Changing paradigms in stratigraphy—"a quite different way of analyzing the record"

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At a time when stratigraphers are congratulating themselves on the explosive growth of their discipline—when the geologic timescale is becoming ever more complex, when Global Boundary Stratotype Section and Point (GSSP) and Global Standard Stratigraphic Age (GSSA) markers are expanding across the globe, and when new sophisticated methods of stratigraphic analysis dominate geology—a few geologists have been quietly crashing the party. Looking for quantitative ways to understand the sedimentary record at a meta-scale, seeing it as a fractal output of a 'stratigraphy machine', they examine the self-similar properties of sedimentary layering and arrive at startling conclusions that appear to invalidate two centuries of stratigraphy.

Stratigraphy has made rapid advances over recent decades. The timescale has become significantly more complex and detailed. Biostratigraphy and isotope stratigraphy have taken advantage of better technology, mathematical tools, and computer data analysis. New methods of dating and analysis, from sequence stratigraphy to cyclostratigraphy to magnetostratigraphy, have taken big strides.

However, in the middle of this rapid growth has come research that could shake the foundations of stratigraphy. A few sedimentologists and stratigraphers have been exploring ideas that challenge key assumptions about the rock record. These researchers have focused particularly on the problems of missing section, apparent piecemeal preservation, and the general incompleteness of the sedimentary record, following the observation of Derek Ager that the rock record is 'more gap than record'. This new approach is seen in a recent paper by Drs R.J. Bailey and D.G. Smith.[1] Additional research into these problems is found in the just-released Geological Society, London, special publication, *Strata and Time*,[2] but this paper will summarize the ideas of Bailey and Smith as of 2010 and note their importance to both uniformitarian and diluvial stratigraphy. Please note that these geologists have no sympathy for creationism, but their work was important enough for prominent geologist Andrew Miall to conclude that they "appear to invalidate virtually the whole of the last two centuries of stratigraphic progress"![3]

This work represents a significant crack in the edifice of Lyellian stratigraphy and, by extension, in secular natural history itself. It may also indirectly point to a paradigm shift of benefit to diluvial geology—a modern perspective on the rock record—that points to how deposition is the result of hydrodynamic action rather than that of hierarchical stratigraphic accumulation.[4] I address six statements of Bailey and Smith[1] that have serious ramifications for stratigraphy (figure 1).

Background

Bailey and Smith believe that stratigraphy should incorporate quantitative methods to evaluate the rock record. They see *sedimentary layering* as a key property and have created a technique called the Layer Thickness Inventory (LTI) that statistically evaluates the thickness of sedimentary layering and its relationship to the frequency at which layers of different thicknesses occur in a given section. Over all ranges of scales of strata, the LTI has shown:

> "… a well-defined power law relationship between layer thickness and the number of layers of that thickness in the section. This scale invariance in layer thickness relationships is the statistical manifestation of the fact that stratigraphic layering shows a similar geometry at all scales and is, in fact, geometrically fractal."[5]

The conclusion that the rock record is a fractal phenomenon is at the heart of their new understanding of stratigraphy. What they mean is that the lenticular geometry of deposited units is *self-similar* from the smallest laminae to the largest basin possible on our planetary scale (figure 2).[7] Likewise, hiatuses show the same similarities on all scales, and because they see loading and unloading in the same way,[8] then hiatuses are likewise fractal.

They have tested their method and found that it "applies to most stratigraphic data series regardless of age, facies, and net rate of accumulation".[10,11] They conclude that, "there may be a general, scale-invariant relationship between layer thickness and frequency of occurrence in the stratigraphic record".[12] This relationship leads them to suggest that:

> "… the fractal layering geometry is a primary stratigraphic characteristic that expresses the scales and frequencies of process related changes in sedimentation on all scales, including the effects of non-deposition and erosion."[12]

