Changing paradigms in stratigraphy—*another* 'new uniformitarianism'?

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After decades of flirtation with neocatastrophism, historical geology is edging back towards its first love, uniformitarianism. That relationship seemed doomed, thanks to exposure of Lyell's forced marriage of gradualism and uniformity. Uniformitarianism seemed washed up—diminished by fancy new semantics and set aside for a flashy neocatastrophism. But amid the uncertainties of 'more gap than record', geologists are reconsidering. Andrew Miall has proposed a 'new' uniformitarianism, where the incompleteness of the rock record is perceptually scale-dependent, and that linking physical and temporal scales can transform the 'frozen accidents' of the past into a coherent story. Analysis of his case shows otherwise.

Historical geology rests on uniformitarianism, whose equivocal meanings were long obscured by "the present is the key to the past". Its real meaning is as a philosophy of history that denies God's works of creation and providence.[1] Despite periodic assertions that gradualism has been rejected in favour of 'methodological uniformitarianism'[2] or 'actualism',[3] and despite flirtations with neocatastrophism,[4] geologists always return to gradualism because naturalism requires scientific certainty. Data may 'distract' them from gradualism for a time, but it always swings back. That is why the neocatastrophism of the late 20th century is being eased aside to ensure the slow, continuous sedimentation needed for the new stratigraphy.[5,6]

But a new deflection has disturbed the compass. The dramatic incompleteness of the sedimentary record has forced some to entertain doubt about major aspects of uniformitarian stratigraphy.[7] Two previous papers discuss this phenomenon. "Not enough rocks: the sedimentary record and Earth's past" questions the ability of uniformitarianism to account for the unexpectedly sparse volume of the planetary rock record.[8] "Changing paradigms in stratigraphy—'a quite different way of analyzing the record'" explores Bailey and Smith's[7] discovery of the self-similar nature of deposition and erosion at all scales in the rock record.[9] This implies a plethora of hiatuses, pauses, or breaks in continuity, in the rock record at all scales, most undetectable, and raises the possibility that the rock record is a series of undecipherable 'frozen accidents' at all scales with no causal connection between each other.

Nonetheless, few geologists see uniformitarianism as a philosophy. They 'know' it is true, even if they cannot define it, and both of these factors get in the way of logical analysis.[10]

Andrew Miall is a prominent Professor of Geology at the University of Toronto. His books are well known in petroleum geology and his walls are filled with professional awards. He has been a voice of caution against bandwagons like cyclostratigraphy (astronomically forced climate cycles within sedimentary successions).[11]

He sees this new problem with uniformitarianism and agrees it is of concern. However, he believes stratigraphy can be saved by an appeal to the scale of sedimentary processes and by rebranding uniformitarianism:

> "The significant differences highlighted in this paper between 1) the preservation of the products of modern sedimentary processes, 2) those preserved in the recent (post-glacial) record, and 3) those preserved in the more ancient record, indicate the need for a modified use in geological work of the concepts of *uniformitarianism* [emphasis in original]."[12]

Note that the bottom line is non-negotiable. Purposefully echoing Challinor[13] he affirms: "Uniformitarianism is still the fundamental principle on which geology is built".[14]

His attempt to reconcile the rock record and uniformitarianism is significant. That a geologist of his stature would address it shows the severity of the problem. It also shows that uniformitarianism is the heart of secular natural history,[15] and that anything can and will be sacrificed to preserve that core.[16] Moreover, creationists who have been leaning on neocatastrophism are in danger of disappointment if Miall can successfully rescue uniformitarianism.

The problem

In 1973, Ager revealed a trade secret: sedimentary processes should have left us a lot more rocks.[4] He saved deep time by embracing an incomplete record. That record became a series of "frozen accidents" and was "more gap than record". Fascinated with the obvious, geologists still refused the logical conclusion of diminished confidence in their natural history. Miall noted:

> "Notwithstanding observations such as this, stratigraphers have tended to operate as if continuous sedimentation was the rule. For example, many of the independent marker horizons in the GTS [Geologic Time Scale] were, at one time, dated by extrapolation or interpolation between well-dated beds (e.g. radiometric dates on bentonites) by assuming a constant sedimentation rate."[17]

Recently, some geologists have carried Ager's work further,[7] merging a fractal view of nature with neocatastrophism to arrive at a pessimistic assessment of traditional stratigraphy.

Fractal aspects of the sedimentary record

B.B. Mandelbrot (1924–2010) was a mathematician who coined the term 'fractal' to refer to natural phenomena that showed repeating complex patterns over wide scales. He used this concept to show that apparently random patterns in nature, such as coastlines, are self-similar at any scale. Mandelbrot's[18] ideas were well received in geology, with applications in geomorphology, sedimentology, and stratigraphy.[19] Plotnick[20] applied the scale-independent self-similarity of complex natural features to stratigraphic hiatuses, providing a mathematical basis for Ager's claim of "more gap than record". He noted:

> "Similarly, the distribution of unconformities appears at first glance to be hierarchical. For example, in the Phanerozoic of Northern Illinois, there are two large-scale unconformities … with durations of 600–900 m.y. and ca. 140 m.y., respectively … . Three other unconformities appear to range from 5 to 20 m.y. These five hiatuses largely correspond to the sequence boundaries of Sloss (1963). An additional six unconformities may be in the 1 to 2 m.y. range. Finally, there are, of course, many more unconformities represented by formation boundaries."[21]

This means that there are gaps of all sizes everywhere in the strata. Plotnick saw sedimentation as a Cantor function (a log-linear relationship between time and sediment accumulation) and developed a Cantor bar, popularly known as a 'devil's staircase' (figure 1) to show that hiatuses are more prevalent over time.

Sediment accumulation diminishes over time?

