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Whether to place the shot in higher velocity sand or lower velocity clay? A case study from Cambay Basin, India.

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Summary

In land seismic surveys placement of shot (blasting of explosive) in an appropriate near surface layer plays an important role in terms of transmission of shot generated energy. An optimally selected shooting layer is expected to result in good energy transmission and better data quality. Normally a higher velocity layer is expected to give rise to better energy transmission and conversely in case of lower velocity. On contrary, deviations from this general expectation, have been observed in North Cambay Basin, India (along eastern basin margin) wherein , at places, sandy high velocity layer results in deterioration of energy transmission from a blasted shot and lower velocity layer with more clay content shows energy transmission which is better than expected from a lower velocity layer. Consequently the recorded energy from shots placed in these two types of layers appears intriguingly at variance from the general belief. This could be, probably, due to lithological variations, nature of stratification in the near surface (thick uniform layer or a layer made up of thin alternating layers of high and low velocity) in and below the layer in which shot is blasted to generate seismic energy. In the present paper Uphole data vis-a-vis recorded seismic data have been analysed and an attempt has been made to draw an empirical relationship between near surface characteristics (variations of velocity, lithology , stratification pattern etc) and variations of recorded data quality in terms of energy(signal to noise ratio) and frequency. Results of the data analysis shows that increased sand content in the shooting medium (the layer in which explosive is blasted) , more stratification(thin layering of alternating high and low velocity), presence of a low velocity layer below and more sand content in the layer just below the shooting layer , tone down the recorded data quality in terms of energy and frequency. Thus consideration of all these parameters, while selecting the shooting medium, help in assessing the overall merit of the near surface layer, as shooting medium .At times near surface conditions are such that it is not feasible to select the best near surface layer qualifying as shooting medium (because of deeper depth and/or difficult to be drilled), then it is wise to select a layer as shooting layer which may be termed as the cheap and best alternative for the best available recorded data quality. This paper presents a case study from Cambay Basin, India, emphasizing role of near surface lithology and stratification pattern as modifying factors after velocity being a weighty factor in deciding the data quality of recorded seismic data.

Introduction

Halisa –Limbodra area in Cambay Basin comprises rising flank of eastern basin margin in Ahmedabad tectonic block. While acquiring 3D seismic data in north of Halisa area in Cambay Basin during Field Season 2007-08, peculiar observations regarding data quality were made. The area is bisected by Sabarmati River trending NNE-SSW (Fig. 1). Generally the seismic velocities of sub weathering layer are quite consistent in the area to the east of Sabarmati River but the area west of Sabarmati River shows acute variations of near surface velocity and thickness of weathering layer. In general the weathering thickness is more near to Sabarmati River and in the area to the west of it. At places the seismic velocities are of the order of 400-1000 m/s up to 60 m from ground surface and there is no option left but to place the explosive in comparatively low velocity medium for taking shot. Such variations result in a constraint on energy transmission from a blasted shot and result in inferior data quality both in terms of frequency and amplitude standout. The lithological variations in the near

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surface (up to 60m below the ground surface) are also very frequent and the near surface largely contains sandy layers. The clay content is generally less and at places increases, at the best, to make an overall sandy clay layer otherwise largely the near surface layers are sand- gravel, sand-gravel-clay, sand- clay with dominance of sand. The water table in the area is very deep (~below 100m from ground surface) and the sands in the near surface layers(up to 60m) are not saturated with water.

Methodology and data analysis

Scanning of the acquired data through field records for quality monitoring exhibited two seemingly contradictory characteristics:

1. In the area to the east of Sabarmati River, the velocity of shooting medium is generally good (1400 m/s to 2000 m/s, occasionally 1200-1400 m/s). The general expectation regarding data quality was good, but in certain patches, the data quality observed is below expectations.
2. In the area to the west of Sabarmati River, in certain patches quality of data acquired is better beyond expectations.

