GEOPHYSICAL TRANSACTIONS 1984
Vol. 30. No. 2. pp. 201—211

VARIATION OF SPECTRAL PROPERTIES OF SEISMIC WAVES IN THE RANGE OF HYDROCARBON DEPOSITS

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The usage of spectral properties of seismic waves for directly detecting hydrocarbon deposits is considered, VEB Geophysik Leipzig developed a special program for an ESR computer allowing the convenient calculation of several dynamic, i.e. mainly spectral, parameters. The method of calculating these parameters is explained, and the results of investigations along one profile across a known oil deposit are demonstrated.

d: direct interpretation, oil and gas fields, spectral properties, computer programs

1. Introduction

The detection of compositional changes of the subsurface using seismic reflection methods is an important task from many points of view. Of special importance among these methods is the direct detection of hydrocarbon deposits. In the range of deposits the change of the pore-content may give rise to alterations in seismic velocities and in the absorption of seismic waves. The magnitude of seismic waves depends on numerous factors — among others on the nature of the pore-content.

Additionally in the range of the deposits (e.g. on gas—water contact) changes of the reflection coefficient (mainly increments) may occur, which lead to amplitude anomalies (bright or dim spots) or to formation of horizontally arranged phase-axes (flat spots).

Besides direct CH detection the indentification of lithological changes offers information which is of great importance in geological investigations. Lithological changes can be verified with velocity and absorption parameters as well as with dynamic parameters, although their effect is in general too small; in other words their verification is successful only if the examined interval is sufficiently large.

At VEB Geophysik Leipzig a great deal of research work has been done in the last few years on the direct detection and on the verification of lithological changes. [Patzer and Pröhl 1980] and [Pröhl et al. 1978].

The use of digital recording- and processing techniques for seismic data provides favourable conditions for determining and processing the dynamic parameters of seismic waves. Digital data processing with high-speed computers

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Manuscript received: 25 January, 1984

applying Fast Fourier Transform (FFT) for computing the spectra enables us to determinate such parameters relatively cheaply.

The mentioned dynamic parameters deliver not only the desired information from the subsurface, but are influenced by numerous disturbances, as varying seismic source- and detection conditions, geometric effects in the range of overburden differences of stratification, interferences between signal and noise of different types as well as the effects of measuring geometry and data processing. In practice it is almost impossible to overcome effectively all conceivable disturbances. However results presented here show that positive results can be achieved even when the possible influence of individual factors is ignored.

In the following the possibilities of determining certain dynamic parameters will be mentioned and the results of investigations will be demonstrated along one profile across a known oil deposit.

2. Computation of dynamic properties

To determine dynamic parameters a special computer program called DYNA as well as a package of additional programs for an ESR computer were developed. These additional programs enable us to further process the data computed with the DYNA program which above all yields:

— samples of the amplitude spectrum between 0 and 100 Hz at a frequency increment of about 2 Hz
— properties derived from the amplitude spectrum (such as dominant frequency, spectrum width, maximum spectral amplitude, spectral amplitude at a given upper or lower frequency limit, etc.)
— time domain parameters such as mean amplitude, mean power, and mean period.

There are three variants for computing these parameters, viz.:

— within given time windows being shifted along the trace by given increments
— within time windows of a given width tracing a specific reflective horizon
— for two half-periods of a reflection.

The further processing of the results obtained by DYNA consists in the sorting of data, vertical and horizontal averaging, elimination of erroneous values, and data preparation for plotting. Thus, a convenient automatic system was implemented enabling a varied determination of dynamic properties from seismic traces at a low expense.

3. Practical example

The effectiveness of the program package was tested by means of direct hydrocarbon detection studies in several survey areas. In the following, the results of the processing of a 12-fold CDP profile crossing an oil deposit approximately perpendicular to the strike are presented. Stacking was carried out without deconvolution applying improved static and moveout corrections.

Figure 1 shows the stacked time section with the location of the deposits. The computation of dynamic properties was accomplished within a 300 ms long time window shifted by increments of 50 ms along the trace. The trace interval to be analysed was multiplied by a window function (hamming window) to avoid boundary effects. Thereafter, the computed data were averaged horizontally (15-fold) and vertically (3-fold).

