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Corrections of severe vertical displacements among 2D lines and 3D surveys of Neuquen basin: when automatic mistie solutions fail.

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Abstract Summary

The correction of seismic lines intersections is an important part of geophysical workflows. Tools for automatic mistie corrections using several techniques are available in several interpretation applications from different companies. However, these tools still present limitations when the seismic dataset to be corrected are composed of seismic of different frequency, phase, level of noise and show severe vertical displacement, sometimes of hundreds of meters or milliseconds. In such cases, tools for automatic mistie correction may not work properly and produce poor results in which is not feasible to perform seismic interpretation properly. This work presents the methodology designed by the authors to perform severe vertical displacement corrections among hundreds of 2D lines from different surveys and 3D surveys of a Petrobras regional interpretation project from Neuquen Basin. A total of 953 lines and 13 3D surveys has the vertical position corrected. The corrected seismic dataset produced can be used to perform proper seismic balance processing and other post-processing correction to enhance seismic datasets correlation. Moreover, the designed methodology can support the development and improvement of automatic mistie correction tools based on machine learning or other automated methodologies.

Introduction

The correction of seismic lines intersections for associated measures are an integral part of geophysical workflows (Herkommer and Whitney, 1994). These corrections turn even more critical when we work with regional projects evolving different 2D line surveys with hundreds of 2d lines and dozens of 3D surveys. Tools for automatic mistie corrections using several techniques are available in interpretation software from different companies. However, such tools still present limitations when the seismic dataset to be corrected are composed of seismic of different frequency, phase, level of noise and show severe vertical displacement, sometimes hundreds of meters or milliseconds. The problem becomes more difficult when geoscientists need to manage onshore 2D lines and 3D surveys which present different vertical range with no surface reference or obvious reference horizon in subsurface. In such cases, tools for automatic mistie correction do not work properly and produces poor results, where is not feasible to perform seismic interpretation connecting the seismic events in the output “corrected” seismic.

In these cases, the work of geoscientists with solid background on seismic data and seismic interpretation are essential to design a feasible mistie correction methodology to achieve satisfactory results. This work presents the methodology used by the authors to perform severe vertical displacement corrections among hundreds of 2D lines from different surveys and 3D surveys of a Petrobras regional interpretation project from Neuquen Basin. Neuquen Basin is the largest hydrocarbon resource of Argentina, responding for 57% of oil and 37% of gas production of the country. In January 2022, the petroleum and gas average productions have reached, respectively, 51.094 m3/d (321.371 bb/d) and 87.2 MMm3/d (data from Federal Department of Energy).

The Neuquen basin is in the South American plate, in the central-West region of Argentina (Brisson, 2023), characterized as a posterior sedimentary retroarc basin, filled by the Pacific paleo-gulf, formed during the Upper Triassic and Late Cretaceus. Its petroleum system is formed by non-conventional source rocks from Los Molles, Vaca Muerta, Agrio inferior and Agrio superior

Formations, intercalated by reservoir rocks from Tordillo, Mulichinco and Troncoso Formations (Lagarreta et al., 2005).

