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Research Article

STRATIFICATION OF REFLECTING HORIZONS IN THE CRETACEOUS DEPOSITS OF SOUTHERN FERGANA BASED ON 3D CDP SEISMIC AND VSP DATA

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ABSTRACT

The article discusses issues related to the stratigraphic tying of reflecting horizons within the Cretaceous deposits using one-dimensional seismic modeling. Stratification was carried out based on acoustic logging (AL) data, Vertical Seismic Profiling (VSP) data, and synthetic seismogram calculations.

Keywords: *Stratification, Hydrocarbon, Oil, Gas, Reservoir, Cretaceous, Reprocessing, Reinterpretation, Synthetic Seismogram, Seismic Exploration*

INTRODUCTION

At present, the Fergana petroleum-bearing basin occupies one of the leading positions in the Republic of Uzbekistan in terms of hydrocarbon potential of the underlying stratigraphic complexes, since this region is characterized by proven commercial productivity within the stratigraphic interval ranging from the Paleozoic to the Neogene. The discovery of prospective oil and gas targets in the lower stratigraphic horizons contributes to the further intensification of geological exploration activities and the comprehensive reassessment of each exploration target.

In this regard, detailed investigation of deep hydrocarbon accumulations, involvement of new oil and gas prospective targets of the lower stratigraphic complexes into the category of commercially significant fields, and their subsequent development represent some of the most urgent tasks of the present time. To address these issues, integrated analysis of geological and geophysical data using modern hardware-software systems and advanced technologies becomes particularly important, allowing geological exploration efficiency to reach a modern stage of development.

Cretaceous deposits are widely distributed within the Fergana depression in the foothill zones surrounding the basin margins. A significant portion of the section is represented by sandy-clayey, less frequently conglomeratic or carbonate sequences forming the red-bed Cretaceous formation of the Fergana Basin. In addition to the red-colored deposits of freshwater continental origin, deposits of inland basins with normal marine salinity are also present, characteristic exclusively of the Upper Cretaceous sediments and playing a subordinate role within the Cretaceous section.

Numerous studies have been devoted to the stratigraphy, lithology, and paleogeography of the Cretaceous deposits of Fergana. The principal object of investigation in these studies was the Upper Cretaceous deposits containing marine fauna remains and therefore more readily amenable to stratigraphic subdivision than the predominantly barren red-bed Lower Cretaceous–Cenomanian deposits.

The principal tool in the exploration for hydrocarbon (HC) accumulations within the Cretaceous deposits is Common Depth Point (CDP) seismic exploration, particularly in its 3D modifications. However, the stratification of reflecting horizons within the Cretaceous deposits, especially in their lower part, presents certain difficulties, and the present work is aimed at filling this gap.

MATERIALS AND METHODS

To solve the stated objectives, previously acquired 3D CDP seismic data from the southern flank of the depression were reprocessed and reinterpreted within the "Paradigm" hardware-software complex, including stratification of reflecting horizons. For this purpose, synthetic seismograms were calculated and one-dimensional seismic modeling was performed in the “Paradigm” software environment.

Calculation of a synthetic seismogram is the process of generating a theoretical seismic signal based on a geological model and petrophysical data, which is subsequently compared with real seismic data in order to verify the correctness of geological concepts and to tie well information to seismic data.

The methodology for synthetic seismogram calculation on the “Paradigm” platform includes several stages: definition of the geological model, generation of wave fields (using various algorithms such as FDTD or BEM), and subsequent visualization of the obtained synthetic seismograms. Accurate calculation requires specification of medium parameters (velocities, density, anisotropy), as well as source and receiver characteristics.

Stratigraphic tying of reflecting horizons was performed based on one-dimensional seismic modeling. To create one-dimensional models, acoustic logging (AL) data from wells located directly within the 3D seismic cube were utilized.

Correction of interval transit time curves for compressional waves (DT) was performed. The wells Chakar-2, Markaziy Avval-31OE, Xankiz-53 and Xartum-14 were selected for analysis because their locations are situated within the investigated territory and in different geological settings; therefore, these wells could potentially be used for seismic-stratigraphic correlation (Figure 1).

