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Common Reflection Surface Stack and its utility: A case study

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Summary

We have successfully applied Common reflection Surface stack (CRS) method to 2D seismic reflection data set acquired in close vicinity of Karsruhe, Germany. It is evident from the result that the CRS stack method can provide better image of the subsurface of the earth with high signal to noise ratio. The attributes gained from CRS stack may also be used for modeling and inverse problem in later stage.

Introduction

Most of the conventional seismic data processing sequences such as Normal Move out (NMO), Dip Move out (DMO), Stack need a accurate macro velocity model for imaging of the subsurface of the earth. As earth is inhomogeneous, at times it is very difficult to deduce appropriate velocity model of the subsurface of the earth. Moreover the above mentioned method uses a limited number of acquired data for its point wise illumination instead of surface wise illumination of the subsurface of the earth (Höcht et al., 1997).These limitations in conventional seismic data processing sequences always produce inaccurate results. To overcome these limitations we need such a stacking algorithm which is independent of macro-velocity model.

Common Reflection Surface (CRS) stack is an alternative tool for seismic reflection data processing which does not require a priori macro-velocity model. This CRS stack automatically extracts travel time information from the seismic data in the form of kinematic wave field attributes. As this method sums the seismic data in CMP direction as well as off CMP direction, it generates seismic stack section with better signal to noise ratio and high resolution. The method uses all reflections in the neighboring CMP gather that are reflected from a common reflection surface. Hence it is introduced as Common reflections surface stack (Hertweck et. al., 2007).

The Data set for case study

The CRS stack method is successfully applied in 2D seismic multifold data set acquired close vicinity of Karlsruhe, Germany by Deutsche Tecnologie (DMT) GmbH along two almost parallel lines having separation of 2.5 Km each. Here one line has been taken for study. The acquisition was performed for HotRock EWK Offenbach/Pfalz GmbH with the intension to obtain structural image of the subsurface relevant for a projected Geothermal power plant.

Preprocessing

This method needs good pre processed seismic data with moderate to high signal to noise ratio. Necessary pre processing, application of geometry, filtering was done with Pro-Max software.

Method

The CRS Stacking operator is based on three wave front attributes of two so-called eigen wave related to normal incident ray (Hubral, 1983). Here two hypothetical experiments were conducted with wave front of two eigen waves. In Fig.1, three layered model is considered and a point source is located at the point R. From this point source a normal incidence ray emerges at the surface location x_0 (shown as blue dashed lines).

An up going Eigen wave is constructed by placing the point source at R which produces a Normal Incident Point (NIP)

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Wave. An exploding reflector experiment (Figure.2) produces the second up going wave called Normal wave. In the vicinity of x_0, both waves are approximated by a circles with radius of curvatures R_{NIP} (shown in green) and R_N (shown in red) respectively.

The CRS stacking operator (Fig.3) can be determined by Geometrical approach of Hocht et.al (1999) which yields the parametric representation of the stacking operator.
This CRS stacking operator based second order Taylor expansion for the point $P_0 = (x_0,t_0)$ in the simulated zero offset (ZO) section can be given by (Schleicher et al., 1993; Tygel et al., 1997)

$$t^2(x_m,h)=\{t_0+2\frac{Sin\alpha}{v_0}(x_m-x_0)^2+2t_0\frac{\cos^2\alpha}{v_0}(\frac{(x_m-x_0)^2}{R_N}+\frac{h^2}{R_{NIP}}) \quad (1)$$

Here h is the half offset between source and receiver and x_m denotes the mid point between source and receiver. The only required parameter is near surface velocity v_0. Now We need to determine three stacking parameters viz. angle of emergence (α), radius of curvature of normal incident point wave (R_{NIP}) and radius of curvature of the normal wave (R_N) at each sample point, $P_0 = (x_0,t_0)$ from the above stacking operator(equation1). This is done by means of coherency analysis.