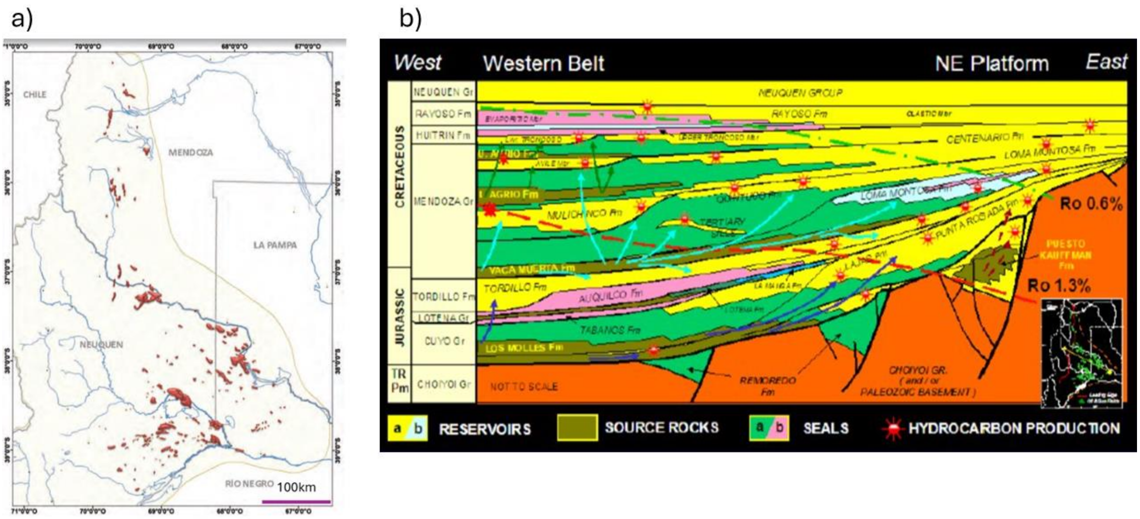

Figure 1: a) Location map showing the main reservoirs of Neuquen basin. b) Neuquen basin petroleum system (Lagarreta et al., 2005).

We have worked in a large interpretation project from Neuquen basin, which includes 953 2D seismic lines from different surveys and dozens of 3D seismic surveys (Figure 2a). The available lines and surveys presented a large range of vertical displacements from each other (from -1500 to +620 ms). Additionally, we have identified significant differences on phase, frequency and level of noise among the different seismic data from lines and 3D surveys (Figure 2b), what turned out to be impossible horizon interpretation, correlations and other geophysical and geological interpretation being performed.

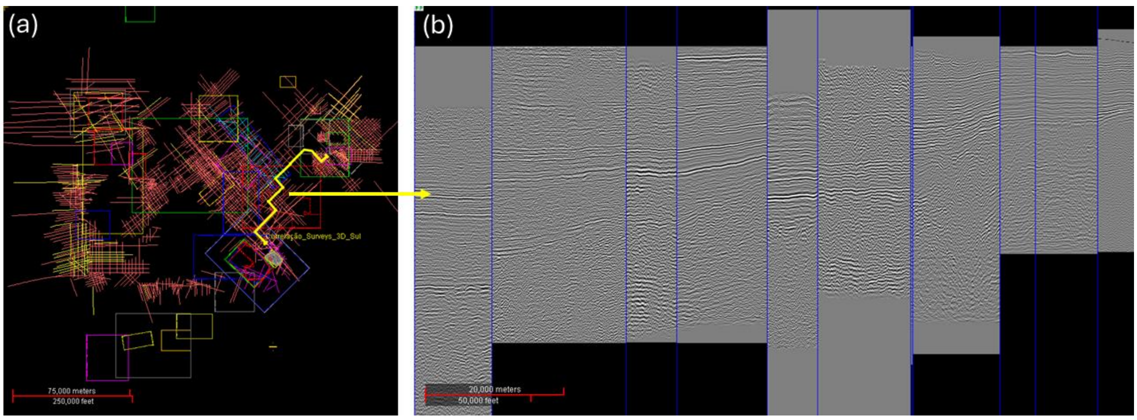

Figure 2: a) 2D lines and 3D survey's location of Neuquen interpretation project. b) An example of arbitrary line crossing several 2D lines from the reference 3D survey in the South to 2D lines in the East.

Vertical displacement correction tests were performed using automatic mistie correction tools in different applications from different available platforms. However, the results have not shown acceptable correction. To solve the problem, one decided to design a correction methodology considering the specific problems and data characteristics of this project to achieve interpreters' exploration objectives and avoid rework. The proposed methodology has been executed step by step on the Halliburton platform and is described with more details in the next section.

Method

The methodology designed to perform the needed vertical displacement corrections among 2D lines and 3D surveys includes the following steps:

1) Review of misties and QC of original seismic data from lines and 3D surveys. Identify important seismic events and choose a clear seismic event which is observed in all or most of the seismic data. Frequently we find lines and 3D surveys with more than one available seismic data with different vertical displacement. In these cases, we choose the seismic data which presents the best quality to perform the correction

2) Define reference 3D survey and/or seismic lines based on trusted data with known vertical datum, with good tie with well data if possible

4) Create a new mistie correction table. Perform mistie corrections of 2D lines close to the reference 3D survey and/or reference lines.

5) Perfom mistie correction of 2D lines around the 2D lines corrected in relation to the reference 3D survey and/or reference lines. Make mistie correction line by line and regularly save mistie correction table and a backup of them outside database to avoid edition problems by other project interpreters.

