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Digital sensors and shallow multiple holes help effectively negotiate With areas posing drilling and energy transmission problems – examples from Cauvery Basin, India.

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Summary

In a land seismic survey, blasting of explosive source in a proper shooting medium is of utmost importance. This requires drilling of shot holes of proper depths so that the explosive can be placed in an optimum medium to result in good quality seismic data. Areas which pose problem in drilling of shot holes, the placement of explosive at optimal depth becomes unachievable (with the drilling technology being used in respective survey) and resultant data quality gets adversely affected both in terms of signal stand out and frequency content. Certain areas exhibit poor reflected energy due to excessive absorption in the near surface. Suchareas warrant alternative ways to endeavorminimization of adverse effect on data quality, at both source and receiver ends.

This paper presents examples from two areas in Cauvery Basin, India. In one area resorting to shallow multiple holes (with equal distribution of explosive in each hole and simultaneous blasting, total charge being equivalent to optimum charge size) helped effectively negotiate with the area posing drilling difficulty (area A)and the data acquired with digital sensors is better than that acquired with analog sensors. In another area (abnormally low amplitude or low energy is observed on field records) use of multiple holes (shallow or normal depth) at the source end for facilitating a sort of reinforcement of down going energy and digital sensors for facilitating recording of feeblest signal at the receiver end has brought out some improvement in data quality.

In some part of the same area (B),being inaccessible for heavy drilling machines, shallow multiple holes (10-12 m) drilled with manual rotary method have shown good data quality comparable or even better (amplitude wise) than that acquired with normal holesin the adjoining patch.

The encouraging results of data acquisition with multiple holes and digital sensors suggest it to be a better alternative in similar areas having drilling/energy transmission related problems in the same basin or elsewhere.

Keywords*: Digital sensors, Multiple holes, Drilling difficulty, Energy transmission problem*

Introduction

Present study pertains to analysis and comparison of (i) 2D and 3D data acquired with digital and analog sensors respectively, in area(A) (ii) 2D data acquired with digital sensors in area(B).

Area (A) falls in Palar sub basin of Cauvery Basin. The Palar sub basin is a shallow basin with expected sedimentary thickness of the order of 3500m. In this sub basin the near surface is quite compact, having fairly good seismic velocity of the order of 1000 m/sec in the top 4-10 m and 1500 m/sec or more below 10 m. Thus it is quite seismic friendly as far as seismic response in data acquisition is concerned. There are gravel and boulder beds in the near surface along with clay and sand. The boulders pose drilling difficulty, collapsing of holes or stuck up of explosive while lowering in the hole.

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During 2D seismic data acquisition in this area shot holes could not be drilled up to optimum depth (as suggested by up- hole surveys), over a considerable portion of the survey area. Therefore shallow multiple holes of 2-7 m depth were resorted to as an alternative to deeper holes, for charge placement. Mostly three holes were used with equal quantity of explosive in each hole and all were blasted simultaneously. The spatial arrangement /pattern of multi holes was nonspecific and the distance between different holes was kept approximately 3 m. Recording was done by Scorpion System with digital sensors.

Subsequently 3D seismic data is under acquisition in the area with the same recording system using analog sensors. Keeping in view the drilling difficulty posed by the near surface, more powerful drilling machines were deployed during 3D acquisition. This resulted in a majority of shot holes drilled up to optimum depth with a lesser number of holes which could be drilled up to 10-12 m. In such patches multiple holes (two holes with equally distributed explosive in each hole and simultaneous blasting) were used. However the depths of shallow multiple holes during 3D data acquisition got much better than that of 2D data acquisition.

Area (B) falls in Pandanallur block ofAriyalur Pondicherry sub basin of Cauvery Basin. The area exhibits abnormally low reflected energy on field monitors due to excessive absorption of down going energy. Any variation in charge size or shot hole depth does not show any appreciable improvement in the data quality.

Taking lead from the encouraging results of data acquisition using multiple holes(with equally distributed explosive in each hole and simultaneous blasting) and digital sensors, as observed in area(A) during 2D seismic data acquisition, a few experimental shots were taken using multiple(two) holes of normal depth as well as shallow depth with equally distributed charge and simultaneous blasting.

