## AMPLITUDE FIELDS METHOD FOR MEDIUM HORIZONTAL INHOMOGENEITIES STUDY

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### A B S T R A C T

A method of the fields of refracted wave amplitudes has been developed for analysis of horizontal inhomogeneities of the medium on the basis of refracted wave attenuation factor. The essence of this method is the transition from amplitudes at the surface to amplitudes at the refactive boundary and then determination of the boundary attenuation coefficients after gliding wave divergence exclusion. The problem of seismic monitoring in chosen region and attenuation tomography can be solved by using the amplitude fields method.

## ΜΙΑ ΜΕΘΟΔΟΣ ΤΩΝ ΠΛΑΤΩΝ ΤΩΝ ΚΥΜΑΤΩΝ ΓΙΑ ΤΗΝ ΜΕΛΕΤΗ ΟΡΙΖΟΝΤΙΑΣ ΑΝΟΜΟΙΟΓΕΝΕΙΑΣ ΕΝΟΣ ΜΕΣΟΥ

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### Π Ε Ρ Ι Λ Η Ψ Η

Αναπτύσεται μιά μέθοδος, που αφορά τα πλάτη των διαθλώμενων κυμάτων με σκοπό τον προσδιορισμό οριζοντίων ανομοιογενιών στο μέσο διάδοσης. Η μέθοδος βασίζεται στον παράγοντα απόσβεσης των διαθλώμενων κυμάτων. Η σημασία της μεθόδου έγκειται, στην μετάβαση από πλάτη που μετρώνται στην επιφάνεια σε πλάτη και συντελεστές απόσβεσης στα όρια της επιφάνειας διάθλασης αφού γίνει η διόρθωση λόγω διασποράς. Συμπεραίνεται ότι με την μέθοδο αυτή λύνονται διάφορα προβλήματα, όπως οι σεισμικές αναγραφές σε επιλεγμένη περιοχή και η τομογραφία της απόσβεσης.

### INTRODUCTION

Time field and interval boundary velocity methods are successfully employed in studies of the horizontal inhomogeneity of a medium and for predictions of its material composition. For certain groups of rocks, seismic wave velocities are similar or identical. For their separation, additional criteria are necessary. We examine the possibility of using attenuation factors based on dynamic characteristics of recordings in studies of horizontal inhomogeneities.

Compared with velocities, attenuation factors are much more sensitive to a change of the chemical composition and the physical properties of rocks. In the range of frequencies from 10 to 100 Hz attenuation factors vary in a broad range from 1 x

$10^{-5}$ (crystalline rocks) to 5 x $10^{-1}$ (loose sand-clay rocks), where as velocities in this group of rocks vary from 0,8 (loose sand-clay rocks) to 6-8 Km/s (crystalline rocks) (Berzon, et al. 1952).

Because of the low accuracy (on the order of 10%) of dynamic calibration of seismic detector channels, the accuracy of determination of the boundary attenuation factor $\alpha_b$ does not exceed 10%. On the other hand, the boundary velocity $v_b$ can be determined within 1-3%. However, even taking this difference into consideration, the attenuation factor should be useful for such studies.

A method of the fields or refracted wave amplitudes has been developed for analysis of horizontal inhomogeneities of the medium on the basis of refracted wave attenuation factors (Doubrovina,et al.1991).

The method rests on Riznichenko's idea of seismic wave intensity fields (Riznichenko, 1954). On the assumption that the medium is isotropic and that wave energy is propagated along rays, Riznichenko formulated and solved the problem of determining seismic waves amplitudes within the medium if the travel time curves and amplitudes of displacements at the Earth's surface are stipulated. On the assumption of homogeneity of the covering layer (v=const, ρ=const) the expression for the amplitudes field has the following form:

$$\ln A_2 = \ln A_1 - \frac{V}{2}\int_{M_1M_2} \nabla^2 t dr - \alpha r(M_1M_2)\,|_{(M_1M_2)}, \qquad (1)$$

where $A_2$ is wave amplitude at the surface (at the point $M_2$), $A_1$ is the amplitude of the wave within the medium (at the point $M_1$), v is the velocity of seismic wave propagation in the medium, $\alpha$ is the absorption coefficient (Riznichenko, 1954).

Our objective was to apply the Yu.V.Riznichenko's theory of amplitude fields for determining the boundary absorption coefficient for head waves in a study of horizontal medium inhomogeneity. The essence of the proposed method is as follows: having the amplitudes of the refracted (head) waves at the surface and taking into account the divergence and absorption of seismic waves from the surface to the refracting boundary, it is possible to proceed from the amplitudes of displacements at the surface to the amplitudes of displacements at the refracting boundary, and then, excluding divergence of a wave glacing along the boundary, to determine the boundary absorption coefficients. The boundary absorption coefficient $\alpha_b$ of a head wave is a physical parameter of the medium characterizing the decrease in amplitude of a wave glancing along the boundary per unit path length.

