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Mitigating Risk and Uncertainty - An innovative approach of Velocity based Pore Pressure Prediction and Special Studies from KG Basin

Summary

Drilling particularly in the deepwater environment is becoming increasingly complex and expensive. A significant portion of all total nonproductive time is due to geohazards. This manifests itself in situations such as blowouts, stuck pipe, losses and wellbore instability. Pre drill assessment of geohazards like abnormal pressure and shallow water flows is required for safe and economic drilling and is an essential component of well planning. Seismic velocity is the only physical parameter available at the pre drill location and is of paramount importance while carrying out any pre drill estimation of geohazards. Accurate estimation of these velocities is the key parameter for geohazard delineation.
The first case study presented in this paper discusses the innovative approach used to carry out Pore Pressure Prediction using freshly picked seismic velocities. The second case study discusses the delineation of Shallow Water flows in offshore area. The methodologies adopted in both the case studies are not standard workflows. The unconventional approach adopted in both the cases has been helpful for derisking the drilling hazards.

Introduction

Pore pressure or formation pressure is defined as the pressure acting on the fluids in the pore space of a formation. Overpressures or geopressure is a subsurface condition in which the pore pressure is above the normal/ hydrostatic pressure. When this overpressure is encountered in shallow sands in deepwater areas resulting in water flows below the mudline, it is known as shallow water flows/shallow hazards.
Seismic velocity is the only physical parameter available at the proposed location. Pore pressure can be estimated from elastic wave velocities using a velocity to pore-pressure transform.Seismic velocities used during processing are designed to optimize the stack/ migration process. Local fluctuations frequently are smoothed out, the velocity pick interval is often coarse and might not have been picked exactly at the proposed location. Therefore, the velocities obtained from processing lack the resolution required for carrying out pore pressure analysis. Pore pressure analysis based on such velocities may not give a viable solution at the target location. Velocity analysis for pore pressure/ geopressure prediction requires a level of detail in the velocity analysis that goes beyond the accuracy of normal stacking velocity used for traditional imaging work. This limitation has been rightly reported by some pore pressure experts. Therefore, determination of accurate fit to purpose seismic velocity is the key for carrying out pore pressure and geohazard studies. Hence, it was judiciously thought of by the authors to carry out fresh seismic velocity analysis in the proposed well location. This velocity is then used to carry out pre drill pore analyis.This innovative workflow is highlited in the first case study.

Delineating geohazards like shallow water flows, areally or in a 3D sense requires integration of different studies. The second case study discussed in this paper highlights how the authors have delineated the zones of shallow water flows/ shallow hazards through the integration of two studies using innovative methodologies/ workflow. Firstly pore pressure analysis was carried out at selected location across the area using freshly picked seismic velocities. Secondly, model based post stack inversion was carried out in an innovative way using pseudo wells. Both these approaches and their integration for delineation of shallow hazards is discussed at length in the second case study.

Case Study 1: Pre drill pore pressure analysis using freshly picked velocity

The target well under study, X, is from KG onland area. The objective of the well is to explore the Raghavpuram play with a target depth of 5500m.There is only one well (A) drilled in the nearby area till the ragharvpuram formation. Conventional pore pressure analysis was carried out for the target well, X using the nearby high pressure well, and seismic velocity provided by the processing centre.

The predicted results from nearby well locations in general give a fairly good idea to the pore pressure at the proposed locations with the assumption of similar geological conditions. The pore pressure predicted at well X on the basis of seismic velocity shows a more or less similar trend to that of hydrostatic pressure, whereas the pore pressure envisaged on the basis of nearby well A shows high pressure after 3000m depth (Fig 2(a)).

Therefore it was thought by the authors to carry out fresh velocity analysis after gather conditioning. Velocity analysis for pore pressure prediction should be able to detect abrupt velocity changes and record them for use in the prediction process. To facilitate this process, seismic gathers should be conditioned to assure the highest possible quality velocity analysis. As it is clear, picking of velocities was difficult as the semblance could not provide a viable velocity trend. Therefore, the CMP gathers were conditioned with the limited available processing module. Supergathers were formed to improve the signal to noise ratio by attenuating the random noise. Automatic Gain Control (AGC) was applied that could enhance the signal at deeper level, thereby providing a reasonably good semblance for velocity picking. Moreover, only those portion of the data were used with good signal to noise ratio for the purpose of velocity analysis. This was achieved by designing suitable inner and outer mutes.

