GEOPHYSICAL TRANSACTIONS 1988
Vol. 33. No. 3–4. pp. 211–220

NEW VARIANT OF INTERVAL VELOCITY ESTIMATION FROM REFLECTION AMPLITUDES

Volker KRUG*

Instead of using single traces as is done with the common pseudo-acoustic log, amplitude variations across adjoining traces along reflective horizons are used in the presented method. Proceeding from a reference trace, the reflectivity-dependent relative velocity changes, which are proportional to the amplitude variations, are determined. Since all amplitude values of a signal are suitable for calculation, signal compression (spike deconvolution) is not necessary. The examples of two profiles demonstrate the achievable results when using the horizontal changes of layer velocities.

Keywords: reflection methods, velocity, amplitude, seislog, signal-to-noise ratio, pseudo-acoustic log

1. Introduction

In recent years, the pseudo-acoustic velocity log has become important for the interpretation of local velocity variations. In particular, it has been utilized for detecting lithological changes within the limits of oil or gas deposits. The pseudo-velocity log in the classical meaning implements the velocity determination sample-wise along the time axis for one trace [LINDSETH 1979, GOGONENKOV et al. 1980]. By that procedure the value of the true amplitude is assigned to the seismic impedance at the respective location thus enabling us to determine the velocity distribution along the seismic trace. Strictly speaking, such a treatment assumes a pulse trace (not to speak about other problems; see below). Similar to a procedure used by BOISSE [1978], an alternative program has been developed which does not consider the amplitude variation along a single trace but across adjoining traces along the direction of correlation of horizons. In contrast to Boisse's procedure not only the main phase (or amplitudes) of the signals of selected horizons is processed for calculation of underlying interval velocities but all samples (sample-wise) between two consecutive horizons. Such an approach provides a more favourable statistical interpretation, especially of horizontal velocity variations.

* VEB Kombinat Geophysik Leipzig, Bautzner Strasse 67, GDR–7024
Paper presented at the 31st International Geophysical Symposium, Gdansk, 30 September—3 October, 1986

2. Principle of procedure

Fig. 1 shows the principle of the algorithm which is used in this paper. A presupposition of the treatment is a reference trace (*a*) recorded near the well. This trace can be obtained by the averaging of several adjoining traces. To this reference trace belongs a corresponding velocity model (V_{a1}, V_{a2}) or reflectivity sequence which is derived from sonic logs of nearby boreholes. The reflection coefficient is

$$R_a = kA_a \approx \frac{V_{a1} - V_{a2}}{V_{a1} + V_{a2}} \tag{1}$$

if the density contrast is neglected ($\varrho_1 \approx \varrho_2$). k is a scale factor, A_a the sample amplitude at time T for the reference trace. For a neighbour trace (*b*) the correspondig reflectivity at the same time (better: at the same horizon or phase position) may be expressed by the velocities V_{b1} and V_{b2}. The corresponding reflection coefficient on trace *b* is

$$R_b = kA_b \approx \frac{V_{b1} - V_{b2}}{V_{b1} + V_{b2}} \tag{2}$$

From the amplitude ratio between reference trace and adjoining trace

$$\frac{R_a}{R_b} = \frac{A_a}{A_b} \approx \frac{(V_{a1} - V_{a2})(V_{b1} + V_{b2})}{(V_{a1} + V_{a2})(V_{b1} - V_{b2})} \tag{3}$$

the velocity V_{b2}, etc. may be determined, provided the velocity V_{b1} is known:

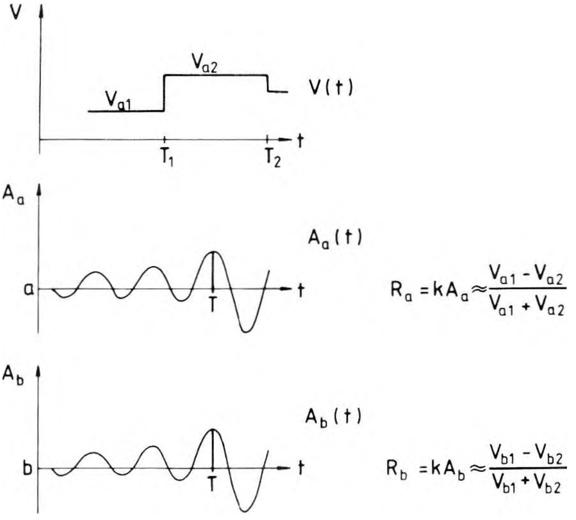
$$V_{b2} \approx \frac{A_a V_{b1}(V_{a1} + V_{a2}) - A_b V_{b1}(V_{a1} - V_{a2})}{A_a(V_{a1} + V_{a2}) + A_b(V_{a1} - V_{a2})} \tag{4}$$

