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Common Reflection Surface Stacking

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ABSTRACT

A new imaging procedure is introduced. The so-called Common Reflection Surface (CRS)-stack belongs to the class of zero offset simulation techniques. But in contrast to conventional methods (e.g.: CMP-stacking, NMO/DMO/stack) it needs no velocity information. Besides that, it is capable of using much more traces for the imaging process as conventional methods. So, the S/N-ratio is highly increased with this method. In this paper CRS-stacking is explained and applied to a synthetic noise-polluted data set as well as compared to standard techniques as NMO/stack and NMO/DMO/stack.

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 the imaging process ((Höcht et al., 1997) and (Garabito et al., 1997)).

CRS-STACKING

To overcome these limitations a stacking trajectory (or surface) has to be used which is velocity 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))

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

where t_0 is the ZO-traveltime, β_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

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and K_{NIP} are the curvatures of 2 fictitious waves along the central ray, which were introduced as the normal-wave and the NIP-wave ((Hubral, 1983)) (see Figure 1).

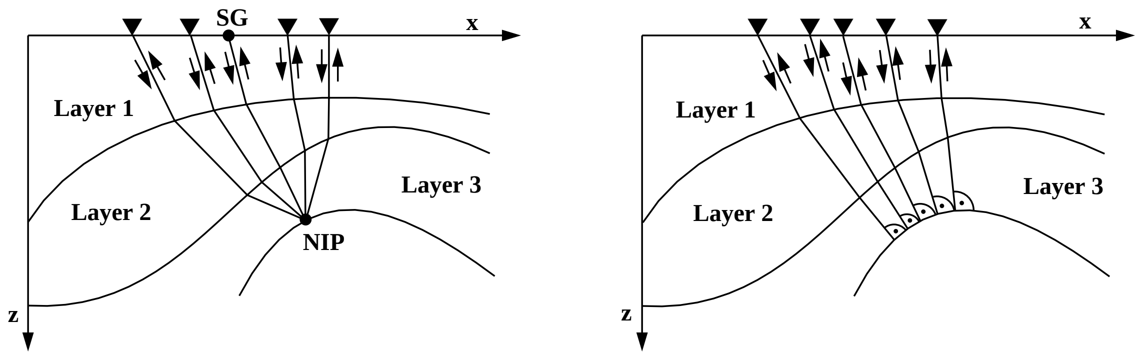

Figure 1: Schematic illustration of the NIP-wave and the N-wave. The left sketch displays the NIP-wave. All associated rays focus at the normal incidence point (NIP) of a specific reflector. The sketch on the right hand side shows the situation for the normal-wave. Here, all associated rays focus on the reflector under consideration. Both waves have in common that their rays use the same ray branches on their down-going and up-going ray paths. In other words a NIP-wave is a fictitious wave that explodes at NIP, while the N-wave is a fictitious wave where the reflector itself explodes.

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:

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

where

$$K_S = \frac{1}{1-\gamma}\left(K_N - \gamma\, K_{NIP}\right) \quad \text{and} \quad K_G = \frac{1}{1+\gamma}\left(K_N + \gamma\, K_{NIP}\right), \tag{3}$$

and

$$\gamma = h/x_m \tag{4}$$

is denoted as the focusing parameter.

Both traveltime formulas enable to calculated 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, β_0, K_N and K_{NIP}). The knowledge of the uppermost velocity v_0 at the ZO-location is sufficient.

Calculating the traveltime surface in the (x_m-h-t)-domain for a given t_0 and a fixed triple of β_0, K_N and K_{NIP} describes the same reflection response as a circular reflector (mirror) located in the subsurface would give. In the constant velocity case this can be