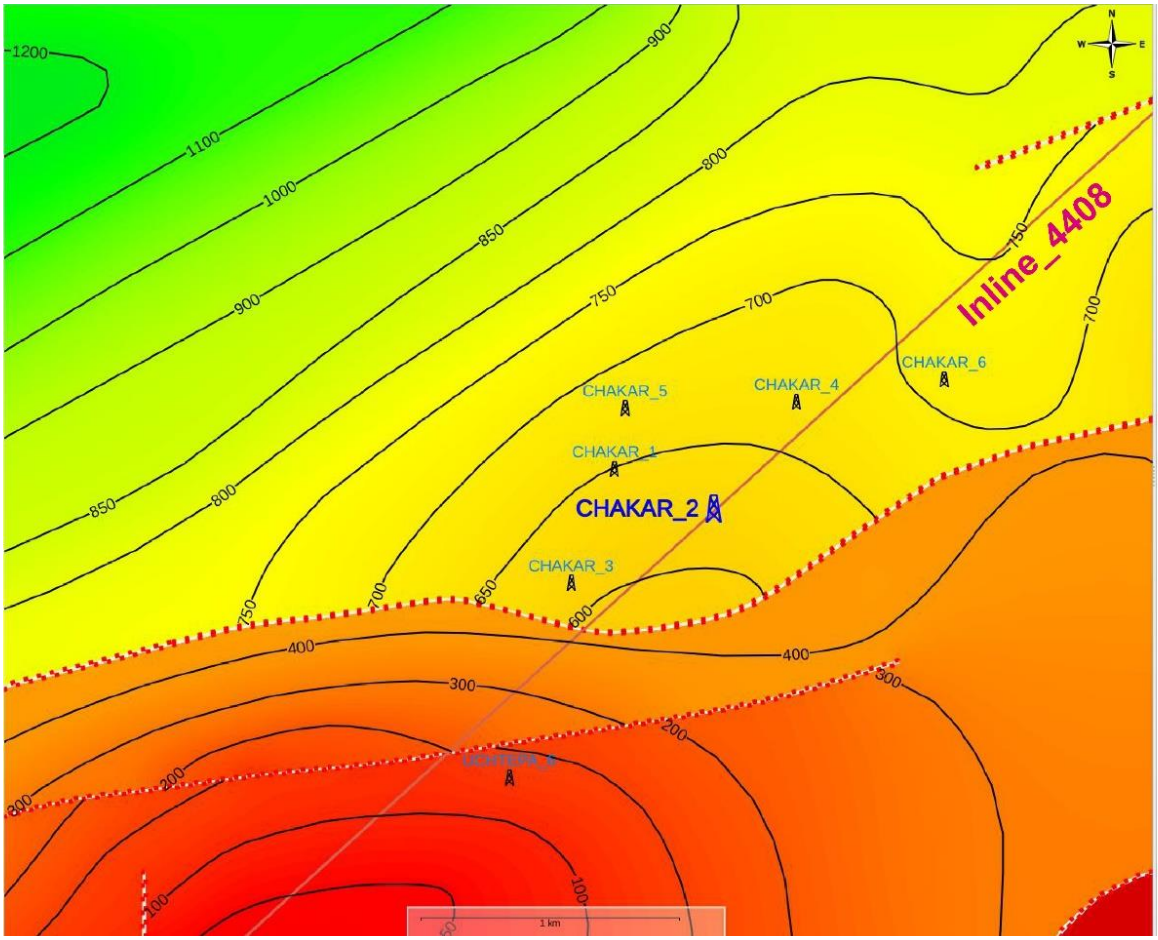


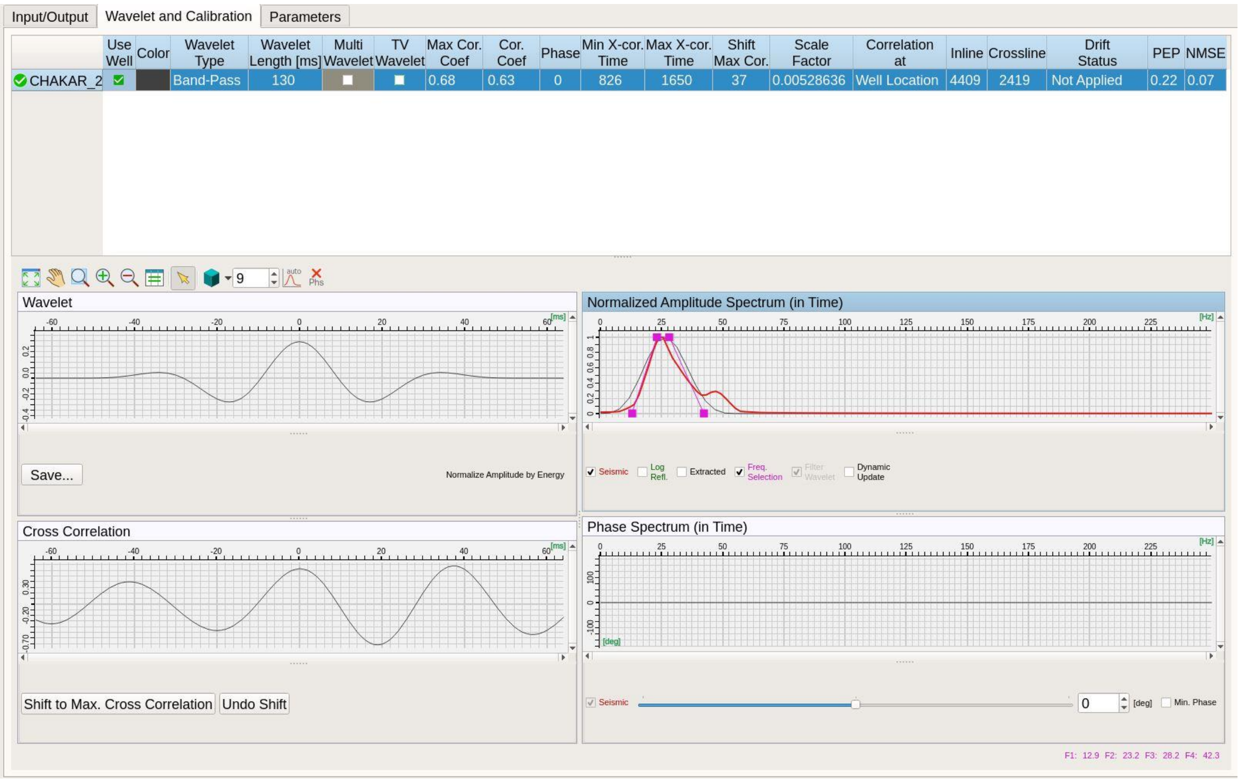
Figure 1. Chakar oil and gas field.
Layout map of exploratory well Chakar-2 and Inline-4408.

Within the study area, VSP data were available from several wells (Xodjaabad-1P, Markaziy Avval-5, Xankiz-53 and Xartum-15), and these data were used for seismic tying. During the calibration of well acoustic models with the wave field, VSP data were utilized as the initial "time-depth" relationship.

The result of one-dimensional seismic modeling is represented by synthetic traces obtained through convolution of the reflection coefficient series with the extracted wavelet, whose amplitude spectrum was determined from the autocorrelation function of seismic cube traces within the modeling interval.

The tying procedure was performed according to the similarity criterion between synthetic and seismic traces. The seismic wavelet shape is zero-phase, while the polarity of VSP corridor stack traces is normal, which means that a positive extremum corresponds to an acoustically harder boundary. Matching of synthetic and seismic traces was carried out by maximizing the cross-correlation function (CCF). The result of stratigraphic tying was controlled by the value of the correlation coefficient (CC) between synthetic and real traces, the CCF, differences between interval velocity plots of the input and output "time-depth" relationships, the extracted wavelet, as well as other input and output parameters shown in Figure 2.

As an example, Figure 2 presents the result of stratigraphic tying for well Chakar-2 (Inline-4408) to the actual stacked trace of the seismic cube. The correlation coefficient calculated between the synthetic and real traces within the analysis window of 500–1700 ms is approximately 0.65 in the frequency band of 8–60 Hz.



