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Pre-Stack Merging™ of 3D seismic surveys
P. I: Weights for trace interpolation. P. II: Design of overlap zones

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Part I: Weights for trace interpolation

3D Seismic exploration in Poland has been performed since 1994. Until present, GT have accomplished 30 complex 3D projects in Poland, going from design phase, through acquisition, data processing to seismic interpretation. Introduction of 3D technology meant a new, fresh breath in geophysical surveys, and offered results of much higher degree of reliability than used to be obtained with 2D technology. Accuracy of exploration drillings performed on basis of geophysical data had rapidly increased. Decisions about planned wells on basis of 2D surveys offered success ratio only 1 of 10 wells, while it turned to 9 of 10 wells drilled on basis of 3D data. Some large oil fields – as for Polish conditions – had recently been documented with use of this advanced technology.
In standard procedure, 3D project is preceded by reconnaissance using 2D technique. If the data concerning oil rocks obtained with 3D technology become confirmed by well data, the area of prospection is being extended. Such situation occurred on BMB Field, and on Koscian Block, where first successful discoveries obtained with 3D technology, resulted in continuation of search along discovered reefs. Koscian Block is composed of 8 overlapping projects, while BMB contains 7 projects (see below).

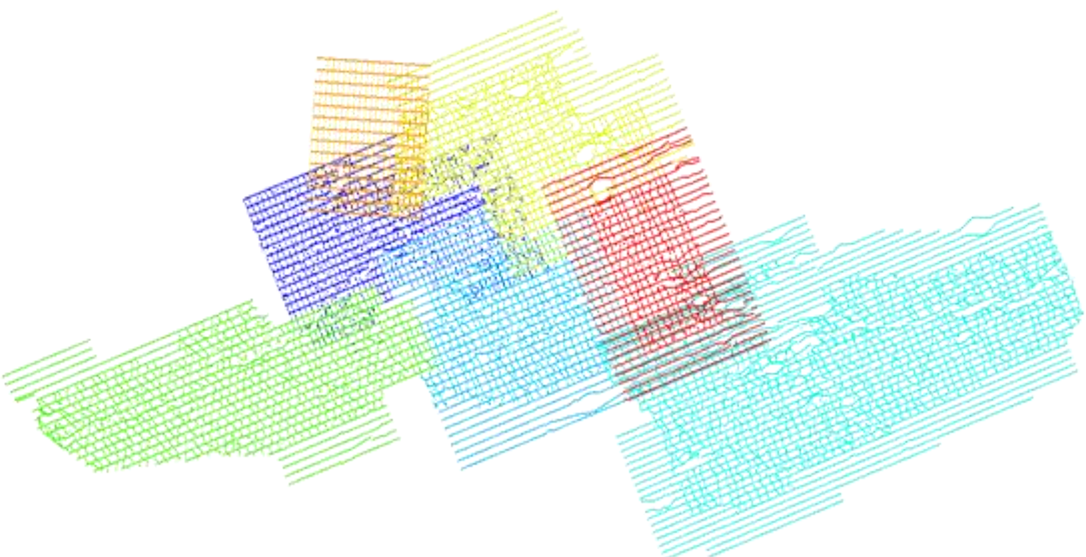

Figure 1. Overlapping areas of the seven 3D surveys, originally recorded as independent ones.

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Data obtained in result of processing of each following 3D project overlapping with previous projects must be coherent with the data generated before and be a continuation of all earlier works.

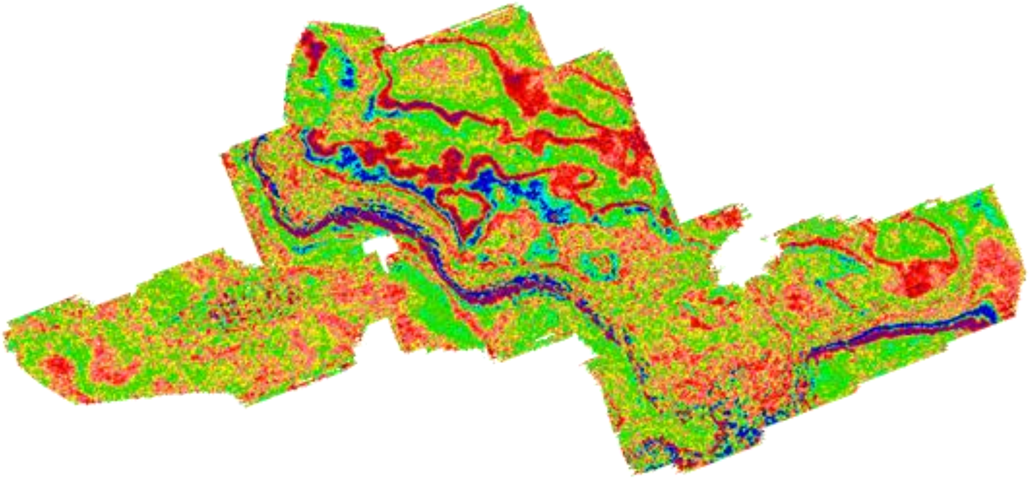

Figure 2. Time slice through merged 3D projects on BMB field.

The basic element of 3D technology – spatial coherency of information from an area of interest. What is typical for a single 3D project, can be obtained for a larger area (2 or more projects) by merging them at pre-stack data processing stage.
In order to perform successful merging further extension of the following project must be considered at the design phase. Proper configuration of overlapping regions must be taken into account as well as realized during acquisition.
Corresponding technology for purpose of 3D Pre-Stack Merging had been designed and introduced in the GT Processing Center. Standard procedures available in basic processing package did not offer full service in this regard, so they had been complemented by GT proprietary software, created for particular procedures.
Technology offers full coherence in the following aspects:

- wavelet shape,
- trace amplitude scaling,
- static corrections,
- kinematic corrections,
- seismic migration.

Repetition of selected surface-consistent processing procedures is usually considered. In 3D Pre-Stack Merging, all the recorded data are being used for creation of composite, but homogeneous, migrated dataset. Edges of the previous project are supplemented by new data, giving in result valuable information in overlapping zone.
In some cases merged projects have different azimuths of receiver lines (difference of presumed azimuths of binning lines). In that case binning rotation (re-binning) must be performed in order to find a common azimuth of binning for merged project. Mentioned operation had to be performed on both BMB Field as well as on Koscian Block. Software used for re-binning in procedure of 3D Pre-Stack Merging bases on the in-house designed algorithm of interpolation.

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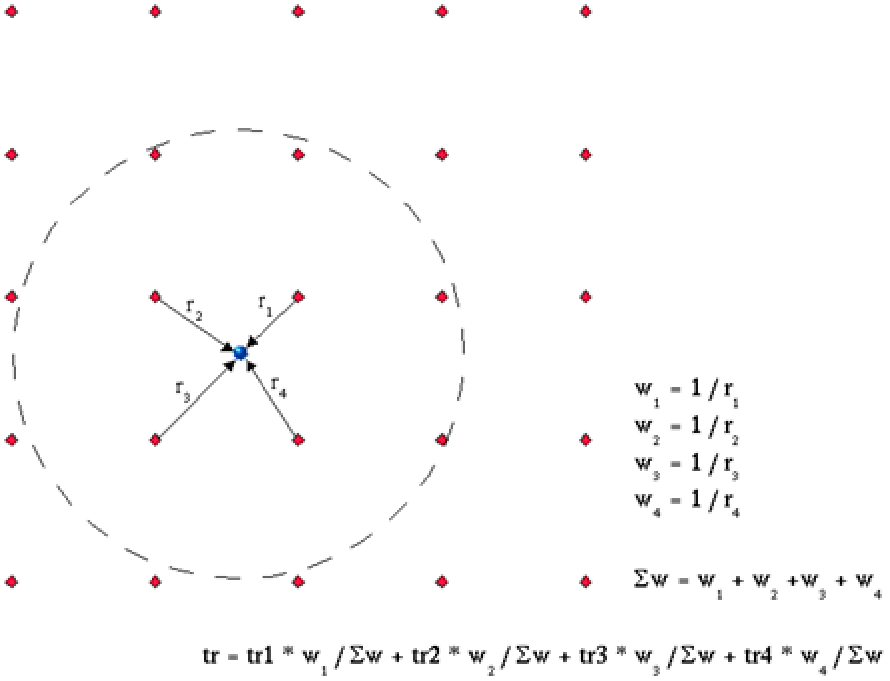

Figure 3. The idea of trace interpolation in the 3D space.