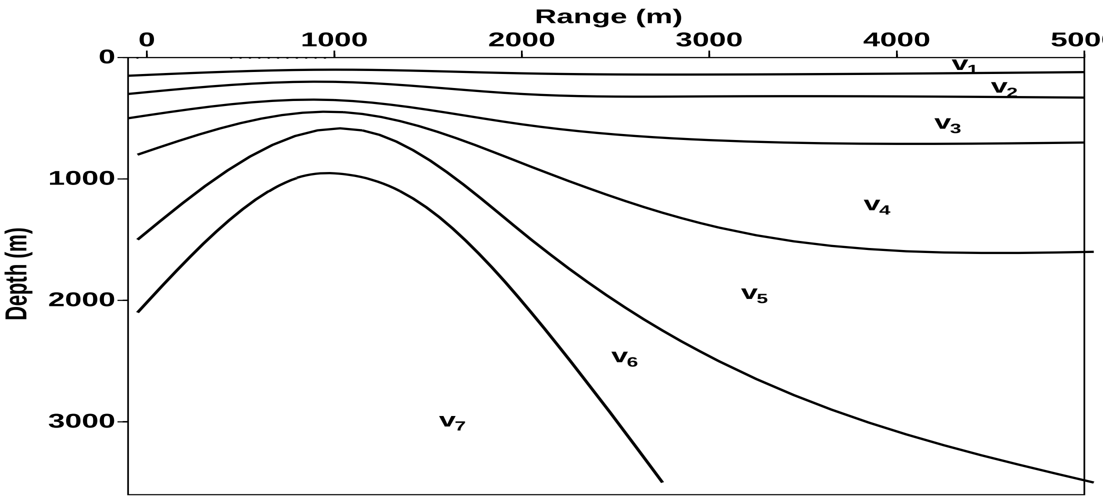

Figure 2: Iso-velocity model. Velocities range from v_1=1200m/s to v_7=4800m/s.

easily explained. Here, K_N describes the curvature of the mirror, β_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 β_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 energy summed into t_0 results from trace being reflected at a common surface (described by the triple (β_0, K_N and K_{NIP})) the procedure is called **C**ommon **R**eflection **S**urface (CRS) stack.

CRS VERSUS NMO/STACK, NMO/DMO/STACK

For an iso-velocity model (see Figure 2) multi-coverage data acquisition has been simulated. Using a ray tracing algorithm the primary reflections of the model were calculated. Figure 3 shows the modeled ZO-section. It can be regarded as the result the stacking procedures should optimally produce. 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. Figure 4 shows the noise polluted ZO-section. One can hardly identify the events. So, in this situation it would be almost impossible to derive a proper velocity model needed for NMO and DMO, 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 5 and Figure 6, 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

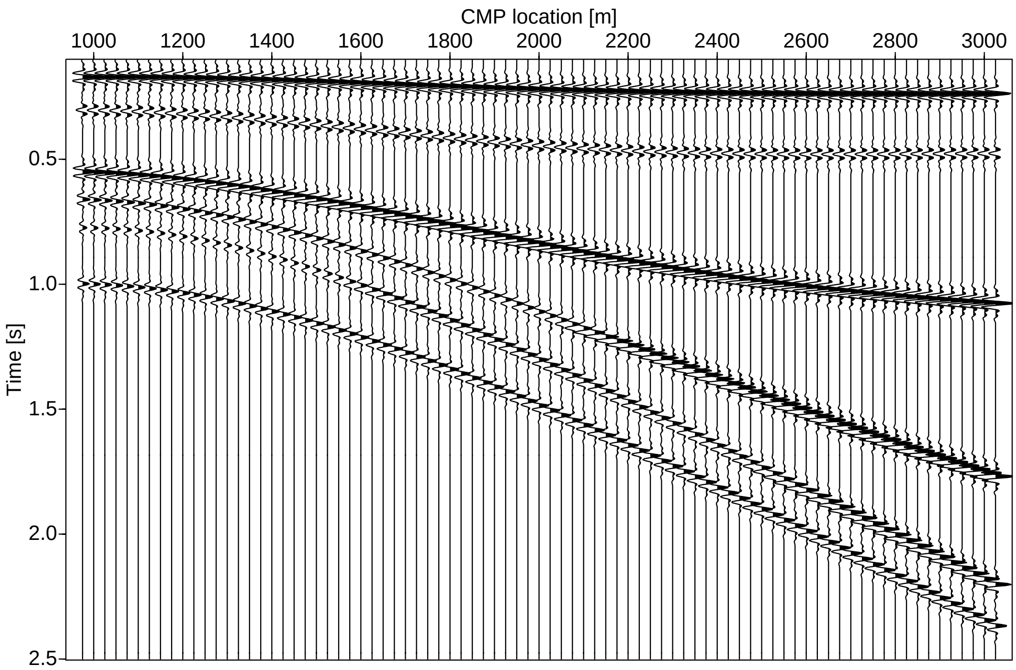

Figure 3: ZO-section from modeled data.

of the CRS-stack (see Figure 7) 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 proposed. 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. By means of a synthetic example CRS-stacking has been compared with NMO/stack and NMO/DMO/stack. It resulted in better stacked images of the CRS method even the correct velocity model was supplied for NMO. If this had to be derived from the data the two conventional methods would give much worse images.

