GEOPHYSICAL TRANSACTIONS 1984
Vol. 30. No. 2. pp. 177—200

INTEGRATED INTERPRETATION OF SEISMIC AND WELL LOGGING DATA IN THE DETAILED PHASE OF OIL AND GAS EXPLORATION AND IN THE SEARCH FOR STRATIGRAPHIC TRAPS

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A description is given of the case history of a western Siberian oil field where the technique of seismic stratigraphy was combined with the most up-to-date dynamic processing of seismic profiles. All geological information, well logs, seismic and petrophysical parameters were integrated to produce a reliable assessment of the hydrocarbon potential of the area.

d: seismic surveys, well logging, integrated interpretation, seismic stratigraphy, oil and gas fields, stratigraphic traps, western Siberia

1. Introduction

In recent years the rapid development of seismic methodology and technology has greatly contributed to the sharp increase in depth range, accuracy and detailedness of the studies of geological sections, particularly in hydrocarbon prospecting. Also, the increased possibilities of the seismic method suggest that these techniques should have an important role in the later stages of the geologic-exploratory process as well, namely, in the stage of the detailed exploration and industrial exploitation of the deposits. It is expected that seismic prospecting in combination with well logging data would help us to achieve substantial cuts in costs and deadlines when opening up new reservoirs. One only needs to recall that usually most of the enormously expensive exploratory drilling is done during the detailed exploration phase. A drastic reduction in the number of exploratory drillings at the expense of deeper interpretation of the available seismic material is one of the most important tasks of exploration geophysics from the economic viewpoint. We foresee a particularly important effect of the more precise determination of the structure of reservoirs. Complex analysis of all available data could also be useful in the planning of post-exploration work, and in the detection of associated deposits, including non-anticlinal traps.

Our study is based on seismic sections, processed by the PGR program package (the Russian abbreviation stands for Prognozirovanie Geologiches-

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Manuscript received: 15 July, 1983

kogo Razreza = Prediction of the (lithologic properties of) Geological Sections, see GOGONENKOV [1981 a, 1981 b]), and subsequently analysed by the methods of seismic stratigraphy [PAYTON 1977]. We also carried out facies analysis on the well log data. The present work describes the methodological foundations of the integrated interpretation and illustrates its effectiveness through a case history dealing with the post-exploration for hydrocarbon reservoirs on a western Siberian exploration site.

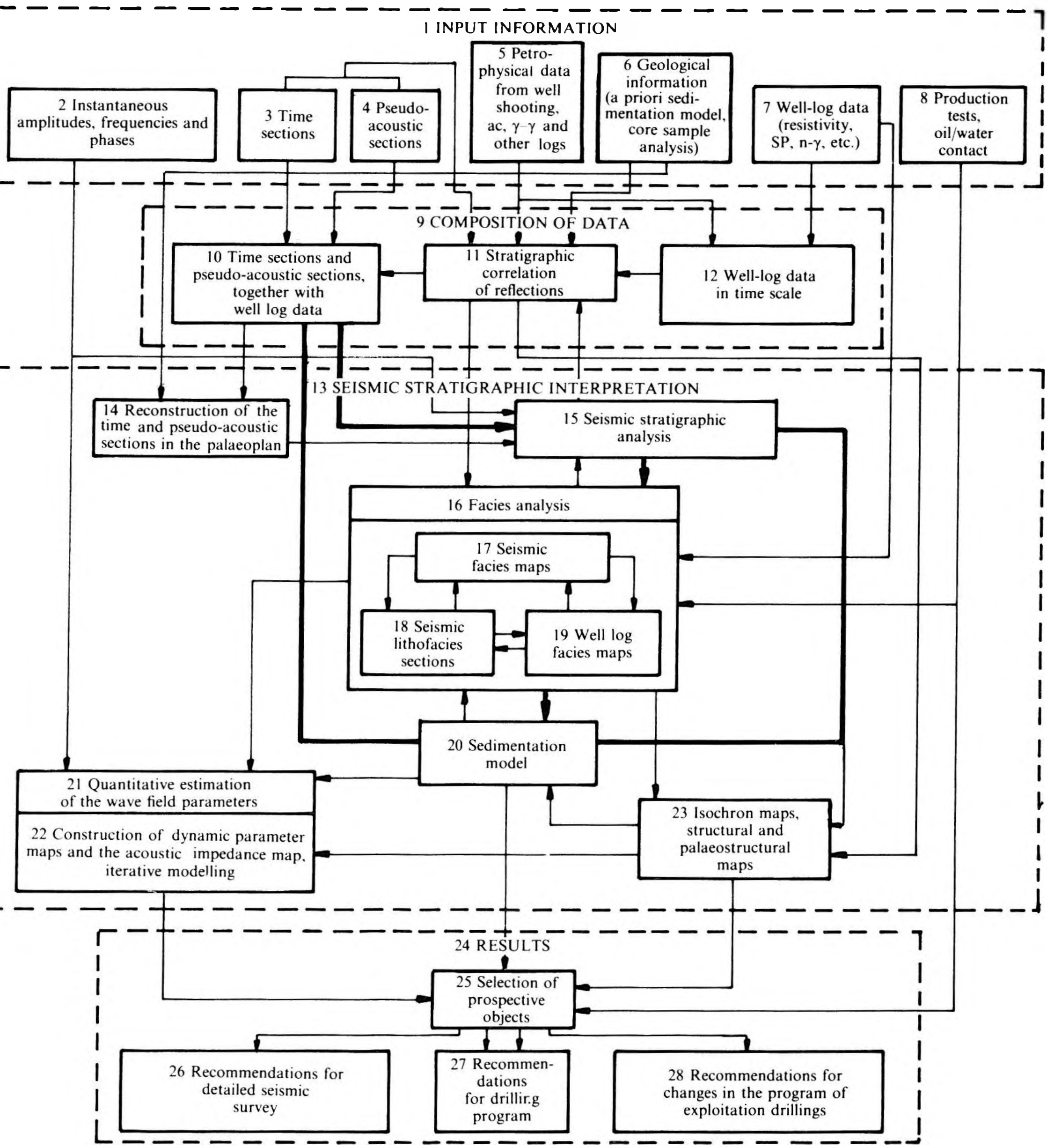
2. Scheme of the integrated interpretation of geological–geophysical data on the basis of seismic stratigraphy

The sequence of, and interconnections between the individual stages of the whole procedure — from the preparation and editing of the input data to the

Fig. 1. Schematic flow-chart of processing of geological–geophysical data by seismic stratigraphy

1. ábra. A szeizmikus sztratigráfiai adatfeldolgozás folyamatábrája
1—BEMENŐ INFORMÁCIÓK; 2—pillanatnyi amplitúdók, frekvenciák és fázisok; 3—időszelvények; 4—pszeudo-akusztikus szelvények; 5—kőzettani adatok akusztikus, gamma-gamma és egyéb karotázs görbék alapján; 6—geológiai információk (a priori szedimentációs modell, fúrási adatok); 7—karotázs adatok (látszólagos ellenállás, PS, neutron-gamma stb.); 8—próbaüzemi adatok, olaj/víz határ meghatározása; 9—AZ ADATOK EGYBEVETÉSE; 10—időszelvények és pszeudo-akusztikus szelvények a karotázs-adatokkal; 11—reflexiók sztratigráfiai korrelációja; 12—karotázs-adatok idő-léptékben; 13—SZEIZMIKUS SZTRATIGRÁFIAI ÉRTELMEZÉS; 14—időszelvények és pszeudo-akusztikus szelvények rekonstrukciója az eredeti síkban; 15—szeizmikus sztratigráfiai analízis; 16—fácies analízis; 17—szeizmikus fácies térképek; 18—szeizmikus litofácies szelvények; 19—karotázs fácies térképek; 20—szedimentációs modell; 21—a hullámtér paramétereinek kvantitatív becslése; 22—a dinamikai paraméter- és akusztikus impedanciatérképek szerkesztése; iteratív modellezés; 23—izokron térképek, szerkezeti és paleo-szerkezeti térképek; 24—EREDMÉNYEK; 25—a perspektivikus objektumok kiválasztása; 26—javaslatok részletes szeizmikus kutatásra; 27—javaslatok a fúrási tervhez; 28—javaslatok a termelő fúrási program módosítására

Рис. 1. Схема комплексной интерпретации геолого-геофизических данных на сейсмостратиграфисеской основе
1—исходная информация; 2—мгновенные амплитуды, мгновенные частоты, мгновенные фазы; 3—временные разрезы; 4—разрезы ПАК; 5—петрофизические данные по АК, ГГК, СК и др.; 6—геологичская информация (исходная модель, осадконаколления, данные анализа керна); 7—каротажные данные (КС, ПС, ГК, НГК, КВ и др.); 8—результаты опробования СКВ, положение ВНК; 9—комплексирование данных; 10—временные разрезы и разрезы ПАК в комплексе с каротажными данными; 11—стратиграфическая привязка отражений; 12—каротажные данные во временном масштабе; 13—сейсмостратиграфическая интерпретация; 14—палеореконструкции временных разрезов и разрезов ПАК; 15—сейсмостратиграфический анализ; 16—фациальный анализ; 17—карты сейсмических фаций; 18—сейсмолитофациальные разрезы; 19—карты каротажных фаций; 20—модель осадконакопления; 21—количественная оценка параметров волнового поля; 22—построение карт динамических параметров и карт акустических жесткостей, моделирование (ПМС); 23—карты изохрон, структурные и палеоструктурные карты; 24—результаты; 25—выделение перспективных объектов; 26—рекомендации на проведение детальных сейсмических исследований; 27—рекомендации на бурение скважин; 28—рекомендации на изменение проекта эксплуатационного бурения


