Submission code: 5QZGXRDB8X

Full Azimuth Multi-rays Pre-stack Depth Migration In the A Block

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Abstract Summary

Usually, the signal-to-noise ratio is low and velocity spatial change is severe in areas where fault traps develop. Seismic data processing brings challenges to geophysicists. It is extremely difficult to improve imaging in deep parts where faults harm wave propagation. Traditional pre-stack data migration imaging methods based on common middle points or common shot points are generated by the geophysical theory hypothesis. To overcome kind of challenge and improve imaging, Full azimuth multi-rays pre-stack depth migration was applied in the A block.

Introduction

Usually, the signal-to-noise ratio is low and velocity spatial change is severe in areas where fault traps develop. Seismic data processing brings challenges to geophysicists. It is extremely difficult to improve imaging in deep parts where faults harm wave propagation. Traditional pre-stack data migration imaging methods based on common middle points or common shot points are generated by the geophysical theory hypothesis. Full azimuth multi-rays pre-stack depth migration brings a new concept. Rays scan is generated from imaging point toward the surface, leading to a simultaneous emphasis on both continuous structure and discontinuous objects such as small faults and small-scale fractures. In this paper, a comparison was conducted between conventional Kirchhoff pre-stack depth migration and full azimuth multi-rays pre-stack depth migration. Sufficient tests have been carried out in the fault-developed areas. Subsequent processing can be conducted on multi-domain gathers from full azimuth multi-rays pre-stack depth migration according to the request of geologists.

Method and/or Theory

Full azimuth multi-rays pre-stack depth migration uses the entire wavefield to make it ideal for solving complex imaging objectives. Rays scan is generated from subsurface imaging points towards the surface. Optimal local tapered beams are internally created and imaged to form high-quality image gathers. Imaging in the local angle domain to achieve uniform illumination from all angles and all azimuths. These produce amplitude-preserved, angle-dependent reflectivity gathers that account for all possible arrivals (“multi-pathing ”) and complex wave phenomena (caustics), as well as compensate for non-illuminated areas and angles. Unlike conventional ray-based imaging methods, ray tracing is performed from the image points up to the surface where “diffracted” rays are traced in all directions (including turning rays), forming a system for mapping the recorded surface seismic data into reflection angle gathers. Based on these developments, the imaged data events are decomposed in the local angle domain (LAD), into two complementary full-azimuth angle gathers: Directional and Reflection.

The combination of the two angle gathers, together with the ability to handle the full azimuth information in a continuous manner, enables the generation and extraction of high-resolution information about subsurface angle-dependent reflectivity in real 3D space. The complete set of information from both angles gather types expands our knowledge about both continuous. Structural surfaces and discontinuous objects such as faults and small-scale fractures lead to accurate, high-resolution, high-certainty, velocity model determination and reservoir characterization. The full-azimuth directional angle gathers the scattered energy into dip / azimuth angle bins at all subsurface points. They contain information about both specular and diffraction energy. Specular energy is associated with reflection waves along continuous interfaces. Diffraction energy is considered to be scattered waves with non-specular directivity.

It has been shown that diffraction energy contains information about local heterogeneities. The ability to decompose the specular and diffraction energy from the total scattered field is the core component of full azimuth multi-rays imaging system. Weighting the specular energy improves the continuity of the reflectors. The specular energy also provides accurate information about the orientation (dip/azimuth) and the continuity of the local reflectors. By weighting diffraction energy, it is possible to emphasize geometrical features that are beyond seismic resolution, such as small faults and even fractures. Our approach consists of three main stages: Ray tracing, full-azimuth angle domain decomposition, and final imaging (weighted stacks).

The ray tracing stage involves shooting a fan of rays from the image points to the surface. Ray tracking including many available attributes, such as travel time, ray coordinates, slowness vectors, amplitude, and phase factors are stored for each ray. The decomposition stage of the full azimuth angle domain involves a combination of ray pairs indicating incident and reflected / diffracted rays.