The above formula of binning offers possibility of presentation of the 3D data (raw stack, final stack, or migration) in new binning order prepared for merging.

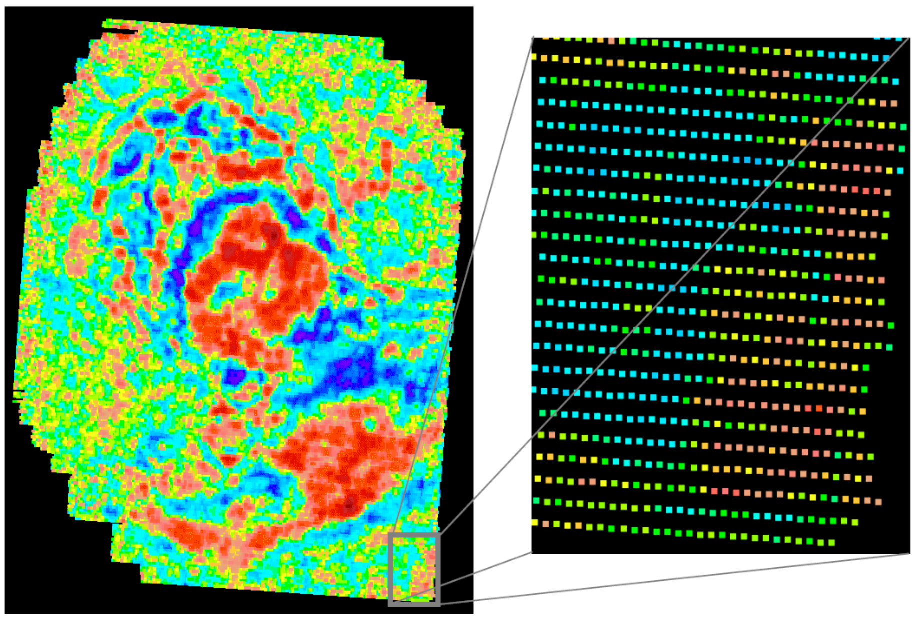

Figure 4. Time slice through the final data of the first 3D project performed on BMB field in original binning order. Azimuth of recording lines: 93°, bin size: 25m x 50m.

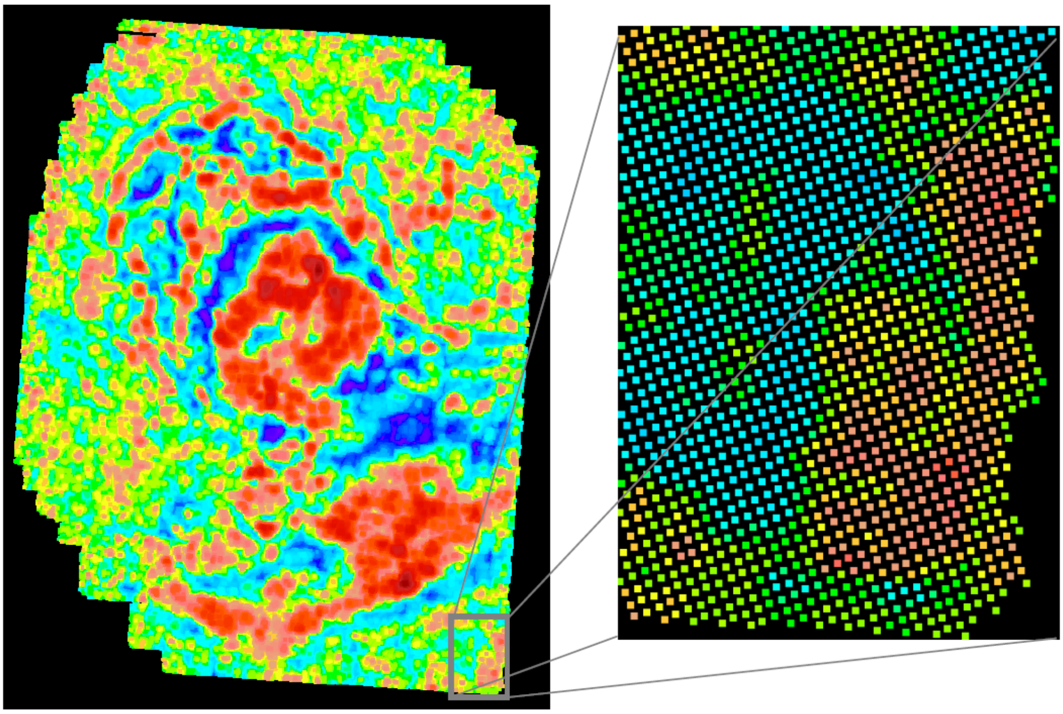

Figure 5. Time slice through the same project in final binning order, coherent with subsequent projects of this Field. Azimuth: 67°, bin size: 25 x 25m.

Presented algorithm of interpolation is also used for extraction of arbitrary lines from 3D data.

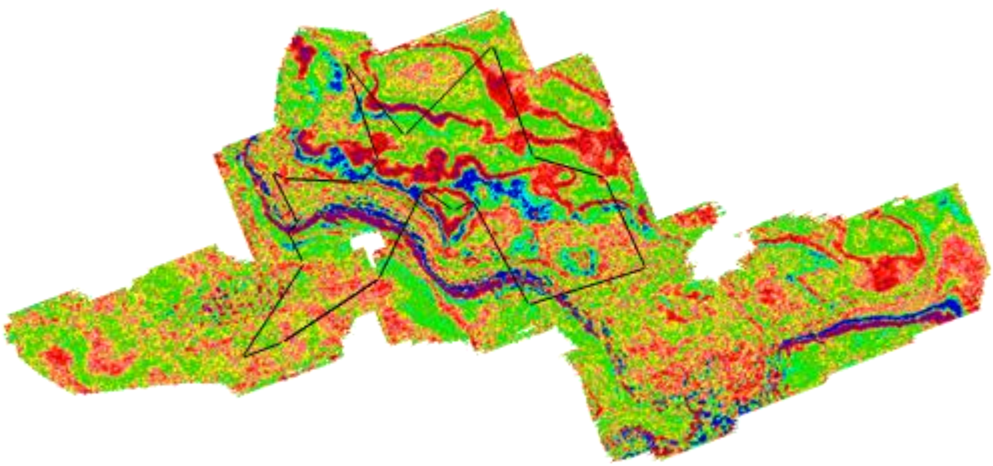

Figure 6. 2D arbitrary line, connecting locations of selected wells'. This way, the fence-diagram section has been designed to be extracted on BMB field.

