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Strain and Displacement Analysis Using the Displacement/Distance Method: Application to 3D Seismic Data from a Deep Water Thrust Belt

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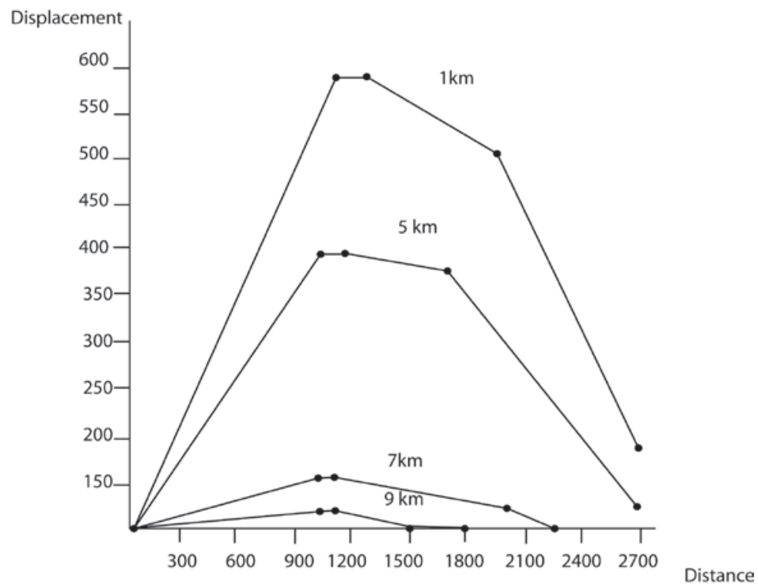
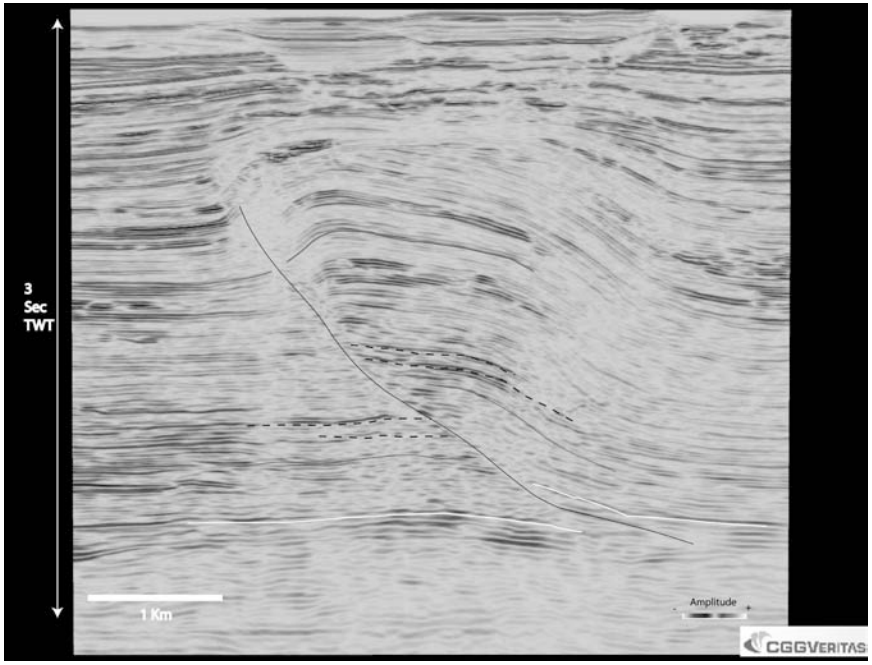
Poor understanding of the distribution, intensity and geometry of strain associated with thrusts is a significant uncertainty in evaluating the structural geology of contractional folds. In deepwater settings these uncertainties can be critical because distributed strain, manifest as small faults, minor folding, layer-confined distortion and tectonic compaction can influence thrust zone properties and, ultimately, reservoir performance. Existing theoretical fold-thrust models rarely consider distributed strain and utilise only a small number of possible structural configurations to predict stratal geometries. However, models of displacement-distance analysis, developed in the early 1980s, offer generalized approach for predicting strain. Recently, these methods have been applied to deepwater folds. Here we take this method furthers, examining lateral variations in structural style along single anticlines, imaged in a 3D seismic volume from the outer part of the western Niger Delta.