In the same area, in scattered patches, due to inaccessibility or constrained entry of heavy drilling machines, only portable manual drilling equipment could be deployed being capable of drilling up to about 12m(in this area) and shots were taken using two holes with 2.5 kg charge in each hole. This also resulted in good quality data in patches of constrained drilling(where only portable manual drilling up to shallow depths was possible) comparable to what has been acquired normally in adjoining part or even better.

Methodology

Field monitor records of close by locations acquired during 2D & 3D (area-A) and adjacent shot locations from 2D seismic acquisition (area-B) have been taken for comparison of data quality in terms of amplitude, signal stand out and frequency. All the records have been displayed with application of TAR (absorption 3.0db per sec) and Band Pass filters. In area (A) 6/12-70/80 hz Band Pass filter has been applied where as in area (B) 6/16-70/80 hz Band Pass filter has been applied. A constant gain of 94 dB has been applied on records with digital sensors and 16 dB on records with analog sensors. From 3D shot record only one receiver line has been shown containing shot or being nearest.

As the location of the shot in different pairs of records for comparison is not same but close by a few m or consecutive shot interval, no one to one comparison can be done and only general comparison is done. Therefore the observational differences seen between compared records include natural variation of data quality from one location to another.

Frequency spectrum has been analyzed in a time window 700-2000ms (area-A) and 1000-3500 ms (area-B) taking 15 traces almost midway of the left limb of the respective record.

Results and analysis

Area (A): with drilling difficulty

In this area 2D seismic data was acquired with digital sensors and subsequently 3D seismic data was acquired using analog sensors, recording system being the same. Apart from the type of sensors used in seismic recording another notable difference between 2D and 3D is shot hole depths. During acquisition of 2D seismic data shallow multiple holes (~6m) have been used for charge placement, in majority, because the drilling machines deployed in the survey were not able to drill shot holes up to desired depths(about 20-22m, as suggested by up hole data).During the acquisition of 2D, data quality of records from shot holes having depths shallower to desired depths (optimum depth was ~ 20-22m over a considerable area) was found to be proportionately better with increasing depth. Therefore, in a case when drilling was not possible up to desired depth, it was desirable to have shot hole depths in the intermediate range as far as possible.

In 3D data acquisition single holes of desired depth have been used for charge placement, in majority. Wherever drilling up to desired depth was not possible, two holes of ~10 m each were used for charge placement with equally distributed charge in both holes (simultaneous blasting). Fig.1.1 to Fig. 3.5 show various shot records of single and multiple holes taken during 2D (acquired with digital sensors) and 3D (acquired with analog sensors), at close by locations. On comparison and analysis of these records, we see:

(1) Seismic record of a single hole of 22m (optimum depth), 3.5 kg charge with digital sensors (Fig. 1.1) appears to be better than that with analog sensors for same charge and depth (Fig. 1.2). The seismic record in Fig. 1.1 shows generally sharper events and strikingly better events in shallow part. Amplitude spectrum of the shot recorded with digital sensors (Fig. 1.3) is wider than that of analog sensors (Fig. 1.4).

(2) Seismic record of three holes of 5.5m depth, 1.0 kg charge in each hole (Fig. 2.2) appears to be better than that of a single hole of 6m depth (Fig. 2.1) in terms of continuity and frequency of reflection events. Similarly, seismic record of two holes of depth 10 m each and 1.5 kg charge in each hole(Fig3.2) appears to be better than that of a single hole of 10m depth and 3.5 kg charge (Fig3.1). Amplitude spectrum of Seismic record of two holes (Fig 3.4) is flatter and wider than that of one hole (Fig 3.3). (3)Seismic records of three holes of 6m depth, 1.0 kg charge in each hole with digital sensors (Fig.2.2 & 3.5) are looking better than that of multiple hole record of analog sensors (Fig. 3.2) with more pronounced seismic events and higher frequency content.

