Technical Note # 19

TEEC

Improved AVO Analysis by Common Reflection Surface (CRS) Technology

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Summary

The Common-Reflection-Surface (CRS) method which was developed in recent years, has increasingly been used for the high resolution imaging of complex subsurface structures. Assuming subsurface reflector elements with dip and curvature, the CRS method renders an increased signal-to-noise ratio and additional subsurface information in comparison to conventional NMO/DMO time domain imaging.

These advantages of the CRS method, however, may as well be used for an improved Amplitude Versus Offset (AVO) analysis. A case study shows that the more realistic subsurface assumptions, and the increased fold of the CRS imaging, allow to extend AVO analysis into noise zones. Extreme fluctuation of AVO parameters is removed, and AVO anomalies are enhanced.

CRS Processing – Implications for AVO analysis

The advantages of the CRS method can be exploited for seismic processing beyond imaging (e.g. Jaeger et al. 2001, Gierse et al. 2002, Trappe et. al., 2001). The local optimization of the stacking parameters renders a large amount of detailed information, e.g. for high-resolution local reservoir studies. On the other hand, the increased fold may allow to extend reservoir studies into deeper areas with low S/N.

The increase of the CRS fold strongly depends on the stacking aperture in CMP direction. A time dependent CMP aperture can be selected by the user. Alternatively, stacking is limited to the local Fresnel zone, which is estimated from the CRS attributes. The Fresnel zone comprises that part of the subsurface reflector element which constructively adds to the reflection at the considered location and time in the stack.

The time dependent CMP aperture defines a supergather at each CMP location, comprising data from several neighbouring CMPs. A moveout correction can be applied to this supergather, using the locally optimized CRS attributes (alpha, R_{NIP}, R_N) of the central CMP to calculate the hyperbolic stacking surface, and then to compensate for the CMP and offset dependent moveout.

Such a moveout corrected CRS supergather can be used for AVO analysis. With respect to conventional AVO on single NMO corrected CMP gathers, the fold of CRS AVO analysis is increased by approximately the number of neighbouring CMP locations contained in the CRS supergather.

The fold of conventional AVO can be increased similarly by collecting neighbouring CMP gathers into a supergather at each CMP location. These supergathers, however, align dipping reflections at different phase positions in the consecutive incorporated gathers, and thus obscure the AVO analysis. NMO correction does not remove the time dependent dip between neighbouring CMP locations.

In contrast to this, the CRS stacking surfaces possess a CMP dependence which compensates for the time dependent dip. Hence, dynamic correction along these stacking surfaces aligns dipping reflections at constant phase across the neighbouring CMP gathers to be used in CRS AVO analysis.

Case Study

A case study was carried out in order to illustrate the possible improvement in both imaging and AVO analysis by the CRS method. As a data example, a 2D seismic line accross a known gas-bearing reservoir was selected. Figure 1 shows the CRS stack of this data. The main reflector at a reflection time of 0.5 s corresponds to the shallow Carboniferous reservoir layer.

