.986	0.169	0.155	7.813	0.012	1.249	0.010	0.015
33		7300	150	0.306	72.590	10.120	7.135	0.985	0.000	4.980	4.195	4.968	2.370	12.199	72.659	1.379	0.356	0.075	0.194	5.091	0.003	0.690	0.009	0.008
34		8110	55	0.042	46.970	19.010	14.905	1.360	0.140	9.635	7.980	4.451	3.366	18.205	60.900	2.163	0.837	0.062	0.133	8.512	0.015	1.337	0.013	0.005
35		8120	140	0.278	47.750	19.145	16.370	1.135	0.485	8.265	6.850	4.534	3.218	17.562	61.372	2.060	0.969	0.054	0.136	8.766	0.018	1.298	0.014	0.006
36		8680	70	0.083	57.500	15.400	11.875	1.650	0.925	7.695	4.955	4.826	2.939	15.539	64.522	1.737	1.145	0.052	0.170	8.050	0.011	0.986	0.017	0.006
37		8730	100	0.167	54.500	15.505	12.255	1.960	1.515	8.670	5.605	4.618	3.288	16.414	61.854	1.852	1.673	0.047	0.253	6.178	0.011	1.125	0.014	0.007
38		8830	110	0.194	72.755	10.555	7.150	1.135	0.635	5.085	2.675	4.956	2.737	11.383	71.500	1.174	1.068	0.062	0.138	6.274	0.006	0.683	0.008	0.007
39		9150	-	-	58.030	18.135	11.190	2.005	0.130	6.740	3.770	4.844	2.941	15.888	65.583	1.541	1.026	0.073	0.116	7.024	0.008	0.930	0.013	0.011

Note: ft= feet, Vsh = Shale volume, Mont = Montmorillonite content of elemental composition in this montmorillonite zone is slightly increased with depth including 7.91 to 19.93% of Al_2O_3 (avg. 12.47%), 2.91 to 10.08% of Fe_2O_3 (avg. 4.79%), and 1.00 to 2.44% of MgO (avg. 1.62%).

Lower unit A: the clay mineral compositions are 28.38 to 62.11% of quartz (avg. 41.62%), 12.94 to 37.65% of kaolinite (avg. 23.80%), 6.67 to 17.66% of illite (avg. 11.53%), 0.48 to 1.92% of chlorite (avg. 1.33%), 0 to 33.09% of calcite (avg. 8.05%), 3.91 to 12.73% of feldspar (avg. 9.04%), and 2.75 to 8.12% of montmorillonite (avg. 9.04%). The montmorillonite content is stable or slightly increased with depth and high value at 4,360, 4,470, and 4,470 ft, respectively. The content of elemental composition in this montmorillonite zone is slightly increased with depth including 11.02 to 19.40% of Al_2O_3 (avg. 14.74%), 9.42 to 10.08% (avg. 4.79%) of Fe_2O_3, and 2.18 to 3.33% of MgO (avg. 2.69%).

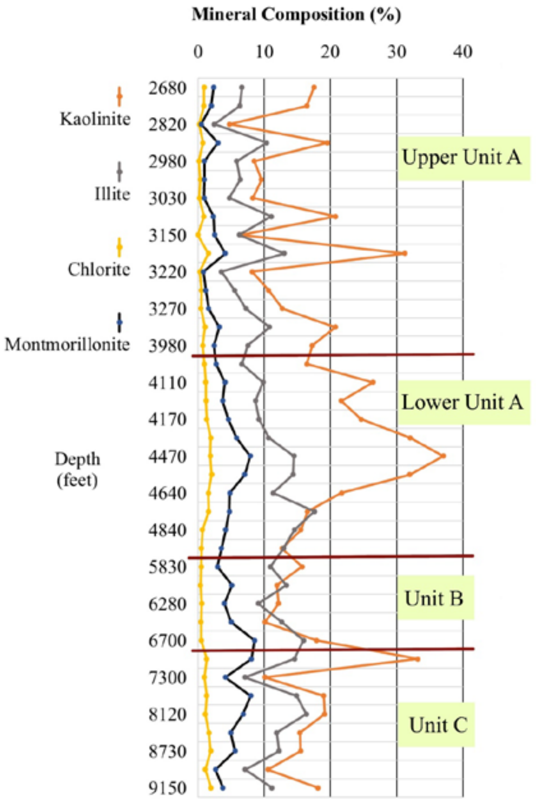


Fig 6. Clay mineral composition of Mae Sod Formation.

