

j20 Geosynclinal theory < Hall, Dana, Stille, Kay >

... every quarter of a century presents our science in so different a phase that a *new reconciliation* [with Scripture] is required.
—James Hall, 1882.¹

Great thicknesses of sediments are typical of continental margins. These and their holding trough that as a unit is destined to be, is being, or was folded orogenically, is called a *geosyncline* (**Figure j20.1**). Hans Stille in 1940 called the continentward part of a geosyncline with shallow-water quartz-carbonate facies sediments, a *miogeosyncline* (less of a geosyncline), and the oceanward part of a geosyncline with deepwater-turbidite sediments and volcanics, a *eugeosyncline* (more of a geosyncline).² Plate tectonic terms (not used in the below) for the three forgoing terms are respectively: *orogenic belt* (if young) or *mobile belt* (if ancient), *miogeocline*, and *eugeocline*.³

The development of seismic imaging techniques, and deep drilling, has recently given us a picture of the extent, structure, and composition, of geosynclines. Historically, such sediment-filled linear troughs were only available for study where fold mountain building has deformed them so that formerly deeply buried strata, where raised above sealevel, have been exposed by erosion. By measuring thicknesses of erosionally truncated strata, and by unfolding the folds, and reversing the fault displacements, the dimensions of former geosynclines can be reconstructed. For an entire fold mountain range, this work was first successfully completed in eastern North America.

In 1857,⁴ James Hall (1811-1898) as director of the New York State Geological Survey was able to report to the AAAS (the triple-A S, or the American Association for the Advancement of Science, then an exclusively geological society) on the prior-to-deformation stratigraphy of the ancestral (Paleozoic) Appalachian Mountains.⁵ Of great interest was that the sediments 1) had filled a borderland trough and 2) had all accumulated in shallow water. That is, filling sediments had kept the trough full, as fast as it had sunk. Hall proposed that fill-weight caused trough-subsidence. In Hall's model, the weight of accumulating strata causes subsidence of the trough as do dishes added to a diner plate-dispenser (its spring keeps the top plate always at the same level). Explained is how each stratum in the trough accumulated in shallow water. But the analogy ends there, as the lower plates can only rise up if the overlying plates are removed. Mountain building implies a rise of a stack of strata that is not due to unloading. The reverse of loading should also provide for fold-thickening of the block that becomes the mountain. At the time, **James Dwight Dana** (1813-1895) quipped: "Hall has given us a mechanism for the origin of mountains with the origin of mountains left out."⁶ Nevertheless, a consistent finding was that great fold mountains have only formed where great thicknesses of sediments have accumulated.



In 1873, Dana with reference to the Uinta mountains of Wyoming and Utah, conjectured that Earth's crust on a cooling and so shrinking interior, will, in response to horizontal compression, elastically originate and grow "ge-anticlinals" (arches) that shed eroded sediments, and "geo-synclinals" (troughs) that receive these as fill into shallow water until their older accumulated strata (pressured lithostatically by deep burial, weakened by entering Earth's heat, and yielding plastically to inward squeezing) fold, thicken vertically and raise a mountain range with "synclorium" roots.⁷ His mechanism was inadequate to account either for the great distance of crustal shortening that can be measured for the folds or for their overfolding always being directed toward the continental interior. In 1889, Clarence Edward Dutton (1841-1912), in his turn, quipped: "It is an explanation which explains nothing which we want to explain." Dutton then added sophistication to Hall's idea by arguing for a teeter-totter continental margin. Gravity measurements, which had revealed an inclination of the plumb-line toward the ocean, indicated that

the ocean-floor crust was denser than continental crust. The asymmetry in elevations at the continental margin was thus primary, but it could not be stable if rock over long periods of time has no strength (as is true). The equilibrium figure of a yielding (weak) Earth is a smooth spheroid of rotation. For this condition, “to which gravitation tends to reduce a planetary body irrespective of whether it is homogeneous or not, I [Dutton] propose the name isostasy.” At the margin of the continent, erosion and transportation of sediments will shift loads so that, over great lengths of time, tens of thousands of feet of shallow water sediment can accumulate oceanward of a rising interior.⁸ Paraphrasing Dutton: “The continentward direction of overfolding that terminates deposition is enacted by the sideways push of the denser oceanic crust.” How so is not clear, but the mind set of the time was attuned to Thomas Chrowder Chamberlin’s planetesimal theory. This postulated a gravitationally shrinking globe comprised of solid wedge-shaped blocks, the less dense of which, maintaining isostasy, must always protrude (the continents) above the upper level of the heavier (the ocean basins). Erosion transfers mass from continent to the ocean-basin edge (continental shelf) and, as a consequence, there is landward encroachment of the sea. Global shrinkage and episodic adjustment to maintain isostasy, fed into to the idea of worldwide unconformities as a basis for correlation.

