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Improving Surface Seismic Resolution using VSP Data

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Summary

Bore hole seismic preserves higher bandwidth than surface seismic data. Here we attempt to improve the surface seismic resolution by extracting wavelet from surface seismic data and matching it to that of VSP. This method was tried at four well locations and the results show improvement in resolution of surface seismic data. Seismic data becomes comparable to that of VSP and has better match. The results are also compared with more commonly used spectral whitening process.

Introduction

Amongst the available techniques of petroleum exploration surface seismic is the most widely used one. This is because of its enormous potential to reveal the details of the subsurface, when compared to other methods like gravity and magnetic. Surface seismic in various forms, 2D/3D/4D, are designed and carried out to seek the desired subsurface details required for oil and gas exploration and exploitation. Modern seismic survey can confidently map major geological boundaries and associated structural features.

But, like any other measuring device, seismic also has a least count. The size of the wavelet put a bar on precise mapping of fine details. The narrow band width inherent with the seismic data is insufficient to provide accurate information about the reservoir, like thin sand shale alterations.

On the other hand, borehole seismic preserves higher band width due to the proximity of the sensors to the reflectors. Zero Offset Vertical Seismic Profile provides a 1D data which can easily and nicely be correlated to the well data. There is a one to one relationship between the known petrophysical properties and the VSP data at well location. This relationship, the knowledge of geology, can be propagated to the other parts of the basin, away from the well, through surface seismic data. The biggest hurdle in transferring the petrophysical information from the well to the VSP and thereafter to the surface seismic is the limited resolution of seismic in general and surface seismic in particular.

Many authors have proposed different ways of improving the resolution of the surface seismic data using VSP and integrating them like Satindra Chopra et al (2003, 2004) and Halina Jedrzejowska et al (2005) etc.

This work is an attempt to improve the resolution of surface seismic data to the level of VSP.

Methodology

2D sections passing through the well with VSP were used for the study.

Wavelets were extracted statistically from the down going VSP wave field and the 2D data. The wavelet of the 2D seismic data was matched to that of the VSP by designing a suitable matching filter operator. The operator was applied on the 2D data. The result was compared with that of the more commonly used Spectral Balanced 2D data.

Discussion on Application

The data used in the study belong to the KG-PG Basin of East Coast, India. The hydrocarbon prospect of this Basin is well established. The method was tried on four well locations across the basin.

1. Well no. A

The objective of the well was to test the sands within Matsyapuri Sandstone (669 - 1666 m) and Vadaparru Shale (1665 - 2416 m) in series of successive Fault Blocks of upper Miocene to lower Miocene age. The

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well has encountered pay sands within Vadaparru Shale.

The seismic data used is a 2D section from a 3D volume available in the area.

The data is PSTM stack. The well seismic is a Zero Offset VSP recorded from depth level 500m to 2375 m, using instrument DFS V, during the year 2005.

The results of the application of the methods are shown in Fig.1 and Fig.2.

Fig.1 & Fig.2 show corridor stack spliced in surface seismic data. In Fig.1 the Spectrum for VSP is shown in black color and for seismic data in red color in the vicinity of well bore. The spectral broadening of surface seismic data is observed in Fig.1b & Fig.1c. Zoomed sections are shown in Fig.2a, Fig.2b & Fig.2c with time window 1300 - 2100 ms. The improvement of resolution and better match with VSP data is observed in Fig.2b (two way time at 1780 ms, 1870 ms with in Vadaparru shale). The paysands encountered with in Vadaparru shale are marked in Fig.2b & Fig.2c and the extension can be mapped.

