PSFault Growth and Strain Localization in a Multilayer Brittle-Ductile System, Halten Terrace, mid-Norway*

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Abstract

Tectonic subsidence in rift basins is often characterised by an initial period of slow subsidence ("rift initiation") followed by a period of more rapid subsidence ("rift climax"). Previous work shows that the transition from rift initiation to rift climax can be explained by interactions between the stress fields of growing faults. Despite the prevalence of evaporites throughout the geological record and the likelihood that the presence of a regionally-extensive evaporite layer will introduce an important, sub-horizontal rheological heterogeneity into the upper crust, there have been few studies that document the impact of salt on the localisation of extensional strain in rift basins. Here we use well calibrated 3D seismic reflection data to constrain the distribution and timing of fault activity during Early Jurassic-earliest Cretaceous rifting in the Åsgard area, Halten Terrace, offshore Mid-Norway. Permo-Triassic basement rocks are overlain by a thick sequence of interbedded halite, anhydrite, and mudstone. Our results show that rift initiation during the Early Jurassic was characterised by distributed deformation along blind faults within the basement, and by localised deformation along the major Smørbukk and Trestakk faults within the cover. Rift climax and the end of rifting showed continued deformation along the Smørbukk and Trestakk faults, together with initiation of new extensional faults oblique to the main basement trends. We propose that these new faults developed in response to salt withdrawal and/or gravity sliding on the evaporite layer above the tilted basement fault blocks. Rapid strain localisation within the post-salt cover sequence at the onset of rifting is consistent with previous experimental studies showing that strain localisation is favoured by the presence of a weak viscous substrate beneath a brittle overburden.

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Base Salt marker

km

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(A) Tectonic subsidence

Time (Myr)

Strain localization After Cowie 1998

(D) Halten Terrace stratigraphy

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. Rationale and aim

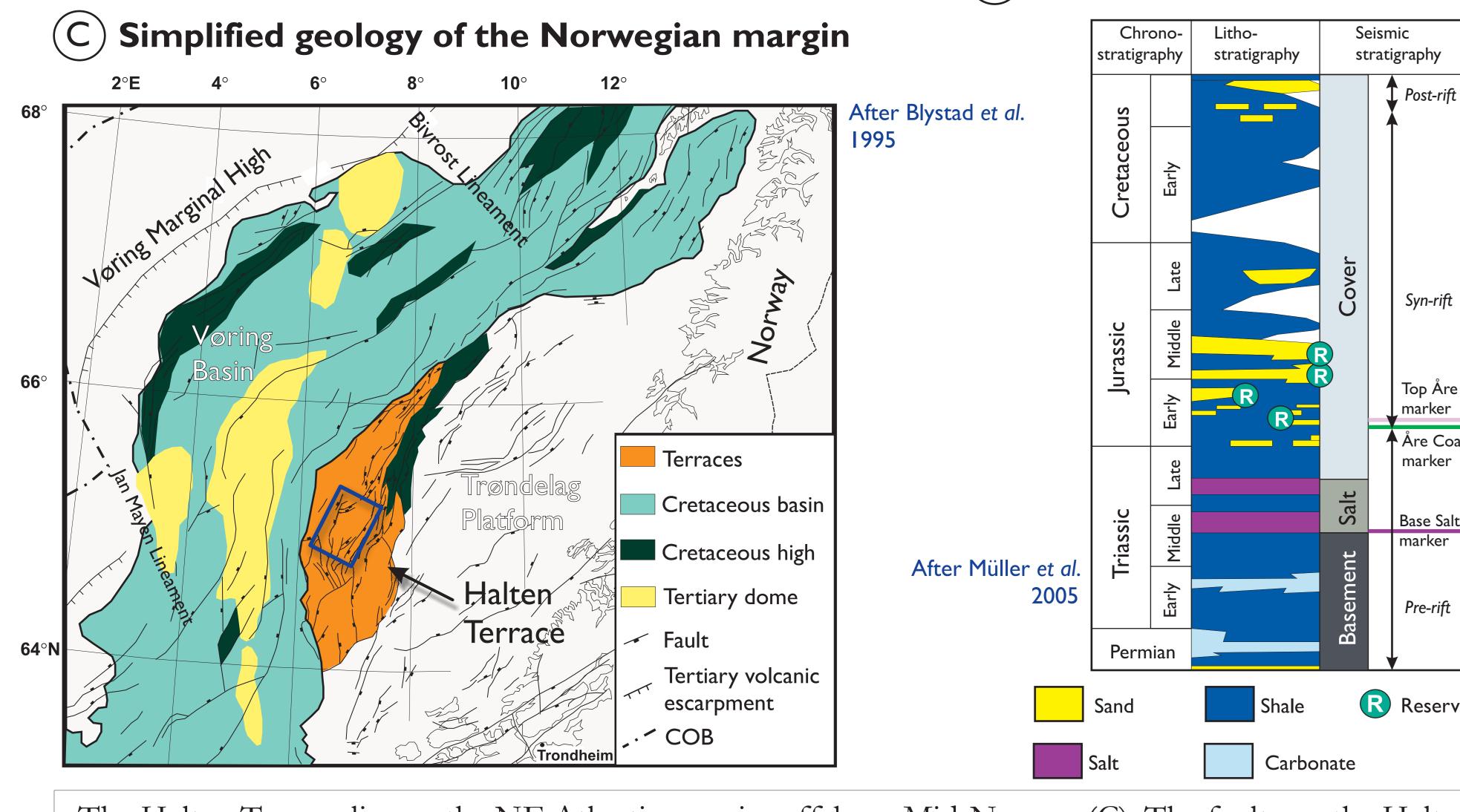
Tectonic subsidence in some rift basins is characterised by an initial period of slow subsidence (rift initiation) followed by more rapid subsidence (rift climax) (A; Gupta et al. 1998).

