# COMMON REFLECTION SURFACE STACK VERSUS NMO/STACK AND NMO/DMO/STACK

T. MÜLLER
Karlsruhe University, Geophysical Institute, Gebäude 6.36,
Hertzstraße 16, 76187 Karlsruhe, Germany

## Introduction

Conventional imaging techniques (e.g.: CMP-stacking, NMO/DMO/Stack) have two major drawbacks. Firstly, they require the knowledge of a macro velocity model, which has to be extracted from the data first. But, the derivation of an adequate velocity model is not always possible. Secondly, all the above mentioned methods use only a limited number of the acquired data for a point-wise illumination instead of a surface-wise illumination of the subsurface structures (Höcht et al. (1997).

## CRS-Stacking

To overcome these limitations a stacking trajectory (or surface) has to be used which is macro velocity model independent and capable of describing arbitrary traces in the vicinity of a chosen ZO-location.

Recent publications (Tygel et al. (1997)) showed that there exist traveltime descriptions which meet those needs. A formulation which can directly be obtained from paraxial ray theory is the hyperbolic traveltime expansion (Schleicher et al. (1993))

$$t_{hyp}^2(x_m,h) = [t_0 + (2\sin\beta_0/v_0)\,x_m]^2 + (2t_0\cos^2\beta_0/v_0)\,(K_N\,x_m^2 + K_{NIP}\,h^2)\,, \tag{1}$$

where $t_0$ is the ZO-traveltime, $\beta_0$ is the emergence angle of the ZO-ray, $v_0$ is the velocity at the ZO-location, $x_m$ and $h$ are midpoint and half offset coordinates, respectively. $K_N$ and $K_{NIP}$ are the curvatures of 2 fictious waves along the central ray, which were introduced as the normal-wave and the NIP-wave (Hubral (1983)).

An alternative traveltime formula was first developed by Gelchinsky et al. (1997) and reformulated by Tygel et al. (1997) using the same parametrisation as for the hyperbolic traveltime. This relationship is described as the multi-focus traveltime:

$$\begin{aligned} t_{multi} = t_0 \; &+ \; \frac{1}{K_S v_0}\left[\sqrt{1 + 2K_S\sin\beta_0(x_m - h) + (x_m - h)^2 K_S^2} - 1\right] + \\ &+ \; \frac{1}{K_G v_0}\left[\sqrt{1 + 2K_G\sin\beta_0(x_m + h) + (x_m + h)^2 K_G^2} - 1\right] \end{aligned} \tag{2}$$

where $$K_S = \frac{1}{1-\gamma}\,(K_N - \gamma\,K_{NIP})\,, \quad K_G = \frac{1}{1+\gamma}\,(K_N + \gamma\,K_{NIP}) \quad \text{and} \quad \gamma = h/x_m\,. \tag{3}$$

Both traveltime formulas enable to calculate the traveltime of an arbitrary ray in the paraxial vicinity of a central ray. Common to both expressions is their dependence on parameters which can be calculated along the central ray only (i.e.: $t_0$, $\beta_0$, $K_N$ and $K_{NIP}$). The knowledge of the uppermost velocity $v_0$ at the ZO-location is sufficient.

In the constant velocity case this can be easily explained. Calculating the traveltime surface in the ($x_m$-$h$-$t$)-domain for a given $t_0$ and a fixed triple of $\beta_0$, $K_N$ and $K_{NIP}$ describes the same reflection response as a circular reflector (mirror) located in the subsurface would give. Here, $K_N$ describes the curvature of the mirror, $\beta_0$ gives its orientation and $1/K_{NIP} = R_{NIP}$ (radius of curvature) depicts its distance from the ZO-location.

The idea of CRS-stacking is the following: Place in every subsurface point a mirror with all possible orientations and curvatures and calculated its reflection response by means of (1) or (2). This is identical to test for every sample in the ZO-section to be simulated (i.e. every $t_0$) all possible combinations of the three stacking parameters $\beta_0$, $K_N$ and $K_{NIP}$. Whenever these traveltime surfaces correlate with the measured data best, the optimal stacking parameters are found and summation along this traveltime surface into $t_0$ is performed. Because the amplitudes summed into $t_0$ result from waves being reflected at a common surface (described by the triple ($\beta_0$, $K_N$ and $K_{NIP}$)) the procedure is called Common Reflection Surface (CRS) stack.

## CRS versus NMO/Stack, NMO/DMO/Stack

For an iso-velocity model (see Figure 1a)) multi-coverage data acquisition has been simulated. Using a ray tracing algorithm the primary reflections of the model were calculated. In order to make things more difficult, noise was added to the data. It corresponds to 10% of the maximum amplitude of the first event. One can hardly identify the events of the shallow reflectors and it is impossible to identify the deeper events. So, in this situation it would be almost impossible to derive a proper velocity model needed for NMO, especially for the deeper events.

