LOW FREQUENCY SEISMIC SIGNALS LEAD TO HYDROCARBON INDICATION AND MONITORING TOOL

by

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Abstract

Recently, South Rub' al-Khali Company Limited (SRAK) acquired a preliminary survey in the Saudi's oil producing area to develop a feasible new hydrocarbon indication and monitoring (I & M) device using low frequency seismic signals. Based on broadband seismometer data, the new Hydrocarbon I & M might predict the possibility of a hydrocarbon basin underneath by way of evaluating the received spectra for an additional energy shell between 2.0-6.0 Hz. Such a study is also referred to as hydrocarbon microtremor analysis and recently some contracting geophysical service companies offer such studies.

This report will concentrate on the hydrocarbon microtremor analysis of synchronized signal of one frequency and an extra re-determination possibly at a separate location. The paper reports on several critical likely misconceptions and examines repeatability of hydrocarbon microtremors. This work indicates that signal generated by manmade operations can yield same tremor as that assumed for hydrocarbon reservoirs. Equally important, the presence of surface waves generated by anthropogenic signal indicates frequency limits ranging from 1 to 10 Hertz as a result of isolated surface waves. The difficulty of isolating any presumed hydrocarbon related tremors from ambient noise hamper efforts of understanding and applying microseism signals to hydrocarbon exploration and monitoring. Repeatability study by Peter, H. & Sascha, B. (2008) raised questions regarding the source of hydrocarbon microtremors.

For improved chances of isolating the implied hydrocarbon microtremors from manmade tremors and near-surface impacts, the data require precise recording based on three metrics, frequencies above 3 Hz should be conserved, highly sensitive seismometers should be engaged, and the data registering time should be enough to register 'tremor-free' readings.

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1. Introduction

A new technique to detect and monitor hydrocarbons has recently been employed by some firms. Initially invented by Russian oil experts in the late 1990s, the technique first surfaced through the work of Dangel et al. 2003 (cited in Peter and Sascha, 2008). In their study, the two illustrate an event same to an underneath vibration which is continuously directly feasible over hydrocarbon basins.

The determination of this seismic tremor in the frequency range indicates a considerable energy increase over hydrocarbon basins between 2.0 Hertz and 6.0 Hertz with an optimum frequency of about 3.0 Hertz. The application of conventional seismic data acquisition is typically not designed to accommodate such passive frequencies. Also, frequencies less than 3.0 Hertz are often automatically out of seismic bandwidth recorded. In addition, the registered amplitude is too low to be registered by normal geo-devices and receptive seismometers usually utilized for tremor analysis must the utilized (Peter and Sascha, 2008). A further advantage of utilizing broad band seismometer devices is that these instruments are very sensitive in the bandwidth 1-10 Hertz (Ernst, 2009). One of the major impediments in the way of utilizing the presumed hydrocarbon microtremors is that it is very difficult to distinguish such signal from natural and anthropogenic ambieint noise. According the paper, Peter and Sascha; 2008, used in this report, also the repearability of the hydrocarbon seismic-microtremors is questionable.

The low frequency passive seismic geophysical exploration uses the natural seismicity (micro earthquake) as the seismic source and portable seismological network as receivers in order to perform a detailed 3-D seismic velocity and Poisson ratio model of the upper few kilometers of the crust. This technology uses both primary and secondary wave velocity structure determination in active tectonic areas. The seismic tomographic images prepared from this technique provide useful information about the underground structure, and lithological data. This is a cost effective method of geophysical exploration for hydrocarbons. They use seismic energy level between 2-6 Hz. The survey usually done using couple of dozen instruments instead of thousands of geophones utilized during conventional seismic survey. The seismometers are placed in regular grid pattern with a grid distance of 500 (distance between geophones). Many of base stations are adjusted to record the earth's background noise during the survey. During the data analysis the frequency range of anthropogenic noise is carefully removed. (Peter Hanseen and Sascha Bussat, 2008).

2. Origin of hydrocarbon-vibration tremor

Due to signature identical to vibration of the hydrocarbon micrometors, it is presently often known as a hydrocarbon-vibration tremor. While peter and Sascha (2008) were still contemplating regarding likely sources of this tremor, Dangel et al. (2003) and Schmalholz et al. (2006) illustrated several likely concepts which could describe the detected impact for example, stationery vibration resonance, selective reduction and wave augmentation. Of these concepts, none has been verified until today. These concepts are as a result of the long-lived hidden earth tremors. Such microseism is governed by constant Rayleigh vibrations showing peaks of approximately 0. 29 Hz and is often known as sea signal crests.

