j24 Cycles of sedimentation < time-transgressive; foredeep, craton >

"The seas go in and the seas go out." —an old saw expressing boredom with historical geology.

In plate tectonic theory, on a continent 1) geosynclinal sediments accumulate marginally during i) a passive phase when seaward of its margin is only an oceanic ridge, ii) during an active phase when subduction is to beneath its margin and tectonism creates a foredeep, and iii) when its margin has arrived at place of subduction and tectonism creates a mountain that sheds detrital sediments cratonward, and 2) platform sediments accumulate interiorly on the craton in cycles of sedimentation that are relatable to two independent causes: i) epeiric changes in sealevel, and ii) epeirogenic platform flexings.[1]

Cycles due to epeiric changes in sealevel, preserved in Phanerozoic platform sediments in North America, are evidenced by six major, unconformity bounded stratigraphic-time units, called *sequences* by Laurence Louis (Larry) Sloss (1913-1996).[2] He named these, in 1963, (from youngest to oldest) *Zuni*, *Tejas*, *Absaroka*, *Kaskaskia*, *Tippecanoe*, and *Sauk* (***Figure j24.1***).[3] Sloss formulated his idea of sequences when the idea of seafloor spreading had become acceptable but before the plate tectonic reality of continents milling about had become known. However, the Zuni and the Tejas can be traced into the Gulf and eastern miogeoclines of North America. In western North America, the Absaroka is traceable into a preserved part of the miogeocline of Southern Laurasia. In eastern North America, the Kaskaskian is traceable into a preserved part of the miogeocline of ORS. In eastern and western United States, the Tippecanoe and Sauk are traceable into preserved parts of Laurentia.

In 1976, Sloss and others by comparing sequences from several cratons (***Figure j24.2***), found that epeiric sea (the Zuni in this 1976 study subsumes the Tejas) transgressions and regressions recorded are sufficiently synchronous so that worldwide (eustatic) change of sealevel can be distinguished from more local and asynchronous tectonic flexing of cratons. Most of long term (100 My) eustatic change of sealevel can in theory be related to rates of seafloor spreading (which determines the width and slope of oceanic rise-ridge systems). An orogeny in the geosyncline is recorded by a tectontic cycle of deposition (***Figure j24.3***) which is the accumulation (instead of limestone and quartz-sandstone shelf and platform sediments) of a thick wedge of detrital sediments (molasse on top of flysh) that filled the orogenic-belt miogeocline and spilled out the while onto the craton platform.

Sloss' platform sequences [4] extend into Phanerozoic passive-margin sediments. In these, around the world, **Peter R. Vail** with others at Exxon Research during the 1970s was able to describe "packages" of beds that occur as superimposed orders of sedimentary depositional cyclicities (delimited by seismic reflectors) with duration ranges of 20,000 years to 150 million years (***Figure j24.4***). The seismic reflectors, called "unconformities," are time lines and, physically, are fines (and sometimes oil traps): Episodic sedimentation is because deposition takes place in the foredeep when sealevel falls and the platform is eroded. The initial response is a flood of sediments shifted to the foredeep from nearby shelf and then a fall off as the local nearby sources are exhausted and the arriving sediments are in their bulk from increasingly far away. Rising sealevel lessens the rate of foredeep accumulation even more and at high stand of flooding, sedimentation almost ends resulting in a seismic reflector ("unconformity") of fines (upon relocated, formerly shelf accumulated, sediments).[5] Vail curves illustrate eustatic rise and fall of sealevel recorded by foredeep sediments and "unconformities." A 'Vail' curve is a proxy for a sinusoidal change in sealevel. Its strange (until you think about it) shape is because the response of system of sediment shedding (as recorded by sediment accumulation in the offshore) is strongly nonlinear with respect to sealevel change.

