Impact of Surface Consistent Deconvolution on Wavelet Stability and Seismic Attributes: A Case Study

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Summary:

The prevention recognition and correction of wavelet instability is critical to exploration success in the present scenario. The proper selection of processing sequence and their quality control can provide improvement for this problem. It has been seen that the effect of random noise leaking into the deconvolution operator cause most wavelet instability problems. This can be minimized by using surface consistent hypothesis. In this hypothesis, a seismic trace is the convolution of source operator, a receiver operator, a reflecdvity operator and offset related operator. Application of surface consistent deconvolution (SCD) on real data shows tremendous improvement in data quality by reducing random noise, removing the variation of amplitudes due to near surface irregularities and improves the statics estimation. On the other hand, single trace deconvolution fails to do so. In this paper effect of SCD on wavelet stability and seismic attributes have been studied by selecting a portion of seismic line from Vindhyan basin, India. Its robust to any kind of noise and estimation of stable wavelets have also been shown and correlated from the single trace deconvolution. Seismic attributes extracted from surface consistent deconvolved data show major differences as compared to single trace deconvolved data. This improvement of seismic data may be highly helpful in extracting micro-detailed information during interpretation and reservoir characterization.

Introduction:

Amplitude of seismic reflections have been of prime interest since the inception of exploration seismology. Presently, the prime goal of seismic imterpretation is to extract more and more information out of processed seismic data and utilize it for interpreting subsurface structure, complex stratigraphic and lithologic feature to define the accurate reservoir models for use in drilling strategies, estimating inplace and recoverable reserves. One way of obtaining such information is through generation of seismic attributes in terms of geometric, kinematic, dynamic and statistical feature of seismic data (Chen and Sydeny, 1997). In the present scenario of advanced technology seismic attributology has been advancing at a rapid pace and is becoming the core of reservoir geophysics. This acts as a bridge between exploration and production seismology with application established in reservoir detection, characterization and monitoring. But all these applications are possible only when seismic attributes are extracted from the seismic data without distorting their characteristics while processing. Any change of amplitude or anomalous behavior may be significant, so it is important to preserve the amplitude of seismic records which is free from outside disturbances such as those caused by near surface irregularities by the energy source and field recording system. The various factors which affect amplitude of seismic data have been reviewed in detail by Sheriff (1973). It is well known that near surface feature create not only time shift or amplitude decay but also a more complicated frequency dependent time varying filtering effect. This drastic effect is not confined to near surface but also present throughout the data. The most difficult task in the processing of seismic data is the recovery of the amplitude of seismic traces, as they would have been, if there were no disturbing factors. Various special processing techniques have been developed to preserve the relative amplitude while processing. Surface consistent deconvolution is one of the method which can be used effectively in onland seismic data processing.

Surface Consistent Deconvolution:

The analysis of seismic amplitude and phase characteristics are probably the most reliable and cost effective methods of predicting subsurface lithology. In some cases, with proper calibration the amplitude anomalies (bright or dim spots) can be successfully used as direct hydrocarbon indicators. Deconvolution is one of the routine processes applied to the seismic data to stabilize the amplitude and phase spectra of wavelets. Seismic data is routinely deconvolved using single trace deconvolution and is based on a basic assumption that the reflectivity series is white. This deconvolution also does not compensate for the distortion in amplitude and phase spectra due to presence of near surface irregularities and source receiver coupling problems. Single trace deconvolution is also known to be very sensitive to random noise level because phase of deconvolution operator is calculated as a function of its amplitude. It has been seen that increase in random level of white noise in seismic data shifts the timing of peak amplitude and alter the phase spectra and this has been studied in detail by Hart (1997). This distortion due to of random noise level in amplitude and phase spectra can be minimized by averaging the amplitude spectrum of several traces. Due to this reason surface consistent deconvolution (SCD) has became the mainstay in processing of land seismic data. Surface consistent solution provides the averaged spectra for each source, receiver, mid point and offset location and there by reduce the effect of on random noise on deconvolution. (Carry and Lorntz, 1993 and references there in). The averaging in this method can be performed iteratively by several ways. In this study it has been carried out in the following steps.

