Does Flood Geology explain the rocks in the Grand Canyon?

Reply to Dr. Snelling's Response

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Introduction

Christians have different interpretations of the Biblical doctrine of creation and how to integrate our understandings of scripture and scientific data. As part of that discussion, in 2024, we published a three-part critique of Dr. Andrew A Snelling's papers that proposed to explain the Cambrian-aged Tonto Group in the Grand Canyon as having formed and deformed during Noah's flood (Mitchell and Tillman 2024a, 2024c, 2024b). (Link to critique.) Dr Snelling has now published his response, also in three parts in “Answers in Depth”, a publication by Answers in Genesis (AIG). Links to his response articles are here:

Responding to “Peaceful Science” Critics on Grand Canyon Evidence, Part 1

Tonto Depositional Processes and Rates: Responding Again to “Peaceful Science” Critics, Part 2

The Tonto Deformation: Responding Again to “Peaceful Science” Critics, Part 3

In turn, we here will provide readers with a reply to this response. We hope to clarify a number of misconceptions and misrepresentations and let the readers make up their own minds.

Dr. Snelling has written over 1200 pages in his reports on the Tonto units, including significant appendixes that document his observations and his interpretations. This is one of the most complete efforts to collect scientific data and place it into a flood geology context. We recognize that he has put considerable effort into this project. As Answers in Genesis’ director of research and editor-in-chief of the online *Answers Research Journal*, he has devoted considerable resources to his effort. While his articles include large amounts of repetition, they do provide a strong effort to document both his observations and his interpretation. He has presented his results in many forums, including several that are available online, e.g. Grand Canyon Folds. As far as we are aware, he has not presented his work at any non-YEC forum. He devoted significant effort to going through our articles and we want to present a response that is meaningful. We will not respond to every assertion that he made but will address many of his comments. We will try to avoid character attacks and ad hominem.

Our response to Dr. Snelling’s articles was in three parts, as was his reply. This counter response also has three sections. First, we reply to his Part 1, in particular to: 1. concerns about who we are, 2. his interpretation of the Great Unconformity, and 3. Radiometric dating, a topic only briefly discussed in our articles.

As we reply to his Part 2, we will look again at the deposition of the Tonto units and Dr. Snelling’s proposal that they were deposited over a matter of days in the early part of Noah’s flood. In Part 3, we will look at the objections to our article on the deformation of the Tonto group and his interpretation that the rocks were folded while soft and that they hardened very quickly before the Grand Canyon was carved. We contend that Dr. Snelling has a steep hill to climb because he must show that the data actually support that the rocks were deposited and folded within a one-year long catastrophic global flood, and also that the sediments hardened quickly and then that the Grand Canyon was carved before humans came along. The hardening and canyon carving, in his proposal, all would have happened within a period of no more than 450 years. We find that the geological data do not support these claims. In our articles, we have focused on the technical geologic details and interpretations, not the Biblical interpretation. We believe that the Bible is the inerrant Word of God, but that it does not tell us how old the Earth is or what the geological effects of Noah's flood were.

Reply to Part 1

About ourselves

Dr. Snelling's Part 1 article suggests that we should have begun our article with biographical information about ourselves. Scientific articles are not written that way, any more than Snelling's articles begin with such. Admittedly, we are not as well-known as he is. He quoted the information that we provided on the "Peaceful Science" website about ourselves, and we are quite happy to be known as Christian geologists and are glad that Dr. Snelling makes that clear. Our disagreements on the age of the Earth and flood geology are between believers.

Why were our articles published on "Peaceful Science"? We appreciate Dr. Swamidass' eagerness to engage in discussions on science and faith. A different option would have been to publish them on Steve's website, Jesus in History and Science, but we hoped for a site with more readership to make it more available. The proposal for the papers was submitted to Reasons to Believe (RTB) but after not hearing back from them, we proposed it to Dr. Swamidas and he was quite receptive. He also has indicated that he is perfectly willing to publish articles from a young earth perspective, including responses from Dr. Snelling.

Dr. Snelling writes, "*Dr. Josh Swamidass, Stephen Mitchell and Kennen Tillman profess to be Christian evolutionists. They also wholeheartedly embrace conventional uniformitarian geology.*" (Snelling 2025). It is true that Dr. Swamidas considers God to have worked through what we see as evolution to populate the Earth with life. Steve considers himself an Old Earth Creationist and has written extensively on this both in his book, *A Texas-Sized Challenge to Young Earth Creation and Flood Geology* (free download available here: Link) and on his website: Jesus in History and Science. He recognizes that many times God probably worked through natural selection and mutation, but believes that God worked more directly at times, particularly in events such as the origin of life and human beginnings with Adam and Eve. Ken believes that God created the universe and the world over deep time, but the details of neither geologic nor life's history are revealed in the Bible. Ken particularly believes that the focus in faith should be on sharing the gospel of Jesus. Christians should focus on countering the philosophy of naturalism, the view that only natural processes work in nature, to the exclusion of supernatural actions, such as actions by the God of the Bible.

How do our perspectives shape our conclusions?

Dr. Snelling's phrase "*conventional uniformitarian geology*" (Snelling 2025) could be used to explain our understanding of Earth's history, but the word "uniformitarian" can be misleading. Conventional geology, over at least the last hundred years, has **not** held that Earth's past as shown in rocks is just a record of the same processes and rates that we observe today. It recognizes that catastrophic events have taken place and that rates have varied tremendously at times in the past.

It is important to recognize that both mainstream geologists and young earth creationists (YEC), such as Dr. Snelling, use data from the present to try to explain how rocks formed in the past. Sometimes it is used as a contrast, such as to say that we see such and such a rate now, but it must have been different in the past, based on the physical characteristics of both. In his 2009 book, *Earth's Catastrophic Past*, Dr. Snelling uses things like modern examples of flood deposits, rapid deposition after the eruption of Mount St Helens and floating forests of Spirit Lake as keys to understanding the past (Snelling 2009a). He uses publications of current rates of river salt and sediment flux to extrapolate into the past, though we would argue inappropriately.[1] Repeatedly he points out that modern wind deposits typically have little mica as "a present is the key to the past" example to argue that ancient sands were not formed by eolian (wind-driven) processes.[2] Clearly, he believes that the present is a key to the past at times.

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[1] Discussions of these YEC claims are found here: The Salty Sea and Deep Time and Ocean sediments and Deep Time

[2] We agree that micas, such as muscovite and biotite, are less common in eolian sand dunes. It is not true that they are never found in eolian dune deposits (Alshakr et al. 2026; Benaafi and Abdullatif 2015; Hubbard et al. 2018; Marković et al. 2024; Muhs and Budahn 2019; Purtill et al. 2019; Zhu et al. 2021). (Zhu et al. 2021; Muhs and Budahn 2019; Alshakr et al. 2026; Purtill et al. 2019; Marković et al. 2024; Hubbard et al. 2018). Consistent with flood geologist reports from ancient units interpreted as eolian dunes, muscovite percentages are small and the size of the flakes found are small. We find that the assertion that mica proves that sediment was deposited by water to be disproven (Borsch et al. 2018; T. Helble 2024; T. K. Helble 2026).

Dr. Snelling writes:

> "*At its core is the belief that only natural processes "must be" used to explain the earth's past history. **God is not involved, only nature operates according to the processes and their rates that we observe today**, only "the present is the key to the past." Since we have never observed a global Flood cataclysm, then one never happened*." (Snelling 2025) *Emphasis in the original*.

Snelling has assumed the assumptions we used. Assumptions are important. Steve has reviewed the assumptions which he makes in assessing the age of the Earth and flood geology, both in his book and in this blog post: Comparing Assumptions for the Age of the Earth and Deep Time. If the claims are that the Earth's rocks are less than 6,000 years old and that Noah's flood was a one-year-long global catastrophic event, resulting in strata such as the Tonto group, then it is important to test that without using circular logic. We are accused of this, but the assumption that the YEC interpretation of Genesis is the only viable option and that the rock record must fit into it is equally concerning. Dr. Snelling writes:

> "*Put bluntly, were these geologists present to observe the deposition of these sediments in question? For example, did they observe mud cracking? Or the slow preservation of traces left by animals? No! Instead, they interpret features such as purported mud cracks and trace fossils as requiring slow depositional processes with pauses in sedimentation because that is what we supposedly observe today. **What they claim are "data" is actually a mixture of observations of rocks and fossils and interpretations of that evidence, based on uniformitarian assumptions**.*" (Snelling 2025) *Emphasis in the original*.

Snelling makes this type of statement several times. It works both ways. What we have are observations that we try to explain. We have to try to examine the data fairly that is reported to see if they support the interpretations given. In this case, we compare the data presented by Snelling and other investigations to see if they support Snelling's timeline and the processes that his interpretation demand. No, we were not there and neither was he. We cannot assume that the Earth is old and he cannot assume that his interpretation of Genesis is true in order to prove his case.

Through these responses, several times Dr. Snelling complains that we have compromised our commitment to scripture and sold out to "uniformitarian geology". For example, he states:

> “Now that we have established the a priori and anti-biblical commitment of Christian geologists Stephen Mitchell and Kennen Tillman to the modern uniformitarian geological interpretation of earth’s past history, it is easy to understand their claimed critique of young-earth creation geologists’ claims about the Grand Canyon.”(Snelling 2025)

It is certainly true that we have concluded that the Young Earth Creation (YEC) interpretations of both Genesis and of the Earth’s geology are invalid. In our response to him, we tried to evaluate the geologic data that Dr. Snelling reported. Of course, we bring in our experience and knowledge. Does Dr. Snelling find what he is looking for because he begins with his conclusion? Here is a statement from Snelling available on YouTube, recorded *while he was on the expedition to sample the folds* in the Grand Canyon:

> “As a Christian, I believe that God’s word is a record, and eyewitness account of what happened, and therefore as a scientist, I can expect that the evidence in God’s world will confirm what we have already read in God’s word.” (Midwest Creation Fellowship 2023)

This confirms that he was not unbiased. Dr. Snelling went looking specifically for data that could be shown as fitting his firmly held interpretation. This does not invalidate his observations, but does say that he can be biased in his interpretation. The question that we continue to address is: did he actually find it?

Two other general complaints that Dr. Snelling makes are: 1) That we have not detailed all of the alternative explanations that YEC writers have made to explain the various features that he describes in the Tonto, and 2) that neither Ken nor Steve have personally visited and studied the outcrops that he describes. First, regarding the various explanations that YEC have given, we have read YEC literature extensively and will deal a bit more with it in this response. As a generalization, it is worth pointing out that just because an explanation has been proposed does not make it adequate or valid. We will look at some examples where in our opinion, the explanations fail. Flood geology still needs to explain the observations in geology more effectively.

