Magyar Állami Eötvös Loránd Geofizikai Intézet
GEOFIZIKAI KÖZLEMÉNYEK
24

ON THE POSSIBILITIES OF TRACING LITHO-STRATIGRAPHICAL CHANGES OF SANDSTONE BODIES

É. KILÉNYI-SZABÓ AND Zs. HEGYBÍRÓ-ROMÁN*

I. Introduction

The sedimentary conditions, genetics, lithological and stratigraphical changes of sandstone reservoirs got into the foreground of interest in petroleum exploration. In Hungary as well—with the possible decrease of unexplored oil and gas bearing structures—exploration for stratigraphical traps deserves ever growing attention.

The variable reservoir properties of Lower Pannonian sandstones raise correlation problems. With the routine seismic field- and processing technique the sandstone layers cannot be separated, geological identification of reflecting horizons is nearly impossible. To detect the lateral changes of sandstone bodies was regarded as hopeless.

To investigate these problems, the Hungarian Oil and Gas Trust started a methodological research program in co-operation with the R. Eötvös Geophysical Institute. In the followings a progress report is given.

II. Correlation problems of electric and acoustic logs

In the literature a good many articles deal with the problem of genetical conditions of sandy-argillaceous sedimentary complexes and with the connection of physical parameters on depositional environments of sandstone bodies. Grain size distribution, sorting, sand/shale ratio etc. are genetical characteristics and at the same time they determine the nature of the log curves.

Saitta and Visher (1968) published a suggestive graph of the PS log patterns representing various shallow marine, deltaic and fluvial environments (Fig. 1). Lately the GR curves are treated similarly. The relationship between genetics and acoustic logs is much more problematic, especially in the case of logging without well-compensation, where a higher noise level has to be taken into consideration. Nevertheless we suppose that stratigraphical changes effect the acoustic logs as well. Without the validity of this supposition no sign of stratigraphical changes could be expected in seismic records.

According to the above described scheme the similarities and differences of electric logs were examined first. On the area, in the southern part of the Great Hungarian Plane, selected for the investigations, three different types of sandstone bodies occur, as presented on Fig. 2. Comparing them with the classification types set by Saitta and Visher, the meander belt point bar, deltaic deposits from primary