These observations intriguingly made the acquisition crew think about factors other than velocity, affecting the data quality. This made the crew analyze all up hole (generally up to 60 m depth) data and correlate various variations like lithology, velocity, stratification pattern of near surface layers especially in which shot is blasted. It was found that though the velocity of shooting medium is believed, by most of the geophysicists, to be the weightiest factor responsible for data quality. But the lithology (sand content) and stratification pattern (whether the shooting medium / layer is comparatively uniform and thick or made up of thin alternating layers of high and low velocity) also affect the data quality quite significantly. This paper presents a case study attempting to develop an empirical relationship under which the variations in near surface lithology and stratification pattern become modifying factors governing resultant data quality. This study emphasizes the role of lithology and stratification pattern (heterogeneity) as modifying factors in addition to near surface velocities.

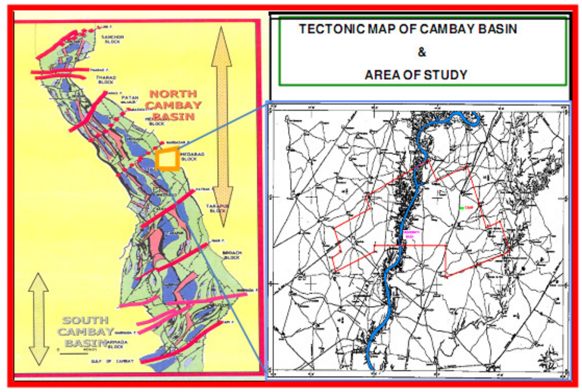


Fig.1 Location of study area

Up hole surveys (generally up to 60 m from the surface) have been carried out in the area in uniform grid of 960m X 960m to know near surface seismic velocities and prepare near surface models to identify optimum shooting medium. All the up hole data were studied in detail for velocity, lithology and stratification pattern of the shooting medium and presence of a low velocity layer just below the shooting medium. After analyzing the various factors enumerated above and thought to be modifying factors for data quality in addition to seismic velocities, all these factors were given weights (the extent to which it affect data quality) and empirically the resultant data quality (dependent on the signal to noise ratio (S/N) and frequency content) was calculated and it is called projected quality index (PQI). In the process of quality monitoring all the records were analyzed on field processing unit (FPU) for frequency spectrum and signal to noise ratio was observed from SQCPRO (quality monitoring system in UL408 recording instrument by Sercel). The weights of the modifying factors were adjusted so that the PQI and observed QI (quality index) are comparable. QI has two components (60 % S/N ratio and 40% frequency). Data quality was assessed as per the following table.

QI	Data quality
➢ 0.95	Excellent
0.85 to 0.95	Very good
0.75 to 0.85	Good
< 0.7	Fair

PQI= (velocity factor) X (lithology factor) X (stratification pattern factor) X (factor for low velocity below the shooting medium)

Weights of these factors are kept as follows:

Velocity factor=1.0 for velocity >=1250 m/s
=0.98 for velocity of shooting medium between 1000 m/s and 1250 m/s
=0.95 for velocity < 1000 m/s

Lithology Factor = 1.0 for sand percentage <=40 % (sandy clay)
= 0.95 for sand percentage 40% to 50 % (clay + sand)
= 0.85 for sand percentage 50% to 60 % (sand+ clay)
= 0.80 for sand percentage > 60 % (clayey sand)

Example for a case where

1. Velocity = 1400 m/s
   : velocity factor is 1.0
2. Lithology of shooting medium is clay + sand
   :lithology factor is 0.95(40 to 50 % sand)
3. There is low velocity layer below shooting medium : thin shooting medium factor is 0.95 (within less than 4 to 5 m below the shot depth)
4. Shooting layer comprises of thin layers of alternating high & low velocity: stratification pattern factor is 0.95

If the factor nos 3 & 4 are absent, no considerations are to be given (factors become unity). In this case PQI= velocity factor X lithology factor Contour maps for velocity factor and sand percentage (lithology factor) have been generated (Fig. 2 & Fig. 3). Contour map for factors like shooting medium stratification and low velocity below the shooting layer were generated together and is shown in Fig.4. Wherever shooting medium is stratified and a low velocity layer below within 2 to 4 m below shot depth, the combined modifying factor is 0.9, otherwise, individually the stratified nature of shooting medium or presence of low velocity below the shooting layer within 2 to 4 m below shot depth, the modifying factor is 0.95.