The most prevalent theory of resonance augmentation by Holzner (cited in Peter and Sascha, 2008) describes the hydrocarbon signal or vibrations by nonlinear interfaces between drying hydrocarbon signals traversing in the water-filled aperture gap of the basin rock. Basically, a more prevalent characteristic of the tremor originating from the basin is its implied upward polarization (Walker, 2008).

Among the theories, only that explained by Holzner has been verified until today, since it is a new concept in the scientific community. Furthermore, the technique still requires further experimental studies to appreciate and or verify any of the above highlighted concepts.

3. Acquisition and processing

A non-positive element of having to utilize strict seismometer is its fragile design and costs. Thus, a study is typically done utilizing a set of dozen devices rather than a thousand geo-devices as in a dynamic seismic study. Basically, an exploration study is performed based on normal grid and threshold separation of about 500 meters between data points. The seismometer is located on an initial pair of grid sets, sealed off, and adjusted ready to capture for an optimum 1 day, prior to their relocation to the adjacent set of predetermined sites. The device can, for instance, be set in a linear pattern, a group pattern, or perhaps in a hop-frog pattern in order to realize steady general offsets.

Several threshold points are lined up that continuously register the Earth’s hidden vibration throughout the study. Ideally, they are placed adjacent to dry wells and directly above the desired hydrocarbon-rich field. While first considered to record the inconsistencies of the seismometers for harmonization benefits, they currently solely act like benchmark readings for quality sustenance in most firms.

In this work, 11 concurrently registering micro-seismometers, registering for 18 hours, were considered. The study region was in Central Libyan Reservoir and partially engulfed by sand dunes. The appliances were set diagonally stretching from the N.W to the S.E traversing the basin’s central point ‘D’ (fig. 1). To conduct a more precise time based modeling (Rode, 2006), the line ends were extended further away from the generating area than usual. This led to a 33 km stretch with identical counterbalances between the registering points.

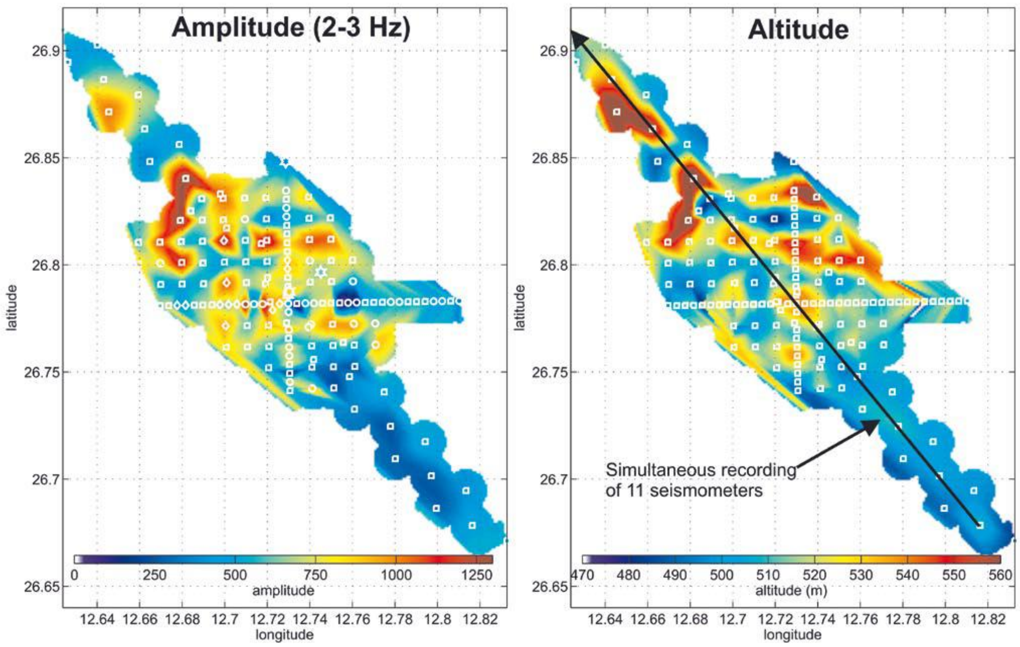

Figure 1: Amplitude & altitude relationship in the micro-vibration incidence

Source: As cited in Peter and Sascha, 2008, p. 118

In total 264 registrations were achieved for the entire study and verification dimensions were obtained on 2 stretches traversing the region, out of which one instance is explained fully in this survey.

