



Cartographic Reprojection of 3D seismic data using OpenWorks: A New vision of data load process.

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Abstract

On conventional exploratory process, the interpretation project covers an area not too large and thus seismic 3D data are acquired and processed in a unique coordinate system.

Nowadays there is a need to work with large areas, and a question arises: How can I load a 3D seismic data processed in a cartographic projection on an interpretation project created in another one?

Recalling that a straight line in a projection becomes a curved line in another projection, the reprojection of seismic grid data can lead to a positional error of up to 400 meters.

This paper aims to detail the problem to prevent new episodes and provide a solution that would minimize or avoid this type of occurrence, using the OpenWorks R5000 solution: data is stored in its original coordinate system, the interpretation project may use another cartographic system (large area fitted) and 3D data is handled in small parts.

Introduction

With the technology development, seismic technique became the most powerful tool for oil and gas exploration and one of the most important in the characterization of petroleum reservoirs.

The seismic interpretation is the analysis of the processed images for exploration, oil reservoirs characterization and monitoring. This analysis are very important for the oil industry because it helps do define the oil reserves location (or gas), evaluate its contents and exploitation feasibility. (MATOS, 2004)

On conventional exploratory process, the interpretation project covers an area not too large and thus seismic 3D data are acquired and processed in a single coordinate system (geodetic datum and map projection). More specifically, the usual cartographic projection used is the UTM (Universal Transverse of

Mercator), which presents a limitation of use for areas with dimension greater than 6 degrees of longitude.

More recently, geologists and geophysicists needed to work with large areas (regional projects) and wanted to analyze geological related but spatially distant features, promoting an increasing search for changes in the properties of maps and cartographic interpretation projects. This adjustment is performed by means of cartographic transformations.

The question that arises is: a 3D seismic data processed in a coordinate reference system (CRS) needs to be loaded on an interpretation project that uses another CRS. And this can lead to serious distortion problems.

The paper aims to detail this problem, highlighting the causes in order to provide a solution to minimize or avoid this type of occurrence.

The 3D Grid Problem

Recalling that seismic data are loaded based on the seismic grid and inlines and crosslines spacing, it is important to note that a straight line in a cartographic projection, when converted to another projection, becomes a curved line.

The simple cartographic transformation of the vertices of the seismic grid ends up introducing serious distortions in data loading, since the new grid is no longer a real rectangle. More than that, the use of reprojected coordinates of the vertices of the grid as a reprojected grid, introduces the error of representing curves by straight lines.

Thus, the reprojection of the vertices of the grid generates errors and distortions that can lead to a geographically mistaken interpretation of seismic data and drilling of wells with positioning errors of up to 400 meters.

The distortion is caused by the change of the cartographic properties of the seismic data that was established during the seismic processing, when the regular grid is constructed. During seismic processing the data geometry is "adjusted" in order to have a regular distribution of data in a rectangular area (just as raster data).

This data geometry "adjustment" is done in a given CRS (usually the same CRS of acquisition) and when the map projection is changed there is a "break" this geometry adjustment and a straight line becomes a curve, to preserve the cartographic projection characteristics. An important aspect is that the distortion (positioning error) is not constant, varying according to region and size grid. Figure 1 shows what happens when a grid is reprojected

using only the four vertices and using interpolated points along the grid. And Figure 2 shows the reprojection distortion and the correct and wrong position of data.

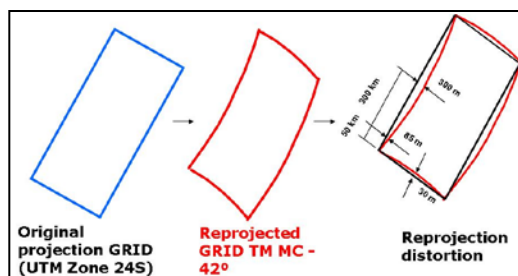


Figure 1 : The Reprojection Grid Effects

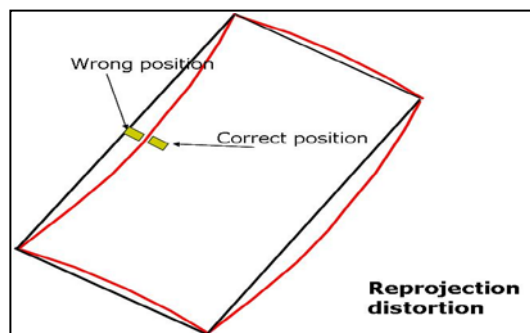


Figure 2 : The Reprojection Distortion

Method

Tests

In this item we described the used procedures to verify the distortion causes and Intensity.