For V_{b1} one can use either the mean velocity derived from the aforetreated layer or from the given velocity model. This will be done for all traces of a stacked time section with true amplitudes.

The position of the reflecting horizons along the x-axis (T_1 in Fig. 1, and see correlation in Figs. 3 and 5) in the time section is visually picked and the intermediate layer velocities are linearly interpolated.

The trace processing sample by sample between two consecutive horizons is done parallel to the upper horizon. Since some problems may arise with thickness variations, the selection of the reference trace is of particular importance. It should preferably be taken from that point where the thickness is greatest.

For calculation, such amplitude values are abandoned which are less than a preselected percentage of the mean value of the trace. Obtained velocity values which surpass or underflow a given level are not further used for treatment. The frequently very scattered individual values on the traces are subjected to a selectable (in x and t), two-dimensional and position-weighted smoothing. As



$$\frac{R_a}{R_b} = \frac{A_a}{A_b} \approx \frac{(V_{a1} - V_{a2})(V_{b1} + V_{b2})}{(V_{a1} + V_{a2})(V_{b1} - V_{b2})} \qquad V_{b2} \approx \frac{A_a V_{b1}(V_{a1} + V_{a2}) - A_b V_{b1}(V_{a1} - V_{a2})}{A_a(V_{a1} + V_{a2}) + A_b(V_{a1} - V_{a2})}$$

Fig. 1. Scheme of velocity estimation

1. ábra. A sebességbecslés vázlata

Рис. 1. Схема определения скоростей.

result we obtain interval contour plots which represent either the interval velocities or the deviation of the interval velocity from the reference trace (ΔV) or its percentual variation. This approach has some advantages over the commonly used pseudo-velocity log:

Advantages

- no spike deconvolution necessary (input is not considered as pulse seismogram but as wavelet)
- no complete frequency band required
- better use of a priori knowledge
- variable smoothing of data
- statistical procedure, robust calculation regime
- no accumulation of errors with time
- better elimination of interference
- application possible also at worse S/N-ratio

Disadvantages

- assumption of horizons with accurate correlation
- problems arising with the sampling if layer thickness changes
- no elimination of distortion (e.g. dispersion)

3. Examples

The next figures demonstrate the calculation results from two profiles *A* and *B* extending parallelly to a distance of 400 m. *Fig. 2* shows for profile *A* the normal stack, the stack with true amplitudes and the isoarea section of ΔV-results (related to reference trace at coordinate 3712 m) for the time interval essential for oil prospecting. The lowest (negative) ΔV values are white, the highest values are black. In *Fig. 3* the time scale was a little extended, the stacked traces (true amplitudes) are shown as wiggle traces and the velocity changes are plotted as ΔV contour lines. In *Fig. 4* an enlarged section is represented where stacked traces in wiggle trace form have been superimposed on the ΔV contour line section and an isoarea section is also presented. Similar plots for section *B* are presented in *Figs. 5* and *6*.

Both seismic profiles cross a carbonate sand barrier of the Zechstein (approximately between the coordinates 3000 m and 5500 m). The velocity estimation has been accomplished within the total Zechstein sequence. The main horizons are correlated in Fig. 3 and Fig. 5. The quality of the time section is poor but, nevertheless, usable results have been obtained. It is obvious that the velocity variations along the reflectors behave like the intensity of the true amplitudes, as expected. The differentiation is clearly greater for profile *B*, especially in the interesting x-interval (4000 m–5000 m). This indicates that the velocity contrasts at profile *A* are presumably lower than at profile *B*. On profile *A* it can be seen that the zone of reduced velocity around coordinate 5400 m extends with a decreasing trend to about 3100 m.

