The application of seismic acquisition technique on prospecting unconventional gas of coal measures

Zhongbin Tian
School of Geosciences and Info-Physics
Central South University
Changsha, China
thinda@163.com

Youyi Shen, Jianqing Wang, Xiaodong Yang
Shanxi Coal Geology Geophysical Surveying Exploration Institute
Jinzhong, China

***Abstract*—The middle-east region of Qinshui coalfield locates in the eastern of Qinshui block depression, which terrain ups and downs and the surface lithology is changeful. How to choice the excitation and receiving parameters becomes the main difficulty. In this paper, the methods of micro logging and refraction encounter were used to investigate the structures of shallow and surface refined. According to well logging data, determined the reasonable excitation horizon in order to assure the exploration-grains explode in the bedrock or dense clay layer; the excitation parameters of well depth, charge mass and well combination for different lithology are obtained through the study of the systematic test of excitation and receiving condition; through the analysis on the test data, we chose the combination of low frequency detectors and built the recording geometry with multifold. Practices had proved that the excitation and receiving parameters of this region can suppressed the interference waves including the surface wave, multiple refraction wave, etc. and solved the problems of low signal-to-noise ratio in mountainous areas, especially for loess areas, which provides useful references for the exploration and development of unconventional natural gas in the future.**

Keywords*—coal measure unconventional gas; seismic exploration; acquisition technique; multi gas CO-exploration; Qinshui coalfield; Multifold

I. Introduction

Located in the eastern part of Qinshui block depression, the middle-east region coal measures of Qinshui coalfield is one of the most important CBM prospecting region, in which the Coal-bearing strata is rich in unconventional gas[1]. According to preliminary calculations, CBM resources reserves in Qinshui coal field are 28316*10^8 m^3, forecasts reserves are 25689*10^8 m^3 accounted for 90.72%[2]. Shale gas resource reserves in the area are amount to 5.6 *10^{12} m3, of which the resources of Taiyuan Formation was 3.2*10^{12} m^3, accounts for about 57% of total resources[3].Coal measures and its overlying strata hold in store of coal seam, shale and tight sandstone gas reservoir which can form industrial development value, so comprehensive exploration of these unconventional gas resources will help to improve the efficiency of the development[4].

Terrain in the study area is relatively complex. General region elevation height is between 880m and 1580m. The exposed bedrock is dominated by Triassic sandstone and mudstone, part of the section is covered by thick loess. The bigger lateral difference of surface lithology causes the serious attenuation of seismic wave energy, the complex seismic wave field and the poorer seismic wavelet consistency; at the same time, various primary and secondary interferences will make the seismic excitation and receiving difficultly.

How to choosing the suitable excitation and receiving parameters to guarantee the quality of seismic data become the important points in the field acquisition. We took the Micro-log and Reversed Refracted Wave Method to achieve the shallow structural investigation in order to determine the well depth in different location. At the same time, we conducted the drilling logging and determine the excitation position according to lithological to guarantee the explosive column explosion in bedrock or dense clay layer. In the regions that is difficult to drill or near the strong interference, we use multiple wells combined with small charge mass as excitation source and chose the dynamite column with Ø = 60 cm in order to reduce the blast radius.

II. The key acquisition technique

A. Shallow Layer Structure Investigation

The Fig. 1 shows that the typical single well logging interpretation chart covered by loess in the south of the study area. According to the near-surface investigation and the reconnaissance, the thickness of low-velocity layer in the study area is 0~26m, the thickness of velocity layer is 4~15m and the speed of high-velocity layer is 2450~3900m/s commonly. Above all, the changes of lateral velocity and thickness are great in low-velocity layers while the interval velocity is relatively stable in high- velocity layers.

