A revised interpretation of the Russkoye field, Western Siberia, using Multifocusing technology

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The development of advanced seismic processing techniques and software is defined by the need to raise both seismic data quality and the quality of their geological interpretation. At present, the primary method for prospecting is a CMP seismic survey, with both two-dimensional and three-dimensional data. At the same time, due to the expanded range of problems being solved by this method (starting from kinematic and dynamic interpretation up to the construction of detailed seismo-geological and digital geologic models), there is a need to raise quality and the level of detail. Furthermore, seismic surveys are now performed in increasingly complex environments. These include complex surface conditions, such as abrupt topography changes; the presence of rivers, lakes, karsts, etc.; heterogeneities in the near-surface section (permafrost zones, sand sediments, etc.); as well as complex subsurface seismogeological conditions (complex fault structure, salt and clay diapirs, etc.); all of which significantly affect key seismic parameters.

Multifocusing: a new processing technique

Standard CMP stacking with NMO correction of common depth point traces assumes knowledge of the exact velocity model along the time axis. Virtually all processing algorithms assume that the traveltime curve for the reflected waves on the CMP gathers is described by a hyperbole; in reality, however, this is not so. As a result, complex zones in both the shallow and deep parts of time sections are characterized either by the complete absence of seismic events, or by a low signal-to-noise ratio. In our opinion, traditional processing has the following basic limitations:

1) The statistical outcome of stacking is limited to a small number of traces in the common midpoint gather.
2) Non-uniform NMO stretching results in non-linear distortions and information losses in the near-surface section.
3) Hyperbole-based stacking can lead to lost target horizons in a geologically complex environment.

A new digital processing technology, called Multifocusing, helps to eliminate these limitations. The technology developed by Geomage includes a new method of calculating and applying moveout corrections, which is not limited by environmental complexity, and which has no non-linear distortions. The general theoretical aspects of this method have been described in a series of publications and conference papers (See References).

Multifocusing technology is based on the patented theory of homeomorphic imaging [6]. Seismic data are stacked on the basis of arbitrarily distributed source-receiver pairs, in accordance with a specific moveout correction. The correction is based on the local spherical approximation of the wavefront in the vicinity of an observation surface and spherical approximation of the separate sections of curved reflectors. Each Multifocusing stack (MFS) sample represents an optimally stacked value that corresponds to the optimal parameters, including the wavefront emergence angle and two radii of curvature. The output stack is close to an accurate zero-offset section.

The traditional CMP method uses only CMP gathers to obtain the central trace. Multifocusing processes all traces located within the limits of the summation aperture. The generalized plain illustration (Figure 1a) shows that to obtain an image point (marked in green), 15 CMP traces are needed (blue crosses). The number of traces covered by the Multifocusing technique (red crosses) is much higher. Real data processing can cover several thousand traces.

Moveout corrections are computed in accordance with the general theory of homeomorphic imaging, without using hyperbolic approximation. In order to obtain one sample of the image, the exact values of three parameters (Figure 1b) for moveout correction of traces located in the vicinity of the central point in the limits of the Multifocusing aperture are required:

- β - the angle of the wavefront approach to the central point of the base
- Rcre - the radius of the wavefront, whose centre is in the common reflection point
- Rcee - the radius of the front formed by normal rays emitted by different points on the reflector

Multifocusing automates the search for the optimal values of the aforementioned three parameters and does not require human intervention in relatively simple geological conditions. Moveout corrections are calculated iteratively.