The confidence level of picking velocity even upto a deeper depth (Two Way Time) was quite good. This was achieved as the semblance has been enhanced because of the gather conditioning and optimizing the velocity analysis parameters. The gather at proposed well X along with velocity semblance/ trend before and after pre-processing along with the freshly picked velocities are shown in Fig 1 . Using this velocity pre drill pore pressure analysis was carried out.

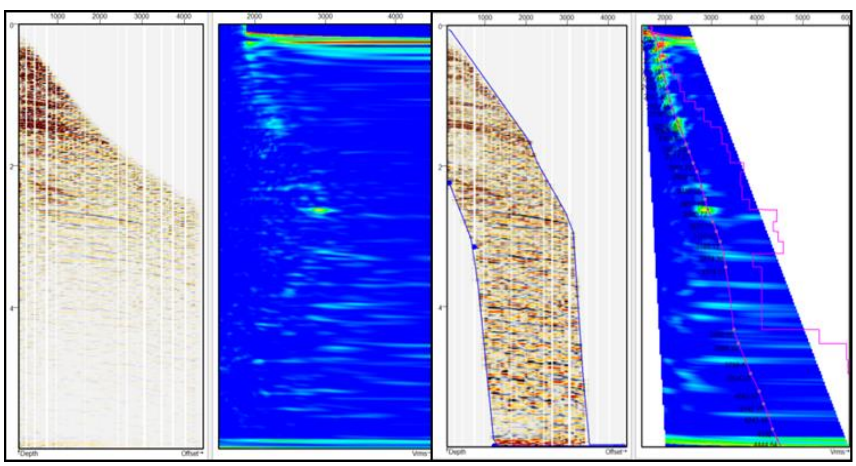


Fig 1. Seismic gathers along with before (left) and after processing (right) along with the picked velocity for target well X .

Analysis of result

The pore pressure derived using the nearby well A and the velocity provided for target well X are completely different at the zone of interset Fig 2(a).Fig 2(b) shows the comparison of pore pressure derived using freshly picked seismic velocity and velocity provided for target well X. The pore pressure computed using freshly picked velocities shows high pressure after 3000m depth which is similar to what is computed using nearby high pressure well A data (Fig 2(c)). Whereas the pore pressure computed using the velocities provided by the processing centre shows hydrostatic pressures after 3000m depth Fig 2(a &b).

Therfore, designing the drilling parameters based on the pore pressure derived from processing centre velocities could have led to dramatic results. The study emphasizes the necessity for freshly picking seismic velocityies fit for carrying out pore pressure studies.

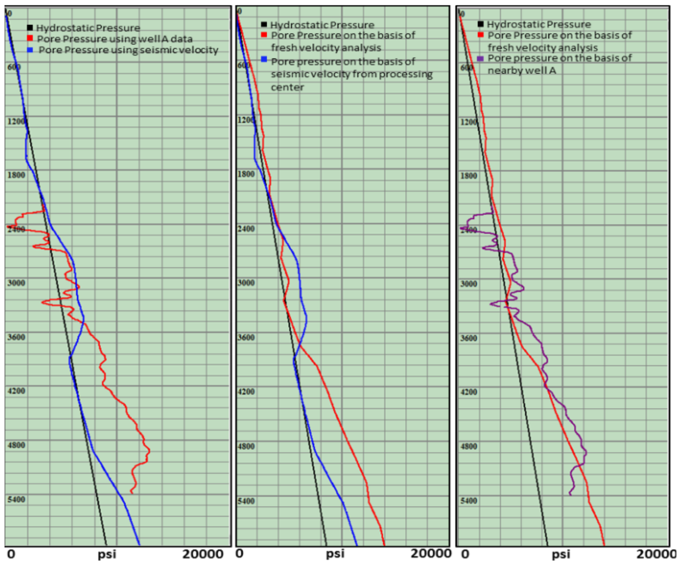


Fig 2. (a)Pore pressure on the basis of nearby well A and velocity provided for target well X, (b) Pore pressure on the basis of velocity provided and freshly picked for target well X , (c) Pore pressure on the basis of freshly picked velocity of target well X and nearby well A.

Case Study 2: Derisking shallow hazards using pore pressure and special studies

The study area lies in the Krishna Godavari basin in the east coast of India (Fig. 3). It experiences very high sedimentation rates from the Krishna and Godavari Rivers. The huge volumes of sediment are accommodated by a major growth fault. Flowing water with sediments and some gas in the wells were encountered in the area at shallow depths. Highly promising Miocene roll structure exist beneth the shallow hazard zones. The wells A & B encountered high pressures at shallow depths. The other wells available (C,D & E) are quite far off and are in a different geological setup.