The rift initiation phase is characterised by distributed extension accommodated by many active faults. The rift climax phase is characterised by localized extension accommodated by a few active faults (B).

Strain localisation is a consequence of interactions between the stress fields of active faults (Cowie 1998). The ability of a fault to grow is itself influenced by the mechanical stratigraphy of the basin (e.g. Soliva et al. 2005).

The aim of this poster is to investigate the influence of sub-horizontal evaporite layers on fault growth and strain localization in rift basins.

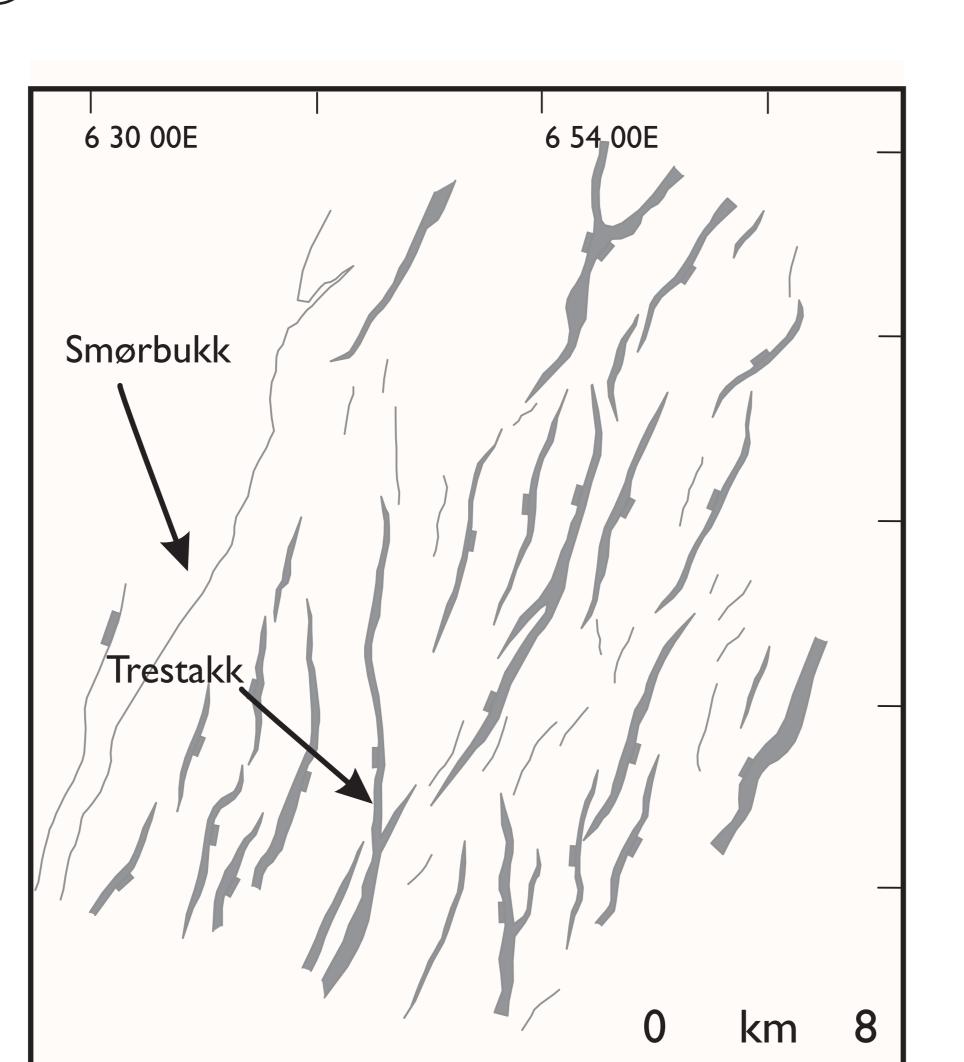
2. Study area



The Halten Terrace lies on the NE Atlantic margin, offshore Mid-Norway (C). The faults on the Halten Terrace were active during Jurassic rifting. Permo-Triassic basement is separated from Mesozoic cover by two 400 m thick salt units (D). This study focuses on the Åsgard area (C, purple box). Large-scale buoyancy driven flow of the salt is not widespread, making Åsgard a good location to study the impact of salt on strain localization during rifting.

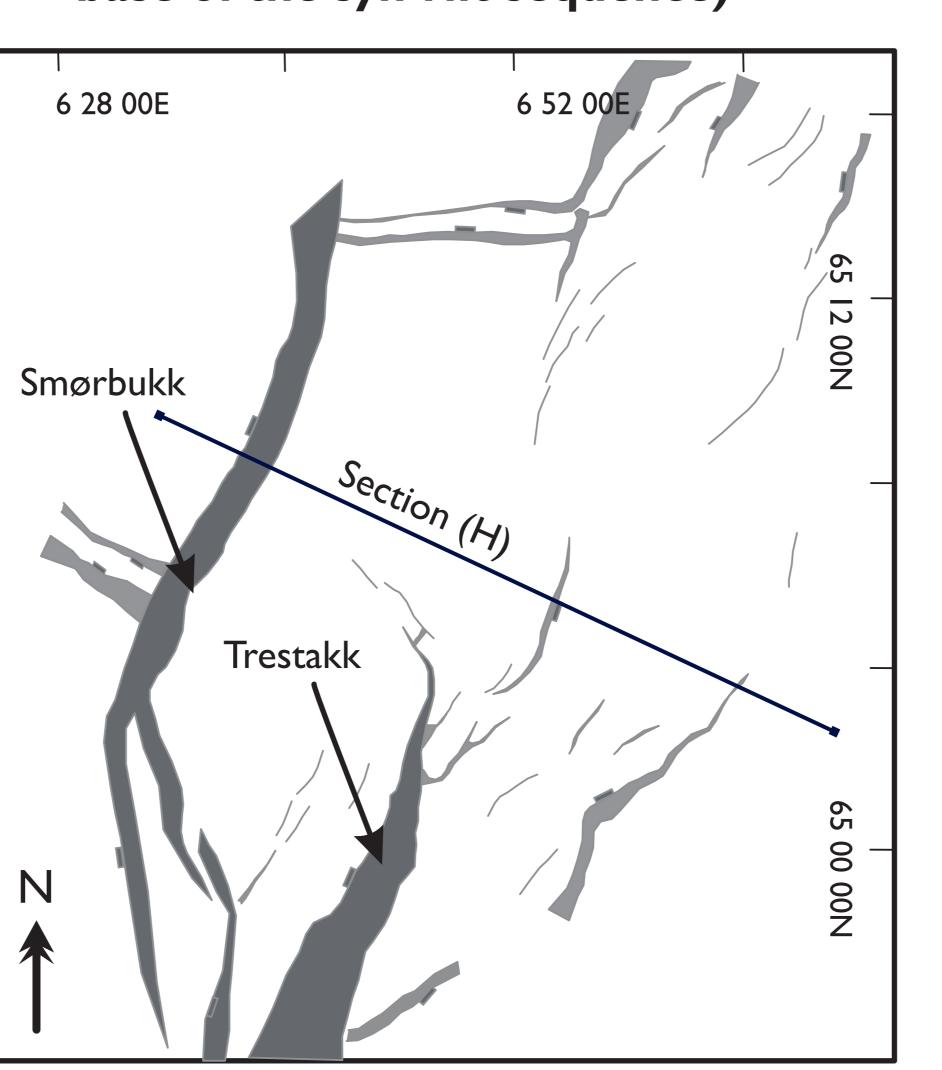
. Fault geometry, growth and strain localization in the Asgard area