* Roland Eötvös Geophysical Institute, Budapest
Manuscript received: 23, 4, 1976

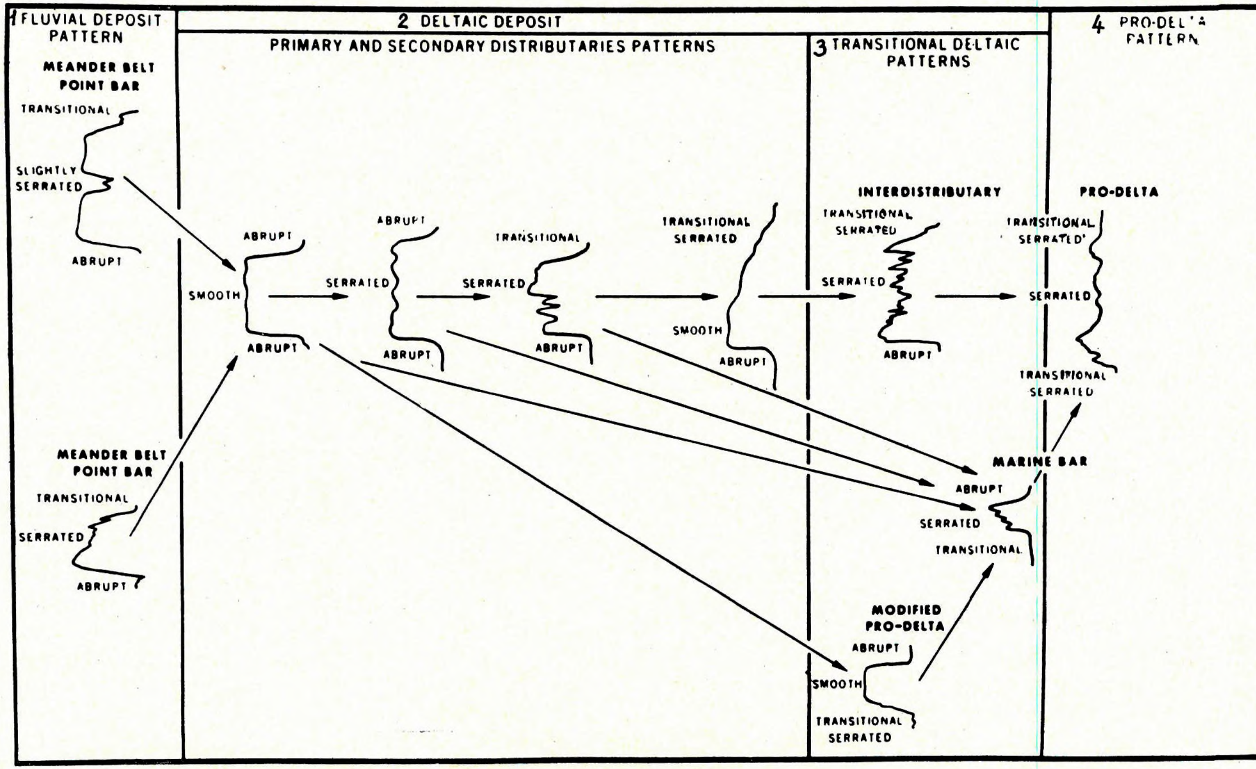

Fig. 1 SP log patterns representing various sedimentary environments (from SAITTA and VISHER, 1968)

1. ábra. Különböző üledékképződési körülményekre jellemző PS-szelvények (SAITTA és VISHER, 1968)
1. *folyami üledék* meanderes kúp-gát 2. *deltaüledék* elsődleges és másodlagos folyóágak 3. *átmeneti deltaüledék* folyóágak közötti szakasz; módosult delta előtti üledékek 4. *delta előtti üledékek* 3—4. tengeri gát homokkő
(transitional = átmeneti; abrupt = éles; smooth = sima; serrated = fogazott)

Рис. 1. Кривые ПС, характерные для различных условий осадконакопления (по SAITTA и VISHER, 1968)
1 *речные отложения* меандрический конус 2 *дельтовые отложения* первычные и вторичные русла рек
3 *переходные дельтовые отложения* участок между руслами рек; измененные отложения перед дельтой
4 *отложения перед дельтой* 3—4. речные песчаники
(transitional = переходные; abrupt = острые; smooth = плоские; serrated = зубчатые)