Regarding the second complaint, he is, of course, right that this is a bit of “*armchair geology*” as he terms it. We bring to bear our experience in other areas. We can also draw on the cumulative expertise of many other researchers in the well-developed fields of structural geology, sedimentology and stratigraphy. Of course, we would like to have the time and funding to do our own onsite investigation. We are trying to assess – did Snelling prove his case? He has provided many photographs of the described folds in his various articles and in most cases, other photographs are available. Many key characteristics are visible. We can, as he does, leverage many studies of the Grand Canyon geology that have been done. Dr. Snelling provided photographs of the samples that he collected. He should not complain that we have studied these photographs. We sent Dr. Snelling a request to use his actual photographs in our articles but never heard from him. We would like to have used his photographs to show interpreted and uninterpreted versions of the folds and slides. Without that permission, we chose to provide our interpretation of folds where we did not have access to photos and interpretations of a selection of the thin-section slides. We shortened and reduced the number of images several times, trying to keep our articles as short as we could, in order to hopefully expand the number of people who would actually read them. We also offered to provide him with a copy of our papers before they were published, but apparently this did not interest him at that time.

The articles that Dr. Snelling wrote and ours deal at times with detailed geologic data. We expect that some non-geologists will see these as technical details that may not really be that important. These are not small details. Here is an analogy. When a car's wheel rim is damaged, it must be replaced. However, not just any rim will do. It must be the right size and beyond that, the holes must line up. Otherwise, it just won't work. This is just like the situation with the deposition and folding of the Tonto units. The holes just don't line up. Table 1 illustrates this.

Below is **Table 1,** as shown in our article, but with some remarks updated (Mitchell and Tillman 2024a). This summarizes our findings and shows the sharp contrast in our perspectives on the units in question. We find that the interpretation, the holes just do not line up with the data using the flood geology interpretations.

	Old Age Models	Flood Geology Models	Comments
Depositional Processes and Rates			
Basal Surface	🟢	🔴	*Weathered sections beneath the surface are a problem for FG. Different ages and lithologies of rocks above the Great Unconformity are problem in calling this the base of deposits from Noah's flood.*
Tapeats SS, Bright Angel FM & Muav Ls			
Petrology	🟢	🔴	*The sorting and rounding of grains suggest time in transport. Overall source of sediment problematic for FG. The presence of oolites required a duration of time to form.*
Areal Extent	🟢	🟢	*Broad areal extent of sands are consistent with either option. Continuous deposition across the Great Unconformity in some areas is concerning for FG*
Basal Breccias & Conglomerates	🟢	🟡	*Perhaps the basal breccias and conglomerate could be fit into a FG model, but need not.*
Channels	🟢	🟡	*Although the channels do not compare to recognized deepwater channels, they may not rule out FG origins. Fluvial braided streams would not fit FG models.*
Sedimentary Structures			
General bedding style	🟢	🔴	*One would expect massive, chaotic beds throughout and a dominance of upper flow regime bedforms that are not observed.*
Herringbone Cross-stratification	🟢	🔴	*Diagnostic features for tidal deposits demonstrate normal tidal cycles over periods of time that were too long for FG models.*
Mudcracks	🟢	🔴	*Indicative pauses in sedimentation that allowed subaerial exposure and drying are incompatible with FG. Tracks on mudcracks and other characteristics prove that some were not syneresis or diastasis cracks.*
Biologic Indications			
Fossil occurrence	🟢	🔴	*Lack of expected modern forms inconsistent with YEC explanation that all kinds created before the flood.*
Ichnology	🟢	🔴	*Multiple bioturbated horizons showing normal distribution of feeding and resting behavior would not have been possible with flood predicted rates of deposition.*
Muav Ls Reefs	🟢	🔴	*In situ stromatolitic reefs well above the Great Unconformity in Cambrian contradict FG.*
Structural Deformation			
Macrofeatures	🟢	🟡	*Timing and modeling of the folding not explained by FG models. Features result from flexural folding of hardened rocks. Precambrian rocks were also folded and these certainly hardened prior to the folding.*
Microfeatures	🟢	🟡	*Lack of "metamorphosis" of the sampled slides is not surprising. Other analog areas also interpreted as flood deposits do show expected characteristic. Slides show shearing, fracturing of grains and other features consistent with the deformation of hard rocks.*
Diagenetic timing	🟢	🔴	*Quartz overgrowths required much time to fill the pore spaces. Fractures cut through the cement and sand grains. Rocks had to be hardened prior to the carving of the canyons. Canyons were cut slowly as the plateau was uplifted.*
General Age Model			
General validity of technique	🟢	🔴	*YEC explanations do not explain why many independent radiometric techniques all point to an ancient earth. Accelerated decay would have wiped out all life from the planet.*
Consistency in Tonto Group	🟢	🟡	*Samples through canyon consistent with depositional order. Multiple populations of grains are found. Some were formed in the Precambrian, while some were formed closer to the time of deposition. Snelling sampled one tuff that could be anomalous but this must be confirmed.*

Table 1*: Updated with new comments from our article. Comparison of strength of models:* ***Green*** *symbols reflect that the data is consistent with the model.* ***Red*** *lights are given when the data are not consistent with the model.* ***Yellow*** *lights reflect some uncertainty, suggesting that there could be scenarios that might fit. Some are* ***light red or light green*** *suggesting that there is overall agreement or disagreement, but some data has not been completely resolved. (FG=flood geology)*

Great Unconformity

Dr. Snelling takes exception to our characterization of the basal surface, the Great Unconformity as a green dot on Table 1 of Part 1 of our articles. He reports:

> "*However, they never mention its areal extent, nor the areal extant of the Tapeats Sandstone and its equivalents. Even in the conventional uniformitarian literature, the Great Unconformity is documented as an almost global erosion surface. Then sitting on top of that Great Unconformity erosion surface is the Tapeats Sandstone and its equivalents, which can be traced in outcrops and drill holes right across North America across northern Africa into the Middle East (Fig. 2) and is also seen again in eastern China and South Korea.*" (Snelling 2025)

We certainly agree that over large parts of the Earth, the top of the Precambrian rocks is an erosional surface. That does not mean that all of this erosion took place simultaneously. In our Part 2, we reported that today's geologists, such as Dr. Karl Karlstrom, consider the Great Unconformity to have been formed by multiple erosional episodes (Karl E. Karlstrom 2019). Important to this discussion is what lies on top of the Great Unconformity. Dr. Snelling, following on from work by Dr. Timothy Clarey, published a map showing extensive sand at the base of the Sauk megasequence. Clarey reports: "*Although there is an extensive blanket sandstone (Tapeats equivalent) at the base of the megasequence, sandstones only make up about 17% of the entire Sauk sequence*." (Clarey 2020, p 197)[3] This interpretation of the base of the sequence is at variance with most workers. Clarey and Snelling consider the sandstones above the Great Unconformity to be equivalent and hence, one extensive sand system, but geologists have long recognized that the sands were not contemporaneous. **Figure 1** shows that sediments above the Great Unconformity are of a variety of ages, ranging from the Ediacaran to lower Ordovician (Dhungana and Flament 2026; Snelling 2025). Sands were often locally derived, usually arkosic, with fragments derived from granites beneath them. A more likely explanation is that sands were shed off of highs and deposited as beds of sand of different ages.

Does this unconformity support, much less demand, a catastrophic flood to explain it? It is quite true that geologists debate the causes that led to this widespread erosional surface. Some propose that the unconformity is at least in part a result of a major glacial episode (Chakravorty 2019; Keller et al. 2019).

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[3] Steve has written a review of Dr. Clarey's book, *Carved in Stone: Geologic Evidence of the Worldwide Flood* can be found here: [Book: Carved in Stone by Dr. Timothy Clarey: An Old-Earth Response]

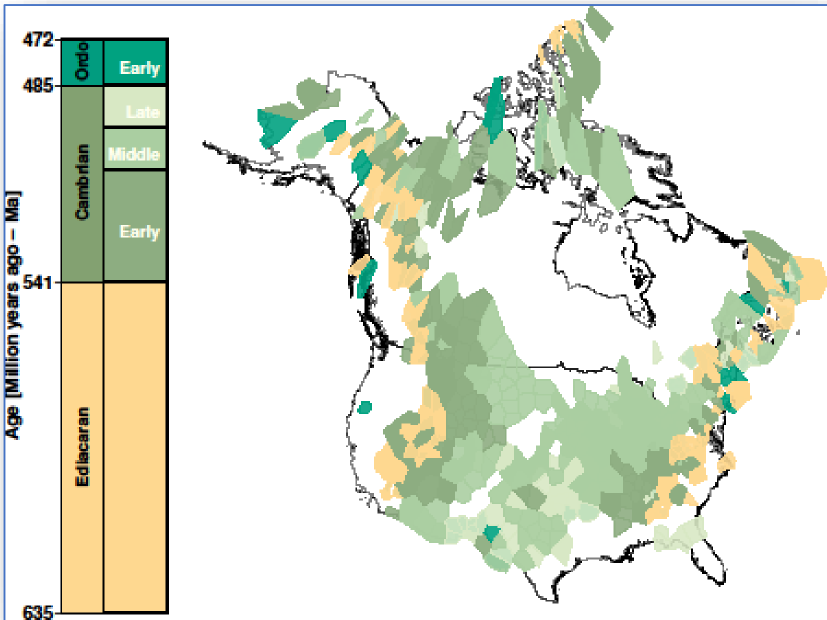

Figure 1. *Map of the stratigraphic age of units sitting above the Great Unconformity in North America. Used with permission from Dhungana and Flament 2026. Dr Dhungana graciously provided this version with just North America. The areal extend shown here is very similar to Dr. Snelling's Fig. 2.*

A different and more common view is reflected by this quote from Shahkarami.

"In most places, the Great Unconformity is a composite. It is actually a composite sequence boundary resulting from successive eustatic episodes of sea-level rise and fall overprinted by multiple tectonic events of subsidence and uplift. This surface should not be used for inter-basin correlations." (Shahkarami et al. 2020)

Such tectonic events can be broad and widespread and as such, they have to be considered a plausible if not far more probable explanation. The different ages of sediment above and below this unconformity are consistent with multiple tectonic events and erosional episodes. (Flowers et al. 2020; Lee et al. 2021; Sturrock et al. 2021; Shahkarami et al. 2020).