The fasted and pragmatic approach to determine the parameter is three one parametric search instead of one three parametric search (Mann et. al., 1999).

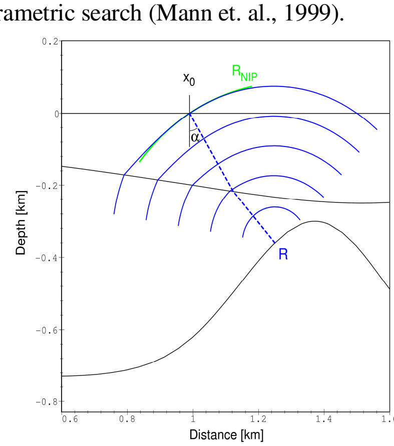

Figure 1: Hypothetical experiment provides Normal Incident Point Wave, Point source at R depleting Radius of Curvature R_{NIP} of the NIP wave front.

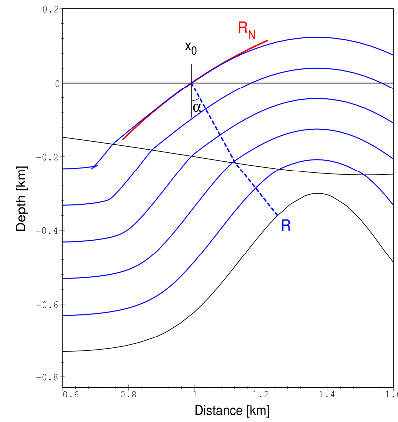

Figure 2: Normal Wave, point source at R on the exploding Reflector depleting the Radius of Curvature R_N of the wave front of Normal wave

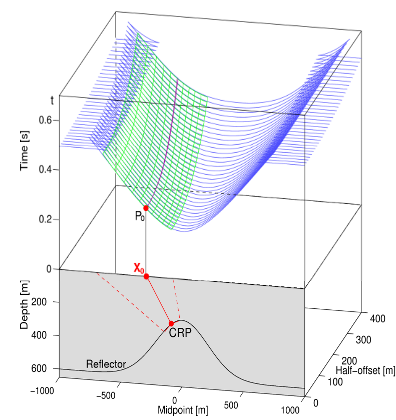

Figure 3: Illustration of Common Reflection stacking Surface (Green) i.e. the paraxial reflection response for all zero offset and finite offset reflection associated with arc segment around CRP. The stack result is assigned to the ZO point P_0.

Implementation

Let us consider to intersection of two dimensional stacking operator (equation 1) with the plane $x_m= x_0$ of the CMP gather. Hence equation 1 is reduced to well known CMP Hyparabola (Hubral and Krey, 1980; Hubral, 1983)

$$t^2(h)=t_0^2+2t_0\frac{\cos^2\alpha}{v_0}\frac{h^2}{R_{NIP}}\} \quad (2)$$

Step 1

From equation (2), let us assume $q = \cos^2 \alpha / R_{NIP}$. For each point P_0 we have to determine coherency value along the hyperbolas given by equation (2) for all possible values of q and we have to select one which has highest coherency value. Subsequently stack is performed along the CMP hyperbola. If we compare equation 2 with the well known CMP Hyperbola,

$$t^2(h) = t_0^2 + \frac{4h^2}{v_{NMO}^2} \quad (3)$$

we get $q = \frac{2v_0}{t_0 v^2_{NMO}}$ where v_{NMO}^2 is the Normal moveout (NMO) velocity . Hence finding out of q value is fully equivalent to finding out of V_{NMO} in conventional seismic data processing.

As this method is similar to conventional CMP stack we may call it automatic CMP stack.