Evaluation by Grid Control Points Coordinates

The test was to evaluate the occurrence and magnitude of the distortion as a function of the 3D grid control points.

For this, we compared the original data grid, with coordinates created by on the fly system, with another one, a product of Cartographic reprojection process.

The OpenWorks® Project cartographic reference system is Transverse Mercator (CM -42), datum SIRGAS2000.

The grid creation is the first step, with the four points original coordinates, as shown in Table 1. After, we created the same grid with transformed coordinates (Table 2), using another cartographic transformation software. After the transformation process, the coordinate values observed were slightly different from those registered in the PROJECT_1 grid.

			SIRGAS-UTM39		SIRGAS-TM42	
	Line	Trace	X	Y	X	Y
P1	190	5100	161526,760	7368785,410	967086,689	7372708,299
P2	190	150	375619,010	7245097,650	1178607,118	7244499,692
P3	12100	150	673229,390	7760906,610	1486955,619	7754914,614
P4	12100	5100	48863,060	7884594,370	1274439,409	7882591,701

Table 1 - Original grid corners (control points) coordinates.

			SIRGAS-UTM39		SIRGAS-TM42	
	Line	Trace	X	Y	X	Y
P1	190	5100	161526,76	7368785,41	967088,310	7368785,410
P2	190	150	375619,01	7245097,65	1178616,390	7245097,650
P3	12100	150	673229,39	7760906,61	1486967,680	7760906,610
P4	12100	5100	48863,06	7884594,37	1275439,600	7883109,870

Table 2 - Transformed grid corners (control points) coordinates.

The difference between the original PROJECT_1 survey coordinates (x, y in meters) and the transformed survey coordinates can be seen in Table 3.

PONTOS	LINHA	TRAÇO	AX	AY
P1	190	5100	-1.621	3922.889
P2	190	150	-9.272	-597.958
P3	12100	150	-12.061	-5992
P4	12100	5100	1000.191	-518.169

Table 3 – Difference (meters) of coordinates of the original grid and transformed grid

The tables evidence the control points coordinate difference that reflect in wells positioning in line and trace.

Evaluate by Data Positioning in GRID

We selected 6 wells positioned at different grid sections, in order to evaluate the grid sector behavior differences, as illustrated in Figure 3. The test consisted in verify the well positioning related to seismic data, using for this Seisworks software. In Seismic View window, select the function "select well section." Thereafter, one obtains the well location on the grid, in line and trace.

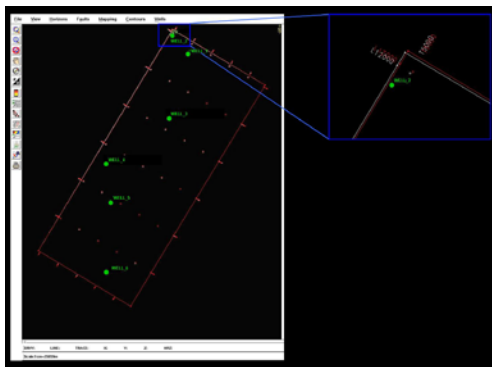


Figure 3 - Wells Spatial distribution on the PROJECT_1 grid.

The WELL_1 and WELL_2 wells are located in the grid northern part (Figure 3). These wells were plotted on grids referenced to different cartographic system.

The WELL_1 has difference that 14 lines and 9 traces (700 and 450 meters respectively). The WELL_2 variation was also higher when viewed in the grid with different CRS. In this case, the difference was 19 lines and 11 traces, 950 and 550 meters, respectively (Figure 4).

The WELL_3 and WELL_4 wells were selected in the grid central region. Well WELL_3 presented a variation of 11 lines and 1 trace, 550 and 50 meters respectively. The well WELL_4 variation was higher, which showed 10 lines and 11 traces difference, that represents 500 and 550 meters, respectively (Figure 5).

The WELL_5 and WELL_6 wells were evaluated in the grid southern part. This wells position change was less significant, only WELL_5 well show some differences, 2 lines and 6 traces, 100 and 300 meters, respectively (Figure 6).

This fact indicates that the grid southern sector has the lowest position variation. Otherwise, the most significant position differences were observed in the grid northern region.