Dr. Snelling and a number of other flood geologists consider the Great Unconformity[4] to be the base of global catastrophic flood deposits that include Paleozoic, Mesozoic and, in some interpretations, much of the Cenozoic record. However, what we see setting on the Great Unconformity surface is a wide variety of sediments of different ages. Even Clarey (2020) includes shales and limestones on these surfaces extending across extensive areas. Dr. Snelling lumps all these together and treats them as if they are all part of a uniform sandstone sheet at the Cambrian level that spans a significant part of North America. The limestone stromatolitic reefs of Cambrian age and found in many regions are particularly

[4] Recently the National Park Service has begun to use a more detailed terminology (National Park Service nd). Where the crystalline basement rock meets the Tapeats it's called the "Great Unconformity". Where the tilted rocks of the Grand Canyon Supergroup meet the Tapeats, they refer to it as the "Great Angular Unconformity". Where the crystalline basement meets the bottom of a Grand Canyon Supergroup layer, it's called the "Great Nonconformity".

difficult to reconcile with considering the Great Unconformity as the base of flood deposits, but this will be addressed further later.

Radiometric dating

In our Part 1, we pointed out a series of four questions that flood geology answers very differently than the consensus of modern geology. We proposed that these were each critical to YEC flood geology, while for the Tonto units, the answers could be very different without significantly impacting the overall validity of the consensus processes or timing. If one unit were deposited very quickly, that would hardly mean that many others were, regardless of the processes, but if the Tonto were deposited over even a five-year period, the flood geology narrative would be invalid. If it were deposited by normal tidal processes, then that would contradict the flood geology model. If the folds developed over a few years, instead of millions of years, it would mean re-interpreting the geologic history of the area but would not prove flood geology. By the same token, a slow folding history would sharply contradict the YEC flood geology proposal. How about the general age model?

Dr. Snelling (2025) has paraphrased our statement to read *"However, they have thrown down the proverbial gauntlet that "if any of these four questions can be demonstrated not to be reconcilable" with old-age models, then it makes the "entire" old-age model "questionable.""*

Recognize that the relative age of the rocks does not depend on how many million years old the rocks are. Geologists (or natural historians, as they were then known) recognized that the earth was much older than 6000 years in the 1700's, long before the first rock was radiometrically dated in 1905. They recognized that the rates demonstrated by the events recorded in rocks imply great amounts of time. The absolute ages, the millions of years, are based on radiometric dating, but depositional processes, folding of rocks and tectonic processes provide many evidences that the earth is far greater than 10,000 years old. For most of the rock record, Snelling's preferred timeline makes them even younger, less than 4,350 years old.

We will not go here into detail on radiometric dating and methodologies. That has been done before and still holds.[5] In this section, we will point out that Dr. Snelling and other YEC

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[5] Examples include: Assessing the RATE project by Randy Isaac, Radiometric Dating: A Christian Perspective by Roger Wiens; Misunderstandings Concerning the Significance of AMS Background ^{14}C Measurements by Taylor, et al.; Radiometric Dating Does Work! by G. Brent Dalrymple.(Isaac 2007; Wiens 2002; Taylor et al. 2018; Dalrymple 2000)

authors recognize that radiometric dating does reflect the same order of rock formation that we see in the rocks and that it shows that vast amounts of radioactive decay have occurred. If this is true, then how do YEC explain these facts? We will briefly give the most common YEC explanations and also why these are not accepted by non-YEC scientists. Dr. Snelling referenced an article of his, with what he sees as invalid assumptions in radiometric dating. Do these mean that radiometric dates are useless? We will give brief arguments against that, quoting works by Dr. G. Brent Dalrymple, formerly of the USGS, now a professor emeritus from Oregon State University and a recognized expert in this field. Then we will briefly discuss the results that Dr. Snelling provides from the Tonto Group in the Grand Canyon.

YEC general explanations

Comparing the age models for an old Earth vs. a young Earth in the Grand Canyon is not a matter of whether the age of the Tapeats Sandstone is 500 million years old vs. another ancient age such as 200 million years old. For the young Earth interpretations to be valid, they depend on demonstrating that the Earth is really less than 10,000 years old. They must explain effectively why all radiometric clocks are wrong. It is not as if there were only one methodology that give ages that contradict young earth timelines. For this hypothesis to work, it would seem to mean that by a miraculous method, many independent decay processes were all deliberately set for the apparent purpose of confusing future investigators.

YEC really need to show a reliable clock from nature that tells us that the Earth is only a few thousand years old. The Bible never tells us how old the Earth is, nor when Noah's flood occurred nor its areal extent. What is at stake is not the Bible, but the YEC interpretation of it. YEC writers recognize that radiometric dates, despite problems that they perceive in many results, give data that is useful. They represent real data that must be accounted for. Dr. Snelling (Snelling 2021b) wrote*:*

> *"However, it could be argued that the accepted radiometric ages of the various Grand Canyon strata, including the basement granites and schists, date those rocks and strata in the **correct relative order, and consistently in hundreds of millions to almost two billion years**, except for the recent lava flows in the western Grand Canyon (Wiens 2016)." However, Vardiman, Snelling, and Chaffin (2005) have demonstrated from six lines of evidence, supported by experimental results, that the reason for this systematic consistency of radiometric ages in the Grand Canyon stratigraphic sequence is because during some catastrophic event in the past there was **a systematic acceleration of nuclear decay rates, potentially by six orders of magnitude.**"* *(Snelling 2021b) emphasis added*

This understanding reflects considerable effort in the "Radioisotopes and the Age of the Earth" study (R.A.T.E.) by many of the most prominent names among flood geologists, including Steven A. Austin, John R. Baumgardner, Steven W. Boyd, Eugene F. Chaffin, Donald B. DeYoung, D. Russell Humphreys, Dr. Snelling, and Dr. Larry Vardiman. (Vardiman et al. 2005, 2000) [6]

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[6] *In order to reflect YEC views of radioactive dating accurately, here is an extended quote from Vardiman, et al, (Vardiman et al. 2005)*

"By the time the first book was published by the RATE group [Vardiman et al., 2000] the majority of the RATE group had decided that accelerated decay would be the primary research hypothesis, but that the other two concepts should be investigated as well. In fact, the final explanations offered by this study are actually a combination of all three hypotheses. ***Accelerated decay during several periods of earth history became the primary hypothesis because of the strong physical evidence the RATE group had accumulated that a large amount of nuclear decay had indeed occurred in the rocks themselves after their initial creation.*** *This evidence suggested that most of the decay occurred during Creation week events, but also that a large amount must have taken place during the Genesis Flood. The RATE group considered the possibility that a substantial amount of decay might have occurred during the Judgment in the Garden of Eden, but then it was concluded that the implied levels of radiation and heating would have been so highly destructive to biology at that point in earth history as to render this possibility unlikely. The evidence for these conclusions comes from the physical presence of fission tracks, radiohalos, and residual He in rocks that contain U and other radioactive elements to be discussed shortly. Most creationists who had previously addressed these issues did not fully appreciate the evidences for radioactive decay beyond the chemical presence of the daughter isotopes themselves. Most believed that the large quantity of daughter isotopes observed today was primarily God's doing during Creation, that is, the concentration of daughter isotopes was non-zero when time began. If this were in fact the case, then the problem could be solved simply by resetting the radioisotope clocks to account for this initial inventory of daughter isotopes. However, the physical evidence argues otherwise. There are many independent lines of evidence that large quantities of daughter isotopes were formed since Creation and even since the beginning of the Flood! These findings and assertions are major departures from the previously-held understanding in creation science.* ***They not only force creationists to discover a much more complex scenario for the decay of radioisotopes than has been considered in the past,*** *but they also require us to link such an explanation to serious Biblical and scientific constraints. Either accelerated radioactive decay accounts for the large daughter isotope residues in a short period of time, or a large amount of decay occurred at conventional rates and the earth is old. The RATE group now believes that an old-earth concept can be refuted on Biblical as well as scientific grounds, and also offers a plausible*

It is very significant that YEC recognize that radiometric dating results are not random but provide ages that reflect the real stratigraphic order in which rocks were formed. They also recognize that the radiometric decay calculated was real, not an artifact of some flawed physics. The physics that forms the basis for the analysis is robust. Certainly, there could be cases where the sampling was poor or the analysis was done incorrectly, but there is no denying that real data supports the calculated ages.

Even so, Dr. Snelling claims that radiometric dating is hopelessly flawed. What issues do YEC consider critical failures for these techniques? Dr. Snelling referenced his article: "*Radiometric Dating: Problems with Assumptions*" where he presents three "unproven assumptions" that he believes invalidate radiometric dates (Snelling 2009b). They are as follows:

> *Assumption 1: Conditions at Time Zero*
>
> *Assumption 2: No Contamination*
>
> *Assumption 3: Constant Decay Rate*

Regarding Assumption 1, Snelling himself reports:

> *"For the other radioactive "clocks," it is assumed that by analyzing multiple samples of a rock body, or unit, today it is possible to determine how much of the daughter isotopes (lead, strontium, or neodymium) were present when the rock formed (via the so-called isochron technique, which is still based on unproven assumptions 2 and 3)."* (Snelling 2009b)

What he is saying is that for commonly used isochron techniques, known as "age-diagnostic diagrams" there is no requirement of knowing or assuming the original amount of the parent or daughter product. Thus, Dr. Snelling recognizes that at a minimum, for some techniques, his unproven assumption 1 is not an issue.

Dr. G. Brent Dalrymple addressed both of the first two assumptions in his book, "The Age of the Earth" in this quote:

> *"As we have seen in the preceding discussion, most of the simple accumulation methods are encumbered with two requirements: (1) that the amount of initial daughter be known, and (2) that the rock has remained a closed system since formation. But how can we find the quantity of initial daughter or determine that the system has been open or closed? These seemingly formidable problems can be solved by the use of simple graphic devices*

> *explanation of how and when large quantities of nuclear decay occurred in a young-earth time frame." (Vardiman et al. 2005)* ***emphasis added***

> *that we will collectively call age diagnostic diagrams. These diagrams and their mathematical equivalents not only provide an age, but some provide an exact measure of the initial daughter, some provide an age for systems that have not remained closed, and all are self-checking. They are especially useful on old rocks with complex histories, and are the basis of most of the radiometric evidence for the age of the Earth." (Dalrymple 1991)*

How does this work? For instance, sometimes different minerals in different parts of an igneous body are sampled. It is unlikely that mineral grains distributed like this would have all been contaminated alike (Dr. Snelling's unproven assumption 2). In isochron plots, open systems will show as scattered points, while closed systems will align, providing a measure of both the age and the original amount of the parent element and a check for the presence of contamination.

