Study of Microseism & Microtremor: A case study from Cambay Basin

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Summary

An attempt has been made to understand the spectral characteristics of the Microseism in relevance to the Microtremors. The three-component passive seismic data from the northern part of Cambay basin have been used in the present study. The Microseism or the ocean wave peaks have been observed with variation in time period ranging between 3-8 seconds. The present study deals with the investigation of the low frequency passive seismic data from five stations from the oil field of Cambay basin. The microseism band (0.05-0.5) Hz and microtremor band (2-4) Hz have been studied. There seems to be a no correlation between Microseism or the ocean wave peaks (0.12-0.28) Hz and spectral peak at around 3 Hz in microtremor band associated with known hydrocarbon reserves.

Introduction

Continuous seismic signals which are usually rather weak and often considered as background noise only. This background ambient noise is present as a certain broadband at every location around the world. However, this noise can carry useful information which is contained in its characteristics, such as the frequency spectrum (H.Gerivani et al, 2012).

Major source of the ambient noise is considered to be a microseism. Microseisms is a persistent oscillation of seismic waves unrelated to earthquakes, explosions or local noise sources, have been observed on seismic records since the 19th century (Robert K. Cessaro, 1994). Microseisms events are believed to occur as result of the interaction between two same frequency ocean swells that are propagating in opposite directions. (Kedar & Webb 2005)

These microseisms consist of propagating seismic waves generated by interactions between the atmosphere, ocean and the solid earth that are observed as peaks within the background seismic amplitude spectrum predominantly between (3-30) seconds period (Martin J. Pratt et. al, 2017)

Ocean dominates the microseism band which is visible everywhere on the earth with amplitude peak at around 0.2 Hz (Mohd. Y Ali etal 2009).

Seismic noise with high frequency >1Hz usually dominated by cultural activity (traffic, factories and others man made activity). Many researchers have been studying the ambient noise or background noise over the years in relation to hydrocarbon prospects (Dangel et al, 2003, Holzner et al, 2005, Mohd. Y Ali etal 2009,).

Microtremors or Low frequency passive seismic (LFPS) is the study of narrow band of low frequency signal (2-4Hz) from the measurements of ambient noise recording. Moreover, it may contain a spectral signature characteristic of the media or environment which it has passed through (Dangel et al., 2003). It was a first ever successful, extensive and systematic study carried out by Dangel etal in 2003 which convinced the world that there was a spectral anomaly (2-4Hz) associated with hydrocarbon reserves. Dangel suggested that the spectral anomaly weakened at the rim of the hydrocarbon reservoir and totally absent above the non hydrocarbon reservoirs. He also pointed out that irrespective of depth, fluid content, rock types and overlying geology of the hydocarbon reservoirs, the spectral peak remains within the narrow band of frequency (1.5-4Hz) (Dangel 2003).

Hanssen and Busat, 2008 observed that there is no correlation between low frequency (1-6Hz) and the microseism signal (<0.25 Hz)

After this in 2009, Mohd. Y Ali et. al, showed that there is no clear relation between microtremor(1-6Hz) and microseisms. This was in contrary to the findings of Holzner et al. 2005 who have suggested that the driving force of the low frequency signals is the microseism events.

In this study we refer to the microseism as the ambient seismic in the frequency band (0.05-0.5) Hz and microtremor in the frequency band (1.5-3.5) Hz. In background of this state of speculation about the microseism and microtremor relations, we intend to study the spectral structures of microseisms in association with microtremors.

Study Area and Data

The study area is in and around the Mansa city, geographically which lies at the juncture of Mehsana, Gandhinagar & Ahmedabad. Geologically it is in the northern part of the Cambay basin. The Cambay basin is a rift basin forming the inland extension of the large offshore west coast basin and located on the north-west margin platform of the Indian Craton, covers an area of 56,000 Sq. Km.

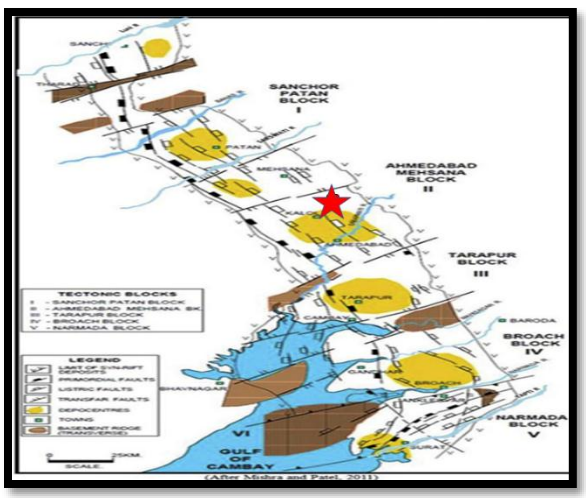

Figure 1: Tectonic Map of Cambay Basin, courtesy Bhowmick P. K. et al, 2010)

The study area lies in the Ahmedabad-Mehsana block in the tectonic map of the Cambay basin (Figure 1)
The study area is highly inhibited by human activity (road network, factories, residential colonies & agricultural activity) which acts a source of anthropogenic noise. The low frequency passive seismic (LFPS) data was acquired in a grid with Tromino 3G sensor with sampling rate of 128 samples/second. The data was acquired during the month of June-July 2019 with a recording length of 12 hrs.

