РЕШЕНИЕ ОБРАТНОЙ ДИНАМИЧЕСКОЙ ЗАДАЧИ ВСП С ИСПОЛЬЗОВАНИЕМ АВТОКОРРЕЛЯЦИОННЫХ ФУНКЦИЙ

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Solution of VSP dynamic inversion problem using correlated wave-fields

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Summary

VSP dynamic inversion problem solution with the use of correlation functions is discussed. The correlation functions are used when dealing with data obtained during the drilling process. An algorithm for the one-dimensional inversion problem solution is constructed. This algorithm involves autocorrelations of source data. The theoretical basis of the method as well as the results of the numerical experiment are described.

Аннотация

Рассматривается возможность использования корреляционных функций для решения обратной динамической задачи ВСП. Необходимость использования корреляционных функций возникает при регистрации колебаний, возбуждаемых буровым долотом. Разработан алгоритм решения одномерной обратной динамической задачи ВСП по автокорреляционным полям исходных данных. Приведены теоретические обоснования используемого метода и результаты модельного эксперимента.

Introduction

An analysis of correlated VSP seismic wave-fields shows that they contain complete information about a geological section along the well. On the basis of the correlated wave-fields it is possible to reconstruct the geological section both below and above geophone string. It is known that inversion problem has a solution also in the case of the deep source. Thus, the drilling bit can be used as a source. The proposed method was tested on the synthetic VSP data. It is appeared that the quality of media reconstruction with the use of autocorrelation wave-fields in comparison with regular VSP procedures results is acceptable. The suggested technique of interpretation of the correlated wave-fields recorded at the free surface allows to solve the problem of the reconstruction of the investigated geological section during the drilling process. The current position of the drilling bit can be determined as well.

Method description

The VSP wave-field corresponding to the horizontally layered media consists of downgoing and upgoing waves. For each record the full seismogram S can be treated as the sum of the downgoing wave S_1 and upgoing wave S_2.

The initial information for inversion problem below the observation level is the reflection serial G, defined as a result of the upgoing waves deconvolution.

Thus, we have:

$$G(\omega) = \frac{S_2(\omega)}{S_1(\omega)}. \qquad (1)$$

An estimation of the reflection serial is also possible in the case when only autocorrelations of the raw wave-fields can be used as the initial data.

There is one vertical direction and two inclined directions in the set of the auto-correlated VSP traces. The first direction is formed by sum of autocorrelations for downgoing and upgoing waves. The second direction is the result of the correlation between the primary downgoing and upgoing waves and the third direction is the result of correlation between upgoing and secondary downgoing waves.

Due to the fact that all these directions can be determined as a result of the wave selection procedure, autocorrelation fields of the VSP traces allow to yield the sum of the downgoing and upgoing waves autocorrelations as well as the mutual correlation of the downgoing and upgoing waves.

This information is sufficient for the estimation of the reflection serial. Let us assume:

$$\begin{aligned} K_0(\omega) &= |S_1(\omega)|^2 + |S_2(\omega)|^2, \\ K_1(\omega) &= S_1^*(\omega) S_2(\omega). \end{aligned} \tag{2}$$

For $\frac{K_0}{K_1}$ ratio, we have:

$$\frac{K_0}{K_1} = \frac{|S_1(\omega)|^2 + |S_2(\omega)|^2}{S_1^*(\omega) S_2(\omega)} = \frac{S_1(\omega)}{S_2(\omega)} + \frac{S_2^*(\omega)}{S_1^*(\omega)} = \frac{1}{G} + G^*. \tag{3}$$

The solution of the above equation is the following expression:

$$G(\omega) = \frac{1}{2}\frac{K_0}{K_1} - \frac{1}{2K_1}\sqrt{|K_0|^2 - 4|K_1|^2}. \tag{4}$$

Numeric experiment

The suggested technique was applied to the synthetic VSP data.

