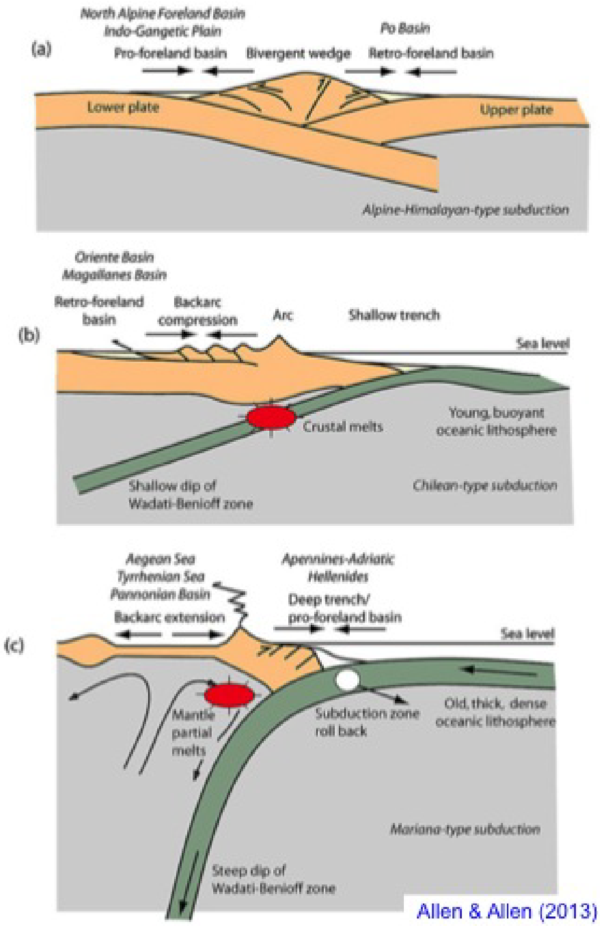
Foreland Basins

1. **Tectonic Settings**
2. **Main types of loads**
3. **From flexure to basins**
4. **A few examples**
5. **Foreland basin systems (DeCelles and Giles, 1996)**
6. **Foreland basin dynamics**



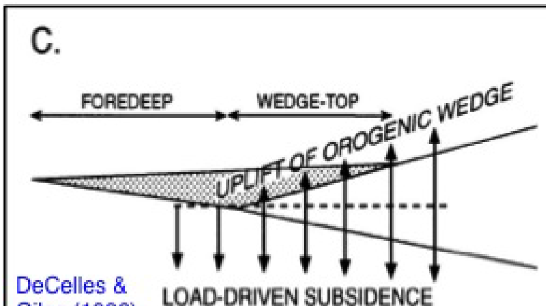
Allen & Allen (2013)

Fig. 4.1 Flexure at sites of plate convergence. Schematic illustration of (a) pairs of pro-foreland and retro-foreland basins at sites of continent–continent collision, as in the Alps; (b) retroforeland basins and ocean trenches at sites of ocean–continent convergence, as in the Andes (especially the Chilean transect) and Sevier belt of the USA, where subduction is or was shallow; and (c) pro-foreland basins and backarc extension related to subduction zone roll-back, as in the Aegean and Tyrrhenian seas, and steep subduction of the oceanic plate, as in the Marianas. Based partly on Uyeda & Kanamori (1979) and Stern (2002).

Types of Loads

1. **Topographic Load**
2. **Basin Fill Load**
3. **Subduction Load**
4. **Dynamic Slab Load**

… and competing effects of:
(i) load-driven subsidence
(ii) Uplift in orogenic wedge



DeCelles & Giles (1996)

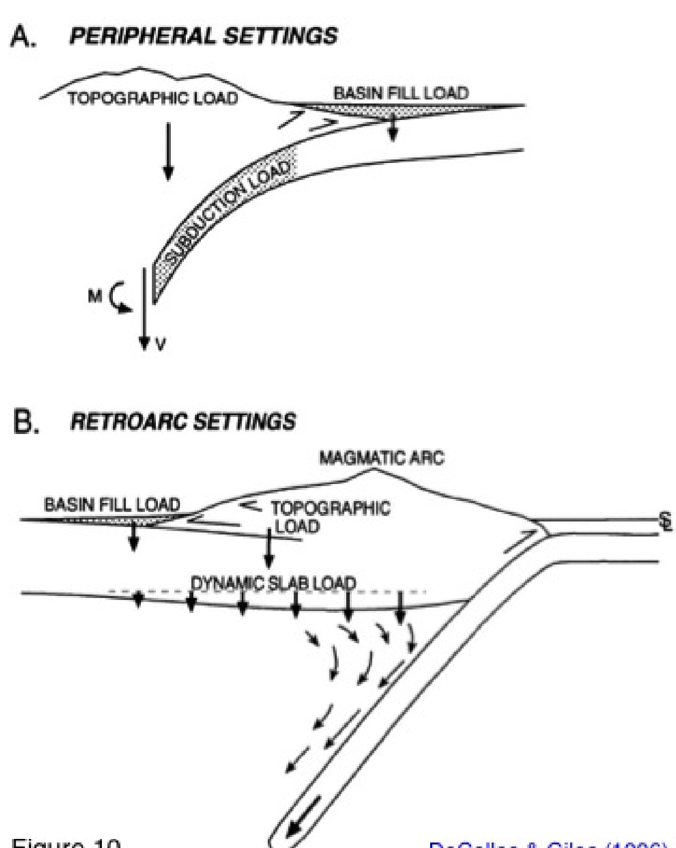


Figure 10

DeCelles & Giles (1996)

