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Analog Study of Fluid Flow on Deformation Band at Petani Formation, Riau, Indonesia

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Abstract. Deformation band at Petani Formation included in the type of disaggregation band, where deformation on this formation resulted from tectonics stress at Plio – Pleistocene affecting sandstone layer that being deformed and resulted strain localization feature, filling with iron oxide sand. The measurement for this research was using grain size analysis, distribution analysis of shear trends, and measurement of permeability for each deformation band. The result shows that grains size dominantly fine sand – medium sand (0.149 mm – 0.297 mm), followed by the distribution of deformation trends showing NW – SE direction, and also good in permeability (3.4 mD– 188.4mD). It can be concluded that the structural features of deformation band can also create good permeability for fluid flow.

1 Introduction

Deformation bands are the most common strain localization features found in porous and sedimentary sandstones, including quartz precipitates, gravitational and tectonic landslides that affect sandstones in hydrocarbon and aquifer reservoirs. This occurs in different types of tabular deformation zones where the granules undergo a shift, rotation and/or fracture reorganization during dilation, shear, and/ or compaction processes. The band deformation with the most common shear component accommodates a sliding offset up to millimeter or cm. Deformation bands can occur in the form of single structures or cluster zones, and are the major zone deformation element in porous rocks. Factors such as porosity, mineralogy, grain size and grain shape, lithification, stress conditions and loading control the type of band deformation that is formed. Of the various types, deformation bands of phyllosilicate and deformation of cataclastic bands show the greatest decline in permeability, and thus have the greatest potential to influence fluid flow. Sorting bands, where non-cathartic, granular flow is the dominant mechanism, show little influence on fluid flow Aided by chemical compaction or cementation [1].

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Character deformation band in Kampar Region has a special character that needs to be mapped and analyzed in detail, this is quite different from the studies commonly found in Tertiary rocks.

2 Geology Regional

2.1 Geology of Research Area

The research area covered with Petani Formation that composed of mudstone, containing carbon, lignite, silt and sandstones. Based on the geological map sheet of Pekanbaru at scale 1: 250.000, at Tapung Hulu and Batubelah Kampar Region, there are three types of formation developed around research area which are Petani Formation, Telisa Formation, and Minas Formation [2]. Structures geology developed in the research area include elongated anticline folds with west-southeast direction. Folds are exposed the lithology formation. This is influenced by the effects of Indian-Australia plates subducted Eurasian Plate, resulting in an inversion tectonic process during the sedimentation of Petani Formation. Kusau Makmur area, Tapung Hulu, Kampar regency, Riau and Batu Belah, Kampar regency, Riau has a considerable distance (+ 35 km) but has a similarly deformed band characteristics. This indicates that the formation of the band's deformation are formed quite widely and evenly and allegedly due to tectonic processes[3,4].

We can assume the conditions on subsurface of the reservoir under certain conditions can be reflected from the existence of rock outcrops exposed to the surface[5,6]. Therefore, it is important to understand the condition of reservoir quality changes in the condition of the deformed band layer, whether the band deformation becomes a barrier or becoming capable of flowing fluid between two layers.

Research area geologically included at Petani Formation that deposited in late Miocene – Pliocene. From two sites of location in Tapung Hulu District and Batu Belah District, deformation band is formed, and if drawn between the two positions is closely related to the tectonic pattern formed at the Plio-Pleistocene age, with the northwest-southeast direction.

2.2 Deformation Band

Deformation Bands are a common type of local strain in porous rocks that are deformed and formed in the form of single structures, clusters, and in fault zones due to fractures[7][8]. Faults are generally considered to be fractures or surfaces across which there is appreciable relative displacement, or to be zones of such fractures or surfaces. Further, small faults with displacements less than a few meters generally are treated as minor, or as secondary structures relative to major faults nearby[7]. In sandstone, deformation band/band deformation is limited to porous granular media, particularly porous sand and sandstone[9]. There are several important characteristics that distinguish deformation bands from ordinary fractures (such as slip surfaces or extension fractures). First, they are thicker and exhibit smaller offsets than classical slip surfaces of comparable length. Also, whereas cohesion is lost or reduced across ordinary fractures, most deformation bands maintain or even increase cohesion. Furthermore, deformation bands often exhibit a reduction in porosity and permeability, whereas both slip surfaces and tension fractures are typically associated with a permeability increase. Strain hardening behaviour, commonly associated with deformation band formation, also contrasts to the strain softening associated with classical fractures. Kinematically, deformation bands can be classified as dilation bands, shear bands, compaction bands or hybrids of these types [10].

Although a kinematics-based classification is logical, it is also useful to classify deformation bands in terms of the dominant deformation mechanism operating during their formation. Deformation mechanisms depend on internal and external conditions such as mineralogy, grain size, shape, sorting, cementation, porosity and stress state. Different mechanisms produce bands with different petrophysical properties. Thus, such a classification is particularly useful where permeability and fluid flow are an issue. The dominant deformation mechanisms are: (1) granular flow (grain boundary sliding and grain rotation)[11]; (2) cataclasis (grain fracturing and grinding or abrasion) [10 -12]; (3) phyllo-silicate smearing[15]; (4) dissolution and cementation[16].

