Study of velocity characteristics of section based on data acquired by seismic technique of Parametric Deconvolution of Reflection

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Abstract. The paper is devoted to more accurate design of velocity model of geological section on the basis of Parametric Deconvolution of Reflections (PRO) technique. CDP technique applied widely does not solve too many problems without resolution of which the petroleum industry in the country will definitely be behind the leading petroleum industries worldwide. The reason of such low economic indexes of geological survey consists in no improvement of resolution ability of CDP technique in Azerbaijan for over 30 years. One of the most complex and important tasks of seismic survey in areas with complicated setting in Azerbaijan consists in evaluation of velocity characteristics of geological environment which is crucial for development of adequate geological model. The paper gives the examples of practical use of PRO method applied to real seismic data from the worldwide practice. Results of PRO velocities calibration with the average velocities of vertical seismic profiling has been shown: the curves almost coincide. It has been noted that detailed development of velocity model by use of PRO allows to successfully resolve kinematic, as well as dynamic problem: velocity anomalies (low interval velocities) are stipulated by gas deposit presence. Results of PRO application in one of the areas of Absheron oil and gas region are displayed. Study of PRO velocities allowed to outline low velocity areas related to overpressure zones and possible presence of oil and gas reservoirs. Recently drilled well recovered oil and gas horizon in Miocene deposits.

1. Introduction
More than 60 years the success of exploration for oil and gas is defined by seismic survey techniques: acquired seismic survey data allow to define well locations and decrease the number of “dry” holes and low output wells [1]. Quantum leap in development of seismic survey has been made 50 years ago with introduction of Common Depth Point (CDP) technique. However, the application of 2D/3D CDP technique has some restrictions: it is efficient only while exploration of boundary surfaces with small dip angles. Multiple attempts made to improve CDP technique were unsuccessful. Too many problems are not solved by use of CDP technique and without resolution of these problems the petroleum industry in the country will definitely be behind the major petroleum companies by some indexes. The reason of such low economic indexes of geological survey in Azerbaijan consists in no improvement of resolution ability of CDP technique. Errors in evaluation of seismic wave velocities (this is one of the major parameters of seismic wave field) by CDP constitutes 10-70% and higher (the errors are proportional to complexity of reflection boundaries, variation of layer thicknesses and velocities in geological targets,
etc.). Due to these large errors in evaluation of velocities by CDP (average, interval) the geological target images are deteriorated and with further complexity of environment they became unclear up to disappearance in the complex interferential wave field in the large portions of studied areas. Through all these years of stagnation in seismic survey the geophysicists were forced “to draw” by unreliable data of CDP the deteriorated and false structures, false faults, etc.

For the past 20-25 years the major petroleum companies around the world provided the quantum leap in geological survey “mostly due to avalanche-like introduction of high-resolution 3D seismic survey (high-resolution version of 3D seismic survey) in the world practice, which prove to be cost-efficient technique due to drop of expenditures for drilling of dry and unprofitable wells by ten folds (in some cases by hundred folds) [5, 6, 8]. However, in Azerbaijan the 2D CDP seismic continues to “flourish” almost in its initial form for over five decades already.

2. Problem statement
One of the most challenging and important tasks of seismic survey in complicated areas of Azerbaijan is evaluation of velocity characteristics of geological environment. Design of reliable geological model of the environment depends on success in resolution of this task. However, while processing of reflection survey data the significant amount of software packages developed up to date is aimed at gathering of time-stacked CDP section. As a result of various formal procedures while iterative calculations of kinematic and static corrections in many cases it is possible to gain coherent accumulation of the signal acquiring time section, which theoretically can be gained without such processing, by record of reflected waves in case of combined source and receiver. It is not required to know velocities at all in this process. In fact, the effective velocities, i.e. stacking velocities $V_{CDP}$ are some parameter of stacking and by their values they far from the real average velocity. Therefore, velocities acquired by downhole measurements (VSP, seismic logging) and interpolated from one well to the other are applied while interpretation. As a rule, the number of such wells are very limited and this is the reason of simplified evaluation of velocity characteristic of environment within seismic survey area.