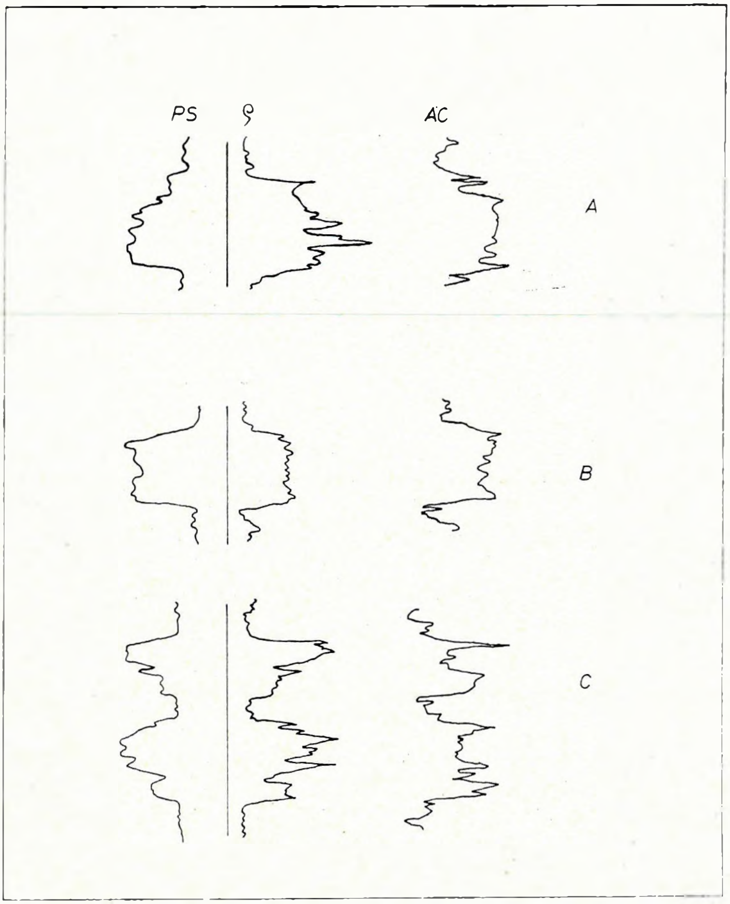

Fig. 2 Typical SP, resistivity and acoustic logs in the area of investigation
A. meander belt point bar, B. deltaic deposits, C. marine bar

2. ábra. Jellegzetes PS-, ellenállás- és akusztikus szelvények a kutatási területen
A. meanderes kúpgát, B. delta-üledékek, C. tengeri gát-homokkő

Рис. 2. Типичные для района работ кривые ПС, ЭК и АК
A. меандрические осадки; B. дельтовые осадки; C. морские осадки

and secondary distributaries and marine bar sandstones can be recognized. The last one is the most widely spread on the area. The characteristic features are best seen on the parts of greatest thickness; on the margins of the bodies they are obscured.

Sandstone bodies, correlated by over- and underlying marls can have different log patterns. Whether these changes are due to facial differences or the sandstone bodies are separated from each other cannot be decided yet. In both cases however detection of alterations contribute to further petroleum exploration.

Correlation of electric logs is routinely done visually. In one of the sandstone layers of our area, prominent differences can be observed in wells of not more them 1–2 km apart. The logs can be grouped into two types separated by a line of nearly N–S direction. Representative logs of the two types are presented in Fig. 3. The

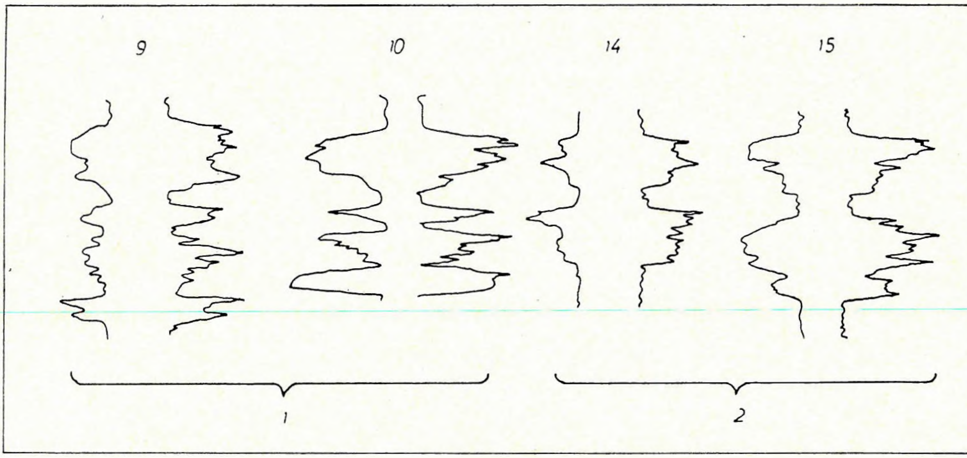

Fig. 3 Representative SP and resistivity logs of a sandstone layer, subdivided into two groups
1. western area, 2. eastern area

3. ábra. Egy kettéosztott homokkőszint jellegzetes PS- és ellenállásszelvényei
1. nyugati terület, 2. keleti terület

Рис. 3. Типичные кривые ПС и сопротивления песчаного пласта, подразделенного на две части:
1. западный район, 2. восточный район

division of the sandstone layer into two parts was checked by mathematical correlation.