From $x = 5400$ m to higher x values one can see growing variations of the layer velocities which are connected with the steeper descent towards the trough caused by the barrier.

4. Conclusions

The quality or reliability of velocity estimations depends strongly on the quality of field data (i.e. on the signal-to-noise ratio). The statistical treatment of numerous velocity data permits a good estimation of relative velocity changes even for poor quality seismic sections. An accuracy of ± 100 m/s to ± 500 m/s should be expected for distances of about 1000 m from the borehole.

The procedure described here has the advantage of being able to use all amplitude values and spike deconvolution is not needed; on the other hand the exact correlation of horizons is something of a disadvantage.

If we are concerned with reliability, comprehensive model knowledge, and precise treatment of the original data, then this technique seems to be suitable for the exploration of large structures as well as for detailed investigations.

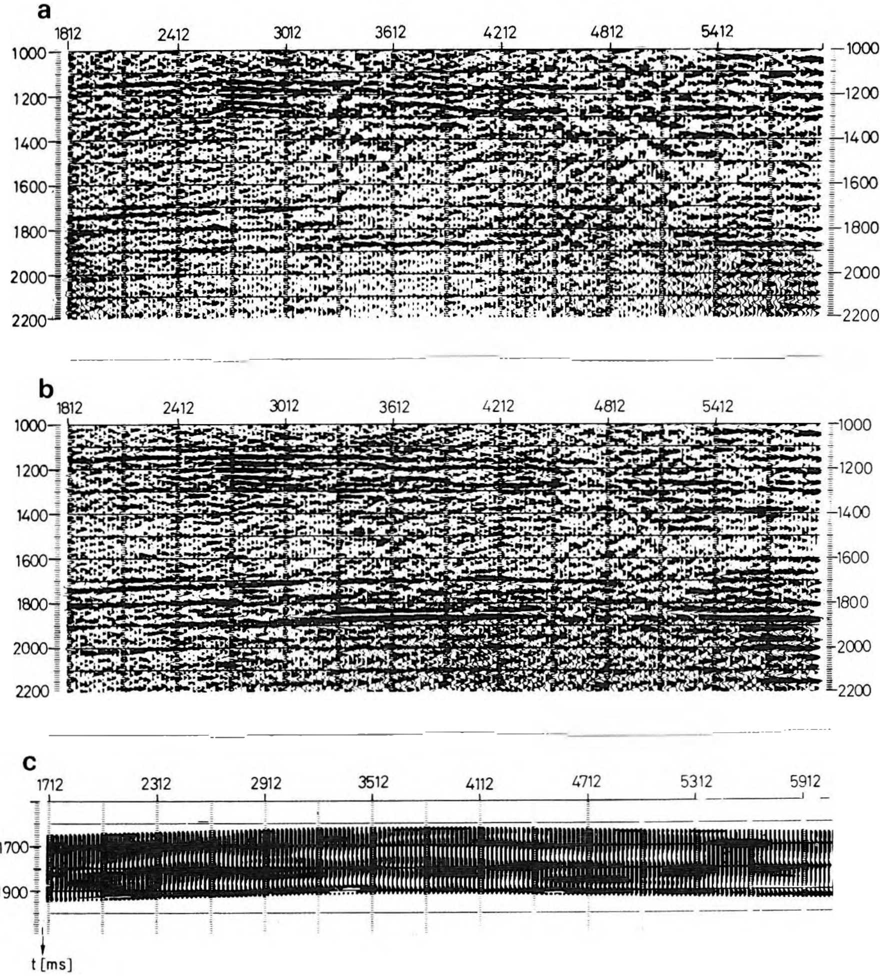


Fig. 2. Time section *A* for velocity estimation. a) Stacking; b) Stacking with true amplitudes; c) Calculated ΔV iso-area section. Velocity range: +400 m/s — −400 m/s in 200 m/s steps from dark to light

2. ábra. A sebességbecslésre felhasznált *A* időszelvény. a) Összegszelvény; b) Összegszelvény valódi amplitúdókkal; c) Számított ΔV szelvény. Sebességtartomány: +400 m/s — −400 m/s, 200 m/s lépésekkel, a sötéttől a világos árnyalatok felé haladva

Рис. 2. Временной разрез *A* для определения скоростей. a) Стекинг. b) Стекинг с истинными амплитудам. c) Рассчитанный профиль изоареалов ΔV. Диапазон скоростей от +400 м/с до −400 м/с через 200 м/с, от темных оттенков к светлым.