Miall agrees with all this, claiming that the increasing resolution of sequence stratigraphy confirms the fractal nature of the rock record.[22] He notes it is nothing new:

> "He concluded: 'only one-sixth of time is recorded' by sediments (Barrell, 1917, p. 797). This remarkable diagram 1) anticipated Jervey's (1988) ideas about sedimentary accommodation that became fundamental to models of sequence stratigraphy, 2) it also anticipates Ager's (1981, 1993) point that the sedimentary record is 'more gap than record;' and 3) it constitutes the first systematic exploration of the problem of preservation potential." [23]

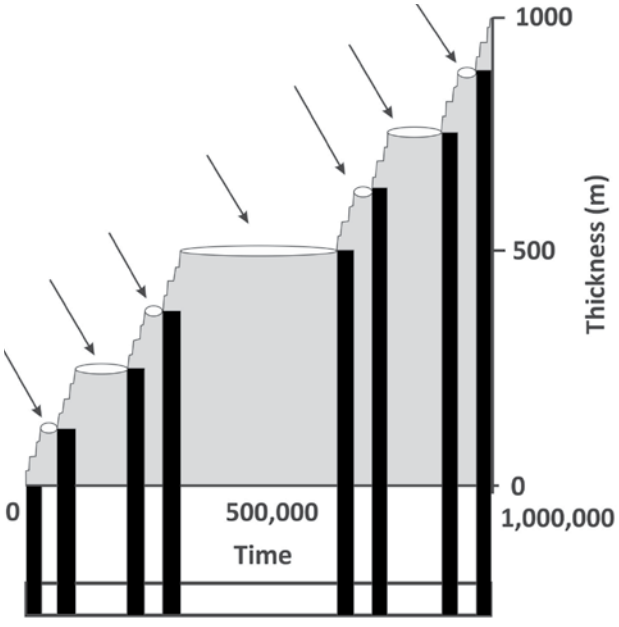

Figure 1. This 'devil's staircase' shows interaction between sedimentation, erosion, and accumulation for a hypothetical 1000-m stratum formed over one million years. It emphasizes the fractal nature of preservation, showing limited times of sediment accumulation (black vertical bars), interspersed with erosion and non-deposition (arrows = major hiatuses). When black bars are extended down (box at bottom), they form a Cantor bar showing sedimentation over time. (After Plotnick.[20])

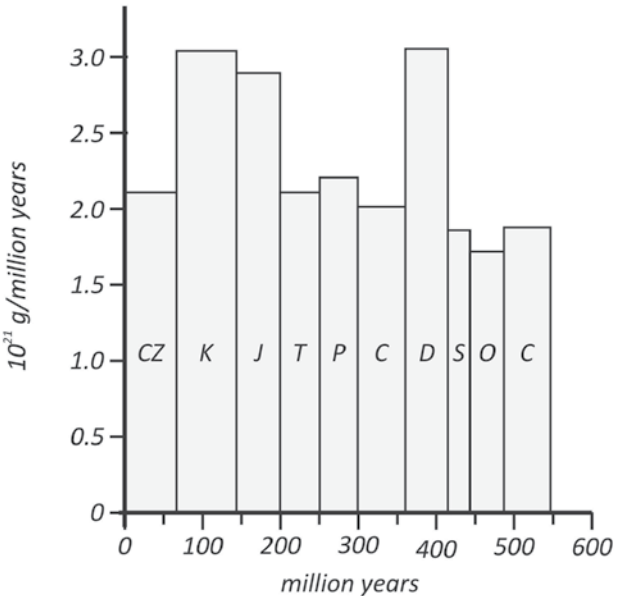

Figure 2. Mass of sedimentary rock on Earth by age. Modified from Ronov's figure 7,[28] this graph does not agree with the log-linear decrease in sedimentary rock accumulation over time predicted by sedimentation rate studies.

He sees a glimmer of a solution in Sadler's study, which compared 25,000 sediment accumulation rates and saw variation over 11 orders of magnitude in an apparent log-linear manner.[24] This means that sedimentation *rates* decrease back in time. He anticipated the fractal model of hiatuses when he noted that "the completeness of sedimentary sections can become very low if we concern ourselves with fine time scales".[25] Miall makes much of this mathematical relationship between stratal completeness and time to preserve uniformitarian stratigraphy:

> "Actual sedimentation rates in most geological settings are always likely to be much higher—typically orders of magnitude higher—than those calculated from the rock record, based on observable geological data, such as extrapolations from datable ash beds or biohorizons, or rates based on regional rates of accommodation generation. There is no conflict between the rapid sedimentation that can commonly be observed in modern settings, and the rates that prevailed in the past. Uniformitarianism is correct, but with the additional proviso that analyses of the past must take into account the ubiquitous hiatuses, many quite cryptic, that occur at all time scales."[26]

In other words, he predicts that accumulating erosion over time would disproportionately affect older strata, showing an artificially low apparent sedimentation rate.[8] Ronov noted this predicted decline:

> "The variations are evidently due to two factors: 1) differences in the rates of sedimentation during different stages of the Neogean (lower rates in the late Proterozoic interval); and 2) processes of erosion and weathering, which could have removed part of the original volume of the rocks. The scale of the loss may be judged solely by statistics, assuming that the older the sedimentary rocks, the greater the likelihood that they have been eroded. In that case, the relative mass of the sedimentary rocks should gradually decrease from younger to older. Gregor … recently came to that conclusion, followed by Garrels and Mackenzie … They established that the relative mass of sedimentary rocks should decrease according to an exponential law, from the present to the distant past."[27]

Six Conclusions of Bailey & Smith (2010)	
Quotes	**Implications**
Continuous deposition … has no theoretical or evidential basis … . It is fundamentally incompatible with the observable layering. Its use as a criterion for the selection of global stratotypes is … flawed.	Continuous sedimentation is a fundamental assumption of stratigraphic type sections, including GSSPs. Thus, the time scale is not anchored in the rock record, and global correlation is not possible via the sedimentary or derivative fossil records.
… the notion persists that at some scale of stratigraphic resolution, continuity in accumulation can be assumed … . This assumption may be operationally convenient, but it is unsupported.	Stratigraphic interpretation is scale dependent, and is subjective because continuity is assumed. It 'works', but has no basis. This may suggest that its utility relies more on a *priori* assumptions than on any strength of the method.
A record in which almost all the operations of the sedimentary system(s) are unrecorded, and in which hiatuses show fractal scale relationships … cannot be relied upon to preserve the sequential relationships on which … Walther's Law depends.	Walther's law of the vertical preservation of adjacent lateral facies requires preservation of these facies. If the record is mostly gaps, and gaps occur at all scales, we cannot know if or how vertically adjacent layers are related.
The power law decline in rates of accumulation with increase in the time span over which they are measured … means that the age of a stratigraphic datum cannot be interpolated using the net rate of accumulation of the interval in which it occurs … all net rates are unique to the interval for which they are estimated, precluding … extrapolation of process rates from one part of the record to another.	Stratigraphers have always used thickness of rock units as a surrogate for time. But this cannot be done because even the rates change over time, and the sparse nature of the record means we do not know how much of any unit has really been preserved. Present day rates are especially poor predictors of ancient strata.
… the record may not be representative of this history … any record represents some small, but essentially immeasurable, fraction of the time span … the other is that in many environments preservation of strata in the record … is very much the exception … atypical of their time, and hence not properly representative.	An axiom of historical geology is that rocks and fossils form coherent historical records sufficient to know the past. Because most time is missing, we cannot know the past. Environmental interpretation is equally flawed by the incomplete sample we possess.
… it is not possible to determine whether currently observable sedimentary processes - the basis of the uniformitarian axiom -are of the kind that will provide records in the future.	Uniformitarianism was saved by the recent emphasis on its use as method. This invalidates that method, leaving only a generic uniformity, and invalidating uniformitarian history.