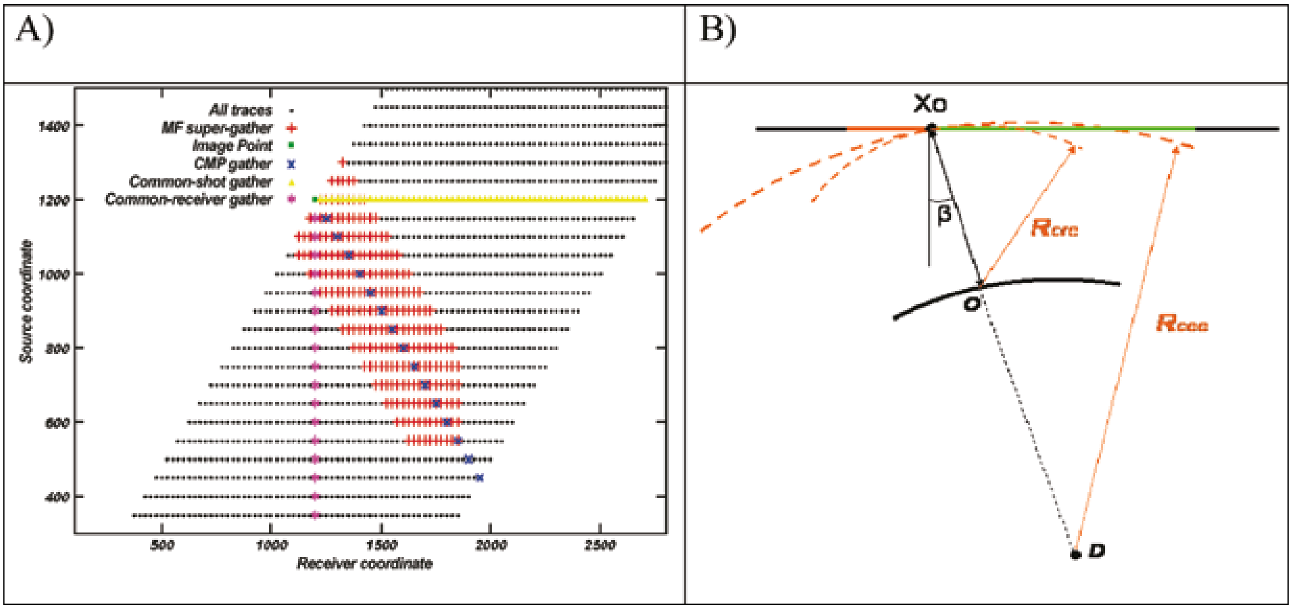

Figure 1a) Generalized plain of stacking points; b) Wavefront parameters.

The interval velocity model is generated and optimized for subsequent processing and interpretation, including migration. A controlled, variable-based method is used to avoid smoothing of the geological features in the horizontal plane. The optimal solution is found using a semblance function.

A core characteristic of Multifocusing is its ability to pick out the diffracting objects. This is extremely useful for tracing faults and facial changes when exploring hydrocarbon pools. The vertical resolution of the section is controlled and regulated throughout all of the processing stages.

Application at the exploration stage

The successful application of the technology is demonstrated in 2D and 3D data processing for the Russkoye field, Western Siberia, Russia. Geologically, the Cenomainian gas-oil reservoir of the Russkoye field is extremely complex. In order to determine structural details of the Cenomainian productive formations and construct a high resolution,

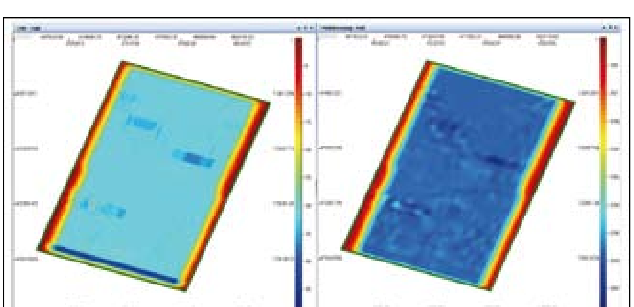

Figure 2 Maps of CMP and multifocusing stacking folds for 3D data from the Russkoye field.

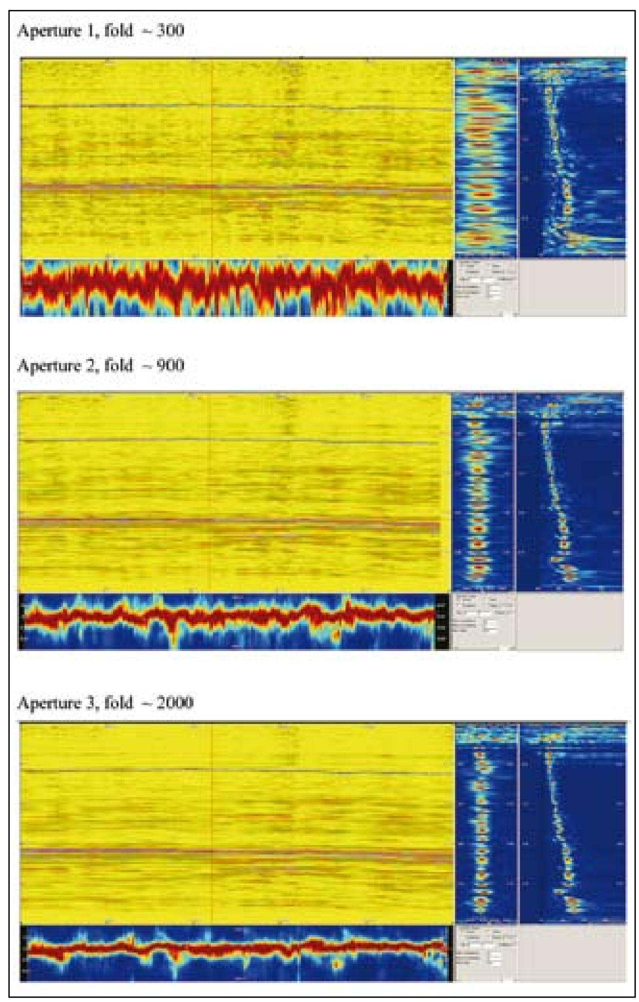

Figure 3 Stacking window for 3D multifocusing data from the Russkoye field.