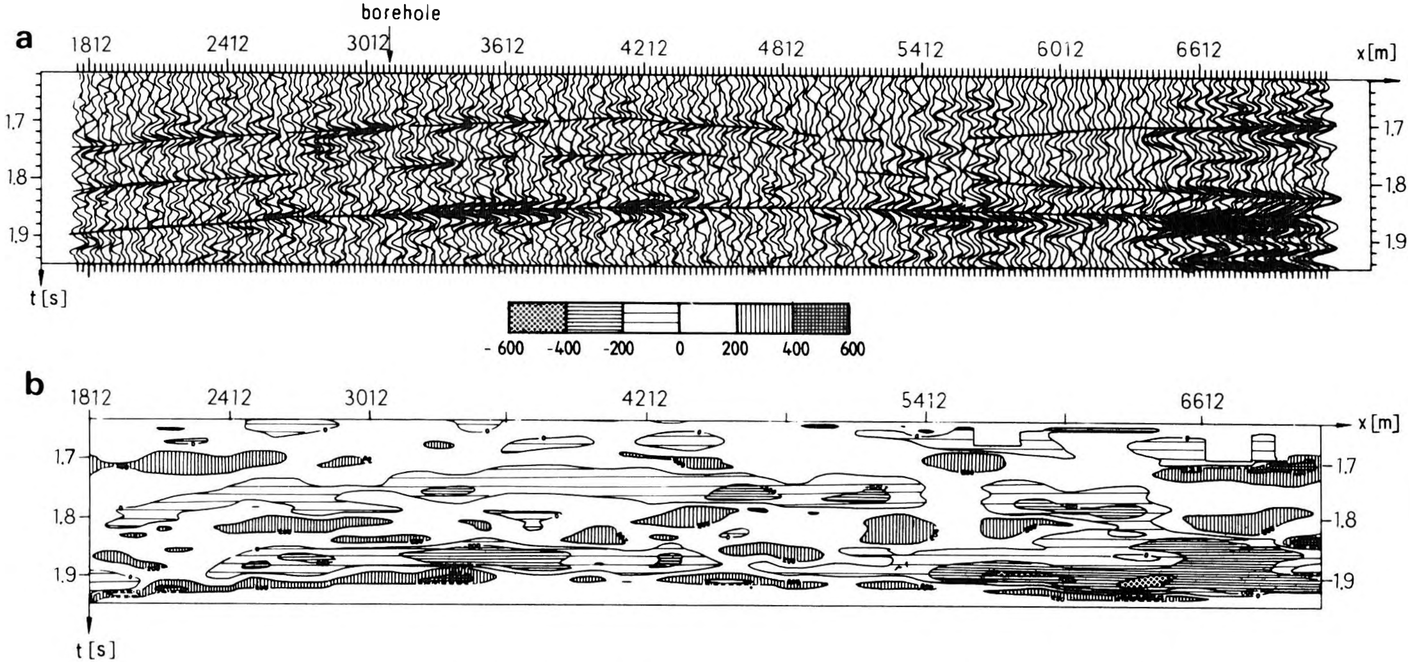


Fig. 3. Time section and estimated relative velocity changes (section *A*). a) True amplitudes (with correlation); b) ΔV isolines in m/s

3. ábra. Időszelvény és becsült relatív sebességváltozások (*A* szelvény) a) Valódi amplitúdók (korrelációval); b) ΔV izovonalak

Рис. 3. Временной разрез и определяемые относительные изменения скоростей (разрез *A*). a) Истинные амплитуды (скорректированные). b) Изолинии ΔV в м/с.