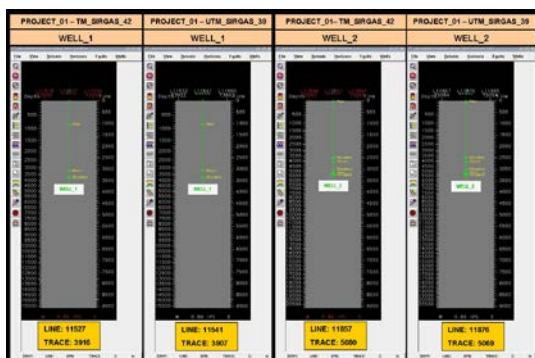


Figure 4 - Test in the northern PROJECT_1 grid with wells and WELL_1 and WELL_2.

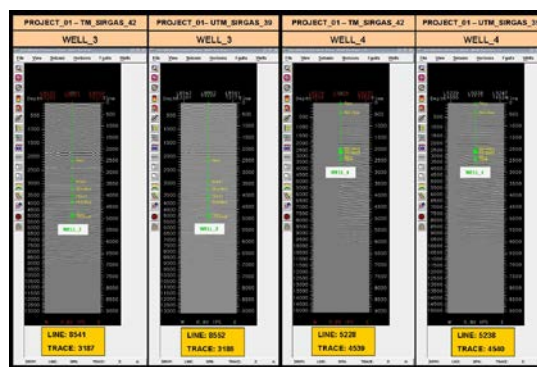


Figure 5 - Tests on the southern grid PROJECT_1 with wells WELL_3 and WELL_4.

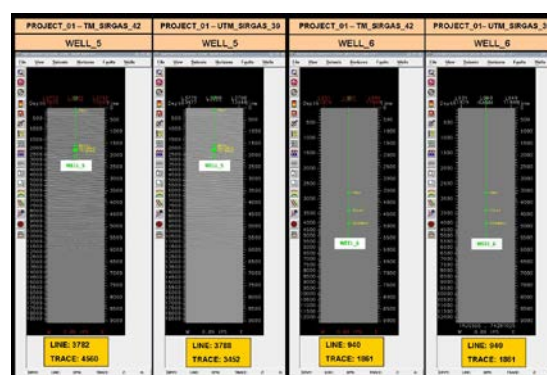


Figure 6 - Tests in the southern grid PROJECT_1 with wells WELL_5 and WELL_6.

Distortion Effect Evaluation on grids with different sizes

To confirm the idea of previous evaluation results, another test was performed.

The test verified the well positioning related to seismic data in a 3D seismic project with smaller area (GRID), in the same geographic location of PROJECT_1, named PROJECT_2. This test came after someone talk about the problem hypothesis is linked to the cartographic projection system, as it was observed that depending on the area and position in the grid, the distortion could be higher or lower. After performed a new series of tests, there were no differences, as shown in Figure 8

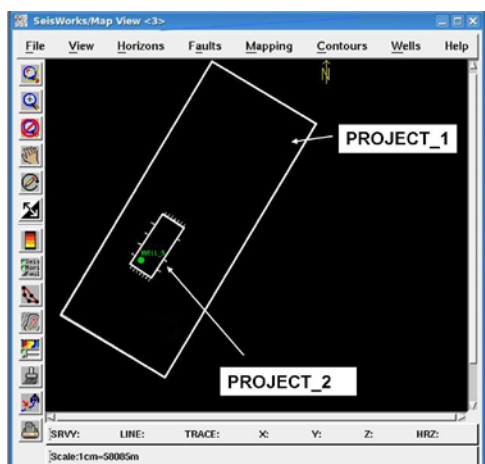


Figure 7 – The two GRIDS tested

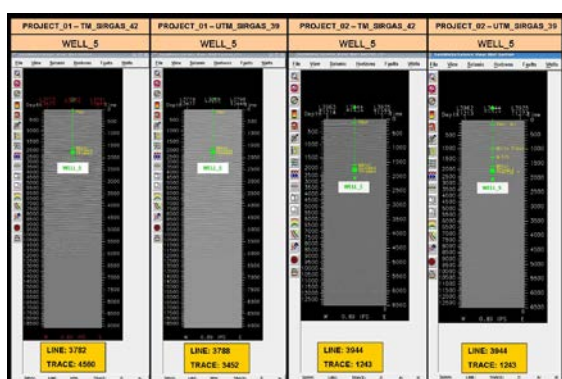


Figure 8 - Tests in the southern grid PROJECT_1 with wells WELL_5

Results

3D Seismic Data Creation in OpenWorks® R2003 and R5000

OpenWorks® R2003

In the version OpenWorks® 2003 the 3D grids are defined by three control points (corner), and the 4th point is calculated from the other. If the angle defined by three points is 90 degrees, the grid will be considered a rectangle. If the angle defined by three points is not 90 degrees, the grid will be considered a parallelogram.

