Passive Seismic for Hydrocarbon Indicator: Between Expectation and Reality

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Abstract. In between 5–10 years, in our country, passive seismic method became more popular to finding hydrocarbon. Low price, nondestructive acquisition and easy to mobilization is the best reason for choose the method. But in the other part, some people are pessimistically to deal with the result. Instrument specification, data condition and processing methods is several points which influence characteristic and interpretation passive seismic result. In 2010 one prospect in East Java basin has been measurement consist of 112 objective points and several calibration points. Data measurement results indicate a positive response. Furthermore, in 2013 exploration drilling conducted on the prospect. Drill steam test showes 22 MMCFD in objective zone, upper – late oligocene. In 2015, remeasurement taken in objective area and show consistent responses with previous measurement. Passive seismic is unique method, sometimes will have difference results on dry, gas and oil area, in field production and also temporary suspend area with hidrocarbon content.

1. Introduction
East Java basin is one of the oil and gas production field in Indonesia. Almost the entire formations are proven in containing of hydrocarbon. There are many play types developed in this basin, from the Eocene formation up to Pleistocene formation are proven to be oil and gas reservoir. At the end of the year 2013, the drilling activity in the exploration well was established in the one of the prospect location. The prospect is located relatively close to the coast and borders the working area. Furthermore, it also be challenging since the prospect surrounded by the many dry hole wells. The total depth that can be aimed by the wells is approximately 7800 ft with the vertical drilling direction. Based on the well test, it was recorded that 22 MMCFD of gas out from an objective zone. Even though the zone was shifted from the previous prediction, which was previously expected that the prospect would be generating oil, however the prospect still interesting to be studied and assessed especially related with the petroleum system which is the background of the area. From this paper, the writer want to review the new play potential from the well evidences based on passive seismic acquisition.

Geologically, East Java Basin is located in the active tectonic zone which has at least three tectonic phases [1]. This basin elongated in the direction of W-E with a length about 250 km and bordered by Karimun Java arc, Sunda Shelf, Meratus high, and Masalembo high. Generally, the basement rocks of this basin is pre-tertiary. The rifting occurred in the lower Eocene, after that in the middle Miocene the tectonic is reactivated and made a few of the folding block. The tectonic phase begins in the Pleistocene until recent which is based on the many references, there are uplift phase and in some zone were occurred wrench fault. Basement rock in the East Java basin is related with pre-tertiary metasediment which its characteristic consist of folding and layering, that can be found in the seismic pattern. The cutting result from some wells that penetrated the basement shows that the basement can be divided based on the minerals namely, slate, volcaniclastic, metasislone, metagraywacks, diorite, marble, metaquartzille, vitric tuff, schist, andesite, phyllite and vitric tuffbasalt. Most of the petroleum system in the basin
formed at the East Java graben system, as a result of collisions that occur in the back arc basin. According to some studies, the source rocks are located in the Ngimbang Formation with the age of Eocene to Oligocene. The formation has two main facies, namely fluvio deltaic and lacustrine. The fluvio deltaic facies is dominantly by calcareous shale and coal, which is type three of kerogen. The lab analysis shows that TOC from the formation is around 2-17% on the shale and 20-80% on the coal, also the HI reach to 100. Otherwise, on the lacustrine facies the TOC result is around 2-4% with HI in 400. The hydrocarbon filling process occurred in the Miocene until Pleistocene. In general, the source rocks from East Java Basin are mature, although in some places are immature, which happens because the temperature and pressure are not working ideally. The dominant trap mechanism in the basin is stratigraphy and structural.

2. Methodology
Passive seismic is a method to find hydrocarbon. Initially, the measurements are performed in the geotechnical field. Along with the development processes, passive seismic measurements are performed in areas containing hydrocarbon that shows a certain frequency (2-6 Hz) there is a pattern and a distinctive character on the spectral amplitude vs. frequency. Whereas in the certain frequency above the reservoir zone that contain hydrocarbon will be shows the changing of amplitude [4]. On the lowest frequency, the natural movement from the oceanic crust in the whole of the earth will be made dominant noise between 0.05 and 0.2 Hz [3]. Furthermore, the human activities and wind movement will be recorded on the higher frequency (>1 Hz). There are several hypotheses about the causes of the emergence of passive seismic measurement anomalies in the areas which containing hydrocarbons.