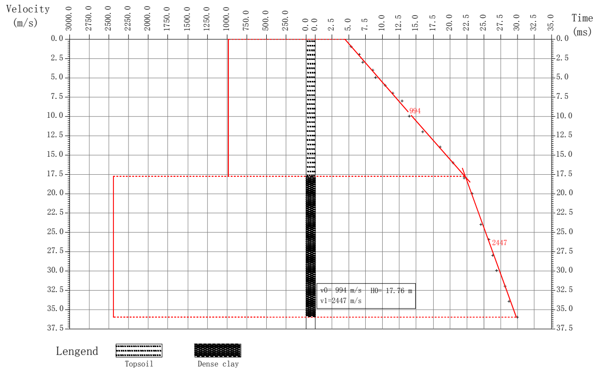


Fig.1. The micro log interpretation results

B. Seismic Shot Mode

（1） Well depth test

At the section covered by thickness loess, when the weight of explosive is 6kg, we chose the depths interval of 3m during 15m-42m as the experiment excitation depths. From the shot records we find that which have poor continuity of coal seam reflected wave with well depth in 15m and 18m. Whereas, it has strong reflection wave energy and good continuity when the well depth is more than 21m, however, the traces nearby the shot point are influenced by the surface wave and sound wave (Fig. 2).

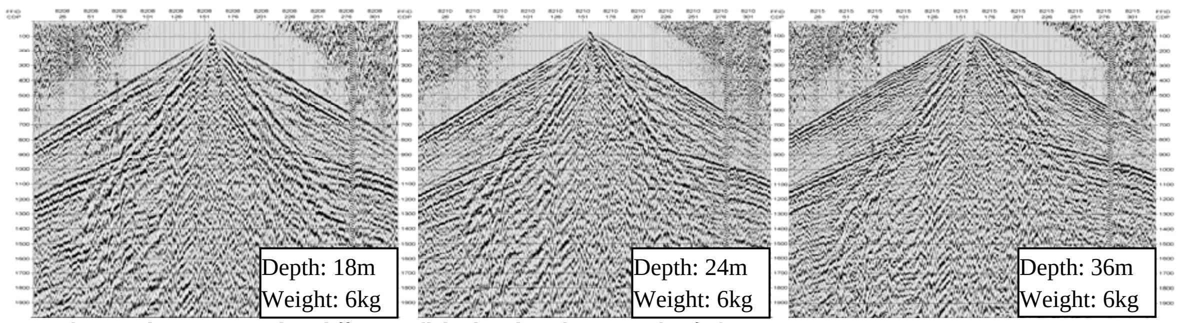


Fig. 2. The typical contrast records in different well depth with explosive weight of 6 kg

See Fig. 3.We analyze the energy, spectrum, the signal to noise ratio (SNR) estimation from coal seam reflected wave records of single shot in the time window of 700 milliseconds up and down and get the results: When the well depth is in 15m, 18m and 21m, the seismic reflection wave energy is stronger. When well depth is in 24m, 27m, 33m, 36m or 42m respectively, the single shot seismic reflection wave energy is approximate. When the well depth is 30m, reflection wave energy is weakest. For Time-Frequency Band, it is relative wider when the well depth is in 21m, 42m and the dominant frequency band range from 5Hz to 50Hz. SNR has larger difference in different well depths, relative high SNR can be get when depth is more than 24m.

To sum up, in thick loess area we should adopt the single well and the well depth is not less than 21m.