1. Computation of the autocorrelations of each trace
2. Averaging of the autocorrelations in each geometry directions to get four averaged autocorrelations namely, common source, common receiver, common depth point(CDP) and common offset(COS)
3. Derivation of the minimum phase inverse of each wave form and its application.
4. Iteration through this procedure to get an optimum result.

The surface consistent deconvointion has three major advantages over single trace deconvolution:

1. Noise reduction : Reliability of filter estimates increases by using more statistics.
2. Amplitude extraction: SCD preserves the relative amplitude effectively as compared to single trace deconvolution and therefore the accepted process for AVO technology and reservoir characterization. The application of SCD on seismic data father improves other processes which rely on trace to trace coherency such as velocity analysis, DM0 and stacking as compared to single trace deconvolution.
3. Statics estimatioin: Residual statics provide better stack response after application of surface consistent deconvolution (SCD) as compared to single trace deconvolution.

Study Area:

Vindhyan Basin is one of the largest onland sedimentary basins situated in the north central part of India with an aerial extent of 1,62000 sq. Km. It is an interior basin which was formed by strike slip tension and rifting on a preexisting rifted continental block (Son-Narmada Mid Continental Rifts). It is filled with polycyclic sedimentary succession which is expected to provide a good amount of oil and gas. Vindhyan Basin is a frontier basin drawing greater attention towards exploration activities after finding gas in the first exploratory well in the basin. The study area falls at the southern margin of Son valley part of the Vindhyan Basin. This area has near surface irregularities which affect the geophone ground coupling and distort the seismic signal. It is therefore necessary to remove these effects from the processed seismic data for reliable seismic interpretation.

Results and Discussion:

Keeping the advantages of SCD over single trace deconvolution in mind, a part of seis

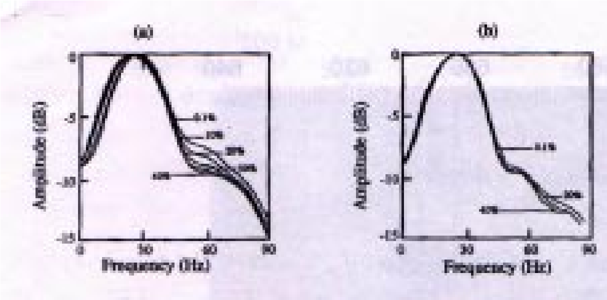


Fig 1: Amplitude Spectra with varying amounts of additive white noise for (a)Single Trace & (b) Surface Consistent De-convolved data

mic line from the study area has been taken up ‘for this study. The effect of varying additive white noise on single trace deconvolved and surface consistent deconvolved data have been studied on amplitude spectra and results are shown in Fig.(1 a,b). It is found that in case of surface consistent deconvolved data, effect of white noise is minimal and there is no lowering of dominant

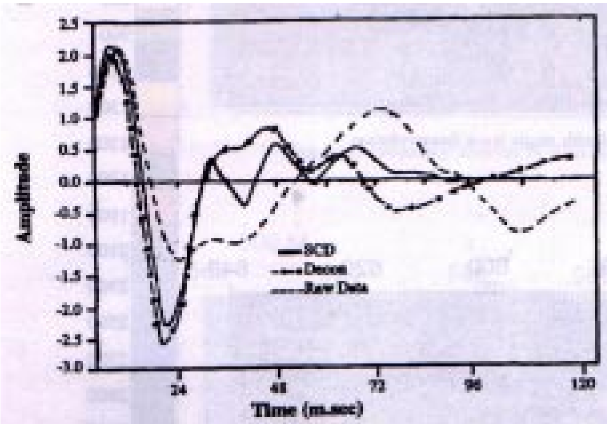


Fig 2: Extracted minimum phase wavelets from raw, single trace and surface consistent de-convolved water.