When evaluating the connection between anomalies of several dynamic properties and the location of hydrocarbon deposits some peculiarities must be considered. Variations in absorption occuring in the range of deposits are — at least for thin reservoirs — usually not detectable and do not explain the amount of both the established change of that parameter and consequently of the dynamic properties derived therefrom. To interpret the effects obtained across the deposits, a seismically effective aureole of gaseous hydrocarbons produced by geochemical processes must be supposed above the deposit. This means that anomalies of seismic parameters may occur not only at the level of deposits but also at a limited distance above them. The fact that geochemical processes can be one of the reasons for the generation of anomalies of seismic parameters points to both the dependence of anomalies (e.g. tectonic faults) on the migration paths of hydrocarbons and also certain horizontal shifts of anomalies compared with the location of the deposit. This must be kept in mind

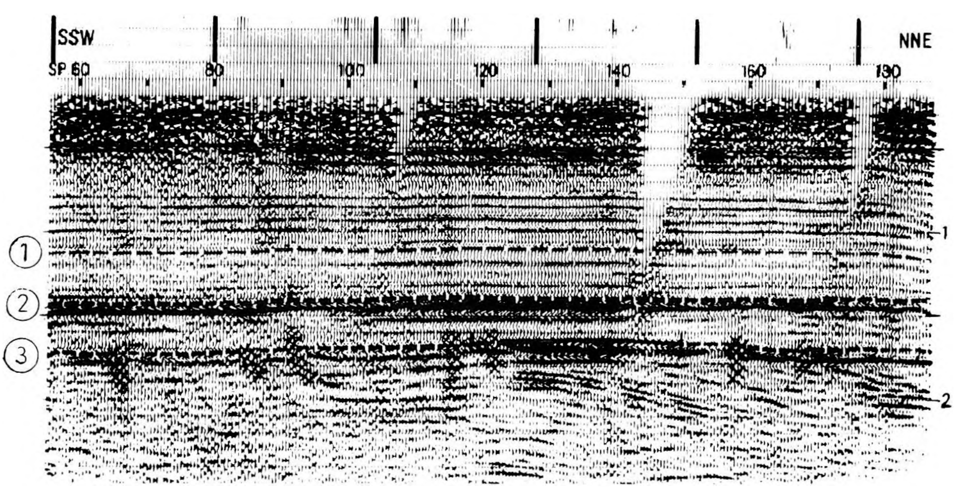

Fig. 1. Stacked section

1. ábra. Összegezett szelvény

Рис. 1. Накапливаемый разрез

when evaluating the measurement results. This means anomalies are also indicative of deposits when they are shifted somewhat vertically or horizontally compared with the deposit. Some selected examples are shown in Figs 2 to 5 in 2D-representation (x, t-plane).

Figure 2 involves a set of properties computed with the DYNA program from the amplitude spectrum. These are: dominant frequency f_v, halfwidth of spectrum f_b, maximum amplitude A_{max}, spectrum area F, and the upper cut-off frequency f_0 which corresponds to that frequency where the amplitude spectrum is decreased to 10% of its maximum value. This figure demonstrates that parameters f_v and A_{max} characterize the deposit quite well. The observed shift to the beginning of the profile which holds also for other parameters is caused by the specific conditions of that area. A small distance away from the profile an additional locally limited hydrocarbon accumulation was detected which contributes to the "shift" of anomalies over the outlined contour of the deposit. For properties f_b and f_0 a connection with the deposit is less clear but it does exist. However the spectrum area F shows no relation to the deposit.

In *Fig. 3* several time domain related parameters are shown additionally to the spectral properties: A_m is the mean amplitude (also determinded within the 300 ms time window being shifted by increments of 50 ms), E_m the mean power, E_{max} the mean energy derived from the peak values of the seismic trace occurring within the analysed time window, and T_m the mean period. The mean amplitude A_m clearly indicates the deposit, the same is valid with minor restrictions for E_m and E_{max}. Considerably less clear is the connection between the distribution of parameter T_m and the location of the deposit.

