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The Effects of Porosity on The Anisotropy Parameters of The Slope Fan Facies Sand Reservoirs in The Deepwater Kutai Basin, East Kalimantan, Indonesia

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Abstract. For good interpretation and modelling, knowledge about the effects of anisotropy and its relationship with reservoir properties is needed. Related to this issue, this study evaluated the effects of porosity on the anisotropy parameters for sand reservoirs deposited in the upper slope fan facies. The study objects are obtained from core plug samples of sand reservoirs in the deep-water Kutai Basin. Core plug samples were collected from 13602.5 ft to 13704.5 MD depth. The ε, γ, δ, and η anisotropy parameters data were obtained by ultrasonic measurements, and porosity data were obtained by laboratory measurement with Coreval 700 apparatus and Boyle's law. The analysis results show that the relationship of the anisotropy parameters with porosity appears when high-porosity sandstone and low-porosity sandstone are separated. The plots of anisotropy ε, γ, and δ, show trends for greywacke, with increasing anisotropy value the porosity increases. The effect of porosity on the high porosity (29%-37%) sandstone shows a steeper change than on the lower porosity (12%-13%) sandstone. The analysis also shows that the higher composition of lithic mineral grain reduces the effect of anisotropy on porosity.

1. Introduction

Kutai basin is Indonesia's second-largest hydrocarbon basin with oil reserves of 2.47 MMBO and 28.7 TCF of gas [1]. Based on the results of the 3D seismic survey, several fields were found in the basin, one of which is the Sadewa Field. The Sadewa Field is one of the fields to be developed, therefore good modelling and interpretation are needed. Good modelling and interpretation require knowledge of the effect of anisotropy, and its relation to the physical properties and elastic properties of source and reservoir rocks. One way to find out the anisotropy of a reservoir is through core samples. This research will discuss the method of measuring anisotropy in the rock core of one of the wells in the Sadewa Field, well SDW-5ST1. After the anisotropy data is obtained, an analysis of the relationship between anisotropy values and the physical properties of porosity is carried out.

Seismic anisotropy is defined as the dependence of seismic velocity on the direction of wave propagation [2]. Weak anisotropy which is considered to be the common case of anisotropy is explained by three anisotropy parameters, ε, δ, and γ [2]. The three parameters can be calculated using the anisotropic medium's stiffness tensor and used to determine phase and group velocity. The relationship of ε and δ shows the non-elliptical part of the medium, the combination of the two parameters introduced as the un-ellipticity with notation η [3]. Anisotropy is affected by three main factors: intrinsic, thin-bed effect, and pressure on the rocks [4]. The intrinsic factor is related to the lineament of minerals forming the rocks [4].

Porosity (ϕ) is the ratio volume of the pores with respect to the total volume of the rock [5]. The comparison is usually expressed in percent. This paper evaluates the effects of porosity on the anisotropy parameters in the sandstone sample cores of the Kutai basin sand reservoirs deposited in the slope fan facies.

2. Data and Methods

The ε, γ, δ anisotropy and η can be calculated from ultrasonic measurements of P-wave and S-wave velocities (Vp and Vs) at specific angles. The ultrasonic Vp and Vs velocity of plug samples were measured by using 1 MHz ultrasonic pulses carriers and receivers equipped with piezoelectric transducers. Figure 1a shows the conventional anisotropy measurement using three core plugs cored at 0^o (vertical), 45^o, and 90^o (horizontal) to the vertical axis symmetry of the plugs used in traditional anisotropy measurements. Core handling in this way should be accurate to ensure angular consistency and accuracy during the drilling of the core. However, this measurement method is difficult to perform if the core plug is damaged or cracked. In this study, the measurement approach used is the single-core plug method introduced by Wang shown in Figure 1 [6]. Measurements were made at 8 points in each sample shown in Figure 2 with the axis of symmetry following the VTI model. There are 10 core plug samples collected from the slope fan facies deposits reservoirs.

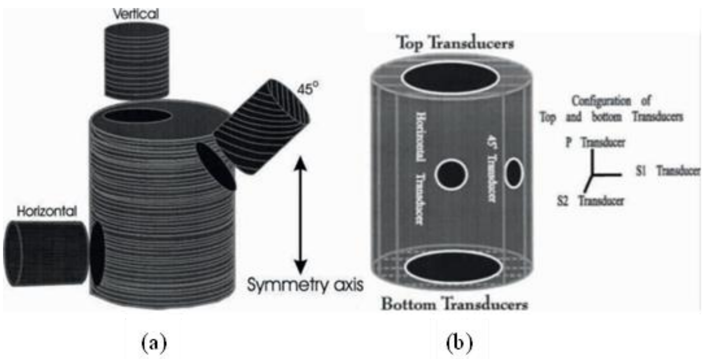

Figure 1. (a) Conventional anisotropy measurement (b) Anisotropy measurement using a single core plug [6].