Dr. Dalrymple also addressed Dr. Snelling's third unproven assumption issue:

> *"There are two basic reasons why significant changes in rates of decay are not expected. First, the nuclei of atoms are extremely small and well insulated by their cloud of orbiting electrons. These electrons not only separate nuclei sufficiently that they cannot interact, but also provide a "shield" that prevents ordinary chemical or physical factors from affecting the nucleus. Chemical activity in an atom, for example, occurs almost entirely among the outermost electrons and does not involve the nucleus at all. Likewise the "compressibility" of a substance may result in slight changes in the configuration of electrons but has no effect on the nucleus.*
>
> *Second, the energies involved in nuclear changes are 10^9 times greater than those involved in chemical activity and 10^4 to 10^5 times greater than the energies that bind the electrons to the nucleus. .. Except for nuclear reactions, such energies are generally unavailable in natural processes such as those that form, change, and destroy rocks on the earth and in the Solar System.*
>
> *It was not long after the discovery of radioactivity that experiments were conducted to determine whether or not the rates of radioactive decay could be changed (Emery, 1972: 766, Hopke, 1974: 517). In 1907, Rutherford and a colleague, J. E. Petavel, placed a sample of radium "emanation" (^{220}Rn, radon) in a steel-encased cordite bomb. They observed **no change in the activity of the sample even though the explosion** generated an estimated temperature of 2,500°C and pressure of 1,013 bars. Madame Curie and M. Kamerlingh Onnes found in 1913 that lowering the temperature of a radium compound to the boiling point of liquid hydrogen (-252.8°C) did not change the radium activity by more than 0.05%, if at all. Other experiments involved varying gravity by measuring the rates on mountain tops and in the depths of mines or by whirling samples in a centrifuge; in yet others the samples were subjected to magnetic fields of as much as 8.3 teslas. **These early experiments and subsequent ones involving extremes of temperature, pressure, chemical state, and electric and magnetic fields have uniformly failed to induce any changes in the decay rates of a wide variety of alpha and beta emitters.**"* (Dalrymple 1991) Emphasis added

This does not prove that small changes in nuclear decay rates could not have occurred, but to support a 6,000-year-old Earth, such changes would have had to be enormous and also all worked alike in the isotope's decay rates for many different elements. Dr. Snelling and other YEC authors have claimed that there is scientific evidence to support their interpretation of accelerated radiometric dating during creation week and during the flood, but it is unpersuasive to non-YEC scientists.[7] They also propose mechanisms to explain how this decay occurred without the associated heat melting the earth or the radiation killing all of life. Again, the evidence is not persuasive. [8] (Isaac 2007; Loechelt 2020)

Dr. Snelling considers the top of the one-year catastrophic flood deposit as the top of the Mesozoic erathem (rocks deposited during the Mesozoic era, regardless of when that was). That would then mean that the accelerated decay, with all of the inherent radiation would have had to occur essentially throughout the entire post-flood Cenozoic period, yet life clearly thrived through this period. If such an accelerated event actually occurred, it is very confusing to try to place it. Given that Dr. Snelling dates Noah's flood to 4350 years ago and Abraham lived about 4000 years ago (in geologic terms, late Holocene), that means that almost the entire Cenozoic record would have been deposited in about 350-450 years. When did the accelerated decay cease?

While the RATE project's proposal of accelerated nuclear decay is clearly motivated by a sincere desire to reconcile radiometric dating with a young-earth timeline, it introduces insurmountable physical paradoxes. If billions of years' worth of radioactive decay were

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[7] Steve wrote about the claimed "helium problem" here: https://jesusinhistoryandscience.com/?p=3729

[8] A second heat associated issue comes from rapid continental movement that is part of what flood geologists refer to as "catastrophic plate tectonics". Dr. Snelling is one of the authors of the original paper proposing that this process occurred during Noah's flood (Austin, et al., 1994). This was proposed as the cause of the vast numbers of tsunamis that he uses to provide the sediments of the Tonto group and much of the geologic record. Accommodating recognized plate movements within a one-year timeframe means that whole continents had to average rates of meters per second. That is an astounding proposal! There are numerous issues involved in this, including a heat concern. Sean Ovis commented:

> "*Plates currently move at cm per year. If you increase the speed to metres per second, then you are increasing the rate by a factor of over 3 billion. That means the kinetic energy involved in moving the plate increases by a factor of around 10^19. Putting aside the issue of where the energy comes from, it is where the energy goes to that is the problem.* ***Stopping a continental plate moving at metres per second would generate phenomenal amounts of heat - quite sufficient to melt the plate***." (Sean Ovis, personal communication) Emphasis added.

I (Steve) remember waiting on my brakes to cool while driving down mountains in the Rockies. Slowing down a continent must have generated heat that would be reflected in the rocks. The combination of accelerated radioactive decay and deceleration of continents should have left Earth uninhabitable.

compressed into a single year during the Flood, the resulting release of thermal energy would have been catastrophic. The heat generated would have been sufficient to melt the Earth's crust entirely, while the massive spike in ambient radiation would have sterilized the planet, rendering the survival of any life on the Ark physically impossible. Therefore, the scientific data does not support accelerated decay as a viable mechanism.

Tonto Dating

It is worth looking at some of the more specific points for the Tonto Group. Dr. Karl Karlstrom, et al., (2018; 2020) provided well-constrained radiometric dates that now represent the accepted dates for the formations that make up the Tonto group. They were able to constrain dates for the base of the Sixtymile formation to 541 MYA and the top of the Muav Formation to approx. 499 MYA. Their dating integrates biostratigraphic data, but numerically they are based on their work with detrital zircon grains. Significantly, they base their estimates on the U-Pb age calculations for the average of the youngest population of grains sampled, recognizing that older grains should be present, due to reworking. We are not surprised to see grains from older eroded rock among the sandstones. Snelling recognizes this good work but also claims to have found a bed with much younger zircons in it.

Dr. Snelling reported the following issues:

> *"Although it often produced apparently concordant U-Pb dates (essentially matching ^{206}Pb-^{207}Pb, ^{238}U-^{206}Pb, and ^{235}U-^{207}Pb ages), there were still many detrital zircon grains that yielded illogically younger ages than the supposed depositional age of the Tapeats Sandstone. Recall that Snelling (2005b) reported CA-ID-TIMS analyses of three zircon grains recovered from a thin tuff bed in the Tapeats Sandstone in the western Grand Canyon that yielded concordant ages of 86.2 Ma, 98.2 Ma, and 90.1 Ma. Snelling (2005b) also obtained single zircon grain fission-track ages of 75 Ma, 158 Ma, and 408 Ma that are very much younger than the Karlstrom et al. (2018, 2020) tandem U-Pb ages for deposition of the Tapeats Sandstone. Yet fission tracks are the physical evidence of the quantity of nuclear decay that has actually occurred. These considerations and highly inconsistent results from what is touted as a superior analytical procedure only highlight the unreliability and fallibility of the U-Pb dating method."* (Snelling 2021b p.239-240)

First, what is the significance of the fission track dates? Is this result important? Is this telling us that this unit doesn't fit the recognized age model? Dr. Karlstrom responded to Dr. Snelling's claim as follows:

> *"Fission track dating is a thermochronometer that measures when a zircon grain cooled through the temperature window of 320-200 °C, not when it formed. Within and above that temperature range, the fission tracks in a crystal get shortened and annealed producing apparent younger ages."* Karlstrom, personal communication (2021)

As you can tell from Dr. Karlstrom's comment, what Snelling demonstrated was that the zircons have had complex heating histories, not their actual ages. It is like confusing the tachometer for the speedometer. Both RPM and MPH have units of time, but they are measuring different things. Fission track data gives a minimum date for the rocks, but does not help in determining the actual age. These minimum ages are problematic in themselves for YEC interpretations.

More interesting is Snelling's claim that he found U/PB data that also is anomalous. He references his 2005 chapter in the RATE II study (Snelling 2005). Here he presented U-Th-Pb analysis from six Muav samples and six samples from the same Tapeats tuff for which he reported the fission track analysis. It is interesting that not even one of his zircons gave the results that reflect conventional dates by a number of studies. Three are older, suggesting that older material is incorporated into each of these beds. The rest of the samples range from 68.2 MYA to 425 MYA. How could such data be explained? Snelling proposes that these are the result of accelerated decay during the flood. It is unclear why these two tuff beds would have experienced so much less acceleration than the rest of the rocks. The problem of the heat that might be needed to reset the zircon data is major, especially given that it seems to apply only to a few particular beds. What kind of process picks out just certain grains in a few beds?

Are there other, less complicated possibilities? The age results of Snelling's analysis reflect less lead in the samples than one would expect from older rocks. Dr. Karlstrom noted that "*Pb loss is common for Grand Canyon basement zircons that got reworked into Cambrian strata*". How does this work? Bowring, et al, 2006 reported one possibility:

> *"Experimental measurements of Pb diffusivity in zircon indicate that Pb loss is not likely dominated by volume diffusion, but rather related to loss from radiation damaged domains through crystal defects and fractures. Once the crystal lattice is distorted and damaged, Pb ions have "short circuit" pathways to diffuse from the crystal, resulting in grains that have a deficiency of Pb." (Bowring and Schmitz 2003)*

The zircons that Snelling shows in his 2005 article do not show obvious visual defects and his chemical abrasion is a recommended procedure to reduce risk of this type of errors.

Could there be issues in the beds that Elston (1989) identified as "tuffs"? We asked Dr. Karlstrom and he replied,

> *"There were several beds that Elston thought were tuffs and I have not visited the one at RM 205, but others (RM 179) have turned out to be clastic sedimentary rocks (siltstones) with reworked Precambrian and Cambrian grains and possibly an ash component. I'll try to visit this one and re-sample it next April." ."* Karlstrom, personal communication (2021)

Unfortunately, Dr. Karlstrom apparently did not follow through on this testing. The fact that none of Snelling's zircons fall in the range of Karlstrom's youngest population suggests a different type of process. It seems for now that it is very possible that the "tuff" bed was a clastic bed with Precambrian zircons that experienced enough lead loss to explain Snelling's results. Perhaps we will have documented zircons from above and below the bed that date to more expected ranges and this will constrain the anomalous material. This would be certainly a useful exercise for future study. For now, the results are just anomalous, but not a help for the YEC proposal.

In his response to our articles, Dr. Snelling questions why some of the zircons in Karlstrom's study yielded dates significantly younger than the 507-508 Ma age. Why would that be? We don't have details on the particular samples, but it is reasonable to hypothesize that the Pb loss resulted through the method Bowring proposed. Dr. Snelling also questions this in this quote:

> "*Nor do they explain from where these "younger" detrital zircons within the Tapeats Sandstone originated.* ***Indeed, how could even the 507–508 Ma detrital zircons be incorporated in the Tapeats Sandstone if the underlying rocks that were eroded to provide the sand grains, including the zircon grains, are older than 507–508 Ma?"*** (Snelling 2025) *(emphasis in the original)*.

