a24 The work of rivers < base level >

> I come from haunts of coot and hern, / I make a sudden sally, / And sparkle out among the fern, / To bicker down a valley. ... And out again I curve and flow / To join the brimming river; / For men may come and men may go, / But I go on forever.
> —Alfred Lord Tennyson, *The Brook*, 1855.[1]

Following from Hutton's insights, the weathering and erosion of emergent land by rivers could be appreciated from the very bulk of known deltaic sediments. The same also provided tangible evidence for geologic time and added vastly to Henri Gautier's 1721 naïve thought to estimate Earth's age from river-turbidity (muddiness) given the yet "primordial relief" (*sic*) of the scenery.[2]

In 1802, John Playfair reasoned inductively from: the dendritic pattern of tributaries to main streams, the fit proportions of each stream to its valley, and the rarity at stream junctions of falls or damming, that the streams have sculpted the scenery by excavating from emergent land the valleys that they occupy. His argument, which reiterated elements of Hutton's theory, refutes the notion agreeable to catastrophists that cataclysmic renting upheavals formed the valleys and that the streams in them are secondary.[3] U-shaped valleys with underfit ("piddling") streams remained a puzzle until they became recognized (after ca. 1840)[4] as sculpted by Ice Age mountain glaciers (*see* Topic *b17*).

In 1846, Andrew Crombie Ramsay (1814-1891) used the principle of lateral continuity to show that where fold mountains have been, little remains in the scenery of their upturned structures apparent from geological cross sections (***Figure a24.1***).[5]

In 1859, early in the exploration of the American West, the naked of much concealing vegetation, spectacular, scenery spurred John Strong Newberry (1822-1892) to an understanding of sculpturing work of running water.[6] In 1862, Joseph Beete Jukes (1811-1869) showed how drainage systems and their development may be treated as geologic history.[7]

In 1875, John Wesley Powell reiterated geomorphology's paradigm: "We may consider the level of the sea to be a grand base-level, below which the dry [*sic*, ***Footnote a24.1***] (emergent) lands cannot be eroded ..." From his understanding that the Grand Canyon was the result of erosion by the Colorado River, Powell was able in 1876 to explain that the Green River gorge through the Uinta Mountains is not a rift feature but was eroded as the mountain range was *slowly* bowed up.[8] The river had maintained its course at *grade*. This latter is a state of dynamic equilibrium, described by **Grove Karl Gilbert (**1843-1918) in *Report on the Geology of the Henry Mountains*, 1877, when neither erosion of the bed nor deposition of sediment is the net effect of the flowing water. According to Gilbert all streams work rapidly toward, and then maintain, a graded condition. Thus, it should not be surprising that major rivers commonly flow in valleys cut across, rather than are diverted around, mountain ranges that have risen across their courses.[9] Thereafter, many including Clarence Edward Dutton (1841-1912), understood that rivers entering the sea will grade their valleys to sealevel.[10] And to what end result? William Morris Davis in 1899 stated that "penultimate denudation" will approach sealevel. That this condition can end, not necessarily by the agency of fold mountain building, but by epeirogenic uparching or by fault block uplift, was recognized by Davis in his study of the Great Plains of eastern Montana. Any land when elevated and subject to normal sub-aerial erosion will proceed if not further disturbed, through several distinct stages of scenery:[11]

Youth when rivers are with steep slope and flow in gorges between which the upland can be flat and little affected.

Middle age when the land is mostly hillslope and trunk rivers are in grade.

Old age is a peneplain (almost a plain) when interfluves are appreciably gone and river tributaries and trunks meander. (Rejuvenation to youth requires only uplift.)