Figure 3. Bailey and Smith's challenges to modern stratigraphy; their quotes to left, author's explanation to right. GSSP = Global boundary Stratigraphic Section and Point.[5]

But then he affirmed that the actual rock record showed otherwise (figure 2):

> "Using the method of the authors just mentioned, I constructed histograms, based on data in Table 7, in which are plotted the relative masses of the sedimentary rocks assigned to each period of the Phanerozoic per unit of time, that is, per million years … Contrary to expectation, *the graphs do not reveal a regular decrease in the relative masses of rocks with increasing time*; instead, they show periodic fluctuations [emphasis added]."[28]

Pessimistic conclusions of Bailey and Smith

Bailey and Smith followed the logic of a fractal sedimentary record to a series of conclusions that undermine traditional stratigraphy (figure 3).[7] The lack of rocks helps shed illusions regarding fundamental assumptions of historical geology. Miall summarized their points:

- The notion of continuous deposition, on which the historicity of the record depends, has no theoretical or evidential basis …
- If there is no continuity in accumulation, the sequential preservation of laterally contiguous facies, according to Walther's Law, becomes questionable.
- Stratigraphic hierarchies are constructs, commonly tailored to human-scale analysis of the fractal record. They are a practical, convenient, but incomplete representation of this record.

- Currently-observable sedimentary processes and facies underpin uniformitarian stratigraphic interpretations. Yet there is no way of determining whether a present day deposit will be preserved millions of years hence … Specifically, are the snapshot 'frozen accidents of preservation' representative?
- As Sadler (1999) has shown, local calculations of accumulation rate are time-scale dependent.[29]

Their conclusions are in line with Kravitz, who noted that "geologists' knowledge of the past is based on … assumptions … [and] *they are products of the geologists' imagination* [emphasis added]".[30] In other words, historical geology is not the empirical, inductive construct commonly perceived; it is one possible template supported by tenuous data. The template's apparent success is virtual, not real.

Miall's solution

To his credit, Miall does not dismiss Bailey and Smith. He correctly sees that "*These conclusions would appear to invalidate virtually the whole of the last two centuries of stratigraphic progress* [emphasis added]*!*"[29] His solution is novel; the problem is not the record's incompleteness but our failure to comprehend physical and temporal scale. He chooses Sadler over Ronov:

> "Sadler (1981) documented this in detail, using 25,000 records of accumulation rates. His synthesis showed that measured sedimentation rates vary by eleven orders of magnitude, from 10^{-4} to 10^{7} m/ka. This huge range of values reflects the increasing number and duration of intervals of non-deposition or erosion factored into the measurements as the length of the measured stratigraphic record increases. … Crowley (1984) determined by modeling experiments that as sedimentation rate decreases, the number of time lines preserved decreases exponentially, and the completeness of the record of depositional events decreases linearly. Low-magnitude depositional events are progressively eliminated from the record."[31]

Miall then builds his solution into a diagram of Sedimentation Rate Scales (SRS), which range from minutes to millions of years (figure 4). Thus, geologists only need analyze at the proper timescale for each kind of sedimentary product (figure 5):

> "Stratigraphic and sedimentologic studies ranging from the micro scale to the regional, and based on time scales ranging from the short-term … to the long-term … are best carried out at the appropriate *SRS*, much like photography uses lenses of different focal length, from macro to telephoto to wide-angle, to focus in on features at the desired scale."[32]

Miall then answers the six points of Bailey and Smith with six of his own, addressed in the following discussion.

Discussion

Bailey and Smith noted the fractal nature of the sedimentary record, with self-similarity between laminae and megaregional strata.[33] Miall embraces self-similarity of the record over a range of scales but subsumes the *physical* scale into the *time* scale (figure 4), even though the timescale is a human construct that assumes uniformitarianism. The different conclusions of Miall and Bailey and Smith suggest a Kuhnian clash between data and paradigm—Bailey and Smith want to test the paradigm; Miall wants to save it. Like many predecessors, he thinks this requires only tweaking the definition and method of uniformitarianism—a classic example of moving the goal posts.

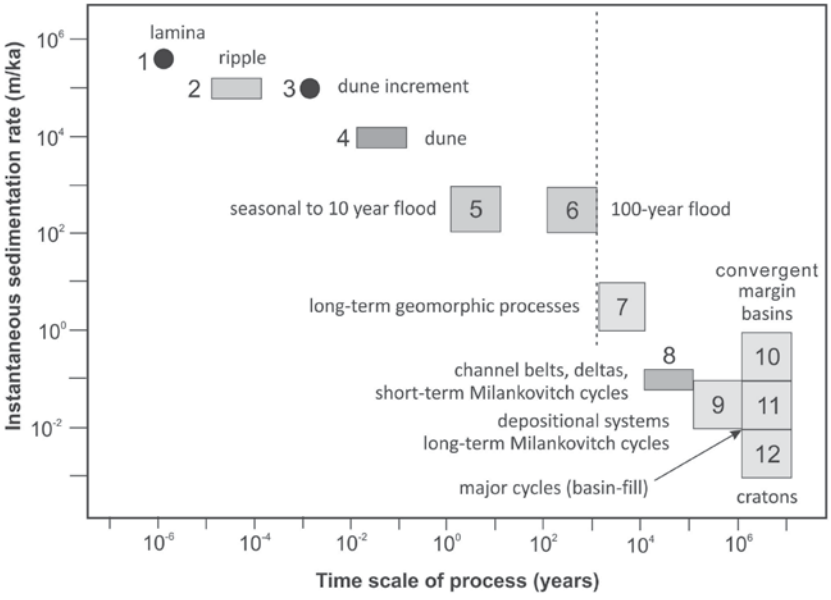

Figure 4. Miall's proposed Sedimentation Rate Scale, showing a range of 12 sedimentary processes, ranging from laminae to cratonic cover. Note that only the first six are open to observation. (After Miall's figure 3.[12])

Uniformitarianism more than a method

Ironically, his solution is all about perspective, yet limiting uniformitarianism to the actualistic method is a very one-dimensional view that avoids past problems of equivocation that began with Lyell's usurpation of Newtonian uniformity.