1 INPUT INFORMATION
2 Instantaneous amplitudes, frequencies and phases
3 Time sections
4 Pseudo-acoustic sections
5 Petro-physical data from well shooting, ac, γ-γ and other logs
6 Geological information (a priori sedimentation model, core sample analysis)
7 Well-log data (resistivity, SP, n-γ, etc.)
8 Production tests, oil/water contact
9 COMPOSITION OF DATA
10 Time sections and pseudo-acoustic sections, together with well log data
11 Stratigraphic correlation of reflections
12 Well-log data in time scale
13 SEISMIC STRATIGRAPHIC INTERPRETATION
14 Reconstruction of the time and pseudo-acoustic sections in the palaeoplan
15 Seismic stratigraphic analysis
16 Facies analysis
17 Seismic facies maps
18 Seismic lithofacies sections
19 Well log facies maps
20 Sedimentation model
21 Quantitative estimation of the wave field parameters
22 Construction of dynamic parameter maps and the acoustic impedance map, iterative modelling
23 Isochron maps, structural and palaeostructural maps
24 RESULTS
25 Selection of prospective objects
26 Recommendations for detailed seismic survey
27 Recommendations for drilling program
28 Recommendations for changes in the program of exploitation drillings

final conclusions and recommendations — are schematically shown in *Fig. 1.* Input data can include all kinds of geological–geophysical information about the study site: seismic data (both in the usual presentation and transformed into instantaneous frequency-, amplitude- and phase sections as described in PTETSOV and GOGONENKOV [1982], or into pseudo-acoustic impedance sections, [cf. GOGONENKOV et al. 1980]; well logging data of exploratory boreholes and analysis of core samples; all available geological information (sedimentation models, stratigraphy, lithology, descriptions of the core samples and of the mud, etc.); and all relevant petrophysical relationships and data, primarily as regards velocities and bulk densities, these having the greatest influence on the seismic wave field.

A few remarks should be made on preliminary seismic data processing, for all subsequent steps basically depend on this very important stage. The preliminary processing should transform the recorded seismograms into a time section that could be considered as an undistorted model of the wave field. The time section should contain only primary reflections from plane-wave sources within the medium, the elastic signal should have zero-phase characteristics in the useful frequency range. Using state-of-the-art processing packages for multiple-coverage seismic data [KOZLOV et al. 1973], and the novel possibilities of true amplitude recovery [AVERBUKH 1982], this goal can always be achieved under favourable seismogeological conditions. Since the final interpretation will have been based on the dynamic parameters of the reflected waves, unusually high requirements should be imposed on the completeness and thoroughness of the processing, both in the design of the processing flow-chart and in the selection of the parameters for the individual steps. The main criteria against which processing quality should be matched is, how does the resulting time section fit to the above-described models? The agreement has to be checked by wave-field analysis, which has become an integral part of all up-to-date seismic processing systems.

The first, and crucial step of integrated interpretation is the juxtaposition of the seismic and well log data to the same scale. In order to do this, the well logs should be rescaled from depth to two-way travel time, by means of the proper velocity function, and superimposed on the seismic sections. (Or, alternatively, we transform the seismic time sections into depth, and use both kinds of data in depth scale). An example of the composite display of seismic data and SP logs is shown in *Fig. 2.* In lack of marker horizons and if the velocity distributions and temporal tie-ins are not accurately known, the combination of seismic and well log data could be an intricate and uncertain task whose proper solution calls for the utilization of all available geological–geophysical information.

Having constructed an intercorrelating network of seismic and well log data, we can proceed to the central part of the investigation, to seismic stratigraphy, where we construct the sedimentation model, and estimate the geological nature and petrophysical properties of the different sedimentary sequences with a degree of resolution allowed by the seismic material.

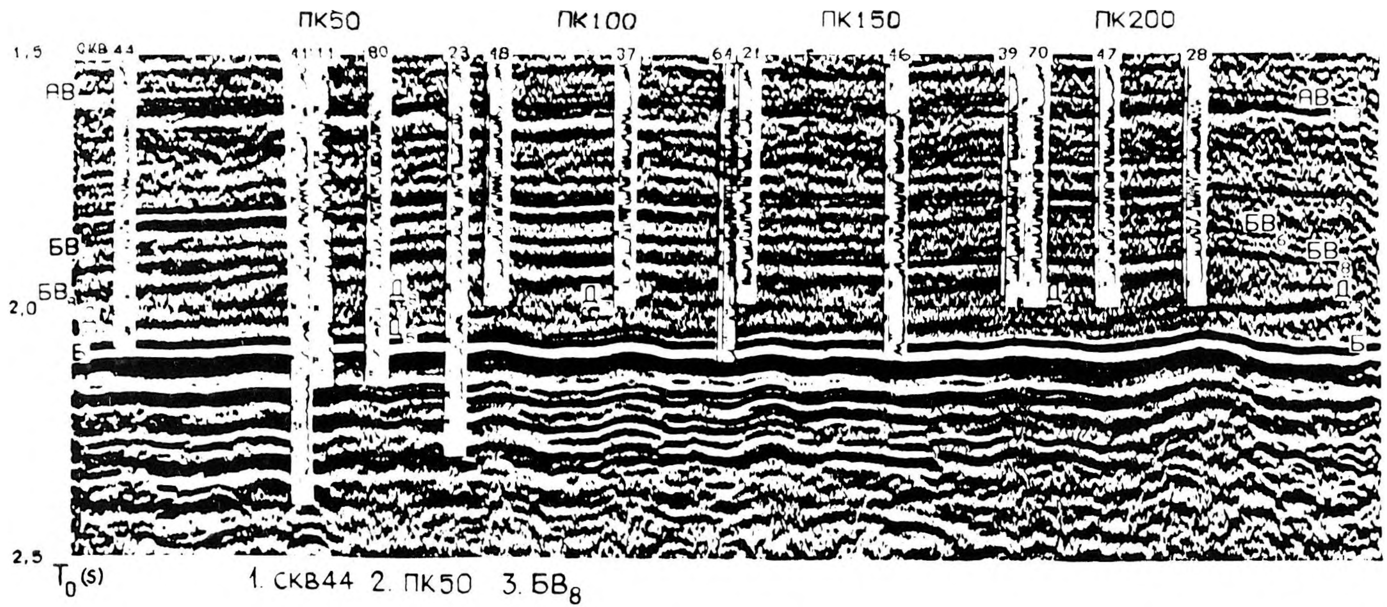


Fig. 2. Composite display of the seismic and well log data (SP log) for Profile 3 of the Pokacheva area

1—borehole; 2—pegmark; 3—payzone

2. ábra. A szeizmikus és karotázs (PS) adatok együttes ábrázolása a Pokacseva terület 3. számú szelvényén

1—mélyfúrás; 2—karószám; 3—termelő réteg

Рис. 2. Совместное изображение сейсмической и промыслово-геофизической (кривые ПС) информации по профилю 3 Покачевской площади

The basic task of seismic stratigraphy is to be able to create geological hypotheses about the sedimentation models of the target (productive and prospective strata). We start out from *a priori* hypotheses, and these are gradually improved as we iteratively proceed through more and more refined variants of the sedimentation model, and by a composite study of the seismic and well log facies.

The following are the basic tasks of seismic stratigraphy in the detailed phase of seismic prospecting:

a) To delineate and analyse the large stratigraphic units (seismic sequences) of the seismic time section, corresponding to long periods (of a few million years) in the development of the palaeo-basin, each of them corresponding to different palaeotectonic conditions of sedimentation.
b) To delineate and study the seismic facies belonging to these sequences.
c) To predict the source rocks.

After performing these tasks we predict the sedimentation conditions and the lithology, delimit the reservoirs and sealing formations, and map the prospective CH-bearing objects. *Figure 3* illustrates the subdivision of a west Siberian time section into seismic sequences. If we have to confine ourselves to the relatively short sections of the detailed survey, we often face a particular problem: the seismic profiles reveal only parts of the sequences so that their structural regularities and their extension cannot be fully clarified. To circumvent this problem, the stratigraphic analysis of local areas should be supplemented by seismic facies analysis.

In order to construct the seismic facies map, the relative positions of the fragments of the analysed time sections should exactly repeat the configuration of seismic profiles (as shown in *Fig. 4*, where the elements of the facies map were taken from a series of E—W profiles of the given area).

