Using of the Proni filtration in geological and production tasks

George Mitrofanov, RAS, Russia, Viatcheslav Priimenko, LENEP/UENF, Brazil, Djalma M.Soares Filho, Roseane M. Misságia, CENPES/PETROBRAS S/A, Brazil, Marcos H. Grochau and Rosenberg G. Lima, UN BC/PETROBRAS S/A, Brazil

This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

Abstract

A new technology for seismic data processing on the based on Proni filtration method is presented. It can be used for different geological and production tasks like some tool for estimating of target horizons of production zones. The tool allows us to locate zones of anomalous of seismic energy scattering and absorption (depending on frequency), which are connected with target seismic horizons. Analysis of these zones permits better understanding of features of target horizons and to correlate these features with the presence of perspective reservoirs. This approach was tested on different seismic data and applied for few types of tasks.

Introduction

Using of the Proni transform allows us to represent an observed seismic signal as a sum of dumping sinusoids with four parameters: **amplitude, attenuation, frequency and phase for each sinusoid** (Marple, 1987). A certain procedure can be constructed after estimation of these parameters from real seismic traces. This procedure makes selection of the estimated values of the parameters on the basis of different criteria and can be called as the Proni filtration (Mitrofanov et al., 1998). Our first experiments of application of such procedure for real seismic data processing show, that it allows us to indicate zones of anomalous attenuation of seismic energy depending on frequency rather effectively than other methods. In this case the high-frequency components, which are usually contaminated with low frequencies, can be separated and analyzed within the wave field. Our experience, which we have during several years, has confirmed that Proni filtering is capable to discover anomalies in narrow frequencies bands and that many of these anomalies are connected with reservoirs properties and fluid's content (Mitrofanov et al, 1998; Brekhuntcov et al, 2001; Soares Filho et al, 2002). Such anomalies can have different types (versus of amplitude or attenuation, or coherence) and they are connected with media features. First of all, anomalies are connected with gas and gas-saturated oil fields; the second, they are connected with fault zones with good porosity, porous carbonates and etc. The hypothesis about non-linear (instance, square-law) dependence between seismic signal attenuation and frequency is in the basic idea of the Proni filtering applying to real seismic data. This fact is suggested by physical experiments and can be explained by non-elastic absorption and scattering of seismic energy in non-consolidated or fluid saturated rocks.

In the result of made up works we have a new technology of the Proni filtering, which was tested on different geological tasks. Firstly, on the basis of it we can estimate non-consolidated and solid zones for target horizons. Secondly, we can clear outline for production field or reservoir. We used the technology for solution of geological tasks, which are connected with search of natural reservoirs of gas above coal layer. These reservoirs can be situated in sand body of delta edge. As rule they have high fracture structure and can give anomalies zones of attenuation and absorbing seismic energy for reflection waves.

Let us give the list of some tasks, where the Proni filtration can be useful.

Simple example of the task is to separate solid and non-consolidated parts of medium. (Seismic task)

Studying of local elements of horizons. Such elements can be determined better for high frequencies. For example, small faults, wedges zones. (Seismic task)

Studying of conditions for a reservoir. For example, we can look what kind of top for such reservoir. (Geological task)

To elaborate an outline for a reservoir in time and space domains. (Geological task)

To determine points with high production for target horizons. (Production task)

To estimate a structure of a production horizon. For example, what the conditions along of the horizon we have. (Production task)

The aim of this paper is to show a possibility of applying the Proni filtering technology to real seismic data and solution of geological tasks. The possibility will be illustrated with different real seismic data including Brazilian ones. These applications will be given in connection with geological tasks, which are solved. Simultaneously, we will try to present the main aspects of the technology and their difficulties.

Basic principals of the technology

Presently we cannot speak about Proni filtering procedure only. During few years in elaboration of the Proni filtration a new technology or tool was created. The general scheme of such tool is the following steps.

Ordinary seismic data processing;
Standard spectral analysis;
Determining of optimal Proni filtration parameters;

Seismic data processing on bases of Proni filtration; Results presentation (stacks, maps and etc.).