In his study of the Appalachians, Davis recognized that the scenery is not everywhere at the same stage. He failed to explain how peneplains at different elevations can persist separated by escarpments and nickpoints (waterfalls and rapids) on stream courses. Walther Penck (1888-1923) in 1922 antagonistic to Davisian image (based, in the absence of documented empirical evidence, on desire) of landscapes aging by interfluve down-wasting and lessening hillslope, made much of the fact that Earth's surface is mainly successive benches. The phenomenon is inferred from the universal back-wasting of slopes in which an exposed steep to vertical face of a rock formation, and debris slope at its foot, must waste back through successive positions, all parallel to their initial positions, to leave, bearing witness, a resultant near-horizontal rock pediment (***Figure a24.2***).[12] Priority for this process is afforded to Osmond Fisher (1817-1914) who published it in 1866.[13] As a caution, empirical proof of the generality of parallel slope retreat has yet to persuade its critics. However, Lester Charles King in 1947 offered the hypothesis that backwasting scarps parallel-retreat at their levels and so scarp-edged plains one above another are not contemporaneous. In support, he marshaled evidence that flat uplands have not, since they were formed, been erosionally lowered, and are not now being lowered. The evidence for this is that these different levels have sceneries that bare, and so record, the imprint of climates different from today. For these existing old-age surfaces that act as base levels for fluvial erosion graded to them he employed the name *pediplane*[14] (a term originally coined by John H. Maxson and George H. Anderson in 1935 for a plain of coalesced pediments).[15] A compromise modern hypothesis of parallel-hillslope retreat is that, where it is found, the evident equilibrium is tied to the rock type, climate and rock structure of the locale.

Processes that sculpt the scenery (geomorphological processes), vary in nature and rate. Descriptive speculation as to landscape evolution (qualitative models of) was exciting and productive for many years after Hutton had shown that the landscape is not primordial. Wonderment led to much description. Qualitative assessment as to rates of geomorphic processes and speculative models soon, however, led to controversy. Finding little to resolve the bewildering questions that arose, geomorphology became merely, and safely, descriptive. No more!

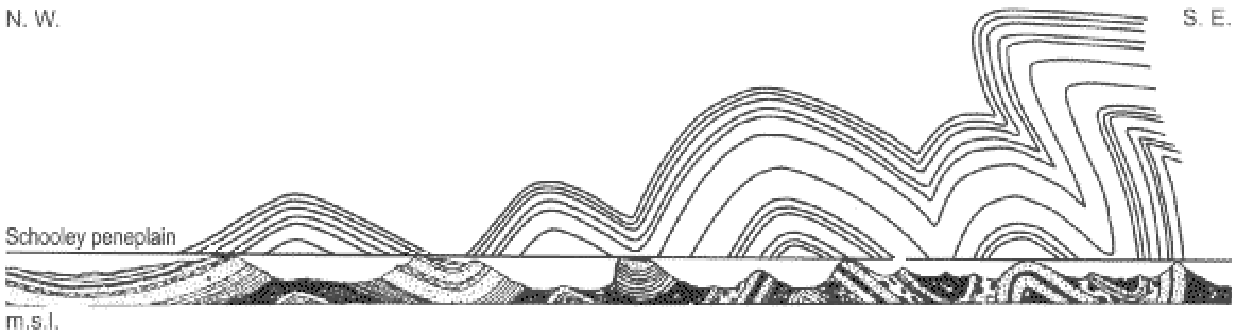
Beginning in the 1950s, a de facto requirement of geomorphic research became the measurement of geomorphic process rates and interactions. Landscape evolution is replaced with landscape histories, which emphasize the uniqueness of landscapes. Quantitative models, as reviewed by Andrew Goudie in 1995, allow for simulation, prediction, and testing.[16]

Water tank experiments performed by R. S. Parker in 1979 under the guidance of Stanley A. Schumm have shown that the erosional response to a lowering of base level is a wave of dissection that travels inland fronted by nickpoints. Significantly, as nickpoints migrate upstream, the drainage area above remains unaffected by the base-level change that initiated them. On valley slopes steeper than 31 degrees from the horizontal, loose material is subject to slumping.[17]

Most recently, remarkable information (such as public-domain data on the Digital Chart of the World)[18] and techniques have returned to geomorphology the excitement that the pioneer geologists must have felt when they realized that the landscape was dynamic and, in principle, understandable. ❑

