Porosity Analysis and Reservoir Potential of Padaung Sandstones in Nyaungnigyin Area, Chauk and Nyaung-U Township

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Abstract

Nyaungnigyin Area is located about 6 km northward from Gwegyo situated between Kyaukpadaung and Chauk. The study area is the southern part of Gwegyo – Tawintaung Range. It comprises mainly Oligocene and Pliocene clastic sediments. Four lithostratigraphic units exposed in the study area are Shwezetaw Formation, Padaung Formation, Okhmintaung Formation and Irrawaddy Formation. The research objective is to interpret the reservoir potential of sandstones in Padaung Formation based on the porosity. Padaung Formation is mainly composed of bluish grey clays, fine-to medium- grained, thin- to thick-bedded sandstones. The sieving analysis was carried on to know the textural characteristics of sandstones and petrophysics properties of sandstones were derived from the porosity analysis. The mean sizes are ranging from 1.93 to 2.5 and standard deviations are 0.96-1.70 for Padaung Sandstones The average mean value and standard deviation interpreted, Padaung sandstones are composed mainly of poorly to moderately well sorted, fine grains. The relationship between porosity and permeability to grain size and sorting value pointed to Padaung Sandstones is from 29% to 36% of porosity and from 400 to 50000 mD of permeability. The effective porosities of sandstone samples of Padaung Formation are 22.0-35.49 percent. Based on sandstone characteristics and porosity value, Padaung Sandstones have good to very good reservoir potential

Keywords: sandstone, grains, porosity, reservoir

Introduction

The Nyaungnigyin area is located at the marginal part of Chauk Township, Magway Region and Nyaung U Township, Mandalay Region. It is about 12 km westward from Kyaukpadaung and 27 km eastward from Chauk. It also lies between North Latitude 20° 50′ to 20° 53′ and East Longitude 94° 58′ to 95° 01′ (Fig. 1).

Geologically, the study area lies in the north-eastern part of Minbu Basin. The study area is underlain by the succession of Oligocene deposits and Latest Miocene to Pliocene fluvial sediments. Although the twin mountain range that are the southern segment of Gwegyo-Tawintaung Range passed through NNW-SSE trending in the central part of the study area, the eastern and western fringes are low land (Fig. 2). Shwedaungnyo peak, the highest point of the study area is 402m (1318ft) above sea level. A conspicuous scarp line develops on the eastern side of the mountain though the western side is gently slope. The study area is mainly exposed the succession of Tertiary sediments especially the Lower Pegu Group and Irrawaddy Formation. In this research work, Padaung Formation of the Lower Pegu Group is emphasized to known the porosity of sandstone beds based on the mechanical properties.

Methods of study

The research conducted according to two methods. The first method is field work. It was carried out along the exposure surface in the study area. Fresh and insitu samples are collected for laboratory analysis. The total of six representative samples was randomly collected from medium-to-thick bedded unconsolidated sandstones of Padaung Formation. Another six samples are also taken from hard sandstone beds of Padaung Formation in the study area.

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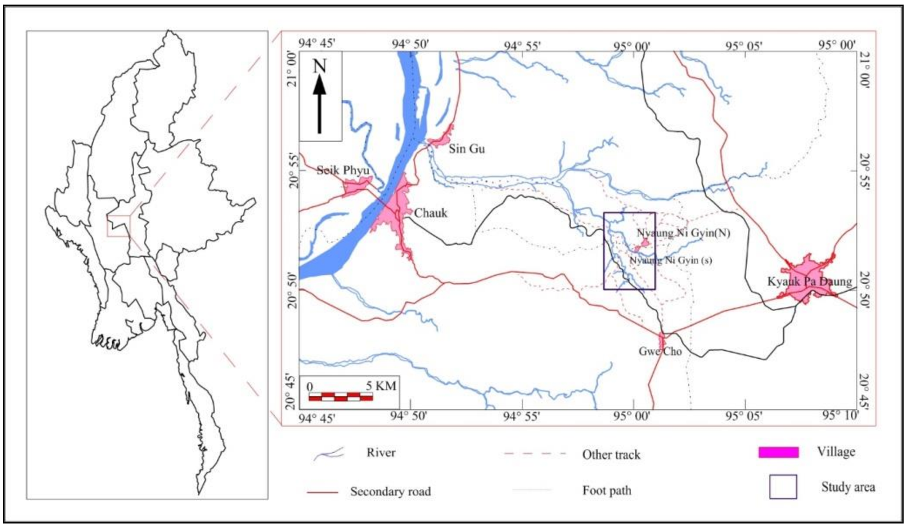

