Application of Advanced Depth Imaging Technique to “Tenpoku Seihou 3D” Data
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ABSTRACT

“Tenpoku Seihou 3D” seismic data was acquired with the seismic vessel “SHIGEN” by METI in 2010. The survey area is approximately 770 sq. km. MOECO reprocessed the data in 2014 to improve the PSTM images obtained by JOGMEC in 2011. Much improvement was recognized in the reprocessing results. However, the PSTM images suggested very complicated subsurface geological structures in the survey area and the application of depth domain processing was required to confirm the structural features in detail. Then, MOECO decided to apply advanced depth imaging techniques to achieve further improvement of the deeper structural images. Under the cooperation with Paradigm Geophysical, both its advanced tomography velocity updating method and Paradigm Common Reflection Angle Migration (CRAM™) were selected as the most appropriate tools for this purpose. The input data were the preprocessed pre-stack gathers derived during MOECO’s reprocessing in 2014. The resultant PSDM images are much clearer than the PSTM partly because the lateral seismic velocity changes were correctly handled in the processing and reflection signals were mapped to the right positions. Flexibility of the CRAM provides several different images through manipulations of decomposed wavefields in local angle domains. Those additional images could be useful to investigate structural features precisely. The interval velocity fields derived through the tomography iteration and residual move-out corrections followed are enough accurate to be utilized for further precise analyses.

INTRODUCTION

Mitsui Oil Exploration Co., Ltd. (MOECO) has explored natural oil & gas in north-west offshore Hokkaido (“Tenpoku Seihou” area) for decades. Until quite recent, only 2D seismic data had been available in the study area. In 2010, Ministry of Economy, Trade and Industry (METI) acquired 3D seismic data in the area using the 3D seismic survey vessel, “SHIGEN”, as part of a fundamental project of surveying domestic oil and natural gas resources offshore Japan. The “Tenpoku Seihou 3D” survey area is approximately 770 sq. km.

Figure 1 shows the survey location map. The acquired data was initially processed by Japan Oil, Gas and Metals National Corporation (JOGMEC) in 2011 and the PSTM images were obtained. Those images modified MOECO’s geological insights very much and two normal faults with large throw were newly interpreted on the seismic sections. However, the PSTM images are not suitable for the precise interpretation due to low S/N caused by remaining residual multiple reflections. In 2014, MOECO reprocessed the data to improve more the PSTM image obtained by JOGMEC in 2011. More S/N and higher resolution was recognized in the reprocessing results. (Minegishi and Orito, 2016)

Figure 1: A location map of the “Tenpoku Seihou 3D” survey.

However, the PSTM image suggests very complicated subsurface geological structures with many faults in the survey area and the application of depth domain processing was required to confirm the structural shape in detail. Then, MOECO decided to apply advanced depth imaging techniques to achieve further
improvement of the deeper structural images. Under the cooperation with Paradigm Geophysical, both its advanced tomography velocity updating method and Paradigm Common Reflection Angle Migration (CRAM™) were selected as the most appropriate tools for this purpose.

IMAGING METHOD

The CRAM, Paradigm’s proprietary software, was adopted as our optimum depth imaging method. The CRAM is an advanced beam migration that utilizes recorded entire seismic wave-field to generate “true amplitude” common image gathers (CIGs) in the subsurface 4D local angle domain (LAD) rather than the surface offset domain (Figure 2). In the CRAM, a dense set of rays are traced from every image point up to the surface in order to perform a sufficient illumination from all available opening and dip/azimuth angles. All arrivals are taken into account including multi-pathing. The data mapped into the 4D LAD space can be manipulated to create the directional seismic gathers and the reflection angle ones. (koren and Ravve, 2011; Ravve and Koren, 2011) Construction of the local beams is optimally performed on-the-fly throughout the imaging stage for each point and for each ray pair.

APPLICATION

Input data to the CRAM is CMP gathers and RMS velocities obtained at the previous PSTM reprocessing. All preprocessing steps such as multiple attenuations and wavelet manipulations were already applied before the CRAM imaging.

Then the following three phase approach is decided:

**Phase 1: Velocity Modeling and Velocity Model Updating**

1. Building an initial isotropic velocity model: The RMS velocity field obtained in the PSTM processing in 2014 was converted to interval velocities using Constrained Velocity Inversion.
2. Updating the isotropic velocity model:
   a. Kirchhoff PSDM with wave-front travel times was applied to the input data using the initial isotropic velocity model and obtained CRP gathers at every 100m interval in both in-line and cross-line directions.
   b. Residual move-out was automatically picked on the CRP gathers.
   c. Isotropic grid tomography was iteratively applied to minimize the residual move-out and to obtain more optimal interval velocities. Three iterations were carried out at this step.

   (d) The CRAM was applied the input data using the updated isotropic velocity model in (c) and obtained

Figure 3: An example of residual RMS velocity and CIG after 5th isotropic grid tomography. The solid line on the gather corresponds to a designed mute.
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CRAM CRP gathers at every 100m interval in both in-line and cross-line directions.

(e) Residual move-out was automatically picked on the CRAM CRP gathers.

(f) Isotropic grid tomography was iteratively applied again to minimize the residual move-out and to obtain the best interval velocities. Two iterations were carried out at this step. Figure 3 shows an example of updating results. The residual RMS velocity is recognized as reasonably small.

Phase 2: CRAM application

The CRAM with specular weighting which provides higher coherency was applied to the input data using the updated velocity through Phase 1. The CRAM created kinematically and dynamically correct angle gathers using a 3 meter depth step, a full aperture of 8000 metres and a dip limit of 90 degrees which were decided as optimum parameters after the tests. In this application, two different types of images, specular and diffraction stacks, were obtained. Figure 4(1) and (2) show them. The former provides more coherent images and the later are more sensitive to discontinuous features.

Phase 3: Post PSDM process

After application of the CRAM, the following processing steps were applied to the CIGs and the images:

(1) Residual move-out corrections
Some reflection events were not aligned perfectly even after 5 times velocity updating by tomography. Those residual move-outs were analyzed and corrected in each CIG gather.

(2) Q estimations and attenuation corrections
Energy absorption due to inelastic nature of the Earth was estimated as quality factor Q. Then the estimated Q functions were applied to the stacked image to get better reflectivity images.

RESULT and DISCUSSION

The CRAM images were converted into time domain and compared with the PSTM results. The final CRAM velocity field was used in the depth to time conversion. Figure 5 shows the comparison of a part of the images. The specular stack image gives more coherency and less noises than the PSTM. At the same time discontinuous features such as faults and terminations are maintained clearly. As the result interpreters can make more precise and accurate geological interpretation in the CRAM images than the PSTM ones. In addition to the image improvement, specular and diffraction stacks enable more precise analyses of the subsurface geological structure.

CONCLUSIONS

The PSTM images of the Tenpoku Seihou 3D data reveals the complicated subsurface geological structures in the area and the time domain imaging has limitation due to rapid lateral velocity variations. As an effective depth domain imaging method, Paradigm™ Common Reflection Angle Migration (CRAM) was selected and applied to the data. The result provides clearer images
than the time domain processing. Moreover, not only a full migration result but also several different types of images were derived as the CRAM’s products. Those are much useful in our precise subsurface structural interpretation.

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REFERENCES


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