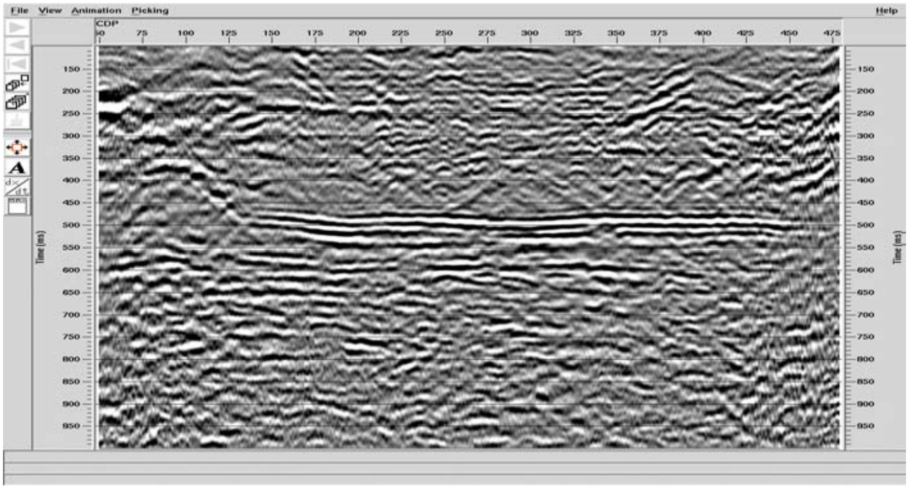


Fig. 1 CRS stack

A smooth stacking velocity field was used for conventional imaging. It was used as a guide function for the CRS parameter search, allowing a relative variation of 3%. The resulting stacking velocity field (Fig. 2) corresponds to the CRS parameters alpha, R_{NIP}. It shows a variation due to the local estimation of the CRS parameters.

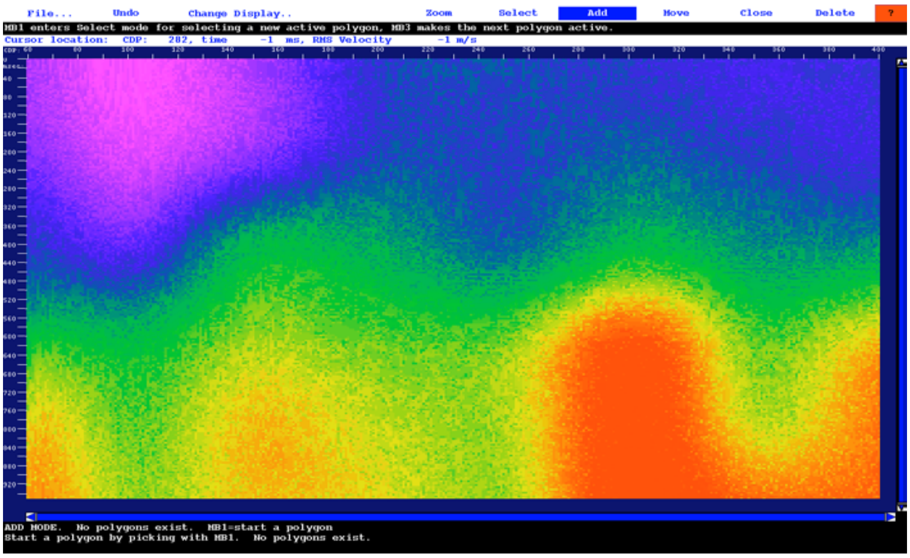
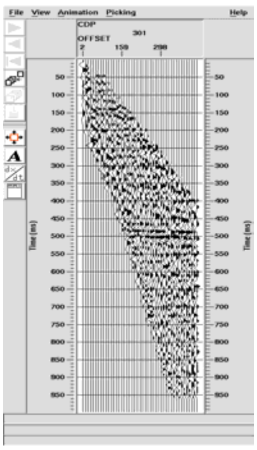


Fig. 2 Stacking velocity from CRS velocity search

After imaging, both conventional AVO, and CRS AVO were carried out on the data, using dynamic corrections from NMO processing, or CRS processing, respectively. AVO analysis was then performed along constant time in the prestack data. At a single CMP location, the data fold strongly differed for conventional AVO, and for CRS AVO, respectively. A dynamically corrected CMP gather for conventional AVO is shown in Fig. 3. For the corresponding CRS supergathers the five central CMP gathers are shown in Fig. 4. Hence, the CRS gather displays contain five times more traces than CMP gather display, leading to larger display sizes at the constant horizontal scale (traces/cm). The dynamic correction of the CMP gather was determined by interactive stacking velocity analysis.

The moveout correction of the CRS supergathers was calculated from the automatically derived CRS attributes (alpha, R_{NIP}, R_N).

The objective of the AVO analysis was to locate the gas-bearing part of the Carboniferous reservoir. These gas deposits are characterised by an increase of the absolute reflection amplitude with offset. Within the analysis, the AVO gradient (G) and the intercept amplitude (P) are calculated for each sample of the zero-offset section. Combined displays of P and G help to discriminate and to underline AVO anomalies. In the conventional gradient stack (P*G) of single CMP gathers (Fig. 5), some larger positive AVO anomalies can be observed in the CMP range 285 to 391. Especially in the right part of the section, however, the anomalies are difficult to recognize. Further positive anomalies with small extension are scattered all over the section, which are most likely caused by artefacts due to poor signal to noise ratio. In the gradient stack (P*G) of the CRS supergathers (Fig. 6), most of the anomalies with small extension disappeared. The resolution is much better throughout the section, than the conventional result of Fig. 5. In the right part of the section, the zone of interest at about 500 ms is much clearer in the CRS result. The positive anomaly values are clearly differentiated from zero or negative values.