Footnote a24.1 L. *sic* for "thus" expresses the sentiment: "Alas, dear reader, this is what was said."[19]

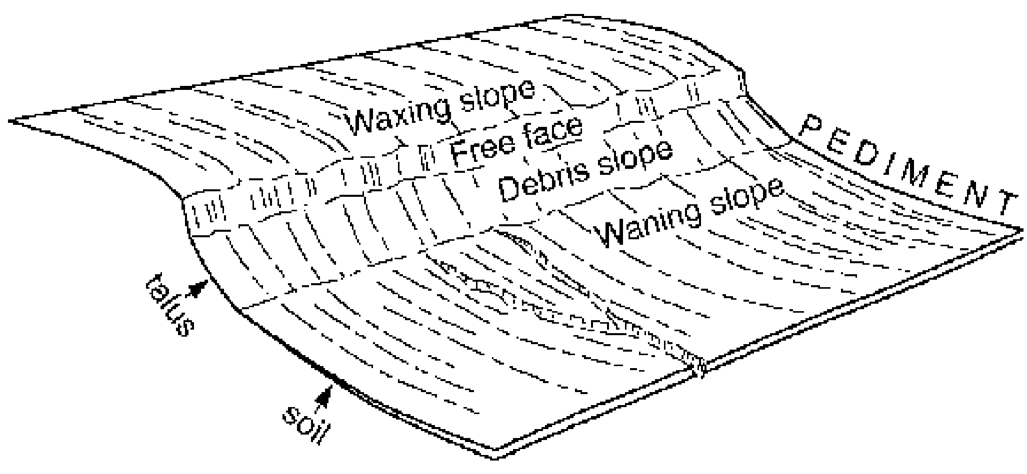
Figure a24.1 [20] One of the first accurate cross sections of a mountain range was published in the *Transactions of American Geologists and Naturalists* for 1840-42. Part of the section by Henry Darwin Rogers (1808-1866) and William Barton Rogers (1804-1882) across the Ridge and Valley Province is reproduced here. In the present scenery, mountain crests between wide valleys accord to an almost horizontal surface. Regionally, this surface, called the *Schooley peneplain*, has the



shape of a broad uparch. The present "middle age" scenery is the result of erosion of the elevated Schooley peneplain. Exposures of the geology reveal a succession of distinctive formations. The present scenery, as Andrew Crombie Ramsay in 1846 called attention to, is clearly not the result of the deformation that produced these folds.[21] Note how in the present scenery, great valleys are where there are up-folds (anticlines) and the mountain ridges between are where there are down-folds (synclines). However when these folds were formed there must have been mountains. These former fold mountains are reconstructed here by using the principle of lateral continuity. The folds so produced indicate that the presently existing Appalachians would have been dwarfed by the ancient Appalachians. However, their incredible height, shown in this reconstruction, would, at the surface, have been kept less by collapse and erosion. In Fortey's poetic words writing of like in the Swiss Alps:

> Geological maps showed that one limb of a massive fold might connect the base of one mountain with the top of the next: interconnecting strata had been eroded away. In cross sections, the "air" became full of dotted lines showing where strata had once passed, only to be removed grain by grain as a result of the operation over millennia of frost and water and wind. Ghosts of vanished mountains could be inferred, faint spectres of topography past imagined.[22]

Figure a24.2 **Elements of hillslope** according to Lester Charles King that indicate pediplanation (parallel slope retreat).[23]



Developed by sheetwash in an arid or semiarid region, a pediment is a broad, gently inclined, waning slope or is a level plain of low relief. The rock floor of the pediment is at most covered by thin soil and following rain it may be left bare or be mantled with a thin and discontinuous veneer of upland-derived colluvium in transit across its surface. As an element of a hillslope, the longitudinal profile of a pediment is normally slightly concave upward, and its outward form may resemble a bajada (a depositional feature) which continues the downslope inclination of a pediment (an erosional feature).