A special cross-correlation program was compiled, in which the selected time window on the first curve can be extended by any desired rate. Supposing, that the thickness of the sandstone body changes linearly, this program eliminates the decrease of the correlation coefficient due to the thickness variations. Considering the remarkable results, it seems that this supposition is permissible.

Two logs from both the western and eastern areas were selected for the cross-correlation, which visually correlate well. These are from the western area logs 9 and 10, from the eastern logs 14 and 15. From the eastern area of larger spread a log was chosen (No 12) which had the worst correlation to the type 14, and at the same time the best to the western type. The cross-correlation was computed for both PS and the normal resistivity logs. Fig. 4 is a presentation of typical correlation curve series versus extension rate for PS and resistivity logs respectively. Results of the correlation computations are presented in Table I. It can be seen, that the correlation values of 0.74–0.82 on the PS logs, and 0.68–0.75 on the resistivity logs mark out the relationship between boreholes.

As our ultimate purpose is the interpretation of seismic cross sections, similar investigations were made for the acoustic logs as well. Results of correlation computations of acoustic logs are presented in Table I. No definite similarities could be proved either by eye or by the mathematical correlation between logs of related boreholes. Although sand layers can be correlated, their characteristics are masked by the superimposed noise to such and extent that they are unrecognizable. Notwithstanding all suitable acoustic logs were transformed to synthetic seismograms. Computations were carried out with high precision (sampling interval: 0.2 m, one

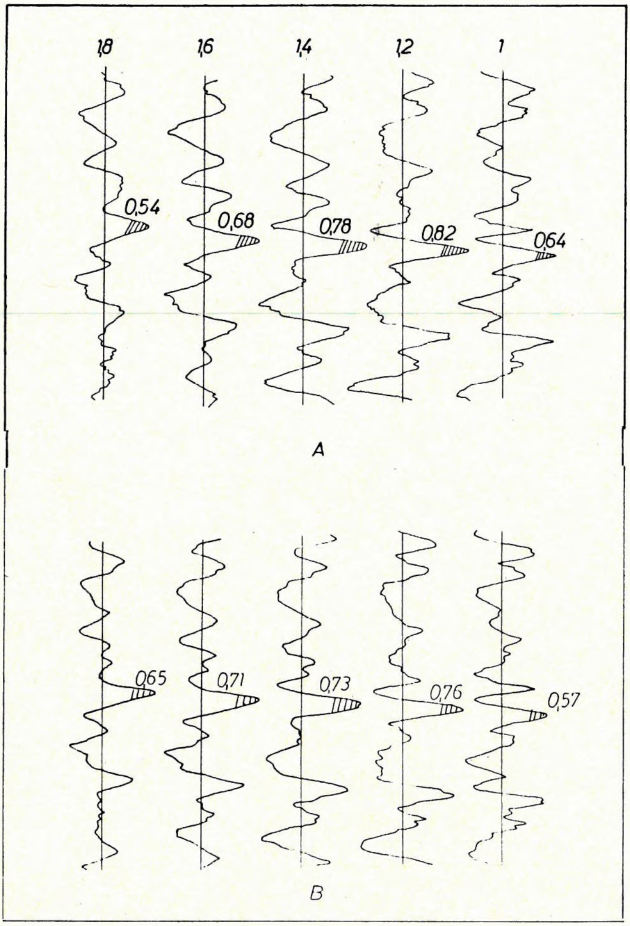

Fig. 4 Correlation graph of the investigated sandstone layer, eastern part (boreholes 14 and 15) A. SP logs, B. resistivity logs

4. ábra. A vizsgált homokkőszint korrelációs görbéi (keleti csoport, 14. és 15. sz. fúrások) A. PS-görbék korrelációja; B. ellenállásgörbék korrelációja

Рис. 4. Кривая корреляции изучавшегося песчаного пласта, восточная часть (скважины 14 и 15) A. кривые ПС; B. кривые сопротивлений

way time interval 0.125 msec, noise filtering by 100 m/sec threshold), for convolution 80 and 54 Hz symmetric Ricker wavelets were used. These frequencies were the median values of the bandpass filters applied to an experimental seismic profile in the area.