The analyses of seismic images of sediment "packages" that Vail and other oil geologists pioneered in the 1980s is enhanced by outcrop, core, and well-log studies.[6] The anally-retentive discipline that has emerged is called *sequence stratigraphy* defined as, "the study of genetically related facies within a framework of chronostratigraphically significant surfaces."[7] In it, the unit of interest is the *parasequence* which is a conformable, vertically changing, succession of beds and bedsets (for which, laterally, Walther's Law holds) bounded above and below by "marine flooding surfaces" and their correlative surfaces. (Don't ask.) A *bed* records an event distinctive in depositional features as currents, waves, tides, combined flow, bioturbation, trace fossils, etc. A *bedset* is a bounded group of identical beds that record a set of depositional processes in an environment. A *facies* is a named bedset.[8]

Experimental stratigraphy investigates how patterns of sedimentation can be the result of sedimentary processes involving four independent variables: sealevel, subsidence (rate and distribution), sediment supply, and transport system efficiency (that varies with, such as, water supply of rivers, wave action, climate control, and tidal range).[9] ❑

Figure j24.1 [10] **Cycles of deposition on what is now the North American craton.**

... each [cratonic sequence] is unified by individualized tectonic modes and geographies and by idiosyncratic petrologies. That is why, for example, experienced stratigraphic folklorists can visit anybody's craton, stop at a road cut, and say 'this is Cambrian' or 'this is almost certainly Cretaceous' without benefit of body fossils or a mass spectrometer. What is going on? —Larry L. Sloss, 1984.[11]