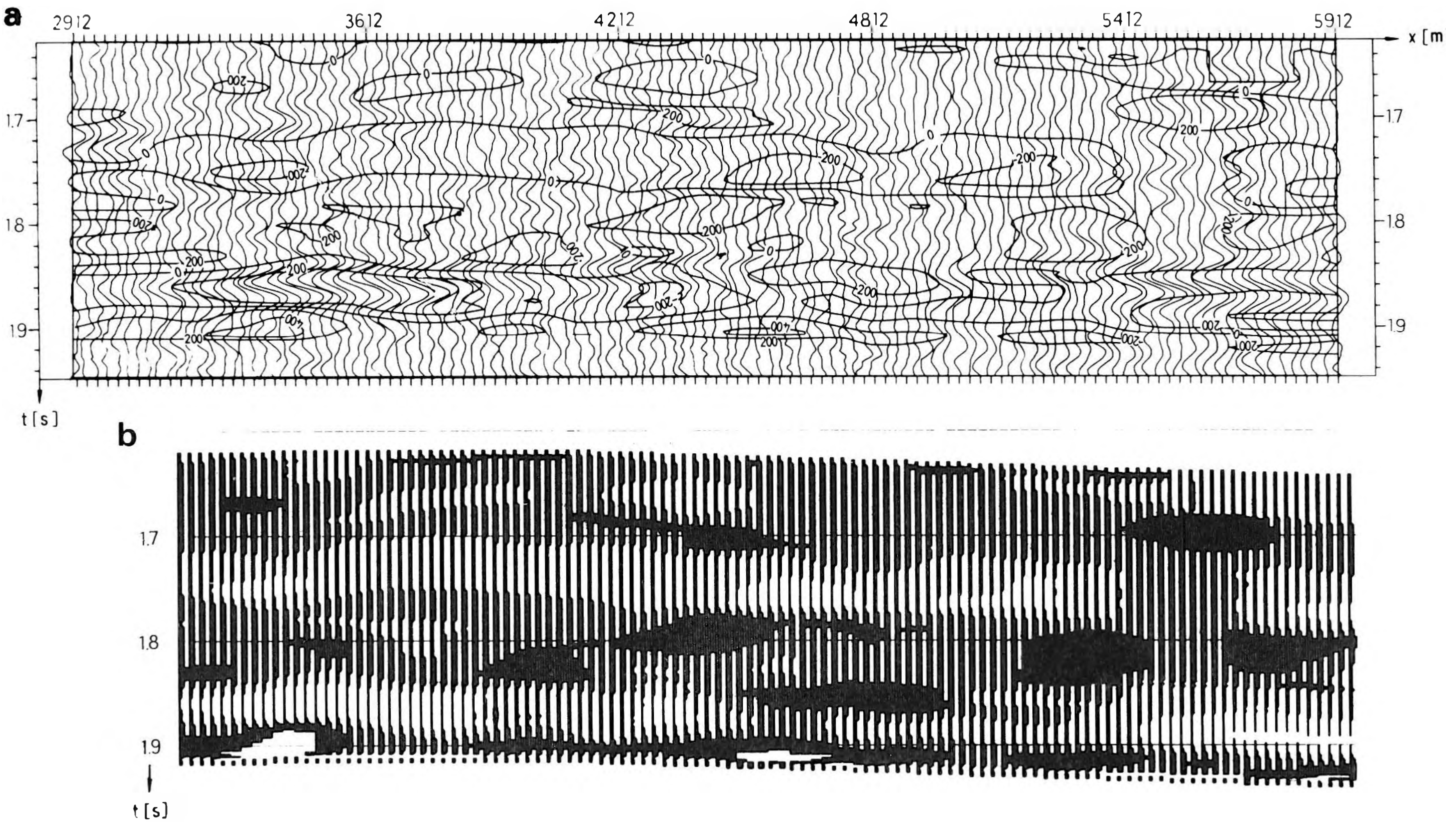


Fig. 4. Time section and estimated relative velocity changes (section *B*) a) True amplitudes: b) ΔV isolines

4. ábra. Időszelvény és becsült relatív sebességváltozások (*B* szelvény) a) Valódi amplitúdók; b) ΔV izovonalak

Рис. 4. Временной разрез и определяемые относительные изменения скоростей (разрез *B*). a) Истинные амплитуды. b) изолинии ΔV.