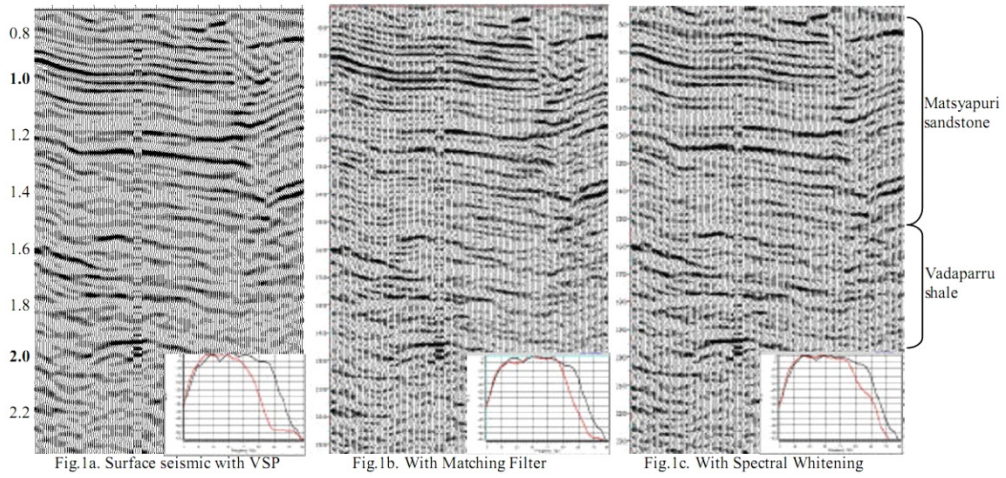

Fig.1a. Surface seismic with VSP | Fig.1b. With Matching Filter | Fig.1c. With Spectral Whitening

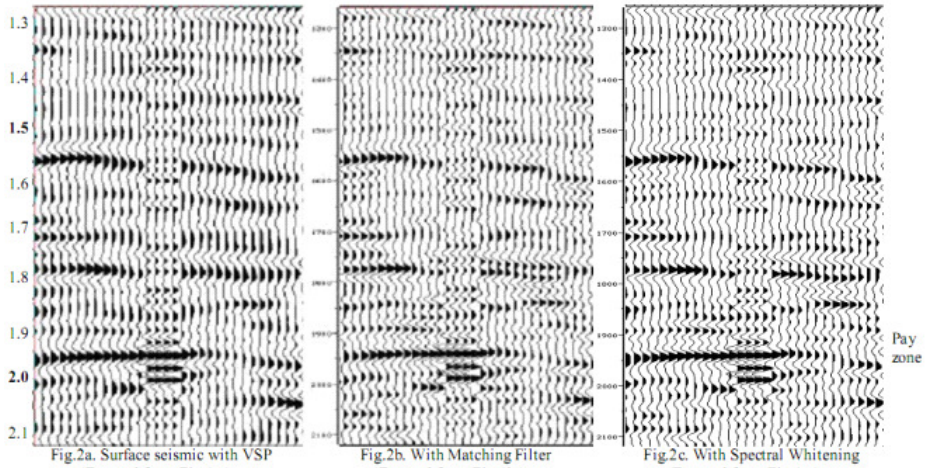

Fig.2a. Surface seismic with VSP (Zoomed from Fig.1a.) | Fig.2b. With Matching Filter (Zoomed from Fig.1b.) | Fig.2c. With Spectral Whitening (Zoomed from Fig.1c.)

2. Well no. B

The well was drilled on a Structural High with the objective to explore Matsyapuri sandstone (815 - 1918 m) and sands within Vadaparru Shale (1918 - 2226 m), age of formation is Mid Eocene to Miocene. The well is producing Hydrocarbons from Matsyapuri Sandstone.

The seismic data used is a 2D section from a 3D volume available in the area. The data is PSTM stack.

A Zero Offset VSP was recorded using instrument DFS V, during the year 2002, from depth level 520 m to 1440 m.

The results of the application of the methods are shown in Fig.3 and Fig.4.

Fig.3 & Fig.4 shows corridor stack spliced in surface seismic data. In Fig.3 the Spectrum for VSP is shown in black color and for seismic data in red color in the vicinity of well bore. The spectral broadening of surface seismic data is observed in Fig.3b & Fig.3c. Zoomed sections are shown in Fig.4a, Fig. 4b & Fig.4c with time window 900 - 1900 ms. The improvement of resolution and better match with VSP data is observed in Fig.4b (two way time at 1380 ms, 1120ms with in Matsyapuri sandstone).

