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GEOFIZIKAI KÖZLEMÉNYEK
23

APPLICATION OF STACKING FOR REFRACTION TIME SECTIONS

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Introduction

Although the methods of multiple coverage, digital recording and data processing became quickly known in reflection seismics, their application in refraction seismics is still not generally accepted. Multicover measurements have been introduced to refraction field techniques long ago coverage however is regarded as an aid to interpretation instead of using it to increase signal to noise ratio.

In literature Peraldi (1969) was the first to adapt the methods developed in reflection seismics to refraction. In 1972 Peraldi and Clement already published a processing package, constructing the refraction horizon by ray charts as a final result. All along the process however their aim seems to be the substitution of conventional interpretation by numerical methods instead of finding new ways to meet new possibilities. For the first time Hirschleber (1971) suggested multicover measurements and stacking in refraction. His solution is somewhat laboured and some delicate approximations are required at certain points, but his final aim, i.e. refraction time section seems to be surely the path of tomorrow.

Suggestive display of results is important in all branches of geophysics, but in seismics it seems to be indispensable. At the same time only attempts have been made even in well developed computerized reflection data processing to make the computer understand in form of different parameters what human eye sees. In refraction picking the change of wave form is even more important than in reflection interpretation. Display of refraction waves in the form of time section represents a new dimension in geological interpretation.

Consequently our aim is identical to that of Hirschleber, but our solutions are supposed to be simpler, easier to realize and not limited to first arrivals.

The problem

The equation of refraction time-distance curve for two layers can be given in the following form:

$$T = t_{0sp} + t_{0g} + (x/V_2)\cos\Theta \tag{1}$$

where

$$t_{0sp} = h_1 \cos\Theta\,(\cos i)/V_1 \tag{2}$$

and

$$t_{0g} = h_2 \cos\Theta\,(\cos i)/V_1 \tag{3}$$

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For further notations see Fig. 1.

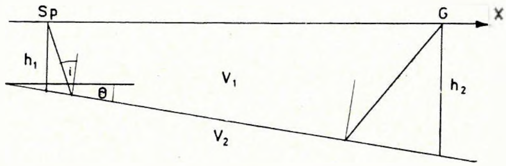

Fig. 1. Display of notations used in formulae
1. ábra. A dolgozatban alkalmazott jelölések szemléltetése
Рис. 1. Обозначения, применяемые в настоящей работе

Definition of delay time:

$$D = T - x/V_R = t_{0\,sp} + t_{0\,g} + (x/V_2)\cos\Theta - x/V_R \tag{4}$$

Where V_R is the reduction velocity.

If $x = 0$, $T = t_0 = t_{0\,sp} + t_{0\,g} =$ intercept time.

Some authors consider D as intercept time and $t_{0\,g}$ as delay time, but sticking to conventional nomenclature we call $t_{0\,sp}$ and $t_{0\,g}$ the shot point delay and geophone delay respectively, keeping the expression of delay time for D.

Arrivals from different shotpoints will represent a continuous time section only if all other terms but the geophone delay are eliminated in the formula of the delay time. If this reduction is carried out by adequate precision, the covering arrivals can be stacked. Two or threefold coverage is at our disposal in every routine refraction profile. Using stacking, according to the $\sqrt{n}$ formula a 1.4–1.7 times increase in signal to noise ratio can be achieved by no extra expenditure. Advantages of stacking concerning first arrivals are important in areas of unfavourable energy transmission and in inhabited regions, but they are always essential as to later arrivals.

Solution

The main point in the solution is to determine appropriate correction, which consists of two parts. The first part, the function of x has to be zero:

$$(x/V_2)\cos\Theta - x/V_R = 0 \tag{5}$$

It concludes that $V_R = V_2/\cos\Theta$ (6)

For possible values of Θ, $0 \leq \cos\Theta \leq 1$; so $V_R \geq V_2$.

Cos being an even function the same reduction velocity can be applied for both directions.

The second part of the correction is the determination of t_{0sp}. Hirschleber suggests a statistical method for the separation of t_{0sp} and t_{0g}. The disadvantage of his method is that it is necessary to determine the reduction velocity beforehand, but it can be done by adequate precision only after having separated the shotpoint and geophone delays respectively.

