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The dynamics of velocity independent partial and full prestack time migration

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ABSTRACT

Velocity analysis performed before the DMO correction yields the dip dependent stacking velocities. However, the migration, which is done to obtain a close image of the subsurface structure, requires migration velocities. There is yet no simple and efficient technique to derive these velocities. This was the motivation to develop a velocity independent dip moveout correction (Gardner's dip moveout, Gardner (1986)) as well as a velocity independent prestack time migration method (Ferber's migration to multiple offset, Ferber (1994)). On output of both methods, the input amplitudes are altered due to a summation procedure. This thesis addresses the dynamics of Gardner's dip moveout and of Ferber's full prestack time migration method, in order to provide amplitude preservation factors, which account for the unwanted changes in amplitudes of both methods, so that the input amplitudes are preserved.

INTRODUCTION

The amplitude preservation factors, derived in this thesis, do not consider spatial spreading or phase shift distortions as these issues can be addressed separately. The knowledge of the shape of the zone of constructive interference is necessary to compute the amplitude preservation factors. Basically, the amplitude correction factor is inversely proportional to the number of traces within this zone. For the computation of the zone of constructive interference, it is necessary to assume a subsurface model, which is a dipping, plane reflector.

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GARDNER'S DIP MOVEOUT (GDMO)

For Gardner's dip moveout the zone of constructive interference (Figure 1) has shown to be one dimensional. Only wavelets within a certain time delay Δt from the apex time contribute to the resulting output wavelet. The width L can be found as

$$L_{\text{gdmo}}(t_0, p) = \frac{2h\sqrt{2\Delta t}\sqrt{t_0}}{\sqrt{t_0^2 + 4p^2h^2}} \quad . \tag{1}$$

where

$$\begin{aligned} t_0 &= \text{zero offset traveltime}, \\ p &= \text{zero offset time dip}, \\ h &= \text{half offset}, \\ \Delta t &= \frac{1}{2f}, \\ f &= \text{dominant wavelet frequency}. \end{aligned}$$

The weighting factor then becomes

$$W = \frac{\Delta x}{L_{\text{gdmo}}} \quad , \tag{2}$$

where Δx is the spatial increment of the traces.

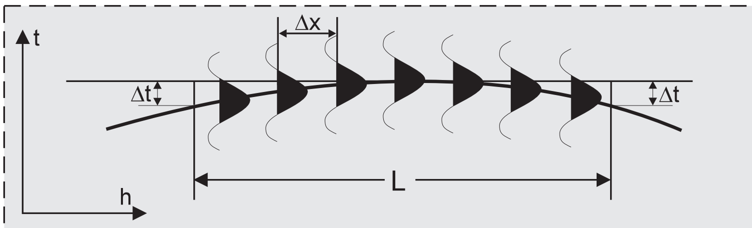

Figure 1: The length L of the zone of constructive interference in a GDMO-panel.

MIGRATION TO MULTIPLE OFFSET (MMO)

In contrast to Gardner's dip moveout, here the zone of constructive interference is two dimensional. Figure 2 shows that the isochrons of the MMO cube—spanned by migration distance r, DMO excursion b and traveltime—look like ellipses. All the traces in this cube are summed up to get one output trace. The isochrons indicate the extension of the zone of constructive interference, which is approximated by an ellipse with the two half axes L_b and L_r. The red ellipse in the inner part of Figure 2 indicates the quality of this approximation. Figure 3 shows a sketch of the zone of constructive interference as well as the position of the two half axes, which are defined by b_1, b_2 and r_1, r_2. Then, the length of these axes can be found as

$$L_\mathrm{b}(t_0, p, v, r_0, h) = \frac{2\,h\,\sqrt{2}\sqrt{\Delta t}\left(\left(t_0 + p r_0\right)^2 - 4\,\frac{r_0{}^2}{v^2}\right)^{\frac{1}{4}}}{\sqrt{\left(t_0 + p r_0\right)^2 + 4\,h^2 p^2}} \tag{3}$$

and

$$L_\mathrm{r}(t_0, p, v) = -2\,\frac{v\sqrt{\Delta t\,\left(-4\,\Delta t + \Delta t\,p^2 v^2 + 4\,t_0\sqrt{4 - p^2 v^2}\right)}}{(pv - 2)\,(pv + 2)} \quad . \tag{4}$$