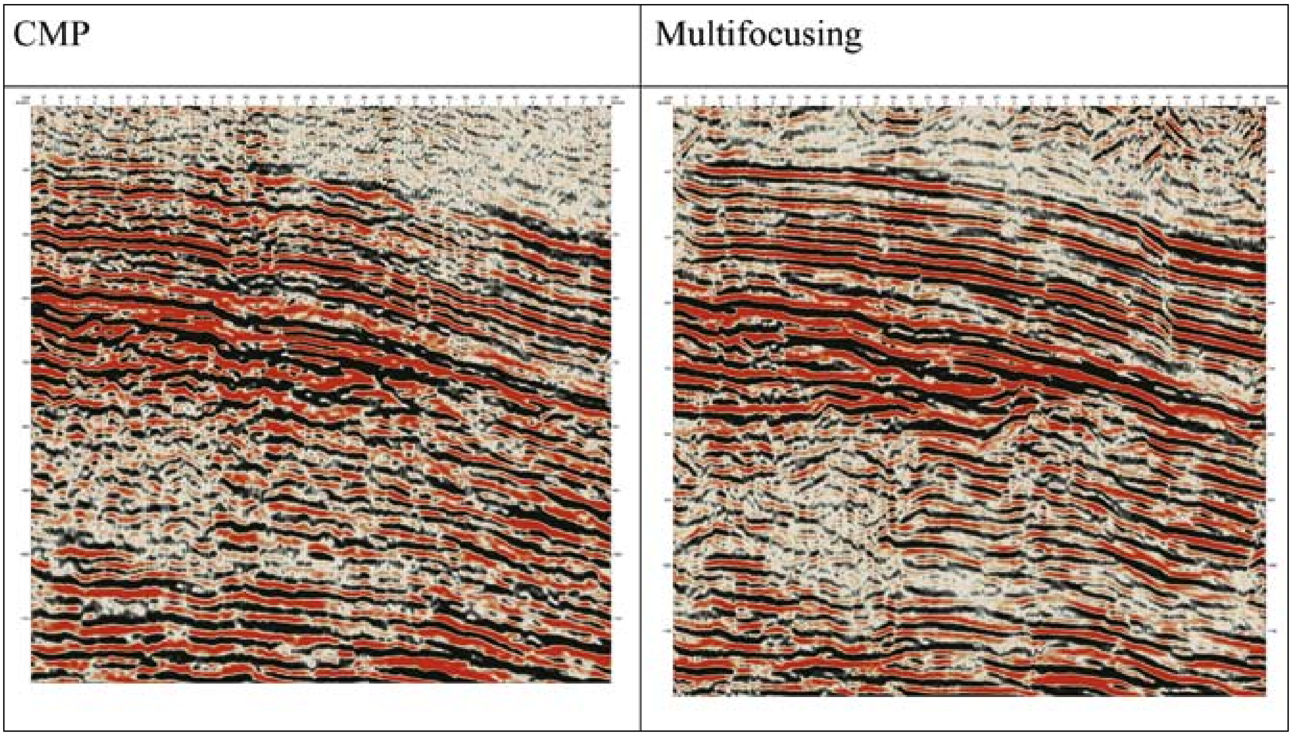

Figure 4 *Vertical sections stacked by CMP and Multifocusing techniques, 3D migrated volumes.*

three-dimensional geologic model, it was necessary to revise the approach to the processing of available seismic data. The goal was to obtain seismic images of high resolution, high coherency, and high signal-to-noise ratio.

One of the complicating factors in seismic imaging is surface conditions, which directly impact the target near-surface interval. The presence of an extensive river network with multiple lakes, tributaries and streams (gul-