Step 2

In this step we make a intersection of two dimensional stacking operator (equation 1) with plane of ZO for h =0. Hence equation1 is reduced to

$$t^2(x_m) = (t_0^2 + 2\frac{Sin\alpha}{v_0}(x_m - x_0))^2 + 2t_0 \frac{\cos^2\alpha}{v_0}\frac{(x_m - x_0)^2}{R_N} \quad (4)$$

This shifted Hyperbola (equation 4) only depends R_N and α. Hence for each point P_0 we have to determine these two parameters. First assuming $R_N = \infty$, equation 4 can be reduced to

$$t(x_m) = (t_0 + 2\frac{Sin\alpha}{v_0}(x_m - x_0) \quad (5)$$

Hence α can be determined from equation 5. After determining α, we can determine R_N from equation 4. With the knowledge of α, we can invert the parameter q gained in step 1 in order to determine R_{NIP}.

Final Optimization

In the final step of optimization we will make a use CRS travel time surface (equation 1)

In this final step of optimization we obtain five optimized attributes like optimized α- section, optimized coherency section, optimized R_{NIP} section, Optimized R_N section and optimized stack section,(Figure 4, 5, 6, 7 and 8 respectively).

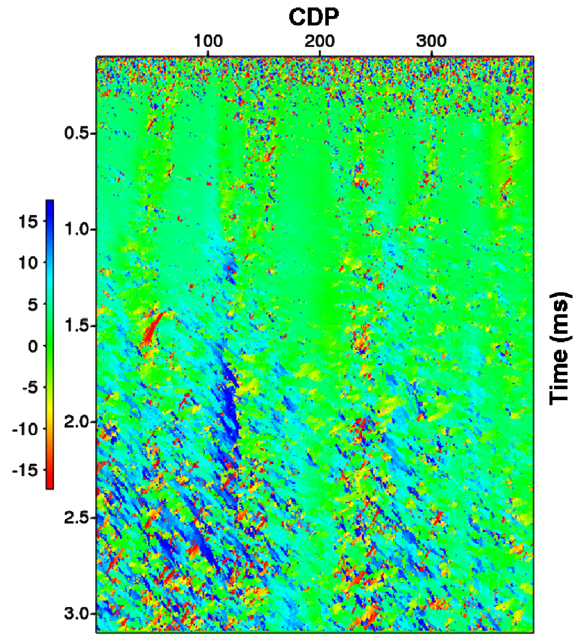

Figure 4: Optimized α - section.

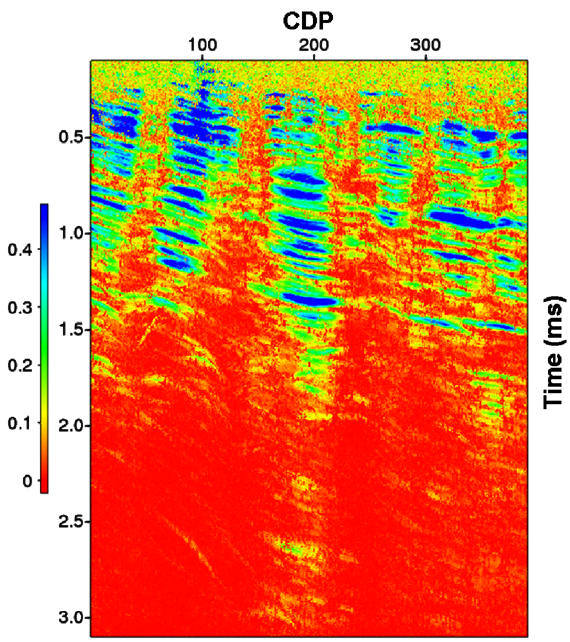

Figure 5: Optimized Coherency section.

