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Review

The evolution of western Scandinavian topography: A review of Neogene uplift versus the ICE (isostasy–climate–erosion) hypothesis

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ABSTRACT

Tectonics and erosion are the driving forces in the evolution of mountain belts, but the identification of their relative contributions remains a fundamental scientific problem in relation to the understanding of both geodynamic processes and surface processes. The issue is further complicated through the roles of climate and climatic change. For more than a century it has been thought that the present high topography of western Scandinavia was created by some form of active tectonic uplift during the Cenozoic. This has been based mainly on the occurrence of surface remnants and accordant summits at high elevation believed to have been graded to sea level, the inference of increasing erosion rates toward the present-day based on the age of offshore erosion products and the erosion histories inferred from apatite fission track data, and on over-burial and seaward tilting of coast-proximal sediments.

In contrast to this received wisdom, we demonstrate here that the evidence can be substantially explained by a model of protracted exhumation of topography since the Caledonide Orogeny. Exhumation occurred by gravitational collapse, continental rifting and erosion. Initially, tectonic exhumation dominated, although erosion rates were high. The subsequent demise of onshore tectonic activity allowed slow erosion to become the dominating exhumation agent. The elevation limiting and landscape shaping activities of wet-based alpine glaciers, cirques and periglacial processes gained importance with the greenhouse–icehouse climatic deterioration at the Eocene–Oligocene boundary and erosion rates increased. The flattish surfaces that these processes can produce suggest an alternative to the traditional tectonic interpretation of these landscape elements in western Scandinavia. The longevity of western Scandinavian topography is due to the failure of rifting processes in destroying the topography entirely, and to the buoyant upward feeding of replacement crustal material commensurate with exhumation unloading.

We emphasize the importance of differentiating the morphological, sedimentological and structural signatures of recent active tectonics from the effects of long-term exhumation and isostatic rebound in understanding the evolution of similar elevated regions.

Contents

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1. Introduction

The Silurian Caledonide Orogeny (450–420 Ma) (Fig. 1) was the consequence of the continent–continent collision of Laurentia and Baltica (Soper et al., 1992; Cocks and Torsvik, 2002), and represents the most recent mountain-building process to affect the region of Scandinavia. Prior to this the Sveconorwegian Orogeny (1.15–0.9 Ga) affected southern Norway and south-western Sweden, mainly as a crustal thickening and topography producing event (Balling, 2000; Bingen et al., 2005) and without much accretion of new crust. Even older records of crustal amalgamation and mountain-building in southwestern Scandinavia date back to the Gothian complex of orogenic events from 1.75 to 1.55 Ga (Bogdanova et al., 2008).

Collapse and rifting processes began to dismember the Caledonides immediately after their formation. These processes ultimately produced the deep late Palaeozoic and Mesozoic sedimentary basins on the continental shelves of north-western Europe and east Greenland and also affected the onshore western Scandinavia (Dunlap and Fossen, 1998; Fossen and Dunlap, 1999; Andersen et al., 1999; Mosar, 2003). The prolonged continental rifting process between the North American-Greenland craton and

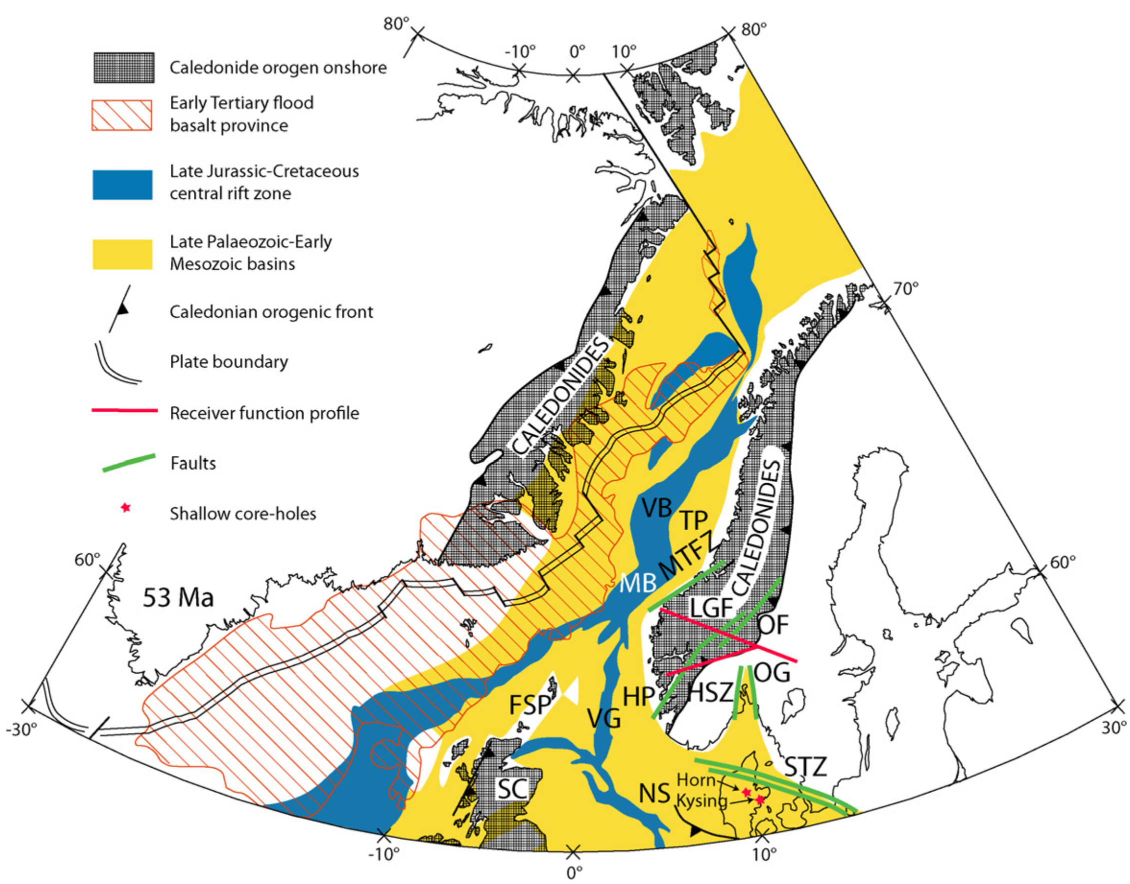

Fig. 1. Plate configuration at the time of North Atlantic break-up with generalized structural elements redrawn mainly after Skogseid et al. (2000) and Andersen et al. (1999). The sedimentary basins separating the onshore remains of the Caledonides are the result of Late Palaeozoic through Mesozoic episodes of post-orogenic continental extension. The position of teleseismic profiles in southern Norway and shallow core holes are shown. FSP: Faero-Shetland Platform; HP: Horda Platform; HSZ: Hardangerfjorden Shear Zone; LGF: Lærdal-Gjende Fault; MB: Møre Basin; MTFZ: Møre-Trøndelag Fault Zone; NS: North Sea; OF: Olestøl Fault; OG: Oslo Graben; TP: Trøndelag Platform; VB: Vøring Basin; VG: Viking Graben; SC: Scotland; STZ: Sorgenfrei-Tornquist Zone.