Construction of a fracture model from the PSDM seismic in the Rio Neuquén Basin

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Abstract

In this paper is presented a methodology used for the construction of the fracture model as well as the results obtained, its applications and comparison with data of curvature and velocities. The study area was a small portion corresponding to a PSDM seismic in the Rio Neuquén Basin - Argentina (Figure 1).

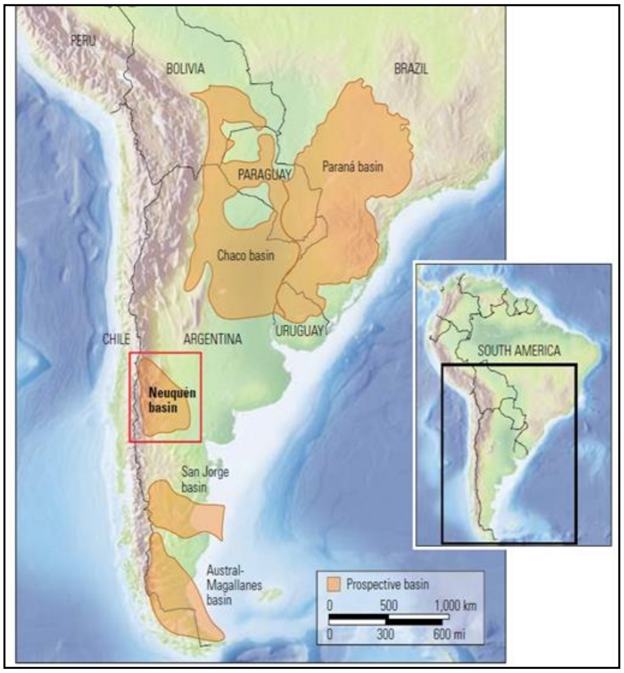

Figure 1: Neuquén basin. Some basins in South America have potential for unconventional reservoirs. The Neuquén Basin in central-western Argentina (red rectangle) is the largest oil and gas production in the country and contains three deposits of deep-water shales - Agrio, Vaca Muerta and Los Molles formations. Source: Badessich et al. (2016).

For fracture modeling, a PSDM seismic was used and 5 horizons and 7 wells were used to control the quality of the results. Among the wells used, 3 wells have image logs.

Introduction

The fractures are the structural features that occur most commonly in the outcrops and have an important impact on the reservoir models and can act as permeability channels. The detection of fractures has been highlighted in recent years due to two important reasons: 1) the improving quality of seismic data and, therefore, it became possible to detect fractures in the available data so that can performer a good historical adjustment of the production data in conventional reservoirs; and 2) The great advance in the exploration of unconventional reservoirs whose fracturing is the main mechanism of production.

For the oil and gas industry, fracture modeling is important for predicting reservoirs behavior in response to production. This prediction can be both in the exploratory scope, aiming to evaluate the recoverable reserves of an accumulation as for the porosities, as well as in the development, exploiting the reservoir in the best possible way (Figure 2).

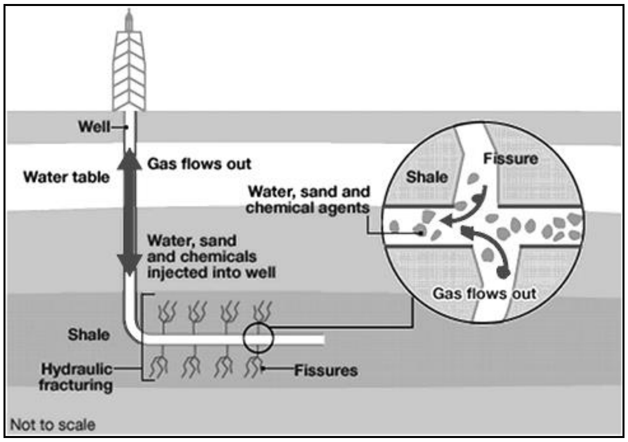

Figure 2: Simplified diagram of shale gas extraction (unconventional shale-gas accumulations).
Source: Hammond and O'Grady (2017).

The fractures can be natural (related to the history of the field of natural tensions) or induced, related to drilling and hydraulic stimulation. Even the induced fracturing - currently evident in unconventional projects, to be successful, must take into account the corridors of rock natural fractures in order to use the energy dispensed to connect the naturally occurring fractures in the region and generate the largest amount of possible fractures.