Since there are more unknowns than equations, the problem may be solved by such a shooting system where in two successive travel-time curves t_{0sp} could be determined graphically (as half of the intercept time). From the equatins of two covering time-distance curves V_R can be computed:

$$T_1 = t_{0g} + t_{0sp1} + x_1/V_R$$

$$T_2 = t_{0g} + t_{0sp2} + x_2/V_R$$

and

$$V_R = \frac{x_2 - x_1}{(T_2 - T_1) - (t_{0sp2} - t_{0sp1})} \tag{7}$$

It is evident that reduction velocity is equal to the apparent velocity but corrected by the difference of shotpoint delays. As a matter of fact this term represents the dip of the horizon. If $(t_{0sp2} - t_{0sp1}) = 0$, the horizon is horizontal (except cases of very little probability), and $V_R = V_{app} = V_2$.

Having V_R, the values of t_{0g} can be easily computed and—according to our basic assumptions—are equal for both curves. If a third covering curve is given, its t_{0sp3} value can be determined from the equation of the time-distance curve supposing that t_{0g} and V_R are equal to the values as defined above. Starting from this perfectly identical point and carrying out the reduction with several possible values of V_R and stacking, the varying value of V_R can be determined by sections. As a matter of fact a method of velocity determination is attained, similar to the constant velocity scan, well proved in reflection seismics. A great advantage over reflection seismics is that errors in static correction do not influence the result of stacking.

The t_{0sp} values of newly incoming covering time-distance curves can be computed by the known value of V_R. The value t_{0sp} thus determined contains beside the real shotpoint delay time also the difference between the "antecedents" of the time-distance curves. Practically it reflects the relative relation between the reduced time values of different shotpoints.

Horizontal offset can be determined from characteristic points of straight and reversed delay time curves. Time differences however can still occur between reduced and shifted delay time curves of opposite direction because of their different "antecedents". In case of complicated structure there is even no hope for stacking delay time curves of opposite directions. The method of stacking seems to prefer one-sided shooting systems instead of correlation systems in refraction as well as in reflection seismics. It remains an open question wether migration—to be solved in future—will allow it or not.

Concerning the case of later arrivals, reduction and stacking by a V_R determined for a given horizon will decrease the amplitude of arrivals of different velocity, because of unfavourable interference. In zones of interference properly reduced waves will gain in signal to noise ratio and will be better picked. The use of constant velocity scan on a broad scale will produce the reduction velocities of all waves of interest, while time sections for each wave can be prepared separately. The mathematical processes involved are simple, to be carried out easily by analog or digital computers.

Examples

Accuracy of velocity determination has been checked by computation on a threefold coverage section of a Transdanubian refraction profile. Fig. 2 shows the chosen part of the time-distance graph. Shotpoint delays were determined for shotpoints

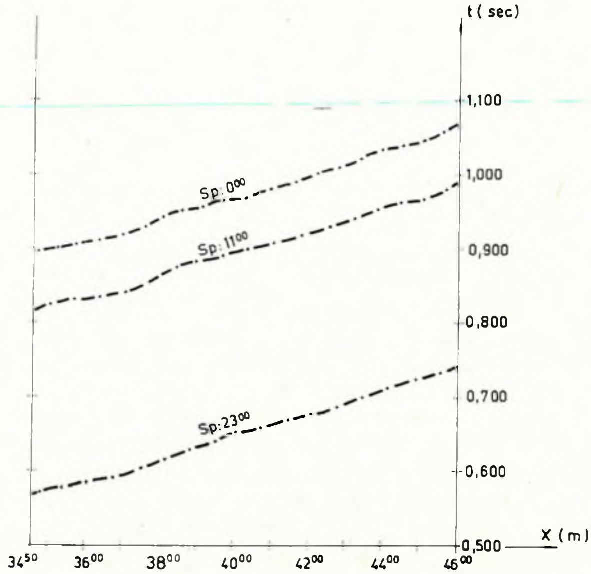

Fig. 2. Part of time distance graph of a refraction profile
2. ábra. Egy refrakciós szelvény út—idő görbe rendszerének részlete
Рис. 2. Деталь системы годографов по профилю КМПВ

23^{00} and 11^{00} graphically. For geophone point 34^{50} as the point of threefold coverage with smallest x values, the reduction velocity was computed by equation (7) from the arrival times of the above two shotpoints. With the resulting velocity of 5910 m/sec, the geophone delay was computed (0.162 sec). By the above results the shotpoint delay of shotpoint 0^{00} was determined and the reduction carried out for a whole spread of 24 geophones.