Although data has been acquired in a grid, but in the present investigation the data from five stations have been analyzed along a diagonal (Figure 2) passing through the known hydrocarbon reserve.

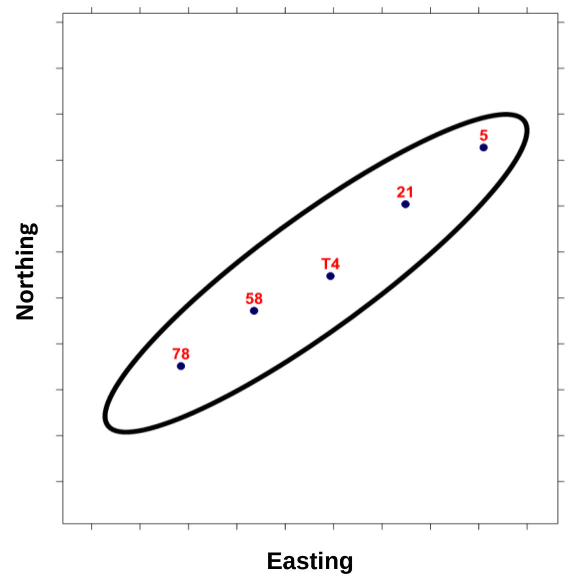

Figure 2: Stations along diagonal under investigation.

The total 05 stations along this diagonal are taken into consideration which are 400m apart. These stations are (5, 21, T4, 58 & 78) and station (T4) is at a producing well in the region. The data for these stations were acquired during the month of June & July 2019.

Data Analysis

The data have been analyzed using MATLAB software. Data has been filtered in microseism band (0.05-0.5) Hz then power spectral densities have been computed. Likewise, power spectral densities have computed with filtered data microtremor band (1.5-3.5) Hz. The spectral density in the microseism band have been plotted for the respective stations along the diagonal and shown in figure 3. Similarly, the spectral density in the microtremor band for all the stations have been shown in figure 4.

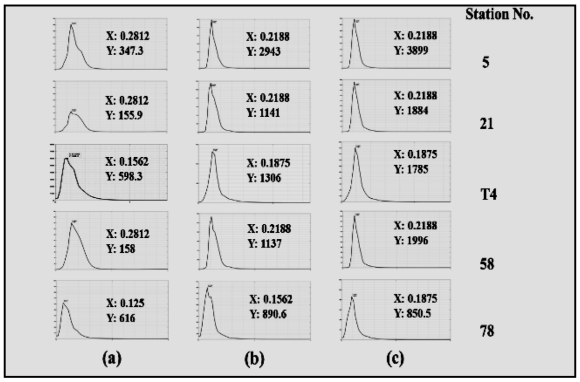

Figure 3: Represents the power spectral density curve (X-axis-spectral density, Y-axis-frequency (Hz)) for the stations in the microseism band (0.05-0.5Hz), 3(a) is PSD for Z-component, 3(b) is PSD for N-S component & 3(c) is PSD for E-W component.

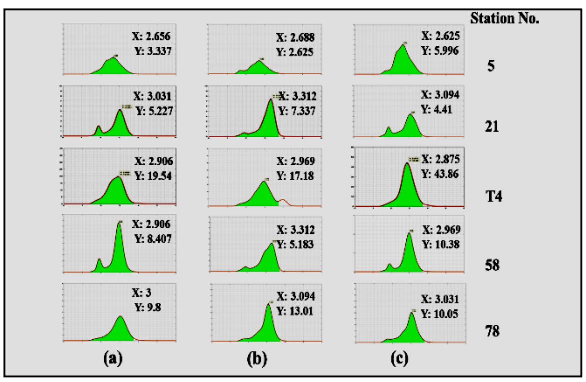

Figure 4: Represents the power spectral density curve (X-axis-spectral density, Y-axis-frequency (Hz)) for the stations in the microtremor band (1.5-3.5Hz), 4(a) is PSD for Z-component, 4(b) is PSD for N-S component & 4(c) is PSD for E-W component.

It is observed from the figure 3 & figure 4 that the Z-component is significantly less as compared to both the N-S & E-W component. The quantification in reduction in peaks of PSD in microseism band has been shown in figure 5 & 6 as the percentage of reduction with respect to E-W & N-S component.