In order to decipher the genetic nature of the seismic facies we use the seismic lithofacies sections and the well log facies maps. The seismic lithofacies sections are constructed from a combined interpretation of the time sections, core samples, grain-size analyses and the whole complex of geophysical well log data. For the analysis, the vertical scale of the sections is transformed to that of the well logs while the horizontal scale will be that of the seismic sections. In the correlation between lithostratigraphic units the well log data should be matched with the seismic sections. In spite of the significant differences between the resolution power of the two methods, we can still avoid the pitfalls in the correlation of the well log information and we shall more accurately represent the geological build-up even at those places where no boreholes were available *(Fig. 5)*.

The seismic lithofacies sections can also be constructed on the palaeoplan. *Figure 6* shows the section of Fig. 5, reconstructed in the palaeoplan. Usually, we take the roof of the thick shale formation as the datum plane in palaeoreconstructions, because of its good lateral correlation. The palaeo-reconstruction of the seismic lithofacies sections reveals the palaeotectonic development

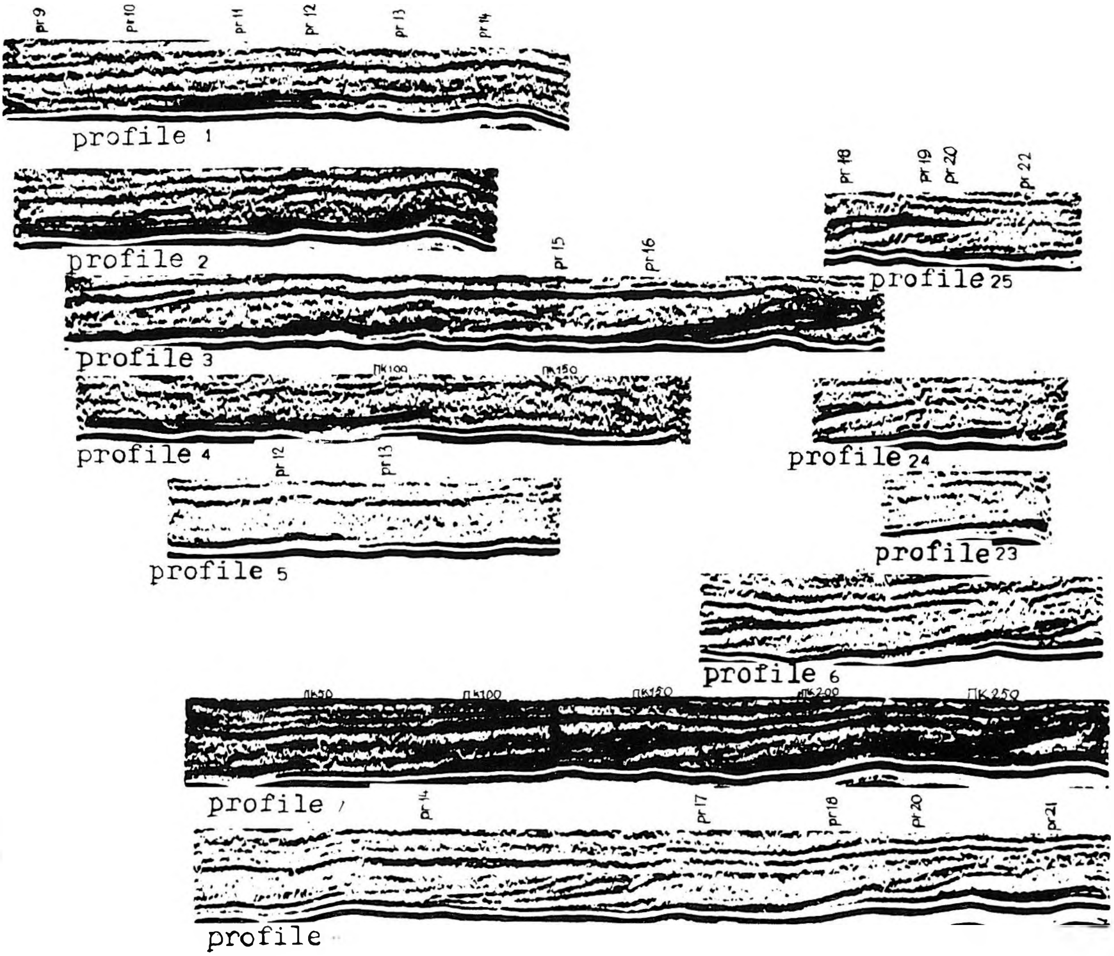


Fig. 4. Elements of the seismic facies map. E–W profiles, Pokacheva area

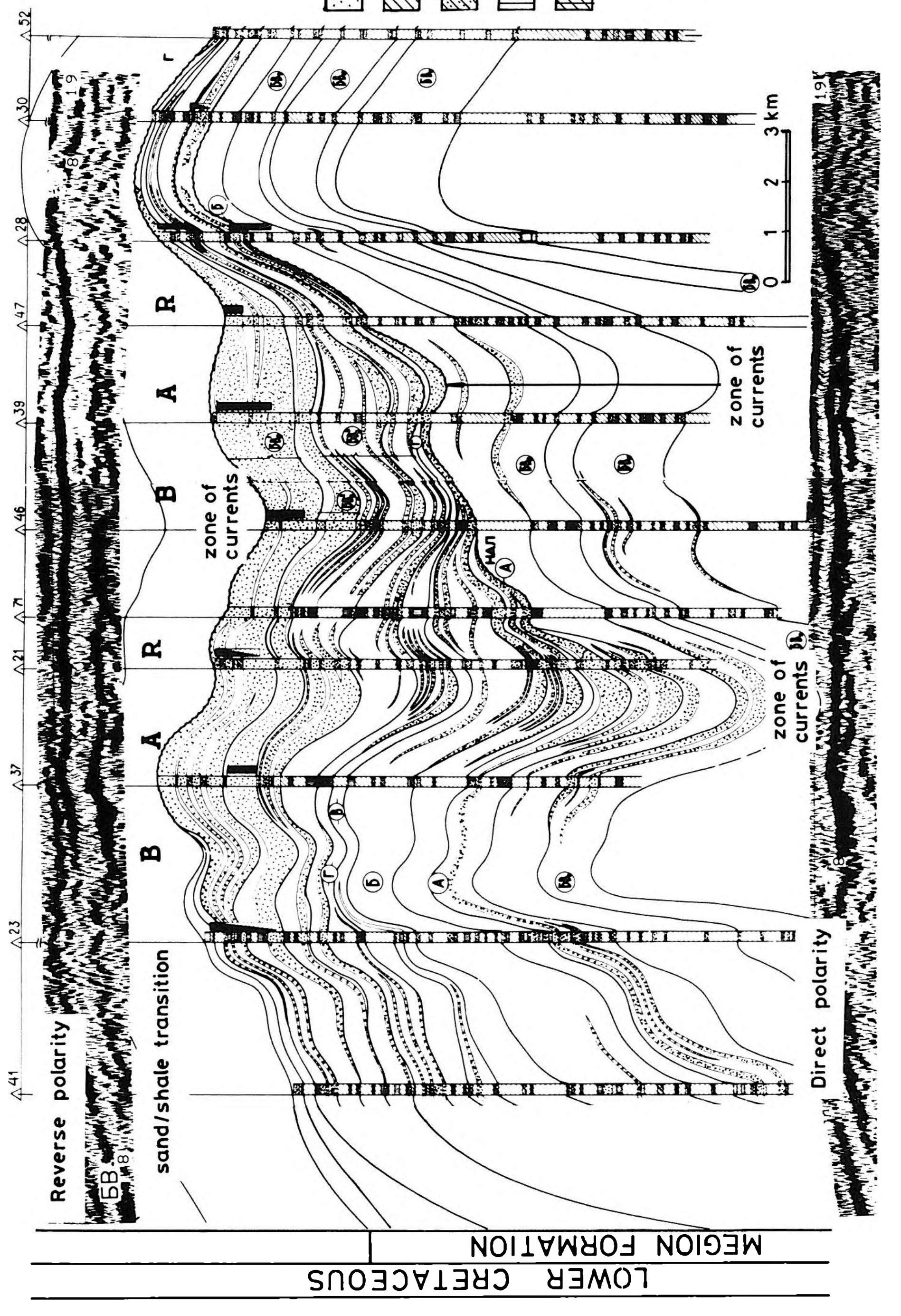
4. ábra. A szeizmofacies térkép elemei. Pokacseva terület, K–Ny-i szelvények

Рис. 4. Элемент карты сейсмических фаций. Профили широтного простирания. Покачевская площадь

Fig. 3 can be found on the last page

A *3. ábra* a füzet utolsó oldalán található

Рис. 3 приведен на последней странице


Reverse polarity
sand/shale transition
BAR
BAR
zone of currents
zone of currents
zone of currents
Direct polarity
0 1 2 3 km
1
2
3
4
5
6
7
MEGION FORMATION
LOWER CRETACEOUS

of the territory, the development history of synsedimantary structures and their connection with the reservoirs or sand/shale transitions.

