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Subduction and exhumation of a continental margin in the Scandinavian Caledonides: Insights from ultrahigh pressure metamorphism, late orogenic basins and 3D numerical modelling

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The Scandinavian Caledonides (SC) represents a plate collision zone of Himalayan style and scale. Three fundamental characteristics of this orogen are: (1) early foreland-directed, tectonic transport and stacking of nappes; (2) late, wholesale reversal of tectonic transport; (3) ultrahigh pressure metamorphism of felsic crust derived from the underthrusting plate at several levels in the orogenic wedge and below the main thrust surface, indicating subduction of continental crust into the mantle. The significance of this for crustal evolution is the profound remodeling of continental crust, direct geochemical interaction of such crust and the mantle and the opening of accommodation space trapping large volumes of clastic detritus within the orogen.

The orogenic wedge of the SC was derived from the upper crust of the Baltica continental margin (a hyper-extended passive margin), plus terranes derived from an assemblage of outboard arcs and intra-oceanic basins and, at the highest structural level, elements of the Laurentian margin. Nappe emplacement was driven by Scandian (∼430Ma) collision of Baltica with Laurentia, but emerging Middle Ordovician ages for diamond-facies metamorphism for the most outboard (or rifted) elements of Baltica suggest prior collision with an arc or microcontinent. Nappes derived from Baltica continental crust were subducted, in some cases to depths sufficient to form diamond. These then detached from the upper part of the down-going plate along major thrust faults, at which time they ceased to descend and possibly rose along the subduction channel. Subduction of the remaining continental margin continued below these nappes, possibly driven by slab-pull of the previously subducted Iapetus oceanic lithosphere and metamorphic densification of subducted felsic continental margin.

3D numerical modelling based upon a Caledonide-like plate scenario shows that if a continental corner or promontory enters the subduction zone, the continental margin descends to greater depths than for a simple orthogonal collision and its modelled thermal evolution is consistent with UHP metamorphic assemblages recorded in the southern part of the SC. Furthermore, a tear initiates at the promontary tip along the ocean-continent junction and propagates rapidly along the orogen. The buoyant upthrust of the subducted margin can then lead to reversal of the motion vector of the entire subducting continent, which withdraws the subducted lithospheric margin out of the subduction channel ("eduction"). Because of the diachroneity of slab failure, the continent also rotates, which causes the eduction vector to change azimuth over time. These model behaviours are consistent with the late orogenic structural evolution of the southern SC. However, during the final exhumation stage the crust may not have acted entirely coherently, as some eduction models propose: There is evidence that some inboard Baltica crust experienced late, shallow subduction before detaching as giant "flakes" that carried the orogenic wedge piggyback, forelandwards. Eduction and flake-tectonics could have operated coevally; the model system does not preclude this.

Finally, the traction of a large educting (or extruding) mass of continental margin against the overlying orogenic wedge may have stretched and ruptured the wedge, resulting in opening of the late-orogenic Old Red Sandstone molasse basins.