Convert simple arrays are built from the conversion between the actual coordinates (corner) and the internal coordinates of the grid.

In Figure 5 the points P1, P3 and P4 are known. The Seismic Data Manager assumes that the grid is a parallelogram, where P2 should be positioned to form a line (P1-P2) parallel to the P4-P3. Therefore, these lines must have the same sides of right triangles, serving as the hypotenuse of the geometric figure, thus having the same length. One can calculate the length Dx, by subtracting the known value of the X coordinate of P4 and P3.

$$Dx = XP3 - XP4$$

Can then calculate the value for X P2, adding to the value Dx known P1 or X

$$Dx = XP1 + XP2$$

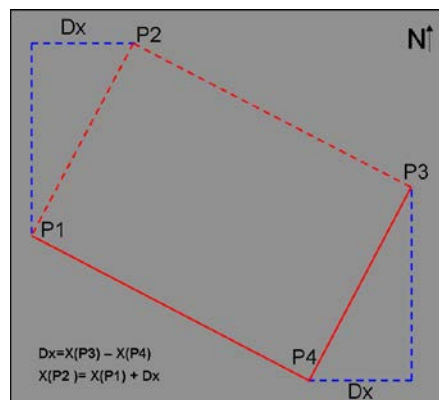


Figure 9 - Parallelogram created by Seismic Data Manager in the 2003 version.

OpenWorks® R5000

In R5000, the 4th point is explicitly added to the data model. This means that a 3D survey can be defined as a quadrilateral. Typically, 3D grids are processed and stored as a rectangle, in its original coordinate system (CRS). However, when a grid is re-projected in a different cartographic system, it still represent a quadrilateral.

To accurately convert the internal grid coordinates, it is divided into small quadrilaterals or polygons, where each has its own set of transformations. Breaking the grid in small areas helps to explain the fact that a straight line in a projection is not necessarily a straight line in another one.

The small polygons transformation is done as follows:

They use the original coordinates to represent a rectangle and calculate a polygons grid that cover the grid with approximately 1 km away.

The polygons are defined by four corner coordinates of the corresponding cartographic system, plus 4 internal grid coordinates. The "Rubber sheet" (bilinear interpolation) transformation is applied to each polygon to convert coordinates between the real and internal.

Rubber sheet is a simple computational method that induces the maps coincidence, regardless of their respective projections.

Triangles are calculated on the map to be transformed, using control points as vertices, and with a procedure called a linear homeomorphism Parties (PHL). These triangles are linearly mapped to corresponding triangles on the map target.

When internal coordinates are converted to the real world, the polygons set are analyzed to identify the quadrangle containing the internal coordinate to convert. Once identified the polygon, the transformation to convert the virtual coordinates to the real world is performed.

For the points conversion that fall outside the limits, elastic transformations are generated from the grid control points (corners).

The software checks whether the definition of the 3D grid in CRS project is rectangular or parallelogram and, if so, uses the simple and quickly transformations. If the grid doesn't represent a rectangle or a parallelogram in the CRS project, the transformation approach is used for small polygons.

Because of the characteristics presented here, a differentiated methodology was developed for loading data into the OpenWorks® R5000, where the data is inserted into software with your original cartographic system (CRS), even if it does not coincide with the Project Database. The cartographic transformation occurs in a virtual way, through the "on the fly" system, without causing changes in shape, position and size of the original data.

It is not recommended to apply 3D grids cartographic transformation outside the R5000 environment. In this procedure, only the four corners coordinates are changed, which allows the internal grid distortion.

Conclusions

The Cartographic Reprojection of 3D seismic data evaluate allowed a methodology work review with regard to 3D grids loading and migration for OpenWorks® projects.

The tests showed that the 3D survey distortion is directly related to the grid size and the positioning of the data within it.

Throughout the text spoke out about the possible methods used to minimize the occurrence of distortions in the 3D grid resulting from the cartographic transformation process.

In OpenWorks® 2003, the found solution was to create OpenWorks® Projects referred to the UTM map projection (Universal Transverse Mercator), because this is the system used in the acquiring seismic data process, thus avoiding the need for the projection transformation.

However, by UTM projection adoption, the user will promote a project work area restriction to 6 degrees of longitude (approximately 666 km), increasing the amount of OpenWorks® projects and difficulting the work with regional projects.

In OpenWorks® R5000 the distortion problem is solved by 3D grids creation method and "on the fly" system, without data pre-loading cartographic transformation.

The "on the fly" system tends to minimize the problems occurrence in cartographic transformations, by being able to show the data in any cartographic system, without the need to transform them.

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