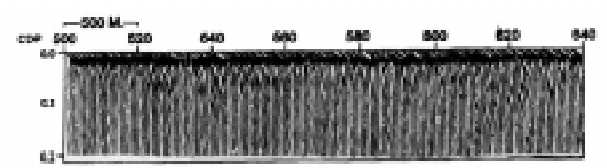


Fig 3(a) Wavelets estimated from Single trace de-convolved stacked data

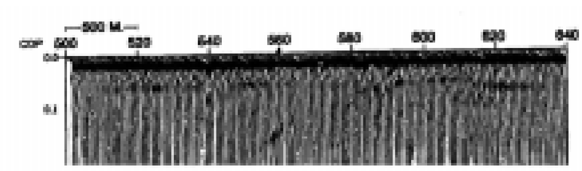


Fig 3(b) Wavelets estimated from Surface consistent deconvolution stacked data

de-convolved stacked data

frequency with increase of white noise percentage whereas in case of trace deconvolution increase in white noise percentage shifts dominant frequency towards lower side and distorts high frequencies. To study the wavelet stability the

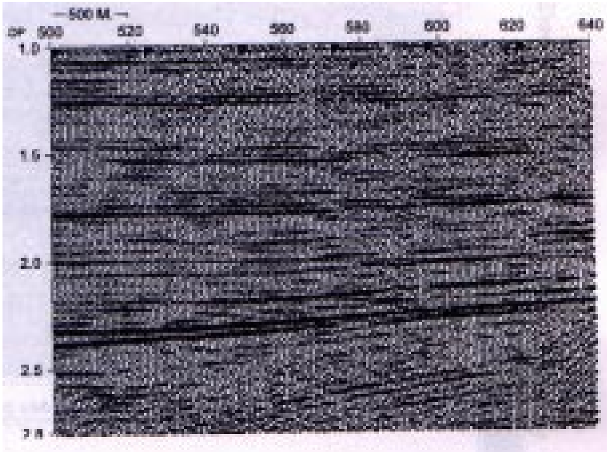


Fig 4(a) : Stacked data processed with single trace deconvolution.

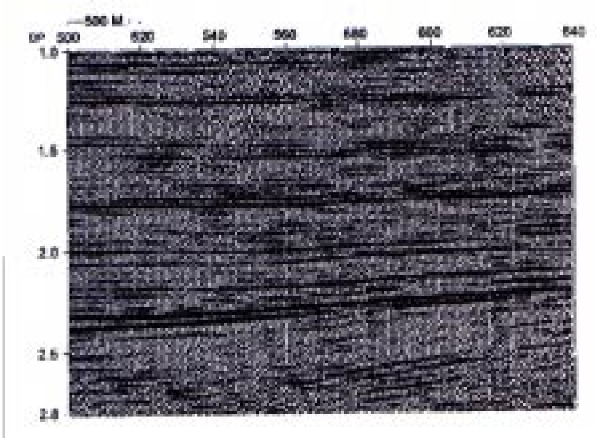


Fig 4(b): Stacked data processed with surface consistent de-convolution.

minimum phase wavelets were extracted from the raw data, after applying single trace deconvolution and surface consistent deconvolution. It is found that wavelets are mostly stable incase of surface consistent deconvolved data as compared to single trace deconvolved data which are shown in Fig.(2). The wavelets were estimated with single trace deconvolved and with SCD separately for a por