4. Analysis

Initial readings of the survey appeared promising. However, to perform a detailed analysis where hundreds of 18 hour passive frequency time-sequences within the frequency coverage, a software application was used. Hence allowing a more intensive analysis that offered a better appreciation of the correlation between the hydrocarbon basin and the recorded signal about 3 Hertz. Furthermore it showed severe setbacks during first-time analysis of the readings. Such analysis faults have to be dealt with to entirely appreciate this trend. In the remaining parts the report proposes a more significant and precise analysis of these seismometer data. This readings analysis offers information regarding the frequency bandwidth of anthropogenic tremor, the constancy in a micro-vibration tremor at about 3 Hertz, and how it correlates with both low and high frequencies. Furthermore, it is possible to detect the source of the observable micro-signal inconsistency over the hydrocarbon-rich basin. Lastly, a computerized time interval selection that is uncontaminated by anthropogenic tremor is conducted. This yields some promising survey results.

4.1 Anthropogenic vibration

In a micro-vibration study, seismometer registers the ambient vibrations that originate from either physical or induced origins. Physical causes, for instance the 1st and 2nd microseisms (at 14 s and 5 s respectively) or earth tremors at a frequency width less than 1 Hertz but, because of aspects like weather attributes, this upper band boundary is higher, particularly along the shores. The origins of anthropogenic tremors are diverse kinds of manmade actions like drilling, trucking, and all other noise generating appliances (Dangel et al., 2003).

A large drawback is to identify the two interacting forms of vibration, earth-based and anthropogenic. Ephemeral earth vibration, due to its transient appearance, or steady anthropogenic tremors (for example, motors traversing at a constant frequency) should be easy to remove, while partly-constant signals are comparative difficult to detect and more difficult to isolate. However, an isolation of such signals is necessary so that the recorded amplitude variance is not triggered through anthropogenic means.

To get an initial intuition of the overall signal position in the study region, the computation of a spectra grid for some days is critical. Fig. 2 indicates 5 days of constant registering along the region of interest about the bandwidth (0.5-0.10 Hertz). A unique day and night unsteadiness trend with low amplitudes (at night) and higher amplitudes (during day time) is observable. The anthropogenic based vibration is high at day time. However, at times it reaches threshold level (0.5 Hertz). Compared to the frequently evident 5 Hertz threshold boundary, manmade actions can really generate vibration as low as 1 Hertz (Ernst, 2009). Furthermore, many anthropogenic signals are not vividly unique from the implied hydrocarbon frequency band or micro-vibration, as frequently argued (Chopra and Marfurt, 2006). Often it proves not possible to detect the necessary signal of a hydrocarbon basin in the presence of human based signals.

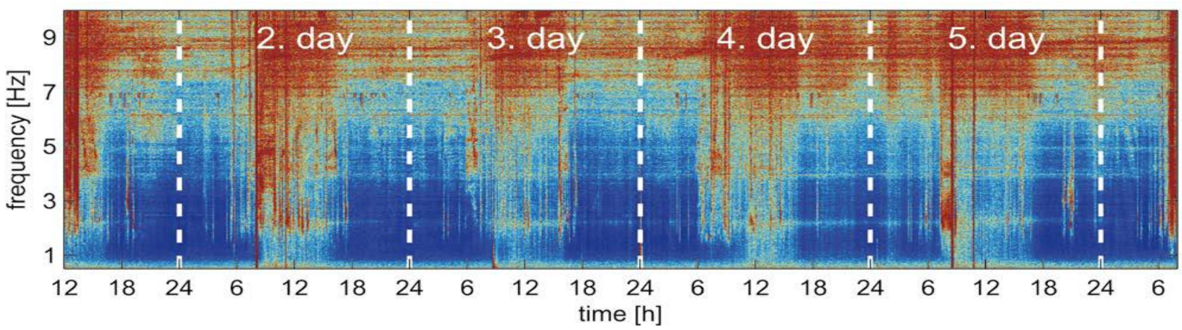

Figure 2: A 5 day constant spectra grid readings from 0.5-10 Hz over the generating region
Source: Peter and Sascha, 2008, p. 112

4.2 Comparing with other frequencies

One potential technique of isolating the hydrocarbon micro-vibration signal from anthropogenic induced vibration is through comparing the amplitude differences for a given time interval of the hydrocarbon micro-vibration frequencies with amplitude differences of other frequencies, as implied by Ernst (2009). Used in this study is a seismometer data over a hydrocarbon-rich basin 10,000 m away from possible human action. The readings show a vivid amplitude variance about 2 Hz (figure 3).