3 Methodology

The methodology used for measuring the deformation band and its connectivity was conducted on several steps. Firstly, taking the eight core samples at field station and conduct measurement on field site such as length, width, thickness, trends, description of the samples by using field geological tools and cluster the data to define the difference between single deformation band and group of deformation band (show in graphic displacement vs thickness in logarithmic scale [17] and also doing measurement in grain distribution of each samples. Then, we plot all measurement trends (105 sets data) on stereographical projection for giving two-dimensional or projection image of the surface of a sphere as a place of geometry orientation of plane and line. This stereographic projection used for solving problems related to geometry of the magnitude of direction and angle in the geological analysis of geological structures because this projection can describe the geometry of the position or the orientation of the plane and line in the field [18]. As we can see the trends of deformation band as geological structure that define stress and relative tectonic direction from measurement of stereographic projection, next we will measure the flow in each size at laboratorium to define the permeability barrier by Permeability measurements using a tool called Gas Permeameter.

Measurement using this tool there are several procedures that must be done, which the core samples should be in a clean and dry condition to get the best results. The sample is cleaned with solvent and dried in an oven before the gas permeability measurement, Core samples will be made in cylindrical core plug that must be perpendicularly sized + / - 0.005 inches to get the best results. After that the process continued to prepare the instrument and ensure there are no obstructions in the chore holder or end stems. Then make sure the tubing fittings are in comfortable condition and leak free. Furthermore, when loading the friable core, a 200-mesh disk-shaped screen is placed at the top and bottom of the sample to prevent sand migration from intake holders of flow meters. After that set the all panels to bypass position, and then perform the core measurements (length, height, and area), next is inserting the cores into the system core test system, then set the pressure of the compressor with the nitrogen and note the pressure, and the flow rate. Then the value of permeability will be obtained by using the darcy equation. The value of this permeability will be plot on graphic distribution to see the flow value of the deformation band.
The equations as follow :

$$K = \frac{\mu Q L}{A (P_1 - P_2)} \tag{1}$$

where K is shown value of Permeability (darcy) , Q shows the flow rate in cc/sec, μ is viscosity, A show value of area in cm2, L is length (cm) , and P is Pressure, atm. So by using this equation, effect from the deformation band between two layer can be defined clearly.

4 Result

The deformation bands in the research area (**Fig. 1**) on the left showed two different characteristics in deformation band, where on Fig 1a shows the characteristic of this deformation band consist of loose fine sand to medium sand (**Fig. 2**), yellowish brown color, good sorting, dominated by quartz mineral and iron oxide, good porosity. deformation band was perpendicular to the layer and also cutting each other, and from stereographic projection shows that stress on the area dominated by NE-SW direction (**Fig 3**).

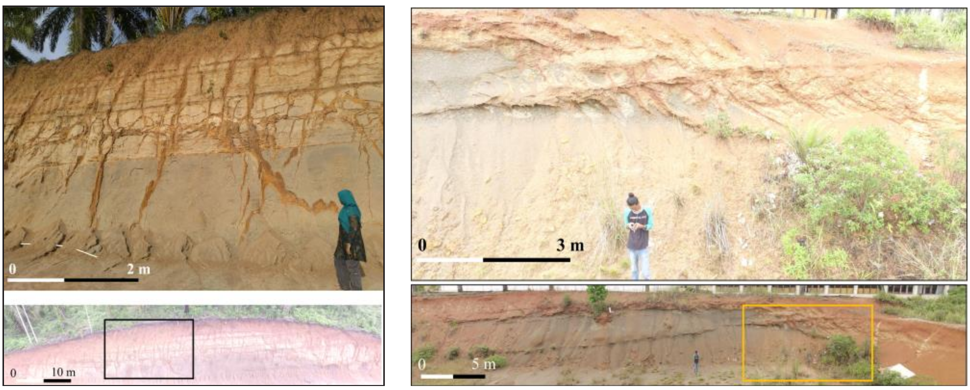

Fig. 1. Structural feature of deformation band at Tapung Hulu (left) and Batu Belah, Kampar (right).

On **Fig 1** on the right, shows the characteristic of this deformation band consists of loose fine sand, reddish brown colour, good sorting, also dominated by iron oxide. deformation band was more gently dip to the layer showing different thickness band that wider between the layer, and from stereographic projection shows that stress on the area dominated more W-E direction (**Fig. 3**).