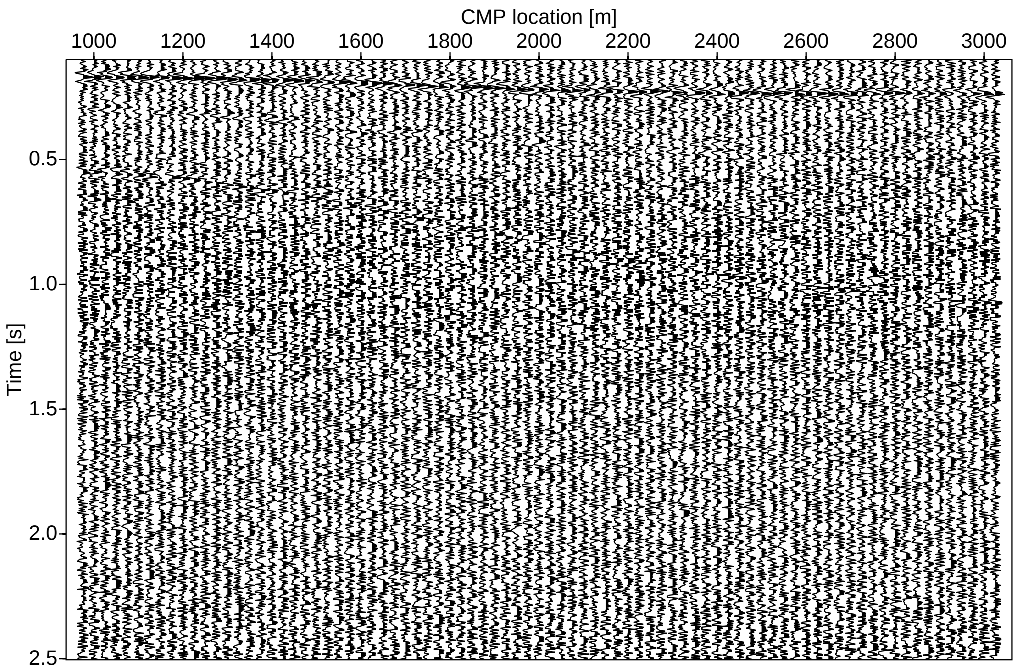

Figure 4: Noise polluted ZO-section from modeled data.

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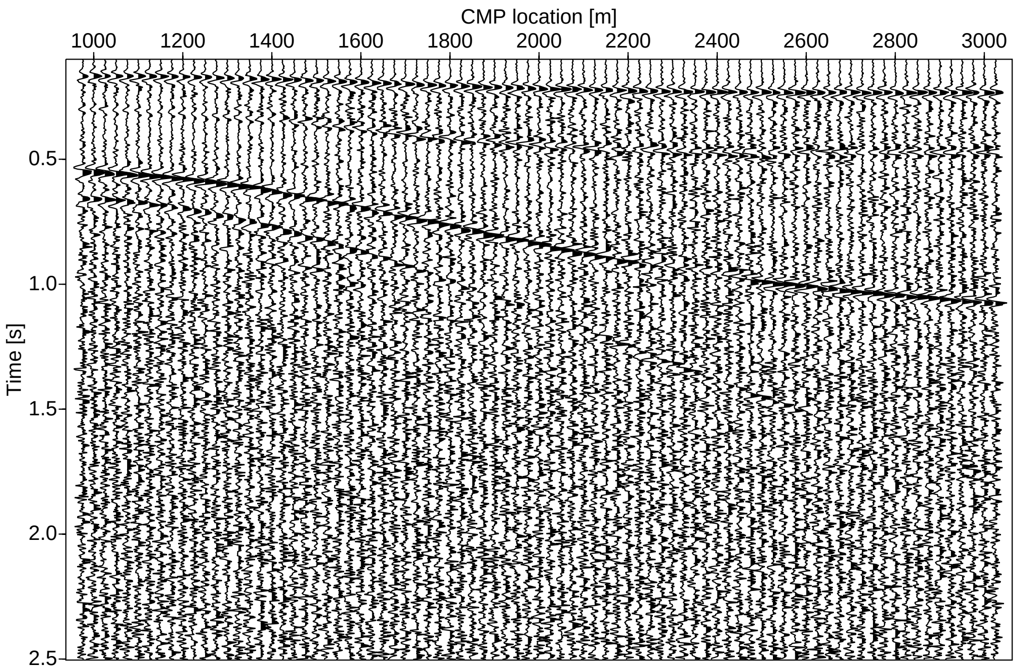

Figure 5: Stacking result of NMO/stack assuming the stacking velocities are known.

PUBLICATIONS

A publication of detailed results is in preparation and will be called *Migrating around in circles Part VI* and will be submitted to *The Leading Edge*.

