High-resolution pseudo 3D seismic data processing: A case study of shallow marine survey for geohazard risk evaluation, offshore Iran

Introduction
One of the inextricably integral parts of the exploration of gas fields to drill the well is geohazard evaluation study. In conventional marine seismic data, information of shallow depth is not profitable for the study of shallow geohazards. Presence of near offset in seismic data play prominent role to indicate the probabilistic natural hazard Moreover, utilizing high sensitive hydrophones and a suitable gun during the acquisition will be helpful to achieve a data with higher amplitude and frequency contents. High-resolution seismic data is the absolute solution to achieve more information from the near offset and also near angle stack with the acceptable quality.

The presented study describes the processing of 2D high-resolution marine seismic data with very dense line spacing and creating pseudo-3D seismic data cube to perform pre-stack migration for high accuracy geohazards detection The study in the North sea was performed by Whiteside et al. (2013) showed merits of 3D migration data quality rather than 2D migration, and also a similar case study was accomplished with 2D high-resolution data in Malasiya by Khan et al, (2018). The current study was executed in one of the shallow marine gas fields in the Persian Gulf, offshore Iran.

Methodology
3D seismic survey acquisition in some explored areas all around the world may not always be applicable. Making decision in some cases such as exploratory wells drilling in area with high risks of geohazard, specifically gaspacket, is complicated and mostly unreliable by only using images of 2D migrated lines. Based on the 3D nature of the geologic features and structures, the 2D image can not be as accurate as 3D cube, therefore, a 3D image could be a desirable solution.

In this study, we presented the methodology of performing 2D high-resolution seismic data processing and merging together to create a pseudo-3D seismic data cube. 2D seismic data has some advantages over 3D seismic data, for instance, achieving more detail information of shallow depths. On the other hand, the achieved image from 3D seismic data can verify true location of geohazards features which in turn reduces the drilling risks. Our study is separated into two main steps, in each step of processing, we tried to preserve and recover the original characters of the seismic data.

The first step was processing of 2D lines. The optimized performed processing workflow is presented in Figure 1. The workflow was applied on 430 numbers of individual 2D seismic lines with a total length of more than 3000 km which were acquired in four different azimuths (Figure 2). Lines concentration in this area was very dense with average spacing of 50 meters.

(a)

(b)

Figure 1: Applied processing flowchart for (a) 2D, (b) 3D steps.

One of the main objects of this project was performing broadband processing, accordingly, de-ghosting was applied to 2D seismic data to recover the low frequencies which was eliminated in the swell noise attenuation step and also notch frequency to enhance the band-width and resolution of the data (Figure 3). One of the best case studies that presented improvement of frequency band-width of marine data after de-ghosting, specifically in the low frequency, was performed in South China Sea, Zhujian Basin by Zhang et al. (2018).
Figure 2: Base map of 2D lines in four different azimuths.

Figure 3: (a) A sample shot record before applying de-ghosting, (b) and after applying this filter. Zoomed picture shows that ghost effect was suppressed after applying this step. (c) Shallow part of stack section before de-ghosting and, (d) after applying de-ghosting filter in addition to the corresponding amplitude spectrum. The amplitude spectrum show recovered low and notch frequencies.

In the second step, all 2D processed lines (Figure 2) were merged into one integrated prestack dataset and 3D geometry was constructed from all hundreds of processed 2D lines. Having multi-azimuth data, a 12.5x12.5 square shaped bin size was defined. Due to the 2D line spacing with respect to the 3D bin size, along with very irregular CDP fold distribution, some data gaps in the area was expected.

To fill the gaps, regularization and interpolation were performed. Desirable result of interpolation highly depends on the quality of the velocity analysis before regularization and interpolation. Moreover, statics shift of all the lines should be corrected in prior. The tidal static correction was applied for every 2D sailing lines. Mis-tie analysis was performed before creating 3D geometry. Because of unknown streamer depth variation in vessel turning routes, wave arrival timing error, with values greater than 2ms where detected, so related shot records were removed in advance of merging step, accordingly.

Source and receiver amplitude correction step is one of the prominent methods of de-stripping in 3D marine seismic data processing. There were some reasons that conventional amplitude correction was not applicable for this data. The first reason was the presence of a chimney structure in the middle of the seismic survey from north to south, and another reason was the short length of the streamer (900m).
prevented a simultaneous data recording inside and outside of the chimney. In this case, any shot consistent amplitude correction leads to boost naturally weak part of the data inside the chimney area. To solve this issue, the relative source energy was estimated from the amplitude of the very near traces of every shot record, and correction coefficients were calculated for every shots of the cube. Amplification coefficients were then applied to every single shot. After the initial steps, the dataset was ready for interpolation that was challenging step of this study to fill the gaps in the seismic survey and make a more regular output. Figure 4 shows the result of 3D regularization on the both sample stack section and time slice, respectively. Either, the continuity of events in regularized data and the signal to noise ratio were significantly improved.

In 2D processing, severe feathering of streamers caused irrelevant traces to be assigned irrelevant traces to be assigned in a bin. However, this was not encountered in 3D PSTM, where coordinate of midpoints were calculated on the 2D surface not at a 1D line. Therefore, only 3D PSTM provides geometrically correct results. 3D migration has some other advantages that can be profitable in seismic data interpretation. Some of very useful advantages of this methodology are 3D attribute calculation, surface (horizon) attribute estimation, 3D geo-body extraction and most important, accelerating seismic data interpretation procedure. In this current case, to have the highest resolution of data after pre-stack migration, various offset plane size was evaluated. Since small-scale phenomena such as, gas pockets or bright spots exist in shallow intervals of the study area, preserving and improving the quality of features after migration was of extreme importance. Therefore, dense offset bins were defined for executing migration. In Figure 5 (b), a section of a crossline after 3D PSTM is shown. For better comparison, the PSTM result of a 2D line in the same location is also displayed Figure 5 (a).

Figure 6 compares conventional 3D data (a) with the PSTM HR pseudo-3D cube (b). It is evident that more details are detectable on HR seismic data with respect to the conventional seismic, especially in the top 500 ms time interval. The indicated shallow brightening anomalies are thought to be originated from gas-charged sediments which are barely visible on the conventional vintage. It should be noted that, neither post-stack processing filters nor smoothing filter were applied on HR cube.
Figure 5: (a) A sample stack section of 2D PSTM and (b) 3D PSTM stack section of the same location.

Figure 6: Comparison of (a) 3D conventional PSTM stack and (b) PSTM HR pseudo-3D stack in detectibility of shallow anomalies.

Conclusion
The results of this study show that converting 2D high resolution seismic data to a pseudo 3D cube to detect the original location of geohazards elements and preserve effects of small features in shallow marine area with geohazard risk is profitable. On the other hand, increasing the quality and image resolution with low cost exploration by using 2D high resolution site surveying can be a solution for shallow marine fields. In addition, 3D seismic cube has several applications in which, more importantly accelerating quantitative interpretative analysis. Increasing the quality of site surveying by using high performance instrument setting such as the cable length, receiver distancing and so on, are highly recommended to accomplish more certain results.

References