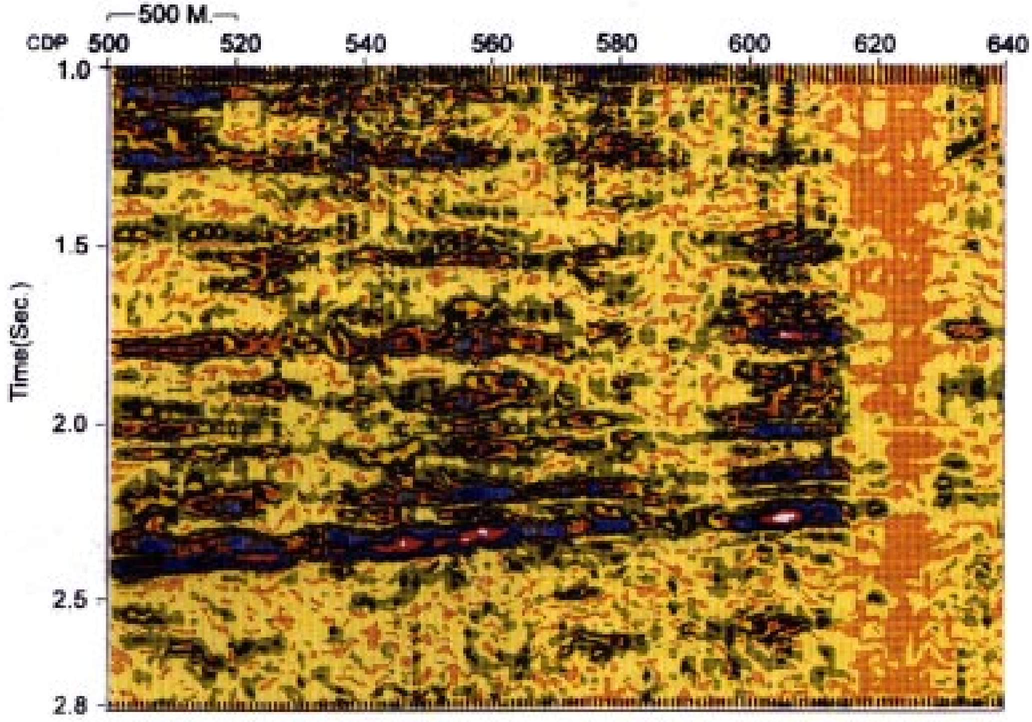
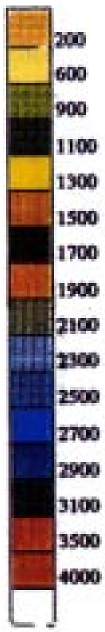


Fig. 5 (a) Amplitude attribute of stacked data processed with single trace deconvolution