A potential hydrocarbon vibration signal originating from a basin should have a periphery origin that is accountable for the agitation of, e.g., vibrations along the hydrocarbon-rich spaces. Such a peripheral origin could be the transient tremor generated by microseisms (below 0.2 Hertz) or, as implied by Dangel (2003), the anthropogenic own vibration. To identify which peripheral force is at work, the comparing of varying amplitudes with time based on discrete frequencies can be conducted. Further, a detailed comparison of the amplitude differences about 2 Hertz with time is necessary. Basically, every amalgamation of signals was accounted and fig. 3 illustrates a summary of key results.

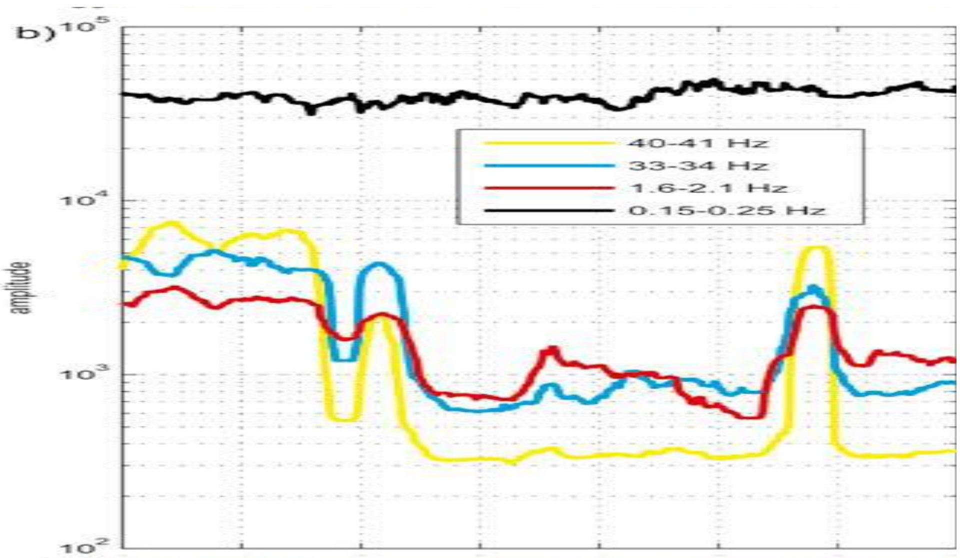

Figure 3: Spectra and phenomenon correlations for two time-interval readings

Source: as described in Ernst, 2009, p. 8

No correlation is evident between the desired hydrocarbon micro-vibration signal (2-6 Hertz) and low frequencies (i.e. below 0.25 hertz), as implied in figure 3. This is evident for micro time-lapses of below 24 hours and for macro time-lapses of some days. This disagrees with most of the concepts discussed under conceptual framework (see section 2) and a synchronization of the hydrocarbon micro-vibration noise with either the threshold station or the micro-seism is so far not promising.

However, the signal about 2.0 Hz correlates well with the high frequencies and particularly with high frequencies of over 30.0 Hertz (fig. 3). This could show a peripheral agitation system due to high frequency bands and not due to low frequency bands. But a big challenge is that until now, it is impossible to identify a potential hydrocarbon vibration signal caused by anthropogenic tremor. Further, it could show that observable change in amplitude at about 2 Hertz directly over the hydrocarbon basin is triggered by earth vibrations, as implied by Ernst (2009) and Chopra and Marfurt (2006).

4.3 Micro-vibration signal continuation

A physical hydrocarbon micro-vibration study based on seismometer requires at minimum 48 hours or some days. To study a big region with a few seismometer devices, each device is relocated during the survey from station to station. Overall, it is needless to capture data at all stations concurrently, if the hydrocarbon vibration signals are constant for longer time-lapse as suggested in various conceptual frameworks and propagated as such by various researchers, e.g. Walker (2008). To verify the hydrocarbon signal or vibration constancy, it is advantageous to re-measure at a future time-lapse and to relate present readings. Figure 3 displays the comparison of 2 readings taken from one local station with a time-lapse of fourteen days. It is vividly apparent that the initial measurement (red line) displays unique 2 Hertz amplitude inconsistency, while similar signal was not present during second measurement (black line). Based on fig. 3 (survey results), it is clear that the second instrument's amplitude was greater and prolonged in the second readings.