The well log facies map serves for a division of the territory according to the type and character of the genetically different facies. The well log facies analysis is based on the changes of the SP patterns reflecting variations of grain size. Changes in the lithologic composition and rock-physical properties — recorded by SP logs — are essential indicators of the sedimentation conditions [TAYLOR 1980]. On the maps, constructed for the given stratigraphic intervals, we also display the corresponding SP pattern *(Fig. 7)*. From its form one can conclude to the genetic nature of the sand bodies. Because of the close connection between certain types of facies and the morphologically pronounced negativ and positive features of the palaeorelief of the basin floor, the genetic interpretation of SP curves should be corroborated by palaeo-morphologic data.

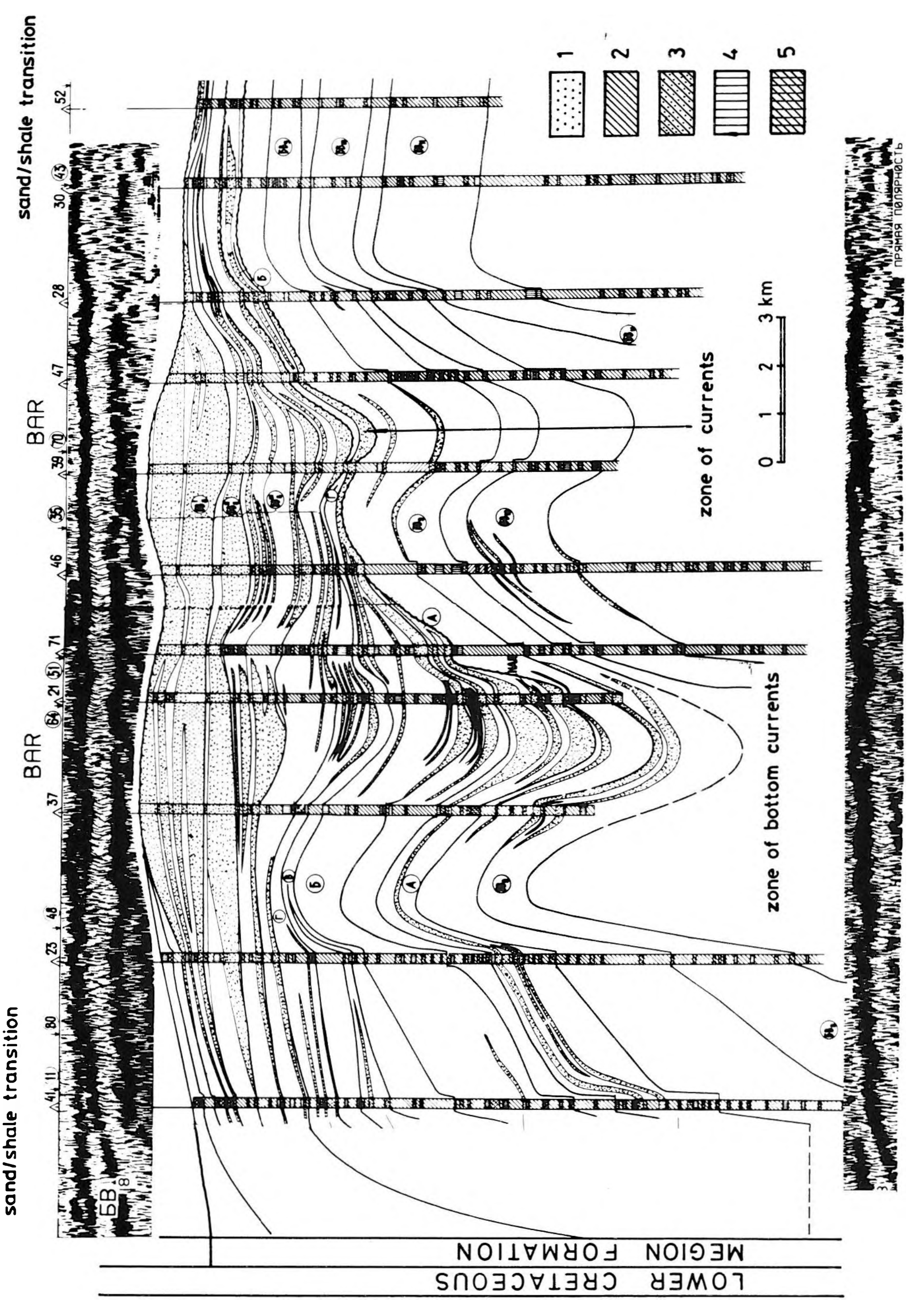
Making use of seismic stratigraphy and facies analyses, and of the correlation of the lithologic parameters to the seismic facies and of lithofacies conditions, we can construct the well log facies map supplemented with data of grain-size analysis. Based on this map, we can form an idea on the sedimentation model, clarify the genetic nature of the sedimentary units and conduct a search for zones of possible reservoirs, for stratigraphic and combined traps.

To estimate the dimensions of the traps, to trace the contours of a deposit, to pick the most promising location of a borehole, etc., we carry out special wave-field analyses by means of the PGR package. The quantitative estimation of wave-field parameters is based on the dynamic analyses (instantaneous amplitudes and frequencies) and on pseudo-acoustic transformation. We construct maps of the dynamic and (pseudo-) velocity parameters along the reflecting horizons corresponding to the prospective pay zones; and establish a correlational dependence between the seismic (amplitude, frequency, acoustic impedance) and geological–petrophysical characteristics (porosity, sand/shale ratio, oil saturation, productivity, etc.). The choice between different models and the solution of some particular questions arising in the analysis of the anomalous wave field are facilitated by seismic modelling techniques.

Fig. 5. Seismic lithofacies section in the present plane (vertical exaggaration 1:100) for Profile 3 of the Pokacheva area
1 — different sands and aleurolites (productive rocks, reservoirs); 2 — shale, argillite; 3 — shaly sandstone; 4 — aleurolite; 5 — shaly aleurolite; 6 — oil; 7 — oil + water

5. ábra. Pokacseva–3 szeizmikus litofacies szelvény (100-szoros vertikális kimagasítással)
1 — homok és aleurolit (termelő rétegek, tárolók); 2 — agyag; 3 — agyagos homokkő; 4 — aleurolit; 5 — agyagos aleurolit; 6 — olaj; 7 — olaj + víz

Рис. 5. Сейсмолитофациальный разрез в современном плане по профилю 3 Покачевской площади
1 — песчано-алевролитовые разности (проницаемые породы, коллекторы); 2 — глины; 3 — глинистые песчаники; 4 — алевролиты; 5 — глинистые алевролиты; 6 — нефть; 7 — нефть + вода


sand/shale transition
sand/shale transition
BAR
BAR
zone of bottom currents
zone of currents
0 1 2 3 km
1
2
3
4
5
LOWER CRETACEOUS
MEGION FORMATION
прямая полярность

The final stage of interpretation is based on the analysis of all data: based on this analysis we make recommendations for additional exploratory boreholes and for the correction of the drilling program of the production wells.

3. Application of integrated interpretation of geological–geophysical data in the post-exploration phase

The effectiveness of the method will be illustrated on the example of a project involving the Pokacheva deposit of the west Siberian CH-bearing province, on the NW side of the lower Vartovo arch. The large, multilayered, Jurassic and lower Cretaceous oil beds had previously been revealed by seismic and well log surveys and prepared for exploitation, some oil producing wells are already operating. In 1981 a detailed seismic survey was carried out as post-exploration of the site, it was interpreted according to the above-described methodology. The exploration was focused on the deposits of the Megion Formation, which was already sufficiently known from exploratory boreholes. While the occurrence of industrial amounts of oil in these deposits has proved the regional presence of oil, general disagreement still existed among geologists as to the regularities of the structure and conditions of development of these deposits. Due to the complicated build-up of the formation and to its lithological inhomogeneity the correlation between well log sections is very uncertain, which explains the existence of different sedimentation models. The top of the Megion Formation contains the productive bed $БВ_8$ which extends all over the lower Vartovo arch and is the basic oil-producing layer of the ocality. In the Pokacheva deposit, the oil-bearing layer is inhomogeneous: both in the western and eastern part of the site sand/shale transition zones were found by drilling. Also, a low yield of oil is obtained from the sandstones of the so-called Achimovy member, which is usually in the lower Megion Formation. Consequently, the structural position of the reservoirs in the Achimovy member and the location of the traps within it have remained unsolved problems in spite of the large number of wells, because of the very complex nature of the logging material.