From Flexure to Basins

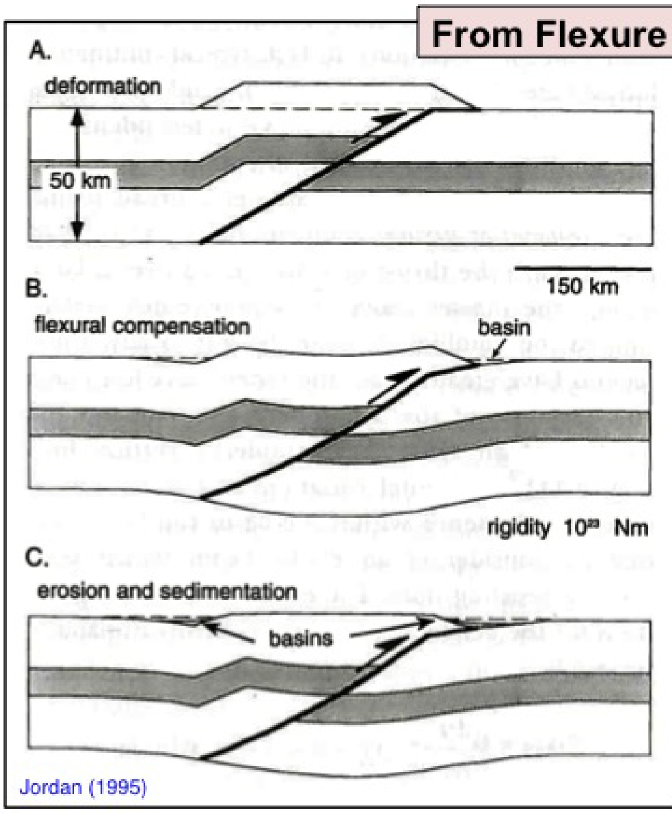


Fig. 9.3 Three conceptual steps in formation of sedimentary basins flanking a thrust belt (V.E. = 3X). (A) Shortening causes thickening above a ramp, acting as a load. (B) Regional compensation of the load deflects the lithosphere. (C) Surface processes strip material from the mountain range and transfer it to the flanking tectonic basins. Simplifies model treats thickening in an orogenic belt as the result of shortening along one master fault that penetrates the crust.

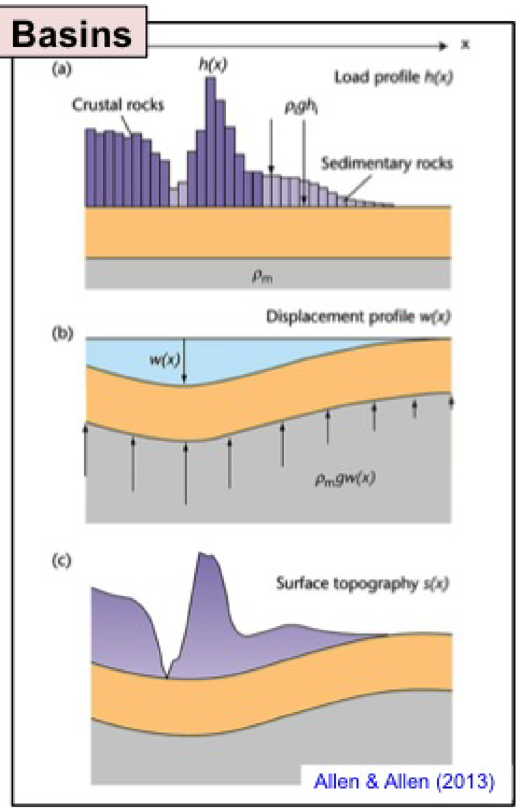


Fig. 4.10 Flexure under a distributed load. (a) The individual deflections caused by load blocks are solved analytically, and summed to give the displacement profile in (b). The distributed load then 'sinks' into this displacement profile to give the resultant topographic profile (c). Based on Jordan (1981), Cardozo & Jordan (2001) and Yong et al. (2003).