As an example of the signal anomaly is the result of amplification or resonance scattering of hydrocarbons in the subsurface. Whereas the assumption is interaction between the hydrocarbon fluid and porous rocks which can distort natural signals from in the earth [2]. The ideal method to find hydrocarbon is not only depends on the one method, but there are many methods that can be tried to support the existence hypothesis of the hydrocarbon. The benefit of the passive seismic method is the data that can be used are from the measurement which is relatively easy, quick, low risk, cheap, and nothing the destructive vibrating source. The measurement can be carried out on the frontier zone with the relatively big population. By calibrating of the precise locations or wells, misinterpretation of passive seismic data can be minimized. The data result is also affected by technical specifications of seismometers. The bandwidth wide and sensitivity of the tools have a little role in the method. Ideally, using three components seismometer, response frequency 0.03-50 Hz, the sensitivity about 2000-3200 V/ms-1, and the dynamic range higher than 145 dB. Dealing with the issue about the noise, it can be minimized in several ways such as measurement time plus, time windowing, or stacking process time series data. It happens because the general noise that appears periodically, while the data tend to be quasi stationary. Process time windowing carried out to improve the S / N ratio.

This research has a goal to test the consistency of the data by doing some variations in the time of the measurement between 90 minutes, 3 hours, and 24 hours. Furthermore, the data processing following the steps namely, demeaning and detrending, windowing, FFT, stacking, smoothing, and attribute analysis. The author uses some passive seismic attributes to test for the presence and consistency of the method. PSD (Power Spectral Density) attribute 3Hz, PSD-IZ, and Attribute V/H ratio are some of the attribute that are used by the author in this research. Attribute PSD 3 Hz is done by getting the value of the Z component (up and down) at a frequency of 3 Hz. In general, the presence of hydrocarbons will be directly related with the signal on this attribute. PSD IZ is the integral of the signal spectrum Z component which has a frequency range 1.7 - 3.7 Hz. This attribute can be used for the highest noise condition. The last attribute is V/H ratio, which is used to reduce the effects of radiation on daily measurements in every measurement. Generally, the hydrocarbon existence anomaly is related with the high of the V/H attribute ratio. Furthermore, all of the attribute will be showed the same pattern and consistency.

As a point for calibration, will be conducted the measurement on more than a few key points, namely wells containing oil, gas, oil and gas wells as well. There are approximately 12 keys as reference point. Measurement is not only done in the area of oil and gas production, but also to plug the well with temporary conditions.
In this study, the data used are time series recorded on three components seismometer. Each data set consists of three time series data toward East-West, North-South, Up-Down. In general, data recorded with duration 90 minutes and sampling frequency 100 Hz. Hydrocarbon characterization is done by extracting some passive seismic attribute data. Ideally some results of processing some attribute show consistency trend.

In detail, the processing is done with several stages:

a) **Windowing** is one way to identify the signal and noise. This step is performed to obtain free noise data. It is based on the ratio between the short-time average (STA) and the long time average (LTA), which signals with minimum noise will have ratio STA / LTA ~ 1. Windowing is done by selecting the signal with a length of approximately 1 minute.

b) **Fast Fourier Transform**, the process of transforming the signal in another form, in this case the recorded signal is the domain of time series. For further analysis of the signal is converted to a frequency series.

c) **Stacking** to improve the signal to noise ratio. Several methods to reduce noise is by stacking on the entire received signal. This is assuming that the incoming noise discrete, not stationser. So it will be reduced if stacking.

d) **Smoothing** performed for doing moving average

e) **Horizon spectra** is to combine spectral components with East West and South North.

f) **Calculate** vertical and horizontal ratio.

![Methodology and Data Processing](image.png)

**Figure 1.** Methodology and Data Processing
Figure 2. Raw Data of Passive Seismic (left) and ratio V/H with several time

Figure 3. Time lapse recording in discovery well, showing the consistency of hidrocarbon signal in low frequencey 2-4 Hz V/H ratio and PSD IZ

3. Conclusion
Passive seismic measurements at several points wells provide quite interesting results. In wells with hydrocarbon content, obtained upside amplitude at PSD attribute IZ, 3 Hz and the ratio of V/H. Increase amplitude, if it can be said to be an anomaly, that are in the range of 2-7 Hz, both in well with oil alone and well layer of oil and gas. For dry wells, on a plot of amplitude with a frequency not showing an increase in both: the amplitude attribute IZ and the ratio of V/H. In this study, also conducted time lapse measurement, i.e at one carbonate prospect. Data obtained at this point is quite interesting. The first data measured in 2009. In the first measurement have amplitude anomaly at all of passive seismic attribute. Subsequently, in 2013 carried out drilling in the those prospect area. The well penetrated the basement, which is dominated by andesite. At the age of Late Oligocene Carbonate results from DST 22 MMCFD gas. This proves that the measurement of passive seismic is valid. Furthermore, in 2015 the passive seismic measurements were taken back to the same well. Conditions at that time in a state of temporary plug wells. The measurement results show the response of passive seismic anomaly that is relatively
similar to previous measurements. Although when we look in more detail, there is little difference in curves. But probably caused by a different instrument specifications, especially sensitivity of the instrument. From this research, it can be concluded that the method of measurement and analysis of passive seismic is one method that can not be ignored. With proper calibration wells is helpful to interpret the data acquisition. Instrument and measurement determine the quality of data to be acquired.

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