When Hooykaas[34] and Gould exposed it, geologists quickly redefined their problem away,[35] shuffling aside uncomfortable parts to accommodate neocatastrophism.[36] This reduced the problem from philosophy to methodology. Miall copies that approach when he says that "sedimentologists and stratigraphers have long had difficulty reconciling the concept of the *uniformity of processes* over time with the wide range of time scales and rates of processes over which sedimentation takes place [emphasis added]".[14]

But how can we frame the "range of time scales" or the "rates of processes" without first assuming a framework of history? How can we determine the "time scales" without prior knowledge of beginning and end, much less any points in between? How do we even know that time is linear?[37] Why rule out processes and rates which are foreign to modern observation or worse, downplay observed rates, as does Miall?

The real problem: the absence of evidence

Miall raises interesting points but fails to see the main problem of lack of evidence. He remains confident that stratigraphy and the rock record are both well grounded in reality, and that uniformitarianism is reliable. Thus, the problem cannot be objective failings of the fragmentary rock record, but the subjective failure of a proper perspective of those fragments. In Miall's thinking, when filtered by scale, stratigraphic history is just fine; its voluminous gaps are easily filled by interpolation. But he cannot escape the problem. Citing Ager, he says:

> "We talk about such obvious breaks [large unconformities], but there are also gaps on a much smaller scale, which may add up to vastly more unrecorded time. Every bedding plane is, in effect, an unconformity. It may seem paradoxical, but to me the gaps probably cover most of earth history, not the dirt that happened to accumulate in the moments between. It was during the breaks that most events probably occurred."[38]

The real problem is evidence and confidence. How much evidence is needed to provide a coherent story? Fifty percent? Ninety percent? Many scientists evaluate confidence with statistical error bars. But secular natural history as a whole seems immune from this kind of evaluation.

Worse, creationists and neocatastrophists note that the remaining 'dirt' was likely emplaced much faster than expected, and that remaining fragments are exaggerated during presentation. Reed[39] called this problem "scale masking". Using the Keweenawan basalts of the Midcontinent Rift System, which were likely each emplaced in hours, he extrapolated 194 such flows from the Texaco Poersch well in Kansas. Optimal coverage over the 21 Ma range would require equally spaced flows, shown as thin lines every 120,000 years (figure 6). More than 99% of the actual time is missing, and we cannot appreciate that percentage on a page-sized figure until we zoom down seven orders of magnitude (figure 6). Since it is unlikely that the flows were so conveniently equally spaced, the evidence in the record of that time is clearly diminished. If most were extruded during one event, the time between data points escalates to almost 21 Ma. That gap in time is a gap in our knowledge.

Miall also fails to see that naturalism requires empirical evidence. Creationists have a revelatory framework to support and constrain data.[40] Unaware of his own worldview, he sees the gaps as mere inconveniences. For example, the most important half of his 12 SRS classes cannot be observed, only inferred. Finally, evidence of catastrophic sedimentation exacerbates the evidentiary problem.

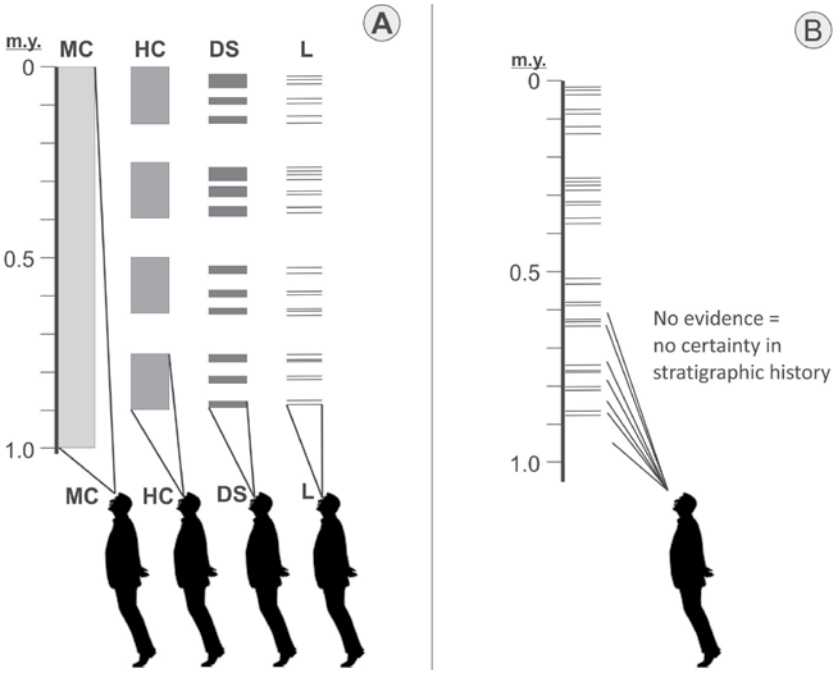

Figure 5. (A) Examination of the sedimentary record requires the proper scale to see missing section. A sedimentary cycle can be viewed on a million-year range (MC), which would record large regional unconformities. The same cycle can be viewed as a series of hundred-thousand-year cycles (HC) with several tectonic/eustatic unconformities, depositional systems (DS), or even lithosomes (L), such as individual channels or beaches. At finer scales, the greater amount of missing section is evident. But this shows (B) that actual sedimentary evidence for the million-year span is sparse, as Bailey and Smith noted. (After Miall's figure 2.[12])

Answers to Bailey and Smith

Miall addresses Bailey and Smith's conclusions (figure 7). Though not a direct point-by-point refutation, he advances six counter reasons for the traditional view. In essence, he is attempting to reconcile sedimentology and stratigraphy, and though he admits that sedimentology is problematic, he comes down on the side of stratigraphy. Close examination of his points reveals that they do not address root issues of Bailey and Smith.