In this area, more often than not, multiple hole records show higher spectral band width than record of a single hole of same depth, lesser shot generated noise and better stand out of signal over noise (Ramkumar et al., 2008).Shallow multiple holes are not substitute of holes of optimum depth and are used as alternative in areas having drilling difficulty. The characteristics of digital sensors to record seismic data having wider and flatter frequency spectrum (Jain, M.K. et al, 2006) coupled with the usefulness of shallow multiple holes towards reinforcement of down going energy, can offer a fairly good alternative to deeper holes of optimum depth in such areas where drilling of deeper holes is not possible.

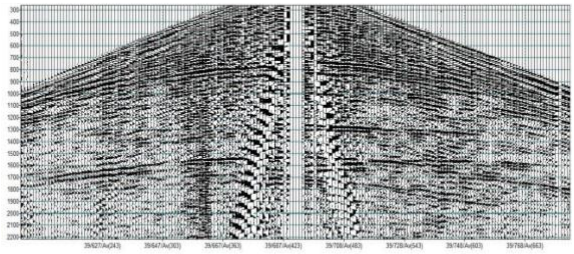

Figure 1.1: Seismic record – optimum depth& digital sensors

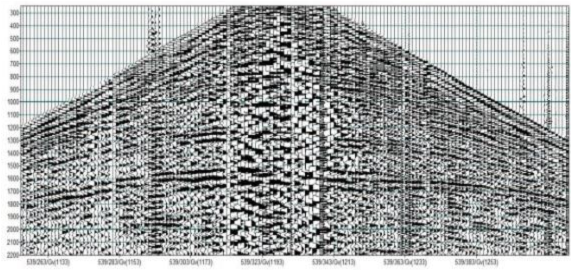

Figure 1.2: Seismic record–optimum depth& analog sensors

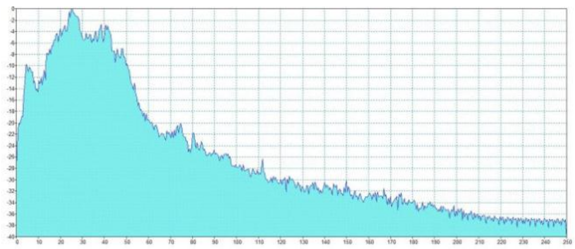

Figure 1.3: Amplitude Spectrum-Seismic record – Fig.1.1

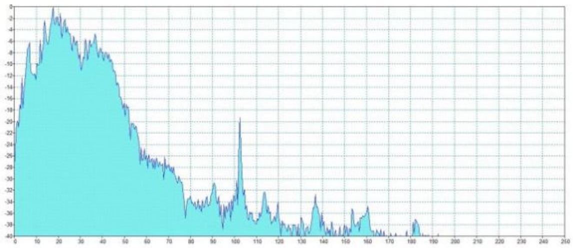

Figure 1.4: Amplitude Spectrum-Seismic record – Fig.1.2

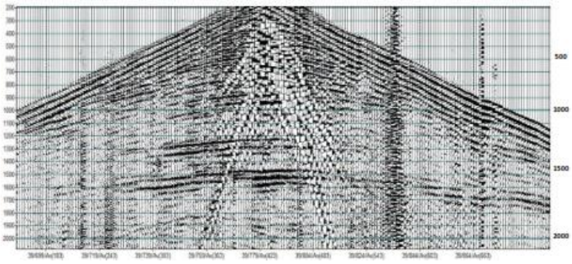

Figure 2.1: Seismic record – single hole & digital sensors

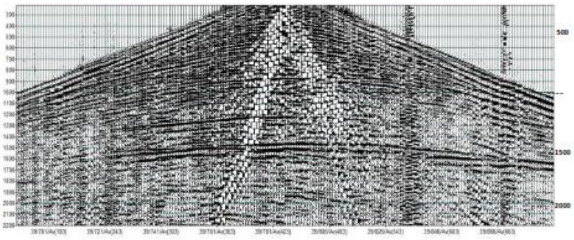

Figure 2.2: Seismic record - three holes & digital sensors

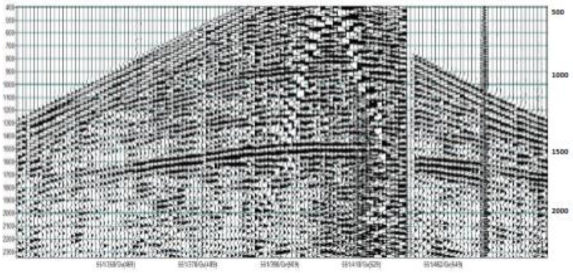

Figure 3.1: Seismic record – single hole& analog sensors

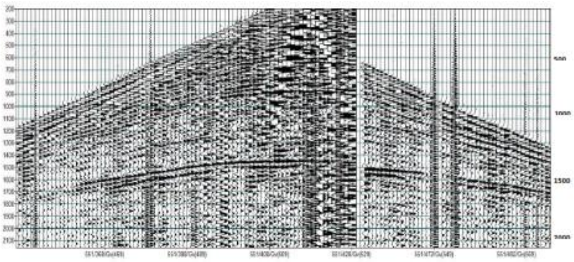

Figure 3.2: Seismic record - two holes &analog sensors