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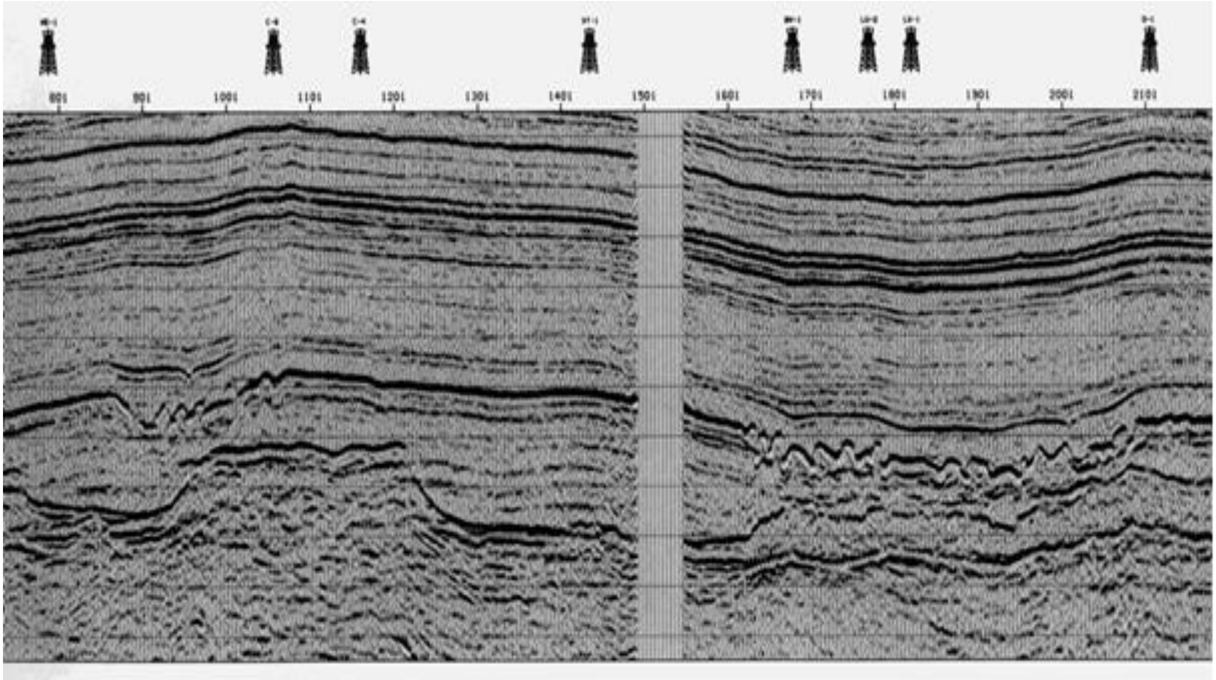

Figure 7. Fragment of arbitrary 2D line extracted between wells locations on merged 3D project.

Arbitrary 2D line extracted on different processing stages allows fast verification and selection of merging parameters. This applies to following aspects:

- wavelet form,
- trace scaling,
- coherence of static corrections,
- coherence of kinematic corrections.

Deterministic method of wavelet analysis, zerophasing, and wavelet processing can be performed on representative, limited dataset. Wavelet can be effectively controlled in area of wells' location with use of such arbitrary line.
Wavelet coherence between merged land projects is fundamental from the early stage of data processing. It is necessary for correct First Break Picking in order to obtain refraction static corrections coherent for each merged project.

FB Picking is thus performed only on the following data, while for previous project archive picks are used – convergency of assumptions between both parts of data is crucial at this stage.

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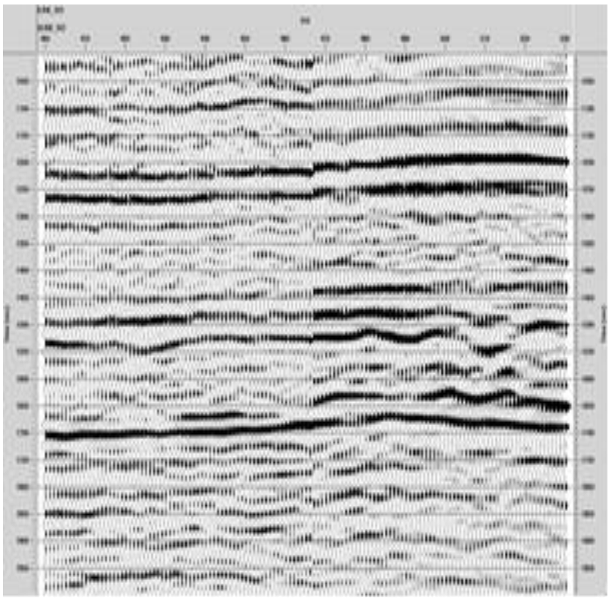
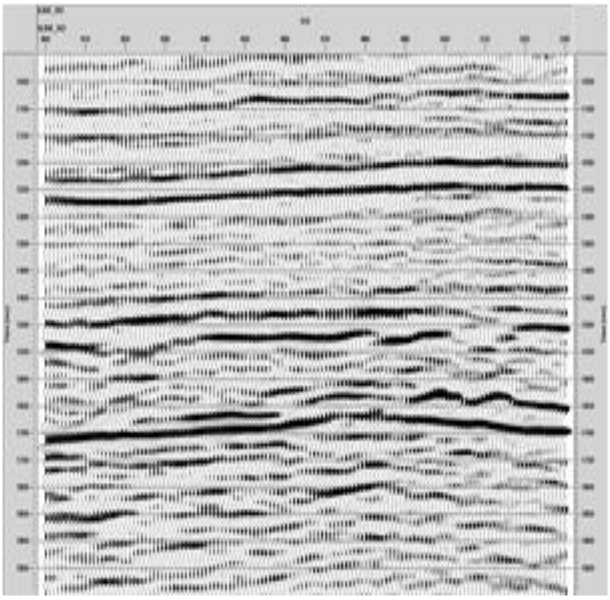
Area of the following survey to be processed in 3D Pre-Stack Merging will then be extended in direction of previous project. Size of extension depends on configuration of overlapping zone as well as acquisition parameters for merged surveys. Merging of full records seem to be more efficient than only parts of them due to surface consistent processing, as deconvolution, trace scaling and static corrections. Stacking velocities (RMS) are supplemented in overlapping zone by archival curves from previous project. All work is performed on extended area but this method allows merging of old stacked cubes with new coherent stacked cube (cubes merged beyond the area of the new project) and performance of migration on even larger area (extended of aperture size), as well as merging of new coherent migrated cube with the previous ones.

Merging of two stacked cubes and possibility application of 3D migration on merged data allows to avoid significant problems always connected with low fold border area in overlapping zones.



BEFORE



AFTER

Figure 8. Example of stacked sections after brute merging and 3D Pre-Stack Merging.

Two other comparisons along sections of the composite 3D survey, after brute (labeled here “BEFORE”), and after GT interpolation can be seen on the following pages.

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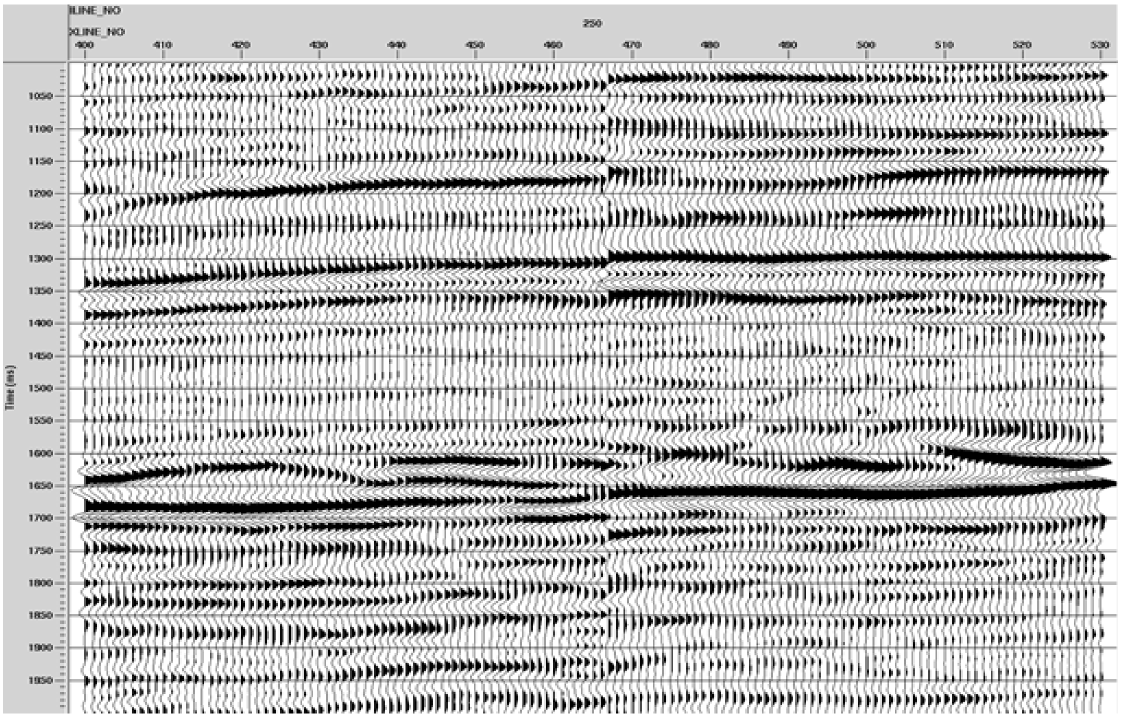