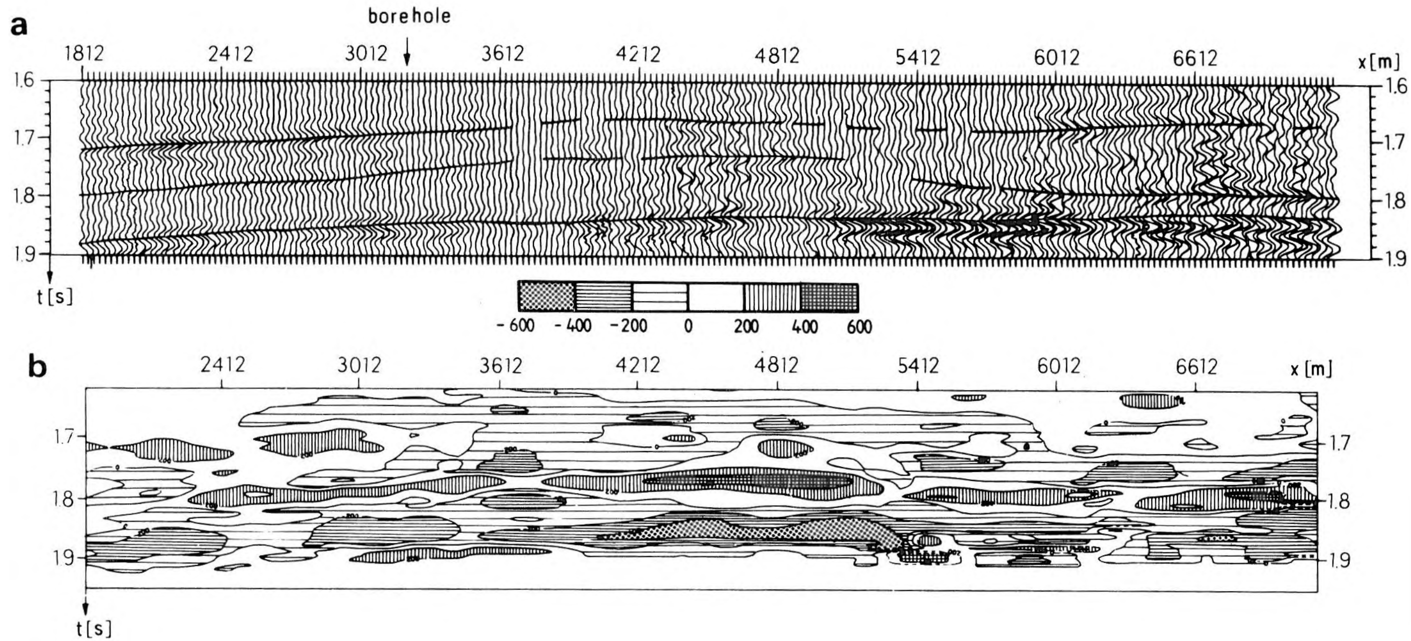


Fig. 5. Time section and estimated relative velocity changes (segment of section *A* a) ΔV-isolines and true amplitude traces; b) ΔV isoarea section. For scale see Fig.2.

5. ábra. Időszelvény és becsült relatív sebességváltozások (az *A* szelvény részlete) a) ΔV izovonalak és valódi amplitúdó csatornák; b) ΔV szelvény. A sebességskálát lásd az 1. ábrán

Рис. 5. Временной разрез и определяемые относительные изменения скоростей (фрагмент разреза *A*). a) Изолинии ΔV и каналы истинных амплитуд. b) Профиль ΔV. Шкалу скоростей см. на рис. 1.