Dating sedimentary rocks, such as sandstones, requires secondary techniques, such as detrital zircons. If Karlstrom had been able to date an igneous intrusion, the zircons would be from the time of the intrusion emplacement. That was not an option for dating the sedimentary sandstones. Even so, Dr. Snelling recognizes that zircons can be formed in volcanic tuffs. We know that such tuffs can be eroded quickly, and we suggest that such a source is likely where the younger zircons in the Tapeats originated, but this cannot be specifically confirmed. Zircons from igneous extrusive rocks that were eroded soon after their emplacement would give dates close to the age of the sediments themselves. The Tapeats has zircons from a variety of igneous sources, but Karlstrom's youngest set give a good estimate for dating the sandstone.

Summary of radiometric dating

In our stoplight table, for the general age model, we broke that down into two parts: general validity of technique and consistency in the Tonto Group. We considered the overall validity of radiometric dating green for old age models and red for flood geology models. We continue to believe this is accurate. This is especially true if we are asking: does radiometric dating support or contradict the proposal that the sedimentary record in the Grand Canyon above the Precambrian is no more than 4,000 to 10,000 years old?

Regarding consistency in the Tonto Group, we recognize that we don't have all of the answers for details in the Tapeats. While we believe that these could be easily resolved, the nature of real data involves some uncertainty and variability. Hence, we colored these lights appropriately for this. Again, however, we do not know of any interpretation of the radiometric dating in the Grand Canyon rocks that would support the flood geology timeline.

Reply to Part 2

Tonto Depositional Processes and Rates: Responding Again to "Peaceful Science" Critics, Part 2

Not surprisingly, Snelling found disagreements with our paper on the Tonto depositional processes and rates. In his model, most of the Phanerozoic record, representing sediment columns miles thick, was laid down in one year. That dictates enormous rates and eliminates many processes and depositional systems. If any bed or set of beds took longer to form than the one-year timeframe, then they cannot be considered as part of deposits from Noah's flood. Thus, flood geology must provide evidence to support this. In fact, as Snelling hypothesizes and we pointed out in our article, the flood geology timeline means that individual formations and units had to form over just days. This has to further constrain the rates and types of processes that can be considered. We are not saying that no catastrophic processes were involved in the deposition of the Tonto group or its equivalents elsewhere, but are assessing if the evidence really supports that all of it was. Geologists recognize that catastrophic processes have acted in Earth's history. Thus, if we could affirm that they could account for the Tonto group, it would not follow that other formations deposited by different processes were also deposited at the same rates. For instance, whatever rates and processes laid down the Tonto group were markedly different from those that formed the thick salt, gypsum and carbonate units in the Permian Basin interpreted to have been formed in ancient sabkhas (salt flats). Rapid deposition in the Tonto Group would not tell us the rates the Permian units were laid down at.

Dr. Snelling makes a series of complaints regarding our papers that come down to either: 1. we would accept his views if we just had read more of the flood geology literature or 2. "we weren't there". Here are examples:

> "And if Mitchell and Tillman had read the Flood geology literature, they would know that during the global Flood cataclysm, rapid-fire devastating earthquakes were generating multitudes of rapidly consecutive humungous tsunamis that surged right across continents, which have been modeled to demonstrate the Tapeats Sandstone and all the overlying units could easily have been deposited within the Flood year" (Snelling 2026b)

This claim assumes that we have not read the voluminous YEC literature. We have read much, but it would be hard to read all of it. It also assumes that if we had read flood geology literature, we would find it convincing. Would we really "know" that during the flood rapid-fire earthquakes were generating multitudes of rapidly consecutive humongous tsunamis? Snelling writes:

> "Furthermore, Flood geologists have demonstrated by their modeling of ocean water conditions during the global Flood cataclysm that global tides resonated to increase their ranges, super hurricanes were generated by the very warm ocean waters, and humungous tsunamis were generated repeatedly in rapid succession by super-powerful earthquakes as plates moved against one another in lock-steps due to catastrophic plate tectonics" (Snelling 2026b)

This is a great example where we have read many of the key articles and listened to supportive videos and found the catastrophic plate tectonic model unbelievable. The issue is that when we do read the flood geology literature, we find major problems. For example, the individual Dr. Snelling cites, Dr. John Baumgardner (2018a, 2018b; J. R. Baumgardner and Novarro 2023), as having "demonstrated by their modeling" that "rapid-fire devastating earthquakes were generating multitudes of rapidly consecutive humungous tsunamis that surged right across continents" never demonstrated what Snelling is claiming. Dr. Snelling wrote:

> "Furthermore, Mitchell and Tillman note my reporting of the modeling research done by Flood geophysicist John Baumgardner on the catastrophic cavitation that could have eroded the needed clastic sediments (sand, silt, mud) and the humungous tsunamis that could have transported and deposited those sediments, but they omit or ignore his most recently published modeling research." (Snelling 2026b)

Given that our article was written in 2023, as was Dr. Baumgartner's latest article, it is not surprising that we did not include this in our article. We appreciate that John Baumgardner has put in much effort to find a scenario that could conceivably provide a mechanism for the claims by flood geologists. The abstract for his 2023 article begins this way:

> "A major challenge for Flood geology is providing a credible explanation for how the staggering volume of fossil-bearing sediment was eroded, transported, and deposited in orderly patterns on the surface of the normally high-standing continents in only a few months' time." (J. R. Baumgardner and Novarro 2023)

We certainly agree with this statement. Baumgardner and Novarro use a computer model, but that in itself proves nothing. They input the paths for the tectonic movements that were published by conventional paleogeographers, Dr. Christopher Scotese (2021) and Dr. Ronald Blakey. (2018). It is interesting that they use this data, though Baumgardner would not accept much of what supports it. As they use positions and movement based on Scotese and Blakey's work, it is not surprising that the program erodes and deposits sediment in areas that are somewhat similar to what is shown in maps by Scotese and Blakey.

Baumgardner assumes the effect of process of cavitation caused by tsunamis on continents to generate tremendous amounts of sediment. This is a large assumption that does not seem to be supportable. For such an explanation to be viable, it would need to generate a wide variety of sediments that would somehow be separated into beds of very different lithologies. It would need to transform granite into well-sorted sandstones, siltstones and clay-rich shales. It would need to generate lime muds for limestones, dolomitic muds for dolomite (or dolostones), halite for salt formations, gypsum and anhydrite for beds of these rocks, and plant material for coal beds. Most of these are totally missing in Baumgarner's models.

Baumgarner states:

> "We recognize that it is difficult to imagine how feldspar in the continental crustal bedrock, even when reduced by cavitation to 0.063 mm particle sizes and smaller, might be transformed to clay minerals in the brief time span available during the Flood. We acknowledge that a significant portion of the clay in the shales and mudstones in the Phanerozoic sediment record may well have been derived from shales and mudstones of the pre-Flood earth." (J. R. Baumgardner and Novarro 2023)

We would suggest that this is inadequate. Cavitation is the complex physical interaction between collapsing vapor bubbles and solid particles in fluid flows. It is recognized as only a minor process in modern rivers (P. A. Carling et al. 2017), but then what other choice does he have?

How does he deal with the heat generated by the processes? Generating huge amounts of new crust automatically brings with it tremendous amounts of heat, and if this happened in a short time, then what happened to the heat?

Baumgardner wrote:

> "The elevated temperature profile of thin, newly formed ocean lithosphere makes it effectively unsubductable. Were hot lithosphere to cover the entire ocean bottom, subduction would cease and the CPT process would come to an abrupt halt. This illustrates the imperative of a vast amount of **active supernatural cooling** of the ocean lithosphere during the Flood." (J. R. Baumgardner and Novarro 2023) Emphasis added.

This cooling by miraculous means would have been in addition to the cooling essential because of their proposal of accelerated radiometric decay and also the heat generated as the rapidly moving continents were slowed down. Overall, Baumgartner's proposal seems to be an attempt to model a miracle. It is a proposal by faith in scientific wrappings. It was generated by a computer and has equations and numerical values and this will make it accepted by many who cannot really evaluate it.

These models propose a large set of unproven hypotheses that lead to continents moving at meters per second for months and generating sediment flows that traveled at the same or higher speeds. Even if we thought that the mathematical simulations were feasible, so much evidence contradicts them.

> "But how can they be so sure when no geologists were present to witness the deposition of the many sandy layers of the Tapeats Sandstone?" (Snelling 2026b)

The fact is that neither of us were there. Both we and Dr. Snelling are claiming that the rocks are telling us the truth about how they were deposited. When we look at the rocks, we try to integrate all of the data and learn what is the best explanation for how they were formed. In this case, we are not claiming to have many of the details about how they were laid down, but can rule out some proposals, including the claim that they were deposited in a few days or weeks.

Dr. Snelling objected to our statement that thin sections do not tell us the depositional processes or rates. He wrote:

> "Their latter claim is absolutely false! Any seasoned sedimentary petrologist will adamantly assert that microscopic descriptions of the mineralogy, grain sizes, grain

> shapes, pores, and textures are all highly relevant to deciphering the depositional processes and rates. Why then do all sedimentary petrology textbooks contain so many photomicrographs of sedimentary rocks and their textures?" (Snelling 2026b)

It is probably worth clarifying a bit. Our statement did particularly address sandstones as this is the subject here. Thin sections are often useful in carbonates and evaporites, though often they are not required. They are, however, critical for sandstones to understand the post-depositional diagenetic history. Why do petrology textbooks contain so many photomicrographs? Because they are teaching petrology, not depositional environments. Sandstone petrology focuses on the composition and provenance of the mineral grains themselves and then largely on their post-depositional history. In my copy of Dr. Sam Boggs, Jr's book, "*Petrology of Sedimentary Rocks*", I find very little on depositional processes in it, particularly for clastics (sandstones and other rocks composed of transported grains) (Boggs 2009). Grain size and sorting are important, but normally hand lens examination is adequate in regard to identifying depositional processes and rates.

How vital are thin sections in identifying depositional environments and processes? I (Steve) pulled a few books off of my shelves to see: Scholle and Spearing (1982); Brookfield and Ahlbrandt (2000); Walker and James (1992); Davis and Dalrymple (2012); Prothero and Schwab (2013).