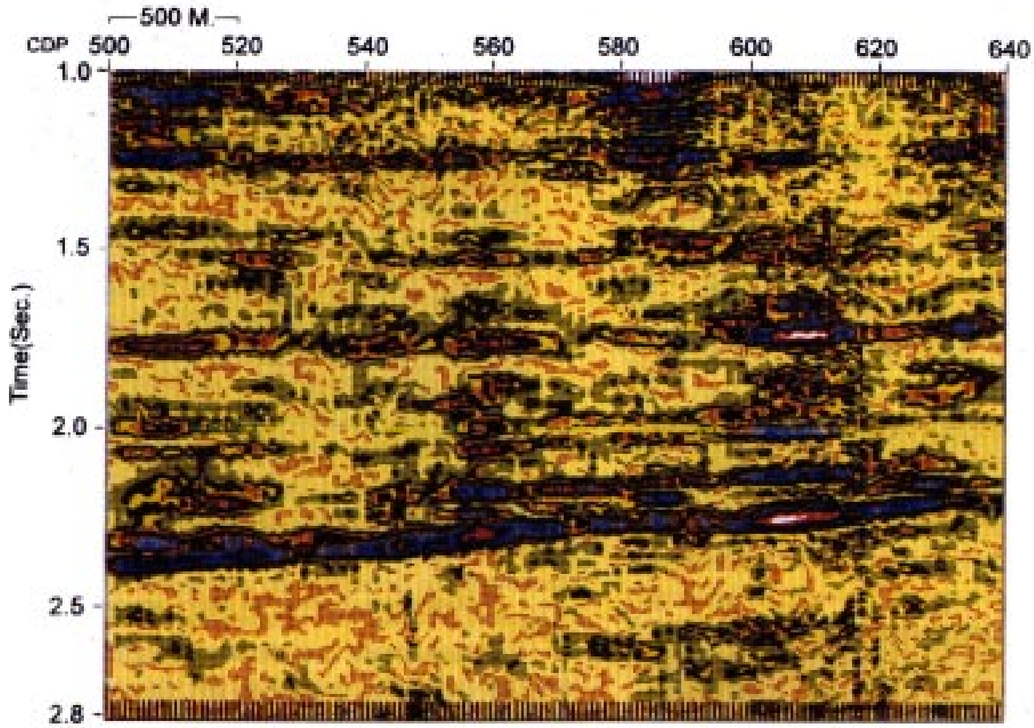


Fig 5 (b) Amplitude attribute of stacked data processed with surface consistent deconvolution

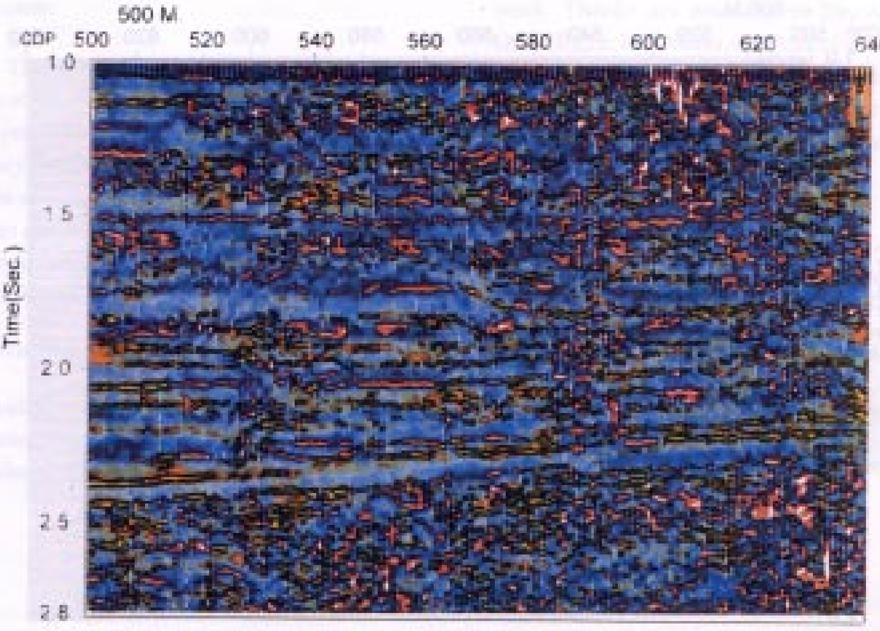


Fig 6 (a) Frequency attribute of stacked data processed with single trace deconvolution

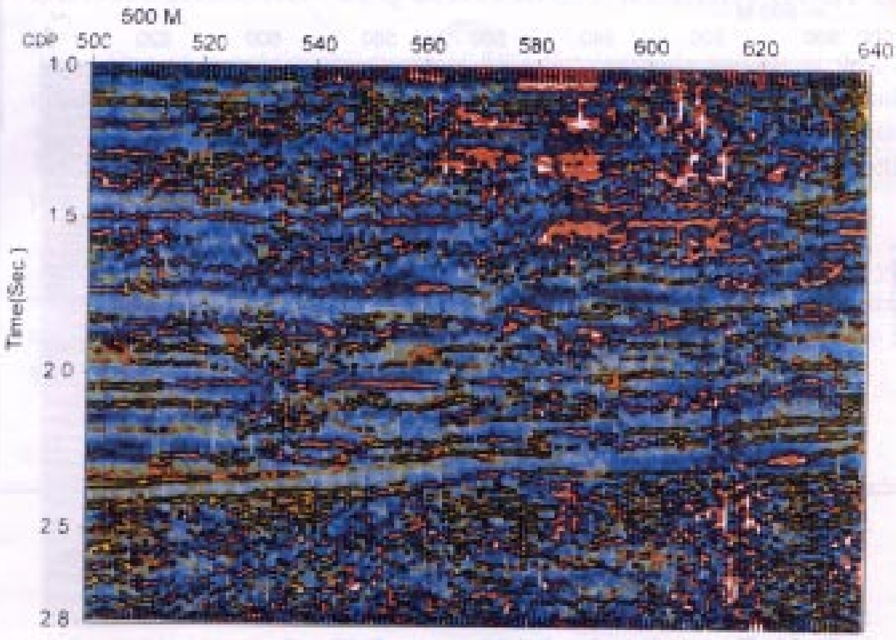


Fig 6 (b) Frequency attribute of stacked data processed with surface consistent deconvolution