The results are presented on Fig. 5 for two selected sandstone bodies. It can be seen, that although no outstanding similarity can be found between interval velocity curves, the synthetic seismograms using 80 Hz wavelet can be separated into two groups. In the case of 54 Hz wavelet, the same phenomenon appears under

Table I
1. Táblázat
Таблица 1

Borehole Fúrás Скважина	Log Karotázs görbe Вид каротажа	Correlation peak Korreláció csúcsértéke Пик корреляции	Extension rate Nyújtási arány Пропорция растяжения	Note Megjegyzés Примечания
window ablak окно				
10— 9	PS RES AC	0,78 0.68 —	1.2	1. Two typical logs of the western group
14—15	PS RES AC	0.76 0.82 0.52	1.2	2. Two typical logs of the eastern group
14—12	PS RES AC	0.75 0.71 0.60	1.2	3. Least similar two logs of the eastern group
10—14	PS RES AC	0.56 0.49 0.70	0.8	4. Typical logs of the western and eastern groups respectively
10—12	PS RES AC	0.57 0.50 0.58	0.9	5. Most similar logs of the western and eastern groups

1. A nyugati csoport két tipikus karotázsgörbéje
2. A keleti csoport két tipikus karotázsgörbéje
3. A keleti csoport két legkevésbé hasonló karotázsgörbéje
4. A nyugati és keleti csoport egy-egy jellegzetes karotázsgörbéje
5. A nyugati és keleti csoport egymáshoz leghasonlóbb karotázsgörbéje

1. Две кривые, типичные для западной группы
2. Две кривые, типичные для восточной группы
3. Две наименее подобные кривые восточной группы
4. Типичные кривые западной и восточной групп, соответственно
5. Наиболее подобные кривые западной и восточной групп

favourable conditions only, such as on the upper sandstone, boreholes 15 and 12. The thinning out of the sandstone layer—borehole 14—causes the characteristic signal form to fade away.

The similarity of 80 Hz synthetic seismograms was checked by mathematical correlation as well. The possibility of window-extension was not exploited this time, because arbitrary similarity can be obtained by it in such a case. Results of cross correlation computations are presented in Table II. The principles of selecting curves for correlation were the same as before: correlation was sought between pairs of two similar and differing curves respectively. The results were surprising; after the low correlation coefficient of the interval velocity logs, we did not dare to hope such a good correlation between synthetic seismograms. It seems, convolution filtered noise and enhanced signal character.