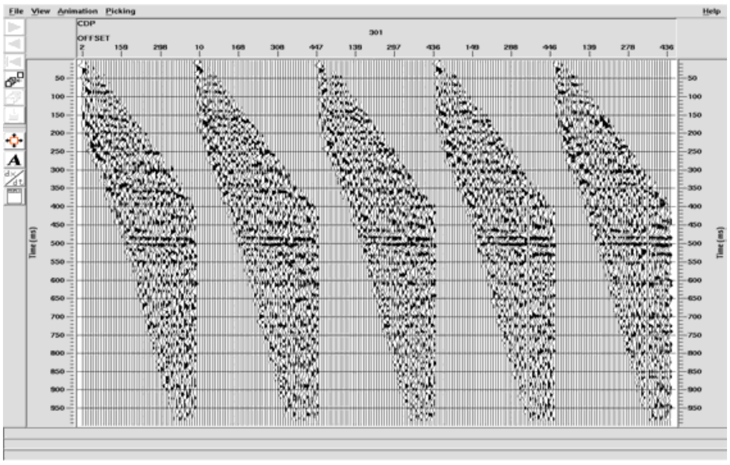


Fig. 3 NMO gather for AVO Analysis Fig. 4 CRS gather, CMP/offset sorted

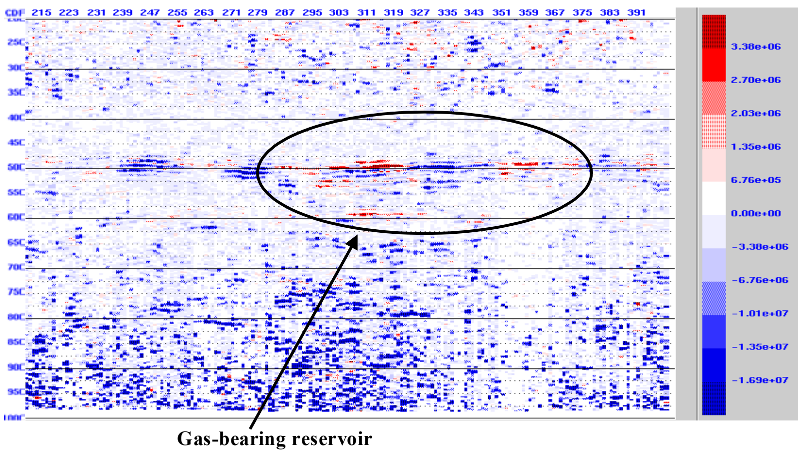


Fig. 5 AVO gradient stack from CMP gathers

In general, the signal-to-noise ratio of the gradient stack has improved significantly by using the CRS supergathers as the basis of the AVO analysis. This is as well supported by AVO cross plots of the gradient stacks. An AVO cross plot displays the behaviour of peak and trough amplitudes in a graph with the intercept P on the horizontal axis and the gradient G on the vertical axis. The cross plots in Figures 7 analyse the main reflector at about 500 ms, including the regions with anomalous AVO behaviour. The analysis window extends over the whole section with a vertical size of 100 ms. For CMP gathers, the AVO cross plot is displayed in Fig. 7 left. The data points are arranged around the diagonal through the origin and the second and fourth quadrants, following the wet trend. For CRS supergathers, the corresponding AVO cross plot is displayed in Fig. 7 right. The ellipse of the wet trend is similarly prominent, but has a shorter length. Due to the evaluation of larger portions of data, the extreme values of the wet trend in the second and fourth quadrants disappeared. In the first and third quadrants, however, yellow and blue background colours mark anomalous data, that appear well separated from the wet trend data accumulation. This data configuration is expected for a class 3 AVO anomaly, including the wet trend, and top and base of gas.

