

Processing and Analysis of Low Frequency Passive Seismic data: A case history of MBA Basin

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Keywords

Low frequency passive seismic, V/H, PS, polarization attributes,

Summary

A pilot study has been carried out to establish the efficacy of Low Frequency Passive Seismic (LFPS) survey to locate oil/gas pools in Ashokenagar area of MBA Basin, Kolkata. The present paper discussed the processing and analysis of LFPS data for deriving various attributes such as spectral analysis, V/H ratio, PSD and various polarization attributes. The anomalous attributes in Ashokenagar area correlates well with presence of hydrocarbon in known oil and dry wells.

Introduction

In Low Frequency Passive Seismic (LFPS) technique, energy of micro-tremors generated from natural seismicity of the earth is recorded on earth's surface using very high sensitive Low Frequency sensors. Various attributes derived by spectral analysis of LFPS data like, Vertical to Horizontal amplitudes Ratio (V/H), Power Spectral Density (PSD), Peak Frequency Distribution (PFD), polarisation attributes etc. show anomalous response in 1 to 6 Hz range over hydrocarbon reservoir and thus help to estimate the presence of oil/gas pools. It is found that V/H ratio over hydrocarbon pools indicate values >1 .

Low-frequency Passive seismic data had been acquired at several locations around Ashokenagar, MBA Basin, India. Spectral attributes calculated from these data, acquired over fields with known and unknown hydrocarbon accumulations, show common spectral anomalies. Verification of whether these anomalies are common to only a few, many, or all hydrocarbon reservoirs may be provided only if more and detailed results are analysed. A survey was carried out above Oil well reservoir and an adjacent exploration area in Ashokenagar. Data from several stations with three-component broadband seismometers distributed in and around Ashokenagar were used for the analysis. Several hydrocarbon reservoir-related microtremor attributes were

calculated, and mapped attributes were compared with known gas intervals, with good agreement.

A layout plan was finalized for recording of LFPS data around Ashokenagar well#A (oil/Gas well), Well#B (Dry well). The emphasis was made on establishing the response at oil/gas well and the dry well before venturing for other proposed locations. About 30 observation points at 200 m interval in and around the target locations including drilled well and proposed locations were found to be optimal for the proposed feasibility study.

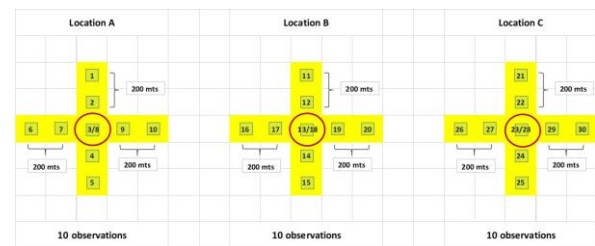


Fig1. Layout plan

The Equipment used:

Four LFPS sensors (TROMINO-3G) deployed by Institute of Seismological Research, Gandhinagar for LFPS data acquisition for this study (Fig.2) were:

- Equipped with 3 velocimetric channels
- Record seismic ambient micro tremor recordings (up to ± 1.5 mm/s \sim).
- Frequency : 0.1 - 1024 Hz on all channels
- A/D conversion > 24 bit equivalent at 128 Hz.

The sensors were calibrated with available software and response of all three components were ensured and the dummy recorded data were analysed as per OEM guideline before deployment in field.

About area

Processing and Analysis of Low Frequency Passive Seismic data: A case history of MBA Basin

Indian part of Bengal basin is bounded by rocks of Indian shield to the northwest, Surma basin to the east, deeper Bay of Bengal to the SSW and Mahanadi basin to the southwest.



Fig. 2 Tromino 3G sensors

Major river systems include Ganga-Brahmaputra, Damodar, Ajay, Rupnarayan, Dwarkeshwar, Kansai, Subarnarekha, Bhagirathi, Hoogly etc. These rivers have been transporting the sediments from the continental areas of Jharkhand and Himalayas and pouring into Bengal Basin. The complex river system has given rise to the World's biggest Ganga-Brahmaputra modern delta system.