By analogy with the interval boundary velocity we introduce the concept of an interval boundary absorption coefficient: $\alpha_{b,int}$ is the absorption coefficient obtained on a definite horizontal base along the refracting boundary. A conversion from $\alpha_b$ to $\alpha_{b,int}$ is necessary in study of horizontally inhomogenious media. The interval boundary absorption coefficient is determined on a base **d** egual to the diagonal of a rhombus formed by a system of counter isochronal lines on a refracting boundary; d = $\Delta t \upsilon_{b.int}$, where $\Delta t$ is the isochronal line interval.

In order to determine the $\alpha_b$ values along a refracting boundary it is necessary to know the amplitudes at points on the investigated boundary (amplitudes of the glancing wave). We obtain them using formula (1). The amplitude of the displacements at the boundary, similarly to the amplitude at the surface, is determined by wave absorption and divergence along the boundary.

$$A_{gl}(x_b) = \frac{A_o e^{-\alpha_b(x_b - x_{in,b})}}{R_b(x_b)} \qquad (2)$$

where $A_{g1}$ is the amplitude of the glancing wave; $x_b$ is the horizontal coordinate along the boundary; $A_o$ contains all the terms not dependant on $x_b$; $a_b$ is the boundary absorption coefficient; $R_b$ is wave divergence along the boundary; $x_{in,b}$ is the initial point of the head wave at the boundary ($x_{in,b} = x_{in}/2$, where $x_{in}$ is the initial point of the head wave).

From (2) we find an expression for the boundary absorption coefficient:

$$\alpha_b = -\frac{d\ lnA_{gl}(x_b)}{dx_b} - \frac{d\ lnR_b(x_b)}{dx_b} \qquad (3)$$

It was shown that the expression for the divergence of a head wave along the boundary had the following form:

$$R_b(x_b) = x_b^2 \left(\frac{1 - x_{in,b}}{x_b}\right)^{\frac{3}{2}} \qquad (4)$$

Substituting (4) into formula (3), we obtain an expression for the absorption coefficient along the refracting boundary:

$$a_b = -\frac{d\ lnA_{gl}(x_b)}{dx_b} - \frac{d\ \ln\left[x_b^2\left(\frac{1 - x_{in,b}}{x_b}\right)^{\frac{3}{2}}\right]}{dx_b} \qquad (5)$$

An algorithm was written and a program was prepared for applying a time field and amplitude field method making it possible to obtain the section of the refracting boundary, interval boundary velocities, and interval boundary absorption coefficients. A number of blocks of the POINT program (Yepinat'yeva, A.M., et al. 1982) were used in preparing the algorithm and program. Counter travel time curves and amplitude curves of head waves area were used as initial data.

The travel time curves and A(X) dependencies were computed for two types of models: with a constant value of the interval boundary absorption coefficient (model 1) and with a variable $\alpha_{b,int}$ (with a horizontal change of $\alpha_{b,int}$, either linear (model 2) or quadratic (model 3). The computations indicated that the deviation of the computed values of the boundary absorption coefficient from the stipulated values does not exceed 1% for a constant absorption coefficient (model 1), 2% for a linear $\alpha_b$

change (model 2), and 3% for a quadratic change (model 3).

Field data, obtained in Russia, Kazakhstan, Uzbekistan by correlational refracted wave method/deep seismic sounding with standard observation systems, were taken for analysis by using the method of amplitude fields. Vibrations were recorded in the frequency band of 5-15 Hz. Counter travel time curves of head waves were tied in using reciprocal points; the amplitudes were monitored. The static corrections for all the used travel time curves and amplitude curves were further corrected in order to exclude the influence of the upper part of the section. The correction method is described in Doubrovina, and Litvin, (1990).

Figures 1-3 illustrate experimental data processing. In order to understand the physical meaning of the anomalies of the attenuation factor, we undertook a combined interpretation of the curves of $\alpha_{b,int}(X)$, $\upsilon_{b,int}(X)$, and $z(X)$. The curves of interval boundary absorption coefficients and interval boundary velocities were averaged by seven points in a moving window. With such averaging, random interference is eliminated, regular interference is weakened, and horizontal inhomogeneities with dimensions of a few kilometers are isolated, which corresponds to the actual resolution power of the method.

A comparison of the curves of interval boundary absorption coefficients and interval boundary velocities shows that, usually, an inverse correlation is observed.

We have anlysed all the profiles in order to see which of the anomalies of $\alpha_b$ and $\upsilon_b$ are caused by tectonic disruptions along the refracting boundary, which by vertical contacts in the refracting layer, and which by a variation of the composition of rocks in the refracting layer (Doubrovina, 1991).

Figures 1-3 show dowonthrow-type tectonic faults obtained as a result of combined interpretation of the plots of $<\alpha_{b,int}(X)>_7$, $<\upsilon_{b,int}(X)>_7$ and $z(X)$. These tectonic faults are confirmed by geologic sections. For all the profiles, the amplitudes of attenuation factor anomalies increased with the downthrow amplitudes and with growing gradient of boundary velocities in the contact region.

By using the results of physical modelling vertical contacts along refracting boundaries were identified on the basis of the plots of $<\alpha_{b,int}(X)>_7$.