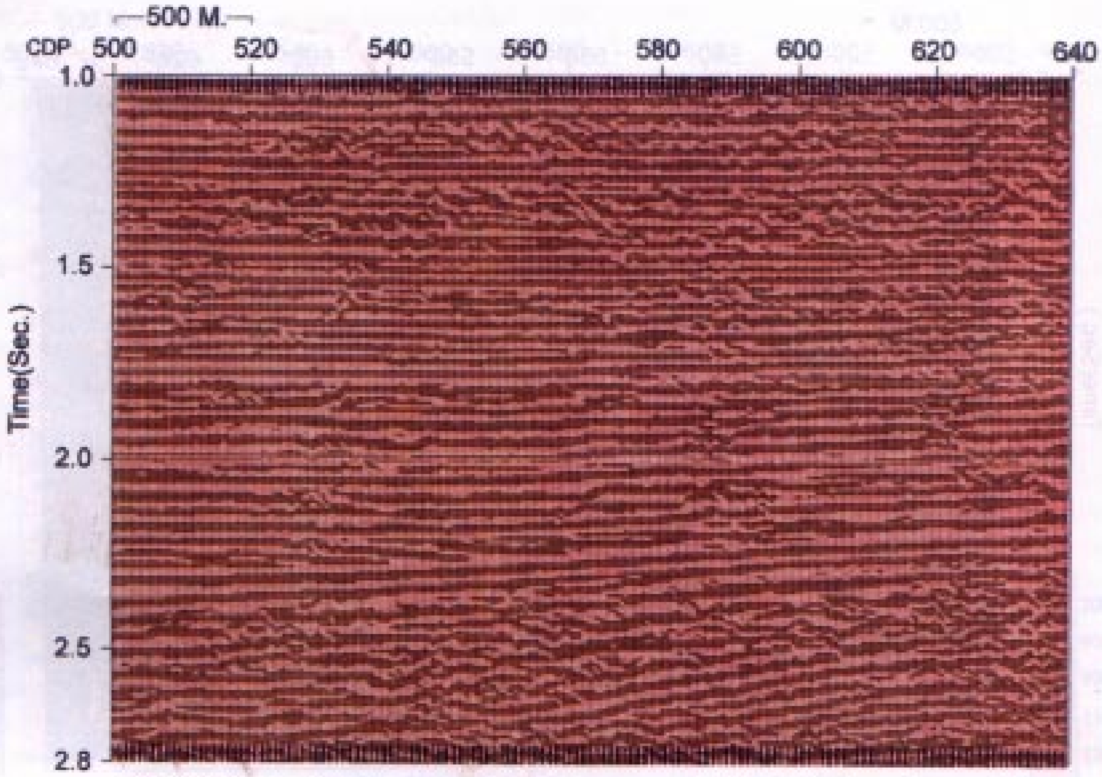


Fig. 7(a) Phase attribute of stacked data processed with single trace deconvolution