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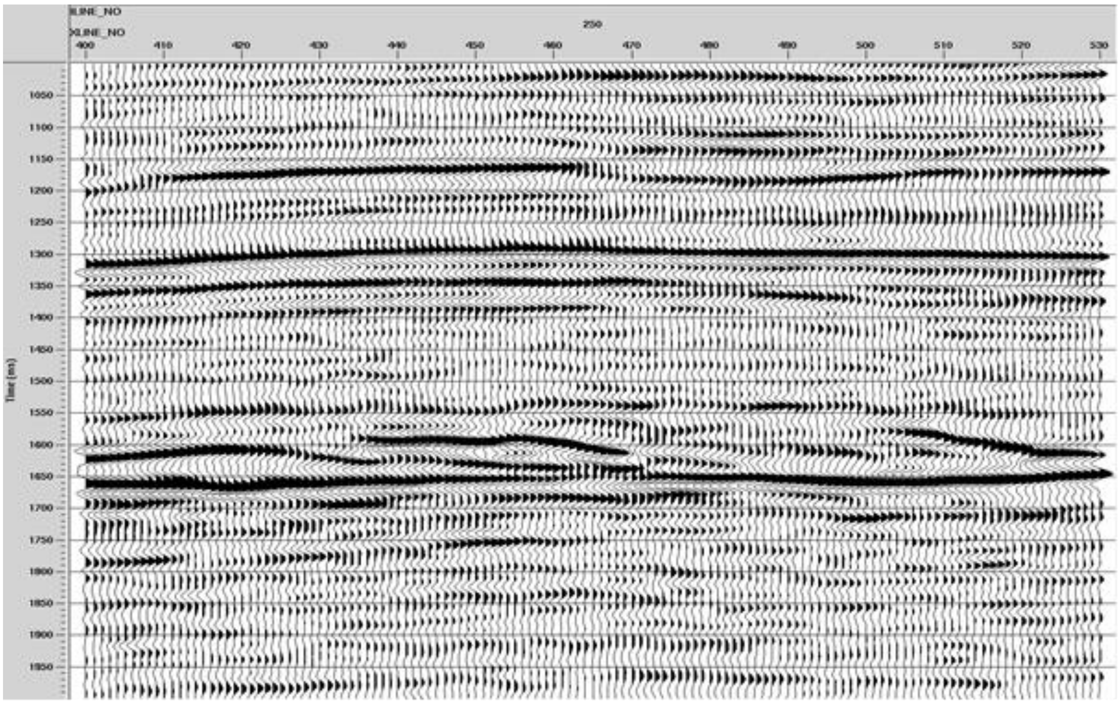

AFTER

Figure 9. Another comparison of brute merging and 3D Pre-Stack Merging final results.

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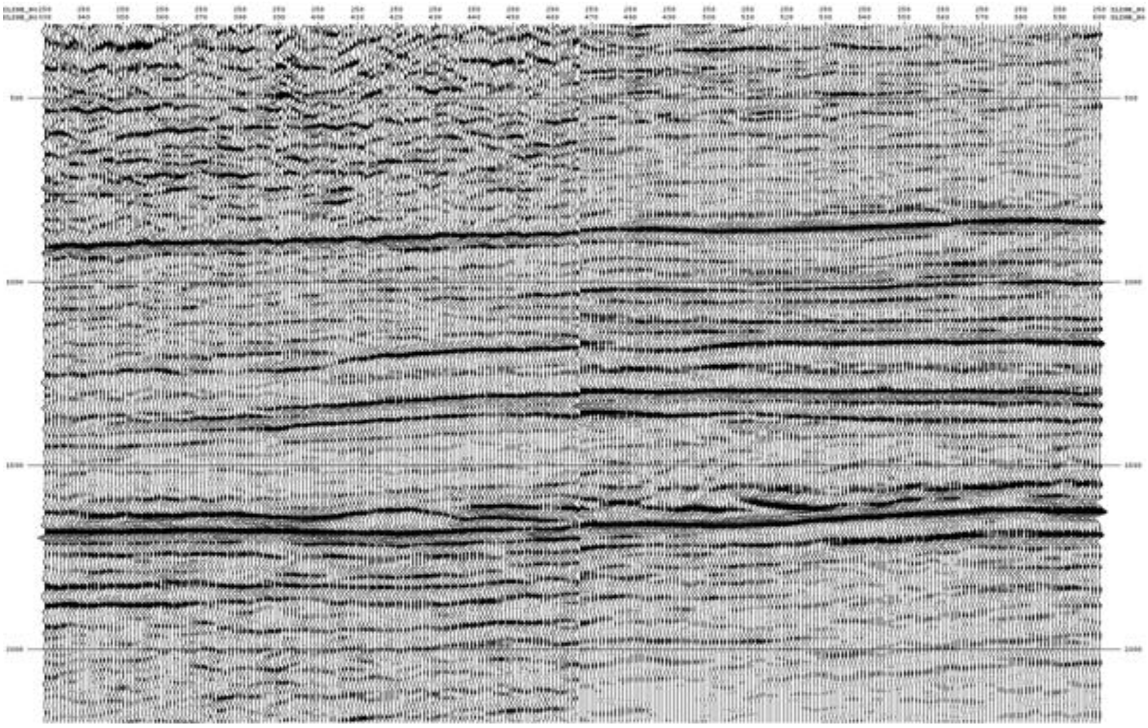
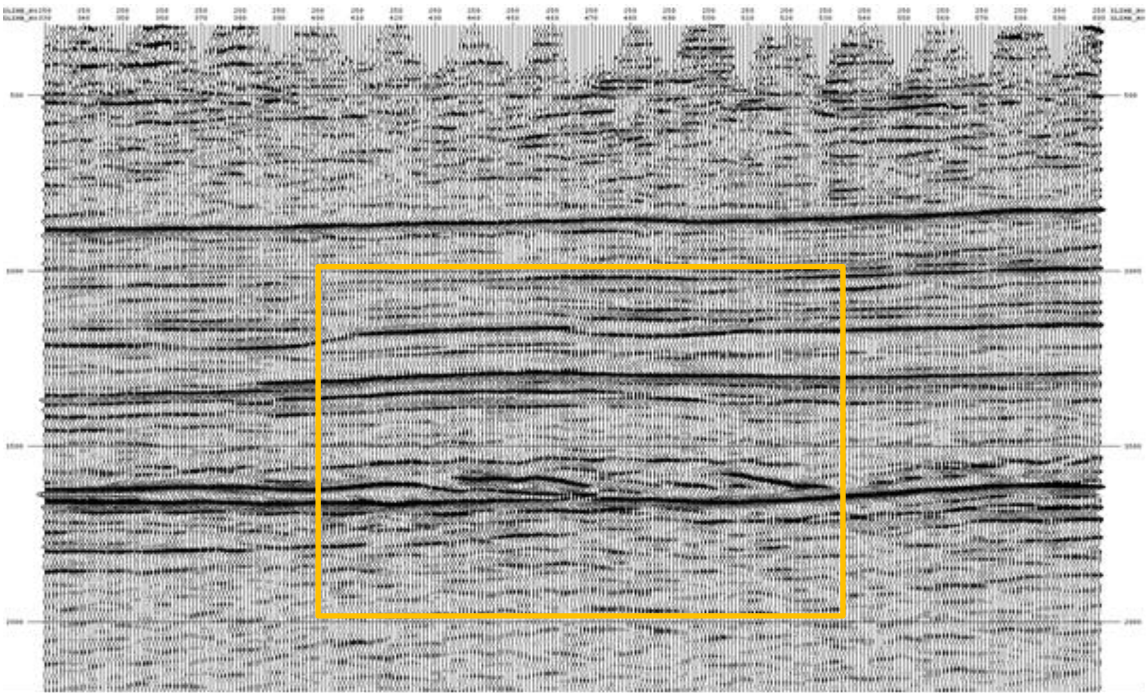


BEFORE



AFTER

Figure 10. More comparisons of brute merging and 3D Pre-Stack Merging final results.