6) Interpret a reference horizon after mistie correction of each line to identify and visualize corrected lines on the map

7) Perform mistie correction of 3d surveys in relation to corrected 2D lines which cross these and other corrected 3D surveys

8) Make corrections QC using zig-zag arbitrary lines from reference 3D survey, passing through several lines and 3D surveys in different directions to validate and check the consistency of the corrections with reference

9) If the corrections are satisfactory, continue the mistie correction to other lines/3D surveys interpreting reference horizon after it. If not, correct the lines/3D surveys with remaining misties in relation to the reference. Sometimes, a perfect mistie correction is not possible due to seismic data processing differences (i.e. differences on phase, waveform, migration, etc). In this case, make the best correction possible to reduce mistie in both sides of the section

10) After validating mistie corrections of all lines and 3D surveys, create a mistie correction table backup in the database and outside it in a safe directory. Generate copies of each seismic data which will be used to apply permanent vertical displacement corrections. We recommend keeping the original data with unaltered misties for future reviews. In some cases, generating 2D line lists for each 2D seismic data helps to organize the corrections

11) Apply mistie corrections recorded in the mistie correction table to the header of each 2D seismic line of copied data. This action generates a new version of seismic data with permanent mistie correction that does not need mistie correction tables to be applied

The workflow described is summarized in the flowchart of Figure 3.

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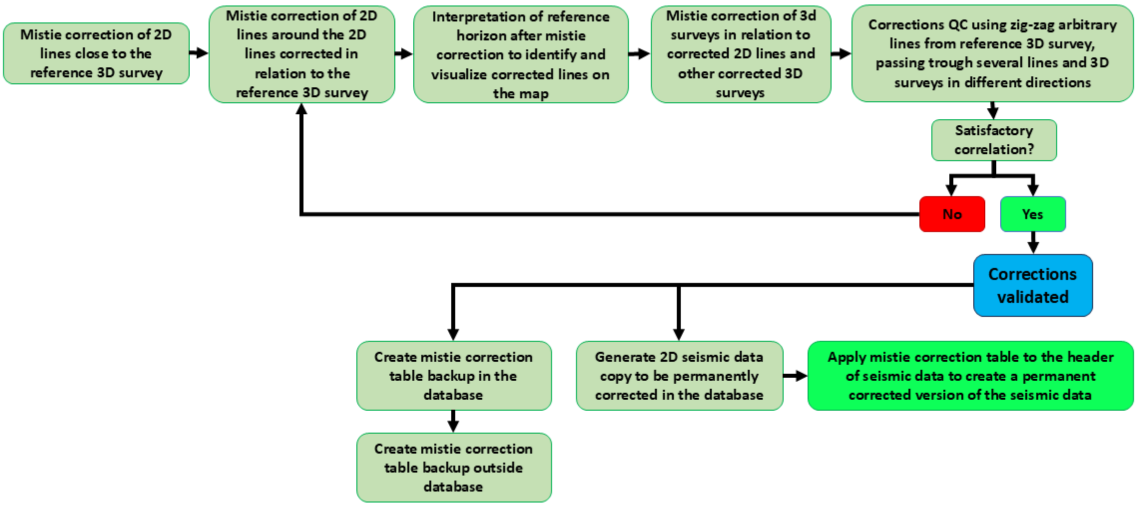

Figure 3: Flowchart summarizing the steps of the mistie correction methodology used to correct the severe vertical displacements among 2D lines and 3D survey from Neuquén Regional Interpretation Projects.

Results

Part of the results of vertical displacement corrections are exemplified by the arbitrary lines illustrated in the Figures 4 and 5. One can notice the excellent correlation among 2D lines and 3D surveys crossed by the arbitrary lines.