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 correspondingly flawed.*	Continuous sedimentation is a requirement of local stratigraphic type sections, including GSSPs. If not, GSSPs are not anchored in the rock record, and exact global correlation is not possible via the sedimentary or derivative fossil records.
Continuity *tends to be a scale-related default assumption in stratigraphic analysis.... 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, laterally as well as vertically. This assumption "works", but has no basis in the rock record. This may suggest that its utility relies more on assumptions than on any strength of the method per se.
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 sufficient preservation of these facies in the rocks. If the record is mostly gaps (at all scales), we cannot know how vertically adjacent layers were originally 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 estimating sediment accumulation. But if net rates are local, rates change over time and the sparse record means we do not know how much of any unit has really been preserved. Observed present day rates are especially poor predictors of rates of accumulation 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.*	The fundamental axiom of historical geology is that rocks and fossils are a coherent historical record by which we can understand the past with scientific certainty. Because much of the record of time is missing, doubt is cast on that premise. 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 is geology's fundamental principle, but any empirical basis for it is called into question by an insufficient sample of the rock record.

Figure 1. Bailey and Smith's revolutionary ideas impact the foundations of modern stratigraphy. Six of their quotes[6] are highlighted, along with a short explanation of their importance. Note that the axiomatic nature of uniformitarianism (bottom) means that *no* empirical sample is sufficient to prove it.

Thus, hiatuses are present at all scales; an inference of the fractal framework, supported by observation of the results of the LTI method in many wells.

This leads them to the idea that:

> "A unifying fractal model … would be consistent with the idea that the complex system that outputs the stratigraphic record—the 'Stratigraphy Machine' (Smith, 1994) operates in a condition of self-organized criticality."[13]

They sum up the revolutionary implications of their work by noting:

> "For more than 200 years, hierarchical systems have seemed the natural basis for classifying strata. The geometrically fractal nature of the layering, without invalidating this approach, provides a quite different way of analyzing the record. It requires accepting the idea that classifications based on layer thickness (Bed < Member < Formation < Group) select arbitrary class limits in what is actually a continuum of layer scales. Class dimensions will vary from section to section and from stratigrapher to stratigrapher for the simple reason that *there are no natural, fundamental, or expected thickness-based stratigraphic units* [emphasis in original]."[14]

Despite their protestation that their work does not "invalidate this approach", it seems clear that it at least challenges some fundamental assumptions of stratigraphy that date to its earliest days, as seen in the following six points.

Point 1: Deposition not continuous

Bailey described the 'Stratigraphy Machine' (SM) as the process, operating at all scales, by which forces of climate, tectonics, eustasy, and fluid dynamics drive the loading and

unloading of the crust, and the subsequent accumulation of rock waste as sediment. He states: "It is manifest, at all scales, by the tendency of the SM to self-organize to a critical condition, on the edge of chaos, in which the perturbations of the system may trigger unloading, i.e. induce the output of a local stratigraphic record."[15] Because it operates at all scales in a self-similar fashion, the record is a fractal manifestation of this machine.

Bailey and Smith argue that if the sedimentary record is fractal in nature and layering is an indication of chaotic changes in deposition over time, then it follows that "any record represents some small, but essentially immeasurable, fraction of the timespan within which it accumulated".[6] This "includes hiatuses on all scales, most of which go unnoticed".[6] That is why Ager's (1973) observation of 'more gap than record' is so powerful. Early geologists thought they could 'read' history up a vertical section of tens to hundreds of metres of layered sediments. On a human scale, outcrops of that scale appeared to be the record of a lengthy history, based on the assumption of Lyellian rates.

But further study has set those outcrops in context. A 10 m outcrop seems insignificant in a basin with 10,000 m of sedimentary rock. Scale drives perception, and even a deep basin fades when compared to sediment accumulating through the depths of time. That is why geologists uniformly speak of anomalously *high* modern depositional rates from nearly all environments and of the relative incompleteness of the rock record.[16] At these observed rates, the rock record should average *hundreds of kilometres* in thickness, not the ~2 km estimated today.[17]

Perhaps the most significant impact of their denial of continuous sedimentation affects the definition of stratigraphic type sections. The new GSSPs require the assumption of continuous deposition because:

> "The requirement for continuous sedimentation across the GSSP level and the bracketing correlation markers is to avoid assigning a boundary to a known 'gap' in the geologic record. This requirement has generally eliminated most historical stratotypes for stages, which were commonly delimited by flooding or exposure surfaces and formally represent synthems."[18]