Results

Application of this method in A block in the Middle East shows that full azimuth multi-rays pre-stack depth migration can improve the imaging quality of medium and deep layers and improves the imaging of small faults and small-scale fractures. Full azimuth multi-rays pre-stack depth migration can use isotropic and anisotropic velocity models to perform reflection and directional imaging in the local angle domain. Migration radius is defined by both aperture and angle. Information from all azimuths and angles is fully involved in the imaging process, which is beneficial for imaging small faults and fractures. Structural attributes such as dip, azimuth and continuity of the target zone can be obtained directly from gathers after migration. High-quality structural imaging results can be obtained by effective reflection enhancement processing on gathers from full azimuth multi-rays pre-stack depth migration. Diffraction wave enhancement processing can be used for geological fracture prediction.

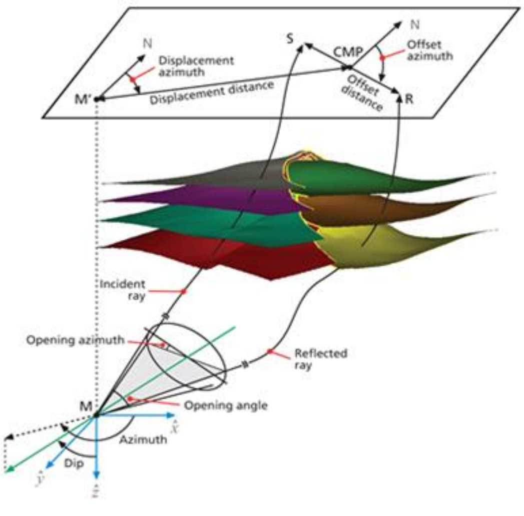

Figure 1: Surface-to-Subsurface and subsurface-to-surface Image Points mapping

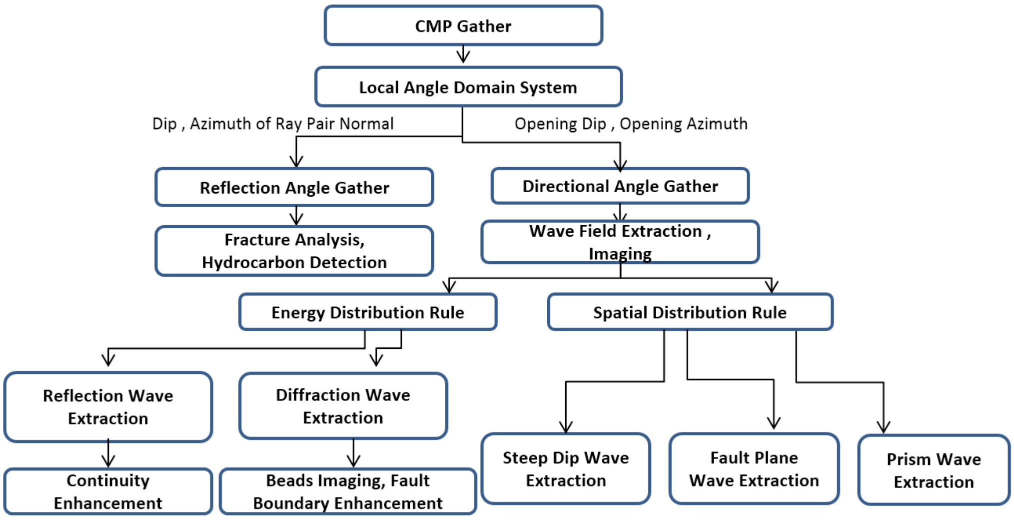

Figure 2: Full azimuth multi-rays pre-stack depth migration workflow

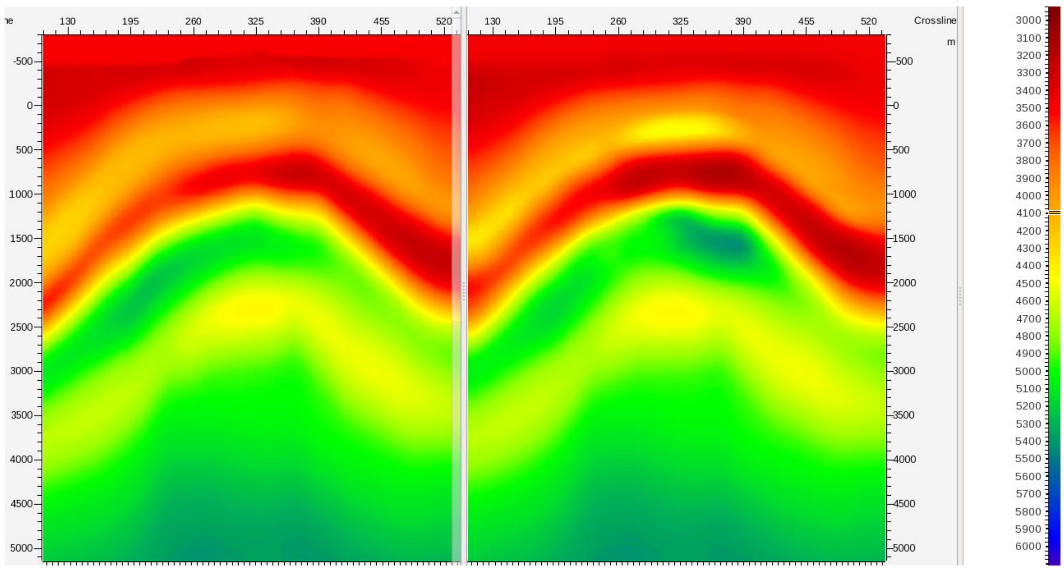

Figure 2: Initial interval velocity section (left), final interval velocity section with well-tie (right)