Here, the weighting factor is composed of the area A of the ellipse and the spatial increment Δx:

$$W = \frac{(\Delta x)^2}{A} \quad . \tag{5}$$

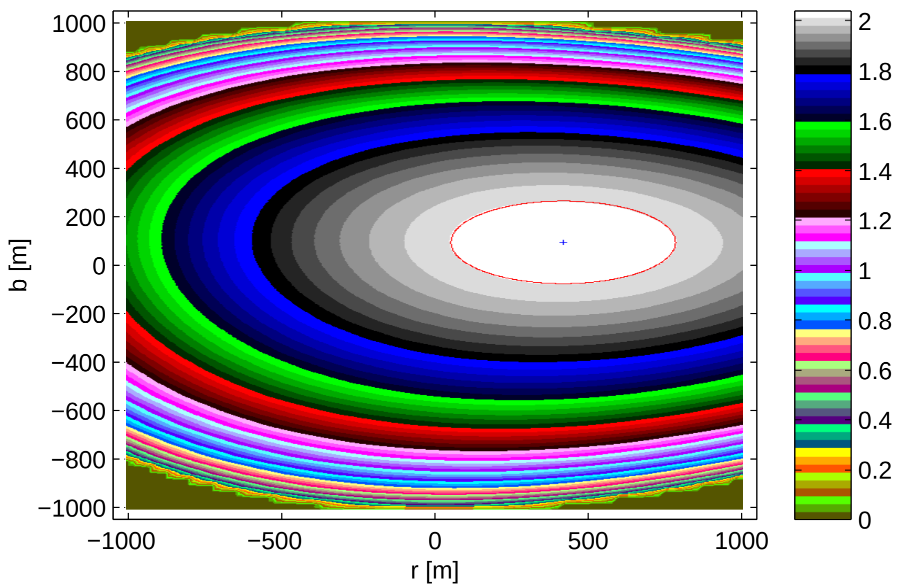

Figure 2: Isochrons of the MMO cube. The inner red ellipse indicates the quality of the approximation. r = migration aperture, b = DMO excursion

CONCLUSION

The objective of this thesis was to study amplitude distortions of the output of velocity independent partial (GDMO) and full (MMO) prestack time migration methods and to

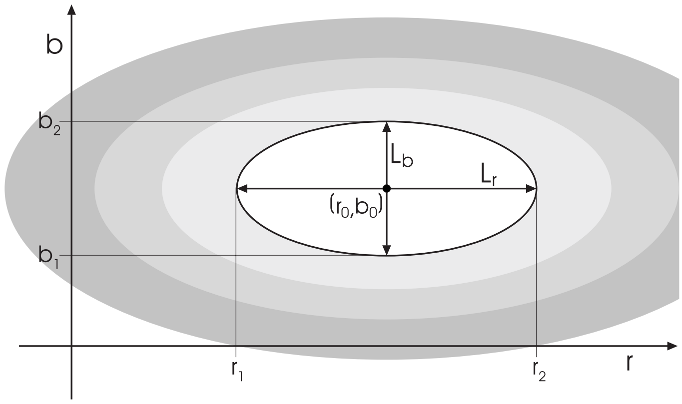

Figure 3: Sketch, how the ellipse can be derived by computing the two half axes L_b and L_r.

provide analytical descriptions of the zones of constructive interference.

For GDMO a simple equation for this one dimensional zone could be derived and an amplitude preservation factor could be found. The zone of constructive interference of MMO is two dimensional, which complicated the equations so that an approximation was necessary. I was able to show that this zone of constructive interference can be well approximated by an ellipse within the two dimensional space spanned by migration distance and DMO excursion. The formulas to compute both axes of this ellipse were derived as well. Unfortunately, these formulas still depend on zero offset time and – even more disturbing – on dip. The objective of the analytical description of the zone of constructive interference could be accomplished and closes this thesis.

REFERENCES

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