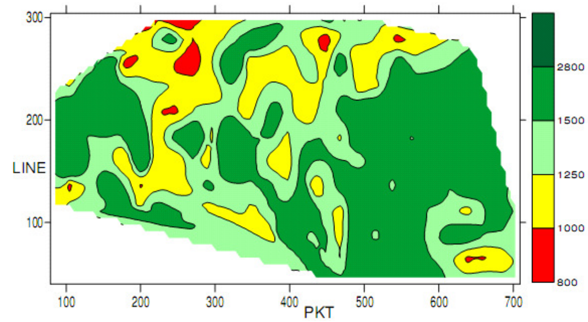


Fig.2 Contour map of velocity of shooting medium

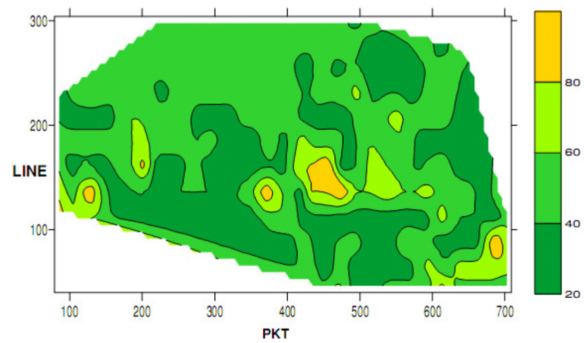


Fig.3 Contour map of sand percentage

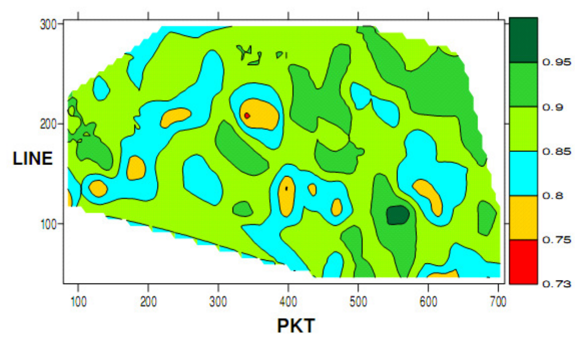


Fig. 4 Contour map of projected quality index (PQI)

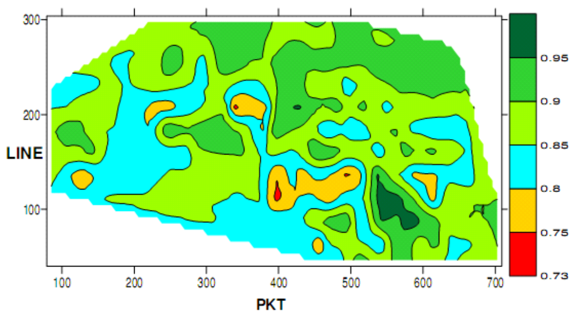


Fig. 5 Contour map of observed quality index (QI)

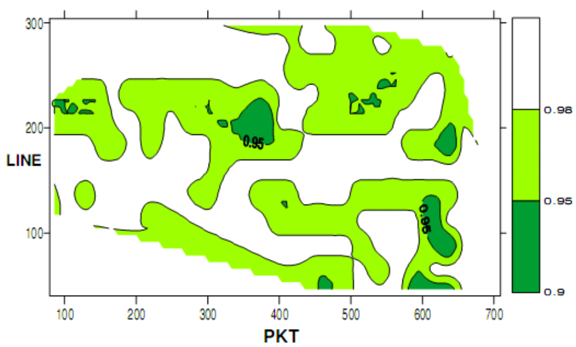
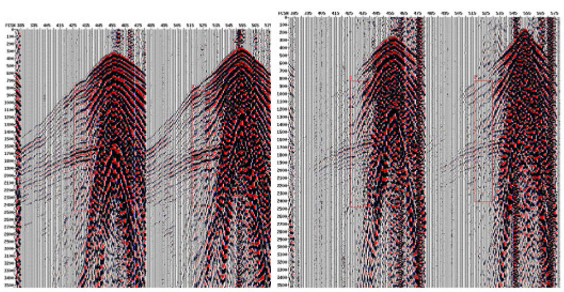


Fig. 6 Contour map for combined factor for shooting medium stratification and low velocity below the shooting layer



(a) (b)

Fig. 7 Monitor records in western part of the area (a) Good record, (b) Fair record

