Analysis of shortening in an active detachment fold, Nankai Trough—an introduction to "thickness-relief analysis"

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Excellent seismic images represent a real opportunity for quantitative insight into both regional structural development and fundamental deformation mechanisms. We present an example of an image of the 5 km wide active detachment fold at the toe of the Nankai Trough accretionary wedge at ODP site 1174 (Moore et al. 1990). However analysis of even this relatively simple structure requires us to separate the actual deformation from the non-layer-cake stratigraphic architecture of this active trench setting, which is a challenge. We make this analysis using a new "thickness-relief method" which is an extension of the Epard & Groshong (1993) method of measuring structural relief on a number of well-imaged horizons to determine shortening and depth to detachment. The thickness-relief method gives us a way to separate stratigraphic complexity from true structural relief by flattening the structure on a key horizon over a region much larger than the structure. In this display, the relative structural relief of adjacent horizons appears as an anomaly in thickness. We measure the area of thickness relief as a function of height above or below the key horizon. The vertical gradient in thickness relief is the shortening of this stratigraphic interval.

The fold analyzed at the toe of the Nankai trough runs for ~50 km along strike and deforms an 830 m thick stratigraphic section of hemipelagic and trench-fill strata overlying oceanic crust. The decollement is in the overpressured hemipelagic sequence as shown by drilling and seismic imaging. The thickness-relief analysis allows us to measure the shortening rather precisely at a number of stratigraphic levels. Shortening in the pregrowth interval is relatively constant as a function of depth at 82 m +/- ~10% showing that there is no measurable distributed bed-parallel simple shear within the thrust sheet. Furthermore the apparent bed-length shortening is ~50% of the area shortening, which shows that layer thickness and bed length are not conserved in this deformation. This detachment fold is growing by a heterogeneous pure shear.

The thickness-relief method is independent of decollement depth and is thus widely applicable, not limited to detachment folds. The method provides quantitative constraints on growth history and amounts of diapiric addition.