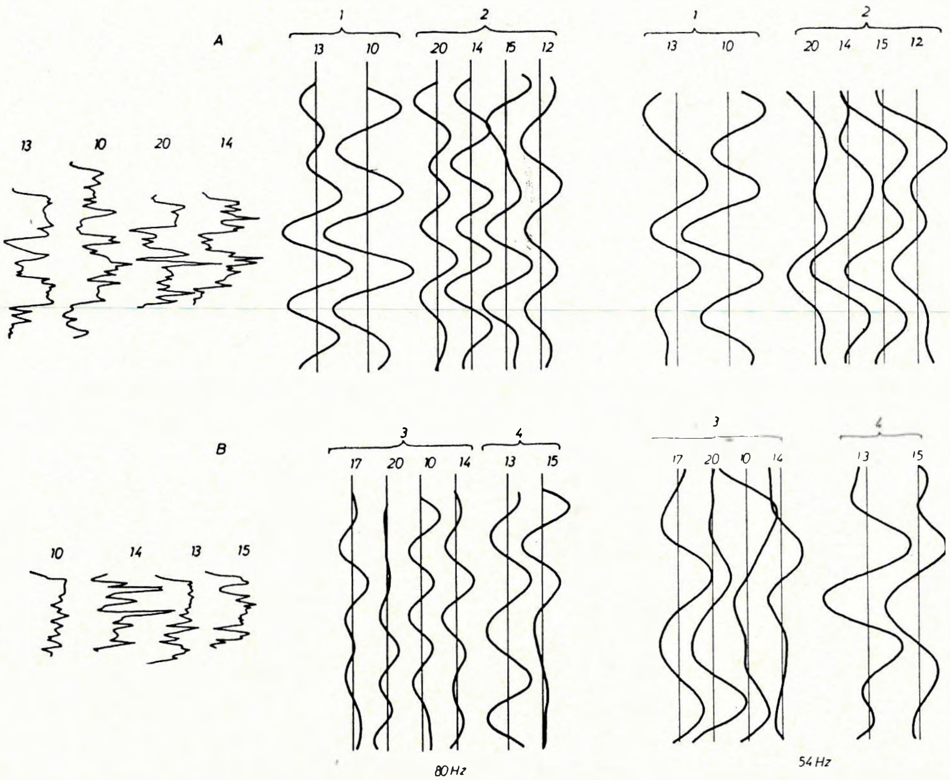

Fig. 5 Comparision of synthetic seismograms and interval velocity logs for two subdivided sandstone layers

A. upper layer, 1. western part, 2. eastern part B. deeper layer, 3. northern part, 4. southern part

5. ábra. Intervallumsebesség-görbék és szintetikus szeizmogramok két kettéosztott homokkőszintre
A. sekélyebb szint; 1. nyugati terület; 2. keleti terület
B. mélyebb szint; 3. északi terület; 4. déli terület

Рис. 5. Сопоставление синтетических сейсмограмм и графиков интервальных скоростей для двух подразделенных песчаных слоев

A. верхний слой, 1. западная часть, 2. восточная часть; B. нижний слой, 3. северная часть, 4. южная часть

III. Conclusions

As a result of our investigations it can be stated that there is hope to reach our set target that is to say to trace the stratigraphic changes in the seismic time section. It is proved by the synthetic seismograms that the theoretical possibility for detection wave form changes exists. At the same time it was revealed as well, that frequency ranges must be shifted towards the higher frequencies. High frequencies cause lots of problems both in field technique and data processing, still we must cope with them to reach our aims.

Our further experiments will be aimed at rendering our results applicable in practice.

Acknowledgement

We would like to express our thanks to the research staff of the Hungarian Oil and Gas Trust who made it possible to publish our results and helped us with data and advice.

Table II

II. Táblázat

Таблица 2

Borehole Fúrás Скважина	Correlation peak Korreláció csúcsértéke Пик корреляции	Note Megjegyzés Примечания	
window ablak окно			
10—13	0.94	1. Typical synthetic seismograms of the western group	SHALLOWER SANDSTONE
14—20	0.96	2. Typical synthetic seismograms of the eastern group	
10—14	0.51	3. Typical synthetic seismograms of the western and eastern groups resp.	
13—15	0.88	4. Typical synthetic seismograms of the southern group	DEEPER SANDSTONE
14—10	0.91	5. Typical synthetic seismograms of the northern group	
14—13	0.66	6. Typical synthetic seismograms of the northern and southern groups resp.	

1. A nyugati csoport tipikus szintetikus szeizmogramjai
2. A keleti csoport tipikus szintetikus szeizmogramjai
3. A nyugati és keleti csoport tipikus szintetikus szeizmogramjai
4. A déli csoport tipikus szintetikus szeizmogramjai
5. Az északi csoport tipikus szintetikus szeizmogramjai
6. Az északi és déli csoport tipikus szintetikus szeizmogramjai