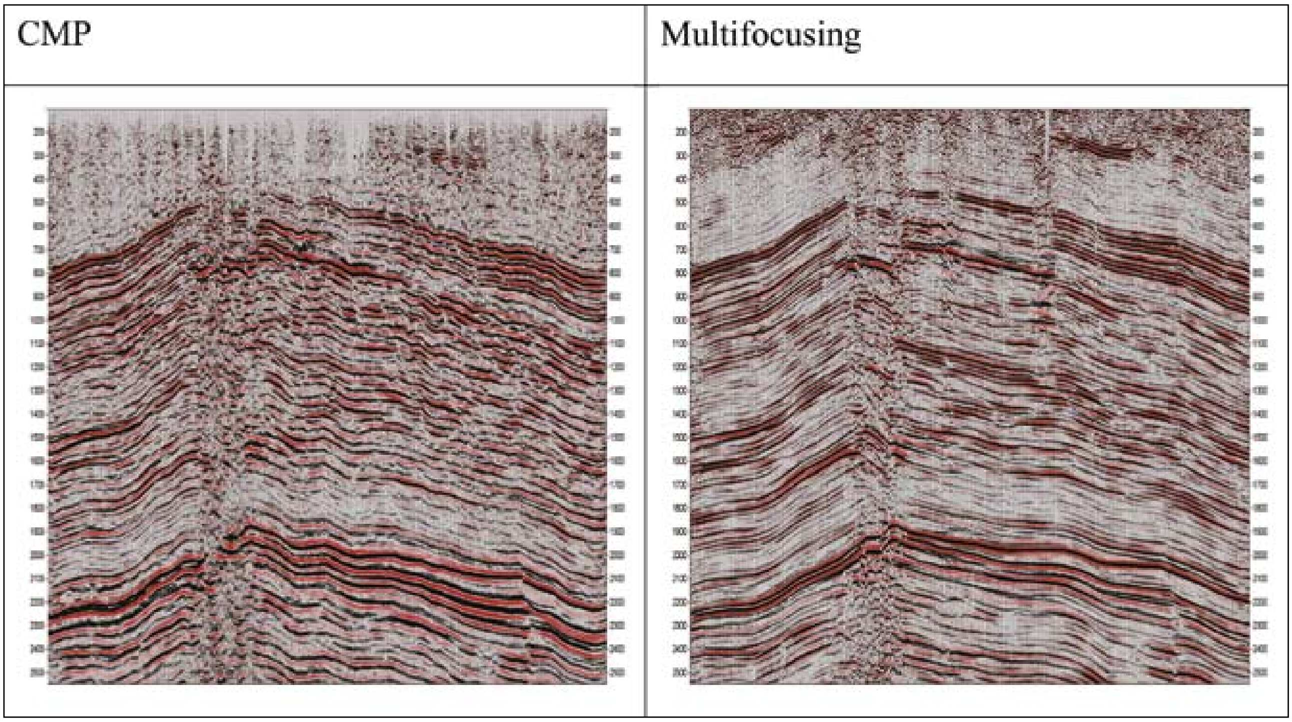

Figure 5 *Time sections (2D) stacked by CMP and Multifocusing techniques.*

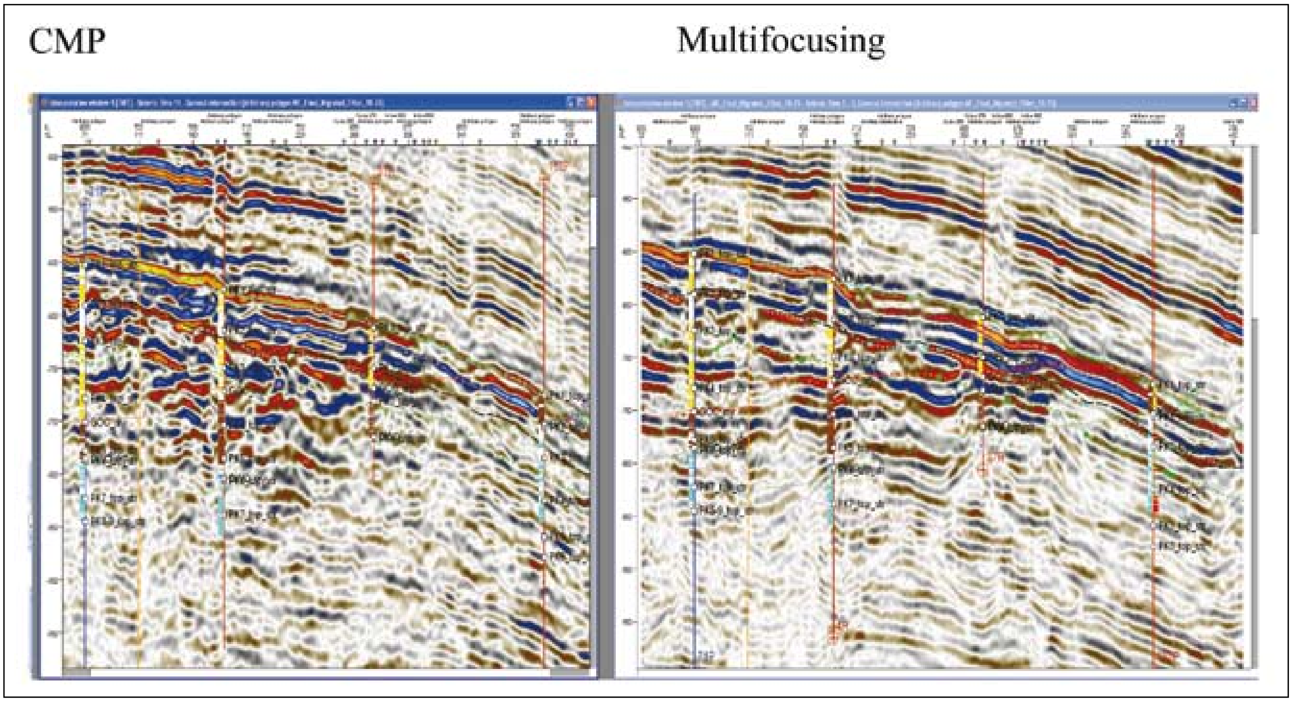

Figure 6 *Vertical sections calculated by CMP and Multifocusing technologies from migrated volumes, the Cenomanian interval.*