Regional Geology

The Rio Neuquén Basin is located at the base of the Andes in central-western Argentina (Figure 1), on the west bank it borders Chile and has an area about of 120,000 km². The Rio Neuquén is an oil-producing basin in Argentina (Legarreta and Vilar, 2011) and the Vaca Muerta formation is the richest in oil of the basin, where 50% of hydrocarbons production in Argentina is obtained (Urien *et al.*, 1995). As Argentina became the focus of unconventional exploration, the play Vaca Muerta represents the main Argentine energy potential and the understanding of the heterogeneities inherent to the reservoir will be essential for the development of effective strategies.

The Neuquén Basin is a terrestrial basin with a thick sedimentary package (Figure 3) filled with several potentially rich units of organic matter and a series of transgressive and regressive cycles (Urien and Zambrano, 1994). The basin is bent by the Andes to the west, bounded by the igneous platform of the Patagonian Massif to the south, and the Serra Pintada Massif to the northeast (Howell *et al.*, 2005). Directly neighboring the Andes, the Neuquén Basin is strongly deformed with several characteristics related to the thrust towards its western margin, but relatively undeformed to the east in the dip part of the basement. In the eastern portion (basement dip part) the basin fill is thicker and presents most of the hydrocarbon fields, with the sediment pack reaching thicknesses of more than 7000 m (Garcia *et al.*, 2013).

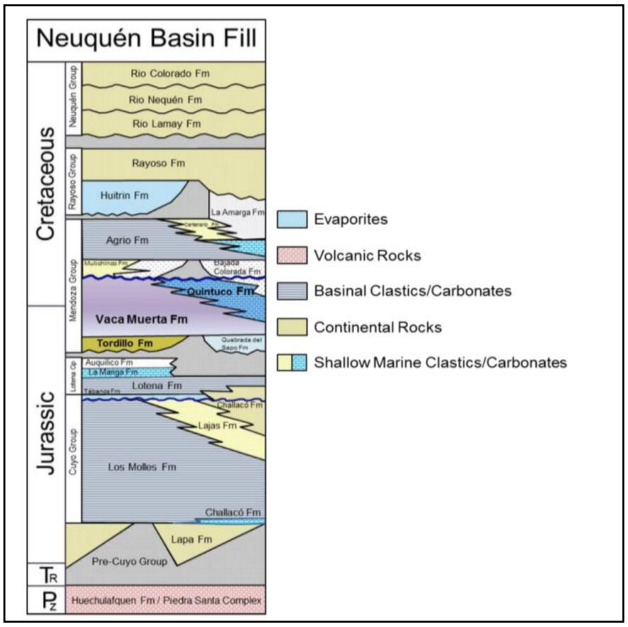

Figure 3: Stratigraphic column for the Rio Neuquén basin (Simplified from Howell et al., 2005).
Source: Bishop (2015).

Method

General flow for fracture detection

Traditionally, faults and fractures are interpreted in sections and slices of 3D time seismic volumes as discontinuity in seismic amplitude or from slices in time of a volume of seismic coherence. Interactive tools were elaborated to support the interpreter in this procedure. Hale and Emanuel (2002) published the results of the research focused on automatic mesh that could be applied to the interpretation of faults, and Pedersen *et al.* (2003) described a semi-automatic process for faults and fractures extraction using a discontinuity volume in fracture modeling.

Automatic fracture extraction technology uses signal processing combined with steps based on intelligent geological rules and a set of interactive tools to allow automated interpretation of faults and fractures in less time and with less effort than completely manual methods (Dorn *et al.*, 2005). The input to this automatic fracture detection process is a 3D seismic data volume which was processed to generate the coherence attribute that provides a quantitative estimate of discontinuities. Instead of reflection amplitude, the output is a relative probability volume of faults and fractures.

Seismic attributes based on detecting discontinuity of events provide useful tools to characterize faults and fractures (Chopra and Marfurt, 2007). The accuracy and quality of these seismic attributes are directly proportional to the signal/noise ratio of seismic data (Santosh *et al.*, 2013). Data conditioning increases the visual identification of faults and fractures in the seismic data and its attributes. Conditional data can be processed to improve the discontinuity capabilities and, therefore, the attributes on that processed data will result in better faults extraction and geometry fractures. The noise distorts the image and makes difficult the task of detection and interpretation of geological characteristics, which aim to illuminate the geometry and the location of the various faults and fractures of larger and smaller scales. Structurally oriented filters using dip and azimuth volumes serve to highlight discontinuities in such attributes. The results of the conditioning of the attribute volumes and fracture tracking are presented in Figure 4.