4.4 Vibration analysis of hydrocarbons

For a basic survey of the implied hydrocarbon indication and monitoring tool along the entire basin, the researcher utilized harmonized data from 11 instruments directly above and next to the basin. The spectrogram (indicating amplitude) and based on harmonized data of the 11 instruments was computed over the entire record width of 18 hrs and selections of specific time-lapses was not used. Fourier-time sequences were determined with a data width of 2 minutes, then later with a pile of entire signal for each instrument. Fig. 4 displays study results on the hydrocarbon-rich basin. A vivid inconsistency in amplitude about 3 Hertz is notable over the basin that appears to be a promising application of low frequency seismic signal in indication and monitoring tools for hydrocarbon.

Additionally, the study observes a remarkable wave height at high frequency bands over the basin, illustrating anthropogenic generation tremor. Amplitude spectrogram comparison between data acquired from a point near the central part of the basin and another data derived from a device located approximately 10 Km away is as implied in fig. 5.

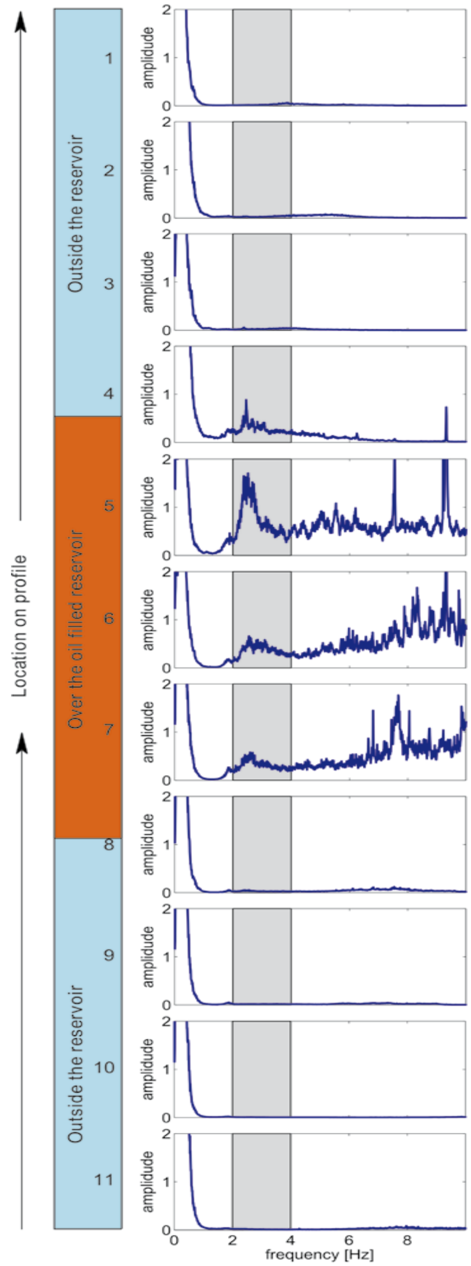

Figure 4: Spectrogram showing amplitudes for 6 concurrent data locations directly above and next to the basin. Source: Peter and Sascha, 2008, p. 114

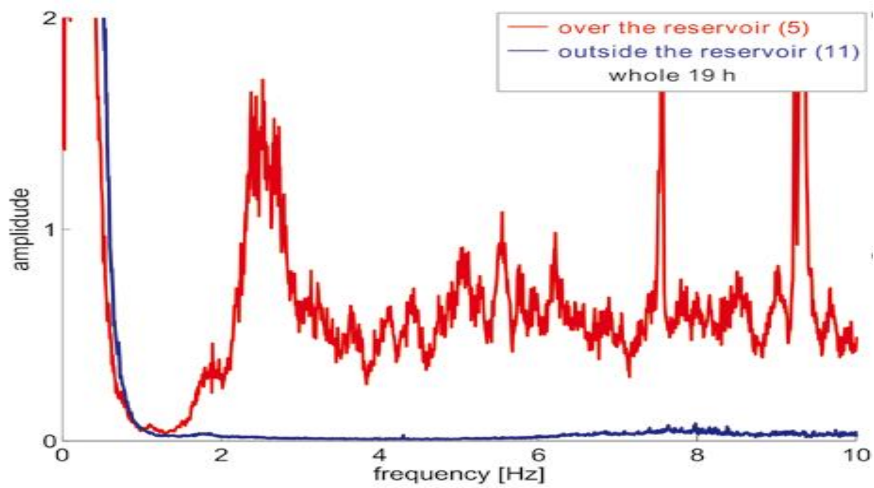

Figure 5: Amplitude comparison (station 5 & 11)