Basement fault polygons (Base Salt maker)

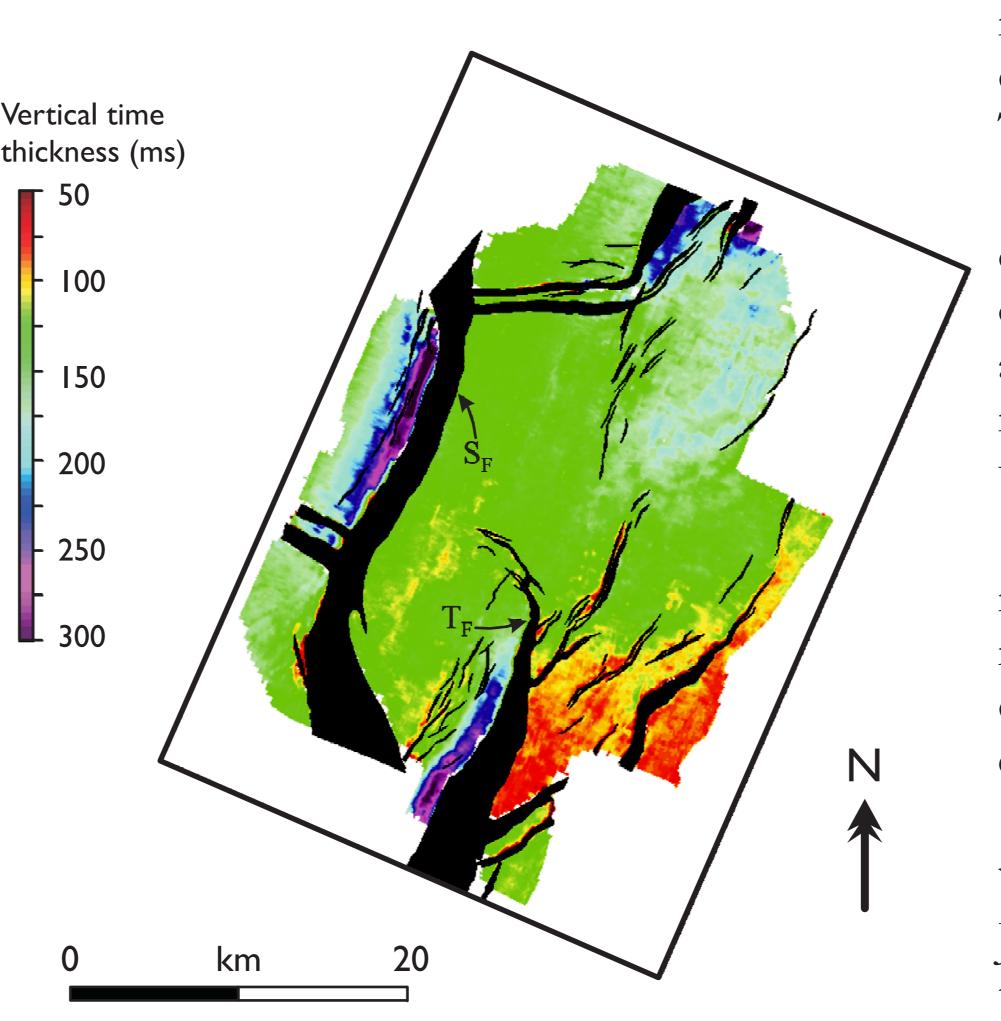


Cross-section

Cover fault polygons (Åre Coal marker; base of the syn-rift sequence)



(G) Early Jurassic isochron map (Åre Coal to Top Are)



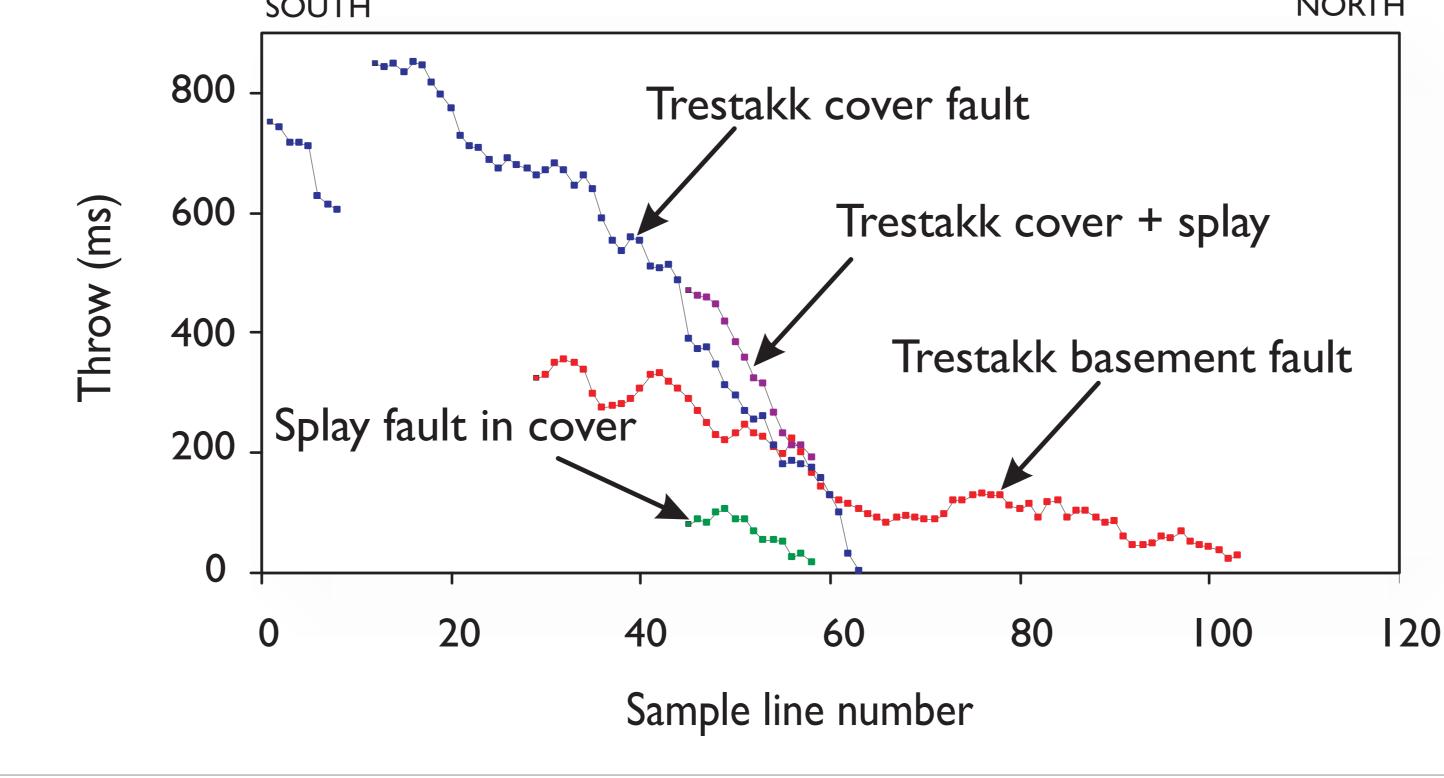
Fault polygon maps show there is a higher fault density within the basement (E) than within the cover at the base of the synrift sequence (F). This implies that strain is more localized in the cover - where extension is mainly accommodated along the Trestakk and Smørbukk faults - than in the basement.