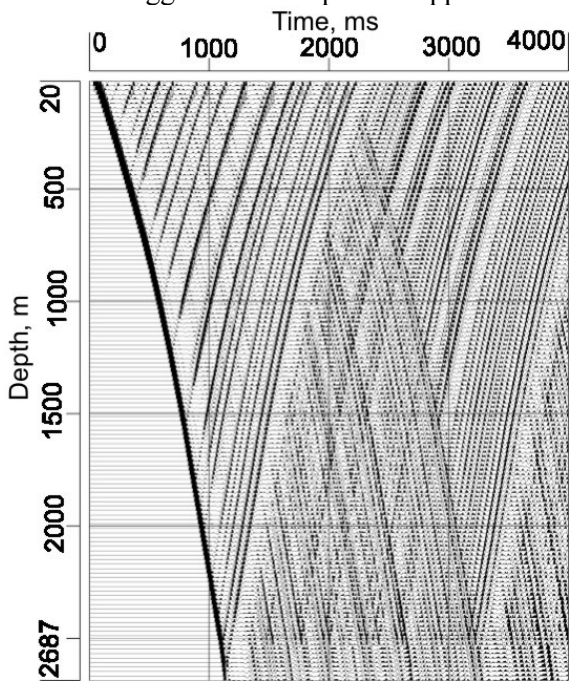


Fig.1. Synthetic VSP wave-field

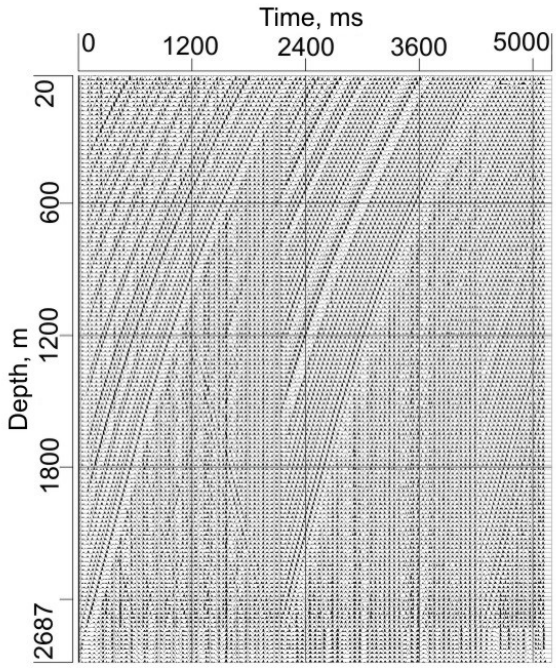


Fig.2. Autocorrelation field of source synthetic VSP data

The synthetic VSP wave-field obtained for the horizontally layered media is displayed in the Fig.1. Primary downgoing waves, secondary downgoing waves as well as multiples are clearly indicated. The Fig.2 shows the autocorrelation field of the source VSP data. Here one can see the vertical direction, the upgoing

waves and the secondary downgoing waves. After applying the selection procedure all of these wave types can be separated. They are shown in the Fig.3. The correlated wave reflected from the free surface is clearly recognized.

