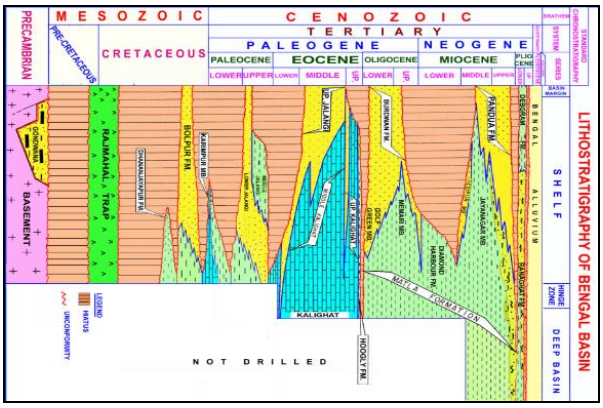

Fig 4 General stratigraphy

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.

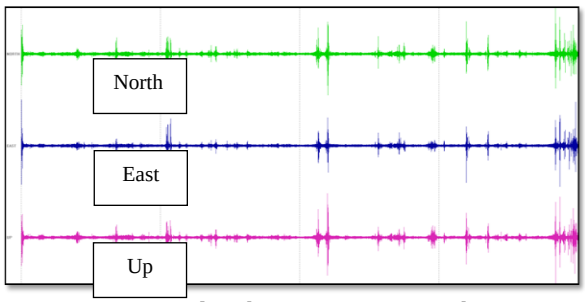

Fig. 5 Raw record with 3 components at observation

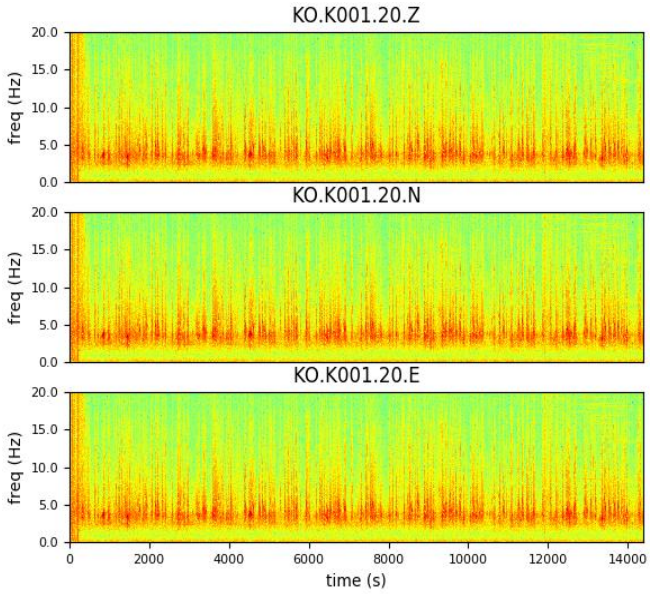

Fig. 6 Spectrogram of all three components of LFPS data (4 hrs)

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

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.

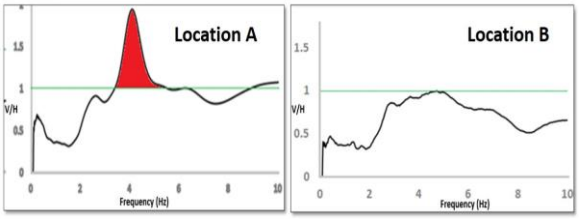

Fig. 7 V/H Ratio attribute over oil/gas well location (A) >1 and dry well location (B) <1

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

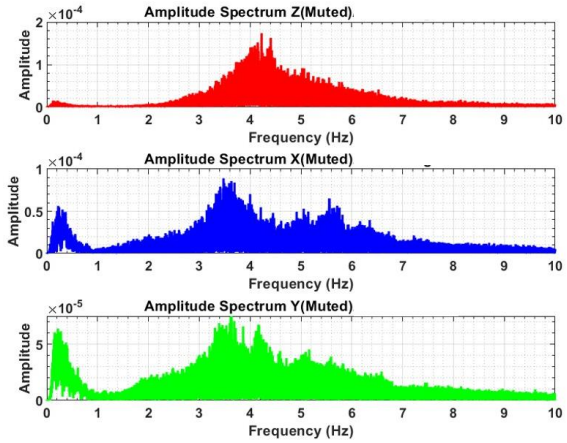

Fig. 8 Spectral Analysis at location A

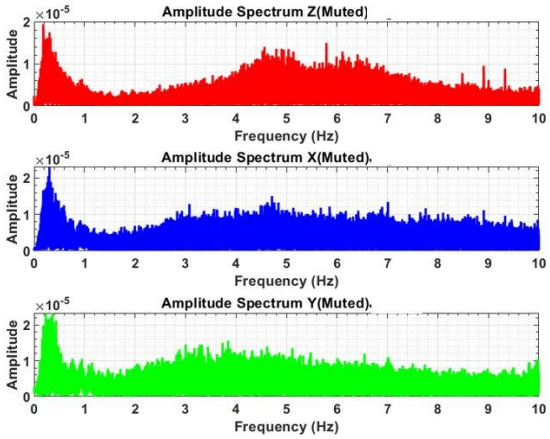

Fig. 9 Spectral Analysis at location B

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.