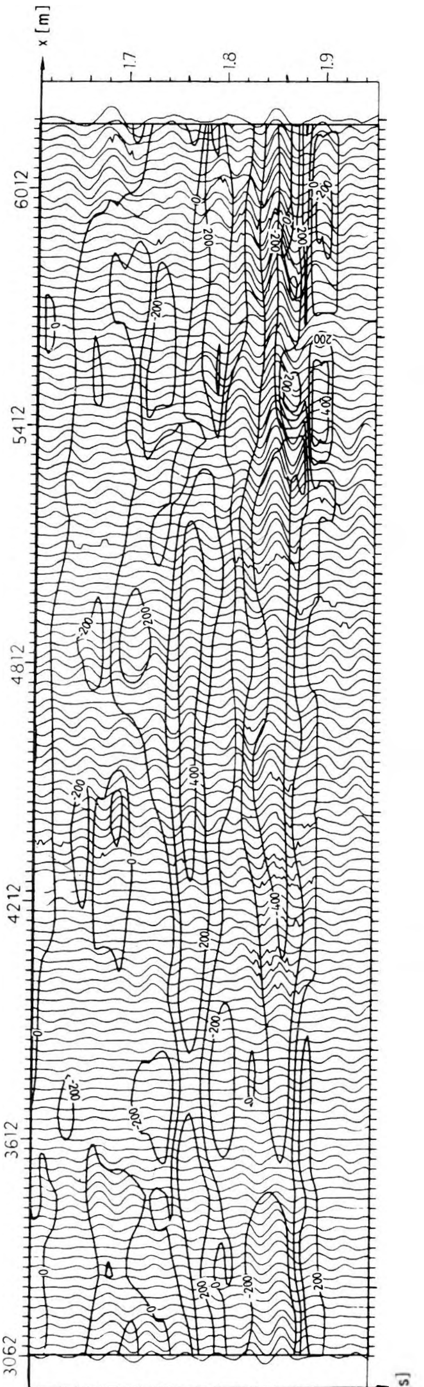


Fig. 6. Relative velocity changes along section *B* (enlarged segment)

6. ábra. Relatív sebességeloszlások a *B* szelvény mentén (részlet)

Рис. 6. Распределения относительных скоростей вдоль профиля *B* (фрагмент).

REFERENCES

Boisse S. 1978: Calculation of velocity from seismic reflection amplitude. Geophysical Prospecting **26**, 1, pp. 163–174

Gogonenkov G. N., Zacharov E. T., Elmanovich S. S. 1980: Determination of detailed velocity structure from seismic data (in Russian). Prikl. Geofiz. **97**, pp. 58–72

Lindseth R. O. 1979: Synthetic sonic logs — a process for stratigraphic interpretation. Geophysics **44**, 1, pp. 3–26

A REFLEXIÓS AMPLITÚDÓK ALAPJÁN VÉGZETT INTERVALLUMSEBESSÉG-BECSLÉS ÚJ MÓDSZERE

Volker KRUG

A tanulmány bemutat egy módszert, amelyben nem egyedi csatornákat dolgoz fel, mint ahogy a pszeudo-akusztikus karotázs szelvénynél szokásos, hanem reflektáló határfelületek mentén vizsgálja a szomszédos csatornák amplitúdó változásait. Egy referencia csatornából kiindulva a reflektivitástól függő, amplitúdó változásokkal arányos, relatív sebesség változásokat határoz meg. Mivel a jel bármely amplitúdó értéke alkalmas a számításokra, nincs szükség spike dekonvolúcióra. A bemutatott két szelvény vízszintes rétegsebesség-változások esetén mutatja az elérhető eredményeket.

НОВЫЙ МЕТОД ОЦЕНКИ ПОИНТЕРВАЛЬНЫХ СКОРОСТЕЙ НА ОСНОВАНИИ АМПЛИТУД ОТРАЖЕНИЙ

Фолькер КРУГ

Охарактеризован новый метод, в котором обрабатываются не одиночные каналы, как это принято в случае кривых псевдоакустического каротажа, а изучаются изменения амплитуд по соседним каналам вдоль отражающих поверхностей. Определяются относительные изменения скоростей, пропорциональные изменениям амплитуд и зависящие от отражательной способности, отнесенные к одному из каналов, выбранного в качестве опорного. Поскольку в расчетах могут быть использованы любые значения амплитуд сигналов, отпадает необходимость в спайк-деконволюции. Представляются два разреза в качестве иллюстрации результатов, полученных при горизонтальных изменениях погоризонтных скоростей.