# Seismic inversion using laterally varying wavelets for retrieving acoustic properties in gas chimney zone: A case study from North Tapti gas field, Western Offshore Basin, India

*Akhileshwar Prasad*, Sunil Kumar Singh* and Kishori Lal**

## Abstract

Gas chimneys attenuate amplitude and cause noise observed on seismic data. Due to the presence of gas chimney, the amplitude of the seismic signal gets masked, and it also distorts the frequency and phase of the data. The aim of this work is to retrieve the acoustic property such as P-impedance of the reservoir in the gas chimney affected area by poststack impedance inversion of seismic data using laterally varying wavelets, which are estimated based on the weight of the horizons extracted outside as well as inside of the gas chimney affected area. These weighted horizons were used as a wavelet interpolation modifier as the inversion process running with the conventional single composite wavelet for the whole area will not be able to retrieve proper acoustic properties. Through this new approach, we demonstrate that with poststack impedance inversion and the use of laterally varying wavelets, it is possible to generate realistic P-impedance properties.

*Keywords: Gas chimney, laterally varying wavelets, poststack inversion*

## Introduction

The study area falls in the northeastern part of the Western Offshore Basin in the Gulf of Cambay (Figure 1).

The North Tapti gas field is an anticline with four-way closure formed as an inversion in response to compression during the Early to Middle Miocene. The generalized stratigraphic chart is shown in Figure 2.

Seven development wells (Figure 1) have been drilled so far. Out of seven wells, only well-3, located on the southeastern side went dry while the remaining were gas producers from pay sands belonging to Mahim, Daman and Mahuva formations. However, the seismic signature of the pay sands in the Mahim, Daman and Mahuva Formation are not noticeable though the formation tops can be correlated with the reflection horizons (Figure 3). The presence of a gas chimney at the crestal part of the structure at well-5 creating the prominent reflection-free zone. Further, make it difficult to delineate the thin pay sands of 4 to 12 m thick and explore new sands expected mainly between the formations, the Mahuva and Mahim. Gas chimneys generally appear as low-amplitude chaotic events, low trace-to-trace similarity, and vertically degraded reflection zones. In the North Tapti area, the presence of such gas chimneys is a very common phenomenon adversely affecting the seismic images.

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The main objective of the study is to recover acoustic properties (acoustic Impedance) in the gas chimney affected zone by poststack inversion of seismic data using the laterally varying wavelets. Five horizons namely H1 to H5 were correlated and shown in Figure 3.

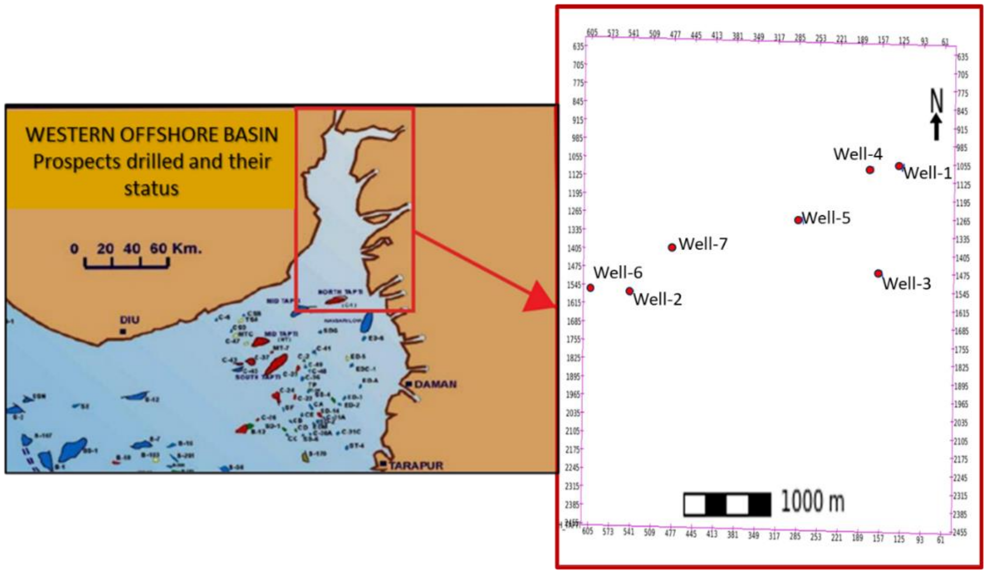


*Figure 1: Location and prospect map of the North Tapti area (Source: Western Offshore Basin prospect map, DGH website).*