Let's go through the scheme briefly.
During the first step we need to keep more of spectrum bandwidth and information about form of reflection signals from target horizon. Furthermore for using of results (for example, for mapping anomalies along of horizon) we need to have information about picking target horizons, which is connected with wells data.
The second step consists in a standard spectrum analysis, which shows us major frequencies of seismic signals and their spectrum bandwidth. The last ones are needed to determine presence of useful components in high-frequency domain. As a rule this analysis makes for time intervals with more width than a lengthwise of reflection signal from the target seismic horizon.
The third part of the technology includes a selection of the parameters for the optimal Proni filtering depending on the problem, which will be solved. These parameters are selected for set of profiles from studying area and for few frequencies including one from major and high domain. As it was mentioned early the process of the optimal parameters selection is not a formal and automatic one. So we need to use some principles for this selection. Usually wells data are important in such choice. As rule we use such information to estimate the correction of our choice in the points of these wells.
In the fourth step the optimal parameters, which were determined for each of the frequency, are used for processing of all data on the bases of the Proni filtration procedures. In results we have few full sets of profiles for different frequencies.
The fifth step consists in using of the full sets of profiles to identify anomalies, which can be connected with production zones of target seismic horizons. For this purpose, the creating sets of the profiles with information about target horizon picking are used for mapping of zones with a different medium reaction for seismic influence.
This tool allows us to locate zones with anomalous seismic attenuation (depending on frequency), which are connected with target seismic horizons. Analysis of these zones permits to understand better features of production horizons and to correlate these features with presence of perspective reservoirs. Under the analysis we use the hypothesis, that high frequency component of wave field indicates fracture, fluid-saturated and broken rocks. Therefore the separation and study of these profiles sets allows us to understand whether the medium has such properties. For last step the information about production and dry wells is also very useful for good prediction.
After Proni filtration the stacks give us more information for analyzing of medium characteristics than we could estimate by formal procedures and we have a deeper interpretation of the given seismic data. For example, we have addition information about top and structure of a reservoir analyzing different time intervals of these stacks for different frequencies. Short and strong response for high frequencies is typical for top of a reservoir. For zones of wave fields connected with the reservoir we have a high attenuation and unstable response for high frequencies. Thus, if we want to keep all information for mapping from stacks after Proni filtration, we need to use few parameters of the result. Now we use two of them: energy of time intervals and coherence.
Our experience says the best correlation between a map structure for target horizons and wells data we have for energy parameters in the case when we analyze ratio between high and main frequencies. So in processing of the Proni filtering both types of frequencies need be analyzed.

Examples

Analyzing of reservoir features. In this case we try to show what kind of additional information about reservoir features we can have when the technology is available. As an example of such case we consider some Chinese data presented from one of a gas province. A kind of the data was 2D seismic stacks after full preprocessing. These data were prepared for geological interpretation and the Proni filtration procedure was applied additionally. Some parts of two profiles with wells data are given at Figures 1 and 2. We can look primary data (a) and results of their Proni filtration on the frequencies: 35 Hz (b) and 55 Hz (c).
The information, which was given to us from the well W10 (see Figure 1), shows that this result of the Proni analysis has good correlation between structure and size of sand and clay layers. There is a big size of sand layers and not so big layers of clay in this well. We believe that it gives wide anomaly of energy attenuation for reflection waves by the time coordinate. For this zone one can observe disturbance of the reflection signals for the coal layers in high frequency like for different zone where the well has a high production too. This fact can be used for confirmation of a geological hypothesis.
If some point can be interesting for us we can use more detail analysis of high frequency domain in the results of Proni filtering. In particular one can determine clearly the anomalies zone and estimate a quality of a cover over the gas reservoir.
Some wells are not production ones in investigated area. We tested few of them with a goal to answer some questions. The first one is: Are there some anomalies in high frequencies in neighbourhoods of the wells, and if we have anomalies zones why these wells don't give a production gas? As rule in the processing of Proni filtration we can determine that conditions for nature reservoirs in points, where these wells were located, are not suitable.
Consider now example of the well W26 (see Figure 1). The results for the corresponding part of the profile are presented at the Figure 2. They show that a good condition for a gas accumulation for the area of the well point is absent. It goes from strong reaction of the medium for high frequency and absent of good cover for reservoir. We need to note that features of studied part of medium are not determined so simple from primary data analysis.

