Subsidence of sedimentary basins due to graitational collapse of topographic lows: mechanism and examples

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Surface elevation and lateral buoyancy forces must not correlate. The former is (in isostatic equilibrium) a function of the vertically integrated densities of the lithosphere (it is linear in thickness); the latter is a function of the vertically integrated vertical stresses (it is quadratic in thickness). While these physical foundations for both parameters have been known for quite some time, the relationship between surface elevation and buoyancy force often confused in the literature in that they are often assumed to correlate directly.

Some of this confusion is evidenced by our intuitive understanding (and misunderstanding) of vertical motions of the surface: We are well-familiar with the fact that - during continental extension - the surface may move upwards *or* downwards: the former is known to us from the subsidence of many sedimentary basins, for example the Pannonian basin, the latter is known to us from uplift of rift margins, for example the eastern African highlands, or the Australian Great Dividing Range. In contrast, it is much less intuitive to us that both directions of surface motion may also occur during lithospheric shortening: Most earth scientists would assume that the isostatically-supported surface elevation goes upwards, i.e. a mountain belt will form, when the lithosphere is thickened. This contribution serves two aims: Firstly, we will discuss the thickening geometries under which isostatic surface subsidence and sedimentary basin formation occurs during crustal shortening. Secondly, we will show that lateral buoyancy forces must not correlate with surface elevation. That is, sedimentary basins may not only extend because they are actively being stretched, but they may also form due to gravitational collapse of a topographic low into a topographically higher region! In order to clarify these relationships, we present a simple one-dimensional model.

In our model, we assume a simple model orogen which undergoes simultaneous thickening due to convergence and sedimentation or erosion at the surface depending on whether the surface uplifts or subsides. Using this model it can be shown that, for reasonable thickening rates, surface elevation may subside or uplift through time (depending on the initial thickness geometry of crust and mantle lithosphere), while the lateral buoyancy force changes from positive to negative (Fig. 1). This counter-intuitive result implies that: in the *early* orogenic evolution topographically *high* regions exert a lateral buoyancy force on topographically *low* regions, while later in the evolution the topographically *lower* regions may exert buoyancy forces on topographically *higher* regions. This may give rise to the formation of sedimentary basins in the fore- or hinterland of orogens that have formed due to gravitational inward collapse of an orogen, and not due to flexural processes.

Present day examples may be the formation of backarc basins where extension in the low-lying hinterland of an Andean-type mountain belt is caused by a gravitational compressive force exerted by the hinterland onto a belt of significantly *higher* surface elevation, but possibly of *lower* potential energy.

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Radiolarien aus unterliassischen Beckensedimenten der Hallstätter Zone aus polymikten oberjurassischen Brekzienkörpern der Torrener-Joch-Zone (Nördliche Kalkalpen, Königsbachgraben, Berchtesgadener Land, Deutschland)

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Der Nordrand des Steinernen Meeres im Bereich der Berchtesga-

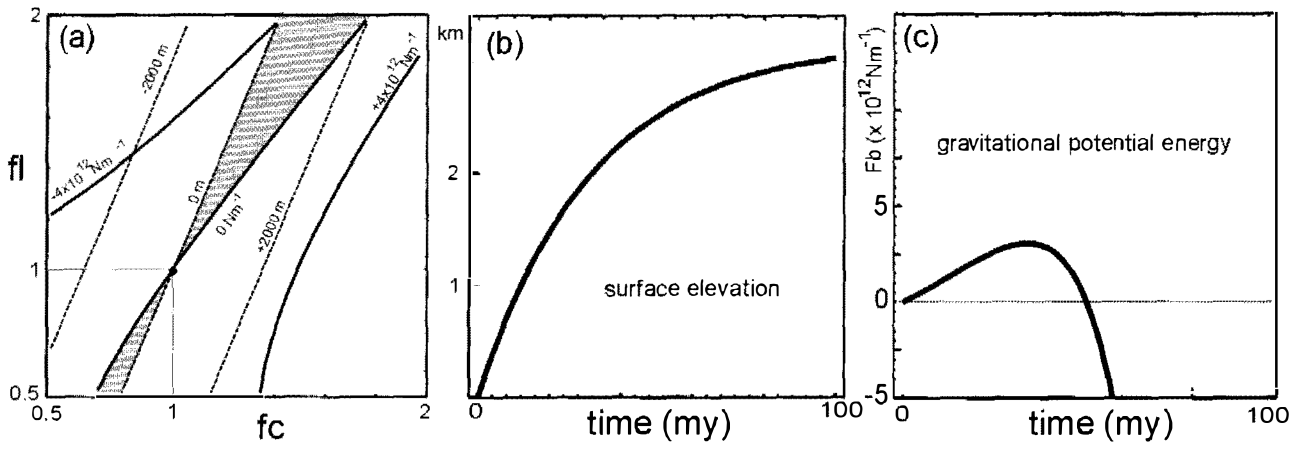

Fig. 1.: (a) The isostatically supported surface elevation (dahsed lines) and the lateral buoyance forces (continuous lines) in the fc-fl plane. *fc* is the thickening strain of the crust; *fl* is the thicekingin strain of the lithosphere, so that the region left and below *fc*=*fl*=1 indicates crustal and lithospheric thinning and the region above and to the right of *fc*=*fl*=1 indicates crustal and lithospheric thickening. the shaded region shows the region where topographic lows, for example sedimentary basins, have a higher gravitastional potential energy than their surroundings and thus extend towards them. (b) The surface elevation and (c) the potential energy (per unit area) of an orogen undergoing simultaneous thickening and erosion at the surface, both plotted as a function of time. The potential energy per unit area may also be interpreted as the horizontal buoyancy force, *Fb*, per meter length of orogen that acts against the tectonic driving force. As *Fb* increases on (b) up to about 20 my, the effective driving force decreases and deformation will wane. After 20 my the effective driving force increases again and a 2nd coaxial deformation phase may thus take place. In this model run, the crust is thickened by a factor of 2.2 and the total lithosphere is thickened by a factor of about 1.8 after 30 my. The difference arises from the thinning of the crust by erosion during the tectonic thickening. Much after 40 my the model becomes geologically unrealistic because of the great thickening factors that arise.