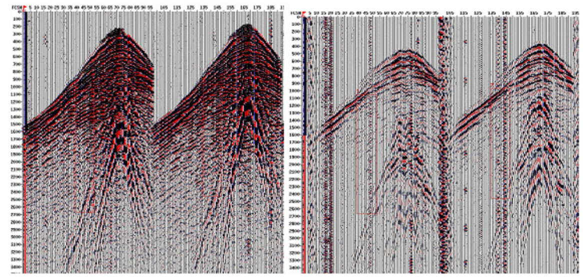


Fig. 8 Monitor records in eastern part of the area (a) Good record, (b) Fair record

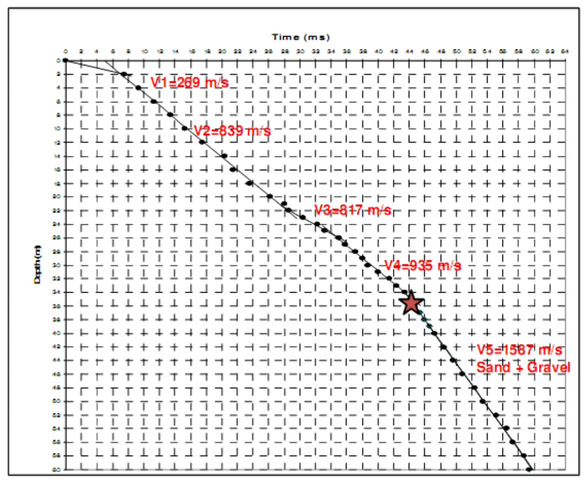


Fig. 9 (a) Hodograph corresponding to high velocity but predominantly sand formation

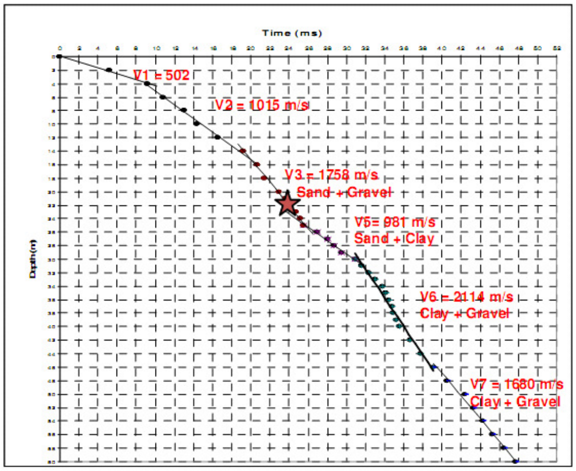


Fig. 9 (b) Hodograph corresponding to high velocity thin medium with clay sand and low velocity layer below

Results and discussions

The shooting medium in the area to the east of Sabarmati River has generally good velocities (of the order of > 1500 m/s), except few patches that have velocity of shooting medium of the order of 1000 m/s to 1500 m/s. (Fig. 2). Thus as per good velocities of shooting medium the data quality in general should be very good. However, a look at the east central part of contour map of PQI or QI (Fig. 4 & Fig. 5) depicts that the north- south trend of very good quality rating is toned down by a cross trend (SW-NE) of lower quality rating, corroborating with a high sand percentage as well as a similar trend shown by the contour map showing composite effect of shooting medium stratification and presence of low velocity below the shooting medium. This results in the ultimate data quality being less than expected (Fig. 8 and Fig 9(a & b).

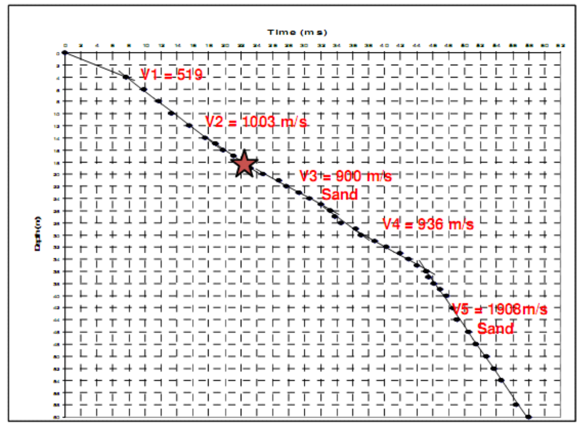


Fig. 9 (c) Hodograph corresponding to sufficiently thick clayee shooting medium (lower velocity) & low velocity below