Figure (1). Location map of Nyaungnigyin area

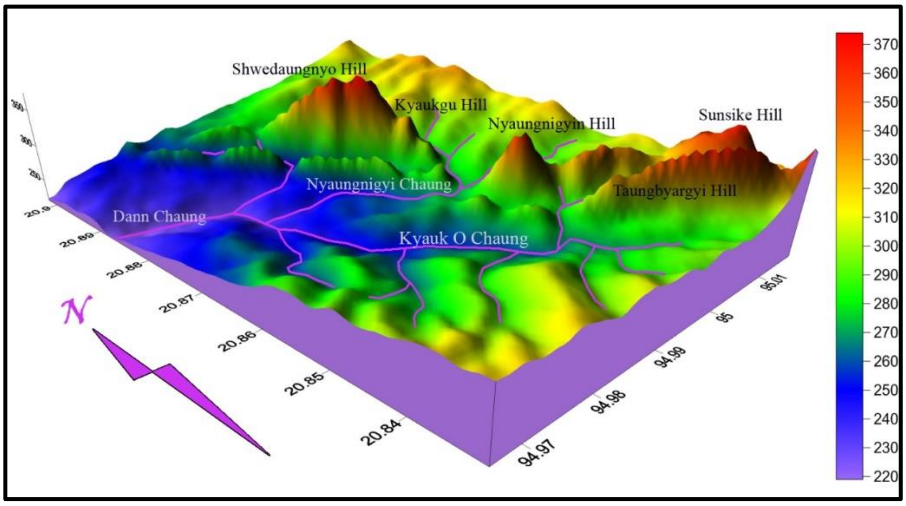

Figure (2). The physiography of Nyaungnigyin area

There are two types of laboratory work; sieving analysis and porosity analysis. The laboratory works include sample preparation before analysis. The laboratory work including sample preparation was be undertaken at the Laboratory of Geology Department in Magway University. After carefully disaggregation of samples, 100 grams each were weighed and sieved with a Standard Sieve Shaker for 15 minutes, using the British Standard Sieves spaced at one- phi interval. The stack of sieves, arranged in order to coarsest sieve is at the top with fine one below (with a pan at the bottom to catch any sediment that passes through the lowest and finest sieves) is placing on a shaking machine. A dry sample is placed in the uppermost sieve in set of stacked sieve. The individual sieved fractions were weighed and recoded. The mechanical data thus obtained were used in the preparation of the cumulative grain-size distributions curves. The phi values of 5^{th}, 16^{th}, 25^{th}, 50^{th}, $75^{th,}$ 84^{th}, and 95th percentiles were obtained from arithmetic cumulative curve. The statistical parameters such as mean and sorting, were calculated by using the methods of Folk and Ward (1957).

Porosity measurement of a rock sample requires the determination of pore volume and bulk volume because porosity is the ratio of pore volume and bulk volume. The bulk volume can be directly calculated from the length and surface area of sandstone sample. Pore volume is measured by saturating a sample in water. The volume of water held in the rock can be determined by weighing the sample when dry and when saturated.

Geological Background

The study area is situated in the southern part of the Gwegyo thrust sheet which is one of the Basin-Center Thrust Sheets in Minbu Basin (Pivnik *et al.*, 1998). This thrust sheet extends for over 50 km along strike and contains minor oil reserves (Soe and Myint, 1976). This structural trend consists of a hanging-wall anticline that formed above a west-dipping thrust fault. The western block of mostly west dipping Oligocene Pegu Rocks are thrown upon the eastern block of east dipping Miocene-Pliocene Irrawaddian rocks. The western block is structurally a thrusted anticlinal shape, but the two flanks are asymmetrical. The eastern flank is steeper and more exposed than the western flank with gentle dip. This area has two parallel mountain ranges which are Nyaungnigyin-Sunsite range and Taungbyagyi range in the central part (Fig. 2).