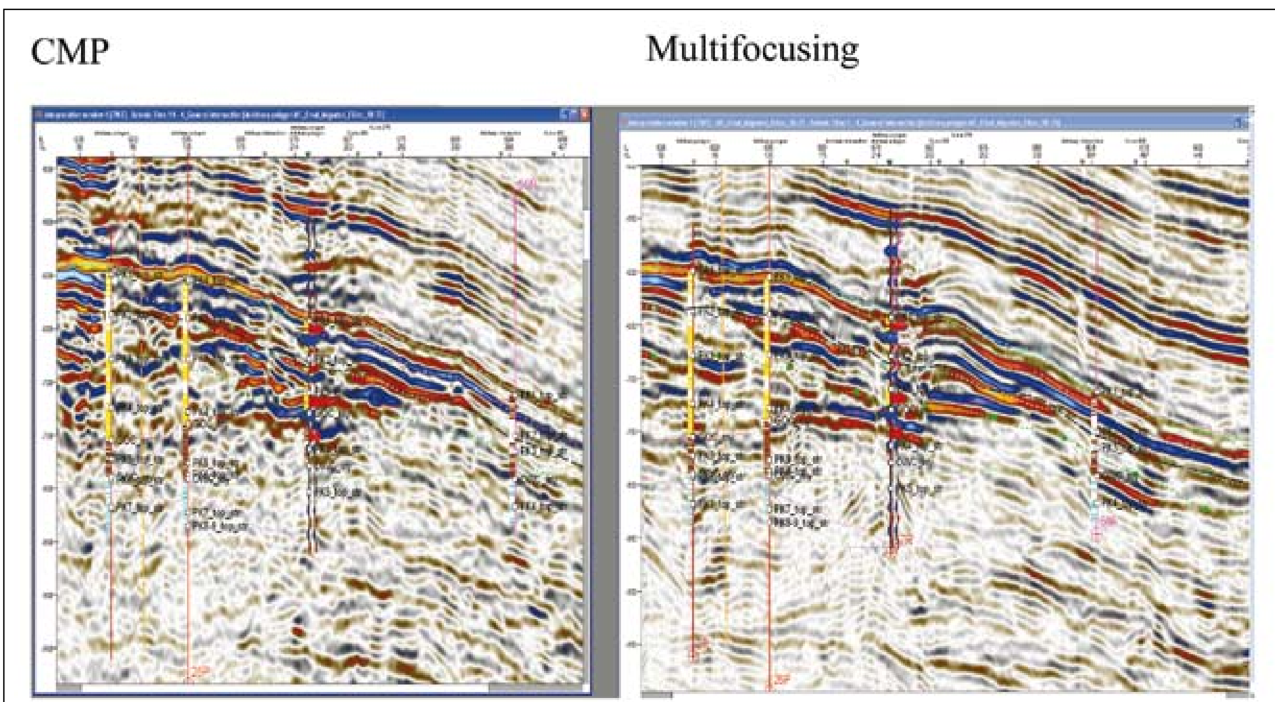

Figure 7 *Vertical sections, calculated by CMP and Multifocusing technologies from migrated volumes, the Cenomanian interval.*

lies, ditches, etc.) also unfavourably affected the folding of the survey due to the gaps in data. Furthermore, the presence of permafrost zones led to distortions in the traveltime curve hyperbolicity that affected velocity evaluation accuracy.

A comparison of stacking fold maps for the Russkoye field based on 3D CMP seismic data (acquired in 2000-2001), processed by standard CMP technology and Multifocusing, showed that the Multifocusing fold was double that of the fold parameter of the CMP method (Figure 2).

The signal-to-noise ratio for the Russkoye data was increased by applying the Multifocusing wide aperture (its size is controlled by the size of the Fresnel zone), which included a great number of traces. Figure 3 illustrates the increased coherency of reflecting boundaries with the increased aperture and resolution of vertical and horizontal velocity spectra. These traces were stacked without a nonlinear NMO stretching extension at short time intervals using the Multifocusing moveout correction formula, and taking into account a complex geological structure. The result is a set of output traces with an optimal set of wave parameters for each point.

Multifocusing time sections illustrate the obvious advantages of the new technology over the standard CMP method. The Multifocusing time sections are distinguished by a high signal-to-noise ratio and resolution. In the productive Cenomanian interval, the processing and subsequent migration reveal structural details of the productive formations. In particular, the segment of a near horizontal reflector, apparently corresponding to the gas-oil contact in the Pokur Cenomanian reservoirs, is now clearly imaged (Figure 4).

Figure 5 shows the stacked cross-sections obtained with Multifocusing technology, as compared to standard CMP processing. Field data acquired in 1990-1992 were characterized by rather low quality. This example shows that the technology makes it possible to obtain an effective result from data acquired many years ago (generally low-fold data).

An integrated analysis of additional information derived from using the technology, enabled an improvement in the quality of the data, and expanded the range of problems that could be solved. The obtained seismic images have now reached a new qualitative level. It also allowed a more exact definition of the spatial location and geological structure of the target object - Cenomanian reservoirs of the Russkoye field.

The high resolution of the computed seismic images improved the reliability of well-seismic ties and provided a clear correlation of seismic events corresponding to the top of the PK1 and PK2 productive formation of the Cenomanian interval. This is distinctly illustrated in Figs. 6 and 7. Low-amplitude faults dividing the reservoir into separate blocks with different gas-liquid contacts are clearly seen. The fragments of near-horizontal reflections, describing a gas-oil contact within the productive interval, are also clearly imaged.