The origin of fold mountains remained a problem of great interest for which there was no solution until the development of plate-tectonic theory and exemplars of its use were given, as by John F. Dewey with John M. Bird in 1970.⁹ Before, fold mountains of various ages were studied and the Alps, although hard to investigate because they *are* geologically young and rugged, had become the focus for study. The role of metamorphism and the ways it changes the appearance of rocks, became better understood. Envisaged was that great thicknesses of sediments that have become folded, invariably include belts that accumulated deepwater-marine sediments *and* great amounts of volcanic rocks in what is now called an “orogenic belt” if active, and (oxymoronically) a “mobile belt” if ancient and no longer active. A craton is a long-term stable part of a continent that does not become deformed when, marginal to it, a geosyncline forms. The craton’s existence is provable where mature quartz-sand formations in the miogeosyncline can be traced into platform sediments on it. However, in the absence of preserved adjacent platform sediments as a result of erosion or, in the plate tectonic model, because the once craton has become separated, the presence of quartzose clastic sediments in the miogeosyncline is sufficient for the inference of a craton as their source.

In 1947,¹⁰ George Marshall Kay (1904-1975) was able to reinterpret the ancestral (Early Paleozoic) Appalachian fold mountains as a geosyncline having an inner miogeosynclinal part that, as in the classic description of geosyncline by Hall in 1859,¹¹ accumulated on the continental shelf, and an outer eugeosynclinal part that accumulated on the deepsea floor. The nonvolcanic, shallow-water sediments of the Appalachian fold mountains is the miogeosyncline. The highly altered metamorphics of New England and the Appalachian Piedmont is the eugeosyncline. In 1951, he interpreted the eugeosyncline rocks as being volcanics of island-arc volcanoes and graywackes derived from them.¹² The paleogeography of the geosyncline marginal to “ancient North America,” which he reconstructed (**Figure j20.2A**), was in accordance to the (false) principle of the fixity of the continents.



Gerald M. (Gerry) Friedman relates this anecdote, recalling 1953: “Two hours were spent discussing sedimentation patterns in geosynclines. I tried to steer questioning into other areas of stratigraphy. To my shock all three colleagues [John L. Rich, Gordon Rittenhouse, and Kenneth E. Caster] protested and contended almost at a high-pitched decibel level, that only geosynclines really mattered. Almost to the closing bell, the examination [of University of Cincinnati Ph.D. candidate Lawrence H. Lattman] proceeded with elaboration on the geosyncline. ... Now, it is surprising in terms of historical analysis of ideas that the term geosyncline is not even listed in the subject index of current textbooks of stratigraphy and basin analysis.”¹³

Kay's *Geological Magazine*, 1967, offering was to be the last gasp for the origin of mountain belts interpreted by deterministic concepts of geosynclines and tectonic cycles.¹⁴ Plate tectonics allows for a far more complete interpretation of continental margin sedimentation and orogenesis in terms of continental fragmentations, driftings, and collisions. The North American craton and bordering Paleozoic geosynclines now brings to view the paleogeography of Laurentia (**Figure j20.2B**).

Cordilleran eugeosynclinal rocks recognized by Colin Hayter Crickmay in 1931 to be deep ocean basin deposits, and volcanic archipelagos,¹⁵ were recognized by Warren Bell Hamilton in 1969 to be fragments of magmatic island arcs conveyed to the continent margin by "underflow of Pacific mantle" (after 1970, this would have been worded: "subduction of the Pacific plate") beneath western North America.¹⁶ The timing, since its Middle Jurassic onset, is recorded by magmatic activity, basin-fill sedimentation (change to nonmarine deposits from marine), deformation, and metamorphism.

Cordilleran miogeosynclinal strata recognized by Dietz in 1963 to be continental shelf and slope deposits, now interpreted in "actualistic" terms as collapsed slope and rise deposits, were thickened in the orogenic phase by compression and thin-skin detachment (sheetlike-blocks thrust faulted over continental basement) tectonics.¹⁷ □

Figure j20.1 Cross section of Eastern North America showing the greatly different craton and geosyncline thicknesses of sedimentary formations.

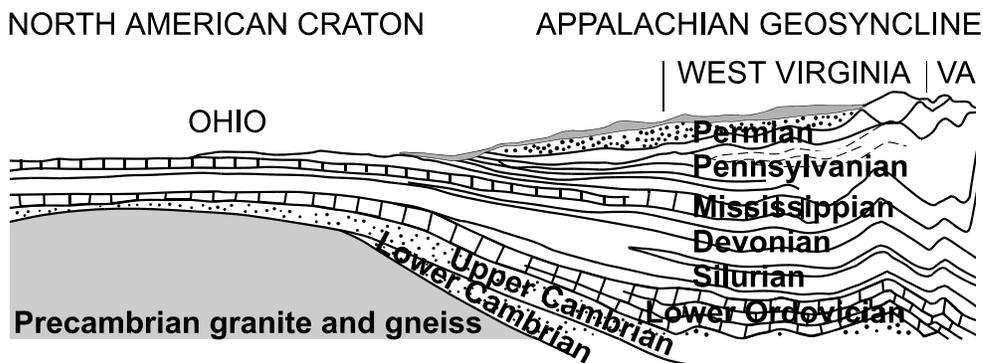


Figure j20.2 Paleofacies maps of during the Early Ordovician Period of:

(A) North America as reconstructed by M. Kay who in 1951 assumed the fixity of continents principle to be true.¹⁸

(B) Laurentia reconstructed in accordance with plate tectonics theory and paleomagnetic information.