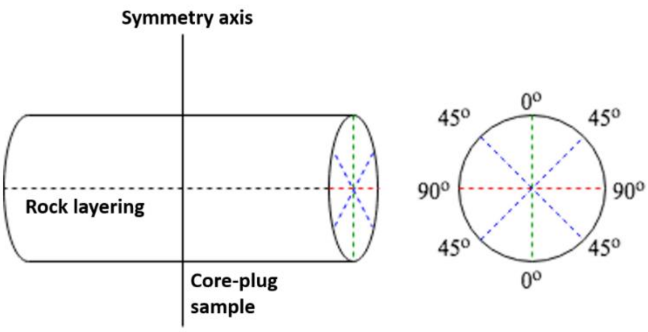

Figure 2. Illustration of 8 measurement points on rock core samples with VTI model.

The sample cores' porosity was measured using Coreval 700 apparatus on which Boyle's law was applied. The method permits grain volume measurement over a range of core plug sizes to an accuracy of potentially less than 0.2% over most core porosity ranges. Any potential for human-related error is minimized by utilizing digital pressure/temperature gauges and a computerized system.

3. Results and Discussions

Seven (7) core-plug samples have been measured for the anisotropy parameters and have been tested for porosity core analysis. The anisotropy parameters values of the sample ranged from 0.0709 to 0.3576 for ε, from 0.0377 to 0.3511 for γ, from 0.0785 to 0.4637 for δ, and from -0.1279 to 0.0034 for η. The samples have porosity values ranging from 12.87% to 37.17% at ambient conditions. The summary result of the measurement of anisotropy parameters and helium porosity for the core-plug samples is shown in Table 1.

Table 1. The anisotropy and the porosity measurement result of SDW-5ST1 core-plug samples.

Samples	ε	γ	δ	η	*Φ* (%)
CICO-001792	0.186170213	0.188498243	0.264489099	-0.051223024	37.17
CICO-001796	0.102051026	0.037735841	0.097966483	0.003415361	29.61
CICO-001800	0.357609033	0.351145555	0.463681757	-0.055035141	36.56
CICO-001804	0.128976367	0.156914842	0.211978654	-0.05828987	34.78
CICO-001808	0.190967023	0.255814183	0.428593516	-0.127949684	13.53
CICO-001812	0.082448154	0.079178907	0.171107739	-0.066054659	13.61
CICO-001820	0.070941027	0.076738928	0.078470149	-0.006507788	12.87

Integration of seismic, well-log, and petrographic data analysis shows that the sand reservoirs (where the sample core plugs were extracted) were deposited in the upper slope fan facies [7]. In the seismic section, the upper slope fan facies are expressed as discontinuous packages of mounded reflectors perched on the front of local upper slopes, which are displayed as serrated log characters corresponding to the intercalation of sand-shale deposits in the core.

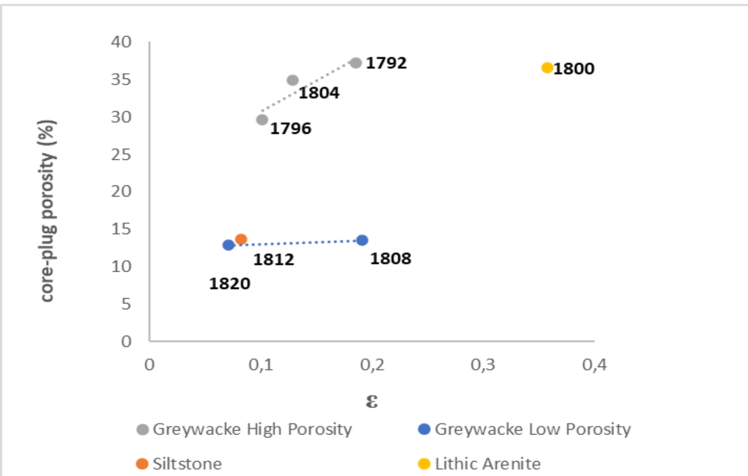

Figure 3. Cross plot of anisotropy parameters ε with porosity.

Figure 3 shows the cross plot of the anisotropy parameter ε with the percentage value of porosity. The cross plot denotes that the relationship between anisotropy parameters ε with porosity appears when high-porosity sandstone and low-porosity sandstone are separated. To help the analysis, the core plug samples are also classified based on their lithology. The cross plot of anisotropy parameter ε shows a trend that for greywacke, with increasing anisotropy value the porosity increases. The effect of porosity on the high porosity (29% -37%) sandstone shows a steeper change than on the lower porosity (12%-13%) sandstone. The same cross-plot analysis results were also generated for anisotropy parameters γ and δ showed in figure 4 and figure 5. The cross plots also indicate that the higher composition of lithic mineral grain (lithic arenite sandstone) lesser the effect of anisotropy on porosity.