Fig. 6. Seismic lithofacies section in the palaeoplane for Profile 3 of the Pokacheva area (vertical exaggeration 1 : 100)
1 — sandy-aleurolithic clastics (permeable rocks, reservoirs). Sealing rocks: 2 — shale, argillite; 3 — shaly sandstone; 4 — aleurolite; 5 — shaly aleurolite

6. ábra. Pokacseva-3 szeizmikus litofacies szelvény az eredeti síkban (100-szoros vertikális kimagasítással)
1 — törmelékes homokkő és aleurolit (tárolók). Záróretegek: 2 — agyag; 3 — agyagos homokkő; 4 — aleurolit; 5 — agyagos aleurolit

Рис. 6. Сейсмолитофациальный разрез в палеоплане по профилю 3 Покачевской площади
1 – песчано-алевролитовые разности (проницаемые породы, коллекторы); 2 – глины; 3 – глинистые песчаники; 4 – алевролиты; 5 – глинистые алевролиты

Fig. 7. Well log facies map for the interval, corresponding to the productive bed БВ$_8$
1 — oil-producing wells; 2 — mixed oil-water wells; 3 — wells giving water with oil film; 4 — water wells; 5 — dry wells; 6 — contour lines showing roof of payzone БВ$_8$; 7 — areas of development of accumulated bar sands; 8 — boundary zones of the accumulation of bar sands; 9 — SP patterns corresponding to bed БВ$_8$

7. ábra. A БВ$_8$ produktiv rétegnek megfelelő karotázs fácies-térkép:
1 — termelő olaj-kutak; 2 — olaj-viz keveréket adó kutak; 3 — olajfilmes vizet adó kutak; 4 — viz-kutak; 5 — száraz fúrások; 6 — a БВ$_8$ termelő réteg fedőjének izohipszái
7 — gát-homokkövek kifejlődési területei; 8 — gát-homokkövek határzónái; 9 — a БВ$_8$ rétegnek megfelelő PS-görbék

Рис. 7. Карта каротажных фаций по интервалу, связанному с продуктивным пластом БВ$_8$
1 — скважины, давшие нефть; 2 — скважины, давшие нефть с водой; 3 — скважины, давшие воду с пленкой нефти; 4 — скважины, давшие воду; 5 — скважины, где отсутствуют данные опробования; 6 — изогипсы по кровле отражающего горизонта «БВ$_8$»; 7 — области развития аккумулятивных песчаных тел барового типа; 8 — краевые зоны аккумулятивных песчаных тел барового типа; 9 — диаграммы ПС против пласта БВ$_8$

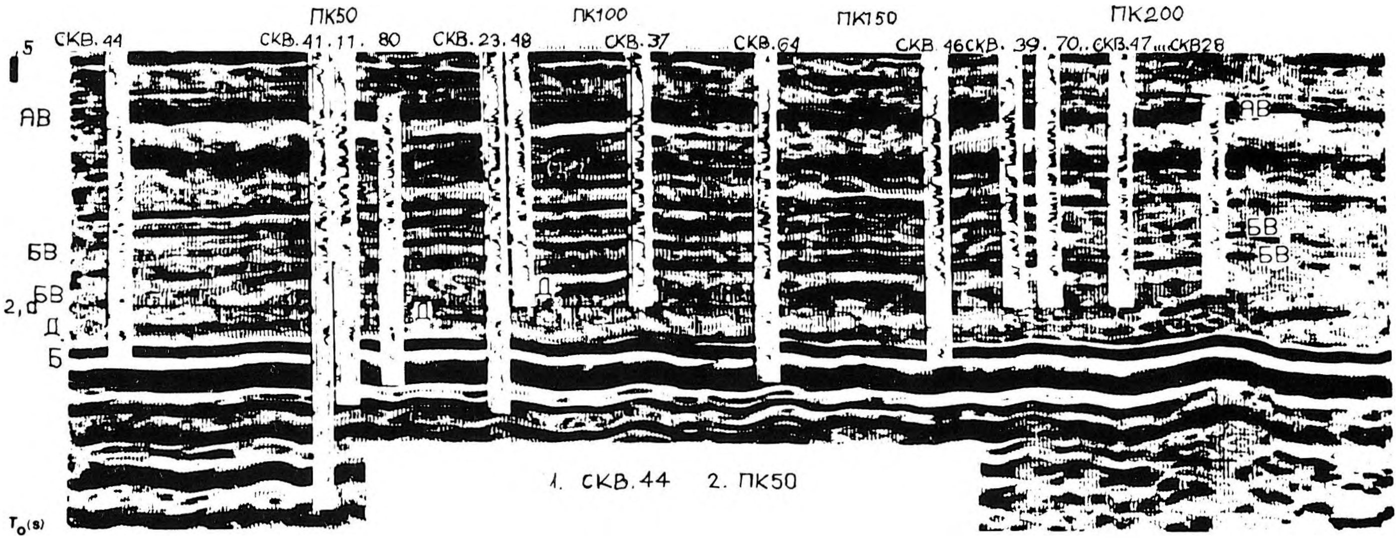


Fig. 8. Composite representation of the pseudo-acoustic section and the SP logs for Profile 3 of the Pokacheva area
1—borehole; 2—pegmark

8. ábra. A pszeudo-akusztikus szelvény és az PS adatok egyesített ábrázolása a Pokacseva—3 vonal mentén 1—mélyfúrás; 2—karószám

Рис. 8. Совместное представление псевдоакустического разреза и кривых ПС по профилю 3 Покачевской площади

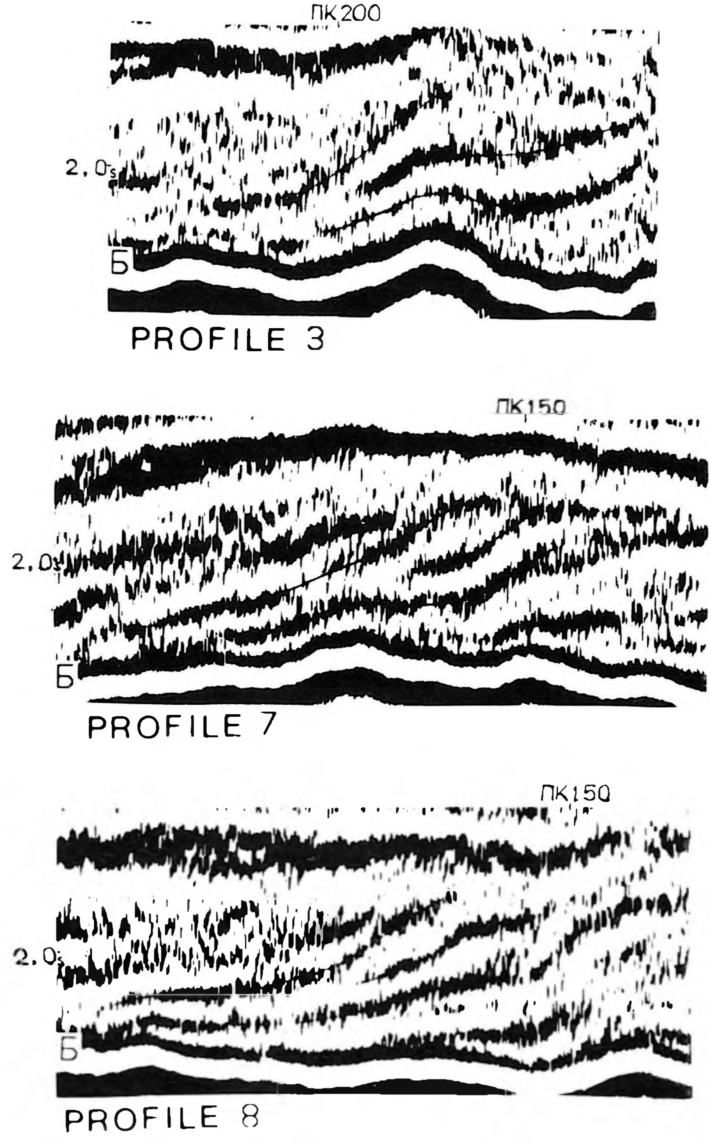


Fig. 9. Sigmoid seismic facies on a series of parallel profiles

9. ábra. Szigmoid szeizmikus faciesek néhány párhuzamos szelvényen

Рис. 9. Сигмовидные сейсмофации на серии параллельных профилей

The clearest representation of the geological information contained in seismic data can be achieved by the pseudo-acoustic transformation of the time sections. *Figure 8* shows the pseudo-acoustic section constructed from Profile 3, proceeding through the dome of the Pokacheva deposit. (The corresponding time section was shown in Fig. 2). When carrying out the pseudo-acoustic transformation the low-frequency components of the velocities had not been taken into account, and a constant density had been asumed, so that the black-and-white shades of the display show the relative changes of the acoustic impedances. In particular, in the given case darker colours signify decreased acoustic impedance values. The time window 1.9–2.1 s corresponds to the Megion Formation, in the upper part of this interval the succession of low acoustic impedance values around 1.9 s corresponds to the productive bed $БВ_8$. The Megion Formation is underlain by the argillites of the Bazhenovo Formation, represented by the marker horizon at 2.1 s.

Stratigraphically, the reflection horizons have been correlated by means of well shooting, acoustic logs and gamma–gamma logs; however, because of the limited number of such measurements, additional information had to be sought from the detailed analysis of the seismic and geological materials. We singled out the most striking changes of the geological section (sand/shale transition within the layer, significant changes in their thickness, fluid saturation of the productive layers, layers of anomalous acoustic impedances, etc.) and compared them with corresponding changes on the seismograms. The final step in the stratigraphic correlation of the reflection horizons took place when we superposed the time-scaled well log curves on the seismic and pseudo-acoustic section (Figs. 2 and 8).