Apennine Foredeep Basin

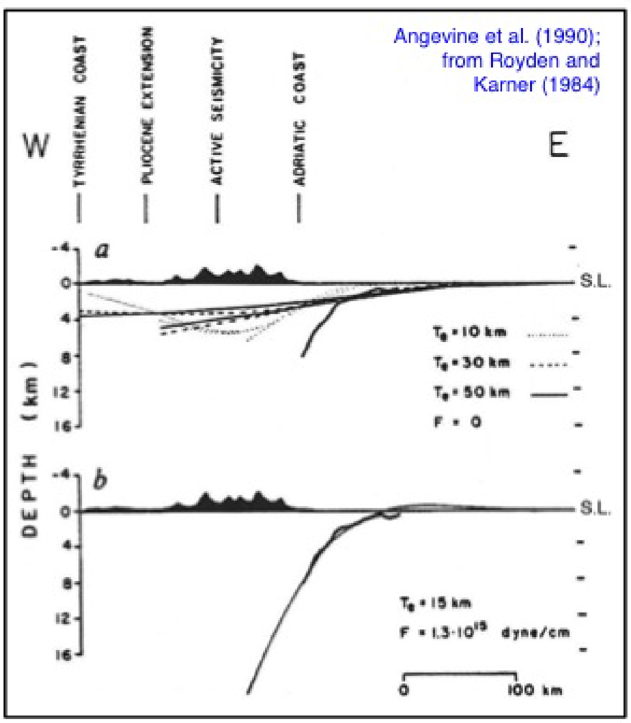


Figure 5.12 Deflection of a basal Pliocene horizon (heavy curve) in the Apennine foredeep basin (from Royden and Karner, 1984).
(A) The topographic load of the thrust belt is too small to explain the observed deflection. (B) A line load is applied at the end of a hypothesized broken plate, under the Apennines, to make the calculated (model) deflection match the observed deflection.

Himalayan Mts and Foredeep

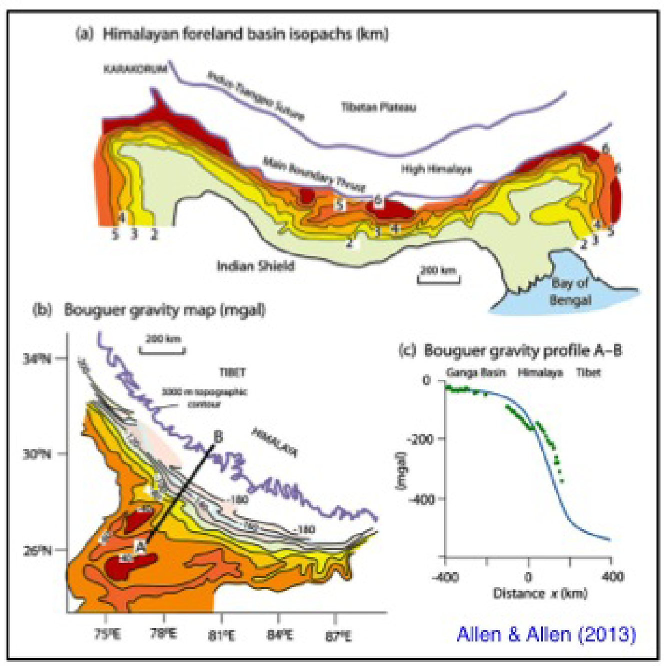
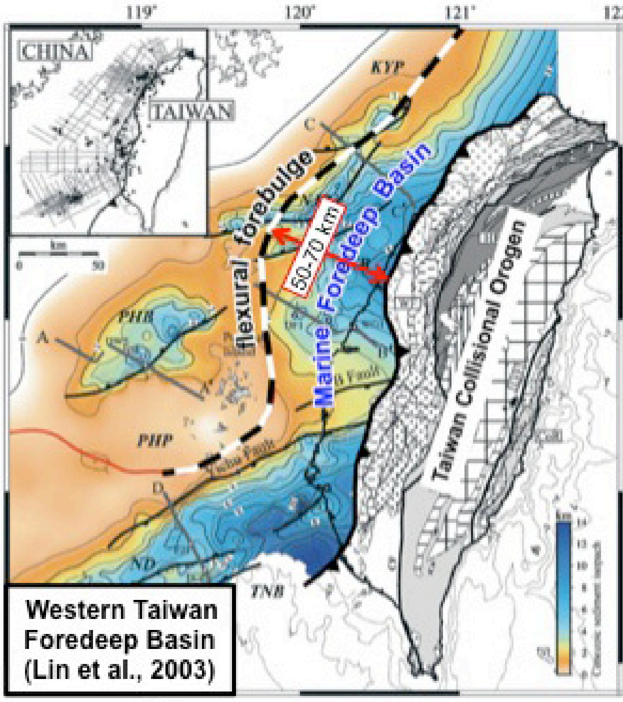
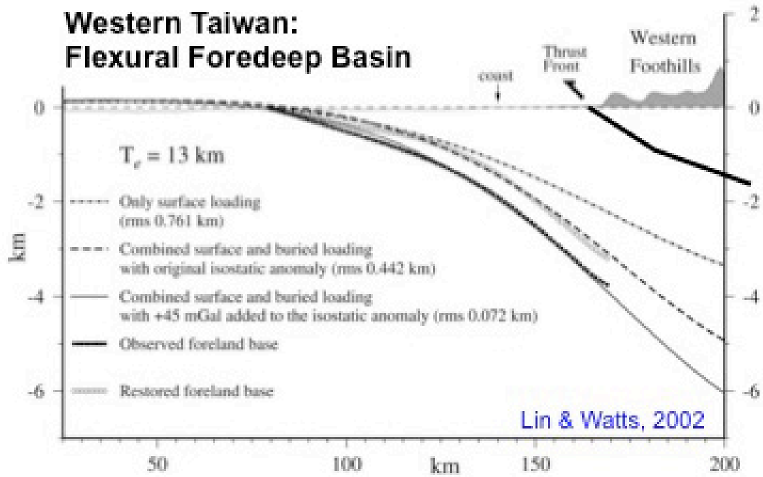