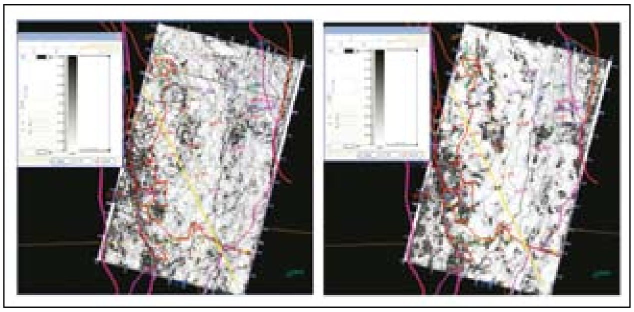

***Figure 8** Comparison of the variance attribute on slices of the PK2 layer, calculated from the CMP and multifocusing migrated volumes.*

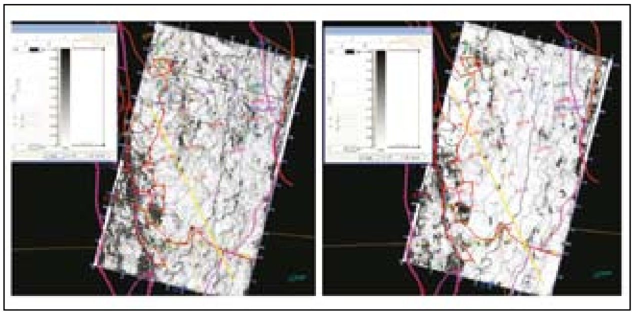

***Figure 9** Comparison of the variance attribute on slices of the PK1 layer, calculated from the CMP and multifocusing migrated volumes.*

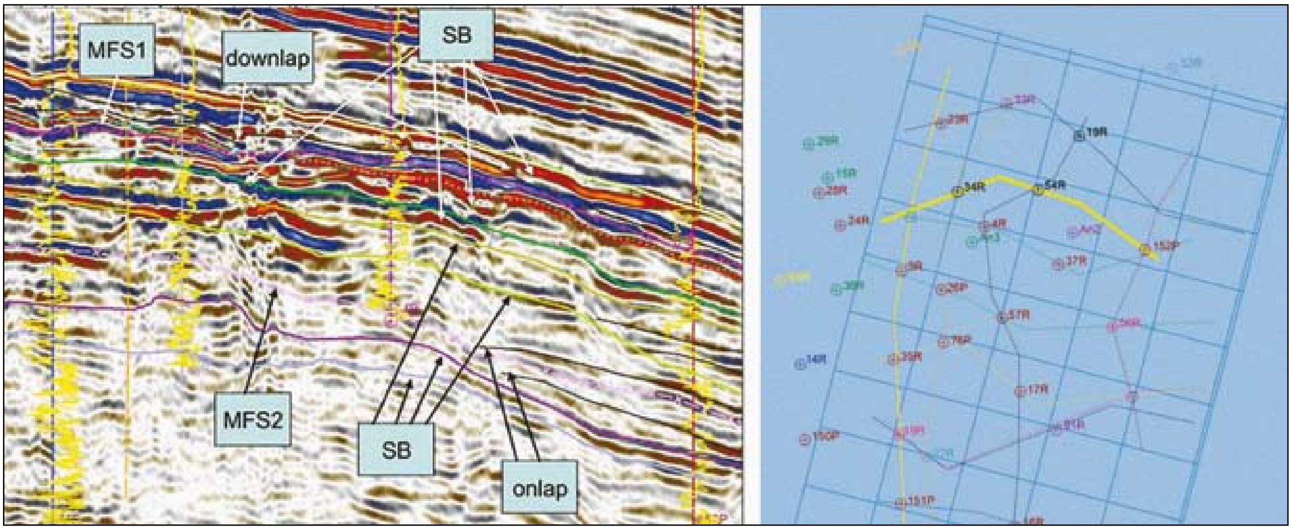

***Figure 10** Vertical slice through the arbitrary line between the wells.*

The maps of one of the seismic attributes - variance, computed along the reflection picking lines, corresponding to productive formations PK 2 (Fig. 8) and PK 1 (Fig. 9) - show the noise immunity of seismic data. In addition, different structural-tectonic lineaments are mapped from these images in more detail.

Figures 10 and 11 show time sections in the target interval after Multifocusing processing. These materials clearly identify structural details of the Cenomanian formations.

In the first stage of seismic interpretation, picking and correlation were performed for the reflection events related to the stratigraphic surfaces of key productive formations in the top part of the productive interval. These include PK (1-8) reservoirs - the main exploration objects in the Russkoye field.

The wavefield displayed the seismic toplap, onlap, and the presence of smaller lineaments inside the interval, bounded by reference surfaces. The geological interpretation of similar anomalies in seismic sections was based on an integrated analysis using well data based on the stratigraphic sequence. The fact that the PK sand bodies can be correlated in the inter-well region only based on rather dense acquisition systems is of primary importance. Based only on the well data, the sedimentary section was accumulated without any visible depositional breaks. Reliable clay barriers between formations are absent, and individual sandy bodies are merged throughout the area.