Unit B: the clay mineral compositions are 7.97 to 41.03% of quartz (avg. 28.37%), 10.18 to 17.84% of kaolinite (avg. 13.68%), 8.48 to 16.60% of illite (avg. 12.31%), 0.46 to 0.68% of chlorite (avg. 0.56%), 8.70 to 46.57% of calcite (avg. 34.67%), 4.22 to 6.31% of feldspar (avg. 5.12%), and 2.99 to 8.90% of montmorillonite (avg. 5.30%). The montmorillonite content is the highest value at 6,700 ft. The content of elemental composition in this montmorillonite zone is slightly increased with depth including 11.2 to 59.3% (avg. 13.46%) of Al_2O_3. 6.87 to 19.73% of Fe_2O_3 (avg. 12.38%), and 2.21 to 2.98% of MgO (avg. 2.76%).

Unit C: the content of clay mineral is 29.17 to 72.38% of quartz (avg. 54.96%), 10.18 to 33.20% of kaolinite (avg. 17.70%), 6.82to 16.35% of illite (avg. 11.84%), 0.90 to 1.99% of chlorite (avg. 1.44%), 0 to 1.71% of calcite (avg. 0.53%), 5.33 to 13.16% of feldspar (avg. 7.99%), and 2.70 to 8.10% of montmorillonite (avg. 5.54%). The montmorillonite content is slightly decreased with the depth and the high value are at 7,110 and 8,110 ft, respectively. The content of elemental composition in this montmorillonite zone is slightly increased with depth including 11.38 to 23.03% of Al_2O_3 (avg. 16.28), 5.09 to 8.77% of Fe_2O_3 (avg. 7.21%), and 2.37 to 3.37% of MgO (avg. 2.96%).

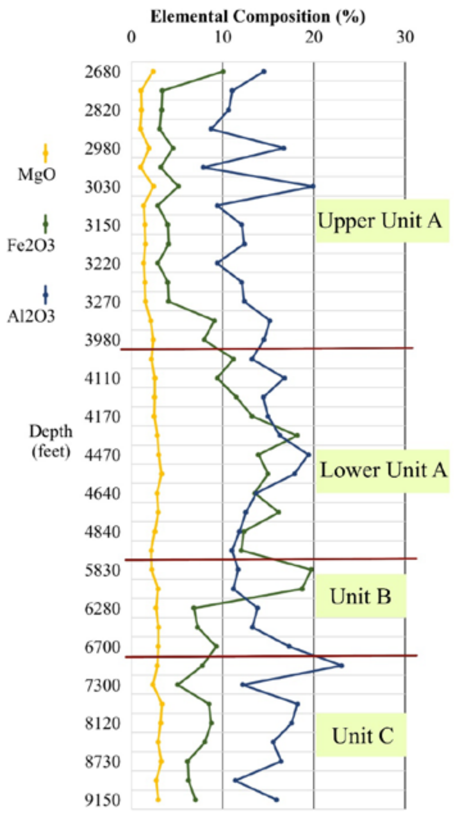


Fig 7. Elemental composition with depth on Mae Sod Formation.

3.3 Prediction of swelling shale zone

Based on the previous study of shale swelling of Fang basin from FA-MS-61-95 well in Mae Soon oil field [8], and FA-PK-60-09 well, Fang oil field, [9], whereas nearby this study area. These well represented that the pipe stuck while the drilling operation occurred from the effect of the shale swelling zone, which is related to montmorillonite content (4.92 to 6.77%) [8], and montmorillonite tends to increase with depth [9].

