IMPROVED SEISMIC IMAGING THROUGH COMMON REFLECTION ANGLE MIGRATION: A COMPARATIVE STUDY OVER CONVENTIONAL MIGRATION APPROACH

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Abstract:

In a conventional migration ray-tracing is done from the surface and it collects whatever arrives at each depth point but in case of single arrival migration approach, the illumination of certain depth points may be limited. Common reflection angle migration is multi arrival technique that operates in the depth-angle domain and ray-tracing is performed from image points up to the surface. It integrates all the seismic data points that are reflected/diffracted at the same angle. All possible ray paths are used. By performing a uniform illumination of image points all arrivals are included, hence, both amplitudes and phases are preserved.

Field of the study:

Present study deals with ray-based migration for obtaining high-quality, amplitude-preserved, angle-dependent reflectivity gathers and image volumes from seismic data surveys. A case study from onland Kalol Field is taken and comparison is made with conventional Kirchhoff migration results.

Introduction:

CRAM is a multi-arrival migration that uses the wave field within a controlled aperture. Unlike conventional ray-based imaging methods, Ray-Tracing is performed from image points up to the surface, forming a system of emerging rays with uniform angle increments. Travel time, geometrical spreading, phase rotation factor and slowness vector (migration operator) are calculated for each ray. Each pair of rays is a potential reflected ray with a given direction (dip and azimuth angles) and a given reflection angle (half opening angle).

Each event of the Common Reflection Angle Image Gathers is constructed by summing all seismic events reflected/diffracted from the image points with the same reflection/diffraction angle. By performing a uniform illumination of the image points; all arrivals are included, and amplitudes and phases are preserved.

There are numerous field examples published which study and emphasize the importance of generating common-image-angle gathers directly at the subsurface points rather than the universally used surface-offset image gathers, especially in complex geological areas where the wavefield includes multipathing. Some of the published documents on this topic can be summarized as Ten Kroode et al., 1994; Nolan and Symes, 1996; Brandsberg-Dahl et al., 1999; Rousseau et al.,2000; Xu et al., 2001; Audebert et al., 2002; Koren et al., 2002; Rickett and Sava, 2002.

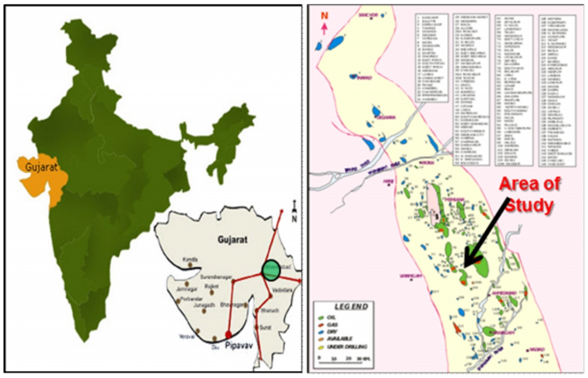

Figure-1: Location map of the Kalol Field

To study the effect of Common reflection angle migration (CRAM) over conventional Kirchhoff migration, Kalol Field is taken as shown in Figure-1. The objective of study is the imaging and identification of stratigraphic traps within Olpad and Cambay shale sequences.

Use of CRAM for identification of stratigraphic traps has been extended to the area of study which was hidden in Kirchhoff Pre stack depth migration. Initially the efforts have been made to prepare the data for Kirchoff Pre Stack Depth Migration. Firstly, conditioning is done on input deconvolution applied gathers and degain the data.it is very important that data should be free from noise .For running CRAM we need conditioned CMP gathers and final interval velocity as input.

Geology of the study area:

Geologically, Kalol structure in the area of operation is a doubly plunging anticline trending NW-SE with four local highs. Structure occupies an areal extent of 200 sq. km. During the middle Eocene, there was a major regression resulting in the development of thick deltaic sediments known as Kalol formation. The facies and thickness of the individual units within Kalol formation vary laterally. The Kalol main area lies in Kalol field. Kalol formation of Eocene age is the main producer of hydrocarbons in the Kalol field and in northern (Wadu-Paliyad field) parts of the 3D area.