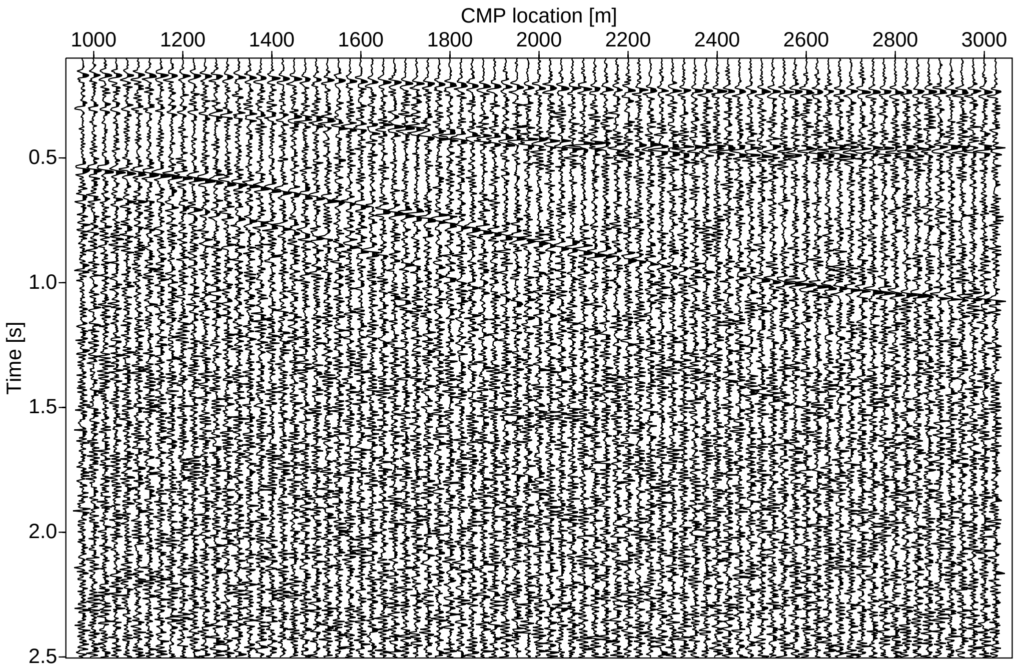

Figure 6: Stacking result of NMO/DMO/stack assuming the stacking velocities are known.

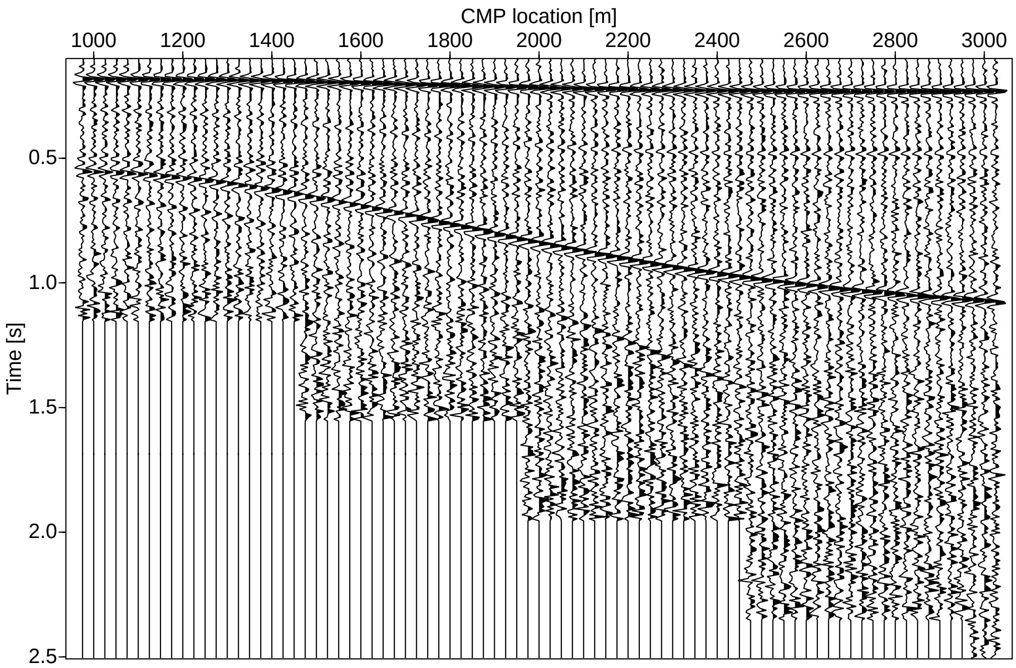

Figure 7: Result of the CRS-stack