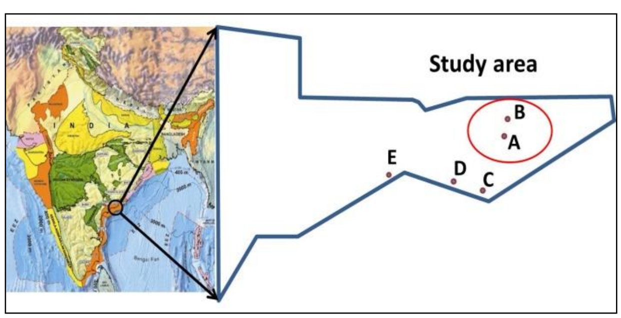


Fig 3. Map of the study area showing the well locations

The study area has only few wells drilled nearby. Conventional pore pressure analysis requires well log data of nearby wells and seismic velocities at proposed location. In this case, the logs in the nearby wells are of limited extent and are missing in the shallow levels which is zone of interest for the present study. Also the geologic setup of the wells is different from the area of interest. Secondly, the seismic velocities obtained from the processing centre lack the vertical resolution required for carrying out pore pressure studies. Also the derivation of an appropriate scalar for scaling down the interval velocities is subjective considering the fact that the extent of the recorded logs are limited and the drilled wells are not in a similar geologicals set up. Therefore carrying out only conventional pore pressure prediction studies using the standard procedures as discussed earlier may not be not be able to fulfill the objective. This necessiated the authors to look for an alternative/ innovative methods for achieveing the objective.

Alternative Plan/ Methodology

The alternative plan to the standard procedure of pore pressure prediction adopted for shallow hazard study is as follows:

- To carry out fresh velocity analysis, using pre-stack gather with best possible resolution and then to carry out pore pressure prediction from seismic velocities freshly picked at these selected locations.
- To carry out post stack inversion: Calibrating inversion results with anomalous zone encountered at well locations and demarcating the areal extent of the hazardous anomaly. Then looking for similar anomalies spread over in other places in the area of interest.

1D-Pore Pressure Prediction

1D pore pressure analysis was carried out at 35 locations in and around the area of interest usimg freshly picked seimic velocites as described earlier.In 1D pore pressure analysis, velocity gradient changes are observed (Fig 4) which may be qualitative indication of high pressure but the pore pressure derived is not conclusive. Therefore the results obtained were not able to satisfactorily explain the zones of shallow hazard.

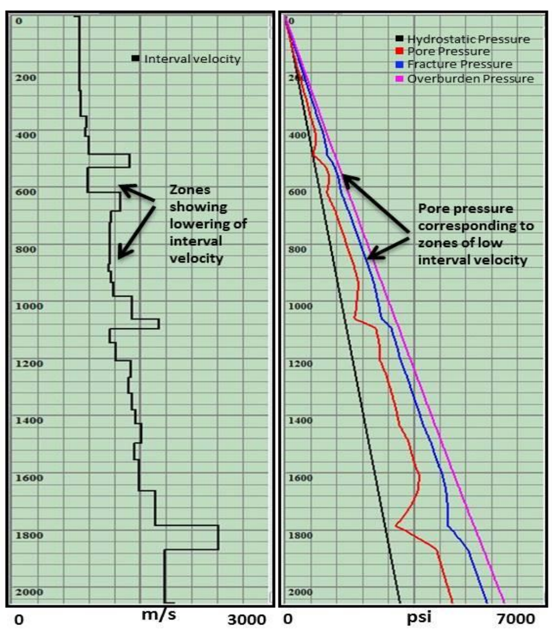


Fig 4. 1D Pore Pressure Prediction at well location A

Post Stack Inversion

To carry out model based post stack inversion sufficient well control is required for derivation of low frequency model and also to calibrate inversion result at these locations. Due to the limitations/insufficiency of well data in the area an innovative/alternate approach was adopted of creating pseudo wells using freshly picked velocities for carrying out model based post stack inversion. Model based Post Stack Inversion requires low frequecy model using the well logs. The velocity analysis carried out by the authors had sufficient resolution to give this low frequency required for the model. For creating pseudo wells velocity analysis was carried out at 16 locations spread in the area.