The sedimentary rocks crop out well in deeply dissected streams, road sections and locally uplifted ridges. There are four lithologic units of formation rank stratigraphic units. They are, in ascending order, Shwezetaw Formation, Padaung Formation, Okhmintaung Formation and Irrawaddy Formation (Fig. 3). The Padaung Formation focused in this research work is well exposed along Taungbyargyi Range, Kyargan Taung, Taungbyargyi Chaung and Thone Chaung section in the study area. This formation is mainly composed of the alternate bed of bluish grey shale and fine-to medium- grained, thin- to thick-bedded sandstones. The trough cross-stratifications, wavy and flaser bedding are also observed in the sandstones According to Khin Thet Htar (2001), the Padaung Formation is about 2400 feet thick in the study area. The debris of Gastropods, Bivalve, Echinoderm and Rugose coral are common in this formation. According to these fossil assemblages, the Padaung Formation may be regarded as of early Oligocene in age (Aung Khin and Kyaw Win, 1969).

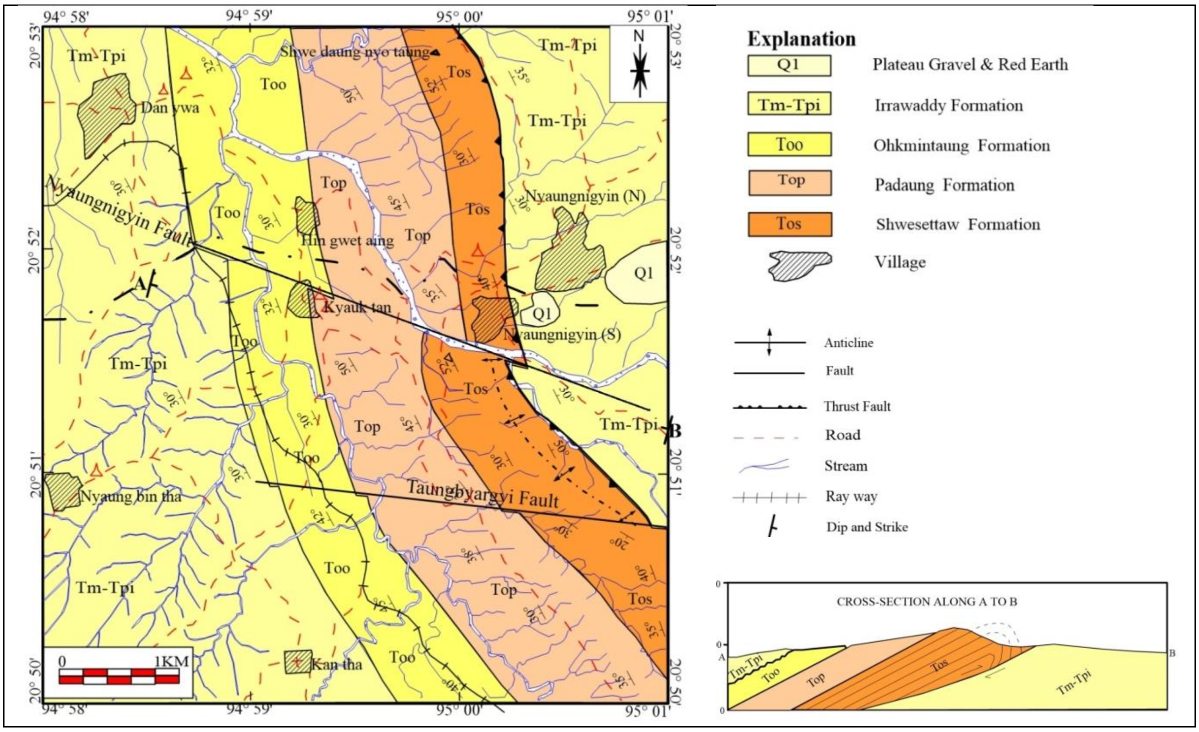

Figure (3). The geological map of Nyaungnigyin area (Modified after Khin San, 1993)

Background Theory

Sandstone is composed of particles that range in size through several orders of magnitude. The grains and matrix, therefore, represent populations of individual particles that vary greatly in size as well as in composition. The principal elements of texture are grain size, sorting, packing, shape, and orientation (Berg, 1986).The first two are the most significant and commonly measured elements.

Grain size is a fundamental attribute of siliciclastic rock. It is one of the important properties of such rocks. Particle sizes are classed according to Udden-Wentworth scale (Fig. 4). A useful modification of this scale is the logarithmic phi (Φ) scale, which allows grain-size data to be expressed in units of equal value. The mean size is the arithmetic average value of all the particles sizes in a sample (Boggs, 2006). The actual arithmetic mean of most sediment samples cannot be determined because of uncountable small grain in a sample. An approximation of the arithmetic mean can be arrived at by picking selected percentile values from the cumulative curve and averaging these values. The commonly used values in this calculation are 16^{th}, 50^{th}, and 84^{th} percentile values (Fig. 5). In calculation, the mean value is the average phi value of the grain size of 16^{th}, 50^{th}, and 84^{th} percentile values. The calculation formula is as following;

$$\text{Mean} = (\Phi 16 + \Phi 50 + \Phi\ 84) / 3$$

The size class of sediments can be easily determined from mean value by correlation with Udden-Wentworth scale (Fig. 4).