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Part II: Design of overlap zones

3D Pre-Stack Merging™ is a method to process multiple 3D projects acquired in different conditions (time of realization, geometry, grid orientation, other parameters). The method offers the same results as in case of single, coherent set of data acquired and processed as one large project.
The proper choice of overlapping zones is a crucial point in 3D Pre-Stack Merging™, determining final result of its performance. Sequential steps of this aspect

determining necessary dataset for multisurvey projects processing are presented in this paper.

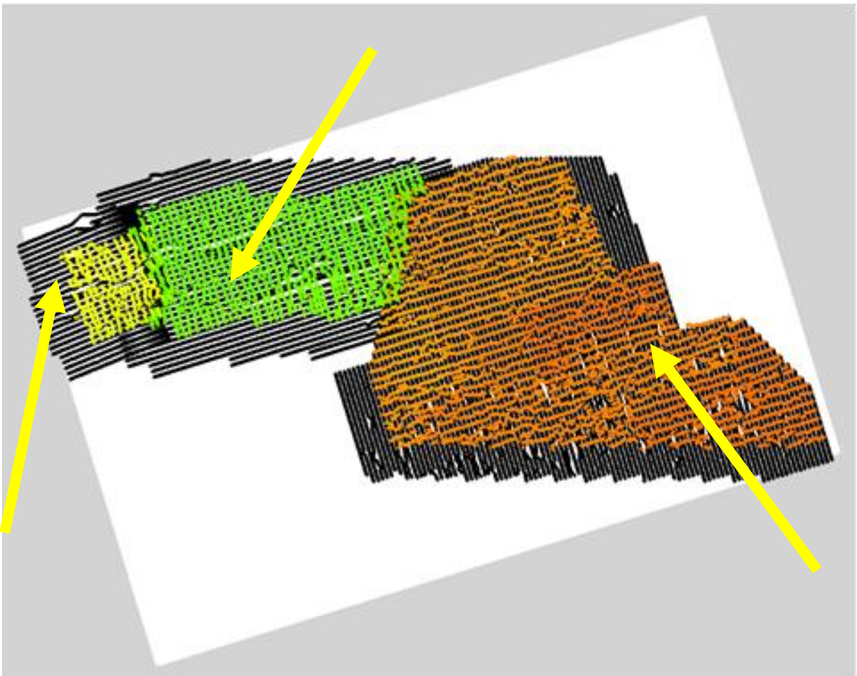

Figure 11. Three 3D projects. The new one is to be merged with two old projects.

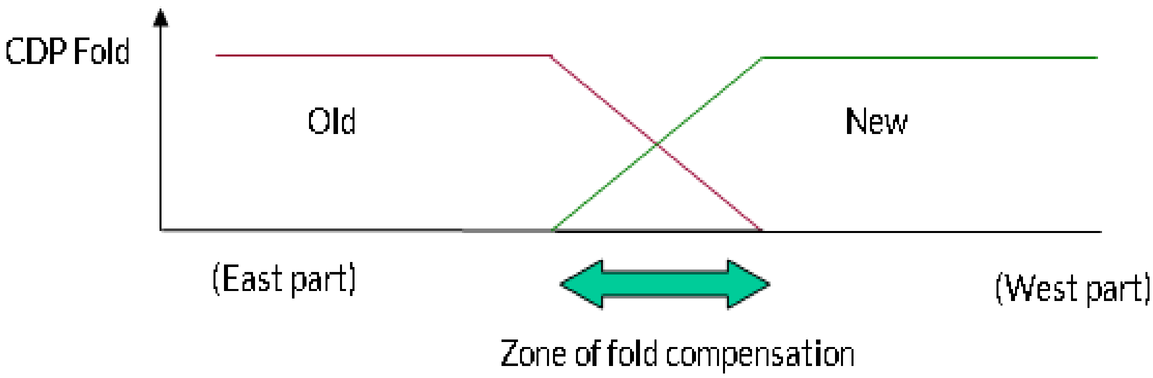

Figure 12. Idea of maintaining CDP fold coherency through overlapping zone.

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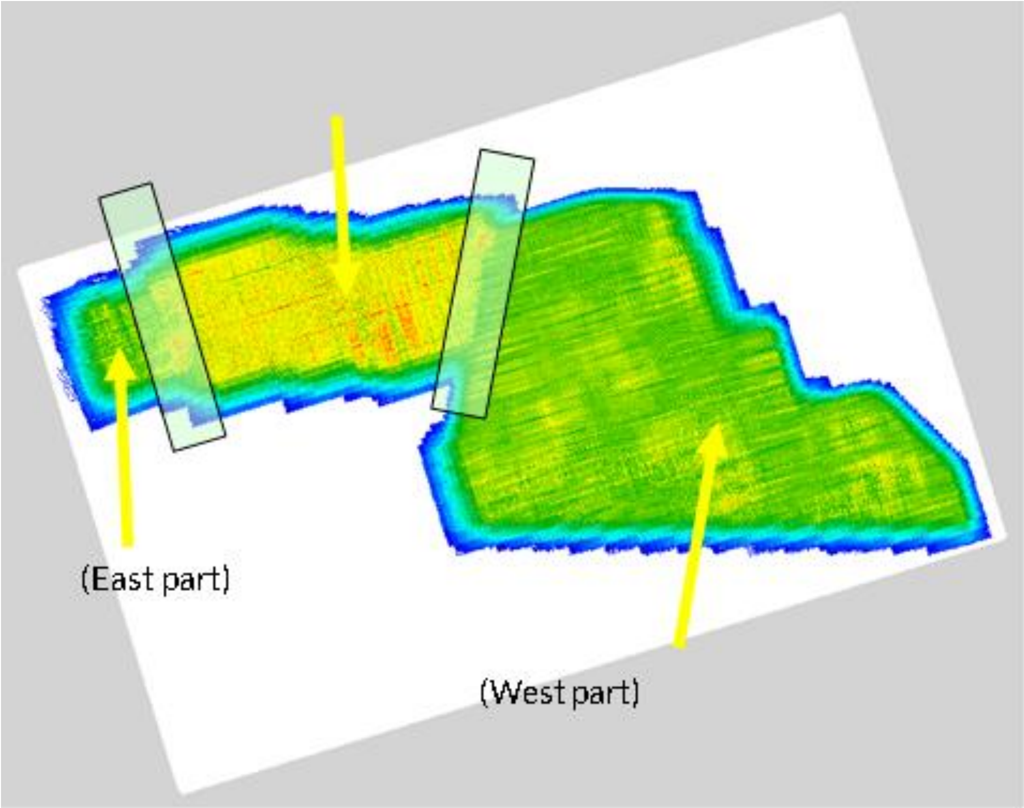

Figure 13. Three 3D projects. Illustration showing overlapping zones.

Fold continuity is a **first criterion** for successfully 3D Pre-Stack Merging™.
In overlapping zones CDP fold must be:

- not higher than average across the highest one
- not lover then average across the lowest one

The fold continuity criteria must be realized at acquisition stage.

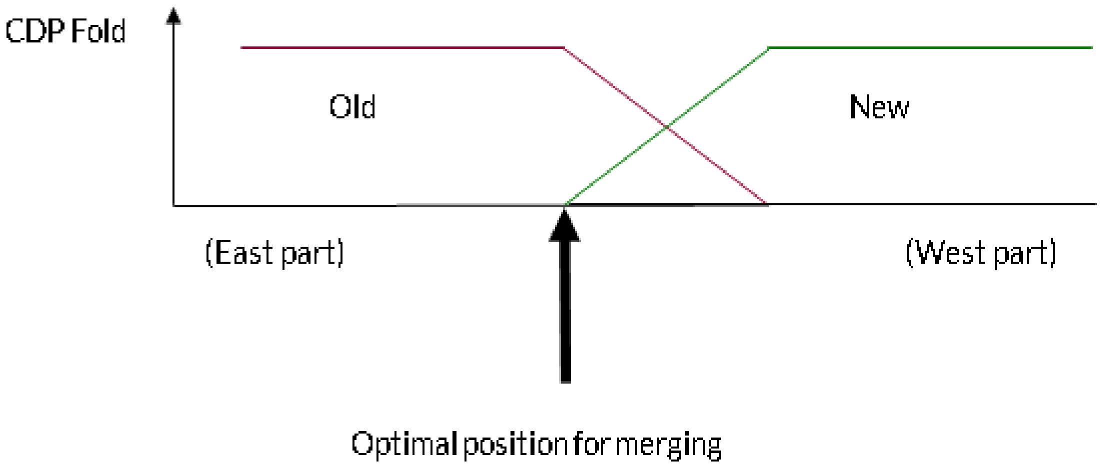

Figure 14. Optimal position for merging relative to overlapping zone.

