Correlating curvature to fault propagation in clay modeled transfer zones

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1. Summary:

Transfer zones are common hydrocarbon traps in extensional tectonic structures. A transfer zone is an area where one fault dies out and its slip is transferred to an adjacent fault. Transfer zones are commonly divided into three categories, convergent, divergent and synthetic, based on the dip of the faults. These zones can be quite subtle and little has been published on their signature in seismic data. Because of the complexity associated with transfer zones and their secondary faults, seismic attributes could prove to be valuable tools. Many of the secondary faults that occur in the proximity of a transfer zone may be below seismic resolution; however, these faults may provide an attribute expression that could aid the interpreter to infer their presence. In this study we compute the curvature of a suite of clay models of transfer zones. We then compare the curvature "attribute" to the underlying faults and fractures seen in the clay model. In this manner we provide a simple analogue model of how curvature, a measure of strain, is correlated to sub-seismic features of interest that can aid in the understanding and interpretation of transfer zone dynamics.

2. Introduction:

Seismic curvature for fault imaging is a popular tool familiar to most geophysical interpreters. Curvature can be useful in delineating not only faults but also events that occur below the resolution of the seismic wavelet, such as fractures (Chopra and Marfurt, 2007). Events not clearly seen in the 3D seismic volume can still give a characteristic response with seismic attributes. Liao et al. (2013) used clay models of a strike slip fault in order to better understand secondary features such as fractures, splay shears and Riedel faults. These features were below seismic wavelet resolution however, with the help of the clay models Liao was able to predict these secondary features using seismic attributes characteristic responses in a 3D seismic data volume. This study analyzes curvature characteristics of the three types of transfer zones: (1) convergent transfer zone where the two main faults dip toward each other; divergent transfer zone where the two main faults dip in opposite directions; and synthetic transfer zones where the two main faults dip in the same direction (Figure 1; Morley et al., 1990).

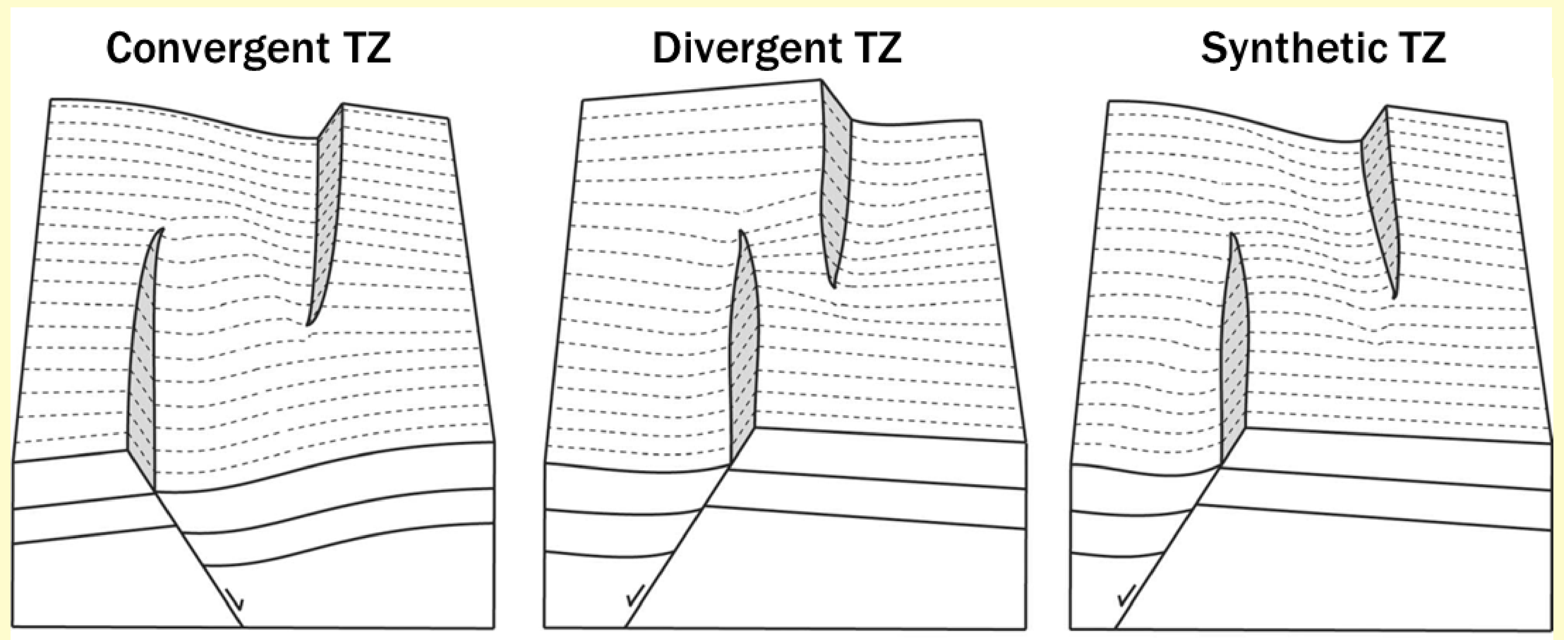


Figure 1: Schematic of the three different types of transfer zones. (Morley et al., 1990)