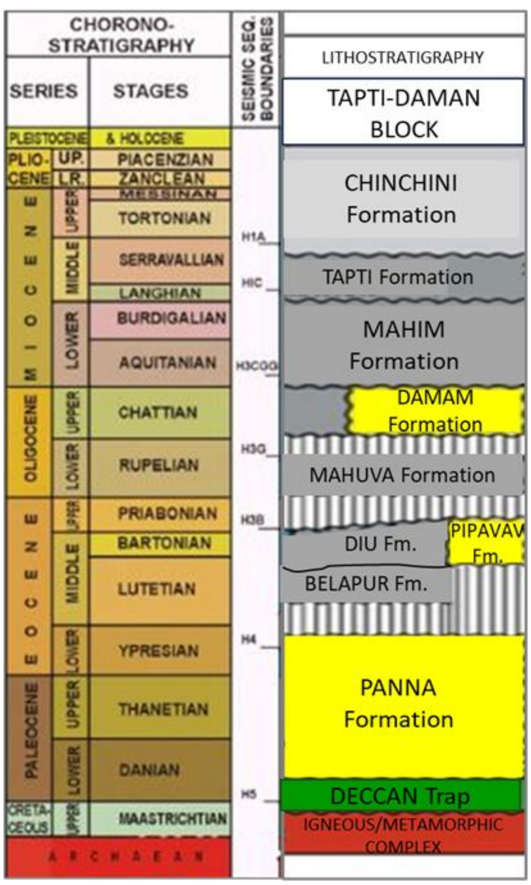


*Figure 2: Generalized stratigraphic chart for Tapti-Daman block. (Source: ONGC Technical Report, Western Offshore Basin)*

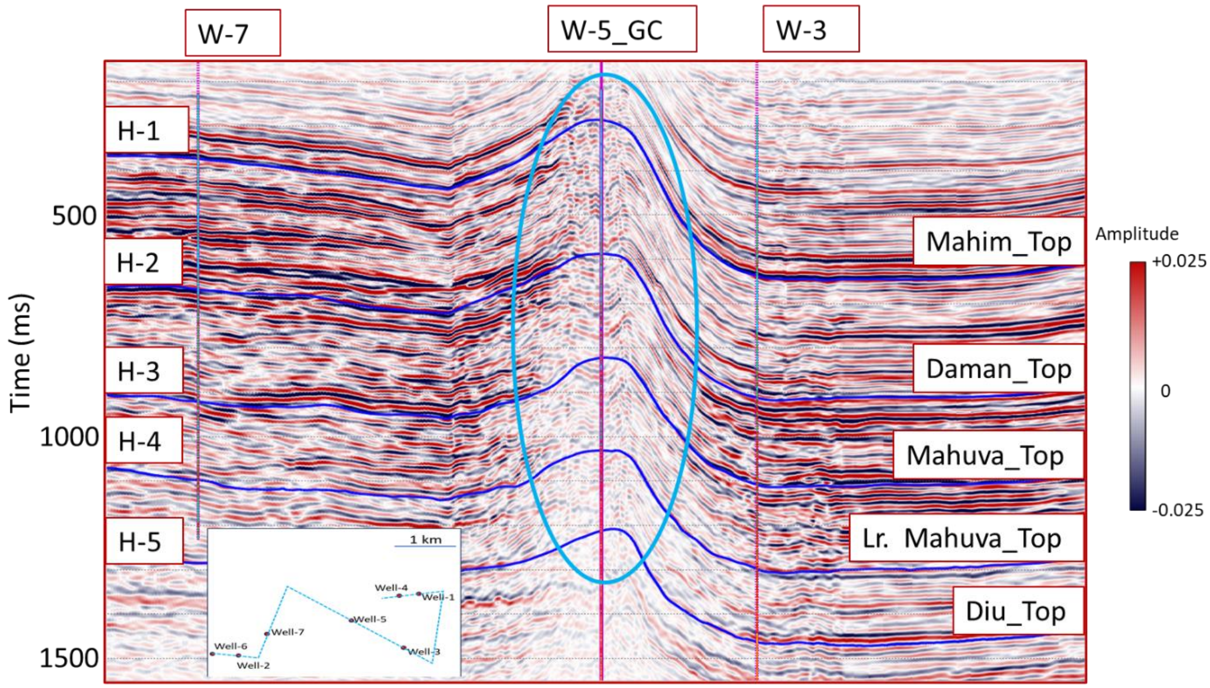


*Figure 3: An arbitrary line extracted from the angle stack traversing through wells 7, 5 and 3. The segment of the line through well 5 exhibits the envisaged gas chimney (blue polygon).*

## Methodology

The 3D seismic data available in the area have a bin size of 25x6.25m which covers an area of approximately 56 $km^2$. The data QCs for all the inputs have been performed before taking up post-stack inversion. The major QCs were the amplitude spectrum and histogram generation, which showed Gaussian distribution of amplitudes and frequency bandwidth of 12db is 8-60 Hz in the data. Subsequently, acquisition footprints were observed on the RMS amplitude maps of angle stacks and were subjected to f-k filtering on time slices to minimize its effect.