The seismic velocities obtained at the 16 locations were then used for creating pseudo wells and logs. As the level of confidence in picking of the velocities is reasonably good, therefore it was thought the velocity trends obtained would suffice the requirement for providing the desired low frequency trend. The RMS velocities were converted to interval velocity in depth and then to sonic log. Using the Gardner's transformation the sonic log was converted to density log. These logs were used as an input to post stack inversion. The post stack inversion results were calibrated at the well locations where shallow high pressure was encountered. High pressure zones correponding to the drilled wells were seen as low impedance zones at the well A and B. Inline and xline passing through the wells A and B pertaining to seismic and inverted volume are shown in Fig 5 and 6. As observed from the above figures the shallow hazard zones correspond low impedance in the inverted volume.

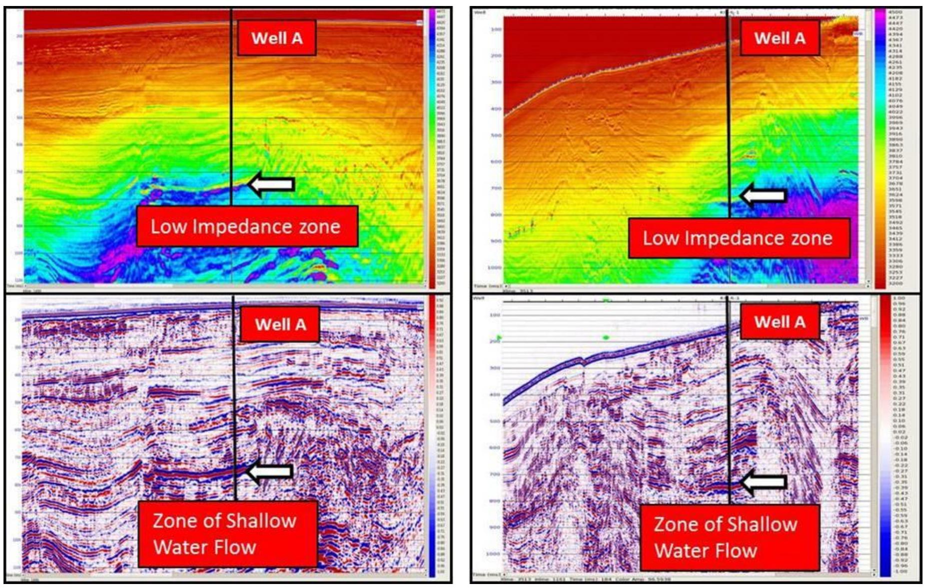


Fig 5. Inline & Xline respectively along the inverted (above) and seismic (below) volume passing through well A

