## THE 10 (Actually ~ 100!) STRATIGRAPHIC COMMANDMENTS: *THOU SHALTS* AND *SHALT NOTS* FOR SILICICLASTIC ROCKS\*

In stratigraphy, valid methods and concepts must be based on "reading" the rocks, but nothing is written on stone tablets! Ideas and concepts rapidly change, slowly evolve, or are (by professional consensus) eventually discarded. Some stratigraphic ideas persist despite subsequent evidence to the contrary. They then become "myths," and we all know that myths never die! Such "geologic" myths tend to survive for decades after they were proven incorrect or were modified to fit with current evolving and growing sedimentary evidence. Inflexibility or unwillingness to study objectively and to test honestly and personally new ideas describes some scientists in all fields. However, don't geologists seem to cling longer, with more tenacity and with greater perseverance to questionable ideas? Rhetoric, preconceived ideas, "gut feelings," and "I just don't believe it," are not substitutes for both intensive and extensive hands-on analysis of real comprehensive data sets. And then "let the chips fall where they may!"

- I. Thou shalt not believe that (a) water depth maps based on benthic microfossils are valid, except for episodes of maximum flooding. They reflect inferred water depths (e.g., outer and middle neritic) during the deposition of marine-condensed sections comprising high organic content and high species diversity and abundance of microfossils. Such bathymetric maps are totally invalid for sediments deposited between floods! And absence of fossils does not necessarily prove "continental" environments. (b) Thou shalt believe that deposition on and transport of sediment across submerged shelves must involve shoreline progradation, entrenched river transport, or rarely, density flow via relict submarine canyons. (a) Thou shalt not forget that sand-rich, commonly deltaic and/or shoreface and associated deposits that exhibit extensive, sheetlike distribution have been deposited on submerged shelves below maximum storm wave base. Such sandstone "sheets" or blankets are internally highly diachronous but homotaxial, and become younger in a basinward direction.
- II. Thou shalt not consider that (a) deltaic and other shoreline depositional systems are "continental" on the basis of fossil absence on vertical (time axis) occurrence charts. Volumes of marine sediments may be "barren" or faunally suppressed because of sediment dilution and/or inhospitable benthic substrates. (b) Thou shalt believe that whether fossils are detected or not, deltaic and coastal systems are dominated by shallow marine and brackish environments existing mostly above maximum storm wave base, and are not continental! (c) Thou shalt not believe that lowstand delta systems are simply the late phase of delta progradation across the shelf and into deep water beyond the shelf edge. They are temporally separated by an episode of relatively falling sea level, erosion, and deep-water density flow transport and depositional processes. On-shelf deltas may prograde across shallow-water ramps underlain by stabilized lowstand deltas until increasing water depth terminates basinward regression.
- III. Thou shalt not forget that (b) the thickness of progradational parasequences (i.e., seismic downlap) reflects equivalent (+ decompaction) water depths. Parasequences are absolute proof of shallow aqueous origin. Remember, parasequences are not deposited below maximum storm wavebase. (c) Thou shalt remember that parasequences are fundamental elements of shallow-marine lithofacies composing systems tracts, but under high sediment supply and low subsidence rates, high frequency sequences (<3<sup>rd</sup>-order) may replace the parasequences, especially in late falling limb

progradational lowstand systems, resulting in a "composite sequence." (c) Thou shalt remember that in the rock record, sequences formed under *greenhouse* and *icehouse* worlds appear identical, which indicates that high-frequency cycles are probably a composite of two or more global processes. That is, a Cretaceous sequence is not different from a Pleistocene sequence, suggesting the old metaphor: "If Pleistocene and Cretaceous fowl both have identical feathers, a long yellow bill, quack and waddle, they are probably both ducks."