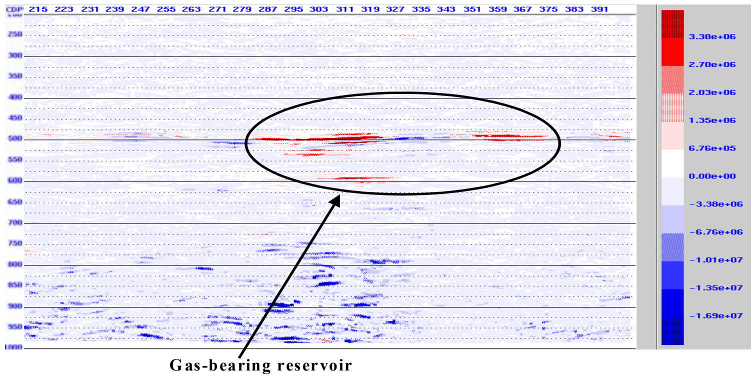


Fig. 6 AVO gradient stack from CRS super gathers

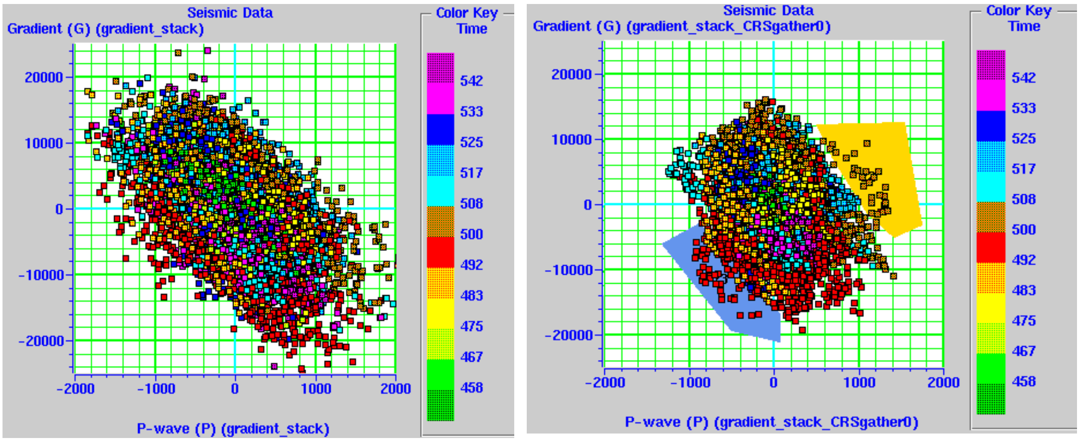


Fig.7 Crossplots of AVO gradient G versus intercept amplitude P
left: from CDP gathers **right**: from CRS supergathers (anomalous regions are marked in blue/yellow)

Conclusion and Outlook

The imaging advantages of the CRS method have already been exploited and discussed in detail in several publications. CRS imaging generally improves the signal-to-noise ratio. It renders a better reflector continuity, and enhances dipping structures. This paper points at another advantage of CRS processing. A case study shows that CRS supergathers may be used for an improved AVO analysis. The signal-to-noise ratio of the gradient stack is much higher than in conventional AVO from CMP gathers. The CRS AVO attribute section clearly distinguishes an anomaly at a known gas bearing reservoir. Cross plots of the gradient stack show a better separation of anomalous zones which may be classified in order tidentify top and base of hydrocarbon deposits. The AVO improvements by CRS are based on CRS supergathers, and on the CRS moveout correction. The moveout correction aligns reflection of any dip across the whole supergather, and the large portion of data in the supergather provides a stabilized AVO result. Supergathers of similar size could be built in conventional AVO as well, but would result in a phase mixing in case of dip. The incorporation of local time dependent dip, and the general increase of signal-to-noise ratio imply an improved AVO analysis by CRS for many types of data. Large benefits of CRS AVO is especially expected in areas of strong dip, and at deep targets with a low signal-to-noise ratio.

References

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Jaeger, R., Mann, J., Hoecht, G., Hubral, P., 2001: Common-reflection-surface stack: Image and attributes. Geophysics 66 (1), pp 97-109.
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