The cause of the $\alpha_b$ anomalies, which were not confirmed by the presence of tectonic faults and vertical contacts along the refracting boundary, can be some variation of the physical composition and physical properties of the rocks of the refracting layer.

In a medium with a sloping boundary, a tendency is observed for a gradual decrease of the boundary attenuation factor with the increasing occurrence depth of the refracting boundary, while $\alpha_b$ grows with decreasing occurrence depth (see Figs.1-3).

The correlations between interval boundary velocities and interval boundary absorption coefficients of refracted waves are illustrated by the composite chart in Fig.4 compiled for these profiles. The chart indicates that the general relationship between absorption coefficients and propagation velocities of seismic wave-the decrease of attenuation factors with increasing velocity-that follows from physical considerations is genrally confirmed. On the other hand, the figure shows also that sometimes a given velocity corresponds to different absorption coefficients. This is indicative of a high sensitivity of attenuation factors to inhomogeneities of the medium as compared with velocities and confirms the utility of attenuation factors of seismic waves as a tool for horizontal inhomogeneity study.

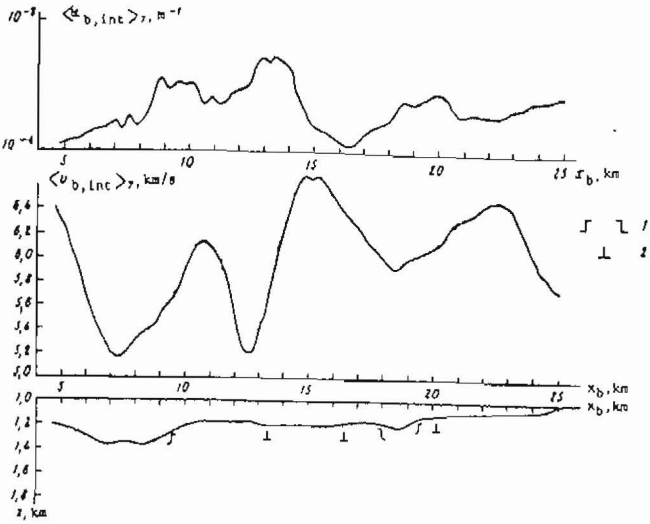

**Fig.1.** Interval boundary attenuation factors, interval boundary velocities, and section of the refracting boundary for the Kaskelian profile (Kazakhstan): 1) tectonic downthrow-type faults; 2) vertical contact.

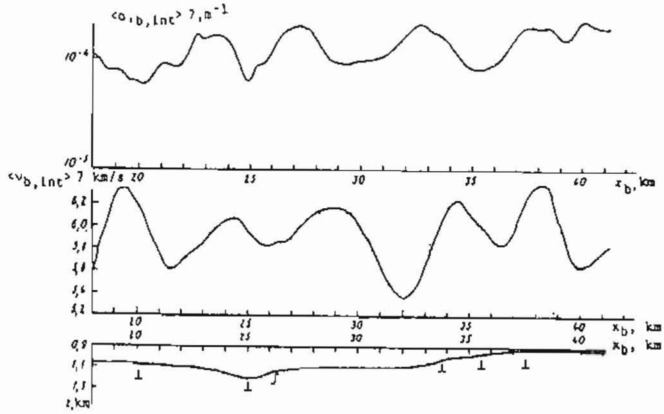

**Fig.2.** Interval boundary attenuation factors, interval boundary velocities, and section of the refracting boundary for the Farab-Tamdybulak profile (Uzbekistan). Notations as in Fig.1.

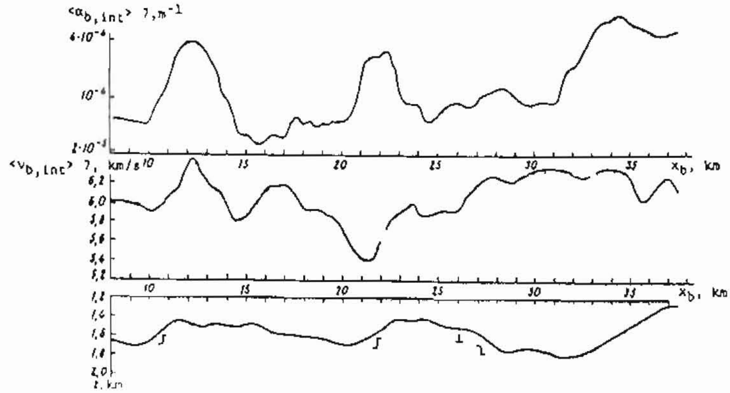

**Fig.3.** Interval boundary attenuation factors, interval boundary velocities, and section of the refracting boundary for the Temirtau-Kuybyshev profile (Kazakhstan). Notations as in Fig.1.

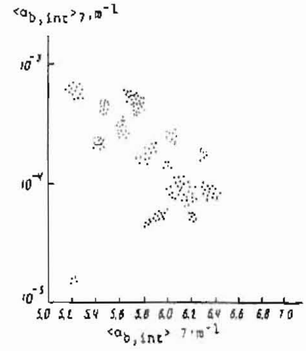

**Fig.4.** Interval boundary attenuation factor as a function of interval boundary velocity.

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