As deposition is not continuous anywhere, and hiatuses of all scales (mostly unrecognized) exist, then geologists cannot know what sediment they are *not* seeing, and thus cannot be sure that the vertical succession actually represents the record they think it does. Ultimately, it calls into question every GSSP.[19]

Point 2: Sediment accumulation is not continuous

The second point is related to the first but at a larger scale. Bailey and Smith make the point that sediment accumulation is not continuous at *any* scale, if the rock record is geometrically fractal. They bring into the light an assumption that has long stayed in the shadows, calling continuity the "scale-related default assumption in stratigraphic analysis".[6] In other words, people assumed that the scale relative to human experience was the default setting of sedimentation and proceeded to build an entire stratigraphic template on that assumption.

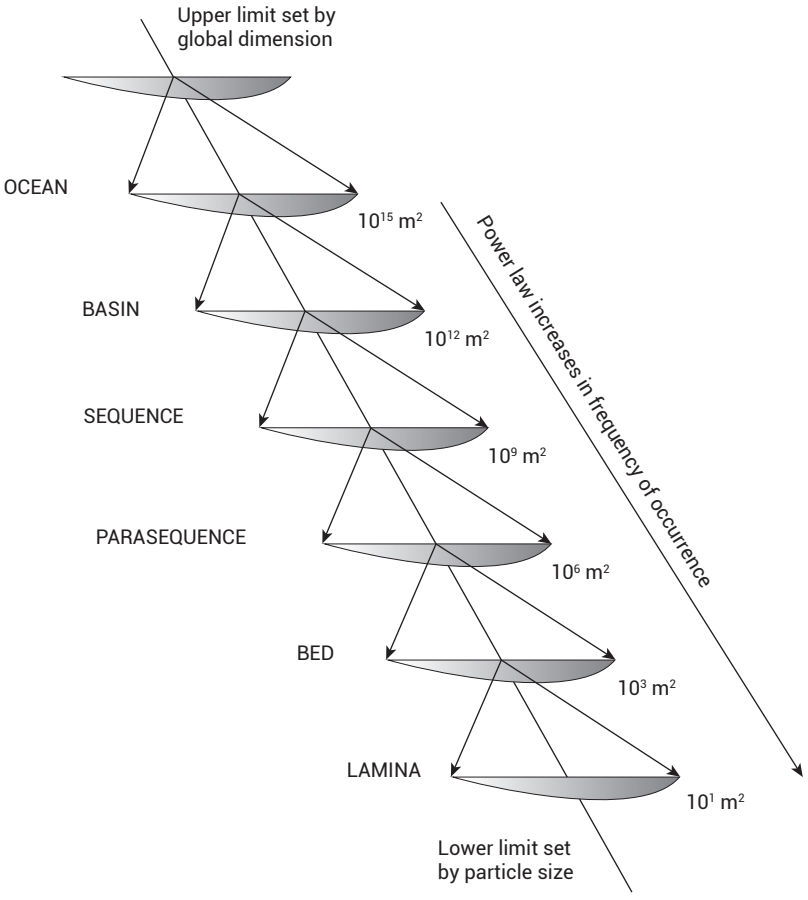

Figure 2. Fundamental geometric units of the sedimentary record are self-similar at the range of Earth scales. 'Ocean' represents the largest possible unit size. (After Bailey.[9])

It is interesting here that Bailey and Smith refer to this default as "operationally convenient".[6] If assumptions drive methods and conclusions, one cannot help but wonder about the importance of data in such a system or what other 'operationally convenient' assumptions are made.

They note that the increasing subdivision of sequences in sequence stratigraphy into smaller and smaller collections of strata and gaps is a tacit admission that the continuity originally assumed in sequence stratigraphy does not exist. In a true hierarchical system, a geologist should eventually reach the scale of the 'fundamental unit'. Sequence stratigraphers may argue instead that the 'bounding surface' (at any scale) is their fundamental unit but a 'bounding surface' is another word for a gap in the record—a representation that left *no* record other than erosional surfaces.