The most interesting results is the distribution of different samples of the amplitude spectrum (Figs. 4 and 5). These are presented in *Fig. 4* for the range between 10 and 20 Hz with a sampling interval of 2 Hz and in *Fig. 5* between 24 and 40 Hz (sampling interval 4 Hz) as well as for 60 Hz. From the results the following conclusions may be drawn:

- Already at a frequency of 10 Hz an anomaly occurs in the range of the deposit. The number of anomalies outside this range is low. This distribution occurs similarly at 12 and 14 Hz. The dominant element is the anomaly of the deposit.
- Changing over to 16 Hz the anomaly of the deposit remains but the number of anomalies outside the deposit is clearly increased. This situation is also encountered at 18 Hz, where the picture of anomalies and especially the anomaly of the deposit becomes smeared.
- In the range between 20 and 28 Hz the anomaly of the deposit no longer occurs. The picture is characterized by anomalies from outside.
- At 32 Hz the anomaly picture becomes totally smeared. The regular configuration attributed to the deposit or to reflectors is changed to a sporadic distribution which continues up to the high-frequency part of the spectrum. It is characteristic that the anomaly of the deposit is always located in an area of low-frequency values.

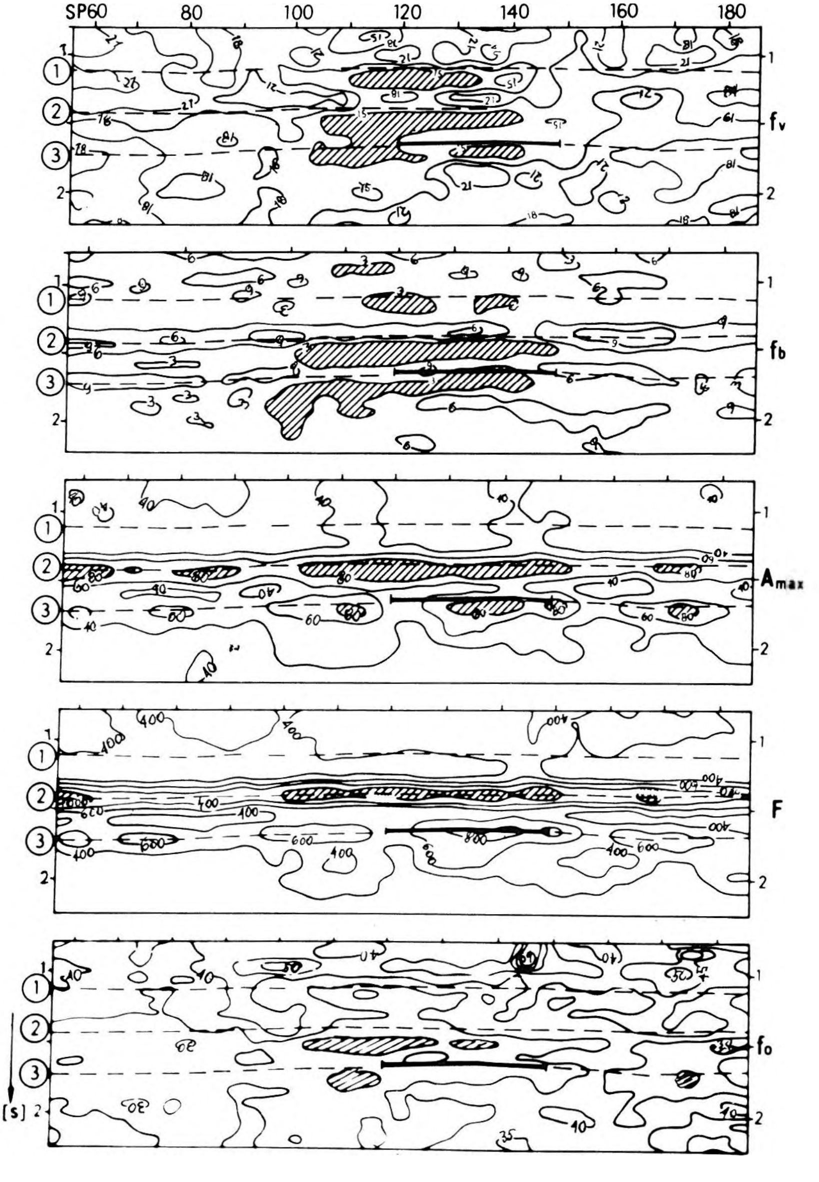

Fig. 2. x, t-plane distribution of selected properties derived from the amplitude spectrum