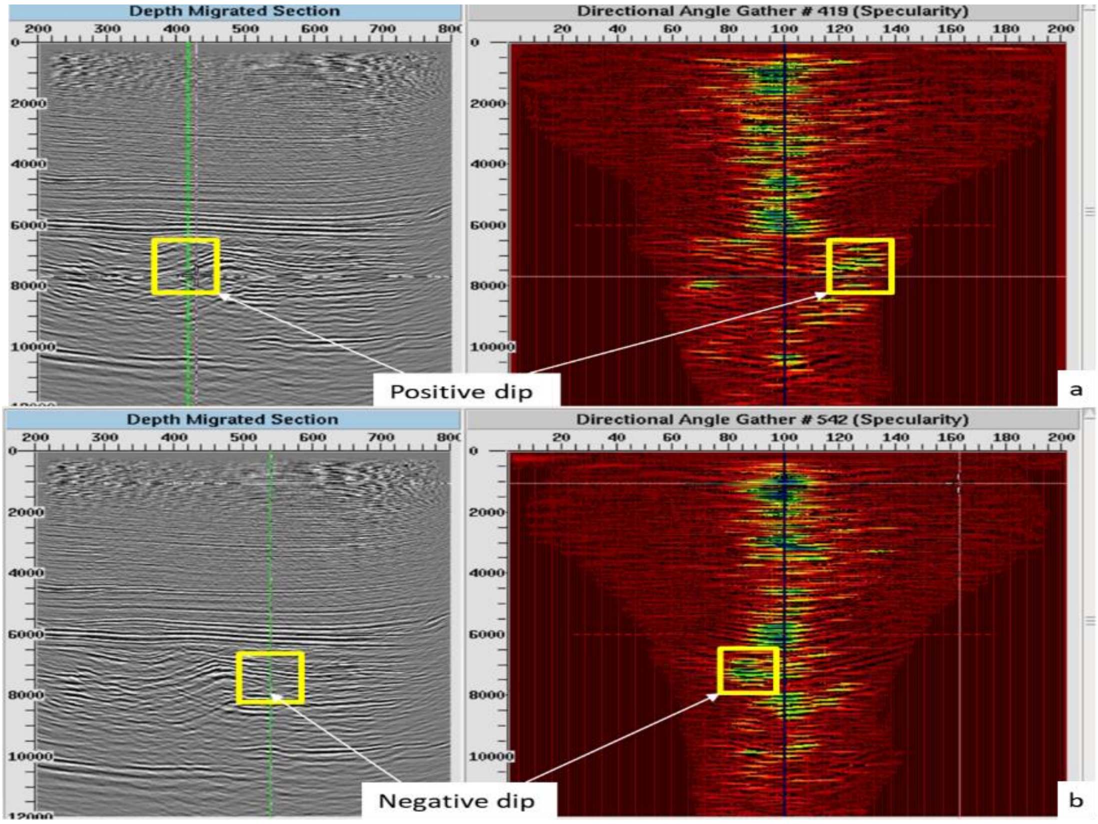

Figure 3: The simultaneous display of PSDM stack section and local angle domain image gather enables QC and monitor observations. (a) show the positive dip on the angle gather, (b) show the negative dip on the angle gather.

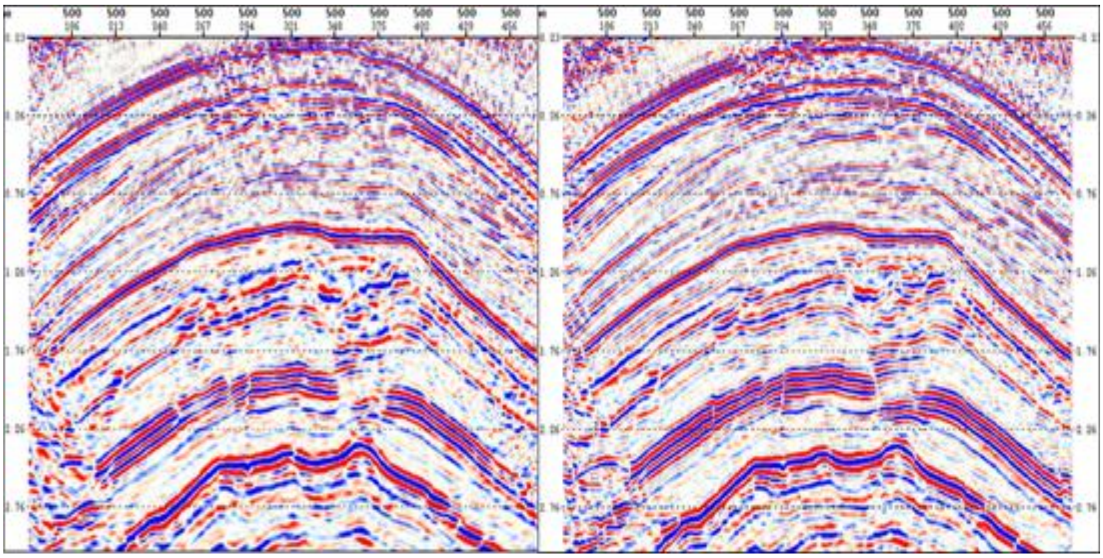

Figure 4: Comparison of Kirchhoff PSDM stack section (left) and Full Azimuth Multi-rays PSDM stack (right) along in direction

Conclusions

This paper investigates the principle of full - azimuth multi - ray pre - stack depth migration, comparing it with conventional Kirchhoff prestack depth migration. Advantages of this method in imaging principle and subsequent gathers processing are analyzed, and it is applied to seismic data of block A's heterogeneous carbonate reservoir. The processed output enhances subsurface imaging and fault delineation. Compared with earlier processed outputs, it demonstrates remarkable improvements at all volume levels, clearly showing reduced noise and better seismic event continuity on the stack section. Depth imaging in the local angle domain provides more reliable attributes for seismic characterization of azimuthal anisotropic reservoirs than traditional time - domain, sectored imaging, and data analysis.

In regions with weak azimuthal anisotropy and complex overburden, applying full - azimuth depth imaging technology is a fundamental condition for project success. From a conventional prospecting viewpoint, this method benefits trap search in complex geological areas. Techniques like bottom - up ray tracing, precise use of irregular surface full views, illumination shadow (vertical and lateral) correction, non - stretch NMO, and decomposition into reflection and diffraction components enable deriving new images from archived 3D seismic shots over conventional geology and high - resolution imaging of new rich - azimuth seismic data. These processed outputs, especially in complex structural areas, offer essential information for drilling and improving production flow by fully describing subsurface parameters, including large fault distribution and fracture properties.

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