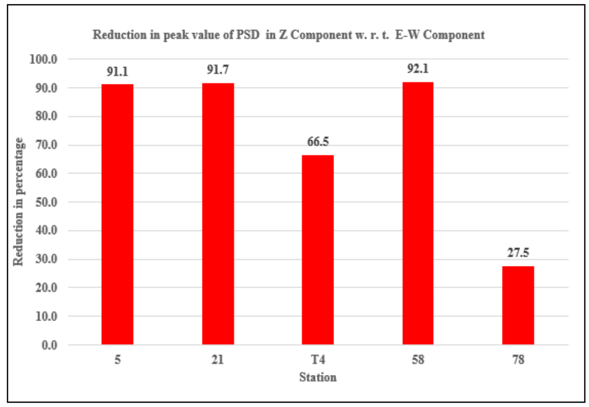

Figure 5: Histogram represents the reduction of peak value of power spectral density in Z-component w. r. t. E-W component in the microseism band.

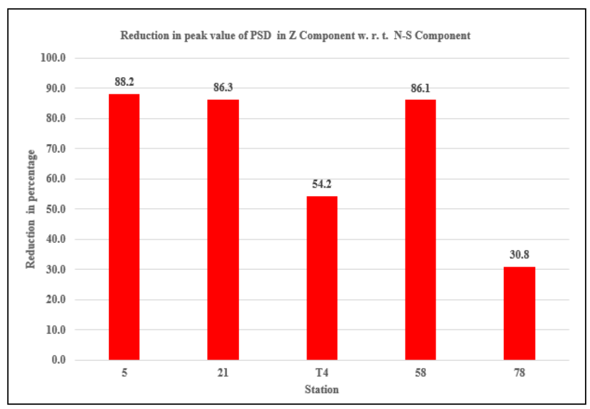

Figure 6: Histogram represents the reduction of peak value of power spectral density in Z-component w. r. t. N-S component in the microseism band.

The peak value from the power spectral density curve for both the frequency bands have been picked and plotted in histogram plots figure 7 & 8.

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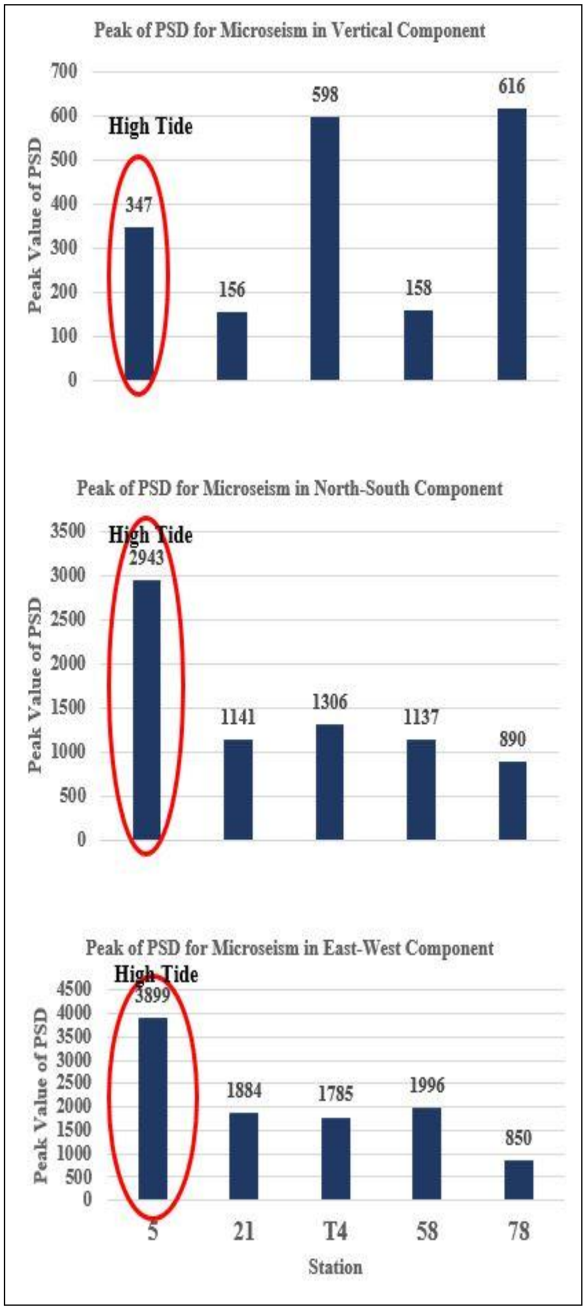

Figure 7: Histogram represents the peak value of power spectral density for the stations in the microseism band (0.05-0.5Hz), for Z-component, N-S, & E-W component.