Results are listed in Table I and shown graphically on Fig. 3/a. It follows from the latter, that the reduction velocity of 5910 m/sec is satisfactory up to geophone point 39^{00}. After this point the reduced time curves diverge. The former calculations for geophone point 46^{00} give a reduction velocity of 6030 m/sec. Reduction of the same data by the above velocity yields the results of Table II and Fig. 3/b. As expected conformity of the three delay time curves from 39^{50} to 46^{00} seems to be excellent. It must be noted however that errors of picking are included in these data and effective stacking may lead to even better results.

Table I.

$V_R = 5910$ m/sec

G	Sp: 23^{00}, $t_{0sp} = 0{,}213$ sec					Sp: 11^{00}, $t_{0sp} = 0{,}260$ sec					Sp: 0^{00}, $t_{0sp} = 0{,}148$ sec				
	x	T	$T - t_{0sp}$	x/V_R	t_{0g}	x	T	$T - t_{0sp}$	x/V_R	t_{0g}	x	T	$T - t_{0sp}$	x/V_R	t_{0g}
34^{50}	1150	0,570	0,357	0,195	0,162	2350	0,820	0,560	0,398	0,162	3450	0,894	0,746	0,584	0,162
35^{00}	1200	577	364	203	161	2400	826	566	406	160	3500	897	749	592	157
35^{50}	1250	581	368	212	156	2450	833	573	415	158	3550	907	759	601	158
36^{00}	1300	587	374	220	154	2500	834	574	423	151	3600	906	758	609	149
36^{50}	1350	590	377	228	149	2550	837	577	431	146	3650	912	764	618	146
37^{00}	1400	595	382	237	145	2600	840	580	440	140	3700	916	768	626	142
37^{50}	1450	605	392	245	147	2650	—	—	—	—	3750	925	777	635	142
38^{00}	1500	614	401	254	147	2700	—	—	—	—	3800	935	787	643	144
38^{50}	1550	625	412	262	150	2750	880	620	465	155	3850	951	803	651	152
39^{00}	1600	635	422	271	151	2800	885	625	474	151	3900	958	810	660	150
39^{50}	1650	642	429	279	150	2850	890	630	482	148	3950	960	812	669	143
40^{00}	1700	656	443	288	155	2900	898	638	491	147	4000	974	826	677	149
40^{50}	1750	657	444	296	148	2950	903	643	499	144	4050	977	829	685	144
41^{00}	1800	662	449	305	144	3000	910	650	508	142	4100	982	834	694	140
41^{50}	1850	670	457	313	144	3050	915	655	516	139	4150	985	837	702	135
42^{00}	1900	679	466	321	145	3100	923	663	525	138	4200	996	848	711	137
42^{50}	1950	683	470	330	140	3150	930	670	533	137	4250	1,004	856	719	137
43^{00}	2000	693	480	338	142	3200	938	678	542	136	4300	1,012	864	728	136
43^{50}	2050	703	490	347	143	3250	948	688	550	138	4350	1,020	872	736	136
44^{00}	2100	712	499	355	144	3300	958	698	558	140	4400	1,033	885	745	140
44^{50}	2150	720	507	364	143	3350	965	705	567	138	4450	1,038	890	753	137
45^{00}	2200	728	515	372	143	3400	967	707	575	132	4500	1,046	898	761	137
45^{50}	2250	733	520	381	139	3450	977	717	584	133	4550	1,053	905	770	135
46^{00}	2300	744	531	389	144	3500	990	730	592	138	4600	1,061	913	778	135

Table II.