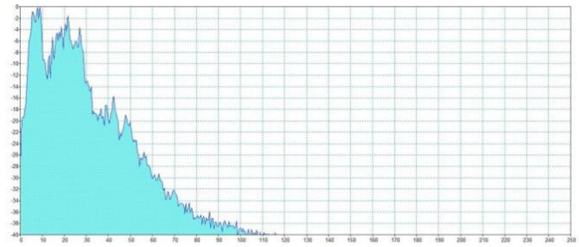

Figure 3.3: Amplitude spectrum – single hole & analog sensor (Figure 3.1)

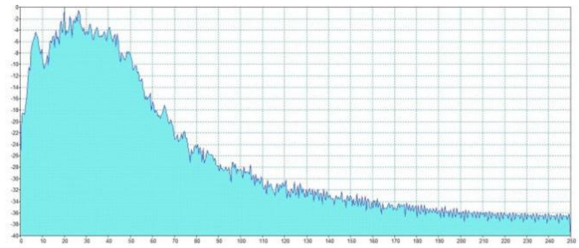

Figure 3.4: Amplitude spectrum - two holes & analog sensors (Figure 3.2)

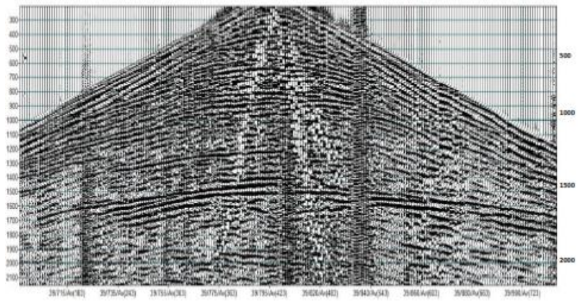

Figure 3.5: Seismic record - three holes &digital sensors

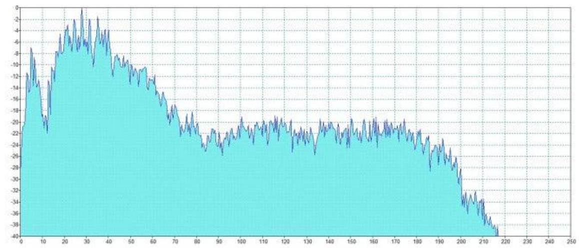

Figure 3.6: Amplitude spectrum - three holes & digital sensors(Fig 3.5)

Fig.3.7 shows brute stack of an inline from 3D volume which has been acquired with analog sensors and mostly single holes of optimum depth for charge placement (multiple holes are used in minority).Fig.3.8 shows brute stack of a 2D line very close to the 3D inline shown inFig.3.7(crossing at a narrow angle). The 2D line has been acquired with digital sensors and mostly shallow multiple holes of about 6m depth for charge placement except approximately 30% part of line on left where most of the shot holes could be drilled up to optimum depth. The lowermost strong amplitude event is very well brought out in both the 2D and 3D stack sections but shallower events which are seen quite continuous and sharper in 2D section are not developed well in the 3D inline. In spite of use of shallow multiple holes, the 2D line shows higher frequency at all levels. This establishes (i) advantage of digital sensors over analog sensors in the form of higher frequency data (ii) use of shallow multiple holes to be a good alternative to negotiate with drilling difficulty and that too is better with digital sensors.