As a result of the seismic stratigraphic analysis of the wave patterns within the time gate of the Megion Formation we could delineate two seismic sequences, differing in form: the clinoform (in Fig. 2 between 1.94 and 2.07 s), correlating with the Megion Formation, including the so-called Achimovy member. Higher up in the section appears the overlying complex (between 1.90 and 1.94 s), which corresponds to those strata where also $БВ_8$ belongs.

The interior structure of the clinoform sequence can be characterized by two types of seismic facies: sigmoid *(Fig. 9)* and oblique reflections *(Fig. 10)*. Based on the characteristics of the interior structure of the complex, the study site can be split into two parts: the back part, characterized by the presence of two zones of sigmoid facies, occupying the SE-half of the area; the front part, extending along the NW-part of the territory, exclusively built up of oblique reflections.

The interior structure of the overlying complex is characterized by lenticular bodies, these correlate from profile to profile and constitute a regularly arranged system *(Fig. 11)*. The lenticular facies is confined to the depression zones and is most wide-spread in the west part of the area characterized by the most complex structure. This stratigraphic analysis has been completed by the construction of seismic lithofacies sections, both in the comtemporary- and the

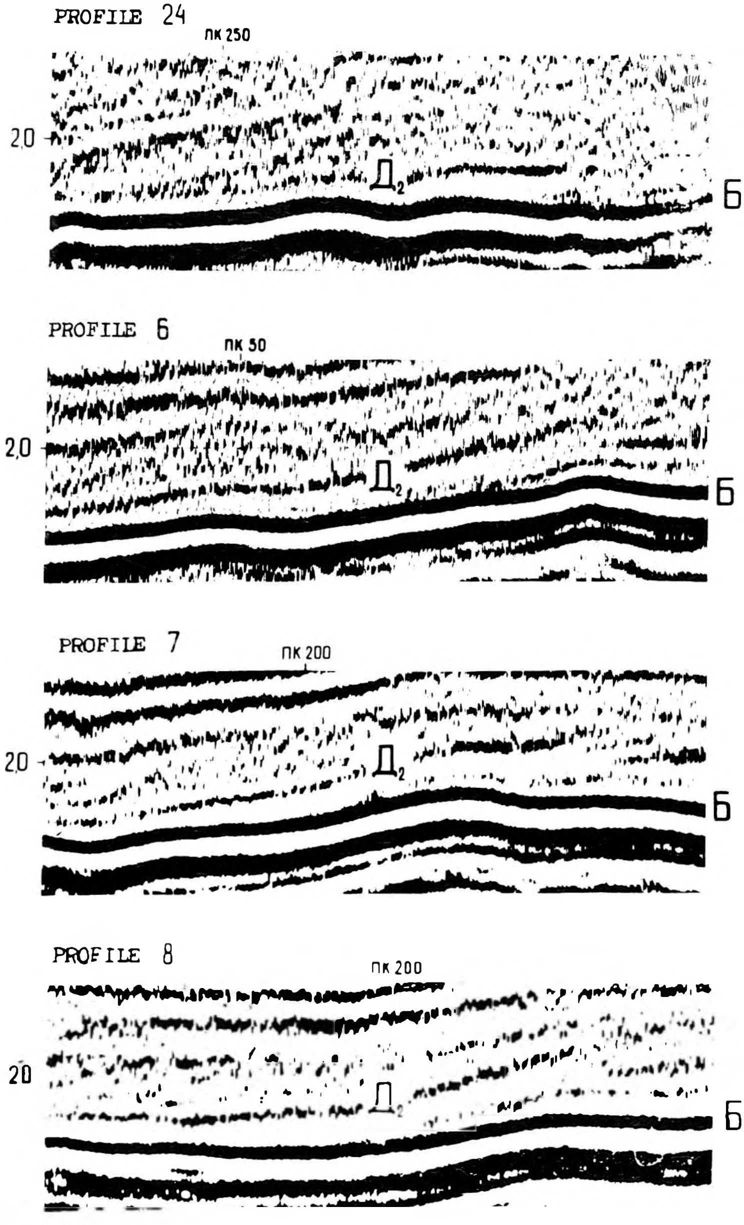


Fig. 10. Seismic facies characterized by oblique reflections on a series of parallel profiles

10. ábra. Dőlt reflektorokkal jellemzett szeizmikus faciesek néhány párhuzamos szelvényen

Рис. 10. Сейсмофации наклонных отражений на серии параллельных профилей palaeoplans (Figs. 5 and 6), and by the well log facies map (Fig. 7). Thus we could genetically interpret the deposits of the Megion Formation.

4. Conclusions

The integrated analysis of the geological–geophysical materials, carried out as outlined above, has provided a sedimentation model of the Megion Formation. In the clinoform sequence of the Megion Formation one can distinguish regularly alternating sedimentation stages, characterized by different tectonic activities and different features of the generated geological bodies, which are considered statigraphic traps. In the initial stage of the formation of the clinoforms the fast lateral accretion of its back part took place passively, without the participation of tectonic movements. At the same time sigmoid lenses of varying aleurolithic–argillic composition whose cyclic structure is due to pulsations in the sediment transport, have been formed due to the prograding clinoforms, and the channel sands lying obliquely at the foot of the slopes having become argillaceous up-dip.

The sigmoid bodies and the sandstones at their feet have been hit by a number of wells. According to the stratigraphic correlation the sandstones have been identified with the dipping reflections, recorded from below the lower Megion Formation revealing six sandstone bodies, denoted in the figures as $Д_0$, $Д_2$, $Д_5$, $Д_6$, $Д_7$ and $Д_8$. *Figure 12* shows the composite map of the isochrons of oblique reflections, corresponding to sandstones of the Achimovy member. The formation of these sandstone bodies is connected with the activity of the bottom currents along the slopes.

The tiled structure of these bodies in the north-western part of the area is very likely due to the fact that the decelerated lateral advance into the basin of the noncyclic front parts of the clinoforms happened at the same time as a noticeable activation of the tectonic movements. In the final stage of development of the clinoforms, their shelf parts are characterized by vertical accretion of sediments. The features of the distribution of the corresponding shallow marine lithofacies are determined by the activation of the tectonic movements. In the depressions the lateral accretion of the clinoforms took place synchronously resulting in extremely varying lithofacies. In the depressions of the shelf, channel sands had been accumulated with lenticular seismic facies (Fig. 11), on the elevated parts there are sand bars (Figs. 6, 7). In the depression zones at the foot of the clayey slope, canyon sand bodies are formed due to the activities of the deep-water currents.

The sedimentation and the structural model of the deposits within the Megion Formation have been used to outline the basic prospective objects. For the obliquely deposited sandstone layers of the lower part of the Megion Formation (the Achimovy member) these are, first of all, nonanticlinal traps, connected with sand–shale transition up-dip. In the overlying complex we mapped the zones of channel sands and bars having the most favourable

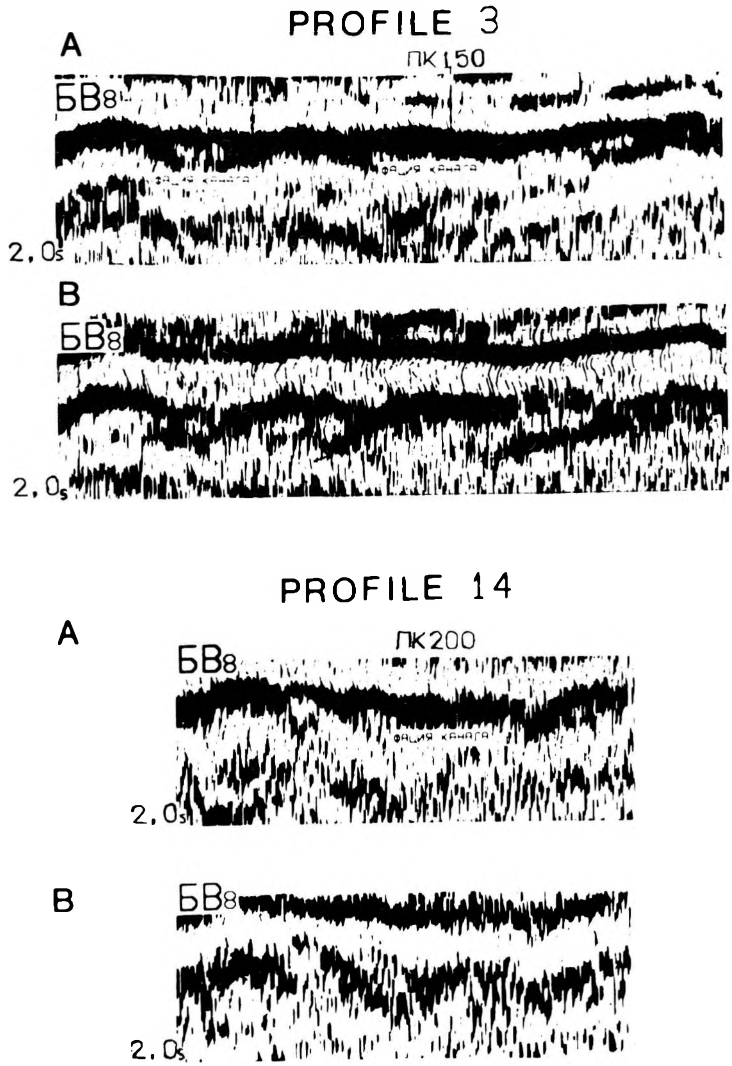


Fig. 11. Lenticular seismic facies, identified with the zone of channel sands
A — time section, direct polarity, B — time section, reversed polarity