The angle stack volume was analyzed through all samples and scrutinized in the f-k domain to identify linear patterns associated with the footprint lineations. Consequently, a highly selective f-k filter was formulated for the area where the footprint was most clearly defined. The sampled slices underwent f-k filtering to eliminate the linear patterns initially in one direction, followed by a similar process in the orthogonal direction. Finally, the filtered individual slices were reassembled to create a consolidated seismic volume.

Basically, the process involves a two-pass f-k filtering of individual time slices from the seismic data volume and recombining them into a composite volume. This is considered equivalent to $k_x$-$k_y$ filtering on time slices which has the advantage of running the process in one step.

For a quality check comparison, a H2 horizon slices (at ~ 625ms) extracted from the input seismic data volume (Figure 4a) and the volume after footprint suppression (Figure 4b). The latter slice displays a clean look after footprint suppression.

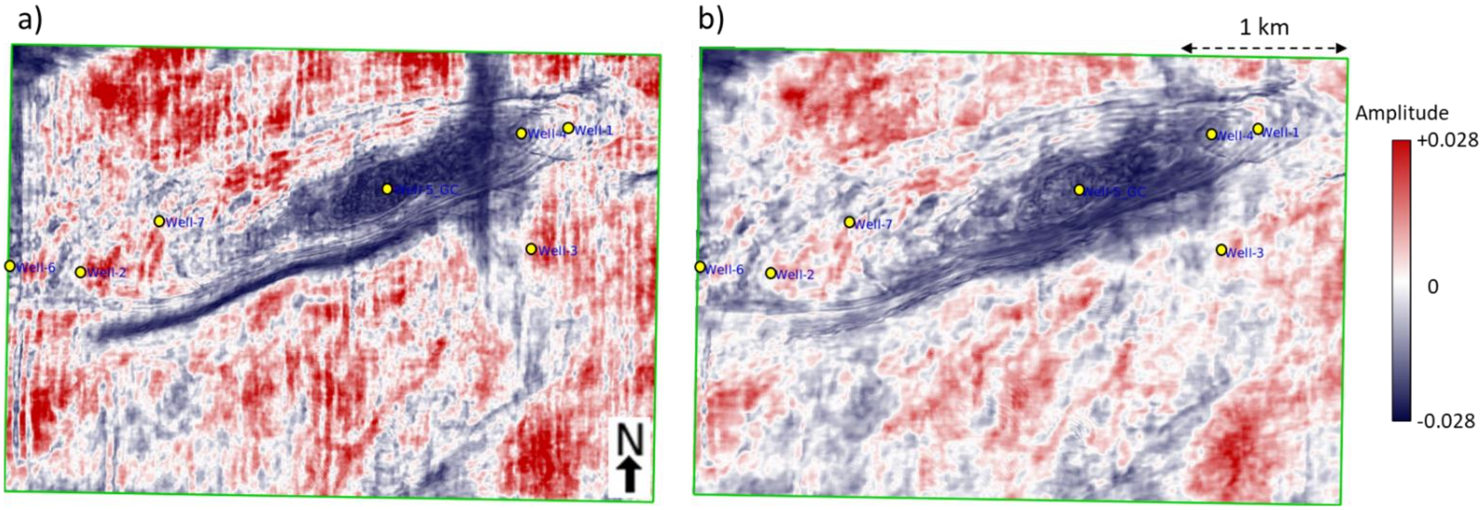


*Figure 4: Horizons slices (625ms) from (a) the input seismic data volume, and (b) the input seismic data volume after acquisition footprint suppression through post-processing. Notice the cleaner look of the display in (b).*

The prominent blue lineament as shown in Figure 4 is no longer visible in the post-processing of stacked data. This comes about due to amplitude balancing brought about with the use of a *surface consistent amplitude correction (SCAC)*. Considering the amplitude on any trace to be a combination of the strength of the shot, the response and coupling of receivers, the offset of the traces, and the reflection from a subsurface level (besides background noise), correction estimates are determined by adjustment of these contributions and applied to the data. This filter enhances the uniformity of the events without masking the amplitudes corresponding to the gas chimney, as illustrated in the section along a crossline shown in Figure 5.