Outline of reservoir estimating. The initial data for this example were presented as part of 2D seismic survey from the Western Siberia. There were given for the Proni processing six seismic lines in stacks form after full pre-

processing. Ones can see in Figure 3 these lines and their position on the oil field (this information was given after final presentation of the results for the oil company).
On the basis of full set of the filtering stacks, which were got for all definition frequencies for each of the primary profiles, an analysis of anomalies zones was carried out. During this analysis we estimated conditions for upper and down parts of medium around of the target horizons. Some consonant result of such analyses is presented in Figure 3 by a different type of gray color. After that we used this result in combination with studying of anomalies zones variation by frequencies for reservoir outline creating. The reservoir positions for each of the profiles are shown in Figure 3. This step was the final one in interpretation with using of the Proni filtering results.
These results were compared with ones of the oil company tested by wells drilled in investigated area. This comparison is presented in Figure 3, too. One can look the complex structure of the field and quality of the Proni technology applied to this geological task.
Ensure from this figure that all points of production wells are situated in reservoir zones created by means of the Proni filtering technology. And all dry wells stand in points outside of these zones. In more parts of the field reservoir zones are congruent old outline of the reservoir. But sometimes they are different. Unfortunately the limitation of the seismic lines does not give a possibility to show more this in any cases.
We can say now that the information based on the Proni filtering results was useful for a clearing of the reservoir outline. The new outline is presented at this figure too.

Prediction of production features. The initial data for this example were presented by 2D seismic survey from the South part of Western Siberia. It was known that petroleum reservoirs of complex structure are presented in this area. The target reservoir was hosted in the shallow layers of Upper Jurassic. In the survey area 14 research wells, which discovered the reservoir, were available. The results of the Proni filtering using for analyzing of target layer were tested by these wells.
The seismic data from 19 profiles were processed on the based of the Proni filtering technology. As rule after Proni filtration the resulting stacks give more information for analysis of medium characteristics than we can estimate by formal procedures. For example, we have additional information about top and structure of a reservoir by analysis of different time intervals of these stacks for different frequencies. Short and strong response for high frequencies is typical for the top of a reservoir. For zones of wave fields connected with the reservoir we have a high attenuation and unstable response for high frequencies. Thus, if we want to keep all information for mapping from stacks after Proni filtration, we need to use few parameters. In our case we use two of them: energy of time intervals and coherence. These parameters were estimated on the resulting stacks for two time intervals: including target horizon and above of it. Calculated values for all stacks were mapping (see Figure 4). The resulting maps were tested by wells data. As we can see the good correlation between prediction zones of production features and data from wells for the map is provided. So it can be used for definition of a new well point.

Conclusions

Using this technology it is possible to locate zones of different absorption for different frequencies in the observed wave field. As a rule, location of such zones in high frequency domain by means of the real seismic data processing is the most interesting for next interpretation.
Processing of real data confirms efficiency of the algorithms for the complex problem of location of zones of anomalous absorption or scattering and studying features of target layers. Thus the Proni filtering can be used for a rather wide range of problems in processing and interpretation of seismic data.
Of course that anomalies changing of frequencies for reflection seismic signals can be connected with different reasons. Thus it is very important in the interpretation step to have enough well data to put up a relation between determining anomalies zones and target horizons features. The best situation is when we will have well data for different kind of horizon features. In the last case one can understand how anomalies zones can be related with fixed kind of features. These relations can be used for prediction of these features. For example, in the case of information about production and dry wells we can predict zones where some product (oil or gas) will be absent.

Acknowledgments

This research was partially supported by CENPES/PETROBRAS S/A.

References

Brekhuntcov A.M., Ilein J.M., Jedkov A.V., and Mitrofanov G.M., 2001, Prediction of Production Features on Proni-filtration Results. Abstract of papers EAEG 63rd meeting, Amsterdam.

Marple S. L., Jr., 1987, Digital Spectral Analysis with applications. Prentice-Hall, Inc., Englewood Cliffs, N. J.

Mitrofanov G.M., Nefedkina T.V., and Girshgorn L.Sh., 1998, Aspects of Proni-transformation applying in seismic data processing, Annales Geophysicae, p 156, Part I, Supplement to Volume 16.

Mitrofanov G.M., Zhan Zhitian, and Cai Jiaming, 1998, Using of the Proni Transform in Processing of Chinese Seismic Data, 68th SEG Meeting, Expanded Abstracts.