Fig. 4.6 The Himalaya and Ganga Basin.
(a) Isopach map of sediment thicknesses in the Himalayan foreland basin, based on Raiverman et al. (1983).
(b) Contours of Bouguer gravity anomaly over the Ganga Basin.
(c) Observed Bouguer gravity anomalies along profile A–B, compared with anomalies computed assuming topography is locally compensated (Airy model) by thickening crust beneath central India. There is an apparent mass excess in the Himalaya and mass deficit over the Ganga Basin (after Lyon-Caen & Molnar 1985).

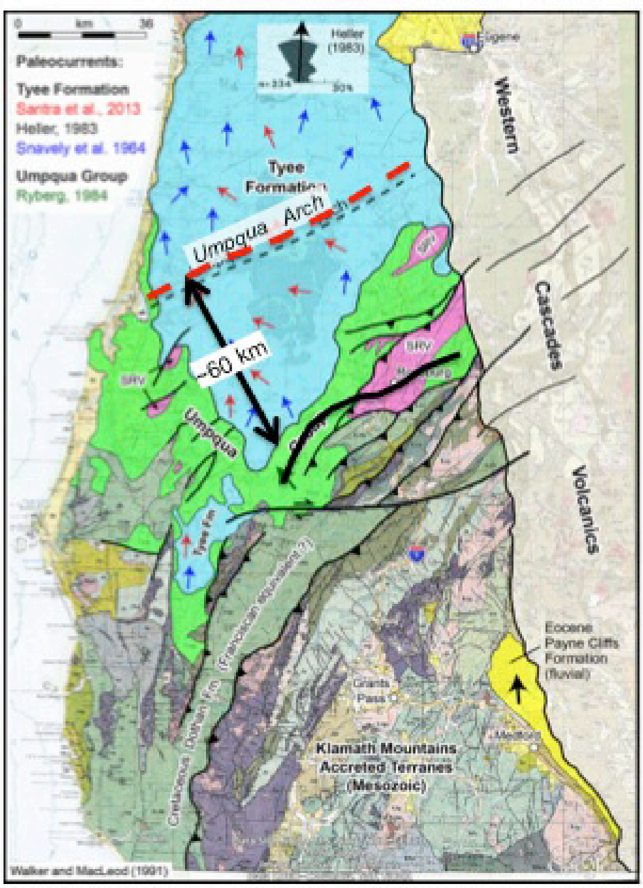
Western Taiwan: Modern Foreland Basin
Classic flexural profile



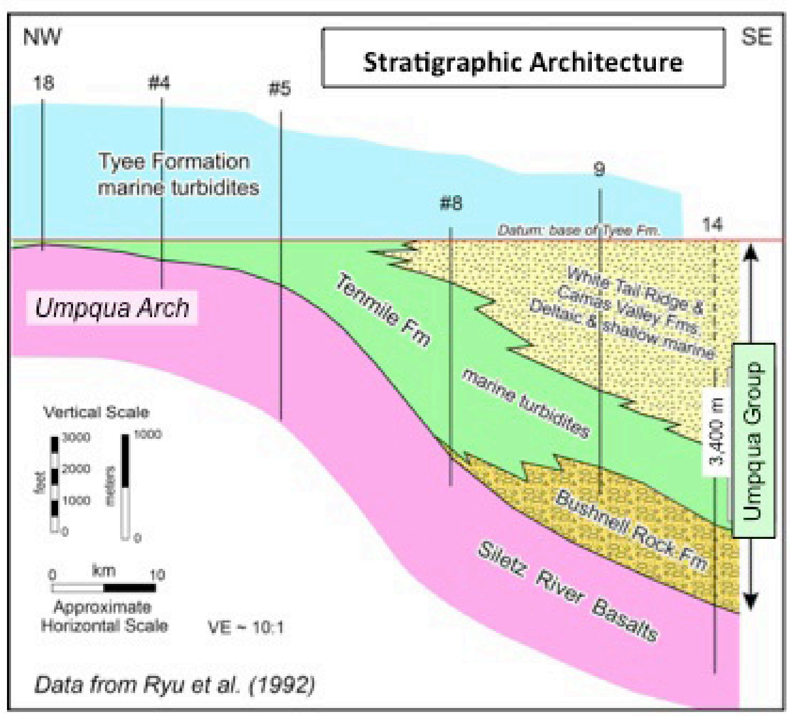


Taiwan Foredeep & Umpqua Basin have similar

- Scale (width, depth)
- Rate and duration (~ 5 Myrs)
- Genetic relation to thrust belt (flexural load)
- Basin migration, progressive thrusting