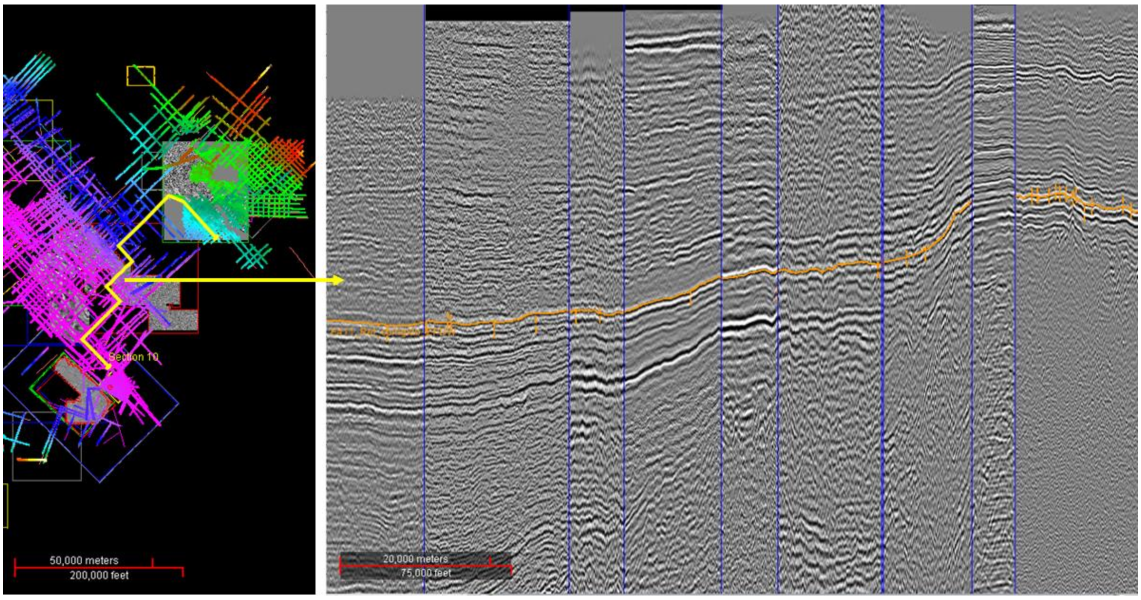

Figure 4: Arbitrary seismic line linking corrected lines from South to the East part of the project. The reference horizon is represented by the orange horizon over the seismic section.

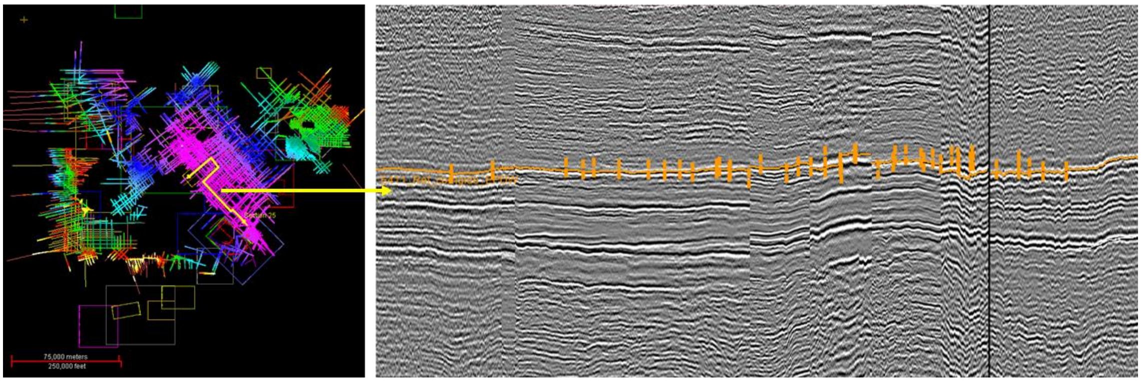

Figure 5: Arbitrary seismic line linking corrected lines from South to the central part of the project. The reference horizon is represented by the orange horizon over the seismic section.

The results of the case study for mistie correction of Neuquen interpretation project includes: 814 lines with negative misties (moved up), 61 lines with positive misties (moved down), 78 useless lines or with no seismic and 13 corrected 3D surveys. A total of 953 lines and 13 3D surveys were reviewed. Additionally, a regional reference horizon was interpreted and a corrected copy of each relevant 2d seismic data were created.

Conclusions

A methodology to perform mistie corrections of severe vertical displacement among 2d seismic lines and 3D seismic surveys were designed and successfully applied in a regional interpretation project of Neuquen. A total of 953 lines and 13 3D surveys has the vertical position corrected. The performed corrections turned possible the correct interpretation of seismic events and geological correlation through the entire area covered by the data. The corrected seismic dataset produced can be used to perform proper seismic balance processing and other post-processing correction to enhance seismic datasets correlation. Moreover, the designed methodology can support the development and improvement of automatic mistie correction tools based on machine learning or other automated methodologies.

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