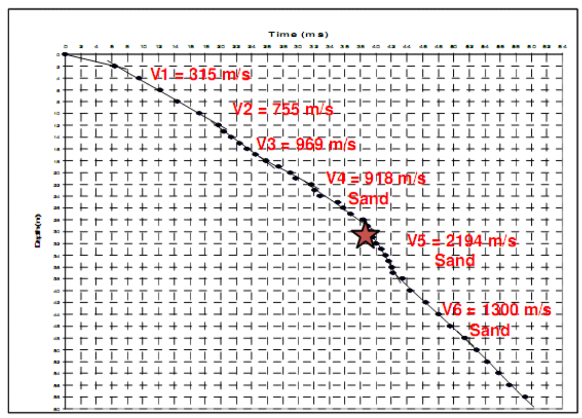


Fig. 9 (d) Hodograph corresponding to Sand + Gravel + Clay lithology and low velocity below

The northern part of the area to the west of Sabarmati River has velocities of the shooting medium on lower side (~ 1000 m/s to 1250 m/s) thus the general expectation about data quality should be fair to good. However the contour map showing QI and PQI (Fig.4 & Fig.5) show the quality rating to be good to very good. This is because the shooting medium though slightly loosing merit on account of velocity but retaining its merit on account of sand percentage being below 50% over most of this area (Fig. 3). Also the shooting medium is not loosing merit on account of shooting medium stratification and presence of low velocity below the shooting layer (Fig. 6). Thus the resultant PQI/ QI in the area is still good to very good. The up hole data analysis vis-à-vis the observed data quality over the entire area suggests that the order of difference of velocity of shooting medium and the layer below decide their impact on modification of data quality through presence of low velocity below. If this difference is low, the impact or extent to which data quality is modified is also low. If the velocity of shooting medium is say approximately 1000 m/s and the velocity of layer below is approximately 700 m/s, then its effect is as if there is no low velocity layer below. But in a case where velocity of shooting medium is around 2000 m/s and there is a low velocity layer (~ 1000 m/s) below, it will have full fledged impact as a low velocity layer present below the shooting medium (Fig. 7 and Fig 9 (c & d). It can be observed from Fig. 9 (c) and Fig 9(d) that the contrast in velocity of shooting medium and the layer below is more in the second case than the first one.

The low QI/PQI pockets just west of Sabarmati River are attributed to composite effect of more sand percentage in shooting medium and more stratification of shooting medium and or presence of low velocity layer below the shooting layer.

There is a good velocity zone in the west-central part of the area. But the very good quality zone is shrinked to further west side as it is modified by higher sand percentage and more stratification and or presence of low velocity below the shooting medium.

There is a general agreement between the maps showing QI and PQI. However, the small variations in trends on the two maps may be due to some more modifying factors other than what have been considered in this paper.

Conclusion

The results very clearly depict the modifying effect of sand percentage, stratification and presence of low velocity layer below the shooting medium within 2 to 4 m below shot depth.

In marginal situations it may so happen that a high velocity layer with more sand percentage and stratification of shooting medium and or low velocity present below the shooting layer (with 2 to 4 m of shot depth) may turn out to be as good or as bad as a lower velocity layer with lesser sand percentage and lesser stratification (lower heterogeneity) and with no low velocity below or being below 4 to 5 m of shot depth. In such marginal areas (more or less represented by the area to the west of Sabarmati River in this case) such an analysis can bring out clear situation whether the scope of selection of optimum shooting layer exists or not. If there is no scope of selecting the best possible medium for placing shot, it is more pragmatic and wiser to opt for the cheap and best shooting medium to result in the best possible data quality. In such a situation use of vibratory source may prove to be better for enhancing the data quality because of more control and maneuverability of the source (mainly energy transmission and amplitude standout) as compared to explosive source of energy.

The present study helps understand the paradoxical results obtained in various pockets in the area not corroborating principally with velocity variations of shooting medium. It may help in selection of shooting medium in similar areas in Cambay Basin or elsewhere.

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