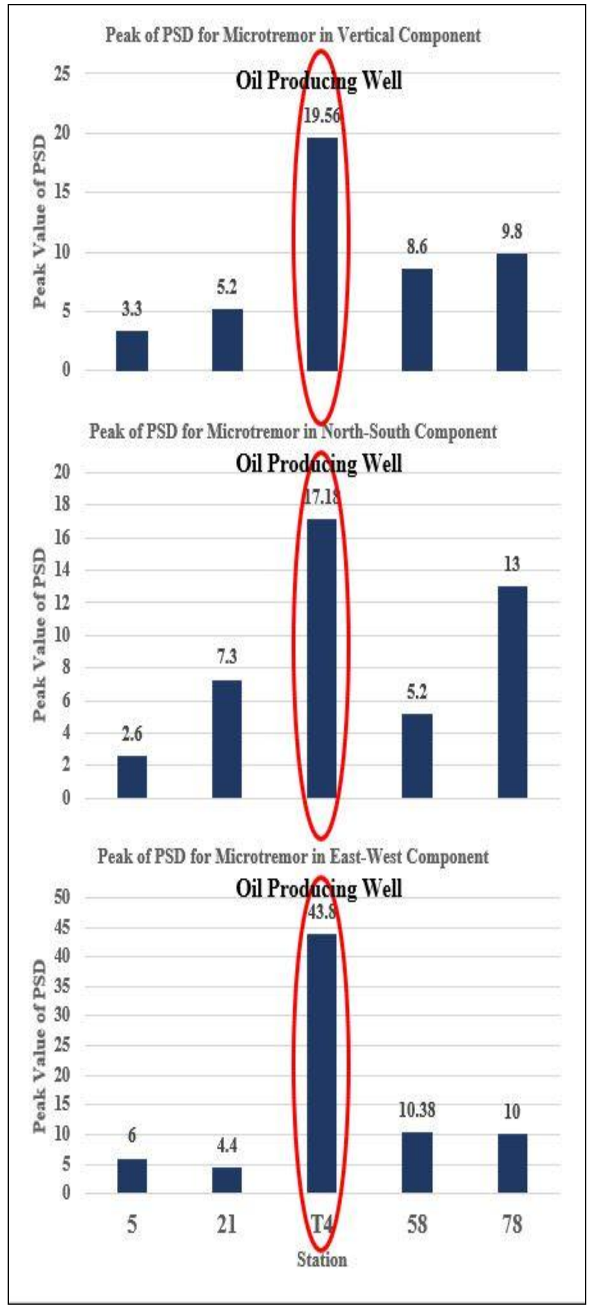

Figure 8: Histogram represents the peak value of power spectral density for the in the microtremor band (1.5-3.5Hz), for Z-component, N-S & E-W component.

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Discussion

Insights into the spectral peaks of microseisms reveals that there is a significant drop of the amplitude levels in the Z-component of the data as compared to the horizontal components, there is as much as 30-88% of drop in the spectral peak of the PSD of Z-component compared to N-S component & 27-92% of drop as compared to E-W component of all the stations. As pointed out by Haubrich et. al., 1963 microseisms are mainly characterized by surface waves including both Rayleigh and Love waves. Here the dominance of the horizontal component suggests the surface waves mainly Rayleigh & Love waves.

The high response in the spectral peak of horizontal components at station 5 (figure 7) is attributed to the high tide, which have been marked with red ellipse. Station 5 data was acquired on 16.06.2019 and it was a high tide on that day as per the tide coefficient at Gulf of Khambat.

If we see the spectral peaks in microtremor band, there is a spectacular response at T4 which is mainly at 3 Hz (figure 8). T4 station is a location of oil producing well in the region. The high response at T4 in the microtremor band, mainly at 3Hz is being attributed to hydrocarbon reserve. Dangel et al, 2003, & Holzner et al., 2005 also established the spectral anomaly between 2-3 Hz associated with hydrocarbon reservoir.

Conclusions

The very high amplitude value of horizontal component as compared to the Z-component suggests there is prevalence of surface waves mainly Rayleigh & Love waves.

Microseism activity is confined within the frequency band (0.12-0.28) Hz.

The horizontal components respond to the tide in microseism band with high peak value at station 5.

The high response in the spectral peak at 3Hz in the microtremor band is attributed to the hydrocarbon reserves.

However, if we compare the response of microseism and microtremor simultaneously (figure 7 & 8) there is no effect of tide activity in the microtremor response.

There seems to be no correlation between the microseism and microtremor response at those 5 stations under consideration. But it is very difficult to imagine any ambient seismic activity without microseisms. More data from different basins need to be studied to acquire more comprehensive knowledge on the subject.

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Tides data have been taken from www.tides4fishing.com

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