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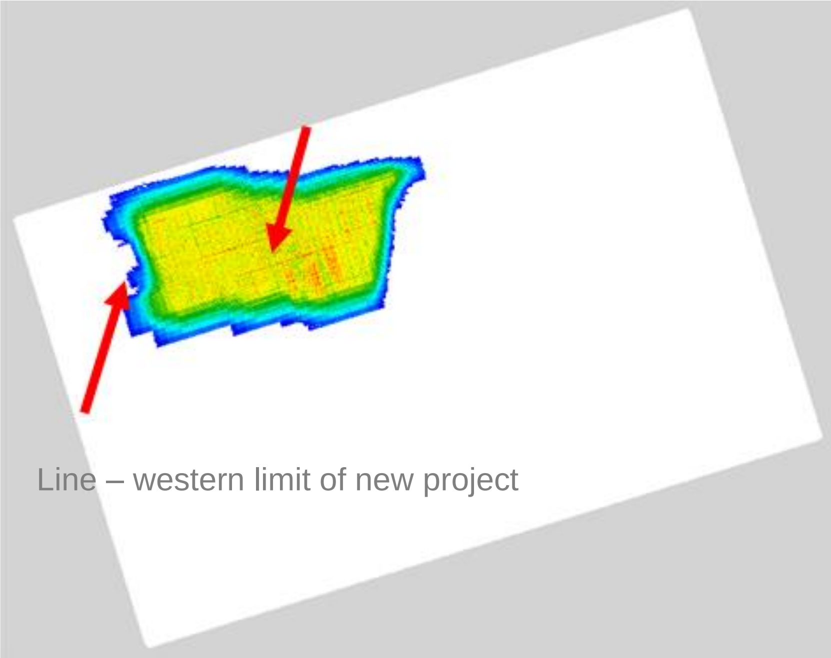

Figure 15. Optimal position for merging line.

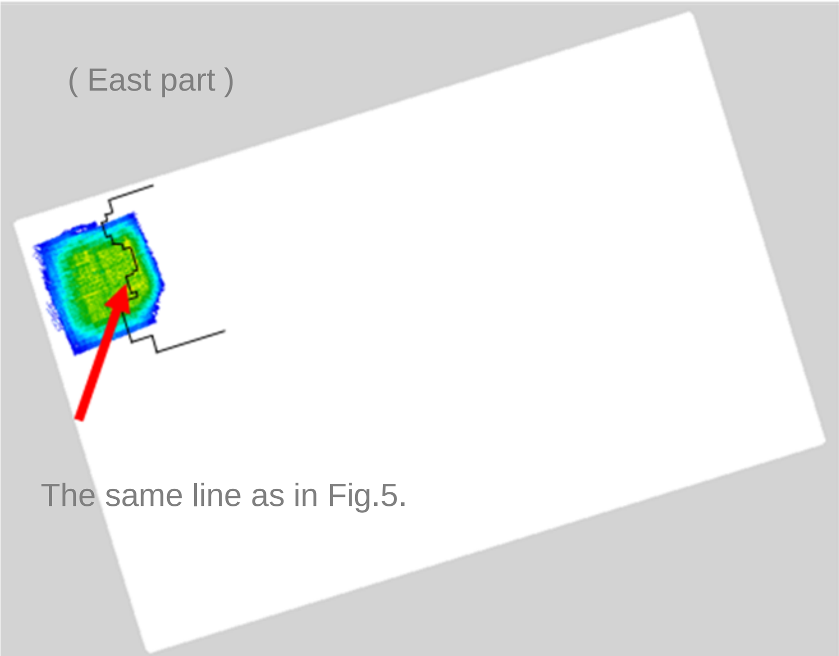

Figure 16. Line for merging overlaying on old project. The merging line positioned on eastern part of old project

Using this line, a polygon for the archive project is built. This polygon is used for data selection in the overlap zone.

Database projection method between CDP and SIN (Source Index Number) order is used.

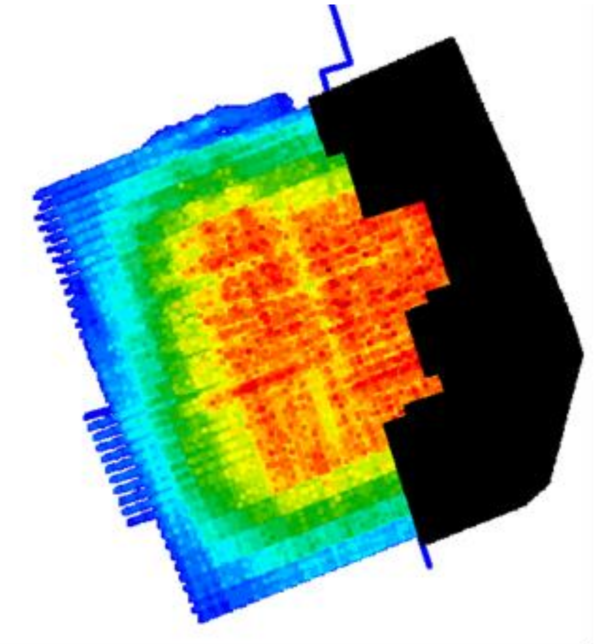

Figure 17. Polygon on CDP Fold Map (black color)

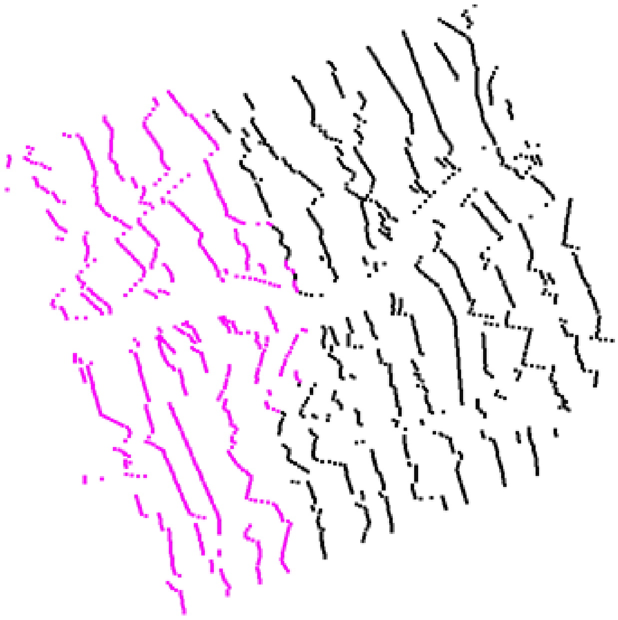

Figure 18. Shot points corresponding with selected polygon (black color).

Semi-automatic method of data selection (for processing) - first for eastern part. This records (black color) must be added to new dataset for new processing (3D Pre-Stack Merging™).

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Next: application of similar approach to the east side

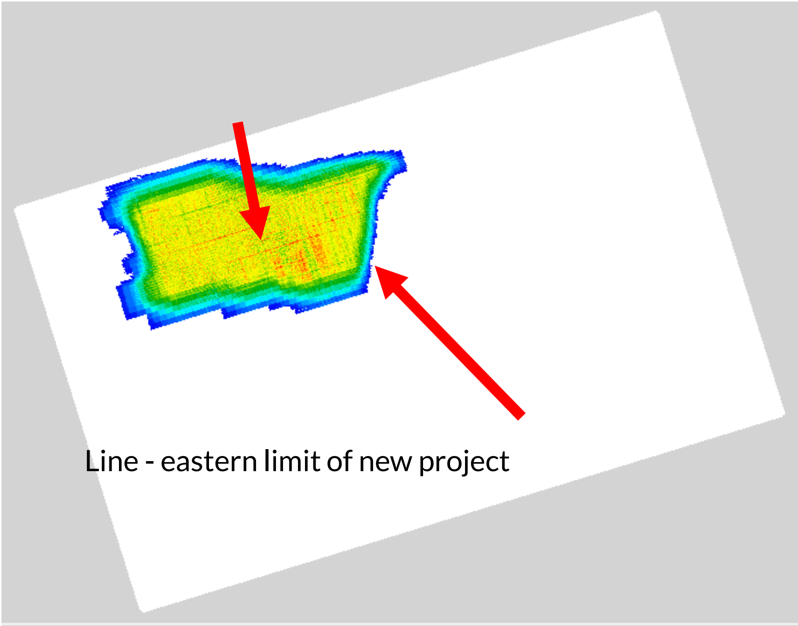

Figure 19. Optimal position for merging line.