> AAPG "Sandstone Depositional Environments" - 404 pages, over 500 photos: 1 thin section photo, 0 SEM photos
>
> Brookfield "Eolian Sediments" - 670 pages: 6 thin section photos, 8 SEM photos
>
> Davis: "Principles of Tidal Sedimentology"- 624 photos: 1 article on carbonates with 18 photos, primarily on oolites
>
> Walker and James "Facies Models" 409 pages: 0 thin section photos, 0 SEM photos
>
> Prothero "Sedimentology Geology: Petrology of clastics chapter with over 20 thin section photos and 4 SEM photos, none in the section on clastic depositional environments. Many slide photos are found in the carbonate sections.

If thin sections are not that diagnostic, how would we learn the depositional processes and rates? Larger features are critical, including: sedimentary structures, the architecture of sandstone bodies and the map patterns of the distribution of features. Interpretations ought to make sense with all characteristics known regionally. Even so, a few features are relatively diagnostic, and we will consider some of these. Sand size distributions and the bedforms of sediments deposited by wind or moving water often form in predictable patterns, as demonstrated in laboratory flume experiments and in studies of recent deposits where the processes were observed. These give us tools to use in examining ancient deposits to characterize their deposition.

We will reply to the objections from Dr. Snelling, grouping the topics in this way:

- Things we would expect to find, but didn't
- Things found that we would not have expected to find

Things we would expect to find, but didn't

Dr. Snelling is correct that we were not there. Just as he references studies of sedimentary bedforms and other characteristics, he recognizes that the sedimentary bedforms that we find or don't find, do tell us about the depositional processes, even though we weren't there (Snelling 2022). Dr. Snelling provides key hypotheses that the rock record can be checked against. He hypothesizes velocities of water currents, and provides duration predictions that dictate average sedimentation rates. These in turn dictate a range in what should be the dominant bedforms through whatever he calls flood deposits. This is not about an interpretation of scripture. It is about does the rock record fit flood geologist's claims.

If the Tonto Group was deposited in a short period by catastrophic processes, we continue to believe that the sediments should reflect this. As noted earlier, Snelling does believe that information from modern processes is useful in assessing the ancient record, such as when he notes that mica flakes are rare in modern eolian deposits. He reports differences between what are found in modern environments vs. the Tonto characteristics. If he can use the modern as a contrast, then the modern is a key means of understanding what is or is not in the ancient record. Of course, a global catastrophic flood would be of a different scale, but there would have been key similarities and some processes just would not have been involved. There is no reason to believe that God suspended the normal physics of how sediments were transported.

Cross-bedding is a common sedimentary structure noted by every observer of the Tapeats Sandstone and Bright Angel Formation. Are what we observe (or don't observe) consistent with the flow rates predicted by flood geology? Planar and trough cross-bedding are common today in many settings. However, the sand bodies and the internal laminations still give us information around how the beds were formed. Sand deposition from moving water forms characteristic bedforms based on the sediment size and velocity. There is no reason to expect that God would have set special rules for flood waters. Snelling gave an estimated "water flow speed of >2 m/sec", presumably as some sort of overall average (Snelling 2021b, 241). For the Tapeats, he predicted that flows "ranged from 1.5 m/sec in the lower parts to 1 m/sec in cross-bedded units (Snelling 2021b, 241). We can compare his predictions with tests where we know the flow rates. (**Figure 2**). If these were large flows moving at the predicted velocities, then one would expect that the original bedforms were antidunes, upper flat bed (one type of parallel laminations) and dunes. Antidunes are described here: Antidune Lithofacies. Few observers report upper flow regime features such as antidunes or parting laminations. All do report low flow regime portions.

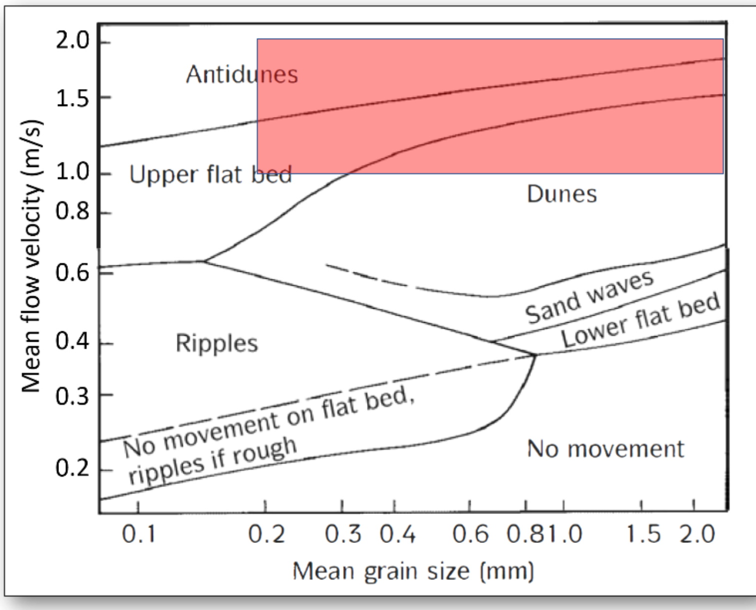

Figure 2: *Relationship between sediment size, velocity and bedforms from physical model studies known as flume experiments. Distinctive bedding and cross-beddings result. Antidunes and upper flat bed features are characterized as "upper flow regime" bedding forms while the others are characterized as "lower flow regime" characteristics (The hydraulics of sedimentation; Flow Regime). (Lewis, 1984)* Tapeats SS grain sizes range from ~0.2 to 2 mm *(McKee, 1945). The red box combines this grain size with Snelling's predicted flow rates.*

Dr. Snelling is not the only YEC to try to explain the Tonto units by Noah's flood. Flood geology writers have several proposals aimed at explaining how units like the Tonto were deposited catastrophically. Guy Berthault used some of his own experiments to put forward the interpretation that layered stratigraphy can develop simultaneously instead of layer by layer (Guy Berthault 2000). This could have merit for small, localized bedsets, but would his ideas scale up for whole formations? That is not the way it works. He proposed this for the Tonto Group in the Grand Canyon:

> "Sedimentological analysis and reconstruction of sedimentation conditions of the Tonto Group (Grand Canyon of Colorado River) reveals that deposits of different stratigraphic sub-divisions were formed simultaneously in different lithodynamic zones of the Cambrian paleobasin. Thus, the stratigraphic divisions of the geological column founded on the principles of Steno do not correspond to the reality of sedimentary genesis." (G. Berthault 2004).

W.R. Barnhart expanded on Berthault's ideas and using observations from the Tapeats Sandstone, proposed to "examine hydrodynamics as a basis for interpretation" (Barnhart 2011). Again, he would have the Tapeats Sandstone as deposited by one or perhaps a few major events. Here are two quotes from this paper:

> "However, hydrodynamic studies of the individual layers demonstrated that strata were laid under catastrophic conditions, with little connection to the suggested facies, indicating that facies models can act as barriers to understanding the rock record." (Barnhart 2011)
>
> "All bedforms suggest rapid deposition under extreme conditions: an overlay of storm waves on a violent flooding event resulted in continuous flooding onto a rapidly accreting surface, with limited evidence of reworking by the sediment-rich current, and no evidence of reworking by tidal currents." (Barnhart 2011)
>
> "Despite many incised channels and evidence of **bidirectional flow**, they were not deposited by tidal currents but by continued catastrophic flooding." (Barnhart 2011) Emphasis added.

To Barnhart's credit, he did reference work in more detail on the Tapeats from outside of the Grand Canyon. He just doesn't deal with characteristics that show pauses in sedimentation. Here he considered how long it would have taken:

> "If a wave train passed a given point every 10 minutes, a depositional rate of only 1.5 m per wave train would deposit the entire 120 m thickness of the Tapeats in only 8 hours. If a wave train striatal package was 3 meters per wave, the Tapeats would have been deposited in as little as 4 hours." (Barnhart 2012)

Of course, Barnhart was ignoring the fact that the Tapeats exists in three dimensions, not just the vertical. Setting aside that inconvenient volumetric problem for the moment, we would not be surprised if some beds and packages formed rapidly. What would we have expected if these formations formed catastrophically?

Megaflood deposits and Megabeds

What type of features should a global catastrophic flood deposit include? We don't dispute that there would be variability. We suggested two analog deposits that provide analogs for what we would expect in a catastrophic deposit that formed quickly and included sediments that moved at his hypothesized extremely high velocities: **megaflood deposits and megabeds**. The analogs demonstrate that geologists recognize catastrophic deposits have been laid down. We looked for the most analogous flow rates and depositional rates, recognizing that in the hypothetical flood model, deposits would be would have been many orders of magnitude larger, but should be expected to share some properties. Dr. Snelling predictably says that anything we use as an analog is invalid.

> "However, these were only one-off localized events and thus cannot be analogues for the biblical global Flood cataclysm during which there were thousands of rapidly consecutive tsunamis that surged right around the globe accompanied by hurricane-force winds." (Snelling 2026b)

What is strange is that in the Tonto formations, if they formed rapidly and catastrophically, the way he proposes, why do they look more like deposits from normal deposition produced by normal water movements? Why don't they more resemble deposits from actual floods with documented extremely high flow rates? Why don't they look like they were produced by huge sediment flows that would add layers at rates on the order of 100 vertical feet per day? Additional photographs of such comminuted (mechanically ground and smashed) materials compared to normal processes are shown by Carling and Fan (2020). Compare outcrops in the Tapeats Sandstone to those from such deposits (P. Carling 2017). It is logical that deposits from a brief global event would include many larger beds and features, such as from megafloods, but it is not obvious why they would not include any features, such as beds dominated by comminuted grains.

The megabeds that we cited are another clear type of rapidly deposited sediment such as might be expected from a dramatically erosional, catastrophic event. Megabeds would particularly have been expected if the depositional setting had been in deep water as interpreted by some flood geologists (Kennedy et al. 1997). However, the Tapeats Sandstone has no equivalent units.