The PK1-8 formations were deposited with an abundant sand material supply. An absence of depositional cyclicity and an uneven alternation of sand-siltstone layers and a

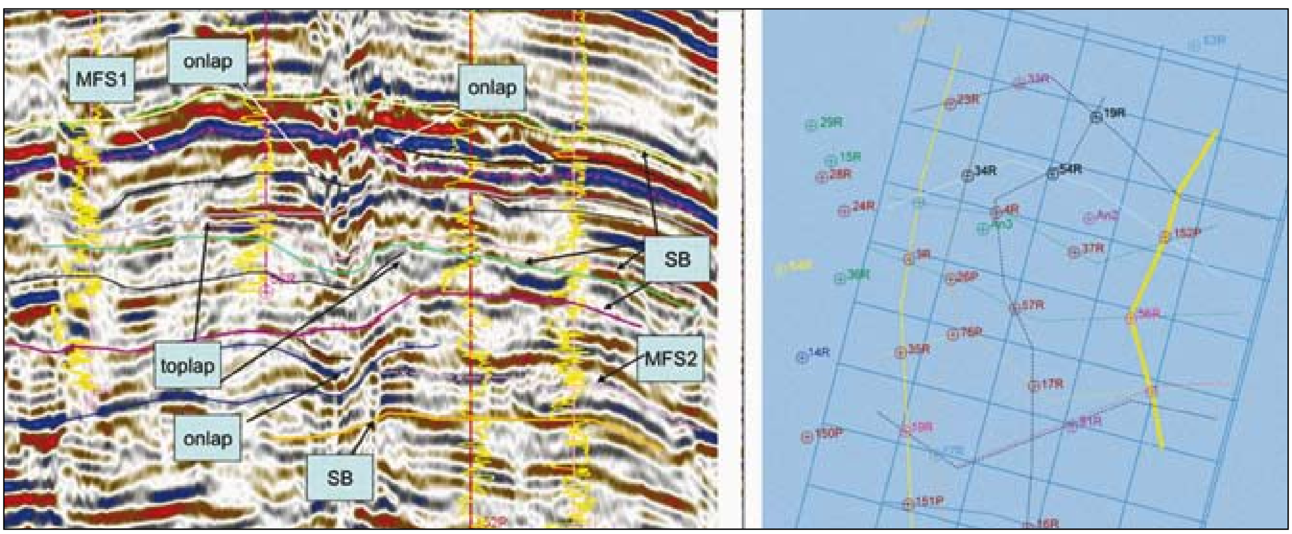

Figure 11 *Vertical slice through the arbitrary line between the wells.*

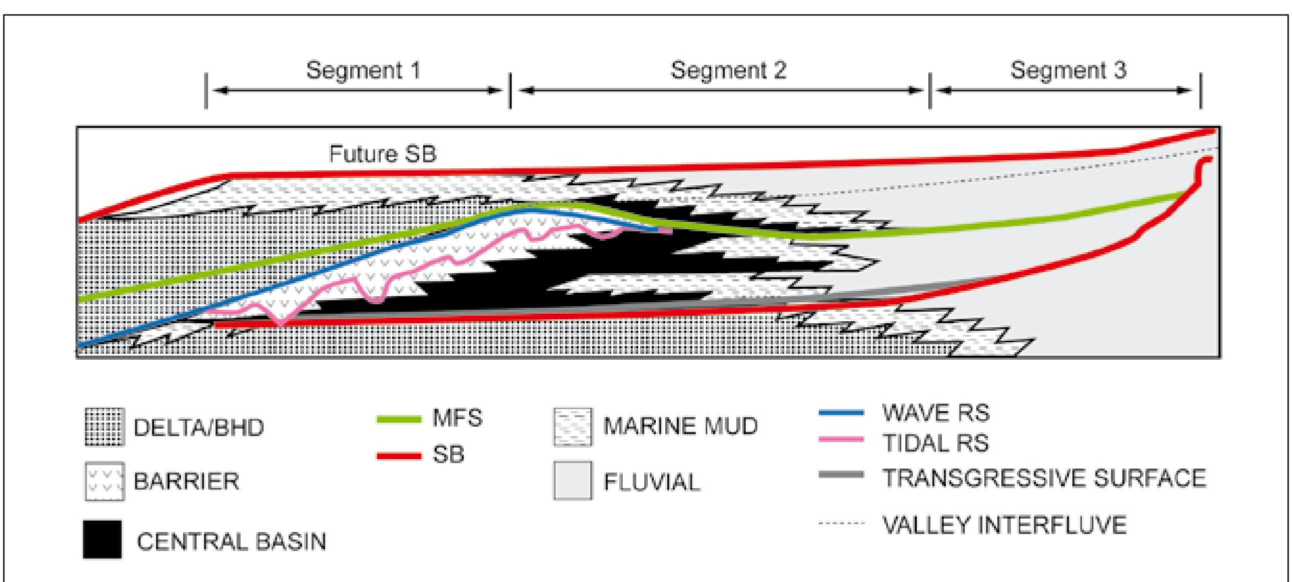

Figure 12 *Main unconformities in the upper part of the Cenomanian formations.*

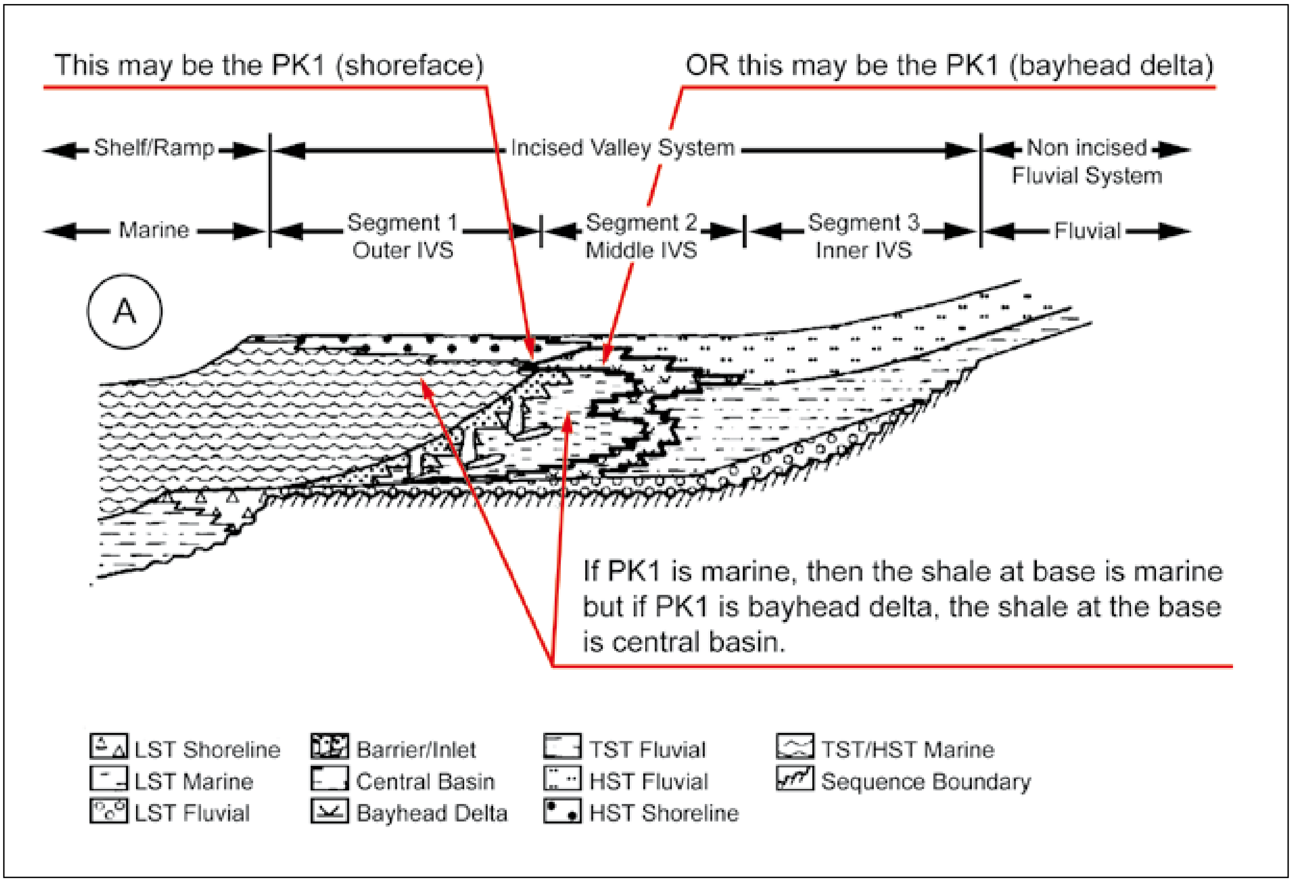

***Figure 13** PK1 reservoir structure model.*

small quantity of shale layers, are typical to fluvial and deltaic sequences. The Cenomanian section is completed by a regressive cycle 2-3 m thick of a blanket type (blanket shelf sand). Above the target interval, the Turonian shales of marine origin were deposited, with abundant fauna typical of relatively deep-water marine basins. All these factors point to a shelf depositional environment, and a deltaic and/or delta front genesis of sediments.

These integrated studies delivered a more accurate concept of the formation origins. The likely depositional models are presented in Fig. 12 (for the key unconformities) and Fig. 13 (for the PK 1 formation).

Conclusion

The integrated interpretation of well log data and seismic data processed by the new Multifocusing technology allowed the revision of the identification of unconformity markers and internal structural details in the northern part of the Russkoye field. Facies of marine origin (clays), slope deposits (shales), as well as shelf and deltaic sands were identified with more certainty using seismic reflections and based stratigraphic sequences, determined from the log data (together with core studies).

The integrated analysis resulted in the construction of a reservoir seismo-geological model of high vertical resolution. It will be used as a basis for revising sedimentation and reservoir origins. The entire set of information will produce a significantly updated hydrodynamic model required for the Russkoye field.

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