Source: Peter and Sascha, 2008, p. 115

The amplitudes (fig. 5, red sketch) about high frequency bands (above 5.0 Hertz) in which the strong tremor is evident, with the wave heights of the possible hydrocarbon vibration signal about 3 Hertz shows that its increased wave heights might also be measured using typical geophones and more sensitive indicating and monitoring tools should be unnecessary. The below discussion section will explain the source of such variation in amplitudes directly over the hydrocarbon basin.

5. Discussions

Possibly the possible hydrocarbon vibration signals are not constant with time, as earlier indicated (fig. 3). A more detailed investigation of this observation required dividing the readings into 60 minute portions and computations of the amplitudes in the manner illustrated above (section 3). All signals were compared and verified the absence of 3 Hz tremor noticeable at all time-lapses for the local stations far from the hydrocarbon basins. Equally, the devices stationed directly above the generating basin indicated a powerful 3 Hertz tremor. However, in case of human induced tremor (e.g. by pump) high peaks were observed during day time and rarely at night time.

When computing wave height spectra for a single time-lapse, it is impractical to get details regarding momentary variance of signal at such time-lapse. The computation of spectra, in this scenario offers some benefits and one gets a resolution of 60 seconds or comparatively improved for the entire readings. It is evident that extremely strong signal was detected (fig. 5). It occurs erratically and its wave length varies with time.

The wave height (amplitude) is extremely high about the basin but without this signal the amplitude of the registered reading was comparable to the heights measured simultaneously at various locally stationed seismometers. In fig. 4, the diagram indicates highest heights between 18:29-19:01 and lowest heights between 19:01-19:19. The resulting wave height spectrum during these two time-lapses are as illustrated (fig. 5), for both point 5 directly above the basin (red sketches) and for a point far from the basin (point 11-blue sketches). This correlation vividly indicates that variation in amplitudes at 3 hertz is triggered through anthropogenic tremors that are in addition strong at high frequency bands during initial time-lapses.

The powerful signal appears mostly at day time-lapses and a pile is unable to reduce it. It fails to assume a constant vibration signal originating from the basin and therefore it is accountable for the high wave heights about 3 Hertz along the hydrocarbon basin (fig. 1).

This variation in amplitude is difficult to interpret as hydrocarbon vibration indication that is propagated via the anthropogenic tremor. Having illustrated that human based vibrations do not lead to a hydrocarbon indication and monitoring tool, removal of all forms of human induced vibrations prior to conducting any hydrocarbon vibration analysis is necessary. However, in case a hydrocarbon vibration signal is detected, a maximized selection based on transient time-lapses may aid to isolate the low frequency signal due to the hydrocarbon basin. A computerised processing is not dependent on prior knowledge regarding the position of hydrocarbon basin and need to be purpose driven rather than physical processing. The following section concludes the study.

6. Conclusions

The report has indicated that tremor caused by human actions e.g. drilling actions, which is associated to the extraction of a hydrocarbon basin, can lower frequencies to 0.5 Hertz. Additionally, human actions are possible sources of surface signals that are common about 3 Hertz frequency band. Thus, this signal interacts with a desired hydrocarbon vibration tremor from the basin and is mostly confused with a direct hydrocarbon indication and monitoring signal. This misleading wave form is correlated to high frequency tremor. For this study region very far from possible coastal basin such waves are not constant. The implied low seismic direct hydrocarbon I & M tool in this survey has a time-lapse of 60 seconds. But the switching, either on or off depends on frequencies more than 30 Hertz. Eradicating all potential strong human actions by utilizing the most silent time-lapses of the readings shows a vivid relationship to the geology of this study region. Only portions directly overlapped by the human actions indicate irregular unsteadiness. Prior to evaluation of hydrocarbon vibration signals, a technique needs to be developed to entirely isolate potential hydrocarbon vibration signal from an anthropogenic tremor. Future studies involving low frequency seismic signal in hydrocarbon indication and monitoring should thus encompass the selective elimination of all human signals and the scaling down of landscape impacts. Failure to perform such processing leads to misleading mapping of the direct hydrocarbon indication and monitoring process. Furthermore, it would be motivating to visualize, how this signal relates to the constant but non-continuous seismic signal from the hydrocarbon basin.

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