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Application of two-dimensional gravity models as input parameters to balanced cross-sections

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Validation of geological cross-sections via 2D forward gravity modelling is a well-established method of de-risking in subsurface prospecting and exploration. The inverse workflow i.e. using 2D gravity forward models to guide the construction of cross-sections has not been so far widely applied. We demonstrate how 2D density models may deliver critical constraints that permit construction and validation of geological models in an underconstrained subcropped fold-and-thrust belt, where existing borehole and seismic data do not allow for a reliable subsurface interpretation.

As a case study, we use a newly discovered and underexplored Variscan fold-and-thrust belt developed above the SW margin of the East European Craton in SE Poland. Abundant shallow boreholes constrain subcrop geology, but existing seismic lines are of a poor quality. It has been only recently that the high-effort POLCRUST-01 and PolandSPAN™ seismic surveys revealed a thin-skinned structural style of this area. Despite of this advance, over large areas, industrial seismic images are often insufficient to constrain even the first order features of the subsurface structure like e.g. the number and amplitude of thrust sheets.

Firstly, we constructed a 2D geological model from gravity data. The model resolves the basement-cover interface and a top-Cambrian horizon. Then, we used this model as a framework for cross-section construction employing at this step also borehole and seismic evidence. Two cross-sections were created to address a source of uncertainty related to non-uniqueness of gravity modelling with different emphasis on gravimetric vs geological evidence. The comparison between the present structure and restorations allowed for separating effects of Caledonian and Variscan shortening.

Density contrasts within folded series is a critical limitation of the presented approach. Many fold belts comprise distinct "density stratification" resulting from a prolonged depositional evolution in a changing tectonic setting e.g. a vertical succession of syn-rift clastics and evaporites, post-rift carbonates and syn-orogenic clastics. As examples one may call the Hellenide fold belt with a 3-layer evaporite-carbonate-clastic stratification or the Zagros fold belt with a similar lithological suite. The separation of the gravity signal into components originating from basement and sedimentary cover can be used as a tool for discrimination between thin- and thick-skinned structural styles. This method should be especially effective for basement-involved thrust belts, where magnetic modelling can support gravity for constraining of the subsurface structural configuration.