Bengal basin, a polycyclic basin, has evolved through two distinct tectonic episodes. It initiated as an intracratonic rifted basin within Gondwana land during the Paleozoic-Mid Mesozoic time and received the continental Gondwana sediments. This phase of basin development ended with wide spread volcanicity during which basaltic sheet flows (Rajmahal Trap) covered the Gondwana sediments. Second phase of basin formation took place when Indian Craton separated out completely from the Gondwana- land and kept on moving northwards. During this journey of the Indian plate the pericratonic part having loaded with Gondwana sediments was sagging eastward and received colossal volume of sediments from Late Mesozoic through Tertiary to Recent times. In its northern journey, it collided with the Eurasian plate and caused up folding and thrusting of Tethian sediments to build the Himalayan orogenic

belt. Further movement of the Indian plate was in the north-easterly direction and ultimately collided with the Burmese plate, the former subducting below the latter and the Pericratonic basin gradually coalesced with the geosynclinal sediments of the Assam-Arakan Basin along a line whose present day surface manifestation is roughly along the alignment of swath-of-no ground at the head of Bay of Bengal and Schuppen belt of NE region through northern part of Tripura (Hail-Hacalua Trend). Presently Bengal basin constitutes the fore deep component of the extensive Assam-Arakan petroleum province.



Fig 3. Study Area Map

Processing and Analysis of Low Frequency Passive Seismic data: A case history of MBA Basin

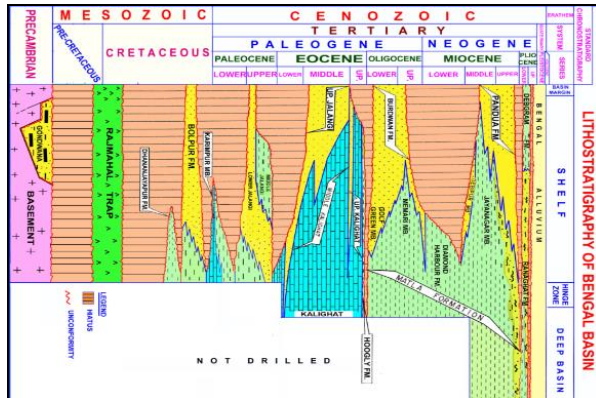


Fig 4 General stratigraphy

Data acquisition:

A detailed reconnaissance were carried out and survey locations were firmed up. The data acquisition was planned with each observation for about 4-6 hrs duration. Recording was usually done in two shift starting from early morning 06:00 hrs to till 16:00 hrs.

LFPS data were collected at many locations for 4-6 hours each in two shifts. The sensors were planted in approx. 1ft deep pits. The observations near oil well was repeated & re-named as observation no. 8. The observation no 23 near proposed location was repeated & re-named as observation no. 28.

Most of the survey locations, in and around Ashokenagar, were in agricultural field except few near village, pond and road. Efforts were made to minimize manmade noise by adjusting observation points away from such locations to the extent possible. The most of measurement were carried out for 4 hour, few observations were taken for 6 hrs also. A raw record with 3 components at observation is shown in fig. 5.

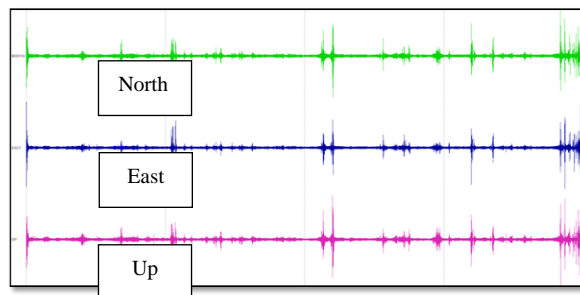


Fig. 5 Raw record with 3 components at observation

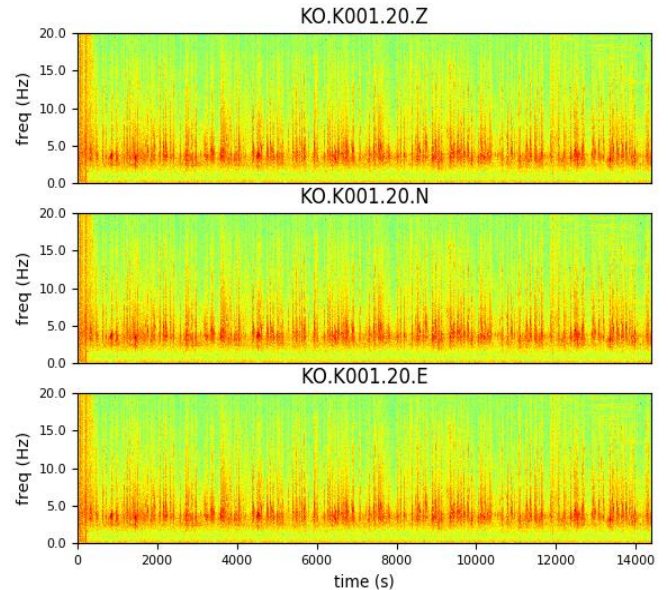


Fig. 6 Spectrogram of all three components of LFPS data (4 hrs)

5. Data analysis

As per published literature, for presence of hydrocarbon, analysis of LFPS data has been carried out and many attributes are derived from it and analyzed. These attributes are studied at known hydrocarbon locations, dry locations and at prosperous but unknown hydrocarbon locations. The similarity of attributes at known hydrocarbon locations and at prosperous but unknown hydrocarbon locations provides us an additional tool. The following attributes which are studied and discussed in various published literature.

