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Interpreting structural geometry in fold-thrust belts: Why style matters

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Thrusts and folds can show a range of different geometries and inter-relationships that, together with challenging seismic imaging, makes the prediction of subsurface structure uncertain. Many existing interpretation strategies apply a narrow range of fold-thrust relationships that make arbitrary choices for strain and fault localisation, especially in the forelimbs. The routine application of this standard spectrum of styles engenders an overly optimistic appreciation of structural risk. The published array of examples has created significant bias in interpretations of fold thrust belts that has probably contributed to a large number of drilling surprises during hydrocarbon exploration.

We address these challenges and discuss strategies to assist in subsurface interpretation of structural geometry in thrust belts. The development of fold-thrust concepts are outlined and illustrated with an array of outcrop examples. The structural interpretations of the outer Canadian Cordillera have evolved considerably since Dahlstrom's "foothills family" of structures was established through the iteration of outcrop, seismic and well data. Yet now-abandoned interpretations are still used to illustrate theoretical fold-thrust models. Structural styles vary along the thrust belt, in harness with stratigraphic variations. The foothills family is larger than once thought! These styles are contrasted with those developed in the equivalent tectonic setting of the external French Alps. Significant variations in the structural geometry exist between the Jura, where the stratigraphic template is dominated by closely spaced carbonate formations, and the Subalps, where these carbonate formations are separated by thick, shale-prone units. In the Jura, folding is broadly harmonic but still shows variations between buckles ("detachment folds") and imbricate thrusting. In the Subalps deformation is disharmonic with layers showing variations in thrust localisation and in the propensity for folding. Many of these contractional structures appear to localise upon pre-existing faults.

These heterogeneities apparently give rise to lateral changes in thrust belt architecture. Forecasting these deformations demands consideration not only of the mechanical properties of the stratigraphic template but also of any pre-existing structures contained with in it. Both the external Rockies and the Subalps apparently involve simple detachment above basement. Elsewhere thrust systems can involve basement – as exemplified by the front ranges of Papua New Guinea. Basement involvement, and reactivation of pre-existing normal faults, can exert a first-order control on thrust system evolution and greatly increase the solution space for structural interpretation.

These studies indicate that successful subsurface interpretation needs to embrace uncertainty – especially when planning wells. Single deterministic pre-drill interpretations are commonly unhelpful – so that wells that aim to miss structural crests but are side-tracked to reservoir targets offer better strategies. Seismic data may become more useful if fully integrated and iterated with evolving structural interpretations.