The three types of transfer zones were experimentally created using clay modeling (Paul and Mitra, 2013) and it was determined that fault propagation and transfer zone geometry was heavily reliant on the type of transfer zone being modeled. Using the clay modeled surfaces created by Paul and Mitra (2013) we try to correlate fault geometry of the three types of transfer zones with seismic curvature. We then compare the curvature and fractures of a clay modeled convergent transfer zone to the curvature and coherence response of a transfer zone in 3D seismic data in order to understand the appearance of sub -seismic faults and fractures on seismic attributes, such as curvature.

3. Methodology:

Paul and Mitra (2013) created clay models of transfer zones to illustrate the fault geometry and the corresponding fracture propagation of convergent, divergent and synthetic faults. They constructed two different density clay layers, one representative of the basement and the other representative of the overlying sedimentary sequences. The basement clay had a density of 1.85g/cm3 with a thickness of 2.5 cm and the sedimentary clay had a density of 1.6 to 1.65g/cm3 also with a thickness of 2.5 cm. In the bottom layer of clay, representative of the basement rock, pre-allocated fault cuts were made with a dip of 60 degrees. Then at a constant rate of 0.0005 cm/s extensional motion along the basement faults was generated. The process was repeated twice for each of the three types of transfer zones. The surface of the clay model was laser scanned at various stages of displacement to generate a point set. The point set had a density of 75 dots per inch, which allowed for faults with a minimum vertical separation of 0.4 mm to be mapped.

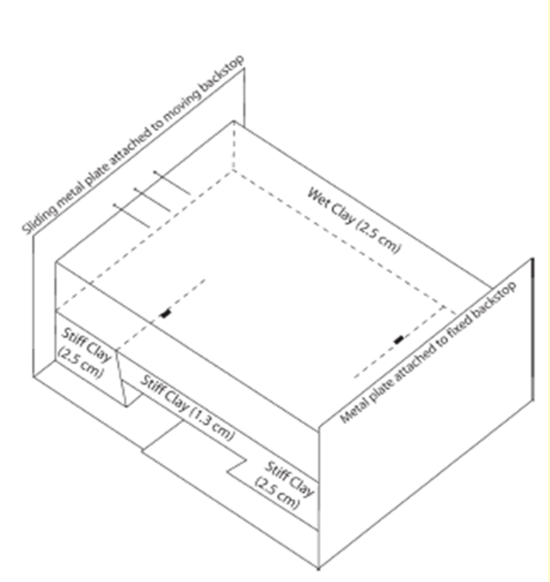
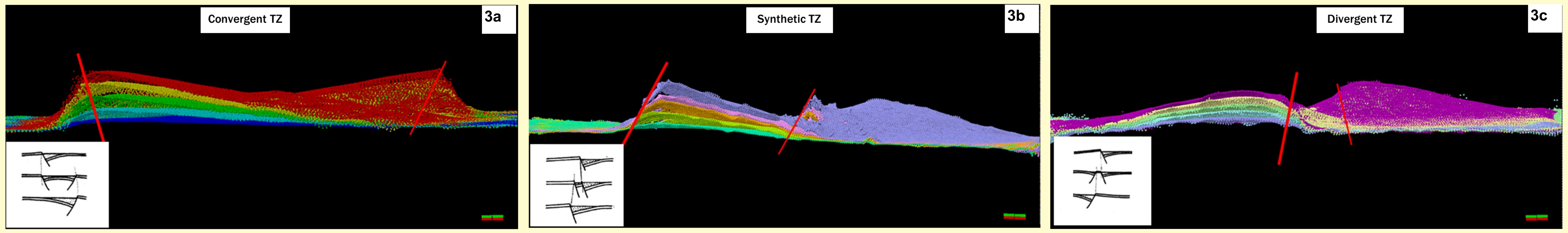


Figure 2: Experimental configuration used to create the clay models.