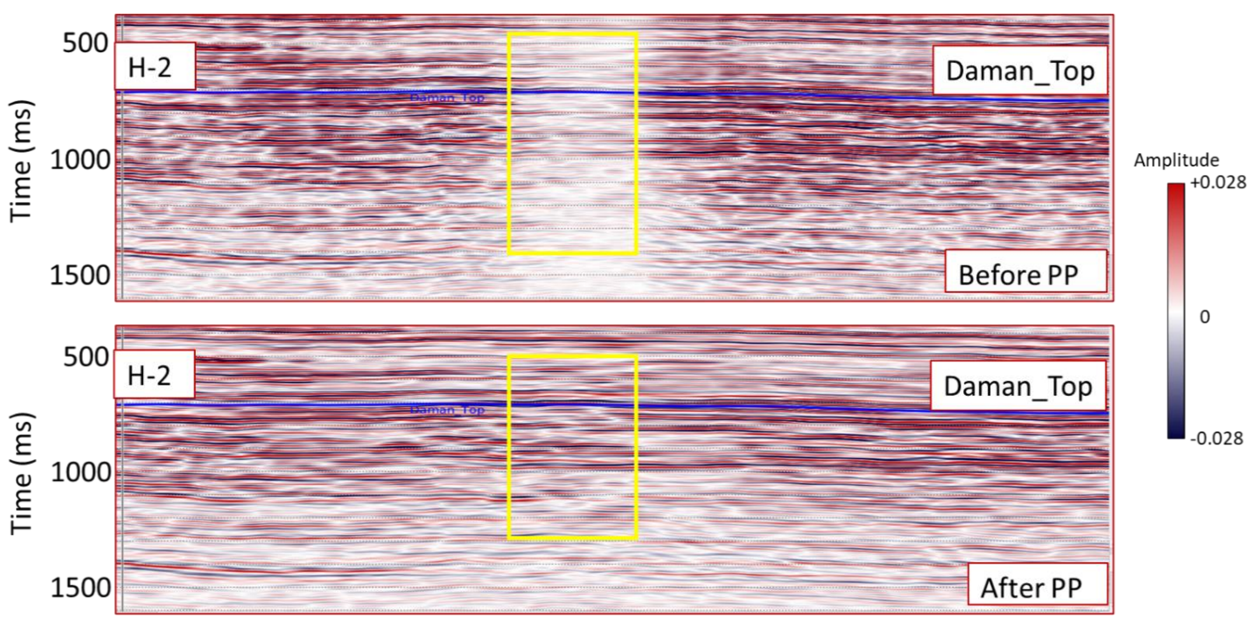


*Figure 5: Segments of a crossline extracted from the full angle stack volume showing weaker amplitudes in the middle of the section (yellow rectangle) (a) before, and which have been enhanced (b) after SCAC.*

## Well-to-seismic tie and wavelet extraction

The well-to-seismic ties were carried out by using the composite well wavelet for all seven wells and reasonable matches have been observed in the seismic and synthetic both. For the schematic presentation, we have shown the well-to-seismic ties for the Well-5 in Figure 6, which shows a correlation of 72%.