3. Research questions
Obviously, for detailed study of velocity characteristics of deep layers there is a need to define the average velocity for each point of seismic section. This is possible by method of Parametric Deconvolution of Reflections (PRO) of the PROspect software package (the product of “Pangea” Ltd.), the part of PANGEA system. In the process of velocity analysis on the basis of PRO [2, 3, 4] the average effective velocities $V_{av(PRO)}$ are defined. The term of effectiveness is in fact the result of two factors – the unknown form of the border and unconsidered refraction at intermediate borders in covering layer. In the PRO method the effect of the first factor is removed as the applied contact transformation provides stacking at the true value of velocity acquired by sorting out for any form and border nature. Refraction factor plays a secondary role, and as processing practice shows it raises the absolute value of velocity gained by stacking up to 4-5 %. Thus, while processing the profiles of PRO velocities are derived within the accuracy to multiplier factor distinguishing from average geological velocities [10].

This distinction is a subject of correction by use of velocity data acquired from nearby wells. At this, the relative error of the average velocity along the profile does not exceed 1–2 % and depends on heterogeneity of the environment. Interval effective velocities $V_{int(PRO)}$ derived by average effective velocities $V_{av(PRO)}$ depending on to inherit their errors also. The important feature is the possibility in the PRO method to define velocities in time domain only by use of scattered and diffracted components of the wave field in case of absence of regular axes of co-phase. In the scattering process the minimal-phase pulse losses its property of minimality as a result of “transferring” of amplitude maximum into the next phases. At this, the energy maximum, used for automatic evaluation of PRO velocity, offsets for more time leading to additional velocity decrease. Thus, in addition to the real decrease of velocity in under compacted rocks the apparent one exists due to the scattering. [7, 9].
4. Purpose of the study
The summary effect identified while PRO velocity analysis is the search feature that makes it possible to identify under compacted and scattered targets such as reef deposits, gas and oil accumulations and fault zones characterized by strong scattering of seismic waves. Search targets may be nonstructural traps of various origin. Their mapping is quite difficult without adequate studies of velocity distribution in the environment. It has been analytically proved that in the PRO method independently from forms of reflecting borders the stacking velocity and maximally effective velocity coincide and are equal to true velocity in homogeneous environment. This allows to consider within the framework of average velocity model the distribution of PRO interval velocities, derived by processing as reflection of geological section along with outlining of structural stages, tectonics, velocity inhomogeneities, reservoirs and stress state of the environment.

5. Research methods
The results of PRO method applied to real seismic data from the worldwide practice are given here [3, 4]. The source data for implementation of detailed velocity analysis are processed CDP diagrams used for acquisition of stacked time section by CDP technique, without kinematic corrections. The acquired result is stacked section acquired for each profile on the basis of PRO method and respective velocity sections (in time and depth scale). To demonstrate the advantages of detailed velocity analysis by PRO method the figure 1, a and b, displays the stacked section along the seismic line with superimposed section of interval velocities $V_{int(PRO)}$ in time and depth scales respectively. To visualize this, the further consideration is done in a larger scale of a fragment of this seismic section.

![Figure 1](image)

**Figure 1.** The stacked section of PRO in time scale (a) and in depth scale (b) combined with section of $V_{int(PRO)}$.

In the right portion of figure 2 (on the plane of velocity spectrum) the velocity curves for a point in well 1 are displayed. These include: $V_{av(VSP)}$ – average velocities defined by VSP; $V_{int(VSP)}$ – interval velocities calculated by $V_{av(VSP)}$; $V_{av(PRO)}$ – average effective velocities calculated by PRO method by use of seismic data; $V_{int(PRO)}$ – interval effective velocities calculated based on $V_{av(PRO)}$. Comparison of $V_{int(PRO)}$ and $V_{int(VSP)}$ displays well correlation of velocity curve forms. This confirms the expediency of PRO interval velocities application as a search feature of under compacted rocks across the section with possible presence of productive reservoirs.
Figure 2. Fragment of stacked section of PRO in time scale combined with \( V_{int(\text{PRO})} \) section.