2. ábra. Az amplitudóspektrum kiválasztott mérőszámai az x—t síkban

Рис. 2. Распределение выбранных свойств, выведенных по амплитудному спектру, по плоскостям x, t

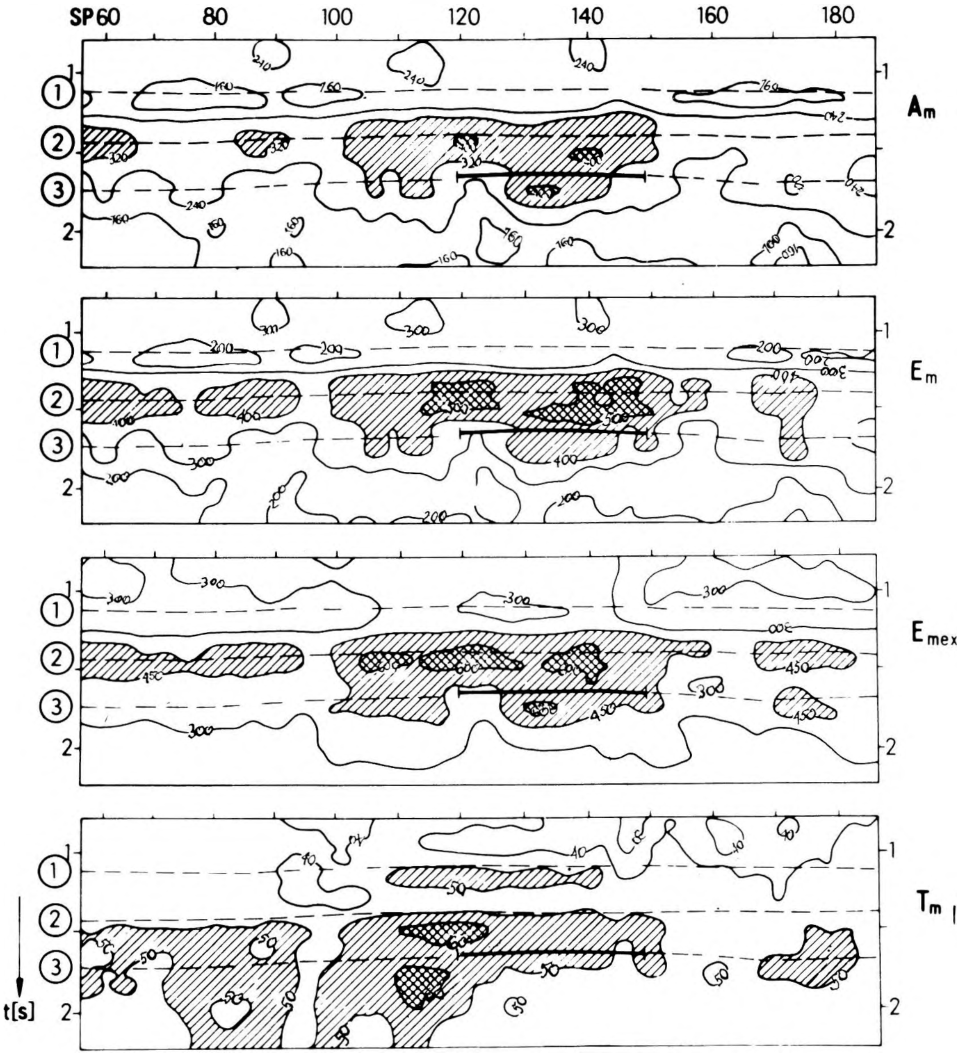

Fig. 3. x, t-plane distribution of time domain parameters

3. ábra. Időtartománybeli paraméterek eloszlása az x—t síkban

Рис. 3. Распределение параметров временной области по плоскостям x, t

These results demonstrate that a narrow low-frequency interval exists where the amplitudes of the spectrum can indicate a hydrocarbon deposit in the subsurface. This effect had been recognized at investigations of other deposits, and underlines the importance of the determination of these low-frequency components of the amplitude spectrum for the direct detection of hydrocarbon deposits under the given conditions. Additionally, it can be stated that the position of the interesting part of the amplitude spectrum varies from on survey area to the other depending on the magnitude of the mean dominant frequency obtained from the corresponding profile. In the present example the deposit is best reflected between 10 and 14 Hz. In other cases a good correlation between anomalies and the location of the deposit is also obtained at 18 Hz.