Discontinuities and reflector terminations define stratal cut-offs which are correlated across thrusts. The offsets of these horizons define displacements and these can be shown to vary along thrust surfaces, both up dip and along strike. As these measurements are mage obliquely along inclined surfaces, they are dependent upon the seismic velocity model used to create depth-converted data. Consequently, different depth scenarios were used to investigate the uncertainties that could arise from inappropriate velocity models. Different parts of the stratigraphic pile show different behaviours on displacement-distance diagrams. These define gradients in displacements from which we infer the parameter of relative stretch (strain) to be distributed in the wall rocks. Within different fold and thrust sheets, the displacement/distance plots indicate non-linear displacement gradients. These include: variable, low values along the detachment; a distinct peak within the core of the thrust and a minimum or zero values toward the tip of the faults (see example in fig 1c). Along strike, the displacement-distance plots show greater variability and these correlate with a qualitative change in structural style (fig 1c). These displacement patterns indicate strongly heterogeneous strain and displacement distributions. It is also observed that when the displacement along the main horizons is maximum, the detachment seem to accommodate a minimum amount of the overall displacement (fig 1a,b and c). Whereas when the displacements along the main reflectors are zero or distributed along two or more main faults (as in "trishear like" or "pop up" like structures), the main deformation is mainly accommodated by folding, partly controlled by the detachment (fig 1b and c). These results indicate how 3D lateral variations with intermediate types of structures could link kinematically. As the overall displacement path cannot be categorized or predicted by any of the classical fold propagation models some new kinematic scenarios taking in account of the variety of style and heterogeneous distribution of the deformation need to be investigated.

Figures





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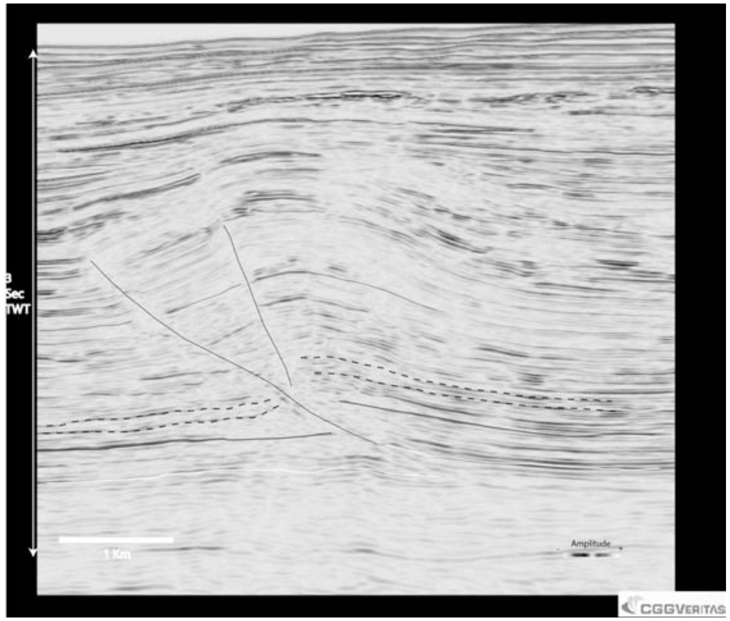

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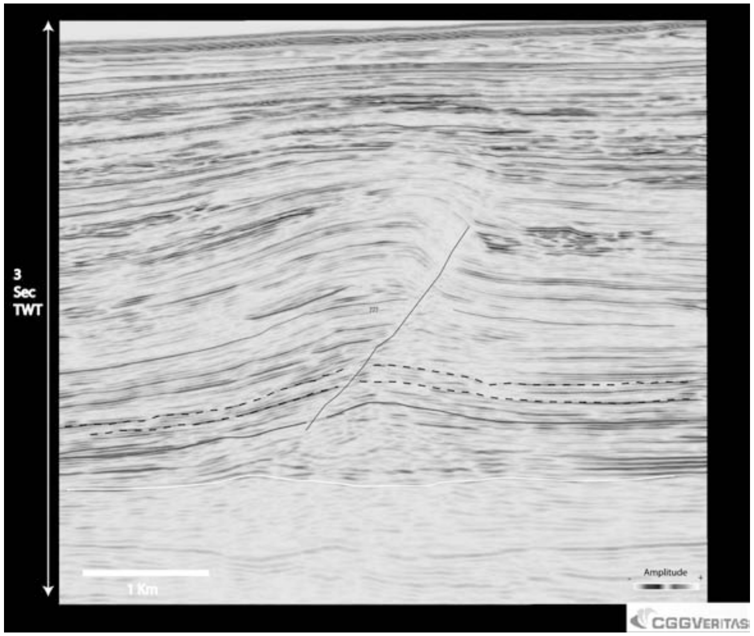

d

Fig 1.
a) Diagram showing the displacement/distance meaurments performed across several sections along strike of a single and thrust lobe. The profile of the curves clearly indicates a displacement gradient both along the thrust ramp (concave profile) as well as along the main strike (1, 5, 7 and 9km). The displacement and distance scale are in m (linear depth conversion).
b), c), d). Three seismic sections (at different places along strike of a single and thrust lobe) with some of the reflectors cut off used to obtain the displacement/distance diagram in fig 1a. In white it is shown the main detachment reflector.