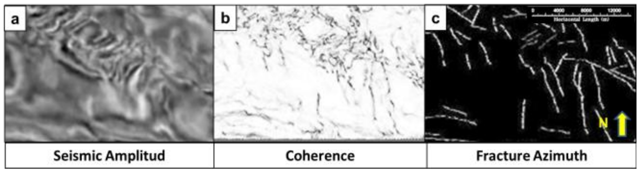

Figure 4: a) PSDM seismic of an area of the Rio Neuquén Basin. b) Volume of coherence obtained through PSDM seismic. c) Fracture azimuth volume representing the directions obtained through fracture detection flow.

Results

With the conditioning of the coherence attributes from the structures, the fracture azimuth volume was estimated and the rosette diagram was extracted. From the fracture azimuth volume obtained in the Rio Neuquén basin seismic area, three fracture direction families were identified with the following ranges of azimuth angles: 54°-90°, 108°-134° and 134°-165° (Figure 5). For each of the three fracture families, the fracture intensity property was created in the stratigraphic grid, in order to observe the fracture behavior with geology (Figure 6). We also selected 7 wells that cross regions with fractures, to observe the behavior of these fractures along the wells. With this, it was verified that there was a variation of the fracture directions along the geological time (Figure 7).

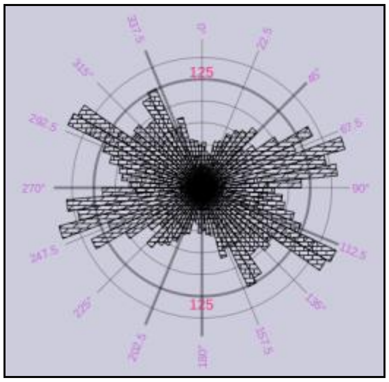

Figure 5: Rosette diagram used to identify three families of fractures.

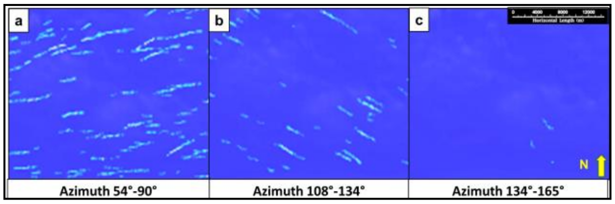

Figure 6: Intensity of fractures of the three families identified: a) Azimuth 54°-90°, b) Azimuth 108°-134° and c) Azimuth 134°-165°.

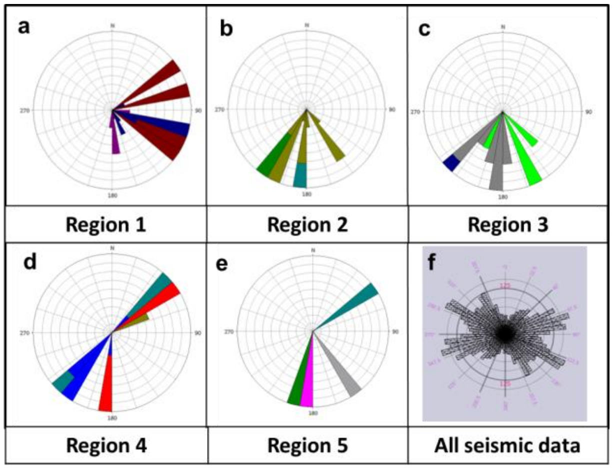

Figure 7: Rosette diagram with the variation of the Strike fractures along the well regions.

Using the rosette diagram that represents the fractures obtained from the image log data of well A and comparing with the rosette diagram obtained with the fracture data detected in PSDM seismic at well A position (Figure 8) , there is a correlation in some directions of these fractures in the two sets of data (Figure 9). This means that the fracture model extracted from the seismic is consistent with the interpretation of the fractures obtained in the image log of the well.

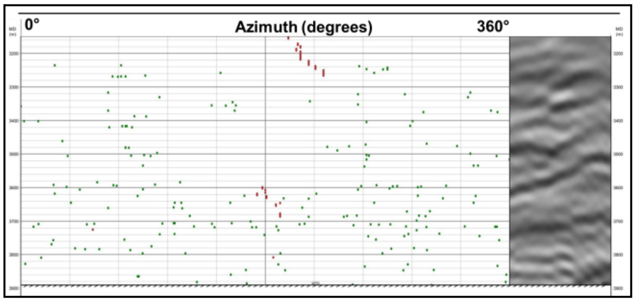

Figure 8: a) Image log of well A (range from approximately 3150m to 3900m depth) with fractures interpreted in green color being compared with fractures obtained from PSDM seismic in red color.