Point 1. Lateral extent of sedimentary rocks explains lack of expected thickness

Bailey and Smith claim that continuous deposition is an illusion. Miall disagrees:

> "While accommodation is typically quantified in terms of vertical space relative to sea level … many important sedimentary processes are dominated by lateral sedimentary accretion."[26]

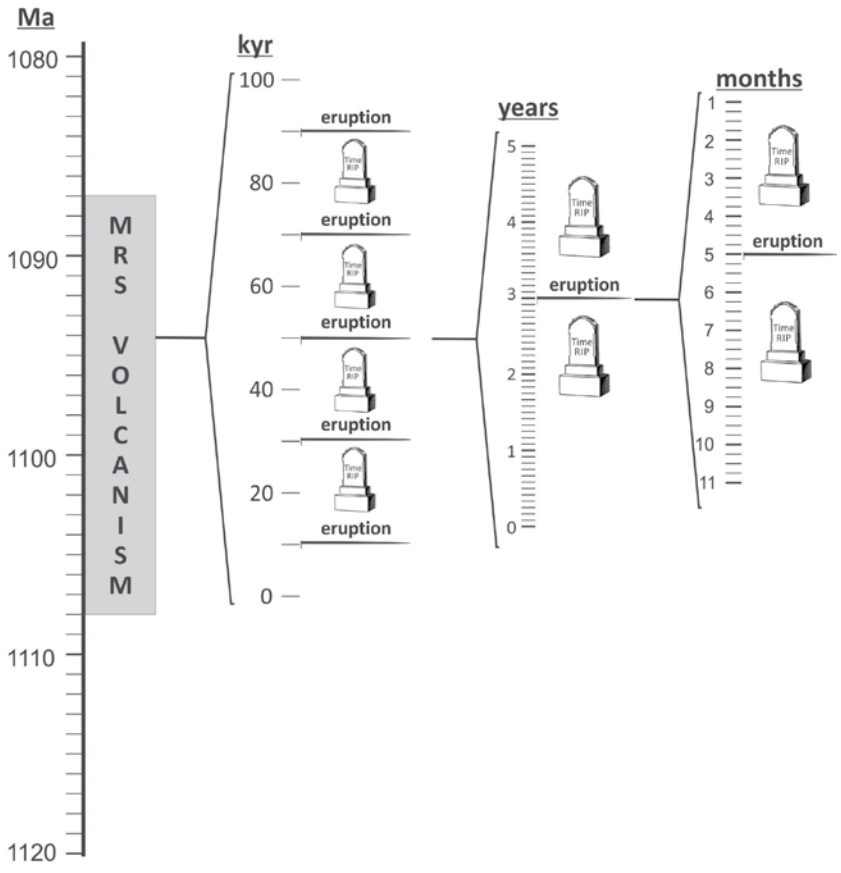

Figure 6. Keweenawan basalt flows at the Midcontinent Rift System demonstrate the problem of scale masking. Purported to have occurred in 21 Ma (1,108–1,087 Ma), the actual flows likely erupted in hours to days. Under Lake Superior, a flow happened on average every 10,000 years, representing 0.0008% of the time, while in Kansas a flow was emplaced every 120,000 years—0.00007% of the time. Both are vanishingly small fractions that cannot be accurately depicted on a typical figure, absent zooming in many times (right).

He implies that Bailey and Smith only analyzed sedimentary thickness rather than three-dimensional volume. While their Layer Thickness Inventory (LTI)[40] does evaluate two-dimensional well logs, all geologists use thickness as shorthand for volume. Ronov estimated the total volume of sedimentary rock on Earth but used average thickness as shorthand. Miall's answer is simply a diversion from the paucity of the rock record in *all* dimensions.

Actualism should be testable by comparing rock volume to observed sedimentation rates. Ronov's estimated total volume generates an average thickness of 2.2 km.[28] Sedimentation varies significantly, but modern rates are *much* higher, as Miall freely admits. If Earth is old, most of the stratal evidence is missing, both vertically and laterally. The typical answer that strata have eroded over time is an argument from a lack of evidence.

This inconsistency is significant because the volume of sedimentary rocks was an early, effective argument against the Flood.[41] Today it is an indictment of secular geology. Early uniformitarians argued that there are too many rocks, but today's uniformitarians do not seem to grasp the logical force of the contrary. Widespread rock bodies also argue for a diluvial explanation.[42]

Point 2. "Geomorphic time scale"[43] explains rapid sedimentation

Miall attempts to address the discrepancy between high modern rates and ancient preservation by finding exceptions to established stratigraphic dogma. Keep in mind that uniformitarians believe that accumulation rates are ultimately controlled by sea level and tectonism. His first exception is the possibility of local high rates sustained by local factors for short periods of time (figure 4):

> "Fluvial, tidal, and other channels, and valleys, ranging up in scale to major incised valley systems, are locations where accommodation is not controlled by base level but are best understood with reference to the buffer concept of Holbrook *et al.* (2006). Accommodation generation on geomorphic time scales is therefore not dependent on tectonic subsidence rates and may be substantially higher."[26]

Uniformitarians see accommodation space, generated by eustasy or tectonism, as the primary control of sedimentation. A gallon of milk poured into a glass will only yield the glass's volume. Likewise, excess sediment is not preserved. Estimated past rates of sea level change or tectonism can also be at odds with observed sedimentation rates.

This is important for diluvialists. Sedimentation controlled by accommodation space generated slowly by eustasy or tectonism is contrary to the Flood, because both were in disequilibrium. Thus, it was not such a limiting factor in the Flood. This fundamental difference needs to be explored by diluvialists.

Point 3. Deposition in some areas not restricted by periodicity of sea level changes

Miall looks for similar exceptions to established stratigraphic dogma in other environments:

> "In two other major settings, accommodation is not restricted by base level: Deposition landward of the shoreline and in inland nonmarine basins is constrained by depositional slopes that are dependent on upstream controls, such as rates of tectonic uplift, river discharge, and sediment load … Also, deep marine sediments are not in any way constrained by rates of accommodation generation, but are largely dependent on sediment supply."[26]

While true, the wholesale applicability of such environments to the rock record is the question. If hiatuses are less likely in deep marine deposition, many such sediments would still be absent via subduction. Thus, many of history's deep marine deposits should not exist. Although buffering can allow local high gradients and rapid sedimentation, sea level is the ultimate base level and control over sedimentation. Uniformitarians appeal to 'frozen accidents' of preservation in exceptional environments, even though they are subject to more active tectonism. Hence preservation would be a happy accident indeed, and these environments would be poor reflectors of orbital forcing, or of Earth history in general.