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.

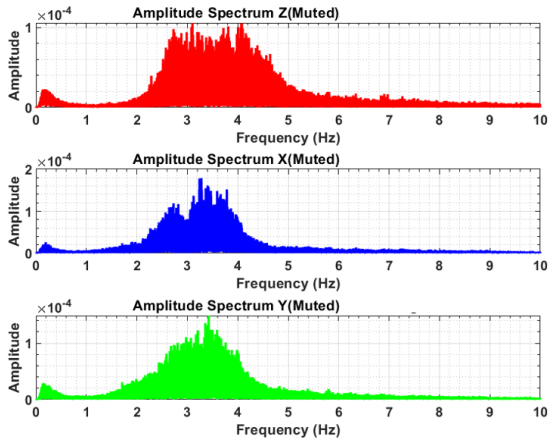

Fig. 10 Spectral Analysis at location C

V/H Analysis

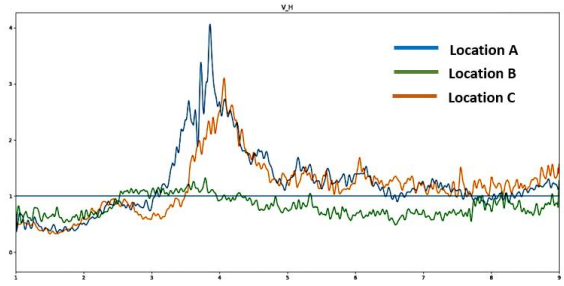

Fig. 11 V/H curve at location A, B & C

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 platted in Fig. 12. The PSD value is more for locations A & C in desired frequency range 2-4 Hz but less for location B.

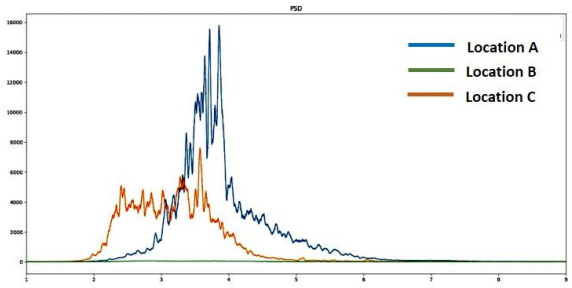

Fig. 12 PSD curve at location A, B & C

Polarization Attributes

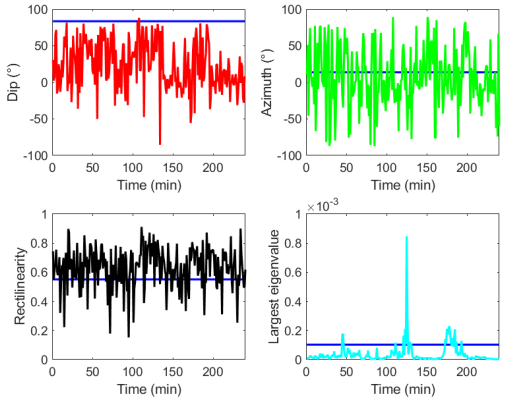

Fig. 13 Polarization attributes at location A

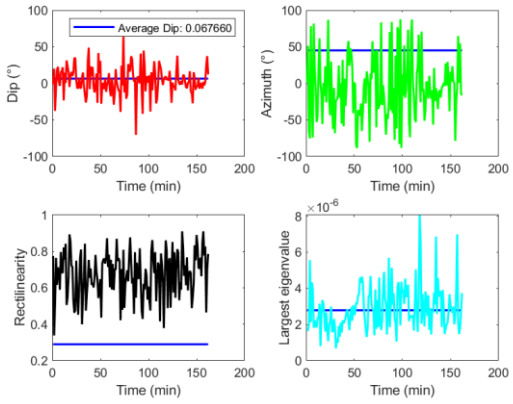

Fig. 14 Polarization attributes at location B

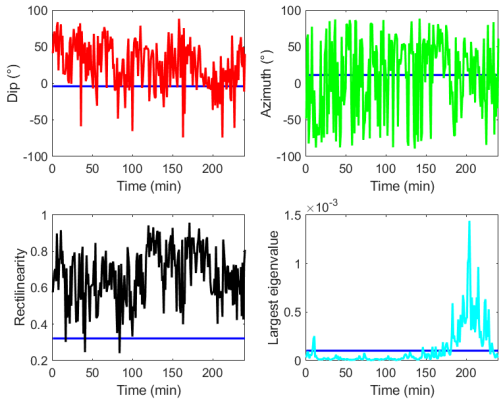

Fig. 15 Polarization attributes at location c
(Time intervals of 40 s are analyzed. The horizontal blue solid line represents the value using data of the whole time period)

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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The views expressed in this paper are those of authors only and do not necessarily reflect their employer's opinion.

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