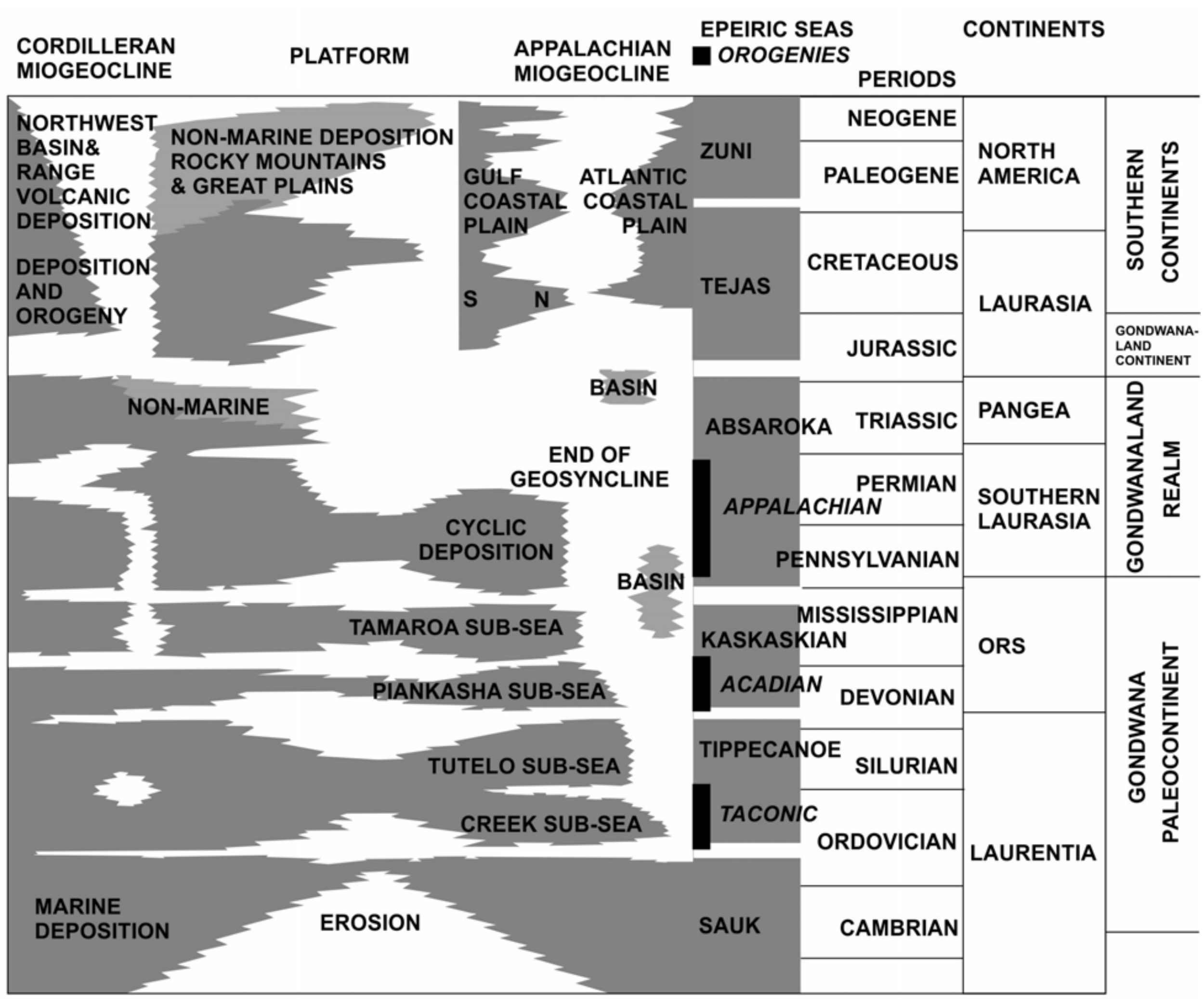

Figure j24.2 [12] Sedimentary accumulations on three separate cratons expressed as area (width of horizontal line, at any time, for all) of preservation. In spite of local structural warping that will have affected the individual patterns, the cumulative record of transgressive and regressive events on these cratons evidence worldwide sealevel changes. Major unconformity-bounded sequences (delineated by horizontal time lines) for North America are named (*after* Sloss, 1976).

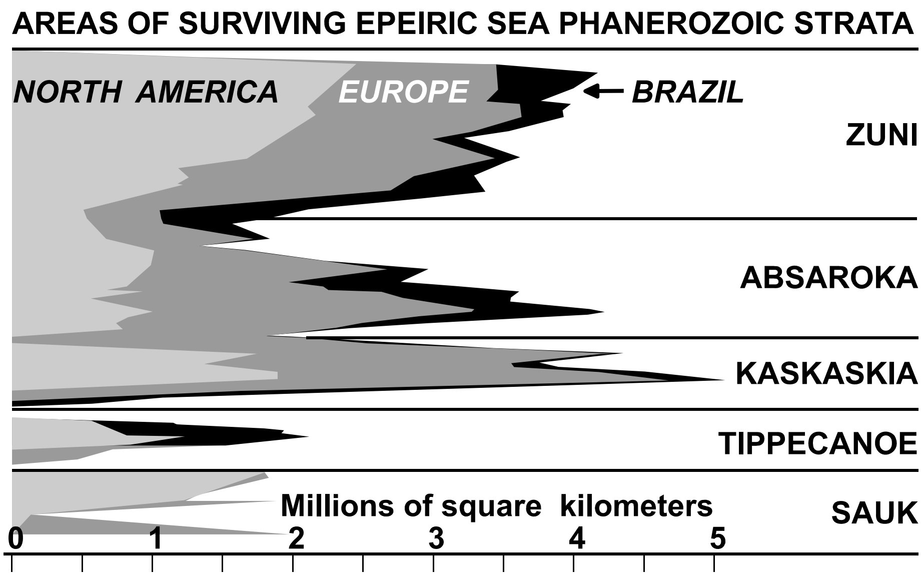

Figure j24.3 [13] Stratigraphic cross section (with vertical exaggeration, folds and faults removed) of the Laurentian platform and foredeep sediments preserved in the central Appalachian province.