	Use Well	Color	Wavelet Type	Wavelet Length [ms]	Multi Wavelet	TV Wavelet	Max Cor. Coef	Cor. Coef	Phase	Min X-cor. Time	Max X-cor. Time	Shift Max Cor.	Scale Factor	Correlation at	Inline	Crossline	Drift Status	PEP	NMSE
✓ CHAKAR_2	☑	■	Band-Pass	130	☐	☐	0.68	0.63	0	826	1650	37	0.00528636	Well Location	4409	2419	Not Applied	0.22	0.07

☑ Seismic ☐ Log Refl. ☐ Extracted ☑ Freq. Selection ☑ Filter Wavelet ☐ Dynamic Update

☑ Seismic 0 [deg] ☐ Min. Phase

F1: 12.9 F2: 23.2 F3: 28.2 F4: 42.3

Figure 2. Extracted seismic wavelet and cross-correlation coefficient (CC) for well Chakar-2.

For tying with seismic data in well Chakar-2, well logging data (WL + AL), VSP vertical hodograph data, a constant density log of 2.0–2.5 g/cm³ throughout the specified interval, and a fragment of the vertical section of the seismic data cube along Inline-4408 were used. Figure 3 shows both the aforementioned input data and the output data (acoustic impedance, extracted traces, and the resulting synthetic trace combined with actual SDC traces) for verification of the correctness of the calibration procedure.

Comparison of the VSP single-reflection stacked trace with a fragment of the vertical seismic cube section along Inline-4408 is demonstrated in Figure 4.

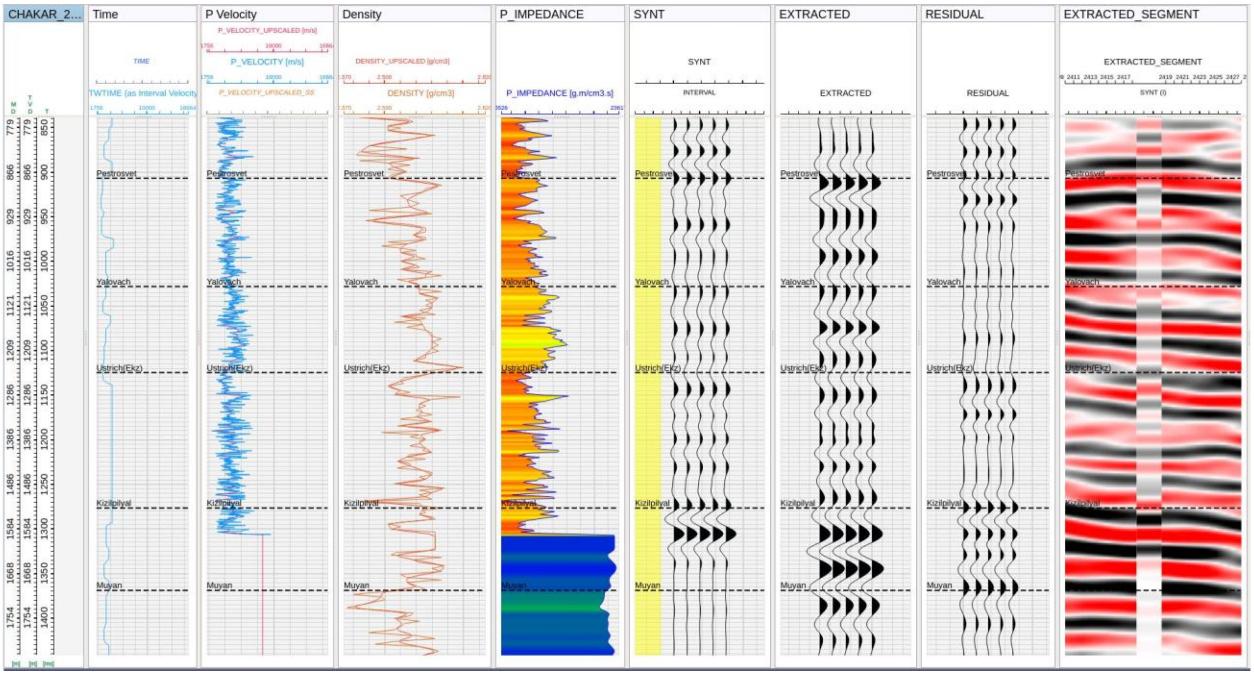


Figure 3. Well-log data panels for verification of the correctness of seismic data tying