Across-fault sediment thickness variations show that activity on the cover faults initiated during the Early Jurassic (G). A key question is to determine whether the mapped basement faults are in fact pre-Jurassic structures, the largest of which were reactivated during Early Jurassic rifting and propagated upwards into the cover.

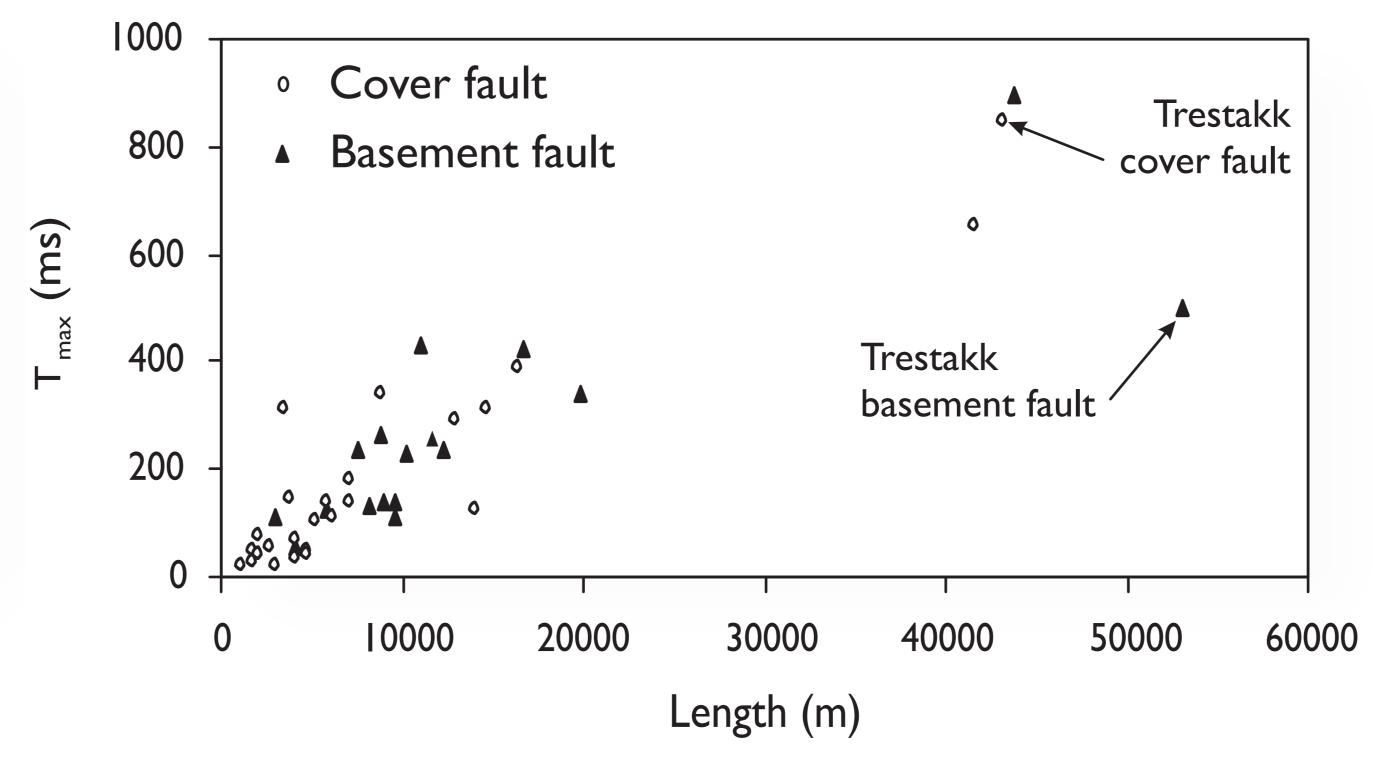
Pre-Jurassic strata are characterised by parallel seismic reflectors, with no evidence for reflector divergence towards mapped faults (H). The patterns of flexure and onlap within the cover sequence suggests that blind basement faults were active during Early Jurassic rifting (H).