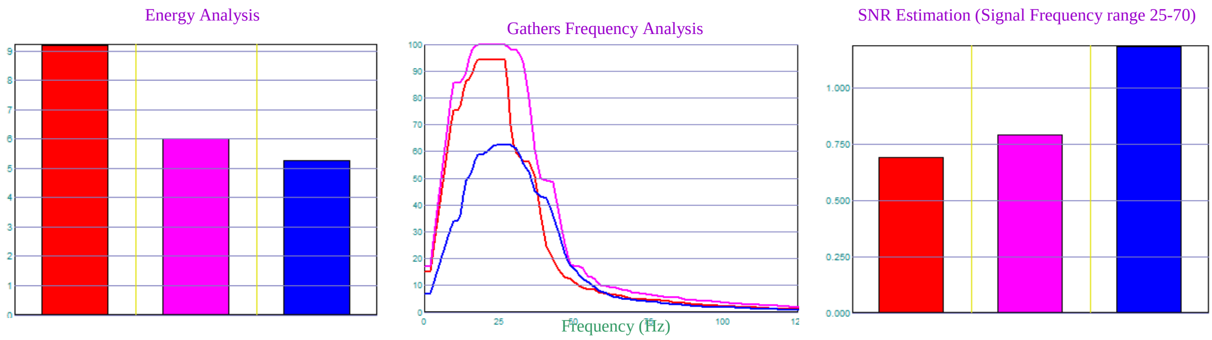


Fig. 3.The seismic wave energy, frequency and SNR comparison in different single shot well depth （Red：18m；Pink：24m；Blue：36m）

(2) Single-shot and Combined-shot test

Analyzing the single shot seismic record, the coal seam reflected waves no matter the excitation is from single-well or combination-well are all clear and the events of the reflected wave are successive (See Fig. 4).

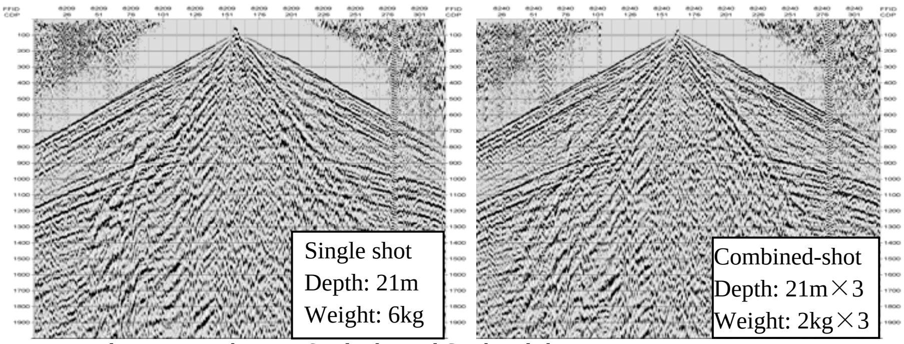


Fig. 4. The seismic wave records comparison between Single-shot and Combined-shot

Through the analyze the energy, gather spectrum and the SNR, when the well depth is in 21m, the energy difference is great between single-well and combination-well, and the wave energy is stronger from single well(See Fig. 5). The Time-Frequency band of the single shot is wider than three-combination shot, however, the difference of SNR between the shot means above is not obvious. So we choose the single well when the well depth is more than 21m.

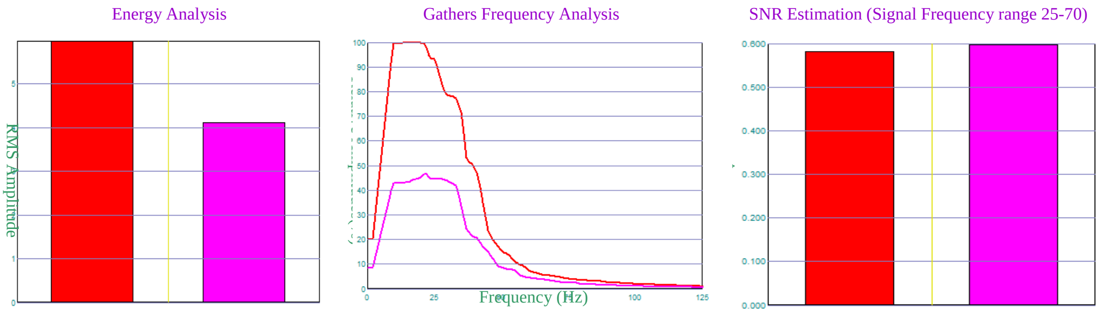
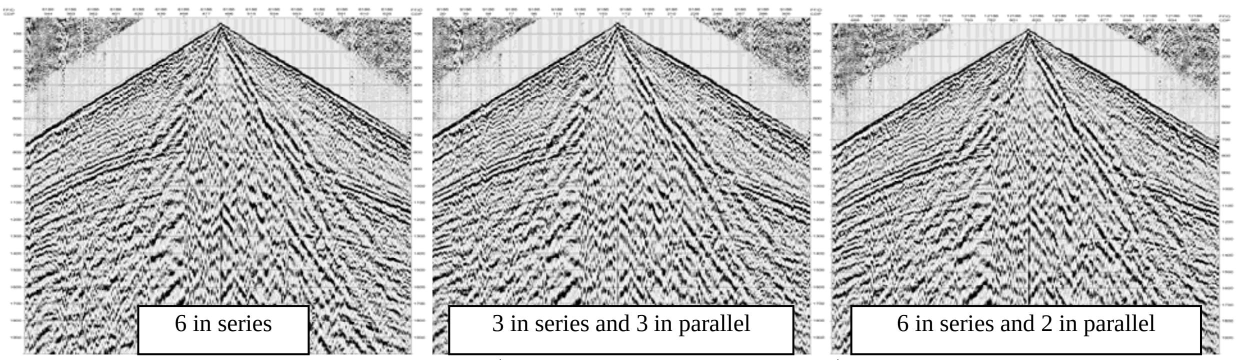