Point 4. Inherent order in sedimentation rates makes fragmentary rock record a 'time' record

Bailey and Smith noted that random low preservation of strata makes application of Walther's law of facies problematic. If a sequence of a marine transgressive sand overlies a deltaic mud, does it follow that the ocean into which the delta prograded was the same, responsible for the transgressive sand? Given a sufficient time gap, any activity could have occurred and had all evidence eroded. Miall rejects that conclusion:

> "Allogenic and autogenic sedimentary processes may generate predictable, ordered stratigraphic patterns at all time scales. The order and predictability may include erosional processes as well as processes of accumulation. This has always been the basis for Walther's Law … Therefore, contrary to the random or chaotic processes accumulation implied by Bailey and Smith (2010), stratigraphic order … may be preserved in the rock record."[26]

Miall plays off a cognitive dissonance in uniformitarianism—strata appear to show pattern and continuity yet are 'frozen accidents'. In this case, he focuses on the former, and says predictable patterns exist. But if hiatuses exist at all scales in a very scant record, how much of perceived order is subjective? He trusts his eyes; Bailey and Smith trust reason. Is stratigraphic interpretation 'exegesis' or 'eisegesis'? Zeller[44] demonstrated the role of human bias towards order and pattern based on discrepant correlations of the same sections by different geologists. They complained that they had been fooled, to which Zeller replied:

> "From the preceding story, it will be seen that our stratigraphic section, composed of randomly selected lithologies, does indeed show most of the characteristics that can be expected in a truly cyclic sequence. At this point the reader may wish to complain that the writer has gone too far in making up samples with which to taunt his

Bailey & Smith (2010)	Miall (2012)
Continuous deposition has no theoretical or evidential basis. Global stratotypes etc. are fundamentally flawed.	Accommodation measured vertically; most sedimentary processes are by lateral accretion.
Continuity is scale-related. Stratigraphic hierarchies are constructs, no basis in reality.	Channels - incised valleys not controlled by base level. On geomorphic time scales, accommodation independent of tectonic subsidence rates.
Impossible to know if present processes are representative of past (actualism).	Accommodation not controlled by base level also landward of shorelines and in inland basins. Depend on upstream controls like slope, uplift, discharge, and sediment supply.
Since almost all sedimentation is unrecorded and hiatuses are fractal, no basis for Walther's Law.	Sedimentary processes generate predictable, ordered patterns at all time scales. Order and cyclicity thus preserved, contrary to Bailey and Smith.
Net accumulation rates are scale-dependent and local. Cannot calculate process rates or relate rates from one area to another.	Sedimentary systems preserve more time in 3-D than local parts indicate. Continuous sedimentation occurs, just distributed across system (e.g., river, delta, shoreline).
Stratigraphic record fundamentally unrepresentative of geologic past.	Depositional rates much higher than those in rock record, but hiatuses at all scales are reason. Thus no conflict between two, and uniformitarianism is valid.

Figure 7. Comparison of the conclusions of Miall and Bailey & Smith

colleagues. Let the reader be assured, however, that the writer's humble efforts at creating confusion are of truly minute proportions when compared to those of nature."[45]

Miall believes that order in the record comes into focus at the proper scale. But if strata include significant missing sections at *every* scale, then the real sequence of processes cannot be known, and his SRS would be circular. On the other hand, real order and pattern in strata over large areas suggest a different paradigm is needed—like the Flood.

Point 5. 'Rock' record is representative at the right scale

Miall tries to square the two assertions that the rock record is fragmentary yet still yields scientific certainty:

> "Although sediment preservation is extremely discontinuous and spasmodic at any one location, the shifting locus of accumulation … means that substantially more elapsed time is represented by preserved sediment in three dimensions than the percentages relating to vertical accumulation noted earlier in this paper. At intermediate time scales (*SRS* 5-8) … sedimentation is continuous for lengthy periods of time, but distributed across an entire depositional system. Our tools for reconstructing these processes in the ancient record are quite limited."[26]

Miall must resort to the fundamental presupposition of global correlation. A layer absent in China is 'covered' by a correlative layer in Canada. This is the basis for all indirect correlation.[46] Note that correlation done by time—an intangible factor—overrides physical evidence: lithology, fossils, isotopic ratios, magnetic stripes, or astronomical cycles. These are only tools to apply a specific time signature to rock bodies, but it is the time that is correlated, not the forensic data. Early stratigraphers could not know if rocks were globally correlative, but assumed so, stretching Steno's original continuity to the breaking point. Overconfidence in this flawed approach is seen in the requirement for only one GSSP per stage for the entire planet.

Miall fudges the physical with the temporal here too. Because strata are part of larger depositional systems, parts that are missing at Point A are assumed to be present elsewhere. We intuit a river from a delta. But if strata are 'frozen accidents', then how can we confidently connect strata that are not physically linked? And does the presence of undetected fractal hiatuses throughout the section throw those apparent links into question? Miall believes that lateral shifts of sedimentary processes capture *time*, even if time captures little *rock*. But this assumes we understand the processes enough to fill in the gaps. Bailey and Smith fear the gaps are less friendly.

Point 6. Apparent conflict between observed rapid sedimentation and inferred slow past rates is a function of decreasing preservation

To preserve uniformitarianism, Miall must find a way to address higher observed rates today with lower inferred rates of the past:

> "Actual sedimentation rates in most geological settings are always likely to be much higher … than those calculated from the rock record, based on observable geological data, such as extrapolations from datable ash beds or biohorizons, or rates based on regional rates of accommodation generation. There is no conflict between the rapid sedimentation that can commonly be observed in modern settings, and the rates that prevailed in the past. Uniformitarianism is correct, but with the additional proviso that analyses of the past must take into account the ubiquitous hiatuses, many quite cryptic, that occur at all time scales."[26]

Miall is attempting to use a significant problem—fractal hiatuses—to solve that of conflicting rates. But his 'new' uniformitarianism contradicts the 'old' uniformitarianism that comprises his foundation. Geology supposedly rejected the Flood in favour of actualism. Now, it turns out that the

	Uniformitarian Framework	Diluvial Framework
Sedimentary Processes	Actualism requires them to be those observed today. Changes in preservation explain discrepancies between modern sediments and those in the rock record.	Empirically determined. Constrained in part by hydrodynamic and sedimentologic physics, but large scale changes may yield qualitative changes too.
Accommodation: Sea Level Change	Sea level changes slowly in response to climate and plate tectonics. Sediment is produced in excess, only preserved when space is available, e.g., a transgression.	Sea level changes rapidly and dynamically, creating large accommodation space. Especially true in early Flood's global, energetic transgression.
Accommodation: Tectonic Processes	Tectonic basins are created very slowly, and capture only a small % of total sediment produced. Preserved in basins over 10^5 to 10^7 time scale.	Rapid tectonism creates basins at every terrestrial scale; preservation is more complete due to rapid formation and burial.
Preservation Potential	Only small fraction of sediment is ever preserved. Hiatuses at all scales. However, analysis of present processes encourages assumptions of continuity and correlation.	Potential large, especially early in Flood. Rapid accommodation generation and rapid burial yield WYSIWYG strata. Hydrodynamic hiatuses may represent no time.
Geomorphic Setting	Major control of sedimentation; in turn it is controlled by climate and tectonics.	Factor both early and late in Flood; landscape less relevant in marine setting; late Flood creates modern landscape at a variety of scales.