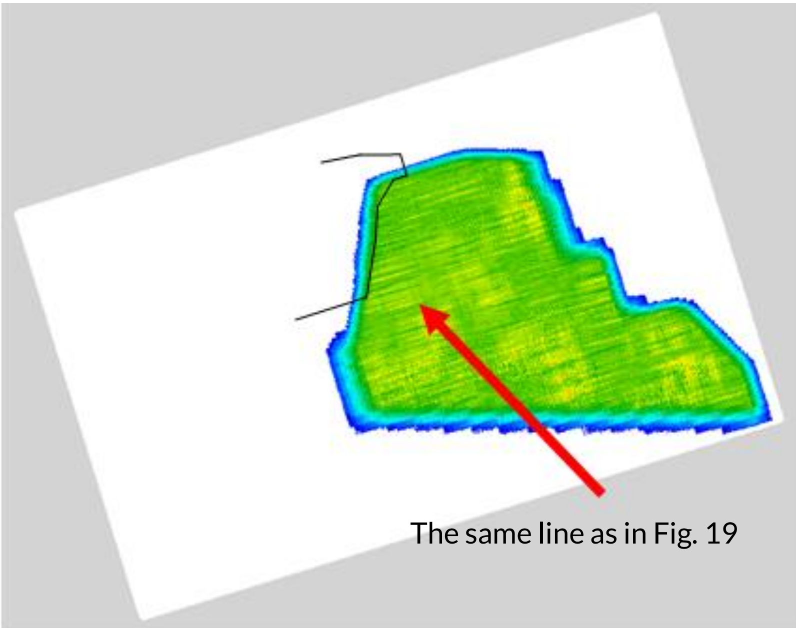

Figure 20. Line for merging overlaying on old project. The merging line positioned on eastern part of archive project.

Using this line a polygon for old project is build. This polygon is used for data selection in overlapping zone.
Database projection method between CDP and Source Index Number order will be used.

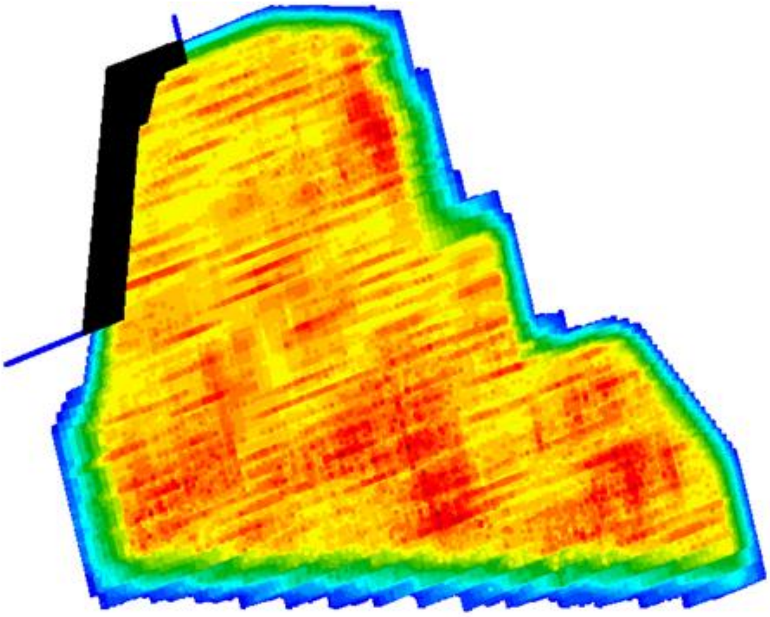

Figure 21. Polygon on CDP Fold Map (black color)

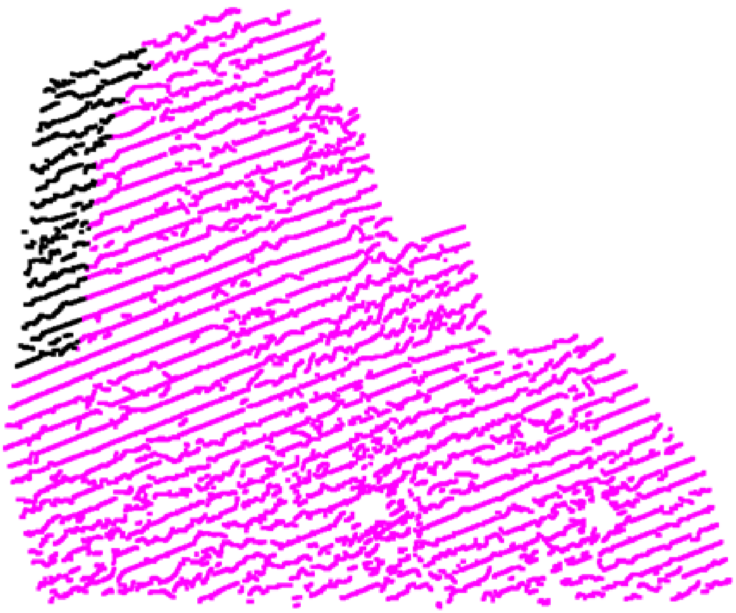

Figure 22. Shot points corresponding with selected polygon (black color).

Semi-automatic method of data selection (for processing) - first for eastern part. This records (black color) must be added to new dataset for new processing (3D Pre-Stack Merging™).

In most of 3D Pre-Stack Merging™ situation records with all traces are added from old data to new dataset. This provide to comfortable situation for respective the **second criterion** for successfully 3D Pre-Stack Merging™– necessary border for surface consistent procedure.

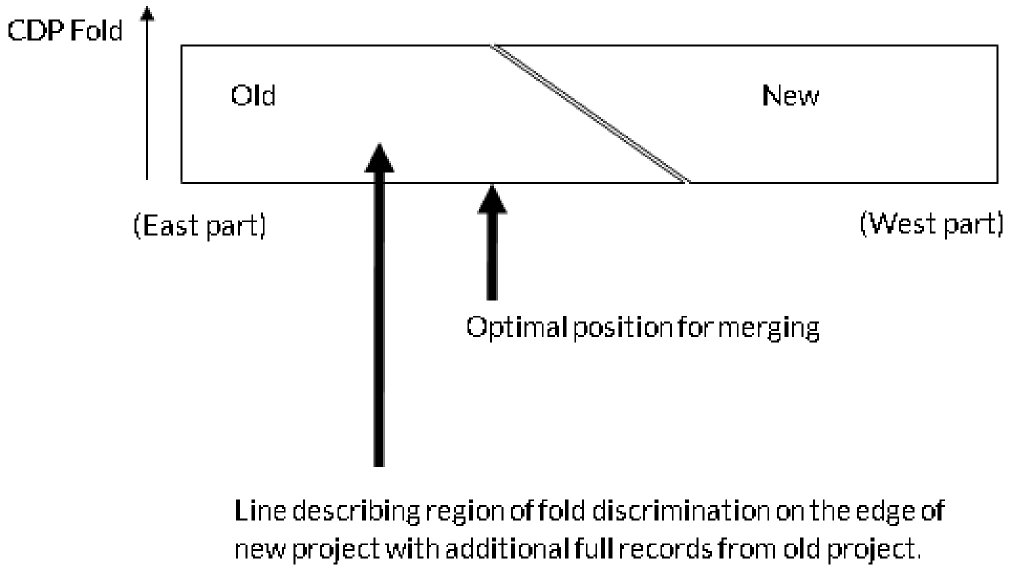

Figure 23. Optimal position for merging and line describing region of fold discrimination.