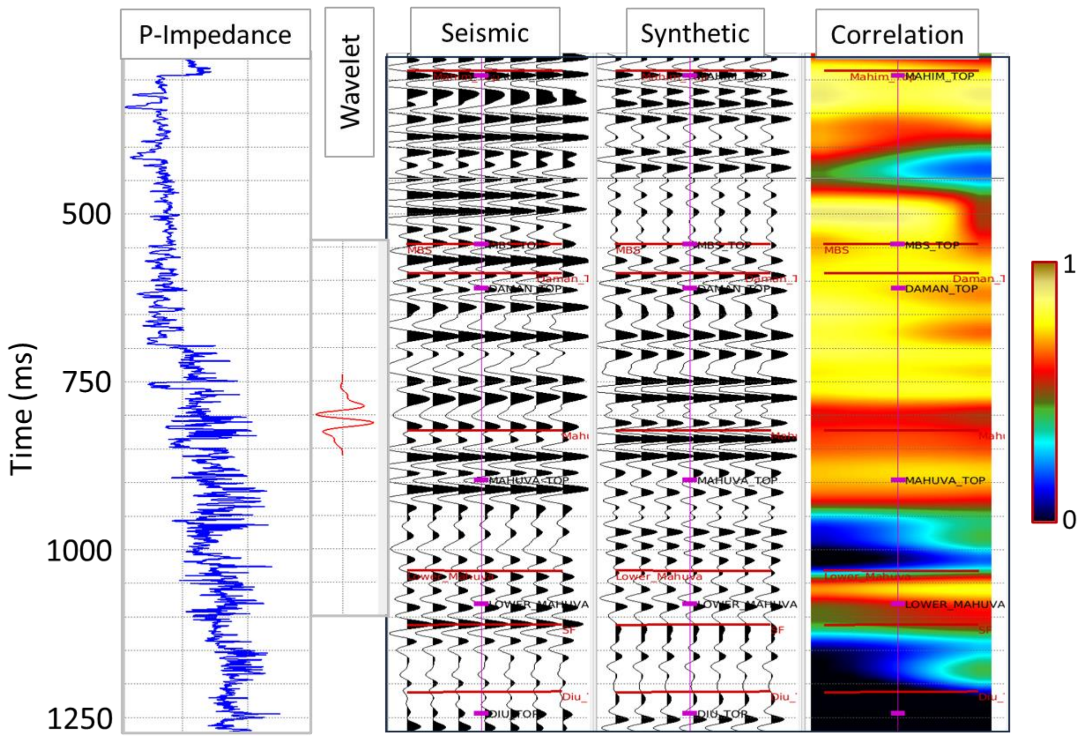


*Figure 6: Well-to-seismic tie for Well-5 shown for the broad zone of interest. The correlation between the synthetic and the seismic traces is about 72 %, which is reasonably good.*

The estimation of laterally varying wavelets for inversion is based on weight horizons, which have been created using an RMS map of the area within a window of 50 ms below the H1 horizon. These weight horizons were used as a wavelet interpolation modifier within Rock-Trace module of Jason software. It has been observed that the wells falling within the affected area have very low amplitude to scale the seismic to synthetic as compared to wells outside. In view of this, RMS slice (Figure 7) for angle stacks has been generated to demarcate the area of influence and general behavior of amplitudes. Based on the understanding of RMS maps, weight horizons ($0 \leq w \leq 1$, where w is the weight for wavelet assigned at every trace location) have been generated for both low and high amplitude areas (Figure-8).

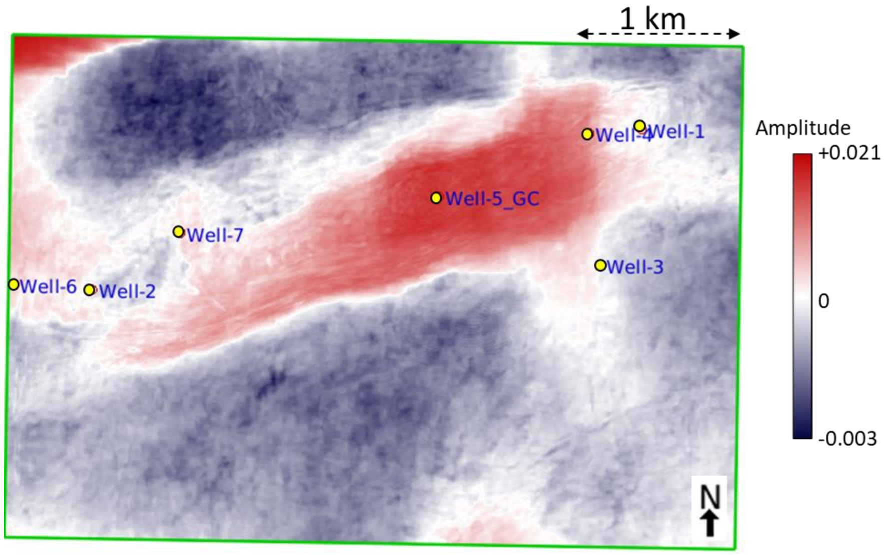


*Figure 7: RMS amplitude slice from the angle stack ( 6 – 21°) and generated for the interval between the H1 marker plus 50 ms.*