Figure 8. Diluvialism provides alternative and innovative answers. One of the most important is that diluvialists expect greater preservation—a 'what you see is what you get' (WYSIWYG) approach, rather than the 'frozen accidents' of uniformitarianism.

concept is more malleable. Why is it acceptable to intuit *lower* past rates, but not *higher* ones?

Furthermore, if present rates cannot be trusted, then why should any uniformitarianism be trusted? Either the present is representative or it is not. Empiricism requires following the data. If the data suggest that the record is too incomplete, then the data should be honoured. Note also the use of "cryptic hiatuses" as a licence to insert a gap wherever needed.

A diluvial alternative

The years have been hard on Lyell's pristine positivism, and uniformitarian geology seems to always shoot itself in the foot. The logical incompleteness of the stratigraphic record illustrates inconsistency between their assumptions and the rocks. Either actualism does not work, billions of years are not really there, the record is not representative, or all three are true. Miall thinks a scale qualifier will solve the problem, but the ultimate incoherence of uniformitarianism transcends his classification system. Another possibility is that a new framework is needed. If history is an unbiased forensic exercise, then alternative paradigms should be welcome.

Diluvial geology has answers for Miall's problems. Sedimentary processes, accommodation space, preservation, completeness, and even geomorphology all have distinct starting points that are worth trying (figure 8).

Conclusion

For more than half a century, geologists have been struggling to define their fundamental principle, but without success.[15] One of the outgrowths of their dalliance with neocatastrophism was an examination of the incompleteness of the sedimentary record. Bailey and Smith followed that logic to a pessimistic conclusion that threatened the foundations of stratigraphy. Miall, in an attempt to absorb neocatastrophism into uniformitarianism, and rescue traditional stratigraphy, proposes another tweak to the ever-malleable definition of uniformitarianism. He thus allows a sliding scale of sedimentary processes to account for any number of rates to cover discrepancies between uniformitarian theory and field examples of rapid rates. Even apart from past equivocation of 'uniformitarianism', Miall faces an uphill battle. Like Lyell, he tries to mask a philosophy of history by presenting it as a forensic method. But he cannot reconcile the unintended consequence of fractal hiatuses, 'frozen accidents', deep time, and actualism. Secular natural history fails all by itself because its only acceptable past evidence is largely gone. Diluvialists are not so constrained by a rigid empiricism, have a pattern for the rock record in the Flood, and are more optimistic about preservation.

Glossary

Actualism. A fundamental axiom of method in historical geology that restricts potential interpretations of the rock record to the limited reservoir of observed modern examples.[15]

Facies. A means to classify rocks according to their physical characteristics rather than their age.

Geomorphology. The earth science discipline that addresses the description and interpretation of landforms.

Methodological uniformitarianism. When it had become clear that the term 'uniformitarianism' was equivocal, geologists in the 1960s and 1970s proposed four distinct definitions for the term.[15] Methodological uniformitarianism, proposed by Gould in 1965, is the most common use today, and is virtually synonymous with actualism.

Neocatastrophism. A school of geology growing out of the 1970s and 1980s that emphasized the (naturalistic) role of catastrophic processes in the past, such as impact events. It is associated in stratigraphy with the work of British geologist Derek Ager.

Positivism. The epistemological commitment to science as the arbiter of truth.

Sedimentology. The study of sediments and sedimentary rocks, including their description and origin.

Stratigraphy. The discipline of geology that orders rock strata according to age; it includes the various methods by which such determinations are made (e.g. biostratigraphy, cyclostratigraphy). The ultimate product of stratigraphy is the geological time scale.

Sequence stratigraphy. A branch of stratigraphy developing in the mid-20th century that emphasized the fine discrimination of sedimentary 'sequences', often using seismic data, and arranged them according to sea level changes over time.

Walther's law. Any vertical stratigraphic linking of ancient facies must be restricted to those observed laterally adjacent to each other in the present. E.g. it is a reasonable interpretation that deltaic facies are vertically overlain by transgressive marine sands.

References

1. Reed, J.K. and Williams, E.L., Battlegrounds of natural history, part II: actualism, CRSQ **49**(2):135–152, 2012.
2. Gould, S.J., Is uniformitarianism necessary? *American J. Science* **263**:223–228, 1965; Gould, S.J., Catastrophes and steady state earth, *Natural History* **84**(2):15–18, 1975; Gould, S.J., Toward the vindication of punctuational change in catastrophes and earth history; in: Berggren, W.A. and Van Couvering, J.A. (Eds.), *Catastrophes and Earth History*, Princeton University Press, Princeton, NJ, pp. 9–34, 1984.
3. Hooykaas, R., *The Principle of Uniformity in Geology, Biology, and Theology*, 2nd impression, E.J. Brill, London, 1963.
4. Ager, D.V., *The Nature of the Stratigraphical Record,* John Wiley and Sons, New York, 1973; Baker, V.R., Catastrophism and uniformitarianism: logical roots and current relevance in geology; in: Blundell, D.J. and Scott, A.C. (Eds.), *Lyell: the Past is the Key to the Present*, Special Publication 143, Geological Society, London, pp. 171–182, 1998.