Point 3: Walther's Law on the rocks

Walther's Law is a crucial foundation of modern sedimentary analysis. I have previously noted:

> "Facies are distinct groupings of sedimentary rocks, usually tied to depositional environments, lithology and sedimentary structures. Walther's Law states that, as long as sedimentation is continuous, the vertical succession of facies represents the lateral distribution of facies at the time of deposition."[19]

Given the ubiquitous presence of hiatuses at every scale of the rock record, Bailey and Smith recognize that apparent facies associations in a given vertical sequence may have no real historical lateral relationship to each other because of the unknown time represented by intervening hiatuses. In that case, paleogeographic maps, facies maps, and other interpretations built on the assumption of horizontal facies associations could all be invalid. As they note, "the sequential relationships of the strata are real enough, but the record, which is fragmentary on all scales, provides only rare glimpses of the environmental history".[6]

If that is truly the case, then environmental interpretations, which are a major part of modern geological analysis, would all be suspect to the extent they assume Walther's Law.

Point 4: Accumulation rates unique to time and place

Prior to the application of modern methods of biostratigraphy, radiometric dating, cyclostratigraphy, and magnetostratigraphy, geologists made field approximations of durations based on stratal thicknesses. During the heyday of Lyellian gradualism this was done explicitly; today it is done on a less conscious level. Geologists see a thin layer and think 'short time'; they see a thick layer and think the contrary. Even when dates are available to demonstrate the great age of a thin layer or the rapid emplacement of a thick one, the tendency remains embedded, perhaps simply an illustration of how scale affects our thinking.

Bailey and Smith note that this tendency is without support in reality.[6] They cite the power law decrease of accumulation rate with age,[20] showing (contrary to the supposedly guiding principle of actualism)[21] that not only do modern rates have little to do with the volume or thickness of ancient strata, but one set of rocks of one age in one location cannot be related in this fashion to another set of rocks in another location.

The idea that rocks can be correlated on a global scale by assigning them a specific time of emplacement, and correlating the *time* rather than the rock, is perhaps the fundamental assumption of the geological timescale.[22] If Bailey and Smith are correct, then support for that assumption must be questioned.

Point 5: Rock record does not represent the past

From Steno on, people have viewed stratigraphy as being a *record*. Whether showing the effects of the Flood or of billions of years of gradualist processes, geologists have all assumed the rocks represent history. Cuvier was famous for his analogy between strata and antiquities—both were forensic evidence of the past.[23]

But if the sedimentary record at any one location is nothing more than a collection of 'frozen accidents' lost in gaps of all scales, that assumption appears to be gratuitous. If most of the supposed history is represented by nothing, then most of the time is 'dead time', not 'deep time', and our grasp on history is tenuous at best. The empirical data needed for historical confidence are called into question, much less that needed for scientific certainty.

This is much more damaging to secular geologists than to creationists because they insist on a worldview with a positivist epistemology—one that sneers at the historical testimony of the Bible and insists on 'hard data'. Unfortunately, it turns out that their 'hard data' are nothing more than a house of cards—the major difference being that a house of cards has a more solid framework and a greater ratio of substance to thin air! As Bailey and Smith conclude: "the record may not be representative of this history …",[6] echoing Bailey's earlier statement that "It is the human reference frame that decides what is stratigraphic and what is ephemeral."[24]

Point 6: Last bastion of uniformitarianism crumbles

Uniformitarianism has always been the bedrock of modern geology. As late as 1968, Challinor called it "the fundamental

principle of geology".[25] However, it was at that time that cracks began to appear in the concept. Work by Hooykaas[26] and Gould[27] spurred geologists to re-examine the theoretical and philosophical basis of their 'fundamental principle' and they discovered that they could not even define the term.[28,29] Furthermore, empirical problems were becoming evident and Hutton and Lyell were morphing from martyrs for science to millstones around the neck of geology, especially after the fiasco of decades of blind uniformitarian opposition to the mounting evidence for the Lake Missoula Flood.[30]

Over the next two decades, geologists brilliantly used one problem to solve the other. They claimed that 'uniformitarianism' was not inherently equivocal but had four distinct meanings.[31] Using this 'four-definition solution', they were able to pin Hutton and Lyell to two of them, and then excise Hutton's deistic eternalism and Lyell's extreme gradualism, leaving the term intact, with acknowledged definitions of: (1) general uniformity and (2) Gould's 'methodological uniformitarianism', which spurred a revival in the ironically prior but long-ignored term 'actualism'. As neocatastrophism waxed in popularity, this version of uniformitarianism became embedded—even the geological dictionaries adjusted their definitions to reflect the new reality.[31]

But, as Bailey and Smith note, if "it is not possible to determine whether currently observable sedimentary processes … are of the kind that will provide records in the future …",[6] then neither can we know if they are the ones operating in the past and represented by the rock record. If correct, then the methodological uniformitarianism that restricts interpretation of past processes to the reservoir of those observed in the present is no longer tenable.