1—3. Sekélyebb homokkőcsoport

4—6. Mélyebb homokkőcsoport

1. Синтетические сейсмограммы, типичные для западной группы
2. Синтетические сейсмограммы, типичные для восточной группы
3. Синтетические сейсмограммы, типичные для западной и восточной групп, соответственно
4. Синтетические сейсмограммы, типичные для южной группы
5. Синтетические сейсмограммы, типичные для северной группы
6. Синтетические сейсмограммы, типичные для северной и южной групп, соответственно

1—3. Менее глубоко залегающие песчаники

4—6. Более глубоко залегающие песчаники

BIBLIOGRAPHY

Bartha F. et al. (1971): A magyarországi pannonkori képződmények kutatásai. Akadémiai Kiadó, Budapest
Dedman, E. V. et al. (1975): Stratigraphic modeling. Geoquest International Ltd.
Gotautas, V. A. (1972): Southwest Lake Arthur Field.... from "Stratigraphic Oil and Gas Fields" SEG. Spec. Publ. Tulsa, Oklahoma, USA
Harms, J. C., Tackenberg, P. (1972): Seismic Signature of Sedimentation Models. Geophysics, 37. 1.
Jageler, A. H., Matuszak, D. R. (1972): Use of Well Logs and Dipmeters in Stratigraphic-trap Exploration, from "Stratigraphic Oil and Gas Fields" SEG. Spec. Pbl. Tulsa, Oklahoma, USA
Laws, W. R. et al. (1975): A Study of the Acoustic and Density Changes.... Dresser Atlas
OKGTGKÜ I—2, I—13, 108, 113 sz. Jelentések. Kérzirat.
Sz. Kilényi Éva (1975): A szintetikus szeizmogram számításának pontossági követelményei. Magyar Geofizika, XVI. 3
Widess, M. B. (1973): How Thin is a Thin Bed? Geophysics, 38. 6

SZ. KILÉNYI ÉVA, R. HEGYBÍRÓ ZSUZSANNA

MÓDSZERTANI KÍSÉRLETEK HOMOKKŐSZINTEK LITOSZTRATIGRÁFIAI VÁLTOZÁSAINAK NYOMONKÖVETÉSÉRE

Egy délalföldi kőolajkutatási terület korrelációs problémáinak megoldására az OKGT az ELGI-vel együttműködve módszertani kísérleteket kezdeményezett, amelynek eredményeiről számolunk be. A homokkőszintek litosztratigráfiai változásait PS, ellenállás és akusztikus karotázsgörbék segítségével vizsgáltuk. Míg az első kettő szemre és matematikai korrelációval is kimutathatóan jelzi a változásokat, az akusztikus görbék jellegét a zaj elnyomja. Az akusztikus görbékből szintetikus szeizmogramokat számítottunk 54 és 80 Hz-es szimmetrikus Ricker wavelet alkalmazásával. A nagyfrekvenciás szintetikus szeizmogramok határozottan jelzik a jellegváltozásokat.

Э. КИЛЕНИ С. — Ж. ХЕДЬБИРО Р.

МЕТОДИЧЕСКИЕ ОПЫТНЫЕ РАБОТЫ ДЛЯ ПРОСЛЕЖИВАНИЯ ЛИТО-СТРАТИГРАФИЧЕСКИХ ИЗМЕНЕНИЙ В ПЕСЧАНЫХ ГОРИЗОНТАХ

Для решения проблем, связанных с корреляцией и возникших в одном из нефте-разведочных районов южной части Большой низменности, по инициативе Треста нефтяной и газовой промышленности, в сотрудничестве с Геофизическим институтом им. Л. Этвеша, были проведены методические работы, результаты которых рассматриваются в настоящей работе. Литостратиграфические изменения в песчаных горизонтах изучались по данным метода ПС, ЭК и АК. В то время, как по данным первых двух методов отчетливо отмечаются изменения как на взгляд, так и по математической корреляции, характер кривых АК искажается за счет наличия помех. По кривым АК были составлены синтетические сейсмограммы с использованием волн Рикера на частотах 54 и 80 гц. На высокочастотных синтетических сейсмограммах хорошо выделяются изменения.