Sixtymile Formation

Dr. Snelling highlighted the Sixtymile Formation as something that we missed that supports his interpretation, apparently considering the breccias from it to reflect catastrophic deposits, somewhat like the megabeds. We pulled out a short section on this formation in an effort to shorten our paper. Although preserved parts of the Sixtymile Formation are limited (**Figure 3**), they show characteristics consistent with deposition over extended periods of time (Billingsley et al. 2019). The Sixtymile Formation is preserved in small areas and deposition was controlled by faults that were active at the time (Donald Parker Elston 1979). The conglomerates, breccias and slide blocks are quite consistent with deposition over time along actively growing fault scarps. Most geologic interpretations consider the Sixtymile Formation to have been deposited largely in continental settings and to have included major landslides. Karl Karlstrom et al. (2018), summarized the Sixtymile

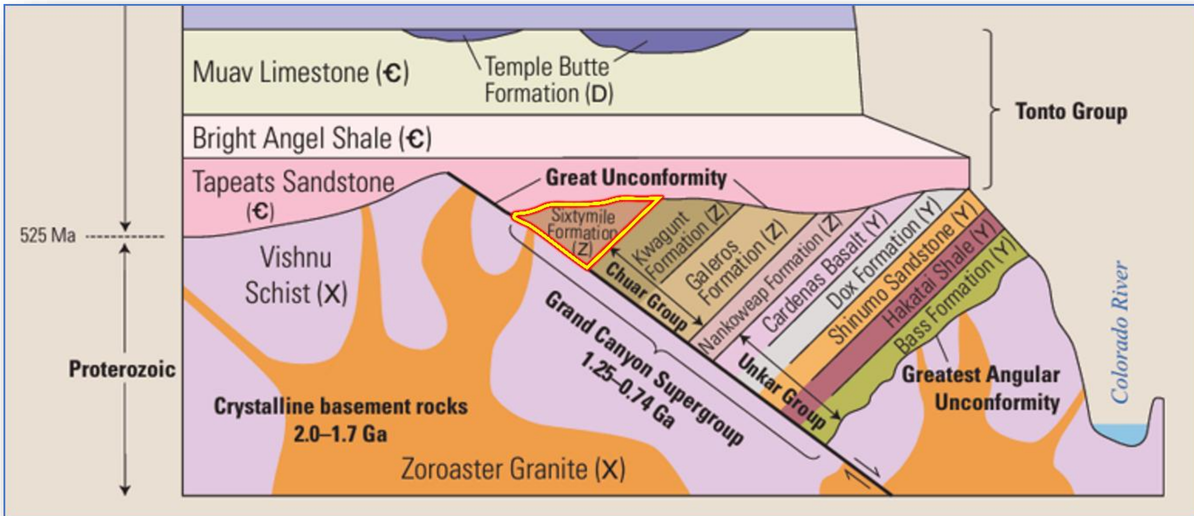

Figure 3*. Stratigraphic relationships in the Grand Canyon showing the Tonto Group, including the Sixtymile Formation. As Snelling noted, Karlstrom et al. (2018) has moved this formation into the Cambrian Period. The stratigraphic relationships have not changed. (Billingsley, et al., 2019)*

Formation deposition this way: "*It includes lacustrine, shallow marine and fluvial units, with numerous landslides or subaqueous slumps in lower units suggesting that its deposition took place in a fault-controlled basin during reactivation of the Butte fault*." No evidence is presented indicative of high velocity fluid movement. The conglomerates are often characterized as "fanglomerates", such as often form with continental alluvial fans in recent deposits. Similar deposits can form in marine settings, but there is no reason to say these, particularly the younger ones, were laid down by catastrophic water movement here.

The Sixtymile Formation includes several zones of chert, a sedimentary rock composed of quartz. The surrounding rocks and internal characteristics of these chert beds lead geologists to interpret them to have formed originally in fresh water lakes (Donald Parker Elston 1979). Oxygen and hydrogen isotope data suggest paleoclimate temperatures that ranged from 27 to 33°C (Kenny 2017). Both Elston and Kenny report the presence of thin brecciated zones of the chert (see Kenny 2017, Fig. 4). Elston's description of the upper member of the Sixtymile Formation includes this:

> "The sandstone is present southwest of the axis of the syncline (fig. 5), is pale red to brown, and contains scattered rock fragments that include chalky-white chert derived from the middle member" (Elston 1979, p.12)

What does this say about how long it took to deposit the unit? It shows silica-enriched fluids moved through the sediments and formed this chert over long period of time. It was then hardened before being broken up into rock fragments. Soft sediments don't break up like those shown by Kenny 2017, Fig. 4. Yet this brecciation took place as sediments were being laid down, not by shattering along a fault, such as a fault breccia. This demonstrates a significant pause in the deposition between the original deposition of the cherts and the brecciation. This is problematic for flood geology, given that the entire Sixtymile Formation was deposited in at most a few days in the most popular flood geology models. It is interesting that Dr. Steven Austin (1994), in his book, "*Grand Canyon: Monument to Catastrophe*" refers to rock fragments in the Sixtymile Formation coming from the underlying Kwagunt Formation, Precambrian in age, but did not mention the chert and other fragments found in the Sixtymile Formation. Dr. Tim Clarey (2018) doesn't mention chert at all. Perhaps these authors recognized that cherts and depositional chert breccias really don't support flood geology proposals.

Fossils

A further example of what we would expect that has not been found is Mesozoic or Cenozoic fossils, animals or plants in the Cambrian Tonto Group. We gave examples of a dolphin bone (or any other modern megafauna) or even plant pollen. Dr. Snelling replied,

> "However, **Flood geologists have repeatedly explained over decades that this pattern of fossils represents the burial order of the global Flood cataclysm**." (Snelling 2026b) (emphasis in the original)

It is true that flood geology has come up with three basic hypotheses. (Roth 1998; Snelling 2010; Clarey 2020). Saying the same thing more times doesn't make it more true. Perhaps Dr. Tim Clarey said it best here:

> "The global pattern of fossils cannot be denied. Why certain animals and plants are only found in certain rock layers is still largely unresolved. Creation scientists have often speculated and proposed various ideas to try and explain the patterns we observe in the fossil record." (Clarey 2020)

Although terminology can vary, these explanations revolve around the same three speculations:

1. The motility factor (Roth 1998); Increasing mobility (Snelling 2010)

2. The buoyancy factor (Roth 1998); Decreasing density and other hydrodynamic factors (Snelling 2010)

3. The ecological zonation theory (Roth 1998); Increasing elevation of habitat (Snelling 2010)

Each speculation could have some validity in local areas. One problem is that none of these would work globally or even in large basins. First, consider the motility factor, where more mobile animals were able to avoid the flood longer. This means that while retreating from advancing seas with massive earthquakes, tsunamis and hurricanes, *every* reptile, dinosaur, and mammal was able to move to higher ground. None were injured and swept out to be deposited. This sounds ad hoc.

Also, the idea of mobile animals trying to outrun flood waters takes advantage of the difficulty many people have in thinking three dimensionally. Once a region of any size was covered over with initial Flood sediments, everything else would have to be swept in laterally by hyper-fast, continent-scale sediment flows. Thus, after initial Flood sediments were laid down, any animal's ability to move from one place to another would be irrelevant – they could only just be "along for the ride" with transported sediment.

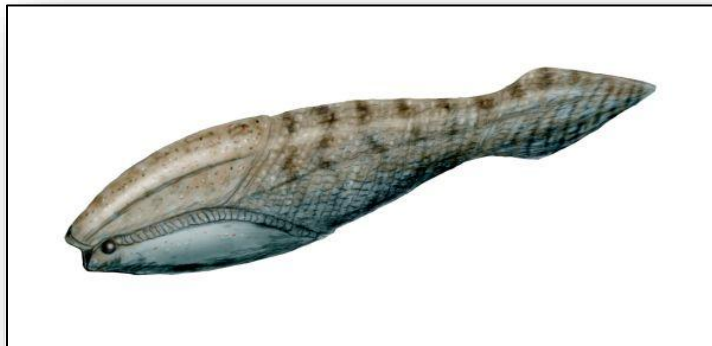

Figure 4. *Arandaspida, early toothless fish (By Nobu Tamura (http://spinops.blogspot.com) - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19460450}*

How about the buoyancy factor? It is really hard to buy that buoyancy separated the fish away from the Tonto and all of the other early Paleozoic sections or that it had any part in separating early reptiles and dinosaurs from mammals. Dr. Snelling pointed out that fish have been found in Ordovician rock (Snelling 2026b), but those fish were really different from those of today. Arandaspida (**Figure 4**), an early jawless fish hardly counts as finding a modern animal in ancient sediment. But it does prove that swimming animals were preserved in early Ordovician sediments. This makes it all the more difficult to understand why there are no examples found anywhere in the world of any more modern fish in earlier Paleozoic rocks or any examples of swimming mammals in any Paleozoic rocks.

Regarding the various elevation zonation theories, again this seems plausible in local settings. However, Roth (1998) observed,

> "The major problems facing the theory all relate to the extreme sorting of many organisms as found in the layers of the fossil record. Current ecological distributions only rarely reflect this. We might explain some of this sorting by extensive lateral transport of organisms from limited source areas during the flood, but the problem seems more general and is not limited to single source areas."

Roth's observation captures the earlier described lateral transport problem that flood geologists such as Dr. Snelling set aside. This ecological zonation explanation seems to contribute little to explaining the global distribution of fossils.

Other fossil types just do not really fit any of the three hypotheses given, even locally. Such fossils include sessile (bottom attached) fauna and many types of microfossils. Sessile forms found in situ, buried where they lived and found throughout the stratigraphic column are highly problematic for flood geology. Another example is the progression of microfossils found that are used so successfully in the oil industry to determine the stratigraphic age of sediments. I (Stephen) have further discussed the issue posed by the microfossils in rocks here: The Microfossil Record.

Dr. Snelling noted the presence of microfossils in the Tonto Group. It is interesting that the Bright Angel Shale does contain fossils known as cryptospores. Baldwin, et al. (2004) studied the cryptospores in detail through the Bright Angel formation and concluded that there was a definite freshwater source for the muds. They observed:

> "Initial correspondence between organic matter content in mudstones and feeding type and intensity (as indicated by traces) is consistent with an estuarine setting for this deposit. The level of organic activity preserved in these sediments indicates that the carbon flux into shallow marine settings due to terrestrial runoff was substantial by Middle Cambrian (Glossopleura biozone) time."

One key significance of the cryptospores is that microfossils were preserved, making the absence of more modern microfossils all the more striking.

What about the preservation of fossils? Dr. Snelling wrote:

> "However, Mitchell and Tillman do not grapple here with the proverbial "elephant in the room." After all, how these creatures were fossilized tells us how quickly they were buried and thus how fast these sedimentary layers were deposited. They never explain how fossils form! In their uniformitarian belief system, creatures are slowly and gradually buried by sediments. But do we see fossils forming today under such conditions? Resoundingly no! Unless creatures are buried rapidly under a lot of sediment, they either move away from danger, rot after death, or are eaten by scavengers. Furthermore, unless animal tracks and traces are rapidly buried and preserved, they are obliterated by the very tidal conditions Mitchell and Tillman maintain were responsible for deposition of the Tonto Group as proposed by their fellow uniformitarians."(Snelling 2026b)

Simply put**, we do not believe there *is* an elephant in the room**. Fossils are preserved in many ways. The scientific study of the processes by which fossils are preserved is called taphonomy. Many taphonomic processes involve rapid deposition. The fact that many fossils were preserved by rapid events in no way proves that they were all formed by the same rapid event. If the Phanerozoic period lasted over 500 million years, then we can safely assume that many, many floods, storms and catastrophes occurred that could preserve fossils.