This leaves the general principle of science as the only uniformity. Since it pre-dated geology, there is no distinct principle that would prevent geology from being classified as a derivative part of physics, etc. Absent any convincing rationale for its 'fundamental principle', historical geology, which many consider to be the one true distinctive of geology as an independent science, has no solid basis.[32]

Meaning for diluvial geology

If the sedimentary rock record is fractal, with layering and gaps characteristically found at all scales, there are a number of implications for diluvial geology. Two, in particular, are important. First, the six points discussed above provide a skeptical *secular* evaluation of the past two centuries of stratigraphy, especially the assumptions of uniformitarianism and a knowable deep time. It cannot be emphasized enough that creationists have an inherent advantage in their worldview because they interpret empirical data with a completely different worldview. They frame history in the context of biblical revelation. When one must rely on only empirical evidence to support one's natural history, and if the implications of one's own view of the rock record lead to the conclusion that much evidence is lacking, then the natural superiority of the biblical approach becomes clear.

Correspondingly, that implies that creationists who advocate the use of the chronostratigraphic timescale as an *empirical* explanation of the rock record (and a basis for Flood models) should exercise greater caution. The clear inference of Bailey and Smith is that the timescale and its stratigraphic roots in the rock record result from unwarranted assumptions about the nature of the rocks and how they are perceived by people. Ironically, it is their *empirical* LTI analysis that reveals those assumptions, especially those deeper ones regarding the relationship of scale to reality. It reinforces the idea that the timescale is a conceptual template imposed on the rocks, not an empirical conclusion flowing from them.

The second relevant issue for creationists is the need to step away from the assumptions and methods of the early 19th century and see the rocks from a more up-to-date perspective. Bailey and Smith demonstrate that the application of statistical methods to measurements made from natural gamma ray logs yield information about the rocks undreamed of by Lyell, Cuvier, or any of the 19th century 'fathers' of the science. One way of seeing the meaning of their work is to see it as the liberation of sedimentology from stratigraphy. This is pertinent for Flood geology because today's methods allow a more rigorous examination of the Flood from a sedimentological/hydrodynamic point of view.[33] If the movement of water occurred in similar ways across a wide range of scales, then the self-similarity of sedimentary layering and hiatuses may have been a natural outgrowth of the Flood and a way to help us understand it.

The major difference between diluvial geology and the ideas of Bailey and Smith is that layer boundaries may represent near-instantaneous changes in flow conditions or sedimentary sourcing, rather than long periods of time. If that is the case, there is more 'record than gap', and stratigraphy can be pursued optimistically, unlike the realistic pessimism that believes there is very little record remaining. Modern examples of mass flows, hurricane deposits,[34] and lahars show us that sedimentary layering, which Bailey and Smith see as fundamental to stratigraphy, can be the result of variations in transport, not vast amounts of time.

Bailey and Smith draw correct inferences from the set of assumptions they have been dealt. Their pessimism over the possibility of stratigraphic analysis as it has been done for many years, and their fear that there is vastly more gap than record because of the fractal nature of hiatuses, opens the door for diluvial geology to examine the possibility that the apparent vertical progressions in strata are, in fact, real, but are the result of large-scale rapid deposition.

Conclusions

As geologists continue to examine the rock record, those willing to follow the data, such as Bailey and Smith, are finding that the old verities are evaporating in the light of empirical analysis. Their work may represent the beginning of a paradigm shift in stratigraphy. For this reason, creationists should be aware of it and recognize the opportunities it presents, both in critiquing the old stratigraphy and in developing our own unique approach to the rock record.

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