11. ábra. Csatorna-homokkal azonosítható lencsés szeizmikus fáciesek
A — időszelvény egyenes polaritással; B — időszelvény fordított polaritással

Рис. 11. Линзовидные сейсмофации, отождествляемые с зоной развития канала
A — временной разрез прямая полярность; B — временной разрез обратная полярность

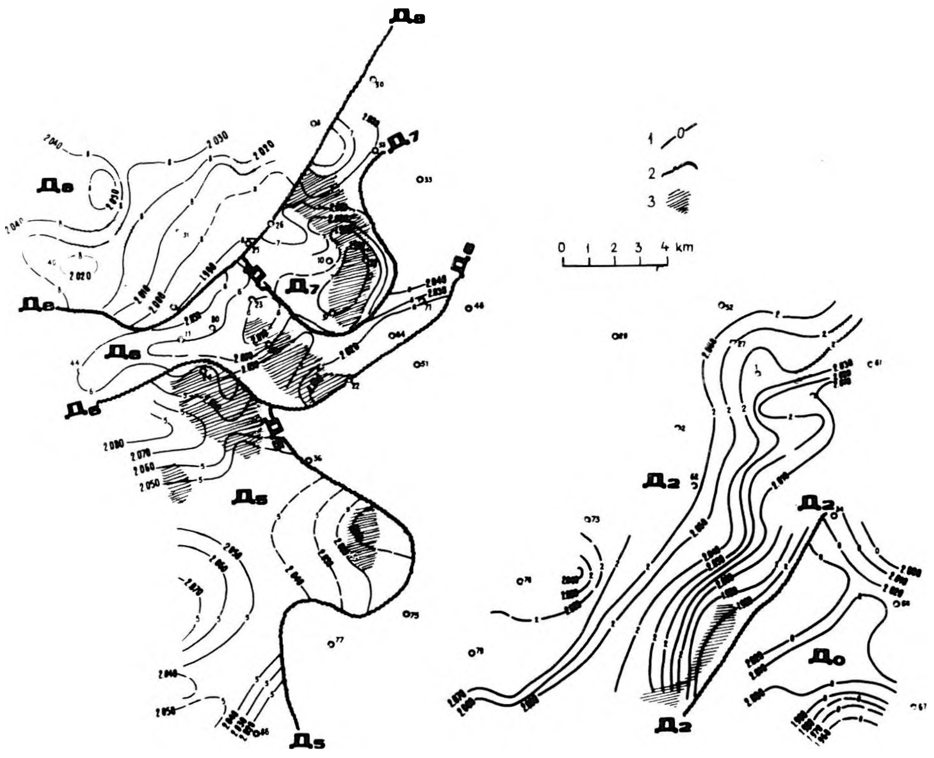


Fig. 12. Composite isochron map of the oblique seismic facies
1 — isochrons of the reflecting horizons corresponding to the roofs of the sand bodies $Д_0$, $Д_2$, $Д_5$, $Д_6$, $Д_7$, $Д_8$;
2 — sand/shale transition line; 3 — zones of decreased acoustic impedance within the beds

12. ábra. A ferde szeizmikus faciesek összetett izokron térképe.
1 — a $Д_0$, $Д_2$, $Д_5$, $Д_6$, $Д_7$, $Д_8$ homoktestek fedőinek megfelelő izokronok; 2 — homok-agyag átmenet vonala; 3 — a réteg belsejében levő csökkent akusztikus impedanciájú zónák

Рис. 12. Сводная карта изохрон наклонных сейсмических фаций
1 — изохроны отражающих горизонтов $Д_0$, $Д_2$, $Д_5$, $Д_6$, $Д_7$, $Д_8$, соответствующих кровлям песчаних пластов;
2 — линии глинизации разрезов пластов; 3 — зоны понижения акустической жесткости пластов

reservoir properties. Within the Pokacheva oil field the structural oil deposits are controlled by bars in the $БВ_8$ bed, while the nonanticlinal hydrocarbon traps are possibly connected with the pinch-outs in the zone of channel sands. High-productivity wells belong to uplifted zones of channel sands.

In order to get additional information on the nature of the changes of the petrophysical properties and of the fluid-saturation of the productive layers the quantitative estimations of the seismic wave-field parameters have been used. We computed, for all prospective objects detected during the construction of the sedimentation model, the velocity maps from pseudo-acoustic data and the instantaneous amplitude map based on the dynamic analysis of the complex traces. The highest inverse correlation has been established between the pseudo-acoustic velocities, on the one hand, and the thickness of the oil-bearing zone and the productivity of the wells, on the other. *Figure 13* shows a comparison of the pseudo-acoustic velocity map with the productivity map displaying the yield of the exploratory wells from the $БВ_8$ bed. Observe the fair agreement of the anomalously low pseudo-acoustic velocities with the highest yield of the wells in the north part of the Pokacheva field. By including all data into the analysis we could delineate the contours of the deposit within the productive bed $БВ_8$, we detected new structural traps and assessed the probable oil content.

In the sediments of the Achimovy member the analysis of the pseudo-acoustic sections and of other data revealed zones of decreased acoustic impedance, which correspond to the most elevated parts of the sand bodies, around the sand/shale transition line of the layers. Characteristic anomalies of the seismic parameters, corresponding to the development of the prospective object $Д_6$, are shown in *Fig. 14*. In zones like this, nonanticlinal hydrocarbon traps can be predicted. As an example *Fig. 15* shows the isochron map of object $Д_6$. On the same map we superimposed the respective intervals of the SP and apparent resistivity logs, characterizing the lithology of the geological body, which clearly show the accurate coincidence of the object $Д_6$ with the development of the sandstone layer. The sand/shale transition line was constructed on the basis of the dynamic analysis of the wave field and has been checked by the available well log data. The results of the integrated interpretation have rendered it possible to work out recommendations for the additional exploration of the oil field.

The investigation presented can be considered as a first step towards a novel technique in the geological exploration for oil and gas, which more fully relies on the up-to-date possibilities of seismic prospecting combined with all available geological–geophysical information. It should be noted that the solution of this task requires a new kind of research team as well, consisting of petroleum geologists, well log analysts and seismic interpreters. Only such team-work together with a thorough cross-analysis of the materials could lead to a synthesis of the ideas on the sedimentation history of the basins which would be in accordance with all available data and could thus be used for the detection of the prospective objects.

There is no doubt that the wide-spread use of the integrated approach of geological–geophysical interpretation—supported by sophisticated seismic techniques—in the detailed exploration and exploitation phase of oil and gas reservoirs would lead to a further increase in exploration efficiency.

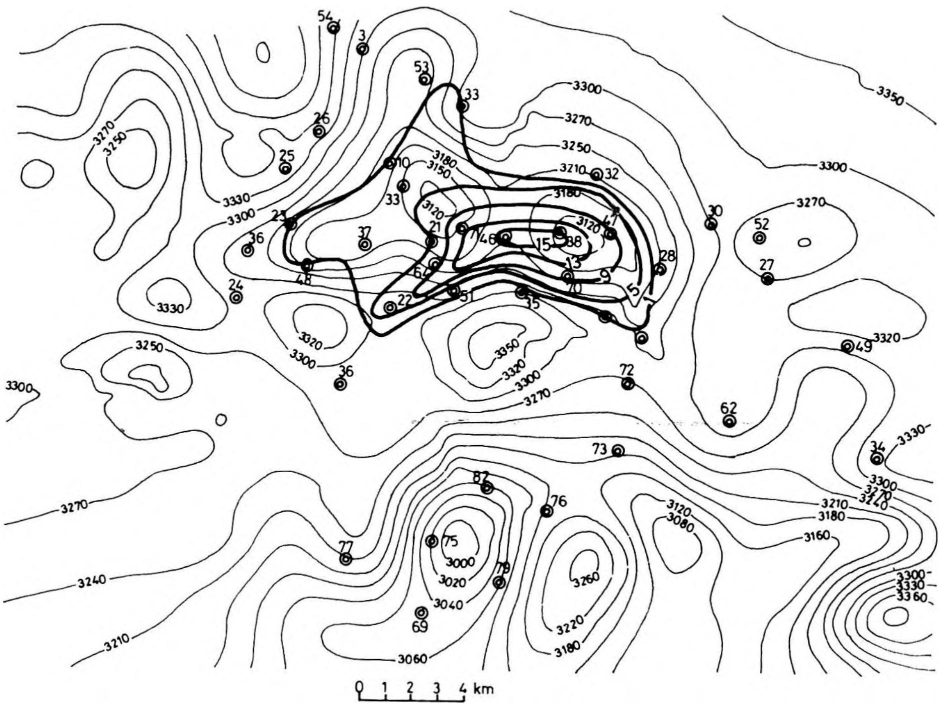


Fig. 13. Comparison of the map of interval velocities computed from pseudo-acoustic logs for the $БВ_8$ bed with the productivity isolines of the exploratory wells