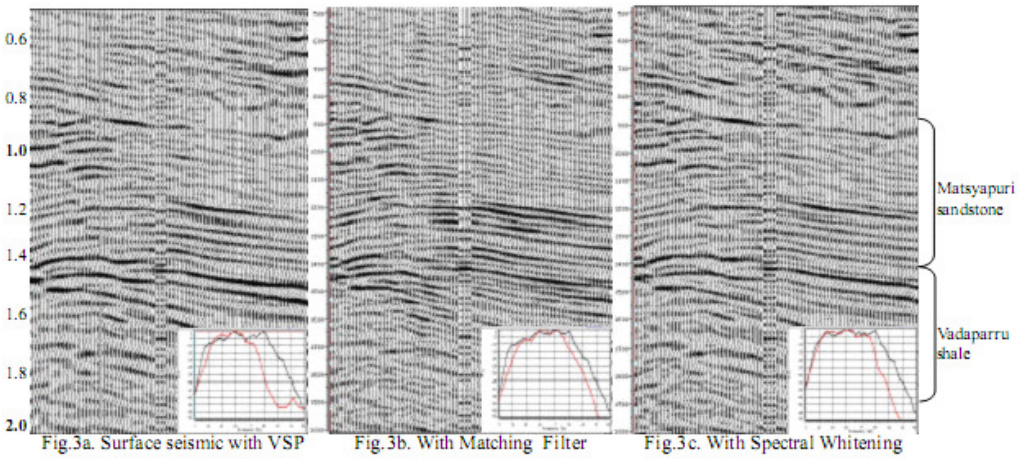

Fig.3a. Surface seismic with VSP | Fig.3b. With Matching Filter | Fig.3c. With Spectral Whitening

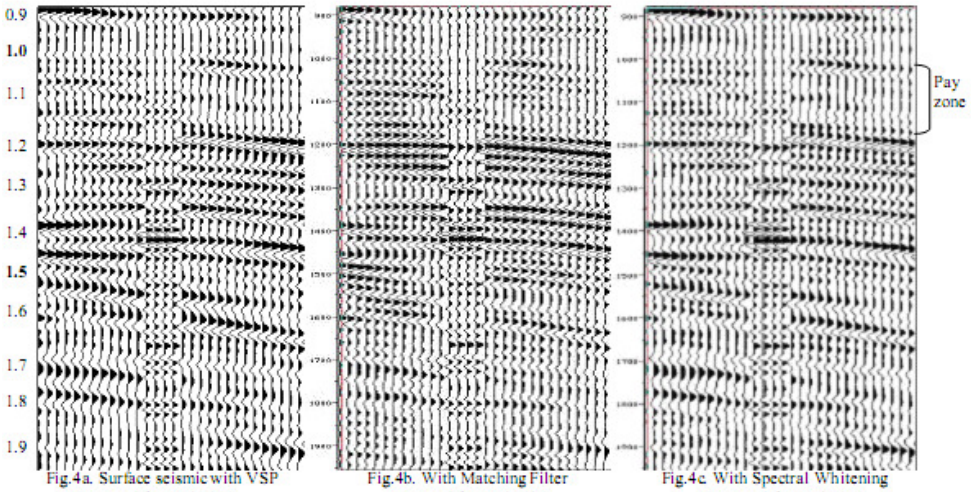

Fig.4a. Surface seismic with VSP (Zoomed from Fig.3a.) | Fig.4b. With Matching Filter (Zoomed from Fig.3b.) | Fig.4c. With Spectral Whitening (Zoomed from Fig.3c.)

3. Well no. C

The objective of the well was to explore the sands within Pasarlapuri formation (1853 - 2842 m) of Lower Eocene, on a Structural High. The well is producing Gas from Pasarlapudi Formation.

The seismic data used is a 2D section from a 3D volume available in the area. The data is PSTM stack.

A Zero Offset VSP recorded from depth level 800 m to 2650 m, using instrument WR-MSR, during the year 2009.