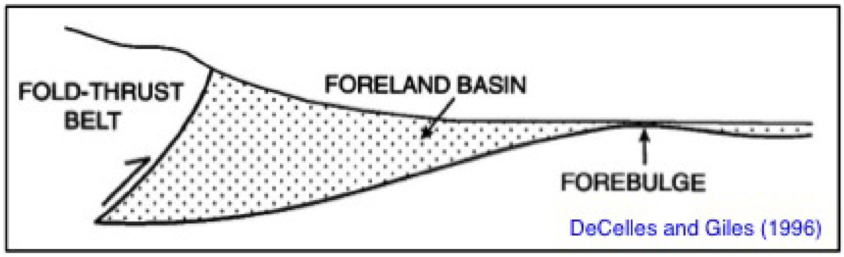


Umpqua Basin – Stratigraphy



Foreland Basin Systems

Traditional Concept of Foreland Basins have some significant issues.



- **Are they asymmetrical?**
- **Is sediment restricted to area of major flexural subsidence?**

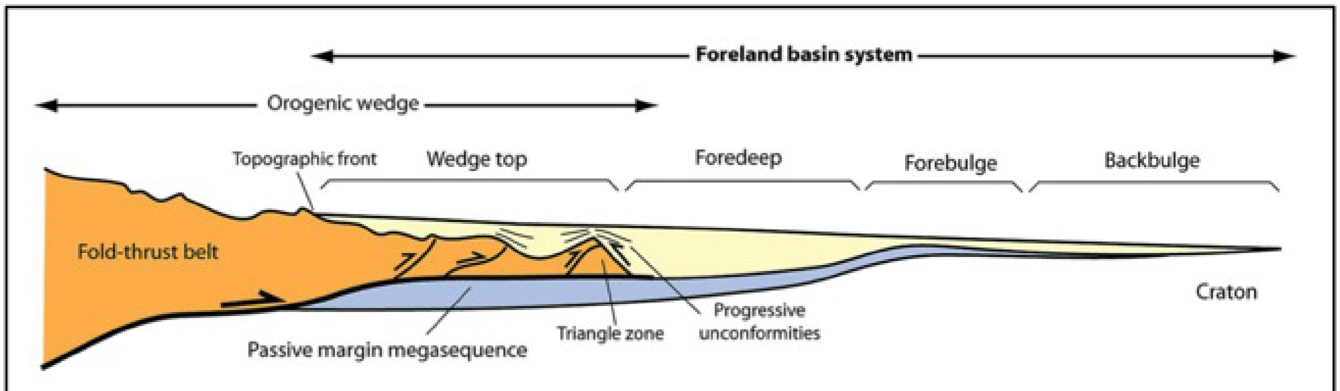


Fig. 4.35 The four depositional zones of a foreland basin system, as envisaged by DeCelles & Giles (1996). Reproduced with permission of John Wiley & Sons, Ltd.

Allen and Allen (2013); modified from DeCelles and Giles (1996)