An interpretation of the relation between the distribution of dynamic properties — computed with DYNA — and the deposit seems possible when the following two effects occur — besides a velocity decrease — in the range of the deposit:

— In the deposit and especially above it (aureole due to geochemical processes) there is a directly computable increase of absorption which leads also to a change of the dynamic properties of seismic waves. From the parameters presented in Figs. 2 and 3 these are the dominant frequency f_v, the upper cut-off frequency f_0, and the mean period T_m.

— The range of the deposit is indicated by amplitude increases (bright spots). These are caused by a change of pore filling thereby generating an increase of reflectivity. Here the parameters A_m, E_m, and E_{max} (Fig. 3) are of interest.

— Both absorption and bright spots superimpose in an opposite sense. This superposition results in an increase of the low-frequency components of the amplitude spectrum as a consequence of the frequency dependence of attenuation. The distribution of the properties A_{max} and especially A_{10} to A_{16} must be attributed to this effect (see Figs. 2 to 5). The decay of the anomaly at frequencies above 18 Hz is considered as an overcompensation of the bright spot effect by attenuation. Model-computations verify these effects.

4. Conclusions

Dynamic properties of seismic waves may be changed characteristically in the range of hydrocarbon deposits due to absorption and variation of reflectivity or the combination of both effects. Hence, their evaluation is an essential element of direct detection techniques.

A very clear connection is revealed between the location of the deposit and the distribution of several low-frequency components of the amplitude spectrum. Due to the interaction of the two effects mentioned above some amplitude samples of the low-frequency part of the amplitude spectrum are increased only in the range of the deposit. This hitherto not described effect could be confirmed by investigations of several objects; it explains the distribution of samples of the amplitude spectra presented in Figs. 4 and 5.

It seems to be expedient to accomplish the computation of dynamic parameters in the manner described above, i. e. within time windows shifted along the seismic trace. Against this, the results of parameter determinations along reflective horizons of for single reflections are less efficient.

In general, one can state that the use of the direct detection method makes a significant contribution to the verifiableness of reflection seismics. Given satisfactory initial values adaptation of this method makes it possible to get information about the presence of hydrocarbons in the subsurface. Depending upon the complexity of the model either statements on the general prospectiveness of one region or — as above demonstrated — additonal data on the localization as well as on the limitation of hydrocarbon deposits are possible. Uncertainties cannot be ruled out.