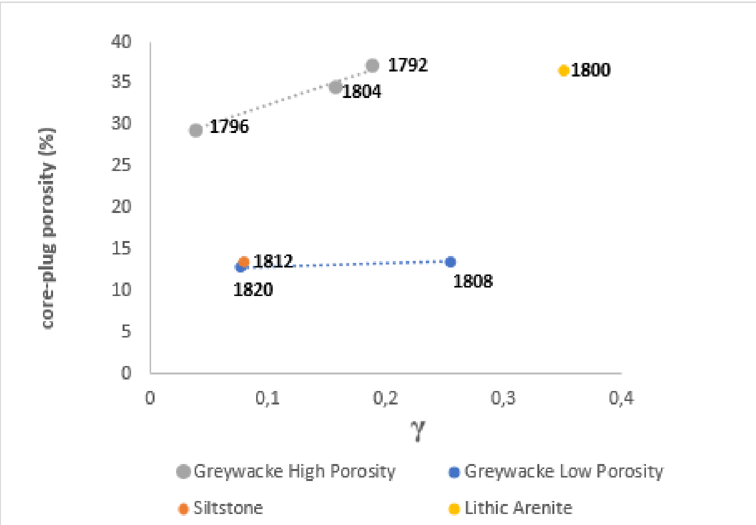

Figure 4. Cross plot of anisotropy parameters γ with porosity.

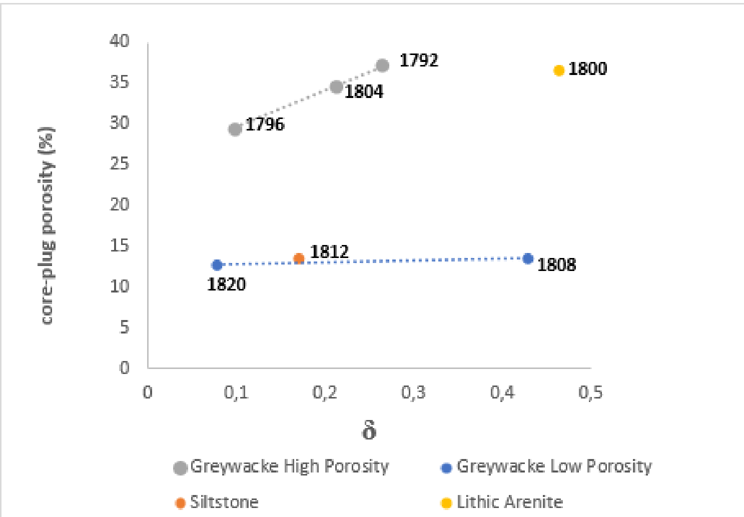

Figure 5. Cross plot of anisotropy parameters δ with porosity.

Unlike the other anisotropy parameters, the relationship between η and porosity could not be seen from the cross-plot shown in figure 6. The relationship between the two parameters still could not be seen when the analysis of the high-porosity sandstone and the lower-porosity sandstone are separated.

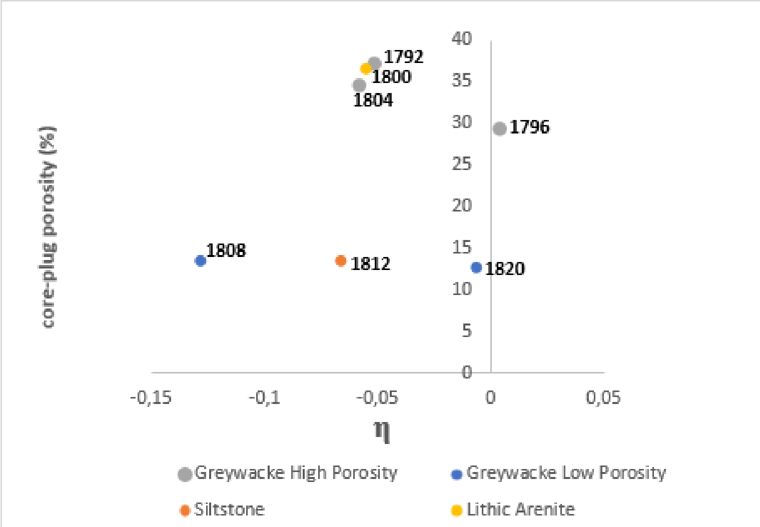

Figure 6. Cross plot of anisotropy parameters η with porosity.

4. Conclusion

Seismic anisotropy of core-plug samples measurement has been done with the ultrasonic approach by obtaining the P-wave dan S-wave data on various angles on a single core plug. Analysis done with the obtained anisotropy data shows that there is a relationship between anisotropy parameters and porosity, with a general trend for greywacke, with increasing anisotropy value the porosity increases. For anisotropy parameters ε, γ, and δ, the effect of anisotropy on porosity is bigger on sandstone with high porosity (>30%). The analysis also shows that the higher composition of lithic mineral grain reduces the effect of anisotropy on porosity.

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