5. Reed, J.K., Toppling the timescale, part III: madness in the methods, CRSQ **45**(1):6–17, 2008.
6. Reed, J.K., Toppling the timescale, part IV: assaying the golden (FeS2) spikes, CRSQ **45**(2):81–89, 2008.
7. Bailey, R.J. and Smith, D.G., Scaling in stratigraphic data series: implications for practical stratigraphy, *First Break* **10**:57–66, 2010.
8. Reed, J.K. and Oard, M.J., Not enough rocks: the sedimentary record and Earth's past, *J. Creation* **31**(2):84–93, 2017.
9. Reed, J.K., Changing paradigms in stratigraphy—"a quite different way of analyzing the record", *J. Creation* **30**(1):83–88, 2016.
10. Philosopher of science Gadi Kravitz admitted that, "the geologists' knowledge of the past is based on pretheoretical assumptions, often of a metaphysical nature, not susceptible to logical or empirical proof. In a certain sense, *they are the products of the geologists' imagination* [emphasis added]". Kravitz, G., The thermodynamics time arrow and the logical function of the uniformity principle in geohistorical explanation; in: Baker, V.R. (Ed.), *Rethinking the Fabric of Geology*, Geological Society of America Special Paper 502, Boulder, CO, p. 21, 2013.
11. Miall, A.D. and Miall, C.E., Empiricism and model-building in stratigraphy: around the hermeneutic circle in the pursuit of stratigraphic correlation, *Stratigraphy* **1**(1):27–46, 2004.
12. Miall, A.D., A new uniformitarianism: stratigraphy as just a set of 'frozen accidents'; in: Smith, D.G., Bailey, R.J., Burgess, P.M., and Frasier, A.J. (Eds.), *Strata and Time: Probing the gaps in our understanding*, Special Publication 404, Geological Society, London, pp. 11–36, 2015; p. 31.
13. Challinor, J., Uniformitarianism—the fundamental principle of geology, *XXIII International Geological Congress* **13**:331–343, 1968.
14. Miall, ref. 12, p. 11.
15. Reed, J.K., *Rocks Aren't Clocks*, Creation Book Publishers, Powder Springs, GA, 2013.
16. Cf. Reed, J.K., Untangling uniformitarianism, level I: a quest for clarity, *Answers Research J.* **3**:37–59, 2010; and Reed, J.K., Untangling uniformitarianism, level II: actualism in crisis, *Answers Research J.* **4**:203–215, 2011.
17. Miall, A.D., Sophisticated stratigraphy; in: Bickford, M.E. (Ed.), *The Web of Geological Sciences: Advances, impacts, and interactions*, Geological Society of America Special Paper 500, Boulder, CO, pp. 169–190, 2013; p. 184.
18. Mandelbrot, B.B., *The Fractal Geometry of Nature: Updated and augmented*, W.H. Freeman and Company, New York, 1983.
19. E.g. Middleton, G.V., Plotnick, R.E., and Rubin, D.M., *Nonlinear Dynamics and Fractals: New numerical techniques for sedimentary data*, SEPM Short Course 36, Tulsa, OK, 1995.
20. Plotnick, R.E., A fractal model for the distribution of stratigraphic hiatuses, *J. Geology* **94**(6):885–890, 1986.
21. Plotnick, ref. 20, p. 888.
22. Miall, A.D., *The Geology of Stratigraphic Sequences*, 2nd edn, Springer, New York, 2010. See especially his chapter 13, Time in sequence stratigraphy.
23. Miall, ref. 12, pp. 11–12.
24. Sadler, P.M., Sediment accumulation rates and the completeness of stratigraphic sections, *J. Geology* **89**:569–584, 1981.
25. Sadler, ref. 24, p. 579.
26. Miall, ref. 12, p. 25.
27. Ronov, A.B., *The Earth's Sedimentary Shell*, American Geological Institute Reprint Series 5, Falls Church, VA, p. 12, 1983.
28. Ronov, ref. 27, p. 13.
29. Miall, ref. 12, p. 13.
30. Kravitz, G., The thermodynamics time arrow and the logical function of the uniformity principle in geohistorical explanation; in: Baker, V.R. (Ed.), *Rethinking the Fabric of Geology*, Geological Society of America Special Paper 502, Boulder, CO, pp. 19–40, 2013; p. 21.
31. Miall, ref. 12, pp. 12–13.
32. Miall, ref. 12, p. 14.
33. Cf. Bailey and Smith, ref. 7, figure 2.
34. Hooykaas, R., *The Principle of Uniformity in Geology, Biology, and Theology*, 2nd impression, E.J. Brill, London, 1963; and Hooykaas, R., Catastrophism in geology: Its scientific character in relation to actualism and uniformitarianism, *Mededelingen der Koninklijke Nederlandse Akademic van Wetenschappen* **33**:271–316, 1970.
35. Rudwick, M.J.S., Uniformity and progression: reflections on the structure of geological theory in the age of Lyell; in: Roller, D.H.D. (Ed.), *Perspectives in the History of Science and Technology*, University of Oklahoma Press, Norman, OK, pp. 209–237, 1971.
36. Cf. Bates, R.L. and Jackson, J.A. (Eds.), *Glossary of geology*, American Geological Institute, Alexandria, Virginia, 1987; vs Neuendorf, K.K.E, Mehl Jr, J.P., and Jackson, J.A., (Eds.), *Glossary of Geology,* 5th edn, American Geological Institute, Alexandria, VA, 2005.
37. Reed, J.K. and Klevberg, P., Battlegrounds of Natural History, part III: historicism, CRSQ **51**(4):177–185, 2015.
38. Ager, D.V., *The New Catastrophism*, Cambridge University Press, Cambridge, UK, p. 14, 1993; quoted in Miall, ref. 12, p. 12.
39. Reed, J.K., *The North American Midcontinent Rift System*, Creation Research Society Books, Chino Valley, AZ, p. 114, 2000.
40. See Bailey and Smith, ref. 7 for explanation.
41. Reed, J.K. and Oard, M.J., Three early arguments for deep time, part III: the sedimentary record, *J. Creation* **26**(2):100–109, 2012.
42. Oard, M.J., Defining the Flood/post-Flood boundary in sedimentary rocks, *J. Creation* **21**(1):98–110, 2007.
43. 'Geomorphic timescale' is Miall's term for a relatively short period of time in uniformitarian scale, thousands to tens of thousands of years. See figure 4.
44. Zeller, E.J., Cycles and psychology, *Kansas Geological Survey Bulletin* **169**:631–636, 1964, kgs.ku.edu/Publications/Bulletins/169/Zeller/index.html.
45. Zeller, ref. 44, p. 635.
46. Reed, J.K., Toppling the timescale, part II: unearthing the cornerstone, CRSQ **44**(4):256–263, 2008.

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