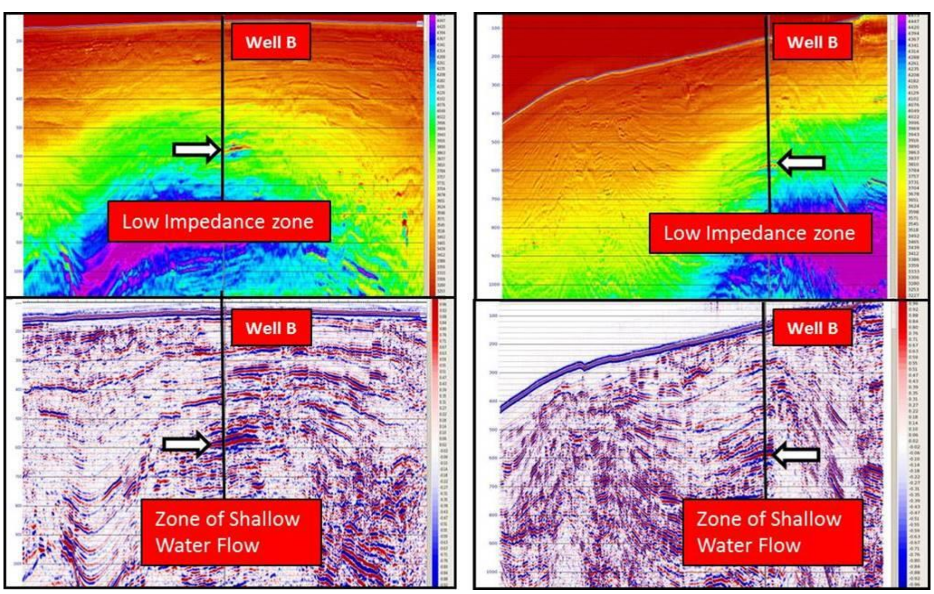
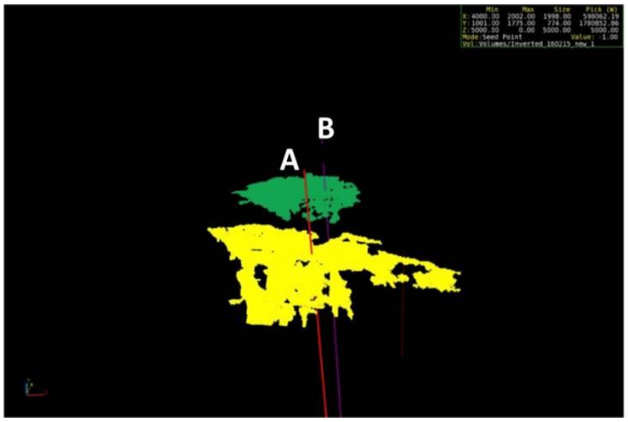
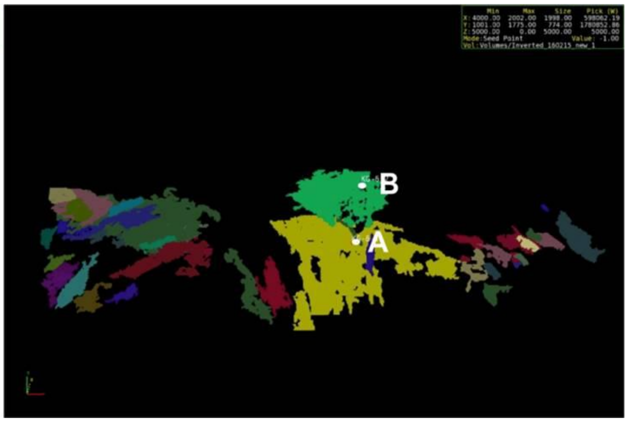


Fig 6. Inline and Xline respectively along the inverted (above) and seismic (below) volume passing through well B

This inversion volume was then analysed in 3D sense using Geo Probe software to find the extension of the low impedance anomalies observed at well A and B and also to identify & delineate similar anomalies in the area of interest.



(a)



(b)

Fig 7. (a) Extension of the low impedance anomaly (high pressure zones observed at well A and B. (b) Low impedance anomalies (high pressure zones) in area around well A and B

The extension of the low impedance anomaly observed at well A and B is shown in Fig 7(a). Similar Geo anomalies at different levels were tracked and identified till 1000ms TWT with different permutation and combination and a tentative area of anomalous zone was identified as shown in Fig 7(b).

Analysis of the results

In 1D pore pressure studies using freshly picked seimic velocities, velocity gradient changes are observed which were used as qualitative indicatiors of high pressure. But the pore pressure derived is not conclusive in the Shallow Water Flow zone.

The post stack inversion volume shows anomalous low impedance zones in the shallow region which are indicative of the high pore pressure zones in the region. The same is validated through the observation at well A & B. The Geo anomalies obtained through tracking the extension of the low impedance anomalies at the wells A and B, and similar anomalies in the nearby areas may indicate the zone of the Shallow Water Flows/ high pore pressure.

The demarcation of probable high pressure zones indicates suitable locations towards the north east of the area.

Conclusion

The first case study rightly justifies the importance of carrying out fresh velocity analysis fit for carrying out pore pressure prediction studies. The pore pressures estimated using the processing centre velocity underpredicts the formation pressures at the zone of interest. Using the same may lead to dramatic results while drilling. Therefore, fresh velocity analysis fit for pore pressure prediction should be carried out to reduce uncertainties in the predicted results.

In case 2, the entire area had lot of drilling complications owing to the presence of shallow hazards. In an area where well logs were not available, carrying out only pore pressure (even with freshly picked seimic velocities) was not suffient to address the issue. Therefore post stack inversion was carried out using an innovative approach of generating pseudo logs from seismic velocity. The inversion results thus obtained are able to demarcate the anomalous (low impedance) zones which may be attributed to high pressure as calibrated at wells A and B. Integrating the results obtained through pore pressure and post stack inversion studies have provided a way to look into the extension of such hazardous zones and tap the reserves beneath.
The methodologies adopted in both the case studies are not standard workflows. The unconventional approach adopted in both the cases has been helpful for derisking the drilling hazards.

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