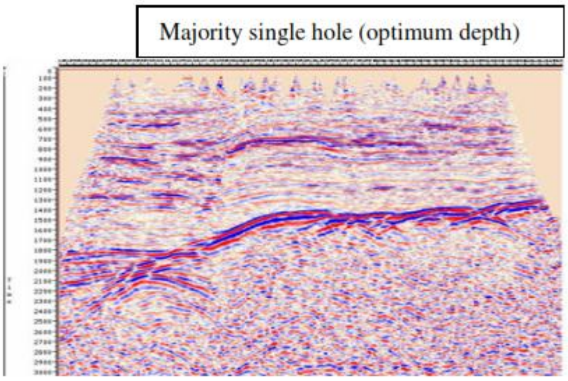

Figure 3.7:Brute stack section from 3D volume

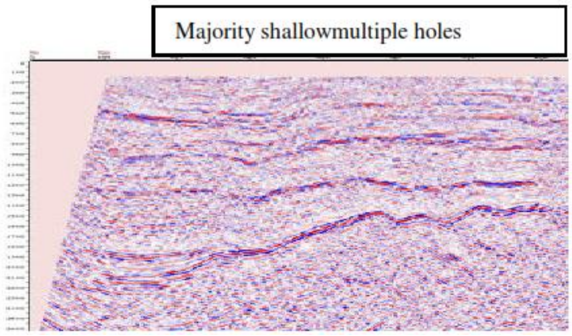

Figure3.8: Stack section of 2D line

Area (B): with energy absorption problem and problem of constrained drilling

In area (B) 3D seismic data was acquired with analog sensors and subsequently 2D seismic data was acquired with digital sensors. Fig. 4.1 & Fig. 4.2 show comparison of 2D seismic shot records with single and multiple holes in an area where energy absorption problem exists. The record in Fig. 4.1 is with one hole of 25 m depth and 5 kg charge whereas the record in Fig. 4.2 is with two holes of 16 m each and 2.5 kg charge in each hole. The two hole record (Fig.4.2) shows significant improvement in event continuity over that of a single hole of (Fig.4.1).

The observed reinforcement of down going energy through use of multiple holes (Fig.4.2)appears to bring in some improvement where nothing could help improve data quality.

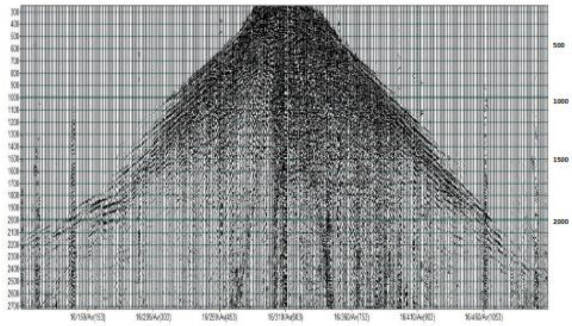

Figure 4.1: Seismic record – single hole & digital sensors

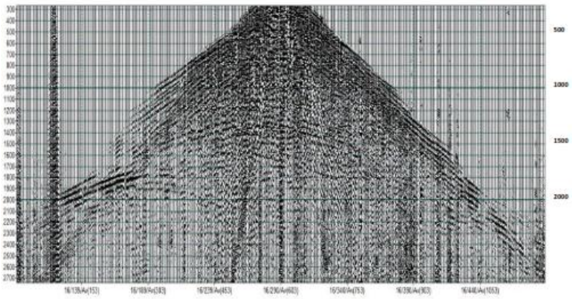

Figure 4.2: Seismic record - two holes & digital sensors

In the same area, in scattered patches, due to inaccessibility of heavy drilling machines, only portable manual drilling equipment could be deployed being capable of drilling up to about 12m(in this area) and shots were taken using two holes with 2.5 kg charge in each hole. This also resulted in good quality data in patches of constrained drilling (where only portable manual drilling up to shallow depths was possible) comparable to what has been acquired with holesof normal depths in adjoining part. A brute stack section of one such 2D line is shown in Fig. 4.3 where multiple holes have been used in one fourth line length in the centre (rest being single holes of desired depth) with digital sensors. The central part of the line where multiple holes have been used shows good data quality comparable to adjoining parts. Shallower portion on the left of both the 2D and 3D seismic sections (Fig. 4.3 &Fig. 4.4) fall in the area where excessive absorption of energy is observed.The quality of data in this portion appears to be better on the 2D lineacquired with digital sensors (Fig. 4.3) than the 3D data acquired with analog sensors as shown in Fig. 4.4. (a close by RC line from 3D volume though not coincident with the 2D line).