1. Spectral Analysis
2. V/H Analysis
 - a) Ratio
 - b) Integral value for V/H>1
 - c) Maximum value of V/H ratio
3. PSD Analysis
 - a) PSD of single component
 - b) Value at prominent frequency
 - c) PSD-Integral Z (above minimal range)
4. Frequency shift of maximum spectral peak (1-6 Hz)
5. Polarization Attributes
 - a) Dip (Φ)
 - b) Azimuth (θ)
 - c) Rectilinearity (L)
 - d) Maximum Eigen value

Processing and Analysis of Low Frequency Passive Seismic data: A case history of MBA Basin

The main attributes which are studied in this paper are Spectral analysis, V/H ratio, Power Spectral Density (PSD), Polarization Attributes (Dip, Azimuth, Rectilinearity Maximum Eigen value). The behaviors of various attributes, at known hydrocarbon locations, dry locations, are discussed in many published papers which are tabulated below.

S No	Attribute	At known hydrocarbon locations	At dry locations
1	Spectral Analysis (1-10 Hz)	Peak in 2-4 Hz	Peak away from 2-4 Hz
2	V/H ratio	More than 1	Less than 1
3	PSD Z component	High value in 2-4 Hz	Lesser value in 2-4 Hz
4	Dip	Stable, high value	Stable, low value
5	Azimuth,	Unstable, as expected for such high dip values	Relatively stable; may point to a surface noise source
6	Rectilinearity	Relatively stable	Unstable
7	Maximum Eigen value	Low, relatively stable,	High value, unstable

The preliminary processing of V/H attribute of acquired data was carried out at processing facility of ISR, Gandhinagar. The preliminary result of V/H attribute shown in Fig. 7 indicates distinct anomaly of V/H attribute values (>1 and <1) over oil well and dry well.

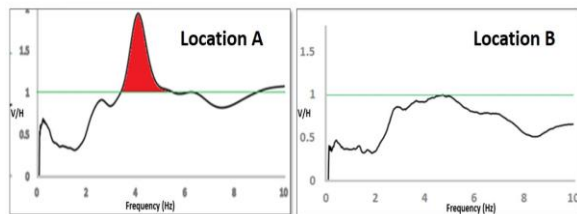


Fig. 7 V/H Ratio attribute over oil/gas well location (A) >1 and dry well location (B) <1

This data was again reprocessed with our in-house developed software. To establish the efficacy of Low Frequency Passive Seismic (LFPS) survey to locate oil/gas pools, various attributes such as spectral analysis, V/H ratio, PSD and various polarization attributes. The anomalous attributes in study area of

MBA Basin correlates well with presence of hydrocarbon in known oil and dry wells.

All the attributes were derived for three locations viz. oil well (A), dry well (B) and a proposed location (C).