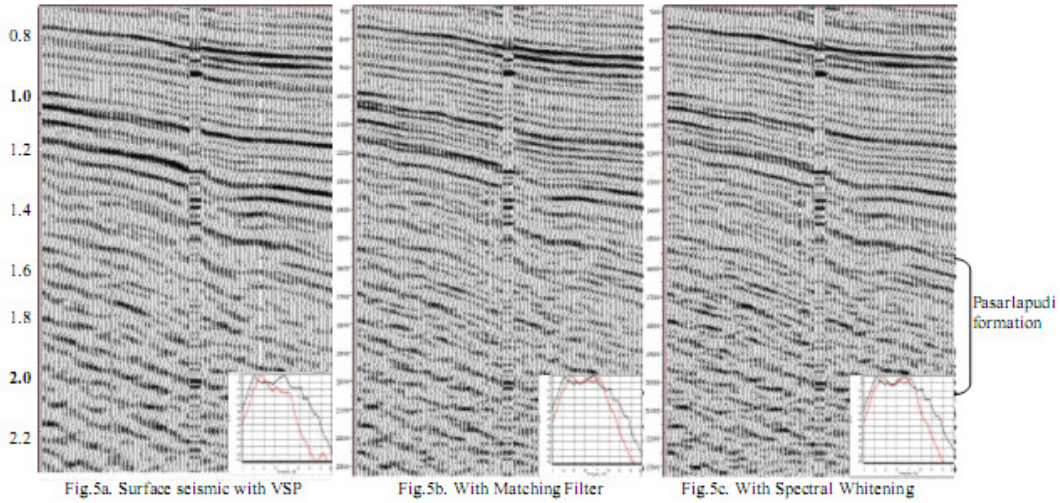

Fig.5a. Surface seismic with VSP

Fig.5b. With Matching Filter

Fig.5c. With Spectral Whitening

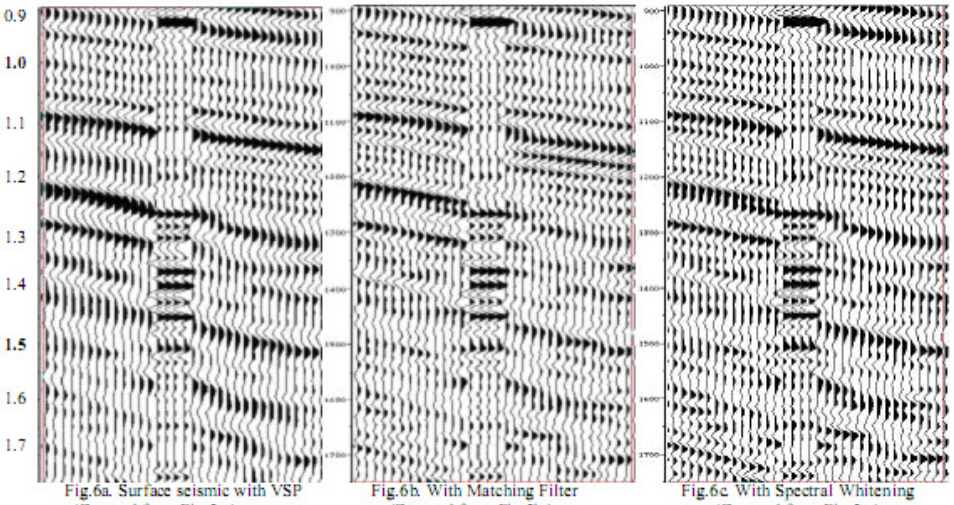

Fig.6a. Surface seismic with VSP (Zoomed from Fig.5a.)

Fig.6b. With Matching Filter (Zoomed from Fig.5b.)

Fig.6c. With Spectral Whitening (Zoomed from Fig.5c.)

The results of the application of the methods are shown in Fig.5 and Fig.6.

Fig.5 & Fig.6 show corridor stack spliced in surface seismic. In Fig.5 the Spectrum for VSP is shown in black color and for seismic data in red color in the vicinity of well bore. The spectral broadening of surface seismic data is observed in Fig.5b & Fig.5c. Zoomed sections are shown in Fig.6a, Fig.6b & Fig.6c with time window 900 - 1700 ms. The improvement of resolution and better match with VSP data is observed in Fig.6b (two way time at 1320 ms, 1500 ms).

4. Well no. D

The objective of the well was to test the Hydrocarbon potential of Arenaceous units within Barakar and Lower Kamthi formations, with zone of interest 1000 3200 m, age of formation is Upper Permian to Lower Triassic and Permian. The Prospect is series of successive Fault Blocks. The well has encountered the interested formations but not the Hydrocarbons.

The seismic data used is a 2D section available in the area. The data is Post stack. The well seismic is a Zero Offset VSP recorded from depth level 500 m to 3075 m, using instrument WRMSR, during the year 2008. The results of the application of the methods are shown in Fig.7 and Fig.8. Fig.7 & Fig.8 shows corridor stack spliced in surface seismic data. In Fig.7 the Spectrum for VSP is shown in black color and for seismic data in red color in the vicinity of well bore. The spectral broadening of surface seismic data is observed in Fig.7b & Fig.7c. Zoomed sections are shown in Fig.8a, Fig.8b & Fig.8c with time window 700 - 1700 ms. The improvement of resolution and better match with VSP data is observed in Fig.8b. Seismic data within Barakar formation with improved resolution is observed at different levels like 980 ms, 1050 ms etc.