But, assuming the velocities are known, the conventional NMO/stack and NMO/DMO/stack would image this data set as depicted in Figure 1b) and Figure 1c), respectively. Both methods managed to image the first four events quite good. DMO shows, as expected, more coherent events than simple NMO. Comparing these Figures with the result of the CRS-stack (see Figure 1d)) where no-velocity information other than $v_1$ was used shows that in the CRS-image one can even identify even the fifth event and the S/N-ratio is been increased compared to the other two procedures.

## Conclusion

A new ZO-simulation technique has been introduced. The CRS-stacking surface approximates the exact traveltime much better than conventional stacking surfaces and can use any trace in the vicinity of a chosen ZO-location for the imaging process. Thus it suppresses noise much more than the other techniques. But the most important and fascinating feature is the procedures independence of a macro velocity model. Its determination is the most crucial step in processing and can simply be skipped with the CRS-method.

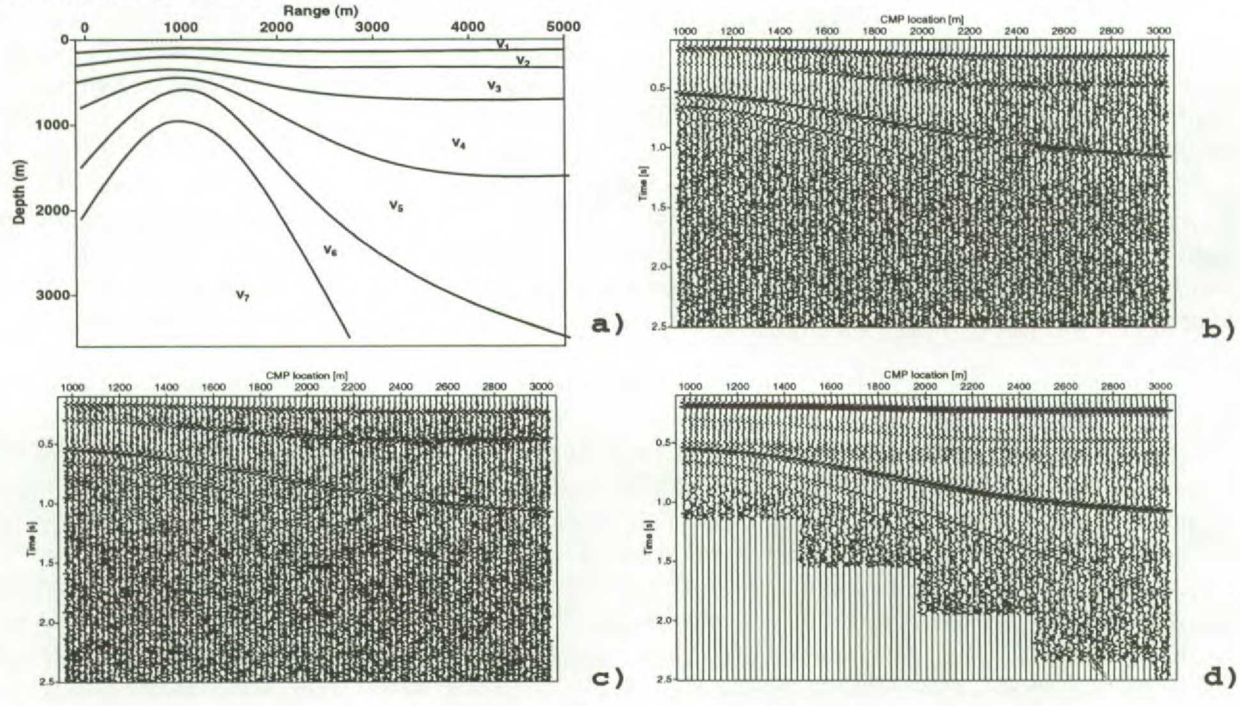


Figure 1: a) The model b) NMO/Stack c) NMO/DMO/Stack d) CRS-Stack

## References

Gelchinsky, B., Berkovitch, A., and Keydar, S., 1997, Multifocusing homeomorphic imaging: Part 1. basic concepts and formulas: Karlsruhe workshop on amplitude-preserving seismic reflection imaging, Geophysical Institute Karlsruhe, Special Course on Homeomorphic Imaging, February, 1997 in Seeheim, Germany.

Höcht, G., Jäger, R., and Hubral, P., Migrating around in circles - Part IV:, submitted to The Leading Edge, 1997.

Hubral, P., 1983, Computing true-amplitude reflections in a laterally inhomogeneous earth: Geophysics, **48**, 1051–1062.

Schleicher, J., Tygel, M., and Hubral, P., 1993, Parabolic and hyperbolic paraxial two-point traveltimes in 3d media: Geophysical Prospecting, **41**, 495–513.

Tygel, M., Müller, T., Hubral, P., and Schleicher, J., 1997, Eigenwave based multiparameter traveltime expansions: 67th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 1770–1773.