Spectral Analysis

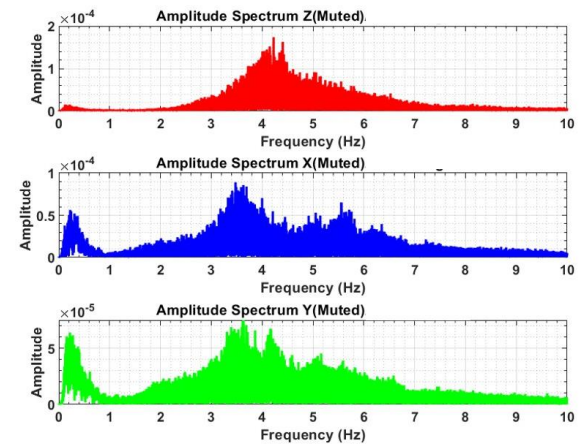


Fig. 8 Spectral Analysis at location A

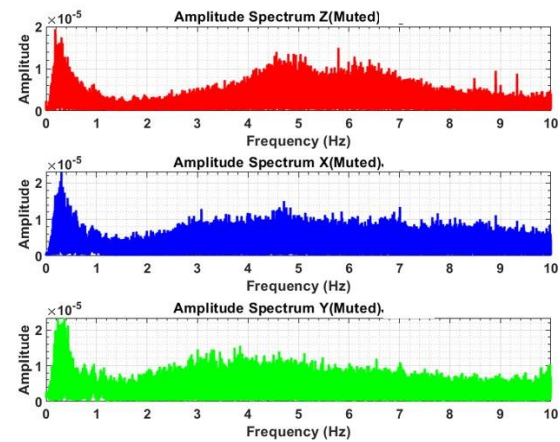


Fig. 9 Spectral Analysis at location B

From various attribute plots, it is evident that there is a distinct LFPS response from all the three areas i.e. at A, B & C. The observations were analyzed with our previous experience and the published literature.

Processing and Analysis of Low Frequency Passive Seismic data: A case history of MBA Basin

The spectral analysis (Fig. 8-10) shows distinct character at all three locations. The peak frequency indicates similarity in location A & C in comparison to B.

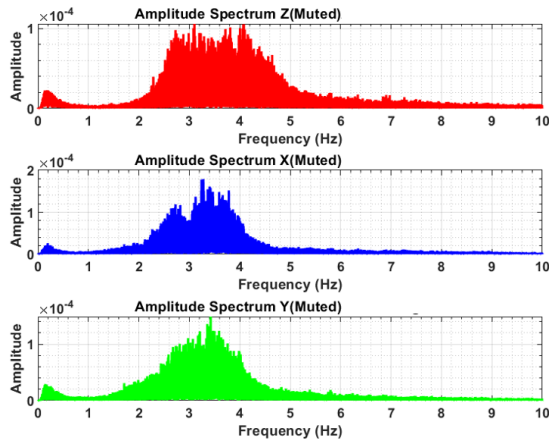


Fig. 10 Spectral Analysis at location C

V/H Analysis

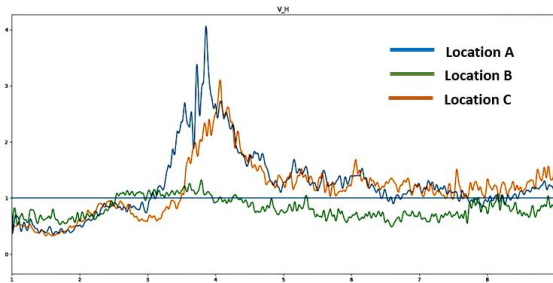


Fig. 11 V/H curve at location A, B & C

The V/H ratio at all three locations are plotted in Fig. 11. The V/H ratio is more than 1 for locations A & C but less for location B.

PSD-Z component

The PSD of Z-component at all three locations are plotted in Fig. 12. The PSD value is more for locations A & C in desired frequency range 2-4 Hz but less for location B.