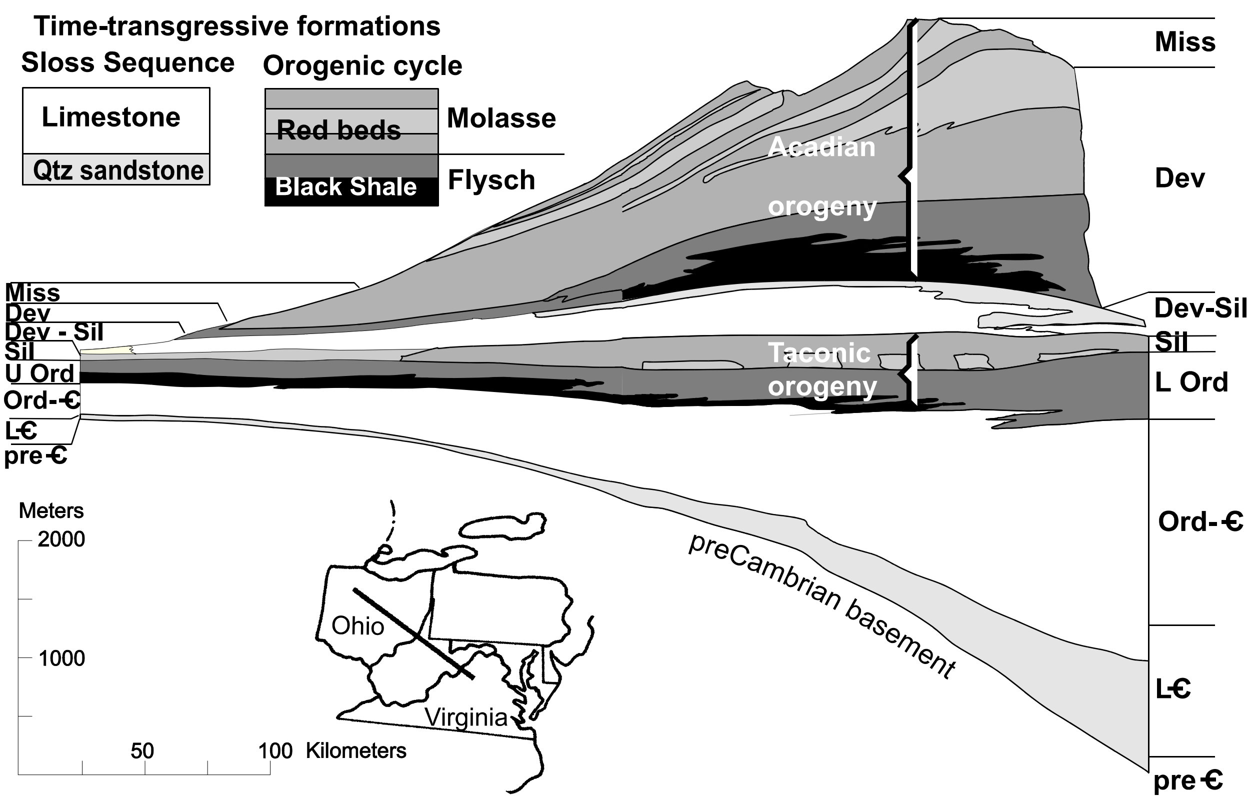

Figure j24.4 "Vail Curves" illustrate cyclic changes in sealevel through time. Sequences of sediments between unconformities (indicated by wavy lines), are called "packages." Those of 10-100 My duration, amplitude 50-100 meters, rise/fall rate of 1-3 cm /1000 yr, are, in Vails' scheme, 2nd order sequences.

The smoothed envelope to 2nd order sequences is a 1st degree Vail curve (gray) with cyclicities of more than 100 My duration.

The 1st degree curve shows sealevel was at a high stand during the breakup of Pangea, with a Late Cretaceous peak when ocean ridge activity was at a maximum. A low stand of sealevel (Early Jurassic-Pennsylvanian) can be associated with coalescings of paleocontinent that formed Pangea. Before, a high stand of sealevel (Mississippian-Cambrian) can be associated with dispersings of paleocontinents. Generalizing from this pattern, the steep rise in sealevel through the Cambrian from the latest part of the Precambrian indicates the, immediately, prior existence of a supercontinent [14] (*see* Topic *j28*).

Vail originally focused on 3rd order curves (1-10 My duration, amplitude 50-100 meters, rise/fall rate of 1-10 cm /1000 yr). These have the characteristic "Vail curve" shape which shows foredeep sediment accumulation is a nonlinear, 90° in advance phase, response to cyclic eustatic rise and fall of sealevel.

This is the converse of Joseph Barrell's (1859-1919) long-standing contention that sedimentation is determined less by the rate of supply and more by the rate of discontinuous basining.[15] The evidence of *diastems* (small-scale interruptions) is that basining, even though sediment load should augment it, is not normally a continuous process. There is, however, no conflict of ideas: Barrell's sedimentation is where basining must precede sedimentation. Vail's sedimentation is seaward of the alluvial plain or shelf. In both instances the stratigraphic record reads like the traditional life of a soldier: long periods of boredom interrupted by moments of terror! (An allusion made by D.V. Ager in *The Nature of the Stratigraphic Record*, 1973.)[16]