Kalol formation was deposited in a deltaic complex traversed by distributory channels influenced by tides and also having marshy and swampy environment marked by

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coal, shale, sand and silt units. Alternations of sand-shale-coal sequences indicate their depositional environment to be of deltaic nature. The sands encountered in Kalol formation are thin, lenticular and discrete in nature, mostly representing channel bars, point bars, crevasse plays etc. The Kalol formation has Sertha (K-XI to K-VI), Kansari shale and Wavel (K-VI to K-I) members. Sertha member contains sands of K-VI-VII and K-IX-X which are the main hydrocarbon producers in this area. Besides this K-XI and K-III-IV are also hydrocarbon bearing in many of the wells.

Basic Theory:

Common Reflection Angle Migration (CRAM) is the technique in which the ray paths are traced from every subsurface image point up to the surface in the "local angle domain" shown in Figure-2, rather than tracing them from the surface down to the reflection point, as with conventional seismic imaging.

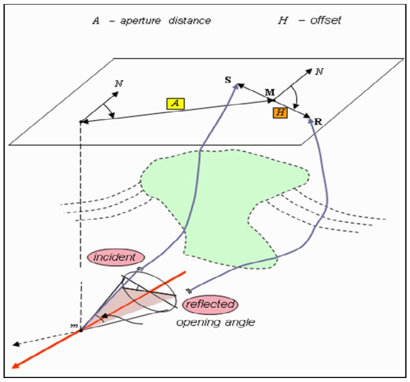

Figure-2: Local Angle Domain – Ray Angles at Reflection Point

Traditional ray based single arrival imaging solutions shown in Figure 3(i) which gathers seismic energy at subsurface points based on the travel times obtained by ray tracing from the acquisition surface. These "input-driven" imaging solutions (migrations) are limited in the data because it is controlled by the acquisition geometry rather than the subsurface geometry. With new multi arrival ray tracing and imaging procedure, the ray tracing is performed at each subsurface point independent of the acquisition geometry shown in Figure-2 & 3(ii). The illumination capacity of the migration can be controlled by the ray trace engine parameters (azimuth and angle) at each subsurface point. The resulting travel times are accurate, rich, and honor the subsurface geology resulting in a more realistic depiction of the subsurface by a better collection of contributing seismic data to each subsurface point. Final result thus generated gives improved seismic imaging, better geologic models, and better prospects for the oil fields.

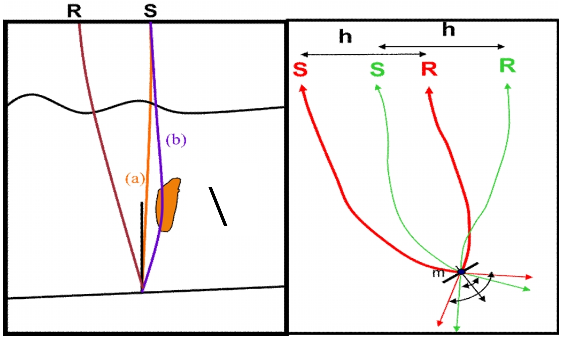

Figure-3(i) Conventional Single Arrival-rays having same offset but missing target zone.

Figure-3(ii) Multi Arrivals – Rays that have the same offset h but different (opening) angles covering target zone

(Courtesy: Paradigm)

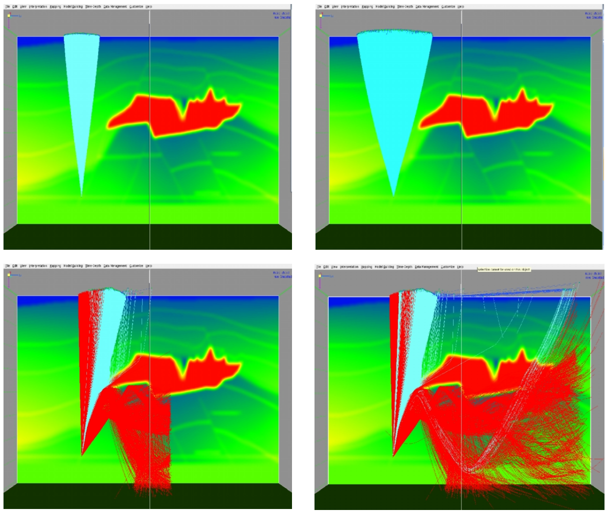

Figure-4 :(i) Rays, opening angle 30 (top) 15 (bottom)
(ii) Rays, opening angle 60 (top) 30 (bottom)
(iii) Rays, Directional angle 30 & aperture 6000
(iv) Rays, Directional angle 30 & aperture 15000

(Courtesy: Paradigm)

Figure 4(i),(ii),(iii) & (iv) shows different cases for better imaging of target.