4. Results:



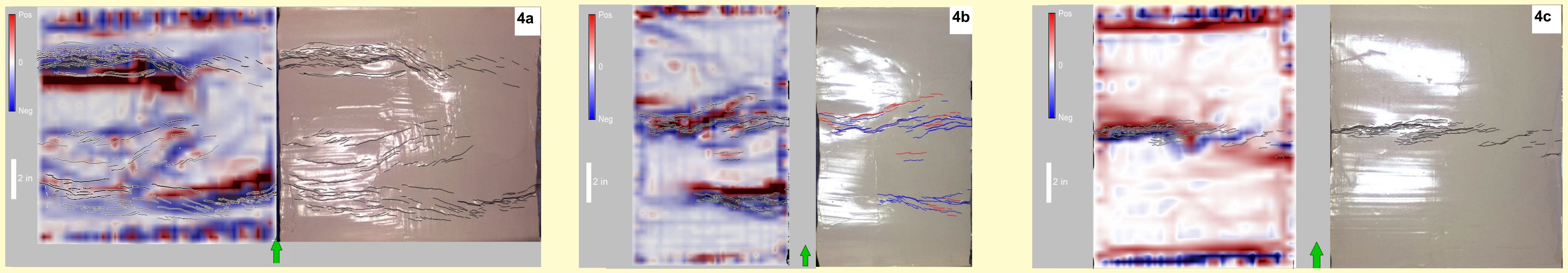
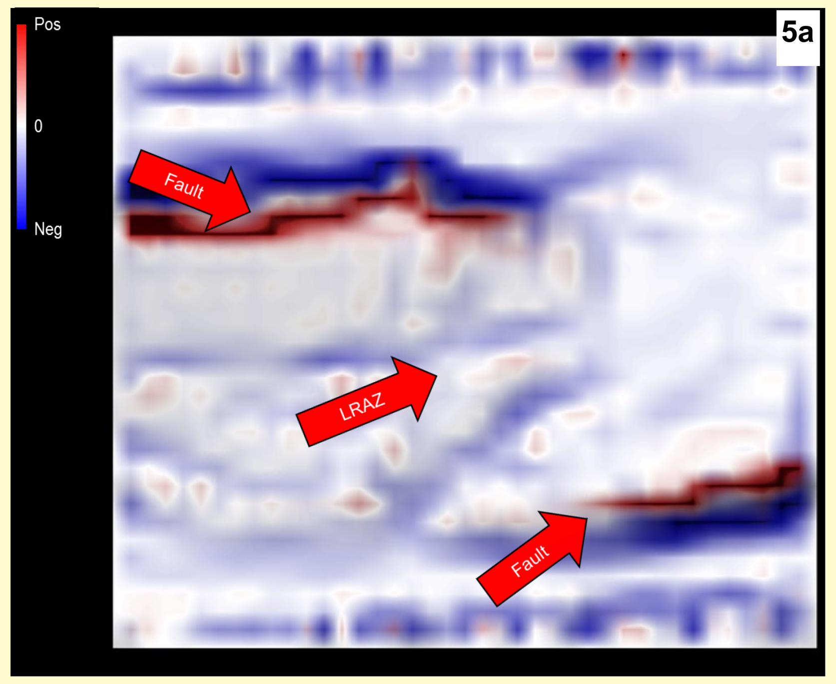


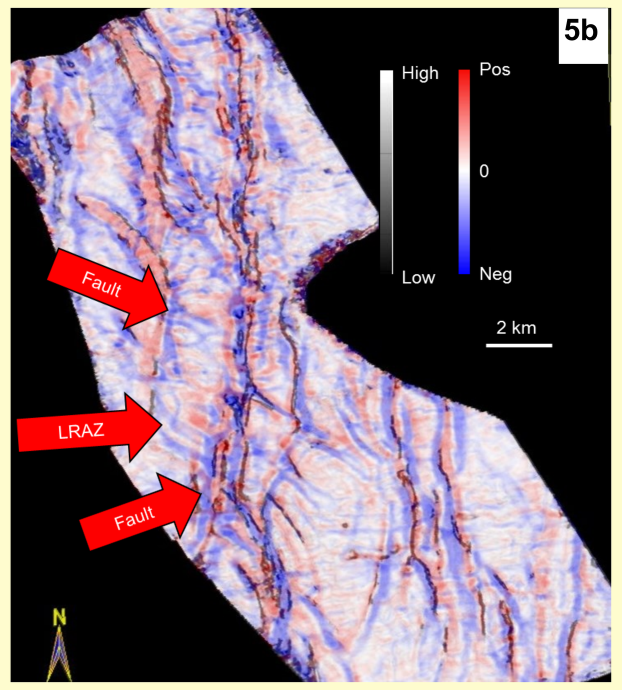
Figure 3a),b) & c): The scanned surfaces for the convergent, synthetic and divergent, respectively, clay models at five different stages of deformation.

Figure 4 a,) b) & c): (Left) Curvature computed over Stage 5 of deformation of the scanned surfaces for the convergent, synthetic and divergent, respectively, with the fractures and faults overlain. (Right) Photograph of the clay model at Stage 5 of deformation with fractures and faults drawn in.

Figure 5a): Curvature of stage 5 of deformation. The arrows point to the two main faults and the formation of a low relief accommodation zone in the transfer zone (LRAZ).

Figure 5b): Co-rendered coherence and most positive and most negative curvature. Using what was learned from the models it appears a LRAZ formed between the two faults. (Chopra and Marfurt, 2010).





5. Conclusions:

In conclusion, curvature computed over clay modeled transfer zones provides an analogue to help us better understand transfer zone geometry and related features, such as relay ramps. curvature is a measure of strain it can be a useful tool in inferring fracture saturation and other sub-seismic features. Furthermore, there us a visually apparent correlation between fracture intensity and curvature amplitude.

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