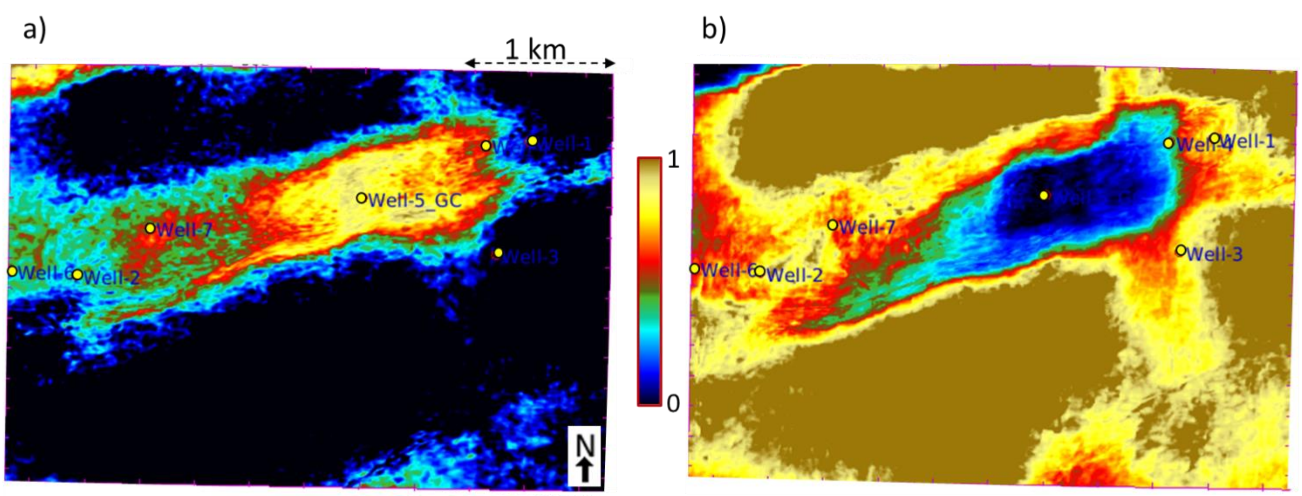


*Figure 8: Weight horizons for lateral varying wavelet (a) outside, and (b) inside the gas chimney affected area respectively.*

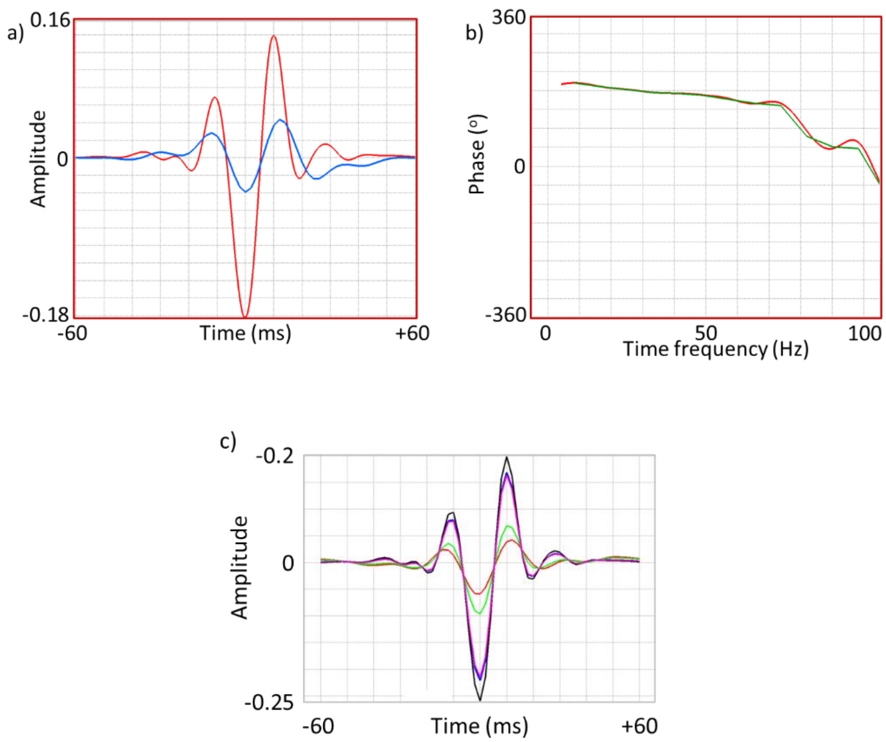


*Figure 9: Amplitude (a) and phase (b) spectrum of wavelet for inside (blue) and outside (red) of the gas chimney affected area, respectively. (c) Laterally varying wavelets along the inline passing through Well-5.*

The combination of two composite wavelets ($w_1W_1+w_2W_2$, where $w_1$ and $w_2$ are weights and $W_1$ and $W_2$ are wavelets), one for the chimney area and other for the area outside the chimney as well as the weight horizons are used to generate wavelets at each trace location. The extracted wavelets inherently exhibit a phase shift of 180 degrees, indicating they are of reverse polarity. By following the above-mentioned method, laterally varying wavelets (Figures 9a and b) have been generated to scale the seismic to synthetic and hence the acoustic properties.

