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Glacially induced stresses in sedimentary rocks of northern Poland

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During the Pleistocene large continental ice sheets developed in Scandinavia and North America. Ice-loading caused bending of the lithosphere and outward flow in the mantle. Glacial loading is one of the most prominent tectono-mechanical event in the geological history of northern Poland. The Pomeranian region was subjected several times to a load equivalent of more than 1 km of rocks, which led to severe increase in both vertical and horizontal stresses in the upper crustal rocks. During deglaciation a rapid decrease in vertical stress is observed, which leads to destabilization of the crust – most recent postglacial faults scarps in northern Sweden indicate glacially induced earthquakes of magnitude ∼Mw8. The presence of the ice-sheet altered as well the near-surface thermal structure – thermal gradient inversion is still observable in NW Poland.
The glacially related processes might have left an important mark in the sedimentary cover of northern Poland, especially with regard to fracture reopening, changes in stress state, and damage development. In the present study, we model lithospheric bending caused by glacial load, but our point of interest lies in the overlying sediments. Typical glacial isostatic studies model the response of (visco-) elastic lithosphere over viscoelastic or viscous asthenosphere subjected to external loads. In our model, we introduce viscoelastic sedimentary layers at the top of this stack and examine the stress relaxation patterns therein.
As a case study for our modelling, we used geological profiles from northern Poland, near locality of Wejherowo, which are considered to have unconventional gas potential. The Paleozoic profile of this area is dominated by almost 1 km thick Silurian-Ordovician shale deposits, which are interbedded with thin and strong limestone layers. This sequence is underlain by Cambrian shales and sandstones, and finally at ∼3 km depth – Precambrian crystalline rocks. Above the Silurian there are approximately 200 m thick Zechstein evaporites, and thick interval of ductile Triassic and Jurassic claystones. Lithological differences are accompanied by changes in rheological character of alternating layers.
The modelling shows that glacially induced isostatic processes may have caused important changes in the Silurian reservoir including hydrocarbon migration through temporarily open fracture zones and faults.