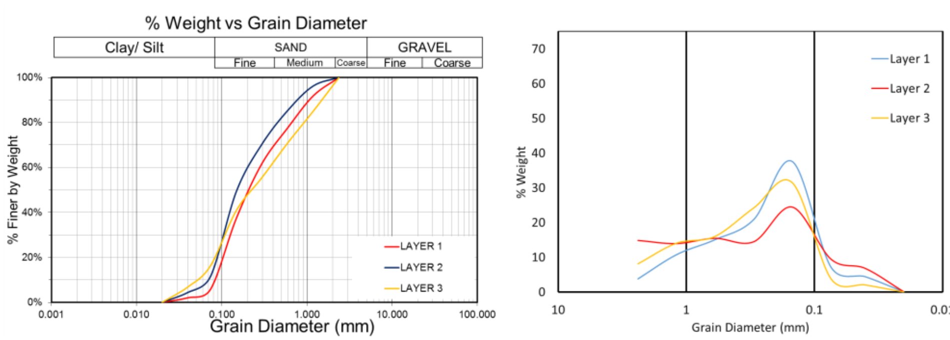

Fig 2. Distribution % weight vs grain diameter analysis and cumulative percentage for define dominant size of grain on different lithology sample.

From reconstruction of historical geology, the deformation was affected by the tectonic process with several phases. Based on the results of the 105 plots of data shows the condition of movement dominated by tectonic movement that trend southwest-northeast resulting deformation band that perpendicular to the stress (**Fig. 3**). Based on[1], pattern that occurs in this area in line with the disaggregation band. This band formed due to the final cataclastic process which then lifted to the surface and produces a tension fracture which then the fracture is filled by sediment material from deposition after tectonic process. Field data show that deformation bands occur as isolated structures, linked systems, complex zones of multiple, interconnected deformation bands.

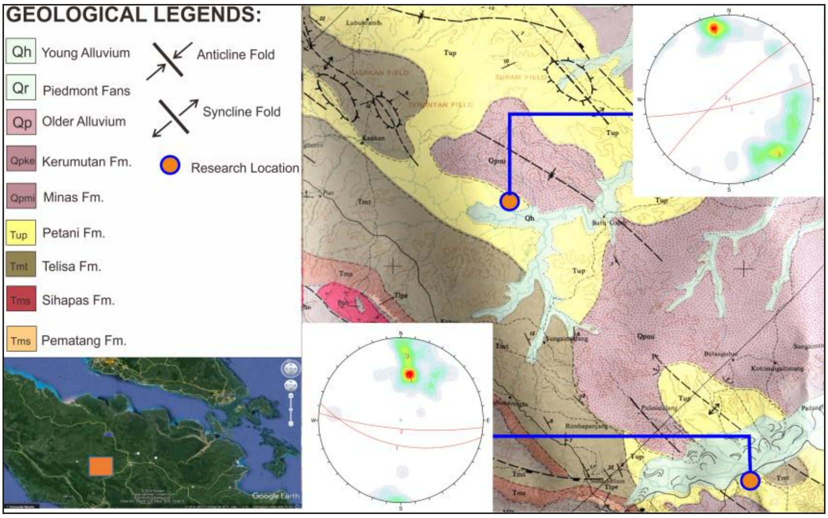

Fig 3. Stereographic projection of deformation band overlay with geological map.

Permeability result showing that deformation bands having permeability ranges from 5.4 mD – 188.4mD (Tables 1). Permeability value result show from northern area site are higher than on the southern site. Tapung Hulu, permeability value ranges from 34 mD–188.4 mD. On Batu Belah area show permeability value ranges from 5.4 mD – 13.1 mD (Table 1).

Based on this different ranges permeability value, probably there can be some factors that can be concluded, such as different level of stress event on this two area, because if there is any difference in the direction of the stress, its also possible to influence process development of deformation band, and also the mineralogical differences, the grain size, displacement and thickness of deformation band also need to be considered when looking at different permeability values between these two locations.

Table 1. Result data of permeability on samples.

Samples	Location	Q high (cc/sec)	Qlow (cc/sec)	High DP (atm)	Low DP (atm)	K (mD)
TP-1	Tapung Hulu	2.53	1.74	0.041	0.025	73.3
TP-2	Tapung Hulu	2.37	1.74	0.082	0.072	94.5
TP-3	Tapung Hulu	2.28	1.75	0.225	0.211	54.2
TP-2	Tapung Hulu	3.17	1.75	0.245	0.234	188.4
TP-2	Tapung Hulu	2.025	1.74	0.327	0.315	34
C2	Batu belah	1.0	0.92	0.361	0.352	13.1
C3	Batu belah	1.3	1.252	0.598	0.585	5.4
C3	Batu belah	1.4	1.35	0.51	0.502	9.3

μ = 0.018 (Viscosity of Nitrogen Gas)

5 Conclusion

So based on this research there are several conclusion can be defined from this research, which is :

1. The deformation band characteristic in research area shows that the pattern is more considered to be disaggregation band after comparing on two location that resulted from stress release after tectonic occurs.
2. Permeability result showed that deformation band at tapung hulu (northern site) having higher permeability than Batu Belah (southern site), this considered to be direction and level of stress and that happens in this two area that resulting different permeability value on this two location.

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