13. ábra. A $БВ_8$ rétegben, a pszeudo-akusztikus szelvények alapján meghatározott intervallum-sebességek, valamint a kutató fúrások egyenlő hozam-görbéi

Рис. 13. Совмещение карты интервальных скоростей по кривым ПАК в интервале пласта $БВ_8$ и изолиний продуктивности разведочных скважин

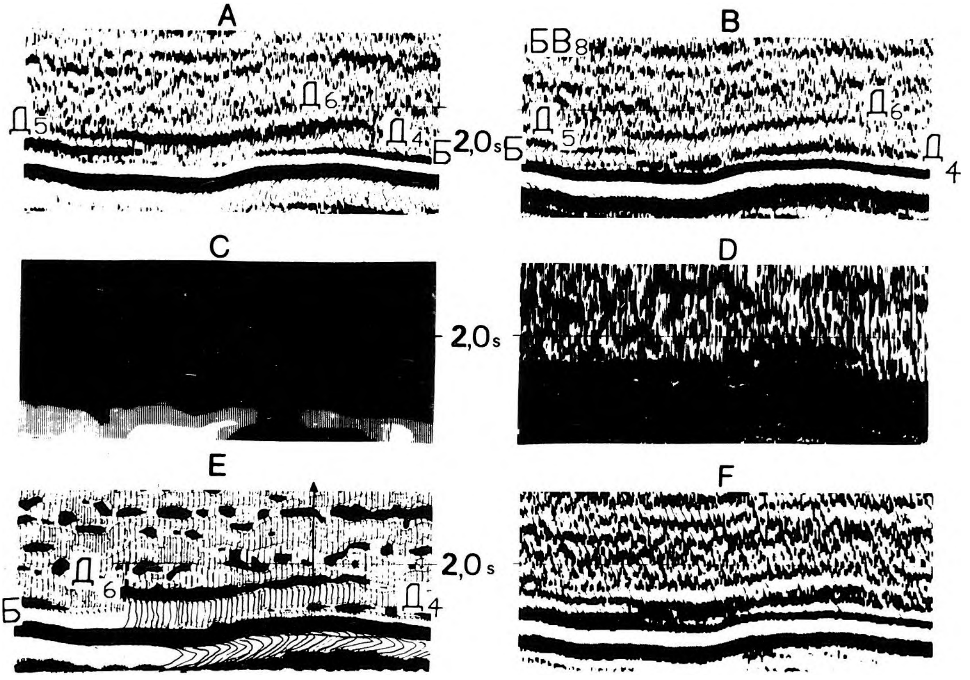


Fig. 14. Seismic wave-field characteristics for the range containing the prospective object $Д_6$ within the sediments of the Achimovy member
A — time section, direct polarity; B — time section, reversed polarity; C — instantaneous frequencies; D — instantaneous amplitudes; E — pseudo-acoustic section; F — instantaneous phases

14. ábra. A $Д_6$ homokkőtestet tartalmazó Acsimovi rétegsor szeizmikus hullámtér jellemzői
A — időszelvény egyenes polaritással; B — időszelvény fordított polaritással; C — pillanatnyi frekvenciák; D — pillanatnyi amplitúdók; E — pszeudo-akusztikus szelvény; F — pillanatnyi fázisok

Рис. 14. Характеристика волнового поля на участке выделения перспективного объекта в отложениях «ачимовской пачки» (объект $Д_6$)
A — временной разрез прямая полярность; B — временной разрез обратная полярность; C — мгновенные частоты; D — мгновенные амплитуды; E — псевдоакустический каротаж; F — мгновенные фазы

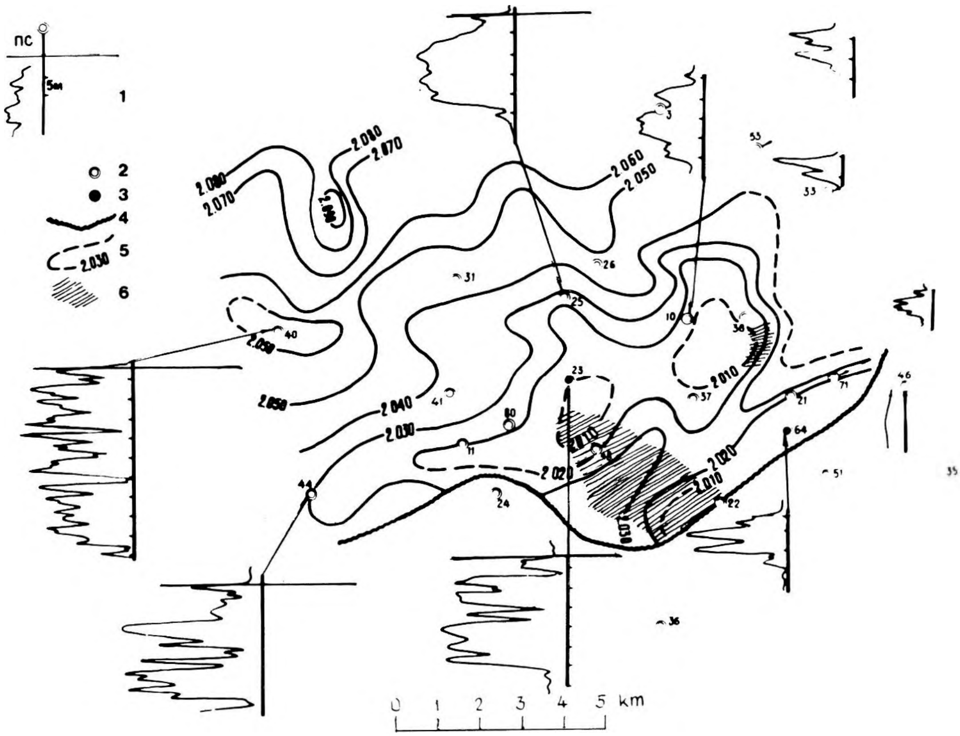


Fig. 15. Isochron map of the object Д$_6$ with characteristic well log patterns
1 — SP log; 2 — exploratory borehole; 3 — oil-producing well; 4 — sand/shale transition line; 5 — isochrons for horizon Д$_6$, corresponding to the roof of the sandstone body; 6 — zones of decreased acoustic impedance within the bed

15. ábra. A Д$_6$ homokkőtest izokron térképe, a jellemző karotázs felvételekkel
1 — PS-görbe; 2 — kutató fúrás; 3 — termelő olajkút; 4 — homok–agyag határvonal; 5 — a Д$_6$ fedőjének izokronjai; 6 — csökkent akusztikus impedancia-zónák a rétegben

Рис. 15. Карта изохрон по объекту Д$_6$ с фрагментами каротажных характеристик объекта
1 — результаты испытания пласта с указанием дебита нефти и воды; 2 — скважины; 3 — скважины, давшие нефть; 4 — линия глинизации разреза пласта Д$_6$; 5 — изохроны отражающего горизонта Д$_6$, соответствующего кровле песчанного пласта; 6 — зоны понижения акустической жесткости пласта Д$_6$

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SZEIZMIKUS ÉS KAROTÁZS ADATOK KOMPLEX ÉRTELMEZÉSE A SZÉNHIDROGÉN-KUTATÁS RÉSZLETES SZAKASZÁBAN

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Egy nyugat-szibériai olajmező kutatásának példáján bemutatjuk a szeizmikus sztratigráfia módszerének és a korszerű szeizmikus adatfeldolgozási eljárásoknak összekapcsolt alkalmazását. A geológiai információk, a karotázs-adatok, a szeizmikus és kőzetfizikai paraméterek integrált felhasználásával sikerült a területen található szénhidrogén-előfordulás megbízható becslése.

КОМПЛЕКСНАЯ ИНТЕРПРЕТАЦИЯ СЕЙСМИЧЕСКИХ И КАРОТАЖНЫХ ДАННЫХ ПРИ ДЕТАЛЬНОЙ РАЗВЕДКЕ НЕФТЯНЫХ И ГАЗОВЫХ МЕСТОРОЖДЕНИЙ И ПОИСКАХ НЕСТРУКТУРНЫХ ЛОВУШЕК

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В настоящей работе будут изложены методические основы комплексной интерпретации и на примере одной из разведочных площадей Западной Сибири проиллюстрирована эффективность ее применения на этапе доразведки месторождений углеводородов.

Основу рассматриваемых исследований представляет обработка сейсмических данных по комплексу программ прогнозирования вещественного состава геологического разреза ПГР и интерпретация полученных данных с применением принципов сейсмостратиграфического и сейсмофациального анализов, а также фациального анализа каротажных данных.