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Inverse modeling of Eocene to mid-Pliocene landscape evolution in Scandinavia using offshore sediment volumes

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The origin of high topography in Scandinavia is highly debated, both in terms of its age and the underlying mechanism for its formation. Traditionally, the current high topography is assumed to have formed by several Cenozoic (mainly Neogene) phases of uplift and dissection of an old peneplain surface. These same uplift events are suggested to explain an increased deposition in adjacent offshore basins on the Norwegian shelf and in the North Sea. However, more recently it has been suggested that prolonged climate-dependent erosion and isostatic uplift of existing topography may also explains the recent evolution of topography in Scandinavia. For this latter view, an increased sedimentation towards the present has been assumed a consequence of a climate related increase in erosion.

In this study we explore whether inverse modeling of landscape evolution can give new insight into Eocene to mid-Pliocene (54-4 Ma) landscape evolution in the Scandinavian region. We do this by combining a highly efficient forward-in-time landscape evolution model (FastScape; Braun and Willett, 2012) with an optimization scheme suitable for non-linear inverse problems (the neighborhood algorithm – NA; Sambridge, 1999a,b). In order to limit our approach to the fluvial regime, we exclude the most recent mid-Pliocene to Quaternary time period where glacial erosion processes are expected to dominate landscape evolution.

The "goodness" of our forward-in-time landscape evolution models is evaluated using i) sediment fluxes based on decompacted offshore sediment volumes and ii) maximum elevation of topography from a mid-Pliocene landscape reconstructed using geophysical relief and offshore sediment volumes from the mid-Pliocene-Quaternary.

We find several scenarios consistent with the offshore sediment record and maximum elevation of our reconstructed mid-Pliocene landscape reconstruction: I) the combination of some (∼0.9 km) initial topography at 54 Ma and minor continuous uplift until 4 Ma (<0.04 mm/yr), II) substantial (∼ 2 km) initial topography at 54 Ma and no induced tectonic uplift until 4 Ma, and III) rapid tectonic uplift of initially low topography (∼ 0.1 km) at ∼54 Ma followed by tectonic quiescence until 4 Ma. However, out of these only scenario II (no tectonic uplift) matches large-scale characteristics of the estimated mid-Pliocene topography well.

Our preferred model for Eocene to mid-Pliocene landscape evolution in Scandinavia is therefore one where high topography (∼ 2km) has existed throughout the time interval from 54-4 Ma. We do not find several phases of peneplain uplift necessary in order to explain offshore sediment volumes and large-scale topographic patterns. On the contrary, extensive peneplain dissection seems inconsistent with the low rates of erosion we infer based on the offshore sediment volumes.

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