As we are increasing the opening angle and changing the directional angles we are coming closer to the target.

Therefore, proper selection of opening angle, directional angle & aperture plays a vital role in imaging the target zones effectively.

Methodology:

Preprocessing included standard signal conditioning techniques without affecting the relative amplitudes.

Residual statics applied conditioned CMP gathers are used for processing in depth domain. Initial Depth-Interval velocity model is created using Constrained Velocity

Inversion (CVI) application of Paradigm. This application enables to create a smoothed and physically credible velocity volume. Residual move out analysis is tested on selected gathers using fastvel tool which is Automatic residual move out correction that uses AVO technique in order to automatically perform detailed residual move out analysis. The application uses AVO technology and therefore enables on the fly enhancements of data prior to velocity analysis. We can apply various filters, amplitude corrections and mute options for improved velocity analysis. The workflow starts with the utility that allows selecting parameters and viewing the results of the procedure on the selected gathers. By optimizing parameters, we can obtain best possible results in terms of the flatness of the gathers. Once satisfied, the residual move out estimation can be performed on the entire input volume. The output of the procedure is residual move out volume. For updation of initial interval velocity model 3D Grid Tomography method is used. After updating the final interval velocity model, CRAM (common reflection angle migration) is run. The input used for the CRAM is conditioned residual gathers (CMP) and the final interval velocity model which is obtained from the iterations of 3D Grid tomography. The parameters like opening and directional angle are tested using the ray tracing that gives the number of failed and successful ray counts. Final values are decided by taking into account the more successful rays and by testing those parameters on some inline having the complex structure.The critical parameters for the testing are Opening angle Directional angle, Pencil distance, Azimuth, Aperture and Reference depth for defining the angles at top and bottom.The opening and directional angle can be tested interactively and for other parameters we have to the run the jobs.

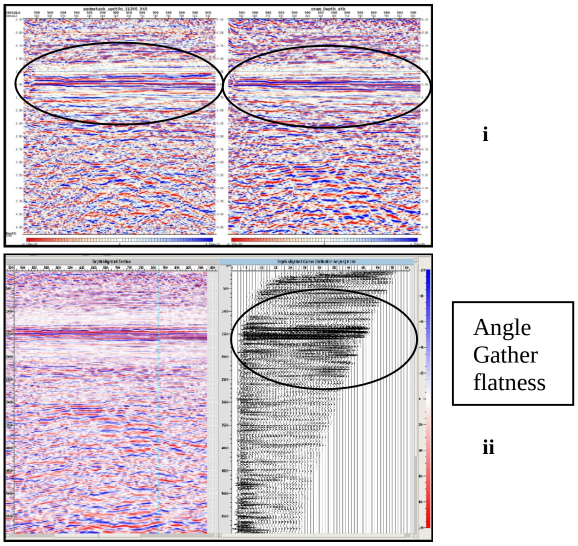

Figure-5 (i): Kirchhoff PSDM Vs CRAM at Inline-500
(ii): CRAM Gather at Inline 500/Crossline 770