Dynamics of the Wedge-Top Depozone

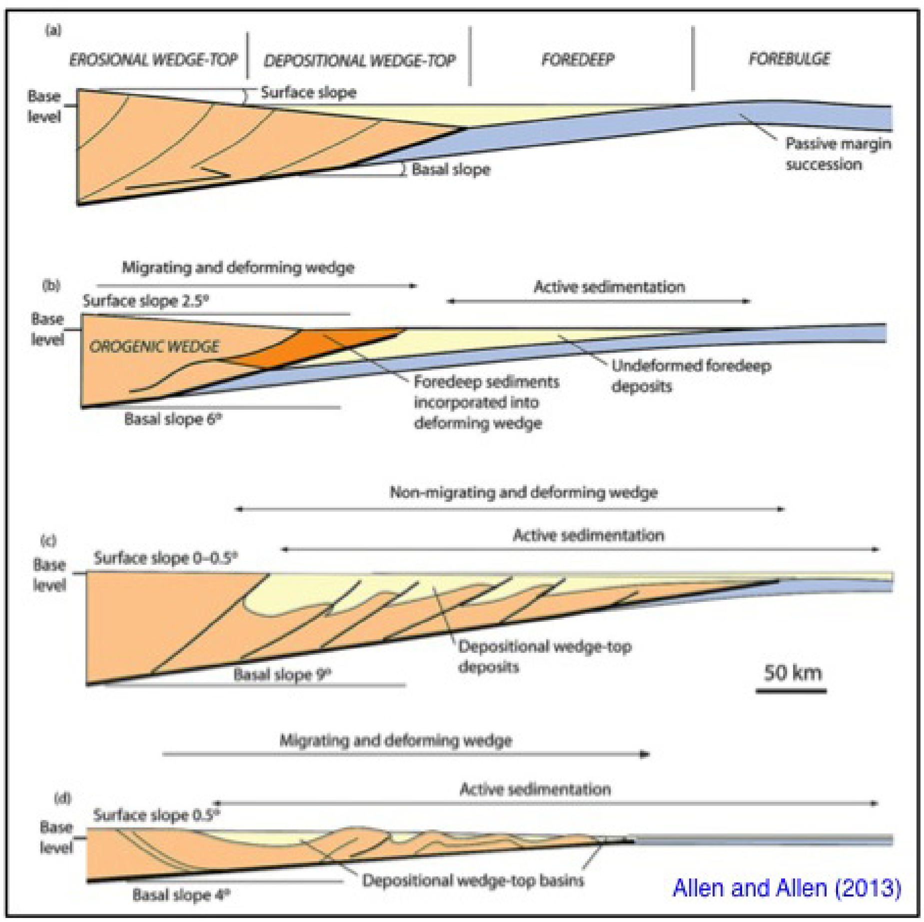


Fig. 4.25 Depositional versus erosional wedge tops, after Ford (2004). (a) The extent of the depositional and wedge-top zones depends on the geometry of the critically tapered wedge combined with the flexural response of the underlying lithosphere, resulting in a basal slope and a surface slope. (b) Basal slope of 6° and surface slope of 2.5°, showing an erosional wedge-top and depositional foredeep, with some foredeep sediment incorporated tectonically into the frontal part of the wedge. This situation may reflect a moderate basal strength of the wedge and a moderate flexural rigidity of the underlying plate. (c) Basal slope of 9° and surface slope of zero to 0.5°, with the wedge filling the deflection, and active sedimentation in wedge-top basins. This situation may reflect a weak underlying lithosphere. (d) Basal slope of 4° and surface slope of 0.5°, causing a narrow taper angle, with well-developed piggyback (wedge-top) basins within a deforming fold-thrust belt. The active sedimentation includes the deforming wedge and the foredeep. This situation characteristically results from the presence of a weak basal detachment comprising salt.

Foreland Basin Dynamics

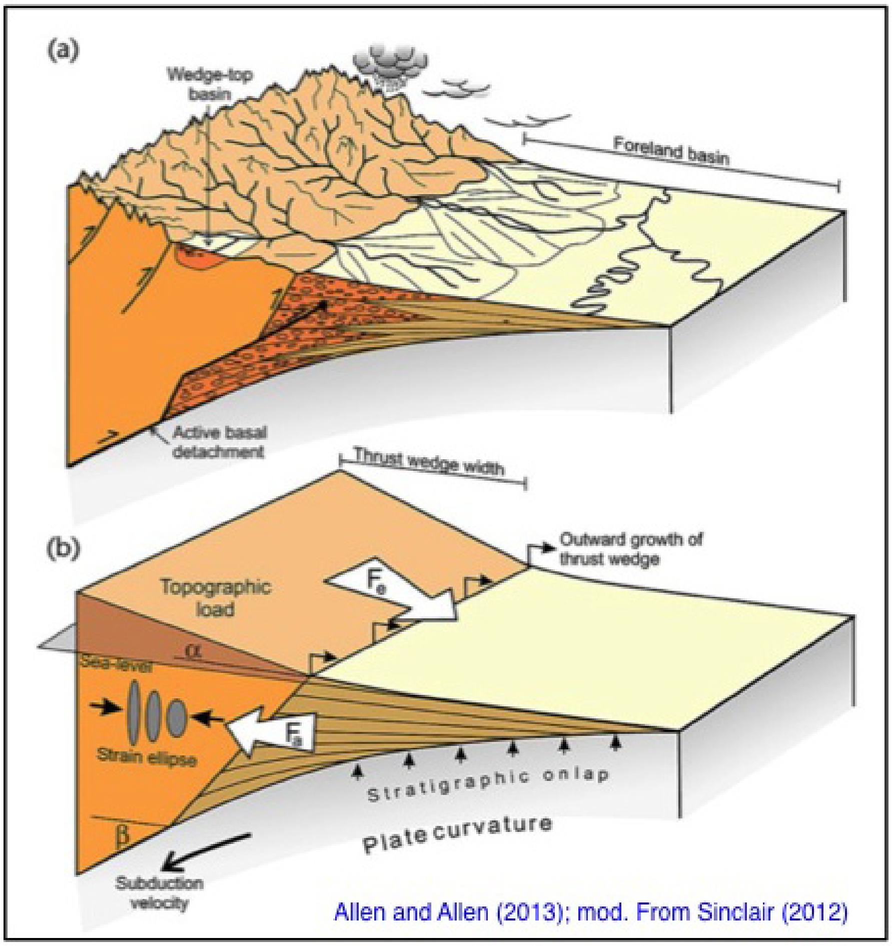


Fig. 4.27 Coupled thrust wedge/ foreland basin systems, from Sinclair (2012) and reproduced with permission of John Wiley & Sons, Ltd. (a) Geological and topographic characteristics showing thrust wedge with ramp-flat staircase geometry of basal detachment. (b) Quantifiable parameters include the erosional (**F**e) and tectonic (**F**a) accretionary fluxes, the mean surface slope of the wedge **α**, and the mean slope of the basal detachment **β**.