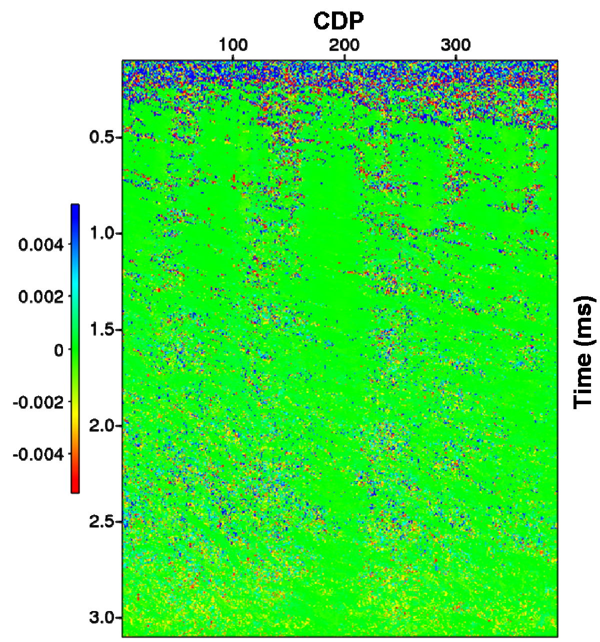

Figure 7: Optimized R_N section

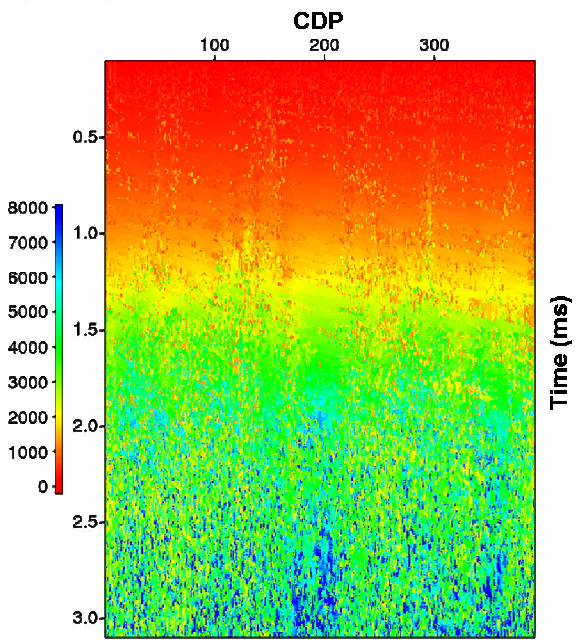

Figure 6: Optimized R_{NIP} section

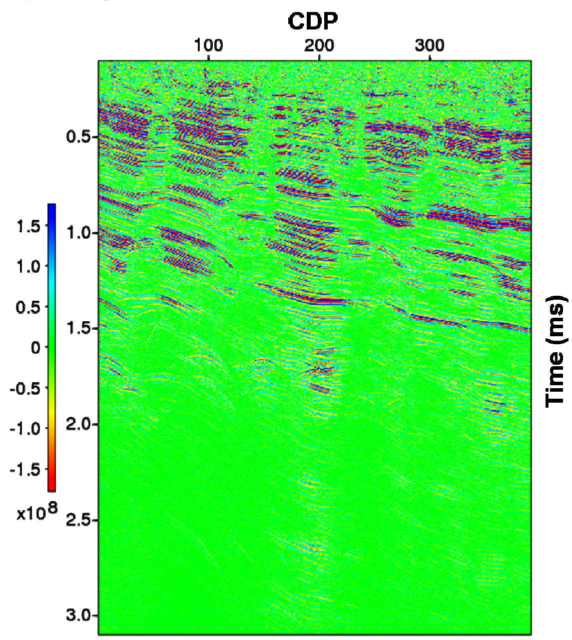

Figure 8: Optimized stack section

Conclusions

The CRS stack method does not require any priori velocity model for its processing. It is obtained that the CRS stack provides a better 2D image of the subsurface as the method takes in to account of neighboring common mid point (CMP) as well. The attributes viz, optimized coherency section, optimized R_{NIP} section, Optimized R_N section and optimized α section. obtained by this methods can be used to determine a velocity model for depth conversion during post stack depth migration.

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