The simplest explanation is that the mapped cover and basement faults initiated at the same time, i.e. during Early Jurassic rifting, and that variations in salt thickness (H) are due to lateral flow of the salt in response to faulting (see also Richardson et al. 2005).

Throw profile for basement and cover segments of the Trestakk Fault



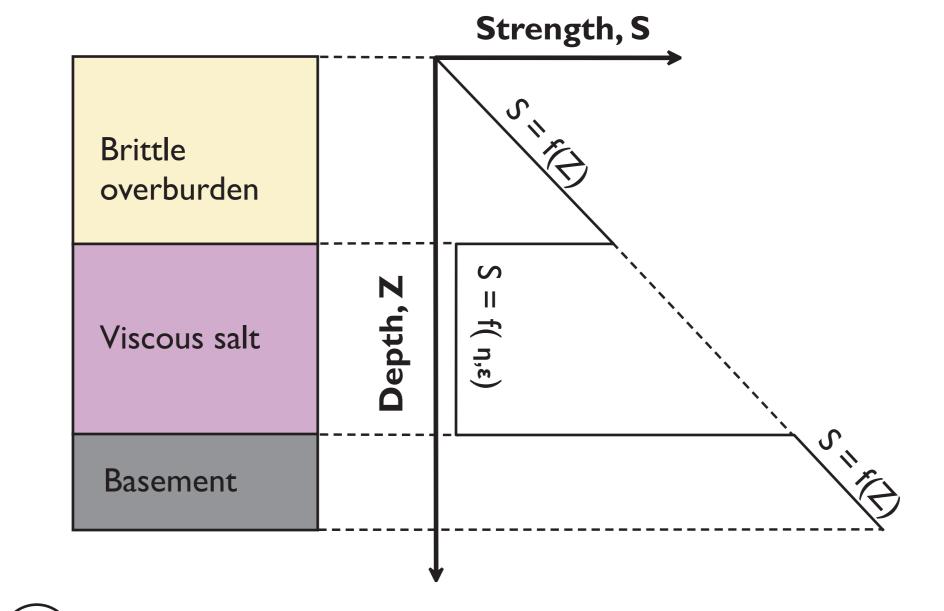
Throw vs. length plot for all Asgard basement and cover faults