The sorting of the grain population is a measure of the range of grain sizes presented the magnitude of the spread or scatter of these sizes around the mean size (Boggs, 2006).It can be estimated in the field or laboratory by using hand lens or microscope and reference to a visual estimation chart. More accurate determination of sorting requires mathematical treatment of grain-size data. The mathematical expression of sorting is standard deviation. The standard deviation can be calculated from the following formula;

$$\text{Standard deviation} = (\Phi 84\text{-}\Phi 16/4) + (\Phi 95\text{-}\Phi 5/6.6)$$

Sorting corresponding to various values of standard deviation (Fig. 6) is defined as follow (Folk, 1974 in Boggs, 2006).

The principal goal of reservoir characterization is to describe petrophysics properties such as porosity and permeability (Lucia, 2007). Porosity is an important rock property because it is a measure of the potential storage volume for hydrocarbons. Porosity is defined as pore volume divided by bulk volume (Selley, 1998).

$$Porosity\ (\Phi) = \frac{Pore\ volume\ (Vp)}{Bulk\ volume\ (Vb)}$$

The quality of reservoir can be determined by the range of porosity. The range of porosity can be evaluated and classified as (Table 1) (North, 1985).

Diameter (mm)	Phi class[a] (ϕ)	Modal class	Sediment	Rock
		Boulders		
256	−8			
		Cobbles		
64	−6		Gravel	Conglomerate
		Pebbles		
4	−2			
		Granules		
2	−1			
		Very coarse		
1	0			
		Coarse		
0.50	+1			
		Medium	Sand	Sandstone
0.25	2			
		Fine		
0.125	3			
		Very fine		
0.062	4			
		Coarse		
0.031	5			
		Medium		
0.015	6		Silt	Siltstone
		Fine		
0.007	7			
		Very fine		
0.004	8			
<0.004		Clay	Clay	Claystone

Figure (4). The Wentworth grain size classification of clastic sediment

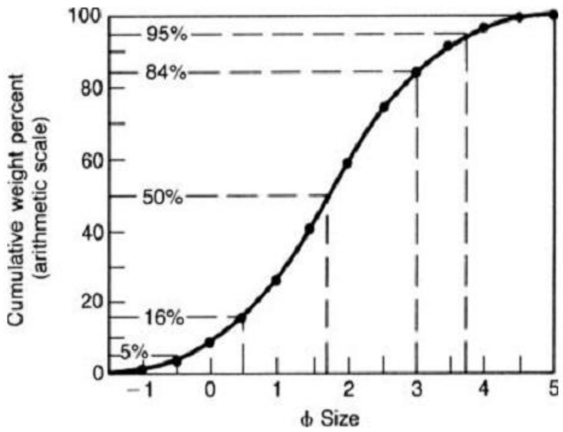

Figure (5). The method for calculating percentage values from the cumulative curve (Boggs, 2006)

Phi standard deviation	Verbal sorting
<0.35	Very well sorted
0.35 to 0.50	Well sorted
0.50 to 0.70	Moderately well sorted
0.70 to 1.00	Moderately sorted
1.00 to 2.00	Poorly sorted
2.00 to 4.00	Very poorly sorted
>4.00	Extremely poorly sorted

Figure (6). Sorting from inclusive graphic standard deviation (Boggs, 2006)

Table (1). Range of porosity classification (North, 1985)

Qualitative evaluation	Porosity(percent)
Negligible	0-5
Poor	5-10
Fair	10-15
Good	15-20
Very good	20+

Results and Discussion

To interpret the textural properties; grain size and sorting, six loose sand samples (KP-90, KP-58, SP-64, SP-102, SP-78 and KP-150) were used. In this study, the arithmetic cumulative curves was illustrated to know the parameters which must be specified for determining the value of the mean and sorting (Table 2). Based on sieving data, the mean value of KP-90, KP-58,SP-64, SP-102, SP-78 and KP-150 samples of Padaung Formation are 2.36, 2.26, 2.4, 2.3, 2.5 and 1.93 (average = 2.29). These values are fine and medium sand size class of Wentworth (Fig. 7). The grains of KP-90, SP-64, SP-102, SP-78 and KP-150 samples are poorly sorted according to standard deviation. The KP-58 sample is moderately sorted (Fig. 8).

