Kinematic 3D Retro-Deformation of Fault Blocks Picked from 3D Seismics

Poster

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Introduction

Movement on fault planes causes a large amount of smaller-scale deformation, ductile or brittle, in the area surrounding the fault. Much of this deformation is below the resolution of reflection seismics (i.e. sub-seismic, <10 m displacement), but it is important to determine this deformation, since it can make up a large portion of the total bulk strain, for instance in a developing sedimentary basin. Calculation of the amount of sub-seismic strain around a fault by 3-D geometrical kinematic retro-deformation can also be used to predict the orientation and magnitude of these smaller-scale structures.

However, firstly a 3-D model of the fault and its faulted horizons must be constructed at a high enough resolution to be able to preserve fault and horizon morphology with a grid spacing of less than 10 m. Secondly, the kinematics of the fault need to be determined, and thirdly a suitable deformation algorithm chosen to fit the deformation style. Then by restoring the faulted horizons to their pre-deformation state (a 'regional'), the moved horizons can be interrogated as to the strain they underwent. Since strain is commutative, the deformation demonstrated during this retro-deformation is equivalent to that during the natural, forward deformation.

Working area

Our working area is located within the northern part of the Lower Saxony Basin. This structural unit is a part of the post-Variscan Central European Basin System. We use 3-D, depth-converted, reflection seismics provided by RWE-DEA AG, Hamburg for this investigation. The seismic database covers an area of ca. $15 \times 10\,\text{km}^2$ and extends down to 7.5 km depth. This is deep enough to reveal the subcrop of Upper Carboniferous and stratigraphically-higher strata.

Construction of a 3-D model

Our particular interest is the Rotliegend strata of this area. The Rotliegend mainly consists of aeolian and fluviatile sandstones, which form an onshore hydrocarbon play. The Top Rotliegend surface lies between 4.5 and 5.7 km depth in the studied area. First, the Top Rotliegend surface was picked at a high resolution, as were fault surfaces which displaced Top Rotliegend and lower strata. Displacement of the Top Rotliegend varies from 0–250 m, mainly caused by normal faulting. These surfaces were then gridded in GoCAD, and then transferred to the Midland Valley software package 3DMove for retro-deformation.

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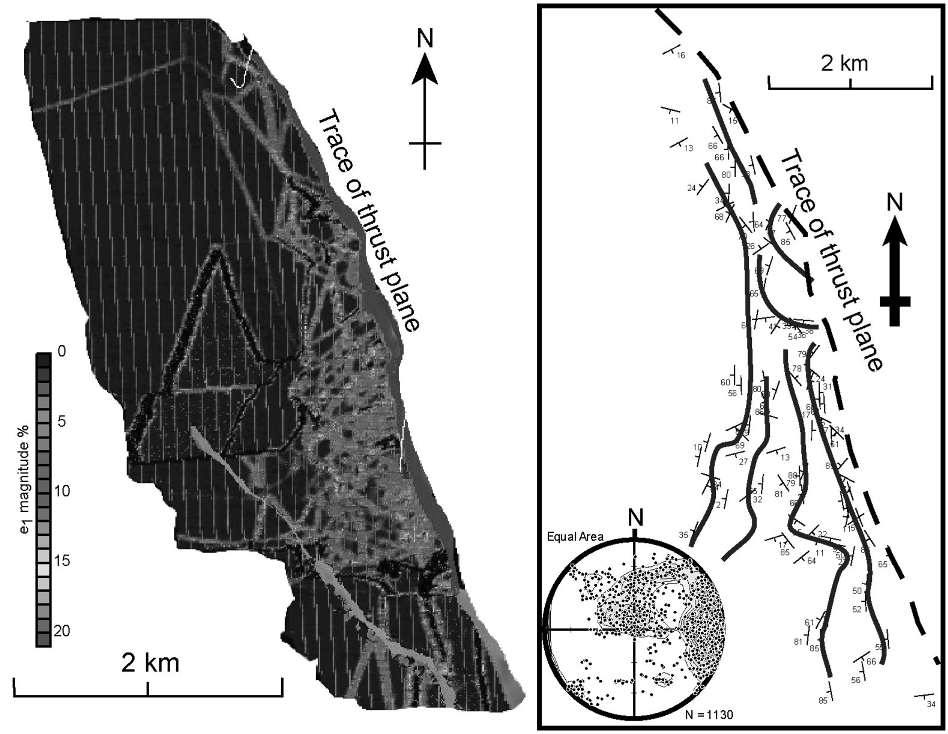

Figure 1: Left: Map view of the hanging-wall of a Rotliegend thrust after retro-deformation, colour-coded for magnitude of the major strain (e_1). Lighter greys are higher strain. Right: Map view of the hanging-wall of the thrust after retro-deformation, showing trajectories (and dip and strike data) of the e_2–e_3 plane, and thus the expected orientation of extensional fractures, caused by thrusting. Insert shows lower hemisphere, equal-area stereonet of poles to the e_2–e_3 planes.

Retro-deformation

For retro-deformation modelling we used the algorithms 'inclined shear' for normal faults and 'fault-parallel flow' for reverse faults, respectively. In the former, the hanging-wall volume of a fault is sheared at an oblique angle to the fault surface, and thus strain is directly attributable to fault curvature. In the latter method, all horizon surface nodes move parallel to the fault surface (as the name suggests), and therefore strain is also related to fault curvature. Figure 1 demonstrates an example of retro-deformation (using the 'fault-parallel flow' algorithm) of a thrust within the Rotliegend, and shows the strain tensor values and orientations which occurred in the surrounding strata. We propose the values of the strain tensor, and thus the magnitude of the strain, are equivalent after retro- or forward deformation. For this example, the e_1-magnitude ranges from 0–20%, but the highest strain intensities are constrained to within 700 m of the fault generally, and up to 1 km locally (Fig. 1). We propose that the e_1-

magnitude can be correlated to the density, and that the e_2–e_3 can be correlated to the orientation, of small-scale structures.

Acknowledgements We thank RWE-DEA AG, Hamburg for allowing us to use their 3D seismic database and borehole data for this project. The project is part of the DFG SPP 1135; we acknowledge DFG grants TA 427/1 and KR 2073/1.