$V_R = 6030$ m/sec

G	Sp: 23^{00}, $t_{osp} = 0{,}213$ sec					Sp: 11^{00}, $t_{osp} = 0{,}260$ sec					Sp: 0^{00}, $t_{osp} = 0{,}148$ sec				
	x	T	$T - t_{osp}$	x/V_R	t_{og}	x	T	$T - t_{osp}$	x/V_R	t_{og}	x	T	$T - t_{osp}$	x/V_R	t_{og}
34^{50}	1150	0,570	0,357	0,191	0,166	2350	0,820	0,560	0,390	0,170	3450	0,894	0,746	0,572	0,174
35^{00}	1200	577	364	199	165	2400	826	566	398	168	3500	897	749	580	169
35^{50}	1250	581	368	207	161	2450	833	573	406	167	3550	907	759	589	170
36^{00}	1300	587	374	216	158	2500	834	574	415	159	3600	906	758	597	161
36^{50}	1350	590	377	224	153	2550	837	577	423	154	3650	912	764	605	159
37^{00}	1400	595	382	232	150	2600	840	580	431	149	3700	916	768	614	154
37^{50}	1450	605	392	240	152	2650	—	—	—	—	3750	925	777	622	155
38^{00}	1500	614	401	249	152	2700	—	—	—	—	3800	935	787	630	157
38^{50}	1550	625	412	257	155	2750	880	620	456	164	3850	951	803	638	165
39^{00}	1600	635	422	265	157	2800	885	625	464	161	3900	958	810	647	163
39^{50}	1650	642	429	274	155	2850	890	630	473	157	3950	960	812	655	157
40^{00}	1700	656	443	282	161	2900	898	638	481	157	4000	974	826	663	163
40^{50}	1750	657	444	290	154	2950	903	643	489	154	4050	977	829	672	157
41^{00}	1800	662	449	299	150	3000	910	650	498	152	4100	982	834	680	154
41^{50}	1850	670	457	307	150	3050	915	655	506	149	4150	985	837	688	149
42^{00}	1900	679	466	315	151	3100	923	663	514	149	4200	996	848	697	151
42^{50}	1950	683	470	323	147	3150	930	670	522	148	4250	1,004	856	705	151
43^{00}	2000	693	480	332	148	3200	938	678	531	147	4300	1,012	864	713	151
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44^{00}	2100	712	499	348	151	3300	958	698	547	151	4400	1,033	885	730	155
44^{50}	2150	720	507	357	150	3350	965	705	556	149	4450	1,038	890	738	152
45^{00}	2200	728	515	365	150	3400	967	707	564	143	4500	1,046	898	746	152
45^{50}	2250	733	520	373	147	3450	977	717	572	145	4550	1,053	905	755	150
46^{00}	2300	744	531	381	150	3500	990	730	580	150	4600	1,061	913	763	150

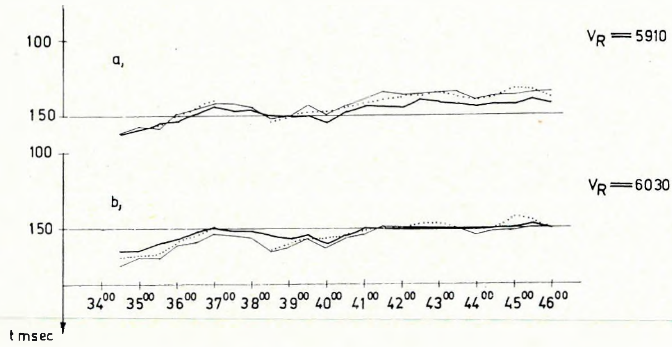

Fig. 3. Geophone delay times

a) reduced by $V_R = 5910$ m/sec
b) reduced by $V_R = 6030$ m/sec
Legend: ———— Sp. 23^{00}
- - - - - - Sp. 11^{00}
———— Sp. 0^{00}

3. ábra. Geofonhelyi késési idők

a) redukcióhoz alkalmazott sebesség: $V_R = 5910$ m/sec
b) redukcióhoz alkalmazott sebesség: $V_R = 6030$ m/sec
Jelmagyarázat: ———— Rp. 23^{00}
- - - - - - Rp. 11^{00}
———— Rp. 0^{00}