Migration of a flexural wave under a moving load system

Allen and Allen (2013)

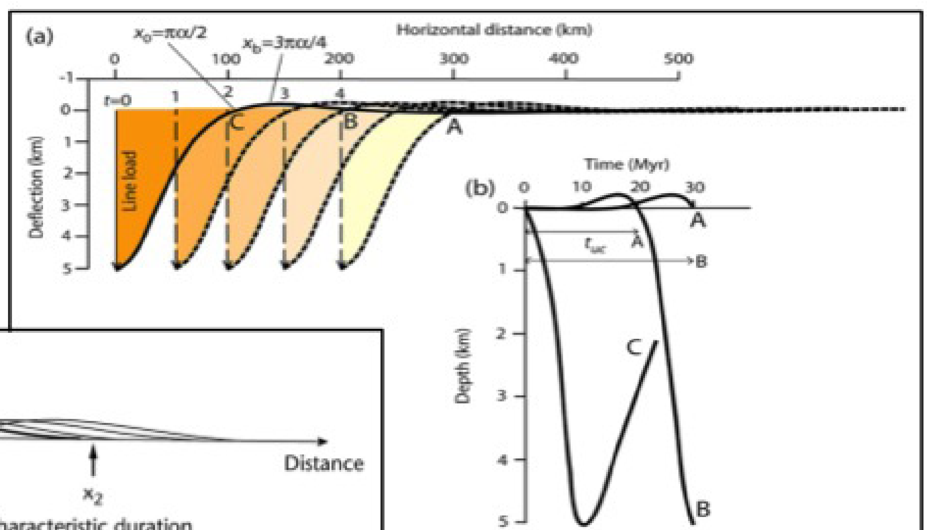


Fig. 4.50 Flexural profiles at times **t**1 to **t**4, to show duration of uplift in the flexural forebulge region, using a broken elastic plate.

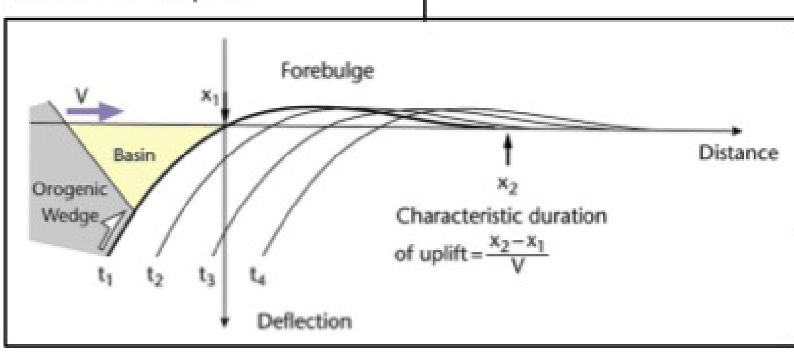
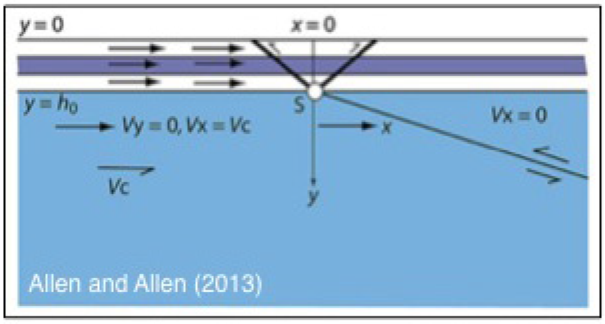


Fig. 4.34 Migration of a flexural wave under a moving load system. (a) Movement of the deflection across a foreland plate as a result of load migration. (b) Points A, B and C experience different subsidence histories depending on their initial location with respect to the load. Point A spends 30 Myr in a backbulge or forebulge position. Point B is initially uplifted in the forebulge, then subsides in the foreland basin. Point C experiences basin subsidence, followed by uplift as it is incorporated into the thrust wedge. **t**uc denotes the time spent in erosional region (duration of unconformity).



Above: Geodynamic model, showing crustal deformation focused at a point S, where mantle of the plate on the left, moving with a constant tangential velocity of convergence Vc, detaches and is underthrusted. Vx and Vy are the horizontal and vertical velocities respectively. Overlying crust has initial thickness h0 to the left of S. The tangential velocity to the right of S is zero. There is no stress on the upper surface. There is no requirement for a 'bulldozer' backstop in this geodynamic model. modified from Willett et al. (1993).