Soares Filho D.M., Priimenko V.I., Mitrofanov G.M., Oliveira S.A.M., Roseane M. Misságia, Gomes E.C., et al., 2002, Processamento de dado sísmico com técnica de filtragem Proní e imageamento WCDP. Programa LENEP/CCT/UENF - CENPES/PETROBRAS S/A. Contrato: 6502178017. Relatório Final, 159pp.

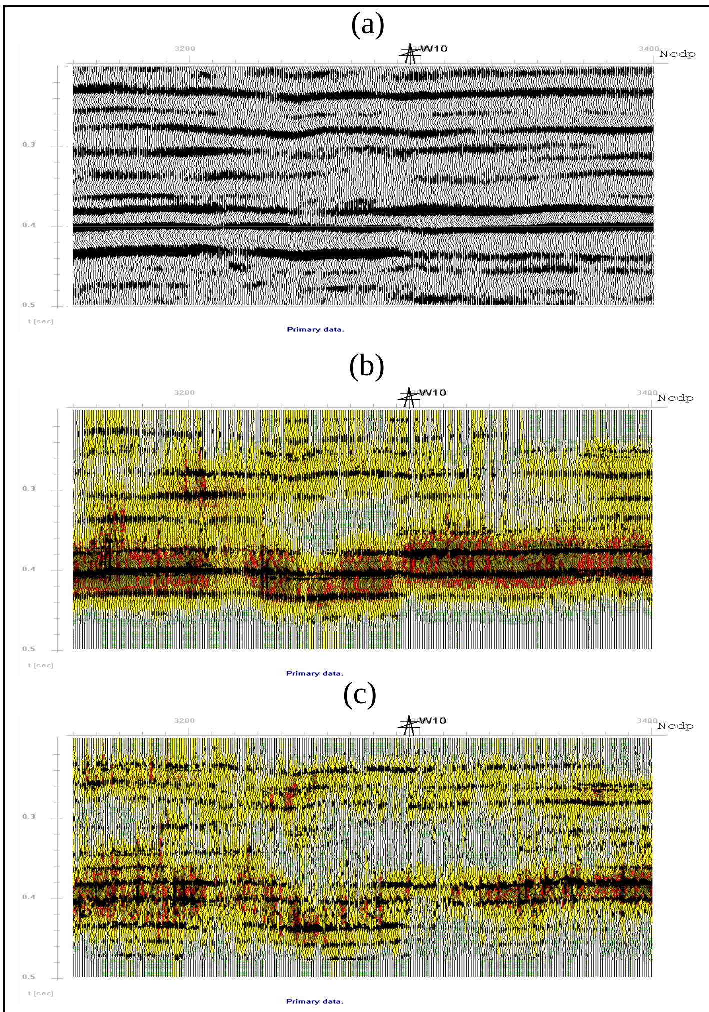

Figure 1

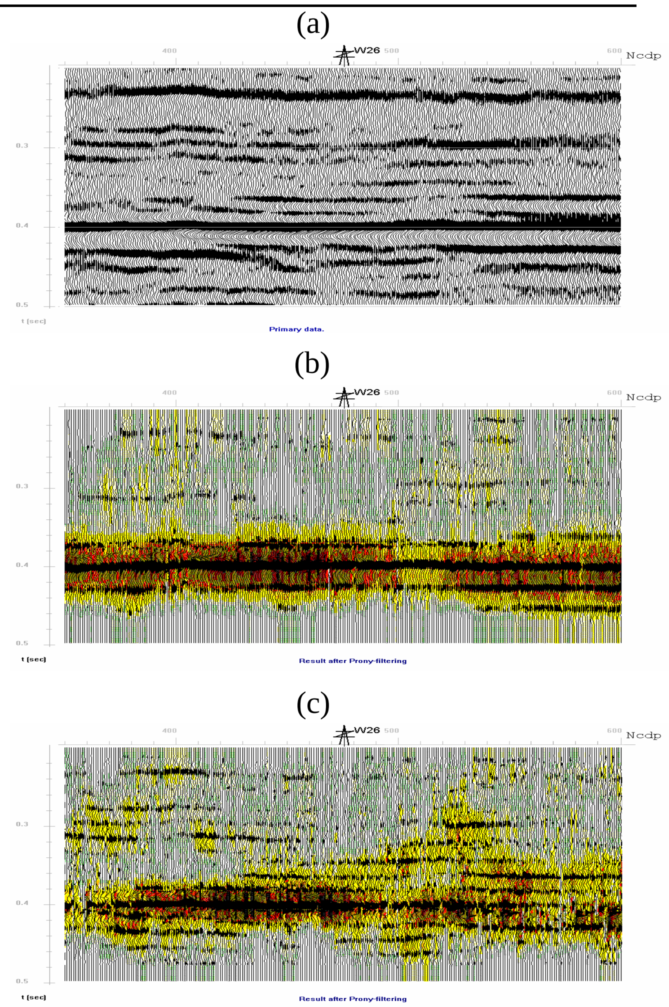

Figure 2

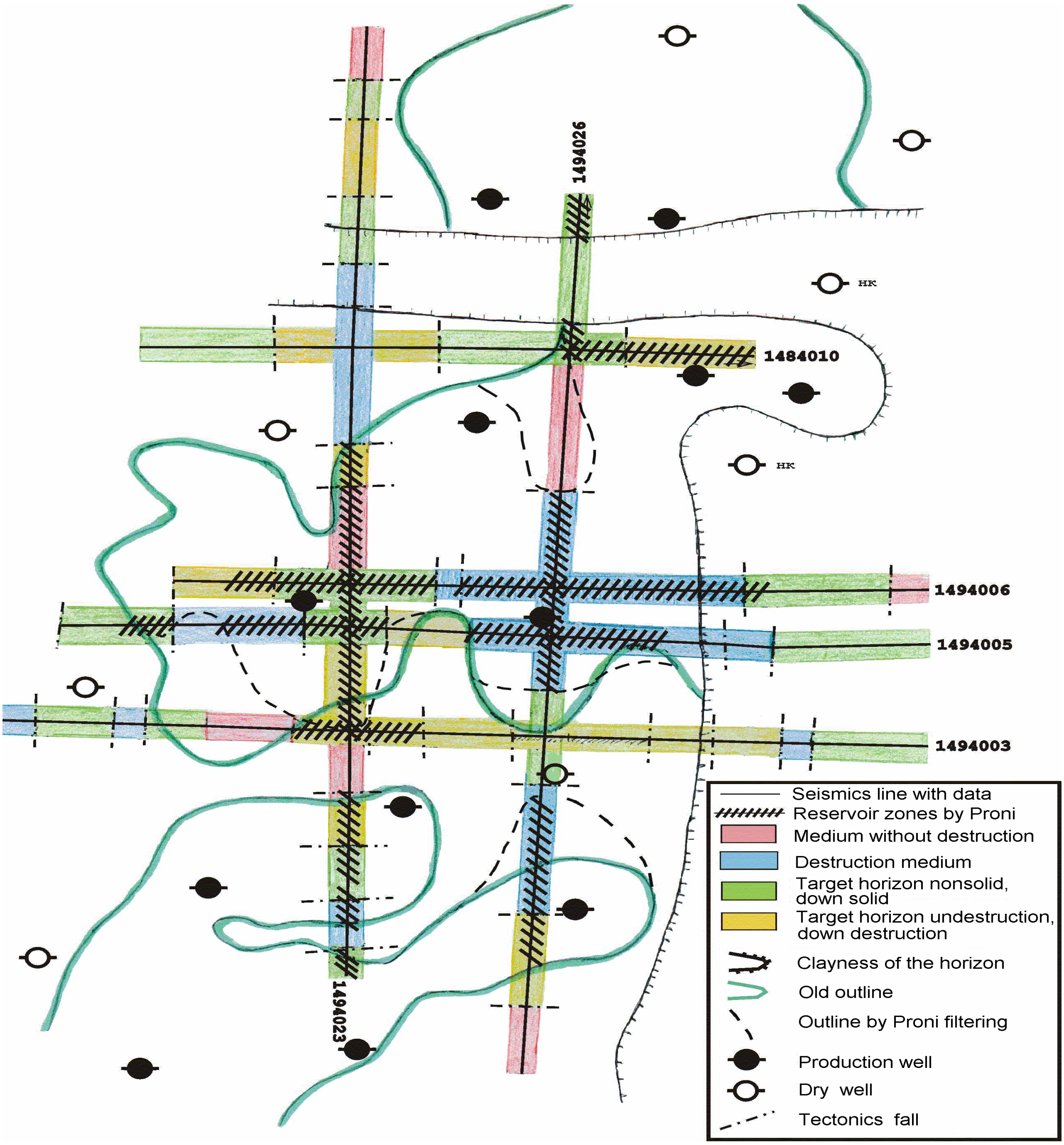

Figure 3. Seismic profile lines and results of the Proni analysis. Early results of the oil company interpretation with tested wells are shown, too.