Рис. 3. Времена задержки в пунктах сейсмоприемников

а) скорость, использованная для редукции — $V_R = 5910$ м/сек
б) скорость, использованная для редукции — $V_R = 6030$ м/сек
Условные обозначения: ———— ПВ 23^{00}
- - - - - - ПВ 11^{00}
———— ПВ 0^{00}

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SZ. KILÉNYI ÉVA

REFRAKCIÓS IDŐSZELVÉNY ELŐÁLLÍTÁSA STACKING ALKALMAZÁSÁVAL

A refrakciós mérések számítógépes feldolgozása messze elmaradt a reflexiós kiértékeléstől. Az irodalomban megjelent ilyen irányú kísérletek főleg a hagyományos kiértékelést igyekeztek megvalósítani számítógépek segítségével és nem alkalmazták a digitális technika egyéb lehetőségeit. HIRSCHLEBER (1971) javasolta először stacking alkalmazását, de megoldása nehézkes és néhol kényes közelítéseket tartalmaz. Jelen dolgozat célja refrakciós időszelvény előállítása stacking alkalmazásával, egyszerű módszerekkel.

A refrakciós késési idő definíciója:

$$D = T - x/V_R = t_{0sp} + t_{0g} + (x/V_2) \cos \Theta - x/V_R \quad (4)$$

ahol t_{0sp} és t_{0g} a robbantóponti, ill. geofonhelyi késési idők, V_R pedig a redukciós sebesség (jelölések az 1. ábrán). Ha egymást fedő sebességágakat összegezni akarunk, a késési idő képletében a geofonhelyi késési idő kivételével minden tagot eliminálnunk kell. A redukció két lépésből áll: először az x-től függő rész levonása, másodszor t_{0sp} és t_{0g} különválasztása. Az első rész a redukciós sebesség meghatározását jelenti, melyre a reflexiós módszerben bevált constant velocity scan módszeréhez hasonló megoldást, t_{0sp} és t_{0g} szétválasztására pedig részben grafikus, részben számításos eljárást javasolunk.

Az ismertetett módszer egyirányú lövési rendszerek alkalmazását teszi lehetővé. A stacking megvalósítása lényeges jel/zaj viszony javítást eredményezhet nemcsak az első, hanem a későbbi beérkezések tartományában is.

С. КИЛЕНИ Э.

ПОСТРОЕНИЕ ВРЕМЕННЫХ РАЗРЕЗОВ КМПВ ПО МЕТОДУ ОГТ

Машинная обработка данных КМПВ далеко отстает от интерпретации данных МОВ. Опубликованные в литературе попытки подобного характера были направлены главным образом на использование ЭВМ для стандартной интерпретации данных, причем не были использованы дополнительные возможности цифровой техники. Впервые Хиршлебер (1971) предложил применять способ ОГТ, но предложенный им способ оказался трудоемким и содержащим деликатные приближения. Целью настоящей работы является построение временных разрезов преломленных волн с применением ОГТ по простым способам.

Время задержки преломленных волн определяется соотношением:

$$D = T - x/V_R = t_{0sp} + t_{0g} + (x/V_R) \cos \Theta - x/V_R , \quad (4)$$

где t_{0sp} и t_{0g} — времена задержки в пункте взрыва и у сейсмоприемника, соответственно, а V_R — редукционная скорость (обозначения см. на рис. 1). Если хотим суммировать перекрывающиеся ветви скоростей, то в формуле времени задержки необходимо устранить все члены, за исключением времени задержки в пункте сейсмоприемника. Редукция осуществляется в два приема: сначала вычиается часть, зависящая от x, а затем разделяются величины t_{0sp} и t_{0g}. Первый прием означает определение скорости, для чего предлагается способ, подобный способу переброса скоростей, эффективно применяющемуся в методе отраженных волн, а для разделения величин t_{0sp} и t_{0g} предлагается использовать отчасти графический и отчасти вычислительный способы.

Предлагаемый метод позволяет использовать встречные системы наблюдений. Использование накапливания приводит к значительному улучшению отношения сигнал/шум не только при первых вступлениях, но и в диапазоне последующих вступлений.