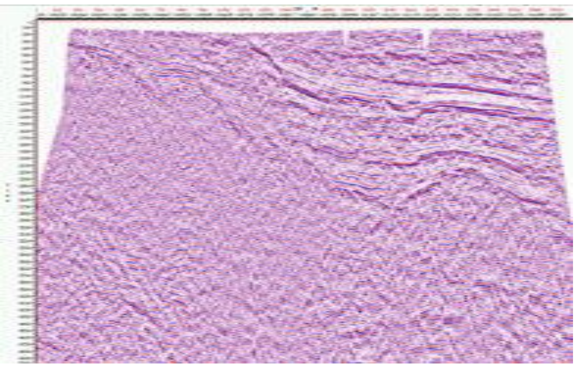

Figure 4.3: Brute stack of a 2D line - shallow multiple holes in the central ~25% part)

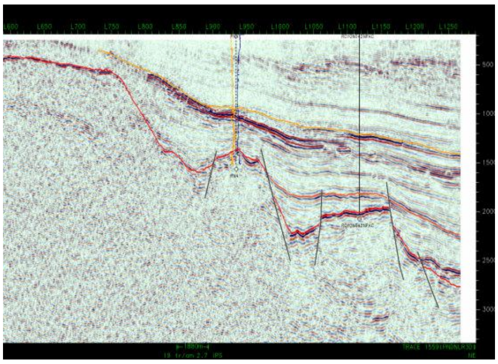

Figure 4.4: 3D data - single holes

Discussion

Quality of shooting medium around the charge placement depth, in shallow as well as holes of optimum depth has a definite bearing on the frequency content and signal stand out in the recorded data. Hence the use of multiple holes is expected to yield positive results in proportion to the goodness of the shooting medium around the charge placement depth. In order to ensure better results it is desirable to properly decide the depth of the shallow multiple holes based on the up hole information or test shots.

Distribution of total explosive to be used for a shot equally in multiple holes helps reinforce the down going energy and reduction in shot generated noise. Distribution of explosive in shallow multiple holes is desirable from safety point of view also as use of a larger quantity of explosive may not be safe to use for shallow depths in gravel/boulder beds.

The optimum number of multiple holes in a group for taking one shot and their spatial arrangement are matter of experimentation and may vary from area to area.

Conclusions

(1) Data recorded by digital sensors appear to be better in signal to noise ratio as well as frequency band width than that of analog sensors for shots with similar charge and depth.

(2) Use of shallow multiple holes is a fairly good alternative when drilling of deeper holes is not possible with the available drilling equipment at the time of survey.

(3) Combination of shallow multiple holes and digital sensors can result in better data quality than that with analog sensors.

(4) More penetration by lower frequency source signal, reinforcement of downgoing energy through use of multiple holes (may be of shallow, medium or optimum depth whichever suits) and comparatively higherfrequency bandwidth of data recorded with digital sensors all integrated are expected to help image better even such areas where excessive loss of energy is observed due to absorption.

The encouraging results brought out in case study may help in acquiring seismic data in areas posing similar problems, in the same basin or elsewhere.

The views expressed in this paper are that of the Author(s) only and may not necessarily be of ONGC.

Reference

Jain, M.K. et al, 2006, Advantage of Digital Sensors Over Analog Sensors in EnhancingSeismic Resolution – A Case Study from Cambay Basin; 6th Exploration Conference & Exposition on Petroleum Geophysics of SPG "Kolkata 2006".

Ramkumar et al., 2008, Negotiating Area having drilling difficulty due to gravel boulder beds in near surface-An Example from Cambay Basin; 7th International Conference & Exposition on Petroleum Geophysics of SPG "Hyderabad 2008".

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