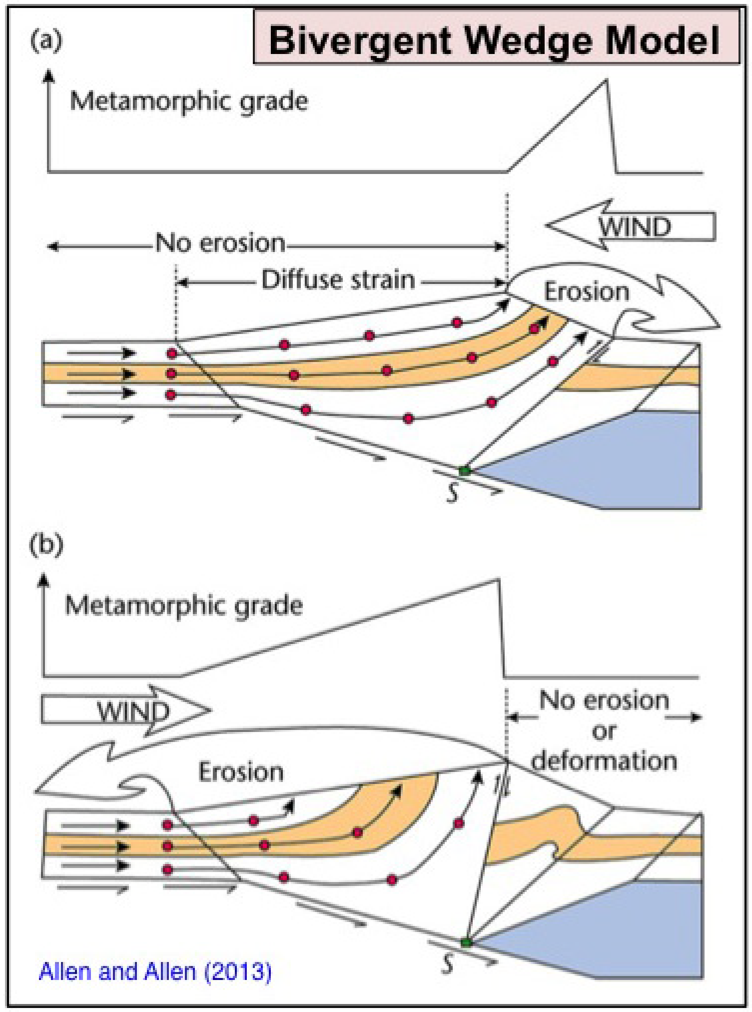
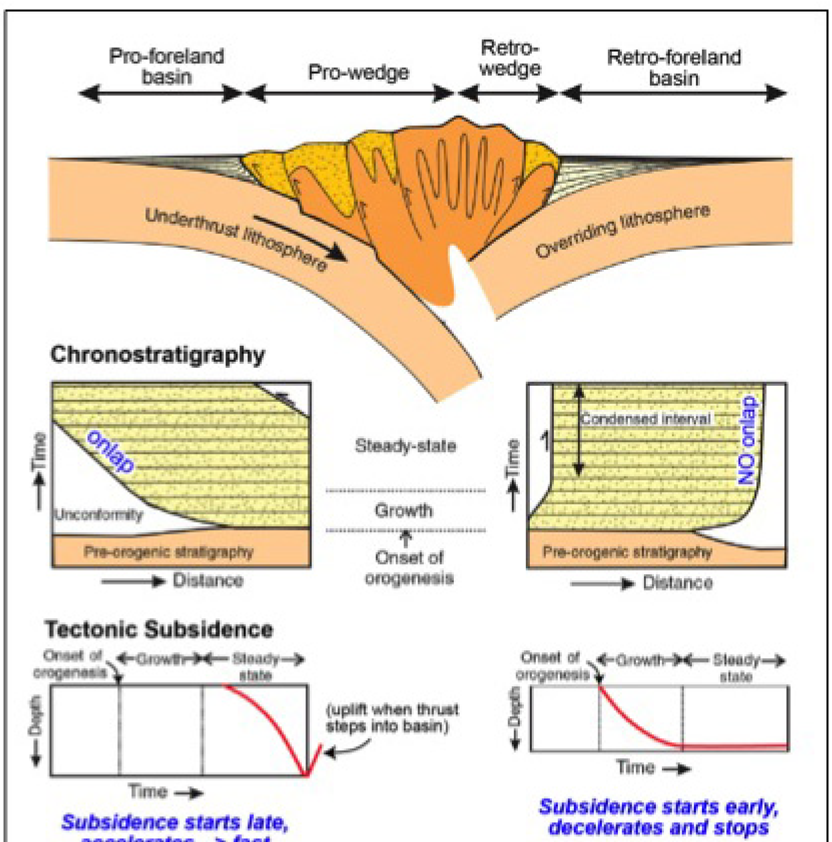


Fig. 4.28 (right) Effects of erosion on a bivergent wedge (Willett et al. 1993). Precipitation concentrated on the retro-wedge (a), and pro-wedge (b) increases erosion, causing an advection of high-grade metamorphic rocks from the middle and lower crust (and even mantle lithosphere) to the surface. Passive shaded layer shows middle crust. Lines are material trajectories, and dots show progressive equal-time positions of points originally aligned vertically.

Predictions of the Doubly-Vergent Wedge Model for *Sedimentary Basins*



Modified from Sinclair (2012)

Pro-foreland basin (flexural):

- ***Thrust belt migrates toward basin*** …
- Subsidence driven by subduction of plate beneath the orogen: starts slow, accelerates → fast.
- Abrupt change to uplift when basin is incorporated into the converging-migrating thrust belt.

Retro-foreland basin (flexural):

- ***Thrust belt does not migrate toward basin*** …
- Subsidence is slow because the only driver is intermittent growth of the retro-wedge.
- No uplift at end, not incorporated into thrust belt.

"Type examples include Taiwan, the European Alps, and the Pyrenees." (Sinclair, 2012)