- IV. Thou shalt not believe that (a) sand-rich grain flow and turbidity flow facies were sourced by slumping distal deltaic or relict shelf edge facies during highstand or transgression, respectively. Typically coarser grained than highstand facies, they were sourced via entrenched rivers and shelfedge deltas during relative fall of sea level. (b) Thou shalt believe that where present, shingled turbidite facies do not result from random slumping! Rather, they rest on 4<sup>th</sup>- and 5<sup>th</sup>-order type 1 unconformities within 3<sup>rd</sup>-order lowstand prograding complexes. (c) *Thou shalt* remember that a transgressive surface and systems tract are directly superposed on prograding complexes, but that type 1 and transgressive surfaces separate highstand prograding facies and superposed transgressive facies. (d) Thou shalt not believe that in marine basins, sandy sediments can be transported directly from river to marine substrate environments. Bed-load fluvial sediment must be deposited for a finite time within a fresh-water wedge, before it can mix with denser marine water and become part of the marine current or density transport systems. (b) Thou shalt remember that shelf-edge lowstand erosional notches are filled during early relative rise of sea level; such features should not be confused with submarine *canvons*, which reflect long-term erosion and preservation of relict accommodation space under low sediment supply rates.
- V. Thou shalt realize that (a) it may make little difference whether unconformities or maximum flooding surfaces are used as sequence boundaries, as long as one understands the genesis and significance of each surface. But it is seriously important that stratigraphers recognize that the entire marine and nearshore sedimentary record comprises cyclic sequences that required highfrequency (<3 my) relative falls of sea level. (b) Thou shalt remember that if flooding surfaces are selected as boundaries, the resulting sequence contains a major erosional and nondepositional hiatus and the surface has diagenetic importance (especially in carbonates) and to correlate the highstand and transgressive shallow-marine sandstone facies with off-shelf deepwater lowstand sandstone facies simply because they occur between the same pair of marine-condensed sections is highly questionable. The condensed sections are ~time surfaces, but sandstones between two mfs's are not necessarily time-equivalent, and major miscorrelations can occur if one does not recognize that when off-shelf sandstone facies are being deposited, the adjacent shelf was subaerially exposed. Hence on-shelf and off-shelf deposition were temporally unique and mark the stratigraphic position of density-flow sandstones. (c) Thou shalt remember that although flooding surfaces are easier to recognize and trace on seismic and wireline logs that is not justification for ignoring major subaerial and submarine unconformities.
- VI. Thou shalt not believe that "pebbly facies" within marine shales necessarily require major (yo-yo) tectonic uplift and are of fluvial origin! Widespread, thin phosphatic, cherty, sideritic or glauconitic and highly fossiliferous "pseudoclastic" facies form *in situ* by authigenic or biogenic processes within euxinic environments in deep basins, on slopes and on flooded shelves in the absence of a siliciclastic sediment source. (b) Thou shalt not forget that marine onlap is an aggradational (filling) phenomenon that occurs normally below shelf edges and is supplied by density flow by-pass. Coastal onlap, on the other hand, must occur when any siliciclastic coastal system progrades onto a subsiding shelf or into a subsiding basin. Downward shifts of coastal onlap can be recognized by more proximal coastal or fluvial facies resting directly on more distal coastal and/or neritic facies (violating Walther's law).
- *VII. Thou shalt not* believe that (a) intensive erosional unconformities, especially angular unconformities, reflect *only* tectonic uplift. They reflect "tectonic dominance." The time that

erosion was initiated, however, was determined by the high-frequency component of relative fall that first brought the erosional base level into contact with the sediments. Erosion ranges from higher frequency (global?) domination to lower frequency tectonic domination, but *both factors* may operate to enhance or suppress erosion. (b) Second-order global cycles, however, may be perturbated by diachronous local basinal tectonic evolution. Gondwana breakup generated global low-frequency (*average*) cyclicity, but individual Gondwana marginal basins may be slightly diachronous (e.g., The average American family has 2-1/2 kids!).

- VIII. Thou shalt not believe that (a) maximum flooding occurs at maximum water (sea) level (except in your bathtub!). It occurs at maximum *rate* of a relative rise of sea level. Furthermore, the maximum flooding surface is not globally synchronous, and its age may vary within a basin, depending on sediment supply vs. accommodation rates. (b) *Thou shalt* remember that type 1 unconformities may result from high-frequency global tectonics (e.g., "chatter" at subduction or spreading centers, orbital and solar cycles, and resulting climatic cycles (i.e., glaciation), as well as lower frequency global and local basinal tectonics. Demonstrating a eustatic synchroneity of all such surfaces at resolutions of <~300,000 years remains rhetorical, but similar, globally distributed sequence successions and magnitudes of erosion at nannofossil resolution are strong evidence of eustasy. And as seismic data quality has improved an order of magnitude since 1970, unconformities have become relatively easy to identify and trace, especially near shelf edges and transverse to incised valleys</p>
- IX. Thou shalt not believe that (a) shoreline regression necessarily requires a *fall* of relative sea level. Regression typically occurs during stillstand or relative rise of sea level whenever sediment supply rates exceed accommodation rates (otherwise, there would be no preserved sets of progradational (parasequences!). *Thou shalt* remember that (b) accommodation space is the algebraic sum of current (and relict) tectonics and higher frequency relative cycles and its interplay with sediment supply rates determines progradation, aggradation, retrogradation or erosion. *Thou shalt* remember that (c) at high frequencies (<~3 my) sediment supply exerts minimal effect on relative sea level but interplays with accommodation rates to determine water depths and lateral shoreline movements. (d) Thou shalt remember, however, that at lower frequencies (>3-5 my) sediment supply (and subsequent isostatic rebound) do accelerate subsidence, growth-faulting, diapirism and uplift and, hence, affect accommodation rates and relative sea level.
- X. Thou shalt not doubt that (a) a subaerial type 1 surface (i.e., paleosols) existed at the tops of highstand progradational parasequence sets and was coincident with fluvial entrenchment and subsequent deposition of valley-fill sediments. Sharp-based proximal fluvial channel-fill facies resting on distal deltaic or even preexisting systems tracts proves a downward shift of coastal onlap that resulted from a relative fall of sea level. (b) *Thou shalt not* forget that leveed distributary channels were deposited during relative rise of sea level and that distributary channels are incapable of eroding much below sea level. (c) *Thou shalt not* extrapolate the unconformable base of an erosional valley laterally through distal coastal marine facies of the previous cycle! Valley-fill facies are excellent reservoirs, but they also may intercept and by-pass secondary floods around reservoirs.

Transcribed in stone On a dark and rainy night Under fear of death, From a loud Voice, Behind a burning bush, On Mount Bonnell November 26, 2001 L. Frank Brown, Jr. (Moses) \*P.S. If this draft copy writ on stone by Moses is angrily broken or is ignited by a burning bush, you may return it for an updated replacement. And remember, stratigraphers, let's have no more of that ole sinful, dancin' 'round those mythical golden calves! (signed) —GOD