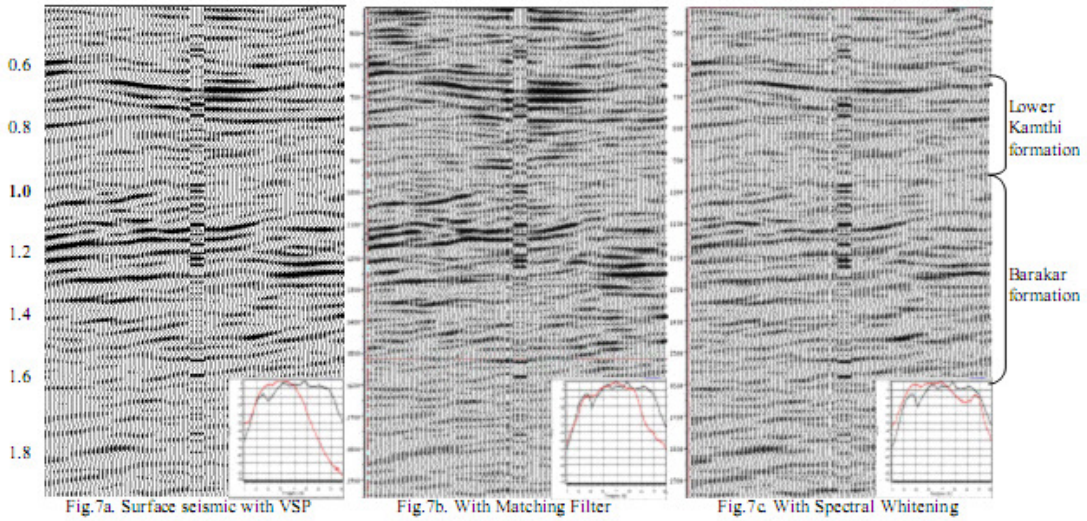

Fig.7a. Surface seismic with VSP Fig.7b. With Matching Filter Fig.7c With Spectral Whitening

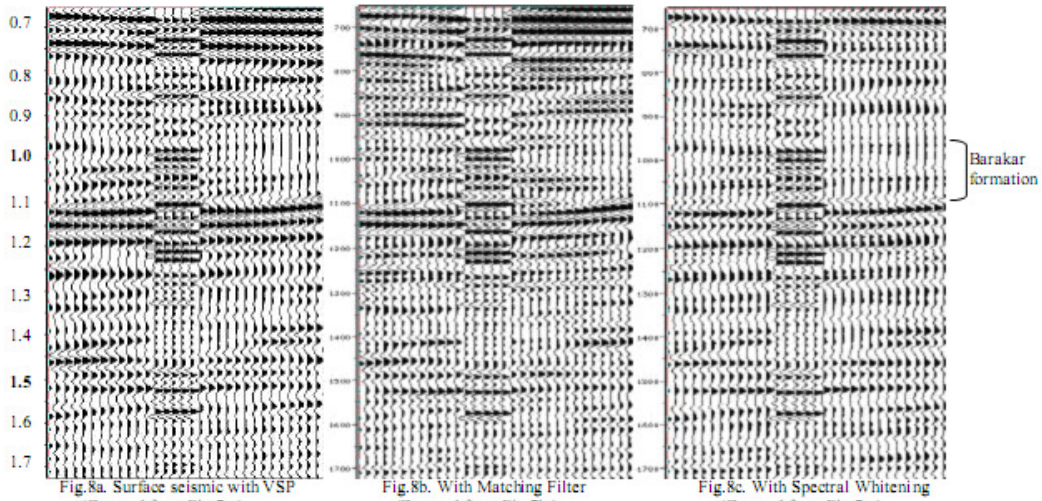

Fig.8a. Surface seismic with VSP (Zoomed from Fig.7a.)

Fig.8b. With Matching Filter (Zoomed from Fig.7b.)

Fig.8c. With Spectral Whitening (Zoomed from Fig.7c.)

Conclusions

The application of a wavelet matching filter operator on the seismic data has improved the resolution and resulted in better matching with the VSP which will enable more confidence in mapping of the areal extension of the pay zone. The method is robust as evident from the results on all the data tested. This method is superior to the spectral whitening with respect to seismic VSP match.

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