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Interactive comment on "The Subhercynian Basin: An example of an intraplate foreland basin due to a broken plate" *by* David Hindle and Jonas Kley

David Hindle and Jonas Kley

dhindle@gwdg.de

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se2020-185, reponse to reviewer comments 3 (Brian Horton).

We first of all thank the reviewer, Brian Horton for extremely helpful and constructive comments on the paper.

The reviewer points out that the fault spacing in the sequence of faults (HNBF - Harz Northern Boundary Fault, Huy - Fallstein - Hakel anticline - HFH) may be a strong control on basin width. This is a very astute observation. In order to generate the localised subsidence which is what has led to both the accumulation and preservation of the Late Cretaceous sediments along the margin of the Harz, there must be an

isostatic subsidence of some kind. Our paper's original intent was just to give a general explanation of the mechanism by which such a subsidence can occur in an intraplate setting and our hypothesis was that a lithospheric weakness, functionally equivalent to a zone of close to zero elastic thickness was a firm requirement for this to be possible in an intraplate setting. We deliberately examined a transect across the basin depocentre to do this. As reviewer 3 has rightly pointed out however, the interplay of multiple breaks is highly significant for how any individual part of the system functions. Hence, the western termination of the HFH (and its assumed blind, basement structure underlying it) marks a point where the SCB becomes significantly wider. It is highly likely that the change in width is explained by the termination of the HFH weak zone shown in our 1d model in figure 5, something we had not realised ourselves.. We can explain the change in width with a simple modification of the existing 1d model, removing or reducing the "HFH break"shown in figure 5 which will indeed, lead to a much broader and shallower zone of subsidence We would therefore suggest making such a model and adding a figure for it. This will allow us to also discuss the wider question of the general role of overlap and spacing of basement structures and their influence on basin geometry.

Reviewer 3 comments on the nature and timing of the HFH anticlines in relation to the HNBF. We have already discussed the HNBF timing in response to reviewer 2 especially. Timing of the HFH fault may be constrained to the Coniacian when a large erosional unconformity developed (Von Eynatten, 2008). This would make it synchronous with the HNBF (well within errors of the various methods for determining ages of fault motion). Regarding the nature of the HFH, what we see at the surface is cover deformation, but it is inferred that there may be a basement structure underlying them (see for instance Voigt, 2004, figure 15). In part, our flexural model also supports the existence of such a basement structure, since we clearly require a weak zone at this position.

Reviewer 3 makes an excellent point with regard to the earlier "tilted block" model of

McQueen and Beaumont (1989) which we were not aware of when we wrote our paper. Regarding how our model would respond to "dipping" faults, the answer is that a truly dipping fault can only exist in a 2 dimensional model of the crust. However, Gunn (1943) gives the expression for calculating the equivalent vertical load imposed on the elastic lithosphere by a fault of arbitrary dip. It is important to note that this is the load imposed by stresses across the fault and not due to the self-loading caused by the lithosphere overthrusting itself. In general however, flexural models suggest that self-loading is the more important mechanism for generating flexural subsidence. For our model, changes in fault geometry would therefore correspond to changes in vertical, imposed load.

Reviewer 3 also asks whether flexure could influence basement weakness development. There is a potential reason why this may be the case that we haven't discussed. This would be the idea of so-called plastic hinges, advanced by both Ranalli (1994) and Burov and Diament (1992). This idea suggests that after a certain degree of bending is reached, plastic deformation begins within regions of a plate where the bending stresses exceed the yield strength of the lithosphere. In a classical flexure model, the fibre stresses increase linearly as a function of distance above and below the "neutral" line of no-bending-induced strain. Hence, top and bottom parts of the plate will weaken first, thereby reducing elastic thickness, which in turn may cause further bending, further reducing elastic strength, and so on. This could be thought to create a run-away effect under some circumstances. However, whether this is really physically possible remains open to debate. We could discuss this issue in the paper however. Certainly, interaction of lithospheric bending with an already weakened lithosphere due to faulting may be a mechanism for generating localised weakening as flexural subsidence continues.

McQueen and Beaumont's model in its simplest form considers a completely rigid block with out of balance horizontal forces due to bounding, dipping faults. These were augmented by vertical loads due to basin infill and balanced isostatically by a mantle

substrate. Perhaps the most interesting and relevant aspect of this model for our work is the general notion of tilted, rigid blocks generating subsidence in intraplate settings.

Since writing this paper, we have continued our development of the novel numerical method and submitted a new article explaining a large number of important mathematical aspects of the flexure equation in general (se-2021-36, Hindle and Besson). Included in this is a comparison of a broken plate flexure model to a tilted rigid block model. Here, we confirm what McQueen and Beaumont had also discussed, namely the fact that as fault bounded lithospheric segments become shorter, they act as if they were more rigid. In terms of a flexure model, we explain this as being due to the larger amount of mantle resisting force when a plate segment is longer. Looking again at the SCB and indeed the entire sequence of basins between the HNBF and the North German Basin, it is clear that the SCB has formed on a very short lithospheric segment.

As an aside regarding Hetenyi's (1946) book, having finally been able to view it, I noted that it is heavily based on engineering cases, whereas Gunn's articles were formulated purely for earth sciences. Gunn's biography (he was a polymath physicist who published across a startlingly broad range of topics, including isostacy and gravity for reasons that appear never to have been fully explained) suggests that anything he wrote on the topic of flexure would have been easy for him to formulate from scratch. He may have borrowed some thinking from engineering, but if so, he made huge adaptations to it, and was almost certainly the first person to find the necessary particular solutions of the differential equations for modelling geodynamic cases.

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