## Poststack inversion

Poststack inversion has been carried out to generate the acoustic impedance volume by using the near angle stack (6 - 21°). This was preceded by well-to-seismic ties at all the well locations and wavelet extraction. The wavelet was extracted based on the RMS map and weight horizons, i.e., laterally varying wavelets. The low-frequency model for impedance inversion was generated using impedance curves for all seven wells with a high cut filter of 10/15 Hz. Constrained sparse spike inversion was run to generate the acoustic impedance volume. The acoustic impedance arbitrary line section is shown correlated with some of the impedance curves in Figure 10, and a good correlation is seen. The distribution of acoustic impedance values laterally looks reasonable, as the gas chimney zone has been brought out nicely. A representative horizon slice corresponding to the H2 and H3 markers has been shown in Figure 11, which explains the earlier observation about all the wells being producers of gas except Well-3. A similar distribution of impedance values was noticed at the other pay levels, i.e., from Mahim to Diu top.

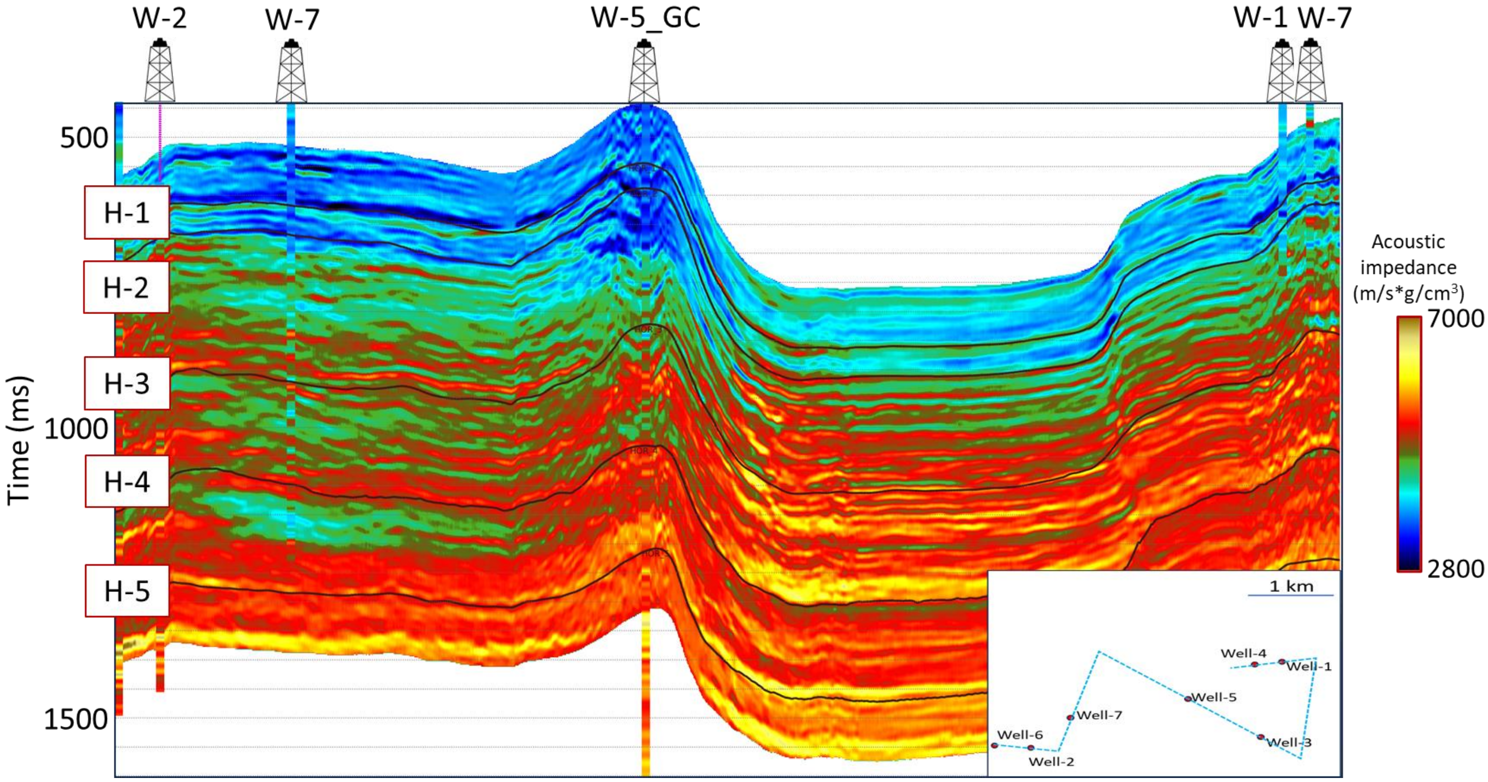


*Figure 10: An arbitrary profile extracted from the acoustic impedance volume and passing through the wells as indicated on the section. The path followed by the profile through the well is shown in the inset.*

## Conclusions

Poststack impedance inversion using laterally varying wavelets in the case of a gas chimney affected area or spatially complex geological setting helps to restore the elastic properties, as demonstrated in this study. The application of the devised workflow to seismic data exhibiting a gas chimney with relatively low acoustic impedance surrounded by high values has demarcated its envisaged boundary. This workflow can now be included in the prestack simultaneous impedance inversion application for the same project, which hopefully will yield more promising results.