Assuming for first two criteria of Pre-stack Merging™ dataset for processing must like as on Figure 25 although new dataset like as on Figure 24.

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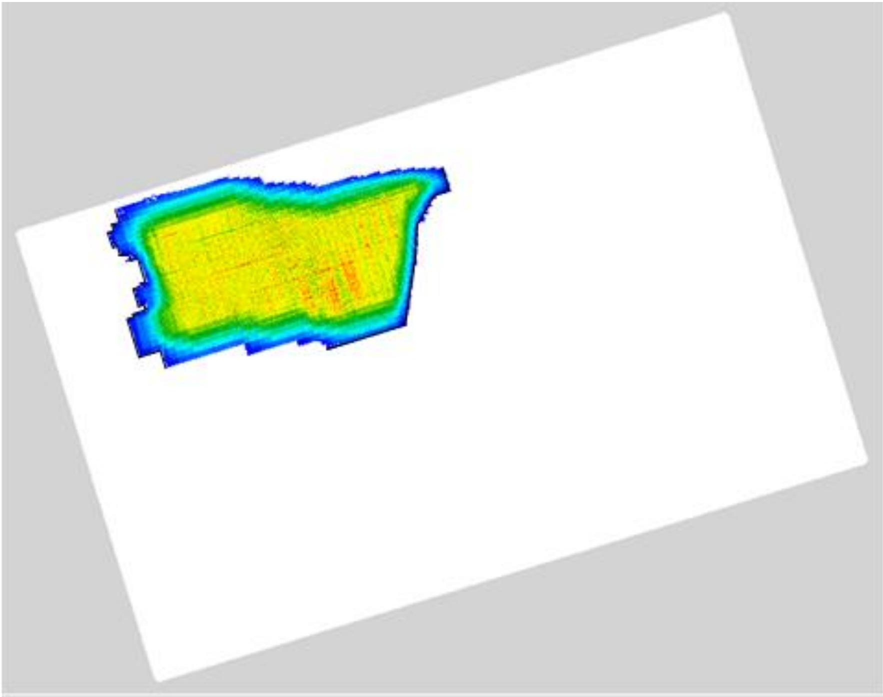

Figure 24. New project dataset (CDP Fold Map)

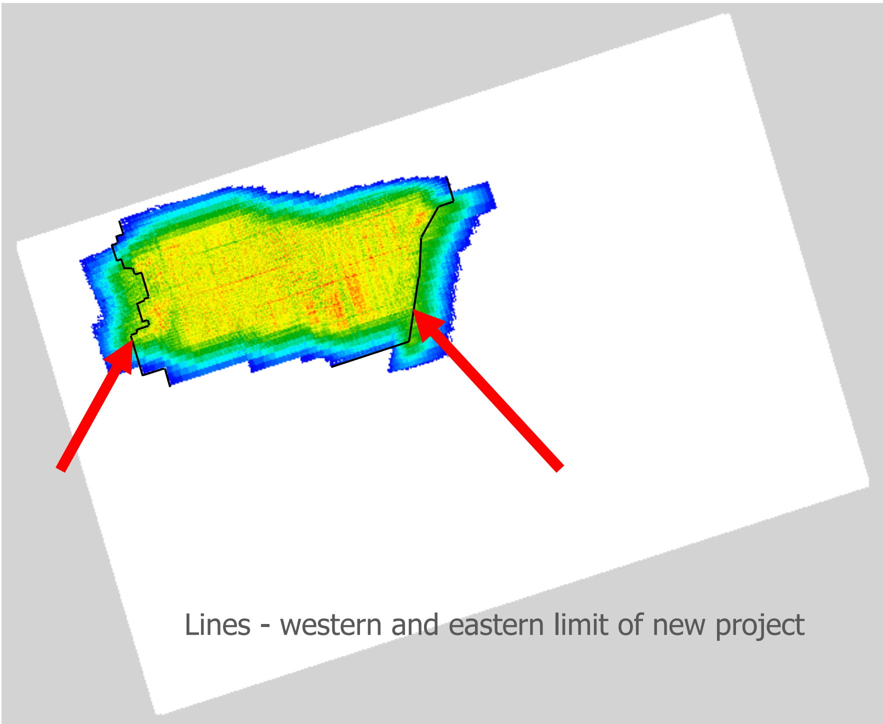

Figure 25. New project dataset with added overlapping subsets for 3D Pre-Stack Merging™

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The **third criterion** is necessary aperture for 3D post stack migration.
To realize migration first we merge new cube with old cubes along merging lines, and then select dataset for migration. Dataset for migration can be as large as we need to despite size of aperture – see the rectangle in Fig.26..

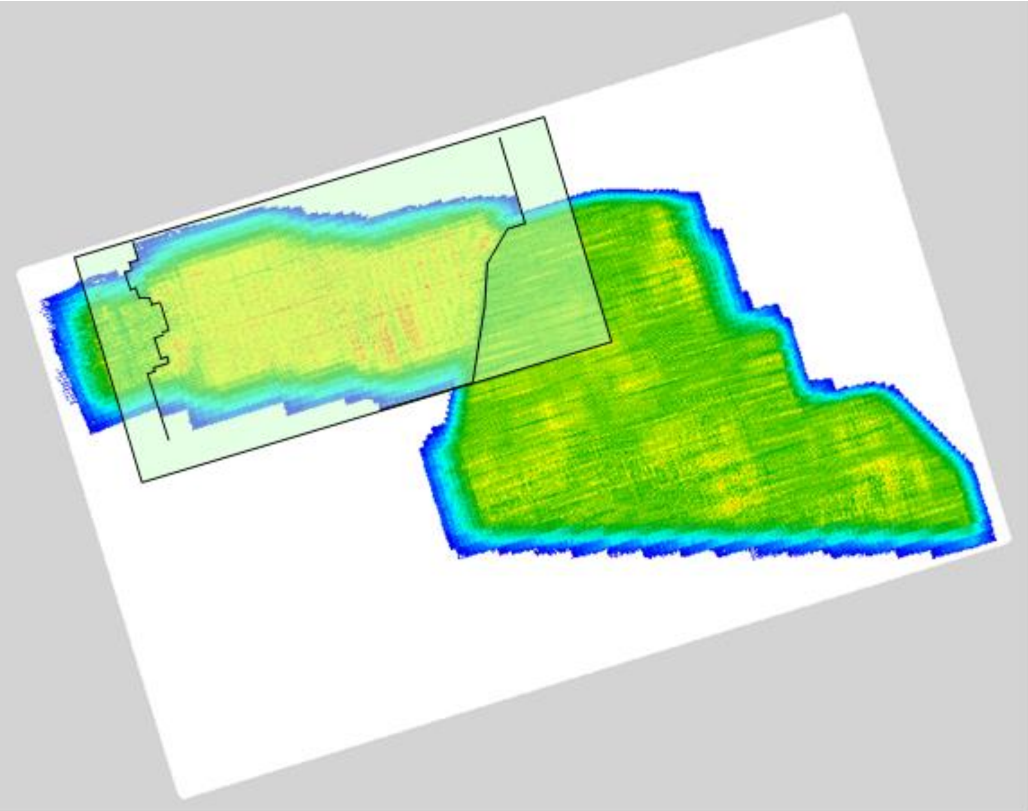

Figure 26. 3D dataset prepared for migration (rectangle)– after merging with archive 3D stack cubes.

After migration of data extended to rectangular (see Fig. 26) the final migrated volume will be merged with old migrated volumes along lines of merging.

Further reading

1. S. Basu, S.N. Dalei and D.P. Sinha, 2008, 3D Seismic Data Merging – A Case History in Indian Context. Geohorizons, Dec., SPG.
2. H. Maldonado, T. Brooks, L.M. Saavedra,G. Gutierez Gilbert, A. Saavedra, P. Watterson, 2009, A case study on the challenges overcome in the merge of seven on-shore 3-D surveys of varying acquisitions in Huila department, Colombia. X Simposio Bolivariano Exploración Petrolera en Cuencas Subandinas, Cartagena, Colombia, July 2009.