Table (2). Grain size and sorting of Padaung Sandstones

Sample No	Φ5	Φ16	Φ50	Φ84	Φ95	Mean	Grain Size	Standard deviation	Sorting
KP 90	0	1.4	2.5	3.2	4.2	2.36	fine	1.08	Poorly sorted
KP 58	0.2	1.4	2.4	3	3.9	2.26	fine	0.9	Moderately sorted
KP 150	-0.9	-0.1	2.4	3.5	4.4	1.93	Medium	1.7	Poorly sorted
SP 64	0.1	1	2.6	3.6	4.1	2.4	fine	1.25	Poorly sorted
SP 102	-0.2	0.6	2.6	3.7	4.3	2.3	fine	1.45	Poorly sorted
SP 78	0.3	1.4	2.5	3.6	4.3	2.5	fine	1.15	Poorly sorted

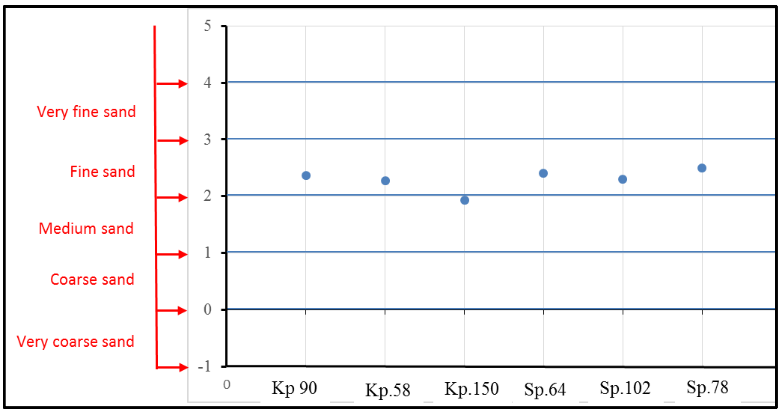

Figure (7). Grain size value of Padaung Formation

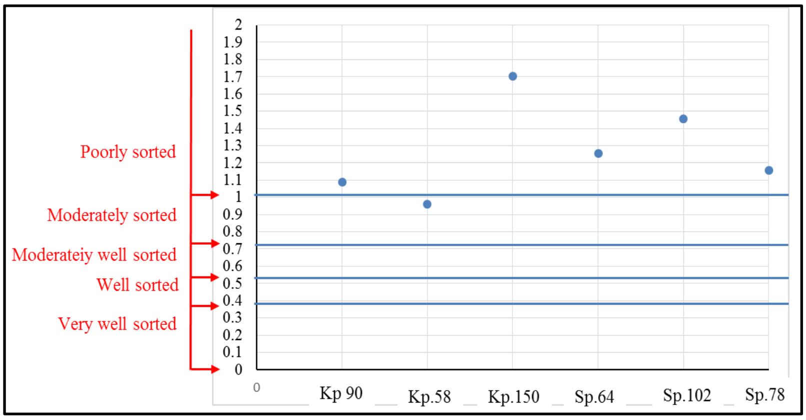

Figure (8). Sorting value of the Padaung Formation (Folk, 1974)

Relative porosity

The porosity and permeability of uncemented sand was related to grain size and sorting value by Beard and Weyl (1973). The relative values of porosity and permeability can be got by plotting on the diagram of Beard and Weyl (1973). The graph of related diagram of Beard and Weyl (Fig. 9) shows that the porosity of Padaung sandstones is from 29% to 36%. The permeability is also from 400 to 50000 mD.