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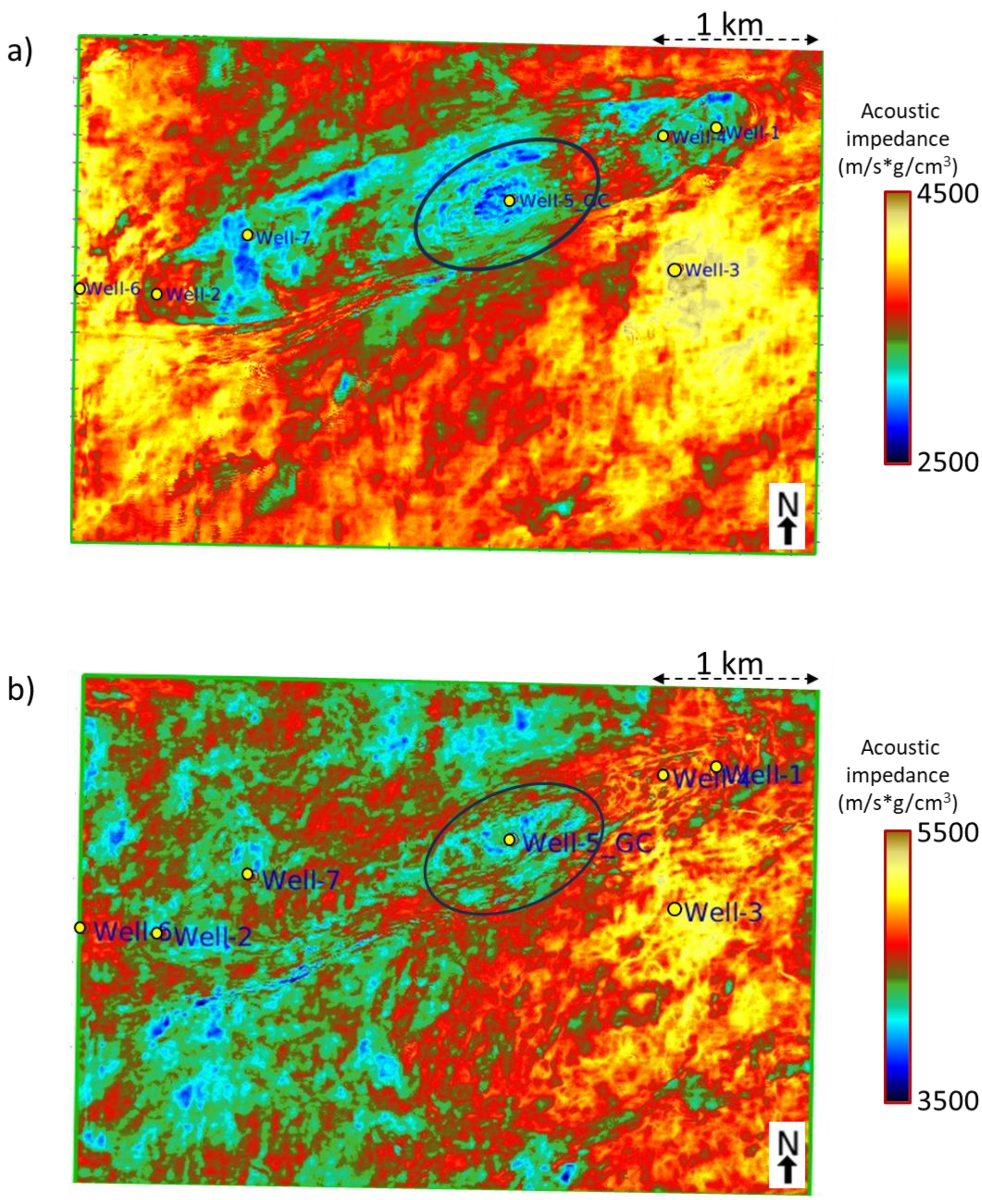


*Figure 11: Horizon slices extracted from the P-Impedance volume shows the lateral changes in this property at the level of (a) H2 marker, and (b) H3 marker levels plus 50ms windows, respectively.*

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