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Role of differential erosion in uplifting continental margins: examples from Antarctica, New Zealand and Norway

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Uplifted and back-tilted continental margins are common but the processes that drive uplift are not always obvious. Isostatic rebound as a response to incisional erosion is an important process that can produce rock uplift of the order of kilometer or two on a time scale of millions of years. Here we compare contrasting continental margins where glacial (and fluvial) erosion have produced fiord structures of the order of a kilometre or two deep, and 1-40 kilometres wide. The uplift response is a function of the depth of erosion, the width of erosion and the spacing of the eroded fiords, relative to the flexural parameter. We calculate the 3D response with a flexural model that allows either a continuous or free-edged plate. By far the largest fiord system we know of is that created by the outlet glaciers of the East Antarctic ice cap as they pass through the Transantarctic mountains (TAM). Here we calculate a rebound response for mountain peaks of ∼ 2000 m, or about 50% of the peak heights. In Fiordland, New Zealand, incision is not as deep or as wide as in the TAM and the rebound for Te =20 km is less at ∼ 150 m. Peak heights in Fiordland are typically ∼ 1500 m so the rebound is about 10% of the peak height. In both the TAM and Fiordland the regions are bounded by major plate-boundary-type faults that suggest a flexural uplift model with a free-edge. The Norwegian margin, in contrast, sits on a continuous plate, with elastic thicknesses that likely decrease towards the Atlantic margin. Here the fiords cut to depths of up to 1300 m but the calculated rebound response is still significant at ∼ 500-700 m (for constant Te=20 km)). Peak heights are up to 2500 m and thus predicted rebound is about 25 % of the peak height. Based on these examples we conclude that magnitude of incision and subsequent rebound is related to climate. For alpine type glaciations of Fiordland over the last 2-3 myr the rebound as a function of the peak height is a minimum. At the other end of the scale some 34 my of glacial history, of which 15 my was in polar conditions, created a condition in the TAM of wet based glaciers efficiently carving deep troughs that are bounded by frozen and thus preserved peaks. The second consequence of rebound from incision is that an apparent isostatic imbalance can be created whereby the mountain peak height implies a crustal thickness which is greater than that observed. This is particularly evident at the TAM where the highest mountain peaks are ∼ 4500m high but the crustal thickness is only 35-40 km. An important contribution of the rebound analysis is partitioning of an observed rock-uplift history into that due to tectonics versus the isostatic response to incisional erosion. This is well illustrated in Fiordland where a flight of uplifted marine terraces can be ascribed to both subduction processes and isostatic rebound.