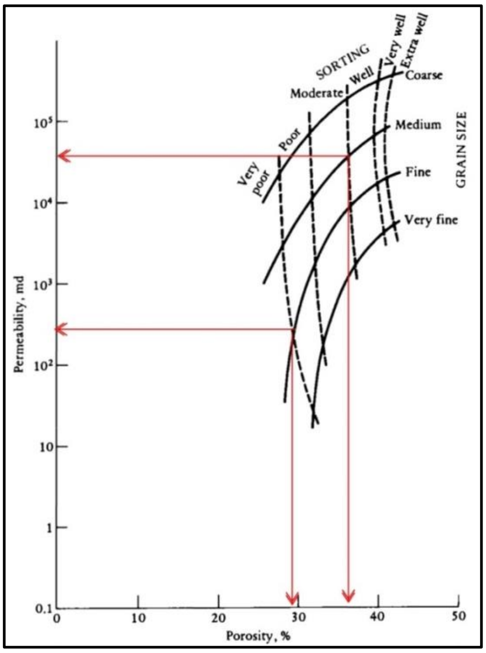

Figure (9). Porosity and permeability relation graph of Padaung Sandstone (Beard and Weyl 1973)

Effective porosity

Porosity analysis was done from six samples for Padaung Sandstone. These are SP-23, SP-78, SP-102, KP-50, KP-58 and KP-90. In porosity analysis, the sandstone samples were saturated in water after measuring of the volume and the weight of sandstone samples. The weight of water in pore is got by subtraction between the weight of wet sample and dry sample. The volume of water is the ratio of the weight in pore and the specific gravity of water. The porosity of sample can be calculated from the pore volume and the sample volume. The porosity data of sandstone samples of Padaung Formationn are shown in table (3).

Table (3). The porosity and reservoir quality of Padaung Sandstones

Samples No	Dry Weight (g)	Wet Weight (g)	Pore Volume (cm^3)	Bulk Volume (cm^3)	Porosity (%)	Reservoir Quality
SP.23	120	132.5	12.5	50.4	24.8	Very good
SP.78	88.7	102.5	13.8	38.88	35.49	Very good
SP.102	146.3	164.9	18.6	63.69	29.08	Very good
KP.50	200	228	28	84	33.33	Very good
KP.58	192.2	215.8	23.6	78.54	30.05	Very good
KP.90	154.4	168.5	14.2	64.32	22.07	Very good

Reservoir potential

The essential requirements for good reservoir rocks are high porosity and permeability and a sufficient thickness and volume. The reservoir rock must have retained much of its effective porosity. Porosity is a basic feature of the sediment and depends on the textural properties. The textural characteristics (grain size, grain shape and sorting) are the main controlling factors of the petrophysics properties of sandstones. Theoretically, porosity is independent of grain size for uniformity packed sands. In practice, however, coarser sands sometimes have higher porosities than do finer sands. Porosity increases with improved sorting. As sorting decreases, the pore between the larger, framework- forming grains are infilled by the smaller particles. Permeability decreases with sorting for the same reason. Porosity might decrease with spherical because spherical grains may be more tightly packed than sub-spherical ones. The standard deviation value of Padaung sandstones pointed poorly to moderately sorted. The porosity and permeability of Padaung Sandstones is from 29% to 36% and from 400 to 50000 mD based on the graph of related diagram of Beard and Weyl. The effective porosity also ranging from 22.07 to 35.49 percent. So, the Padaung Sandstones in Nyaungnigyin Area are very good to excellent reservoir quality according to their porosity and permeability.

Conclusion

The study area is covered by Early Oligocene to Late Oligocene marine sediments and Late Miocene to Pliocene fluvial sediments. The formations exposed in the study area are Okhmintaung Formaion (Late Oligocene), Padaung Formation (Middle Oligocene), Shwesettaw Formation (Late Oligocene) and Irrawaddy Formation (Late Mio-Pliocene). The Middle Oligocene strata include bluish grey clays and fine-to medium- grained, thin- to thick-bedded sandstones. Based on sieving analysis, the mean size ranging from 1.93 Φ to 2.5 Φ for Padaung Sandstones with 0.96-1.70 standard deviations. The average mean value and standard deviation interpreted, Padaung sandstones are composed mainly of poorly to moderately well sorted, fine grains. The relative porosity and permeability of Padaung sandstone are from 29% to 36% and from 400 to 50000 mD based on the relationship between porosity and permeability to grain size and sorting value of Beard and Weyl (1973). The effective porosities of six sample of Padaung Formation show 22.0-35.45 percent. Both relative and effective porosity value of Padaung Sandstones interpreted good to very good petroleum reservoir potential. However, this research work cannot perfect to apply for exploration without combination of another works. The volume calculation of sand beds and trap estimation could not be conduct in the present study because of time limited and the other conditions. Actually, subsurface data will need to explain detailed stratigraphy and reservoir potential. Geophysical analysis is also recommended to know the structural style that is important to mention about trap formation.

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