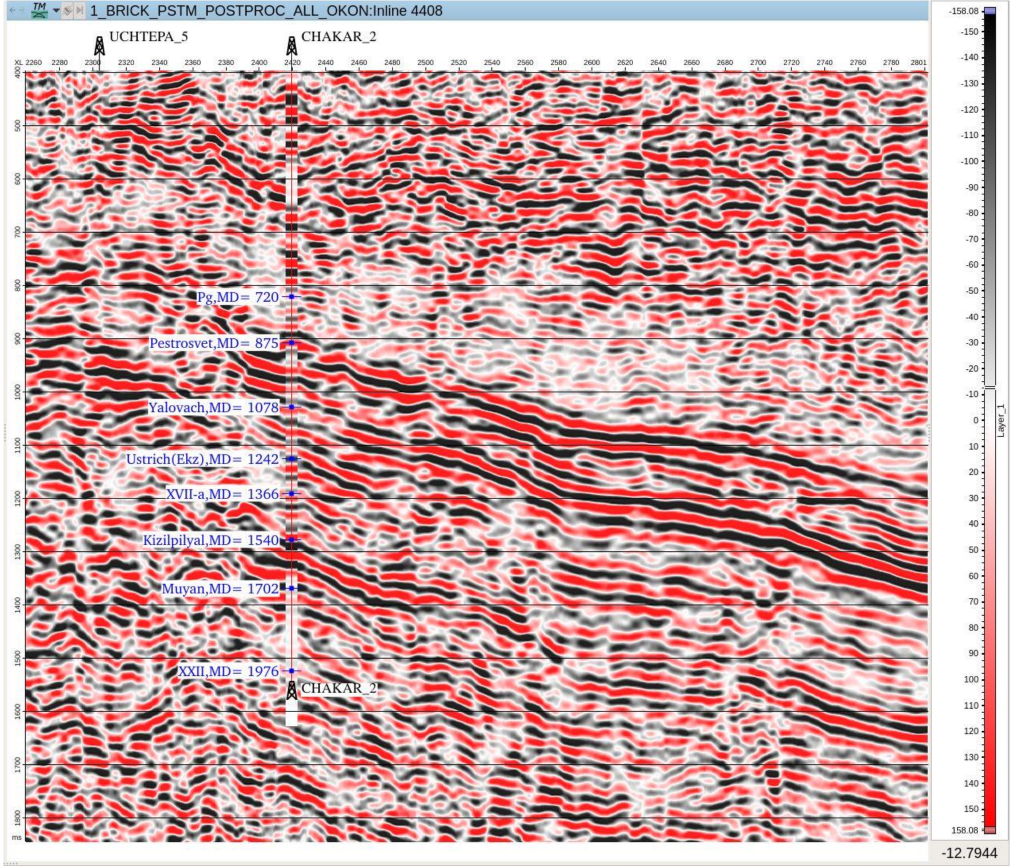


Figure 4. Fragment of the vertical stacked-trace cube section along Inline-4408 with synthetic seismogram.

A similar sequence of operations was also performed for wells Markaziy Avval-31OE, Xankiz-53 and Xartum-14, after which the obtained results were compared with one another. At the same time, different results were obtained for each well, i.e., reflecting horizons varied within the section of each well.

CONCLUSIONS

Based on the results of the performed work on stratification of reflecting horizons within the Cretaceous deposits of the southeastern part of the Southern Step of the Fergana depression, it can be noted that the Cretaceous section contains numerous reflecting boundaries of varying continuity, intensity, and stratigraphic affiliation. These horizons may be used for areal, partial, and inter-area correlation with subsequent structural mapping.

Thus, the results of the conducted investigations allow the following conclusions to be drawn:

- there is no unified regional marker reflecting horizon throughout the entire territory of the Southern Step within the Cretaceous deposits;
- the wave field of the Cretaceous deposits contains numerous reflected waves with varying continuity, intensity, and stratigraphic affiliation;
- the dynamic and elastic properties of reflected waves differ significantly across various parts of the investigated territory;
- the most intensive reflections are generated from reflecting boundaries associated with the Kizilpilyal, Ustrich, Yalovach and variegated Cretaceous suites;
- structural mapping and hydrocarbon exploration based on these Cretaceous reflecting horizons may lead to the discovery of new oil and gas fields within the poorly studied and weakly explored areas of the Southern Step of the Fergana petroleum-bearing region.

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