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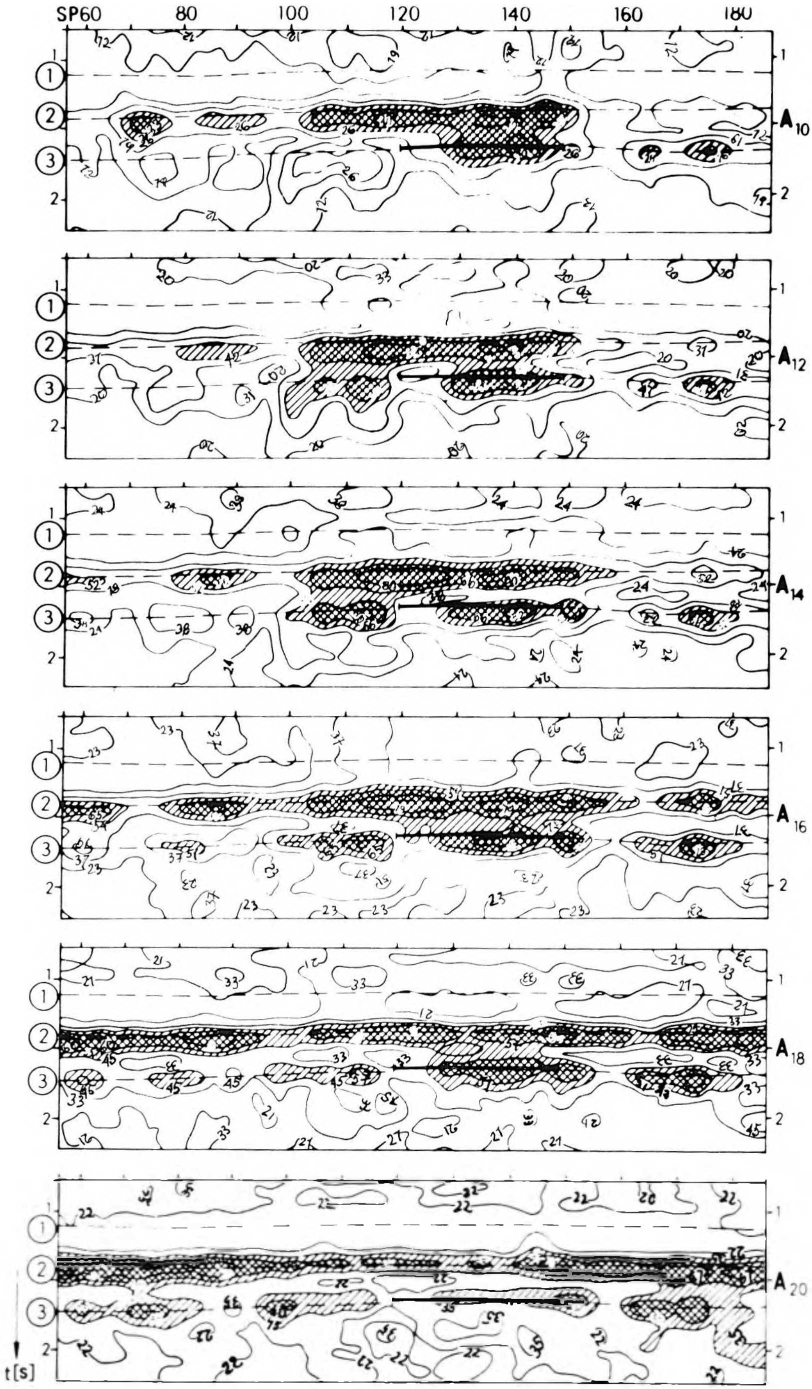
Fig. 4. x, t-plane distribution of the amplitude spectrum between 10 and 20 Hz

4. ábra. Az amplitúdóspektrum eloszlás függvénye 10 és 20 Hz között az x—t síkban

Рис. 4. Распределение выборок амплитудного спектра между 10 и 20 Гц по плоскостям x, t