Fig. 5. The seismic wave energy records comparison between Single-shot and Combined-shot
（Red：6kg；Pink：2kg with 3 shots）

C. *The Comparison in Different Numbers of Geophones.*

According to the experiences, we made the comparison tests on the combinations with different numbers of low frequency geophones which the natural frequency is 10Hz forthrightly. From the analysis of the seismic records, in the condition of different numbers of geophones, we find the first arrival wave is clear and the reflect waves of target stratum are continuous, the main interference waves are surface waves, the industrial electric wave with 50Hz and the random interference waves. Surface wave is mainly distributed in near offset traces (See Fig.6).



（Red：18m；Pink：24m；Blue：36m）

Fig. 6.The energy, frequency and SNR comparison in different numbers of geophones. (Red: 6 in series; Pink: 3 in series and 3 in parallel; 6 in series and 2 in parallel

Through the comparison and analysis of the seismic records (See Fig.7), the difference of SNR is not obvious about the different numbers combination of the geophones. The reflection wave energy of coal seam is stronger and the frequency band is wider when 6 geophones are installed in series or 6 geophones is parallel connected with another 6 geophones. However, the wave energy is relative weaker and the frequency band is not wide when the 9 geophones is in the combination of 3 groups in parallel which the group is made by 3 geophones in series.

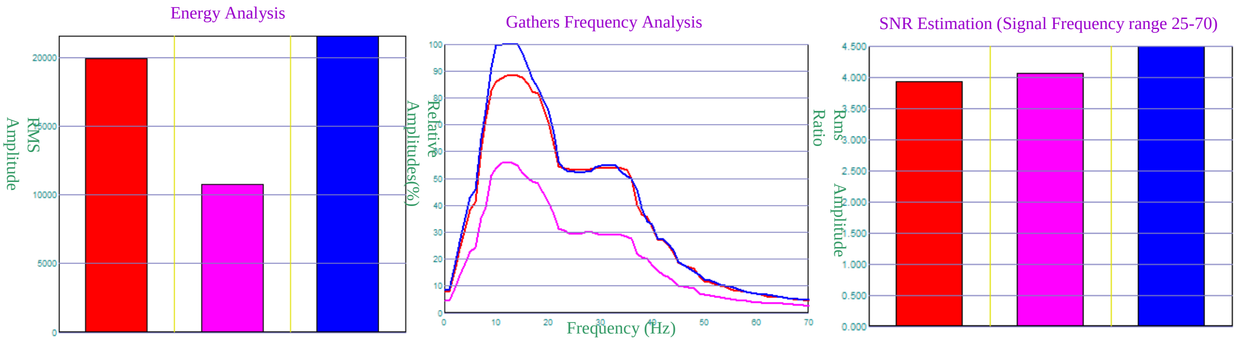


Fig. 7. Seismic records with well depth 8 m, explosive weight 6 kg in different number of geophones.