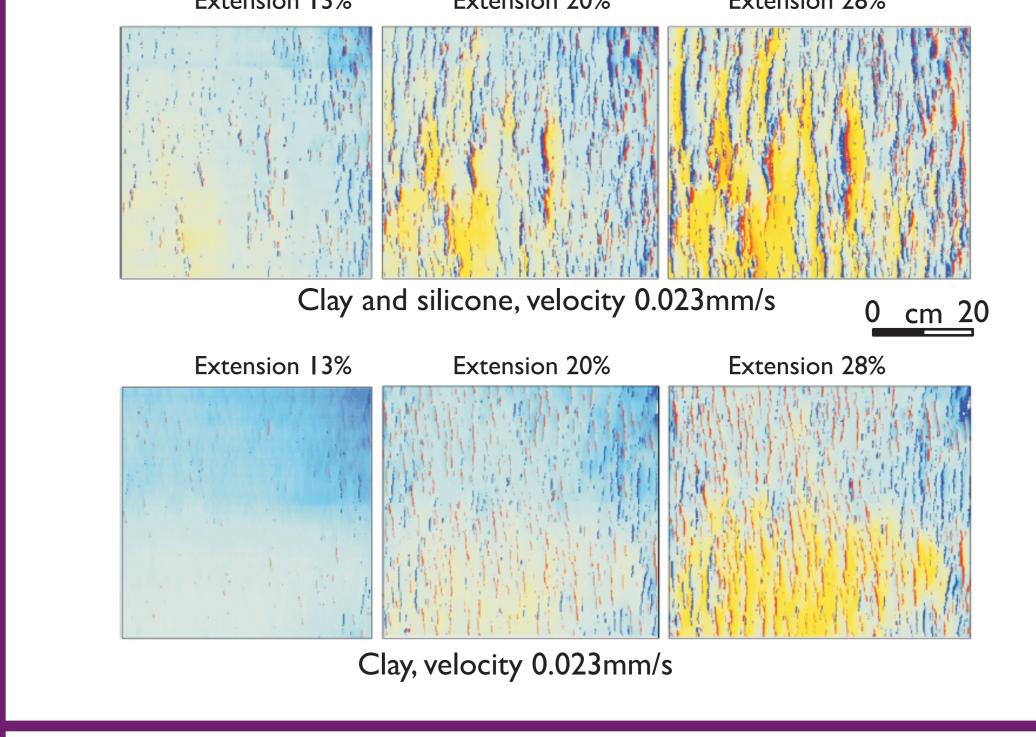
The throw profile for the basement and cover segments of the Trestakk fault faults (which can probably be attributed to flexure of the cover above blind (I) shows that for much of its length, the cover segment has a higher throw basement faults; H), there is little difference between the populations of than the basement segment. This observation is consistent with the more basement and cover faults. The total geometric moment estimated on distributed deformation in the basement than in the cover. A plot of basement (Base Salt) and cover (Åre Coal) markers agree to within ca. 5%. maximum throw vs. fault length (J) shows that apart from the smallest cover This suggests extension in the cover balances extension in the basement.

6. Discussion

Strength vs. depth profile for a basin containing salt After Vendeville and Jackson 1993



Fault growth in single and multilayer analogue models After Bellahsen et al. 2003



Observations from the Åsgard area show that faulting in the post-salt cover sequence is more localized than extension in the pre-salt basement. Faults in the basement and cover appear to have been active at the same time, i.e. localization was rapid on a geological timescale. In comparison with previous studies, there is no strong evidence for progressive strain localization upward through the growth sequence (e.g. Walsh *et al.* 2003).

The strength of salt is a function of viscosity and strain rate, whilst the strength of the brittle sedimentary cover and basement strata is a function of depth. Salt is likely to be much weaker than the cover or basement rocks (K; Vendeville and Jackson 1993). This suggests that the salt units in Asgard may act as sub-horizontal weaknesses.

Analogue models of fault growth show that localization of strain onto a few large faults occurs at lower magnitudes of extension in clay / silicone multilayers than in single layer clay models (L; Bellahsen et al. 2003). The low viscosity silicone underlying the clay allows faults to accumulate large throws in the multilayer case.

We suggest that the presence of weak salt layers may have enabled unrestricted growth of the Trestakk and Smørbukk faults in the cover, promoting rapid strain localization. The early onset of strain localization has implications for the nature and distribution of early syn-rift reservoir sands in the

7. Conclusions

- Rifting in the Åsgard area of the Halten Terrace initiated during the Early Jurassic and was accommodated by faults above and below two 400m thick salt layers.
- 2. The pre-salt basement is characterised by distributed deformation; the post-salt cover is characterised by localised deformation along the Trestakk and Smørbukk faults. To a first order, extension in the cover appears to balance extension in the basement.
- By comparison with analogue models, the apparently rapid strain localisation within the cover may be due to unrestricted fault growth above the weak salt layer.

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