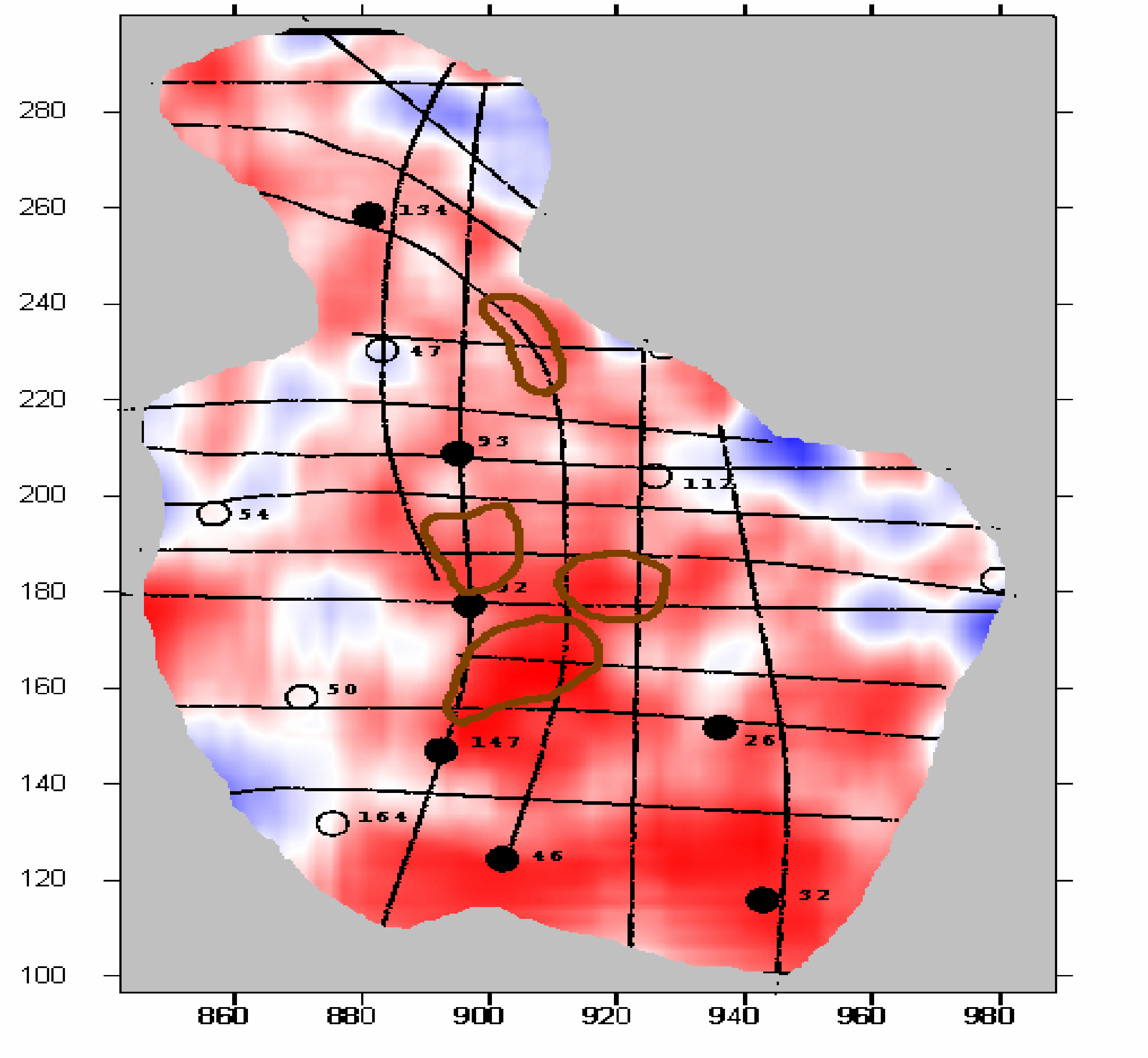

Figure 4. Map of prediction features for one production horizon (Western Siberia) created on the bases of Proni filtering. Results of drilling for this area are shown, too.