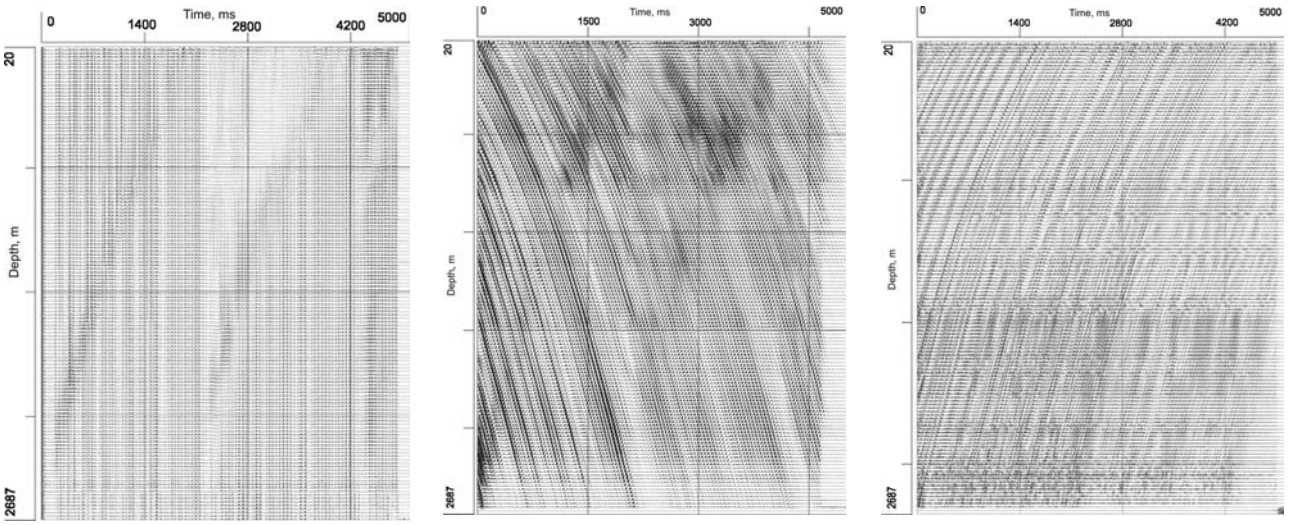
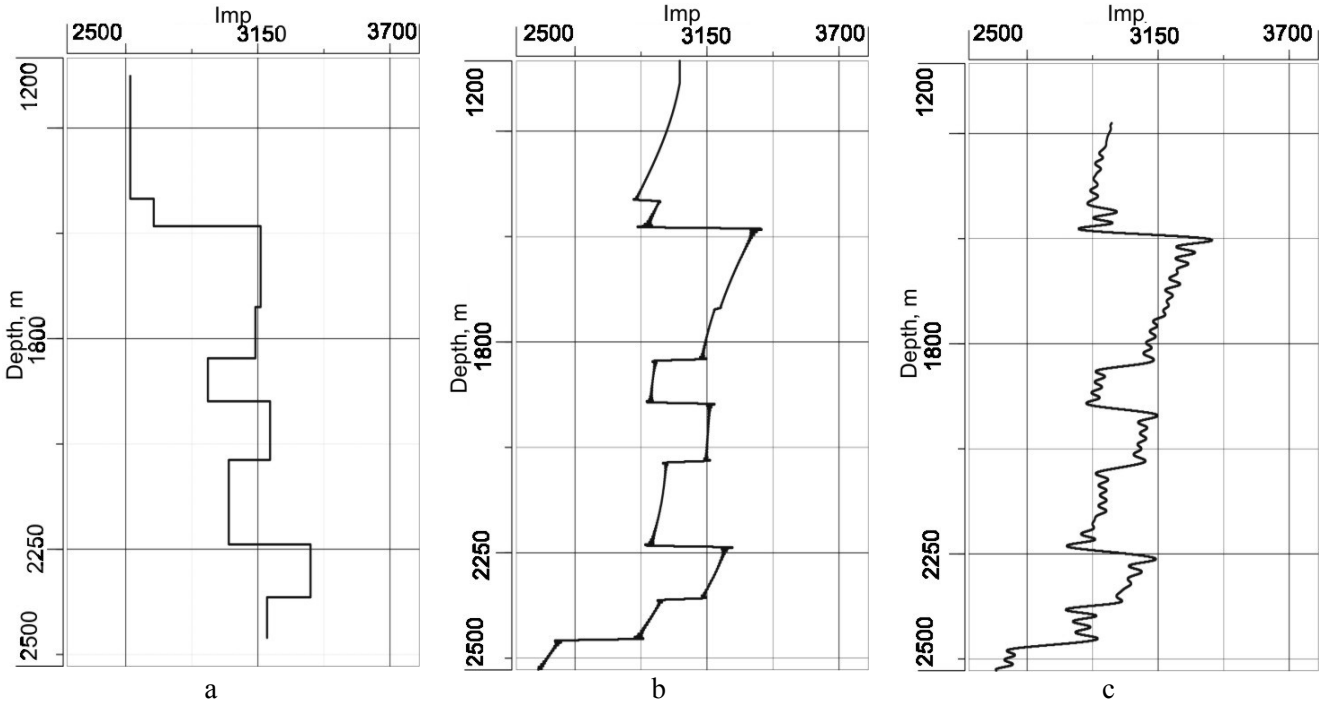


Fig.3. Autocorrelation wave-fields after selection procedure

Fig. 4 shows the acoustic impedances reconstructed below the observation area (a – source impedance used in modeling, b – impedance reconstructed by VSP data, c – impedance reconstructed by auto-correlated VSP data).



a b c

Fig.4. Acoustic impedances reconstructed below the line

Conclusion

The method of the media reconstruction below the drilling bit involving autocorrelation function is proposed. It is shown that substitution of the ordinary VSP records by their autocorrelations allows to solve the inversion problem for the investigated section. The suggested technique of interpretation of the correlated wave-fields recorded at the free surface allows to solve the problem of the reconstruction of the investigated geological section during the drilling process. This technique increases the possibilities of the reconstruction

of the high-resolution section below the downhole based on the using of drilling bit as source because reference geophone on drilling tubes is not used. The introduction of such monitoring during drilling process can appear rather effective due to more and more wide development of inclined and horizontal wells.

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