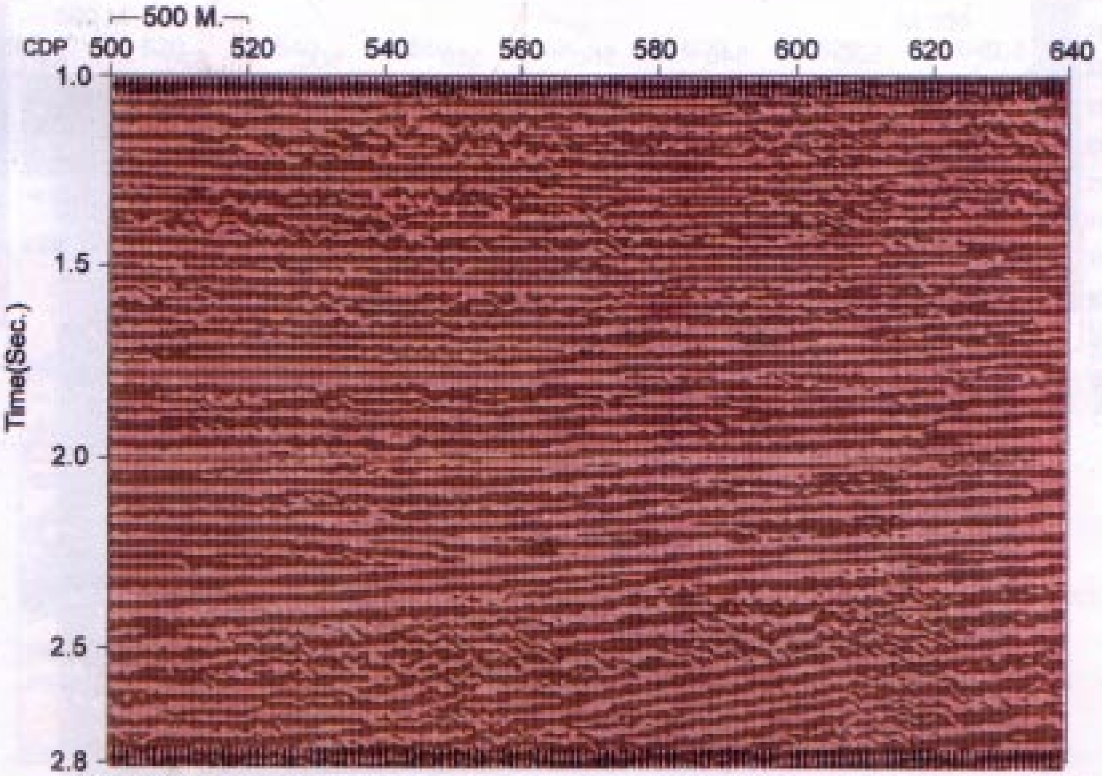


Fig. 7(b) Phase attribute of stacked data processed with surface consistent deconvolution

tion of seismic data and sections are shown in Fig(3a,b).lt is seen that wavelets estimated with SCD show more lateral continuity, where as single trace deconvolution show more trace to trace variation. A portion of seismic data is processed by applying single trace deconvolution and surface consistent deconvolution and stacked sections are shown in Fig. (4a,b). The processed data with SCD shows pronounced increase in the lateral continuity of the wave forms and overall signal to noise ratio as compared to single trace deconvolution. Extracted amplitude attributes of both seismic data processed by applying single trace deconvolution and SCD show major differences specially in amplitude attributes as shown in Figs.(5a,b). The effect of random noise level is very strong in single trace deconvolved data where as it is minimum in the surface consistent deconvolved data. This clearly shows that SCD reduces the effect of additive noise . It is also very interesting to observe that amplitude attributes with SCD clearly show the tuning effect near CDP -5 92 at two way time 2.25sec where as this effect is not visible in case of single trace deconvolved data. The frequency attributes with SCD and single trace deconvolved data have also been extracted and are shown in Fig.(6a,b). These frequency attributes do not show any major change. Phase attributes shown in Figs.(7a,b) with SCD show better bed boundaries indentification where as single trace deconvolved phase attribute do not.

Conclusion:

This study concludes that SCD gives better estimate of wavelets and seismic attributes which improves further processing sequences relying on trace to trace coherency as compared to single trace deconvolution. Thus, the seismic data processed with SCD and seismic attributes extracted from it may be helpful in providing lead to hydrocarbon exploration and exploitation in the Vindhyan Basin.

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