SP60
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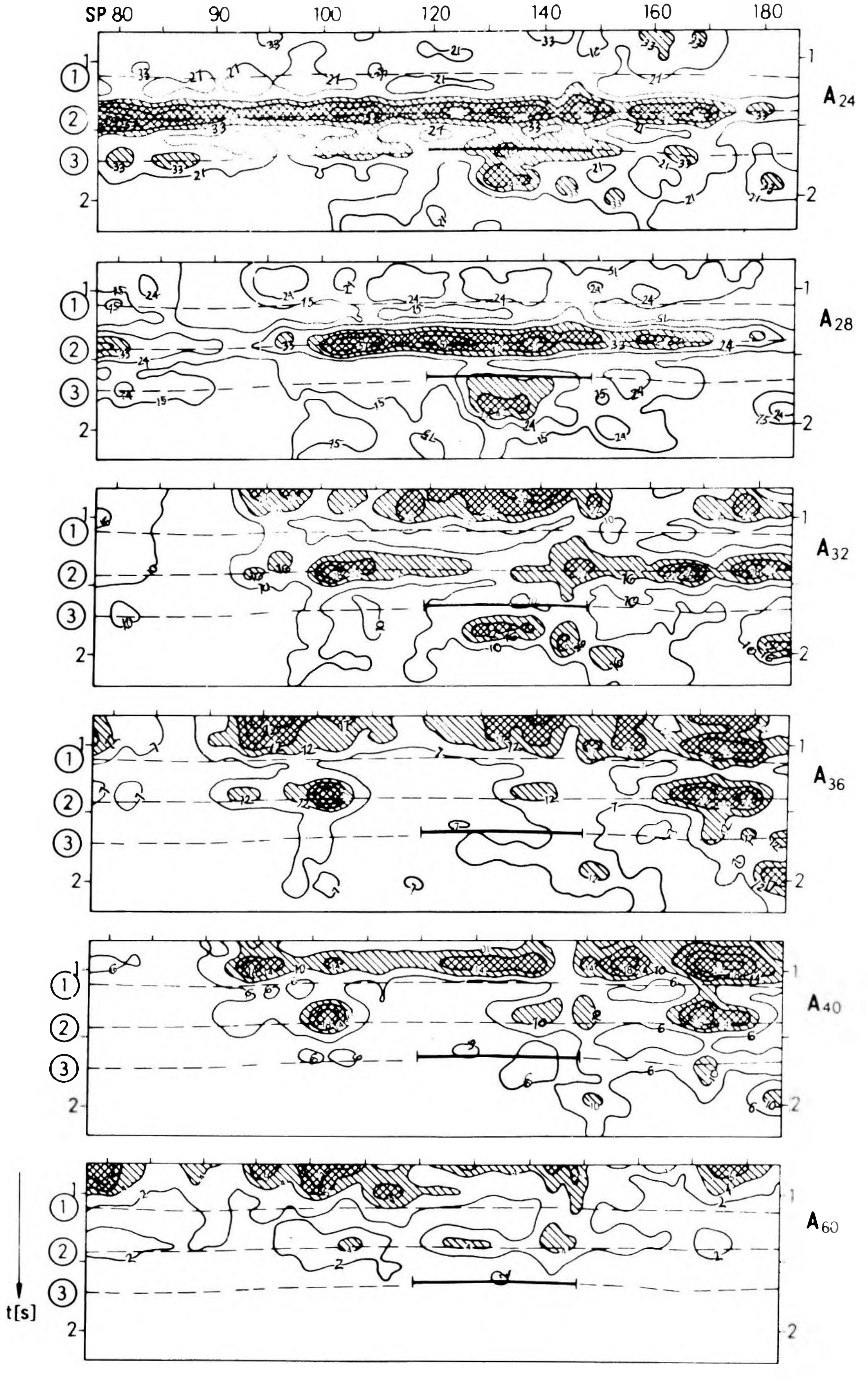
SP 80
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A32
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A60
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A SZEIZMIKUS HULLÁMOK SPEKTRÁLIS PARAMÉTEREINEK VÁLTOZÁSAI A SZÉNHIDROGÉN-ELŐFORDULÁSOK KÖRNYEZETÉBEN

Stefan PRÖHL

Áttekintést adunk arról, hogy a szénhidrogéntelepek közvetlen kimutatásában a szeizmikus hullámok spektrális paramétereinek milyen alkalmazási lehetőségei vannak. A lipcsei VEB Geophysik-nél ESzR számítógépre kidolgoztak egy programot, mely a különféle dinamikus mérőszámok, mindenekelőtt a spektrális paraméterek kiszámítására alkalmas. Ezen paraméterek kiszámításának módját ismertetjük és eredményeinket egy kőolaj-előfordulást keresztező szelvény feldolgozásának példáján mutatjuk be.

ИЗМЕНЕНИЕ СПЕКТРАЛЬНЫХ СВОЙСТВ СЕЙСМИЧЕСКИХ ВОЛН В ПРЕДЕЛАХ НЕФТЕГАЗОВЫХ МЕСТОРОЖДЕНИЙ

С. ПРЁЛ

В работе обсуждаются вопросы применения спектральных свойств сейсмических воли для прямых поисков месторождений нефти и газа. На предприятии ВЭБ Геофизика г. Лейпциг (ГДР) была разработана специальная программа для ЕС ЭВМ, которая позволяет удобно рассчитать некоторых динамических, в том числе спектральных параметров. Описывается метод вычисления этих параметров и приводятся результаты исследований, проведенных по профилю, пересекающему известные нефтяные залежи.

Fig. 5. x, t-plane distribution of the amplitude spectrum between 24 and 60 Hz

5. ábra. Az amplitúdóspektrum eloszlásfüggvénye 24 és 60 Hz között az x—t síkban

Рис 5. Распределение выборок амплитудного спектра между 24 и 60 Гц по плоскостям x, t