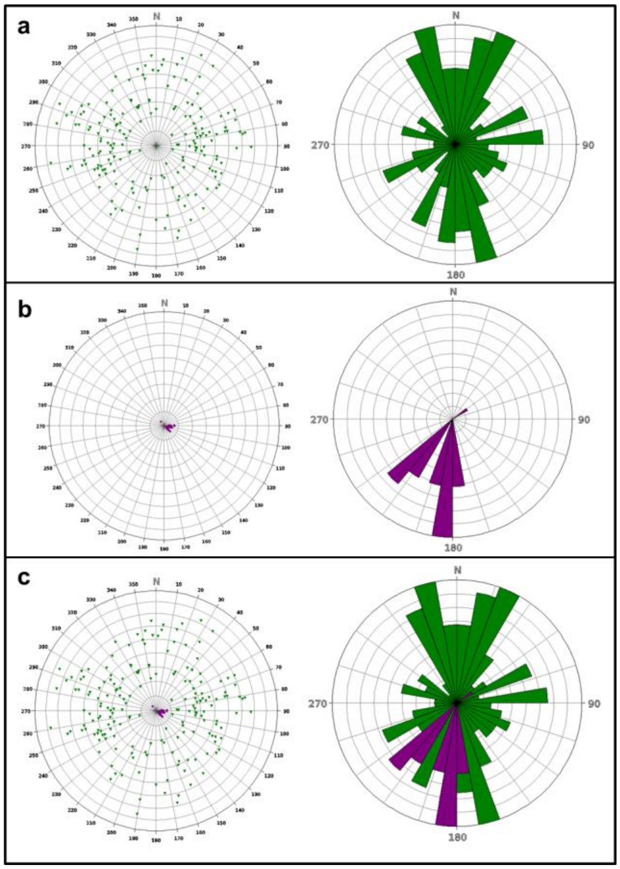

Figure 9: Rosette diagrams with the Dip and Strike fractures obtained from: a) Image log of well A; b) PSDM seismic at well A position (fracture azimuth volume); c) Image log (green color) and seismic PSDM (fracture azimuth volume) at the position of well A (purple color).

The mean curvature attribute was extracted from the horizons used in the PSDM seismic area in the Rio Neuquén Basin. Thus, the area with the highest mean curvature value was compared with the fracture model (fracture azimuth volume) and seismic velocity (Figure 10). It was observed from this analysis that the area with higher values of curvature coincides with zones of higher density of fractures and lower velocities, which may indicate possible anomalies such as gas accumulations.

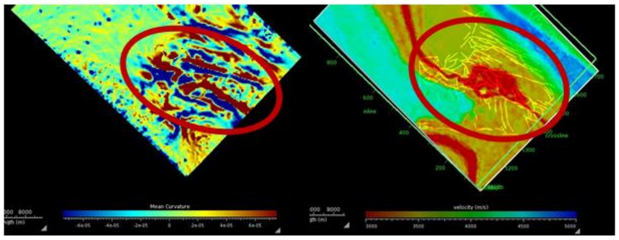

Figure 10: a) Mean curvature attribute extracted from the horizons in the area of the Rio Neuquén, highlighting the red circle showing the region with the highest values of curvature. b) Model of fractures superimposed on the velocity model corresponding to the Rio Neuquén PSMD area. The region of low velocity and greater fracturing, highlighted in the red circle, coincides with the region of greater curvature.

Conclusions

The attributes calculated from the automatic extraction of fractures that were used in this work demonstrated that this methodology is effective to identify certain fracturing patterns that can indicate changes in the tensions field along the geological history of a sedimentary basin (Figure 7).

The families of fractures 54°- 90° and 108°-134° are predominant in the areas with higher values of curvature in the region of the seismic data studied in the Rio Neuquén Basin.

The fractures interpreted from the image logs of the wells proved the effectiveness of the automatic extraction of fractures from the seismic (fracture azimuth volume), since the fracture directions from the seismic coincided with part of the directions from the image logs.

The integration of curvature, fracture and velocity data can be used to indicate possible hydrocarbon reservoirs.

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