III. Analysis of Application Effect

The parameters of this seismic acquisition were as follows: we adopted the single well to excite and the depth of the well in bedrock area is not less than 10m or not less than 21m where in loess area; however, adopted the combined-shot means to excite at the region that difficult to drill or near the strong interference sources. We adopted the receiving mode of combination in series with 6 low-frequency geophones and the group interval distance is zero. Take into consideration the size of the geological body, the highest frequency aliasing and the transverse resolution, we chose the trace spacing of 20m, the shotpoint spacing of 40m and the fold number of 80 which make it is able to suppress the random interference, multiple interference and ensures the precision of velocity analysis and static correction. Thus, the reflected in phase axes of the target strata are real and the reflection of structures are distinct. The group characteristics of reflection waves are obvious, especially for the target strata of Shanxi Formation and Taiyuan Formation that the reflected in phase axes are continuous, with strong energy and contain abundant geological information, the reflection wave groups are distinctly not only in the shallow but also the deep seismic interface, which lays the foundation for the establishment of subsequent earthquakes sequence framework, inversion prediction and comprehensive research (See Fig.8).

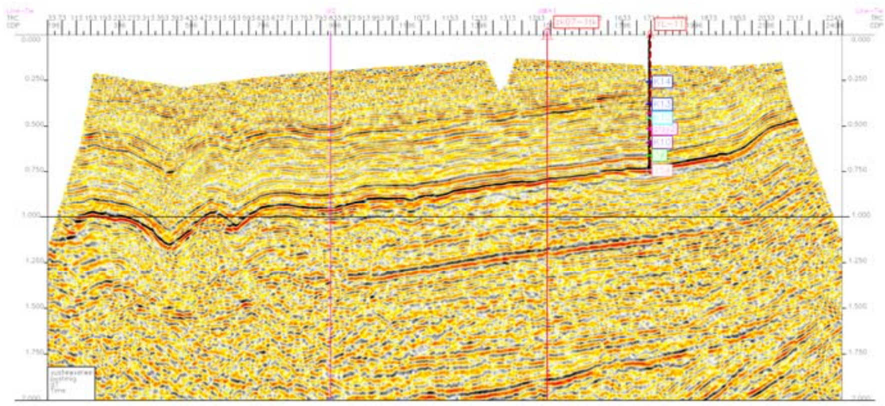


Fig. 8. Pre-stack migration time profile

IV. Conclusions

Investigate the shallow strata structure with Micro-log and Reversed Refracted Wave Method, and make sure the distribution range and depth for the best excitation combining with the integrating drilling logging data, which ensure the excite happened in high-speed layer in favor of improving the SNR. In the region that is difficult to drill or exists near strong interference, we should take combination of multiple wells with small charge mass to explosive which is in favor of improving the excitation energy, guaranteeing the bandwidth and suppressing interference to improving SNR. Take the combination technology with the low frequency geophones, which is good for suppressing interference; enlarge energy and further improving SNR for seismic primeval data. We take a series of techniques such as small interval of traces, multifold and so on, which are in favor of improving the seismic SNR and resolution in mountain areas especially in loess areas.

References

[1] ZHAO Jin-zhou, SHI Bao-hong. Division of Qinshui basin coal bed methane enrichment units[J]. Chinese science bulletin. 2005, 50(B10)：126-130

[2] ZHU Feng. The CBM distribution feature and exploration prospection analysis in Shanxi Qinshui Basin[J]. China Coalfield Geology. 1999(2):32-34

[3] ZHU Yan-Ming, ZHOU Xiao-gang, Hu Lin. The Taiyuan formation Shale gas accumulation structural control in the south of Qinshui Basin[J]. China Coalfield Geology. 2014, 26(08).

[4] QIN Yong, LIANG Jian-she, Shen Jian rtc.. The gas logging show and gas pool type of den2014(8):34-38se sandstone and shale in southern Qinshui Basin[J]. Journal of coal. 2014, 39(8):1559-1565