b14 Post-glacial uplift < sediments, sealevel, tilt >

> The nature of things is resistance to change, while the nature of process is resistance to stasis.
> — Heat Moon

The response of Earth's crust to loading is to flex down in proportion to the weight added. The subcust volume displaced is partly accommodated peripherally by crustal uparching. Since the end of the Ice Age, glaciated areas are rebounding from the low elevations they had when the ice sheets that weighted them down vanished. This phenomena was noted by Thomas F. Jamieson in 1865:

> In Scandinavia and North America, as well as in Scotland, we have evidence of a depression of the land following close upon the presence of the great ice-covering; and, singular to say, the height to which marine fossils have been found in all these countries is very nearly the same. It has occurred to me that the enormous weight of ice thrown upon the land may have had something to do with this depression.[1]

Vanished now are former northern ice sheets: the European (Fennoscandian and British) and the North American (Cordilleran, Innutian, and Laurentian with its Keewatin, Labrador, and Baffin sectors). As can be anticipated, post-glacial uplift is most at the places from which ice sheets spread.

In Scandinavia, raised more than sealevel has risen, are shorelines and shell deposits at elevations of 1000 feet (300 m). Jamieson in 1882 reasoned that these places had been depressed below sealevel (to as much as 100 m) by the weight of now vanished glacial ice.[2] Here too, Beno Gutenberg in 1941[3] was able to martial three lines of evidence for vertical uplift and its rate (***Figure b14.1***):

Sealevel engraved-and-dated marks since Anders Celsius (1701-1744) time for the nearly tideless Baltic show an ongoing *apparent* lowering of sealevel. (This is a measure of the *rise* of Baltic shores as tide gage records worldwide show little sealevel change during historical time.)

Upward change in sections from marine muds to freshwater bog deposits. (A hare and tortoise event: Glacial melting caused sealevel to rise rapidly 100+ meters by 6000 years ago after which glaciers stayed at near their present volume (***Footnote b14.1***). The land, from when it was relieved of its ice burden, has rebounded slowly and is still rising. So lands that had been depressed by ice load to *below* sealevel, have now risen *more* than did sealevel.)

Tilt of ground from careful geodetic surveys.[4] (The rate and amount of uplift is greatest near its center where the former ice sheet was thickest, and lessens to zero at its once edge.)

As in Scandinavia, rebound in North America is recorded by a succession of raised beaches about centers of maximum uplift, and the vertical movement continues.[5] At glacial maximum (or sealevel minimum), the Laurentide ice sheet was 5 kilometers thick from where it radiated (where shallow Hudson Bay now is and which area had been weighted down to 1 kilometer below present sealevel).

In North America, the freshwater basins of the Great Lakes, lake Champlain, and lake George, were for a while at the end of the Ice Age flooded by the sea until rebound raised and thereby separated them in their outlets from the Atlantic. Post-glacial uplift of the Great Lakes is recorded by strandlines, concentric to the present lakes. These show the lakes, during the millennia since the last glaciation have progressively, and greatly, shrunk in area. Ridges (dunes) that formed at the back of former beaches are different in their present vegetation in the sequence:

Near the present lake are specialist grasses, poplars (cottonwoods), pines.

Far from the present lake are oak forests.

Henry Chandler Cowles, who first described this sequence about Lake Michigan in 1889, realized that distance of a dune ridge away from the present shore line is a proxy for its time of being. Therefore, the different vegetations could be stages of plant communities that replace each other sequentially. Cowles called the vegetation that comes to replace all, and is not itself replaced, the "climax" vegetation.[6] The excitement generated was that, by such observations, the successions of colonizing life from pioneer to climax can be known even when the time taken far exceeds our ability to directly observe. However, excitement should be tempered as the model is no guarantee that an observed succession is real (oak forest may never come to replace dune grasses) because unpredictably variable in time are climate and species (both plant and animal) that arrive, leave, evolve or go extinct.[7] The northeastern U.S. white pine, eastern hemlock, and American beech, "climax" hardwood forest with its shade-tolerant seedlings could, before logging, keep at bay sun-loving faster growing, red maple, tulip tree, white ash, wild cherry, and yellow birch.[8]

Worldwide evidence is that periglacial regions are now subsiding (***Figure b14.2***). By inference, these areas had bulged upward during the Ice Age.[9] The cause is modeled as a response to deep seated exiting flow of formerly outward displaced asthenosphere.[10]

Satellite Laser Ranging (SLR), today, keeps track of global height change due to post-glacial rebound and the secular changes in Earth's pole position that the rebound and long-term changes in ice-sheet mass balance cause.[11] BIFROST records daily GPS measures of Baltic shield rebound.[12]

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Footnote b14.1 Enough ice remains in the ice sheets of Greenland and Antarctica to further raise sealevel 7 m and 61 m respectively. However, in response to global warming, the Greenland ice sheet, has thickened (!) at its center at high elevation (above its snowline) where it yearly continues to accumulate snow[13] while in its margin it has contracted somewhat and its outlet glaciers have shortened.[14]

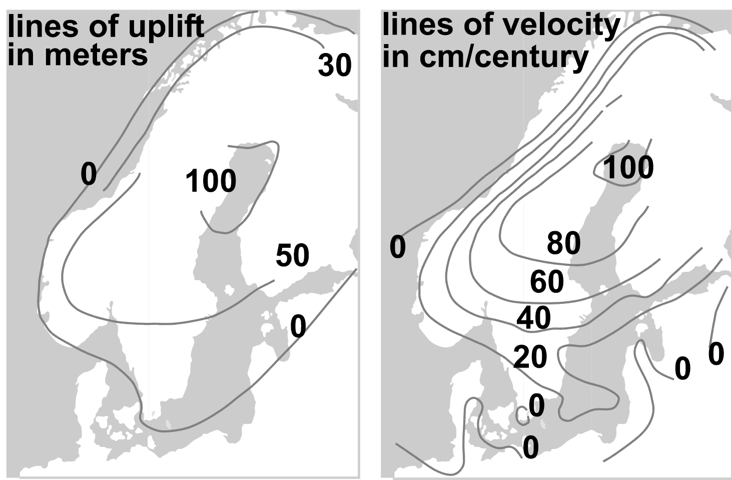

Figure b14.1 [15] Post-glacial rebound of Fennoscandia as determined by Gutenberg in 1941.

Figure b14.2 [15] Post-glacial rebound that continues today.