Figure 3 displays the results of calibration of \( V_{av(\text{PRO})} \) velocities to \( V_{av(\text{VSP})} \) velocities. Coincidence of these curves is observed on the velocity spectrum plane. This fact is shown in coincidence of calculated interval velocity curves. It can be noted that the type of interval velocities section is not changed significantly as a result of calibration applied to VSP data.

Figure 3. Fragment of stacked section of PRO in time scale combined with section of \( V_{int(\text{PRO})} \). \( V_{av(\text{PRO})} \) are calibrated with \( V_{av(\text{VSP})} \).

Figure 4 demonstrates the results of recalculation of seismic section from time to depth scale with effective velocities \( V_{av(\text{PRO})} \) and after their calibration to \( V_{av(\text{VSP})} \) respectively. Acquired depth sections in comparison to time sections are not influenced by velocity anomalies (low interval velocities), caused by presence of gas deposit. It must be noted that the project for drilling of well N1 has been drawn on the basis of exploration works. As no data on velocity characteristics of the section at target depth was available the hypothesis on presence of large depression zone has been accepted while geological model design. As a result, the recovery of thick series of commercial type of reservoirs was supposed. Drilling data have not proved the adequacy of geological model based on interpretation of CDP stacked time section data only. Detailed velocity analysis by PRO method made in addition to CDP technique has excepted the supposed presence of depression zone before the interpretation process. Application of PRO technique allows to decrease the risks and more accurately outline the productive portions in section.
Figure 4. Fragment of stacked section of PRO in depth scale combined with section of $V_{\text{int}(\text{PRO})}$ (a). $V_{\text{av}(\text{PRO})}$ are calibrated with $V_{\text{av}(\text{VSP})}$ velocities (b).

6. Findings

To analyze PRO seismic velocities, the cubes of interval and mean-square velocities acquired in the Hovsan-Zykh study area were downloaded. Study of PRO velocities enables us to identify the low velocity zones related to overpressure zones and possible presence of oil and gas saturated reservoirs. Figure 5 shows the map of maximum values of interval velocities between the reference horizon KaC$_2$ – IIIa (interval of KaC$_2$ and KaC$_3$ layers). Low interval velocity areas for Qala suite layers in Hovsany field coincide with zones of maximum thickness of oil saturated layers KaC$_2$ и KaC$_3$ outlined by drilling. The first anomaly of velocities from 3500 to 3700 m$\text{sec}$ coincides with wells of the West Hovsany. The second one is in the south-west from the center of Hovsany paleouplift to the west from well 1867 (approximate velocities are as 3400 – 3650 m$\text{sec}$). Another large anomaly of low interval velocities (lower than 3500 m$\text{sec}$) is located in the east from Hovsany field and coincides in plane with the alluvial cone area for Qala suite layers.

Figure 5. The map of maximum values of interval velocity between horizons KaC$_2$ – IIIa (interval of layers KaC$_2$ and KaC$_3$).

Figures 6 shows the sections of interval velocities in time scale according to Inline 362 and 366 through wells 1867 and 1870.

Recently drilled well N 1870 has recovered the oil and gas bearing horizon in the Miocene (i.e. velocity anomaly at 3100 – 3200 msec).
Figure 6. Interval velocities section in time scale according to Inline 362 for well 1867 (a) and Inline 366 for well 1870 (b).

7. Conclusion
The method of Parametric Deconvolution of Reflection (PRO) allows to define the average effective velocities in the each point of seismic section.

The important feature of PRO method consists in defining velocities in time domain only by scattered and diffracted components of the wave field at the absence of regular co-phased axes due to the specular reflectors. Consideration of local lateral variation of velocity within the line length makes it possible to more accurately define the shape and sizes of local uplifts and enhance the adequacy of hydrocarbon reserves evaluation.

PRO interval velocities can be used as a research attribute of under compacted rocks in section plane, which may include producing reservoirs also.

Study of PRO velocities makes it possible to define the low velocity areas related to overpressure zones and zones of possible presence of oil and gas saturated reservoirs.

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