Based on the results of mineral and elemental contents of Mae Sod formation from FA-SS-35-04 well has approximately 2,600 to 9,200 ft of depth. The mineral compositions are 17.97 to 82.20% of quartz (avg. 51.26%), 5.05 to 37.65% of kaolinite (avg. 17.68%,), 1.75 to 17.66% of illite (avg. 9.97%), 0 to 1.99% of chlorite (avg. 0.99%), 0 to 46.57% of calcite (avg. 6.83%), 3.91 to 17.49% of feldspar (avg. 9.27%), and 0.59 to 8.90% of montmorillonite (avg. 3.99%). The content of elemental compositions is 7.91 to 23.03% (avg. 4.02%) of Al_2O_3, 2.91 to 19.73% (avg. 8.67%) of Fe_2O_3, and 1.0 to 3.37% (avg. 2.35%) of MgO. The data reveals that the most of quantity of clay mineral composition of shale drill cuttings from FA-SS-35-04 well are kaolinite, illite, montmorillonite, and chlorite. These clay mineral compositions are slightly increased with depth, especially the montmorillonite affected by the shale swelling zone. Moreover, the average montmorillonite content represents 2.02 % of upper unit A, 4.96% of lower unit A, 5.30% of unit B, and 5.54% of unit C.

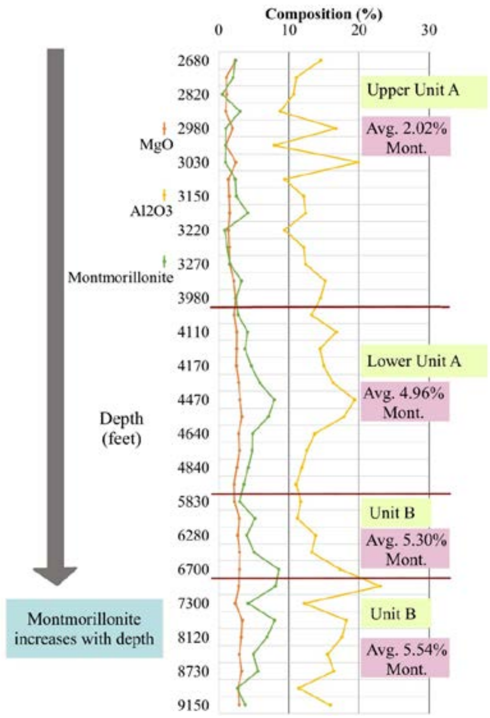


Fig 8. The high content of the montmorillonite zone.

4. CONCLUSIONS

The ranges of shale volume in Mae Sod formation are 17 to 88% based on the estimated by GR log, and thirty-nine drill cuttings of Mae Sod formation from FA-SS-35-04 well were also analyzed by XRD and XRF, respectively. The analyzed results represented 4 types of clay minerals including kaolinite (5.05 to 37.65%), illite (1.75 to 17.66%), chlorite (0 to 1.99%), and montmorillonite (0.59 to 8.9%). This montmorillonite impacts significantly shale swelling, which it represents in all units of the Mae Sod formation increasing with depth. The result showed that the increase of montmorillonite was associated with an increase of Al_2O_3, Fe_2O_3, and MgO.

The trend of montmorillonite content increases with depth according to the upper and lower of unit A, unit B, and unit C, respectively. As the montmorillonite content is more than 4.92% [10]. It could be caused to the swelling shale zone. This high content of montmorillonite relates to the shale layer of unit C (at 7,170, 8,180, 8,120, 8,680, and 8,730 ft depth) tends to be more swollen than unit B (at 6,160, 6,450, and 6,700 ft depth), lower unit A (at 3,180 ft. depth), respectively. In summary of this study, the lower zone (units C and B) of the Mae Sod formation could be aware of shale swelling while drilling operations. According to the results, it can be used as a prerequisite for planning to drill through this formation in the Fang basin area for the future drilling well.

5. ACKNOWLEDGMENTS

This research has been supported by the data access and sample from the Northern Petroleum Development Center Defense Energy Department (Thailand). The author would like to express gratitude to all the staff at the Suranaree University of Technology laboratory for using equipment and advice. One believes thankful to another person for suggestions and all their help.

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