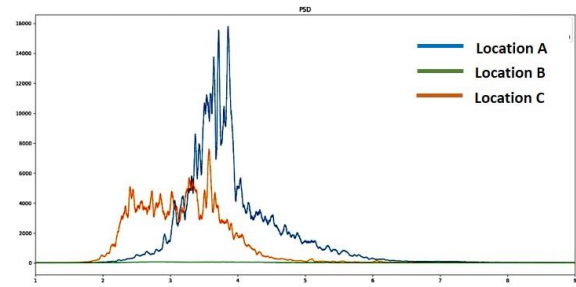


Fig. 12 PSD curve at location A, B & C

Polarization Attributes

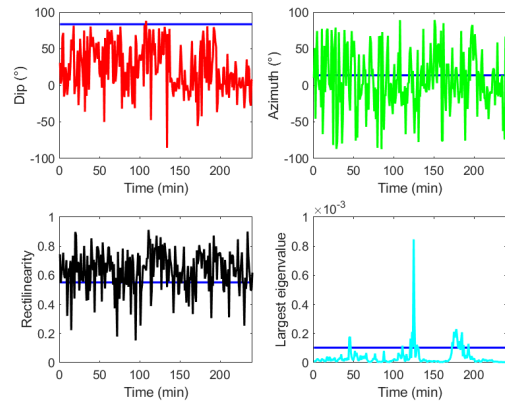


Fig. 13 Polarization attributes at location A

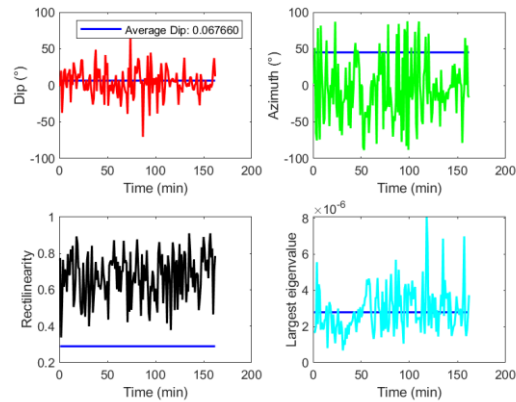


Fig. 14 Polarization attributes at location B

Processing and Analysis of Low Frequency Passive Seismic data: A case history of MBA Basin

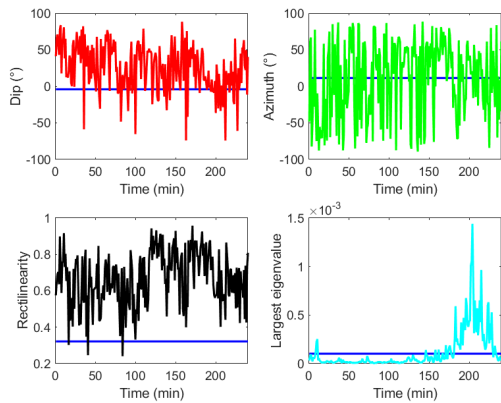


Fig. 15 Polarization attributes at location c (Time intervals of 40 s are analyzed. The horizontal blue solid line represents the value using data of the whole time period)

This polarization analysis is useful for a detailed analysis of the passive seismic wave field. It provides information about the time variability of the microtremor phenomena related to hydrocarbon reservoirs. The time variation of the largest eigenvalue and the azimuth Figure 13&15 seems typical for stations above a reservoir, whereas a relatively low largest eigenvalue and a relatively stable azimuth are more typical for an anthropogenic noise source figure 14.

The polarization attributes (dip, azimuth, largest Eugene Value & rectilinearity) (Fig. 13-15) shows distinct character at all three locations. The similarity at location A & C in comparison to B. The dip value is more at location A & C in comparison to location B. Similarly the azimuth is closure to zero for location A&C. The largest Eigen value have similarity in location A & C and shows anomaly at location B. The rectilinearity characteristics are different for location A & C.

Based on above analysis, the LFPS attributes tabulated below for all three locations i.e. at oil well (A), dry well (B) and at proposed location (C).

The similarity of attributes at proposed location (C) with location (A) may be attributed as prosperous location.

S No	Attribute	At Oil well locations (A)	At dry well locations (B)	At proposed location (C)
1	Spectral Analysis	Peak in 2-4 Hz	Peak away from 2-4 Hz	Peak in 2-4 Hz
2	V/H ratio	More than 1	Less than 1	More than 1
3	PSD Z component	High value in 2-4 Hz	Lesser value in 2-4 Hz	High value in 2-4 Hz
4	Dip	Stable, high value	Stable, low value	Stable, high value
5	Azimuth,	Unstable, as expected for such high dip values	Relatively stable; may point to a surface noise source	Unstable, as expected for such high dip values
6	Rectilinearity	Relatively stable	Unstable	Relatively stable
7	Maximum Eigen value	Low, relatively stable,	High value, unstable	Low, relatively stable,

Conclusion:

The various attributes of LFPS data such as spectral analysis, V/H ratio, PSD and various polarization attributes ascertained the presence anomaly over oil/gas well and at dry well. Further, the data at proposed location with anomalous higher V/H ratio, PSD value and polarization attributes may be correlated with oil well. The prospective location shows good anomaly but extent of anomalous zones can be further estimated by LFPS survey in 3D grid pattern around those locations.

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Processing and Analysis of Low Frequency Passive Seismic data: A case history of MBA Basin

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References

Erik H. Saenger, Stefan M. Schmalholz, Marc-A. Lambert, Tung T. Nguyen, Arnaud Torres, Sabrina Metzger, Robert M. Habiger, Tamara Müller, Susanne Rentsch, and Efraín Méndez-Hernández, (2009), "A passive seismic survey over a gas field: Analysis of low-frequency anomalies," *GEOPHYSICS* 74: P29-40.

Ebrahimi, Mostafa & Moradi, Ali & Seidin, Hamid. (2018). Analysis of Low-Frequency Passive Seismic Attributes in Maroun Oil Field, Iran. *Journal of the Earth and Space Physics*. 43 : P11-26.