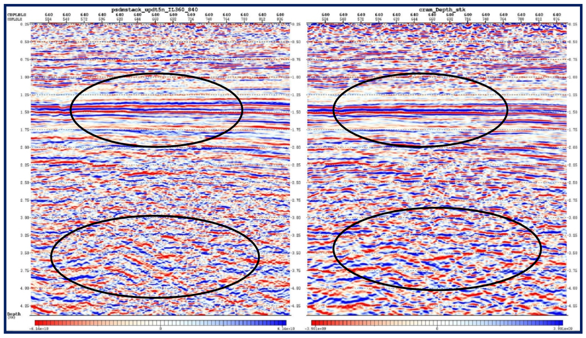

Figure-6: Kirchhoff PSDM Vs CRAM IL-640

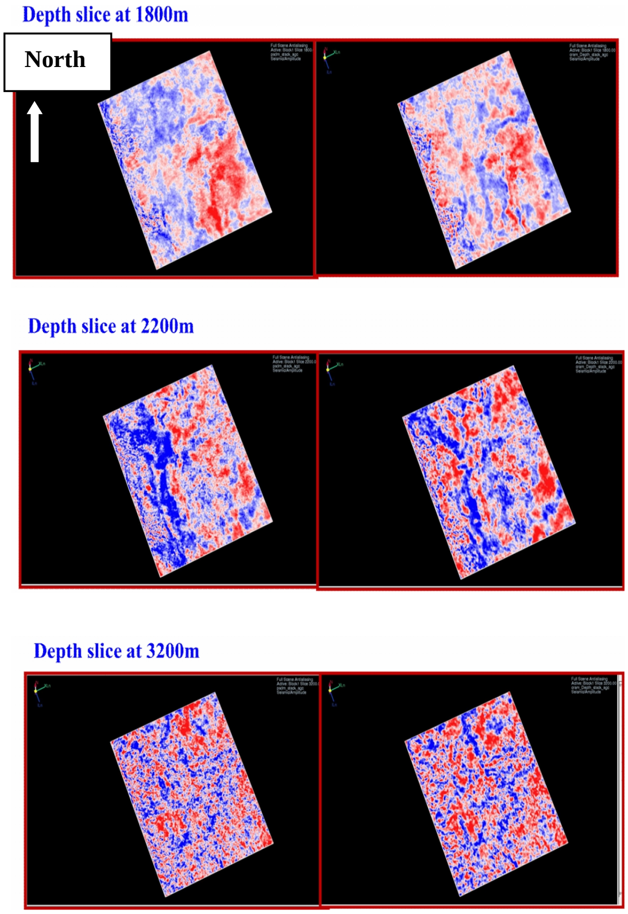

Figure-7: Kirchhoff PSDM Vs CRAM depth slices

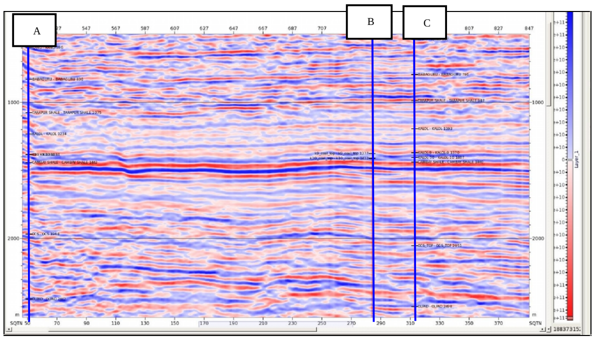

Figure-8: RC line through different wells (Well-A, Well-B, Well-C) CRAM depth stack

Figure-5(i) & Figure-6 shows Kirchhoff Pre stack depth migration over common reflection angle migration at inline -500 and 640. There is appreciable improvement in imaging of shallow as well as in deeper zones including Olpad and Cambay Shale. Figure 5(ii) shows gather flatness upto the appreciable range (as the shallower up to 60^0 and at deeper level up to 30^0). CRAM directly gives angle gathers which can be used for AVO studies without going to common offset domain as in conventional migration technique.Figure-7 shows Kirchhoff PSDM over CRAM depth slices, where there is improvement in the imaging at the shallow and deeper levels. Figure 8 shows CRAM depth stack RC line passing through different wells (Well-A, Well-B, Well-C)where it was found while doing well tie analysis that mismatch is of range 2 to 30 m, which is within permissible limits.

Conclusions:

This is a case study and gives the practical approach for using Common Reflection Angle Migration over conventional migration. In this unique technique, amplitude and phase are preserved by performing a uniform illumination of the image points where all arrivals are included. Input CMP gathers should be properly conditioned before going to depth domain for improved imaging. The study has clearly brought out improved seismic imaging through CRAM, which was not visualized in conventional single arrival migration technique.

Finally, CRAM processed depth stack volume shows very good reflection character and better resolution in the zone of interest. It has great potential in complex lithological areas where conventional imaging algorithm fails which has given a lead for future exploitation and development strategy of the field.

N.B.: The views expressed here are those of the authors only and do not reflect the views of ONGC.

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