Things found that we would not expect to find

Normal marine, fluvial and other paralic (non-marine) deposits

Field work and descriptive geology continues today, in part because of the number of classic exposures found in Arizona. Yet, no one reports the type of chaotic, high velocity deposits that one would expect from a global cataclysmic flood. What do recent studies report? In November of 2024, Dr Carol Dehler et al. (2024) published a refined stratigraphic model for the Cambrian of the Grand Canyon. Their refinement was based on more measured sections and extensive biostratigraphic analysis. Building on the work of previous investigators, they describe the environments this way:

> "Rather than being fully marine in origin, these sequences were formed by a mosaic of depositional environments including braided coastal plain, eolian, marginal marine, and various shallow marine environments." (Dehler et al. 2024)

They present a series of generalized paleogeographic maps for eight different portions of the Cambrian system in the Grand Canyon area. Environments range from fluvial and shallow marine in the Tapeats Sandstone to marine with local carbonate banks higher up in the Muav Formation. These are interpretations, but they are consistent with all of the observations. They also are consistent with the limited observations that we (Steve) have made more recently. (**See plates at the end**). We continue to see evidence that sedimentation was not continuous but had many pauses of various durations.

Dr. Snelling believes that the features that he has observed are consistent with tsunamis, but what we see are many small channels, particularly like those from settings without vegetation. (See Plates IV to XII, particularly Plate XII.) A recent study of the Tapeats Sandstone highlights this relationship (Myrow et al. 2025). They compare channels exposed in the Tapeats Sandstone outcrops around Payson, Arizona to characteristics of fluvial systems elsewhere. They find that the systems in the Tapeats shared characteristics with other low-sinuosity river systems, particularly those in areas without vegetation that would have increased tendencies toward meandering styles. The facies suggest "low sinuosity meandering rivers in a sandy floodplain", with well-preserved point-bar packages.

Interestingly, they report that in their study area, the Tapeats includes ~7.5% to 13% shale, considerably more than in sections measured along the Grand Canyon. At one location, they report “cobble to boulder conglomerate that rests inside bedrock incised valleys that are several meters deep and include clasts up to 28 × 15 × 18 cm in size”. This is entirely consistent with preserved stream channels where the Tapeats onlapped basement. This fits well with the interpretation from Dehler, et al., 2024 of the lower Tapeats transitioning from a braided plain/delta in the east to more open marine conditions in the west. Increasing storm deposition in the units moving up the section is also predictable. These types of mappable facies systems would be physically impossible to form under a sedimentation regime that deposited on the order of 100 vertical feet per day over the continents.

Sedimentary structures

Dr. Snelling doubled down on his interpretations of the features that we presented as inconsistent with flood geology. Again, every hill is a hill to die on for flood geology. Here we will look at his positions again for herringbone cross-stratification, mudcracks, and fossils, such as the stromatolites and trace fossils.

Herringbone Cross-Stratification

One surprising thing to find is strong evidence of tidal deposits that reflect normal tidal ranges. We noted that six different investigations reported a specific type of cross-stratification with alternating ‘V’ shaped bedding, known as 'herringbone cross-stratification’ in the Tonto Group and it is also found in other Cambrian formations in the southwestern U.S. The reversal of the bedding demonstrates a reversal of fluid flow in a relatively short time frame. We know that this type of bedding forms today in some tidal settings. Finding these delicate, cyclical tidal signatures through the Tonto Group is a clear indicator of daily, rhythmic tides operating over vast stretches of time, which directly contradicts the chaotic, unidirectional flow expected from a global mega-tsunami.

Dr. Snelling wrote, “Herringbone cross-stratification (Fig. 5J) has been reported in all of the Tonto Group formations, although it is not as common as Mitchell and Tilman claim (Figs. 5 and 6).” (Snelling 2026b) This is not actually accurate as we never addressed the amount of herringbone cross-stratification. We did note six articles that referred to its existence in the Tonto units (Hereford 1977; Fedo and Prave 1991; Middleton, L.T. and Elliott, D.K. 1990; Baldwin et al. 2004; Rose 2006; Snelling 2022). Where we differ is in the explanation and significance of these beds.

Dr. Snelling proposes that such sedimentary structures can be formed during hurricanes and tsunamis but provided no support for this beyond the fact that formations that he interprets as resulting from Noah's flood contain such features. Hypothetically one could have enhanced tides during prolonged storms, but none seem to have been reported in the literature, though perhaps a more extensive study might identify such.[9] It does seem clear that such stratification would be rare.

Dr. Snelling included in his Figure 7, two illustrations of water motion as waves approach the shore (Snelling 2026b). Motion from hurricanes and tsunamis would largely be the same. It is not clear what he thinks these prove. Water motion for all waves works this way. Such waves do not form herringbone cross-stratification and there is no reason to suggest that larger waves would do differently.

Neither we, nor Dr. Snelling have produced photographs showing examples of herringbone cross-stratification from the Tonto Group. We can however show a photographic example from what he would consider an equivalent unit, based on Snelling's Figure 1 (2025), though it is better dated to Early Ordovician in age. Here in the Bliss Sandstone, we see preserved at least portions of 16 cycles, representing deposition over a minimum of 4 days (**Figure 5**). Remember that this is a tiny portion of the Bliss Sandstone (Bentley 2014). Other examples of tidal deposition in units that would be flood deposits in flood geologic

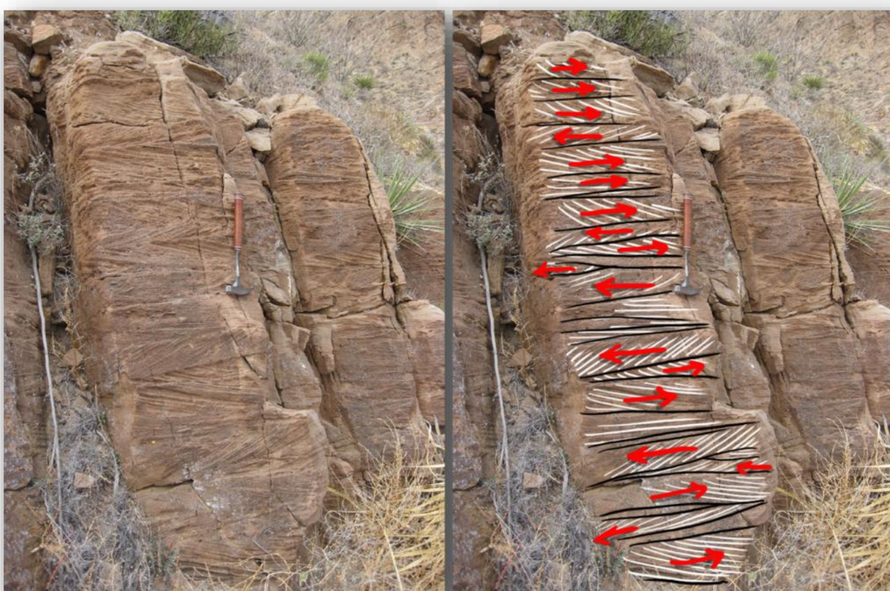

Figure 5: Herringbone cross-stratification from the Bliss Sandstone, Franklin Mountains, El Paso, TX. Used with permission of Callen Bentley (Bentley, 2014)

[9] How about in the interpretation of ancient rocks? Two articles were found that described herringbone cross-stratification that also discussed storm deposits, but the herringbone cross-stratified beds were not part of the beds that are really comprised of storm deposits. (Varela et al. 2011; Leckie and Walker 1982)

models are found here: here: Tidal Clocks and Flood Geology. In one case, daily and monthly tidal bundles have been documented representing **six years** of continuous deposition. Certainly, flood geologists would try to come up with other explanations, but would they be valid?

Other Sedimentary Structures.

Hummocky cross-stratification (HCS), typically considered indicative of storm deposition, is reported by many in the Tonto Group. Snelling quite rightly notes that in our published version, we inadvertently failed to include the bibliographical information for the modern tidal flats of South Korea (Yang et al. 2006). Here we correct this:

> Yang, Byongcheon, Robert W. Dalrymple, and Seungsoo Chun. 2006. "The Significance of Hummocky Cross-Stratification (HCS) Wavelengths: Evidence from an Open-Coast Tidal Flat, South Korea." Journal of Sedimentary Research 76 (1): 2–8. https://doi.org/10.2110/jsr.2006.01.

This reference is significant in this context, because it shows that one cannot rule out either tidal or proximal shallow marine settings for the Tonto based on the identification of hummocky cross-stratification. We have not claimed that any of the depositional models is totally correct but that features such as the herringbone cross-stratification are not consistent with the flow and depositional rates proposed by Snelling. Many characteristics of the Tonto Group are consistent with tidal settings with braided or low sinuosity stream input. Dr. Snelling complains that we did not, in our short paper, address other sedimentary structures. We simply chose to address those that we feel are diagnostic and inconsistent with flood geologic rates and processes. All of the sedimentary structures he has reported fit easily into deep-time understandings but some don't fit with flood geology.

Mudcracks

In our article, we included a discussion of features from the Tonto Group interpreted by several investigators to have resulted from desiccation, as sediments dried out. These features, called "mudcracks" provide a real challenge to flood geology.

Dr. Snelling recognized the issue that these features raise in this quote:

> "Today these polygonal features are indicators of at least some time of exposure and drying of sediment surfaces. **Thus, such features in the Tonto Group layers, if validly interpreted, would be difficult to reconcile with either the rapid rate of sedimentation** or the limited time available during the biblical, yearlong, global Flood

> cataclysm because their formation demonstrates periods when deposition stopped." (Snelling 2026b) Emphasis added

Dr. John Witmore put it this way:

> "It is unlikely that true desiccation cracks would have formed at the height of Noah's Flood because of the time needed to expose, desiccate, and crack the sediments. It is even more difficult to imagine forming multiple layers of desiccation cracks during the Flood."(Whitmore 2009)

This is another hill to die on. Flood geologists really cannot bend too much on this, given that the number of apparent beds with these polygonal features surely numbers in the thousands, often with multiple levels in the same section.

In the following quote, Whitmore indicates that mudcracks can form quickly and as such could be found in flood intervals:

> "Also (surprisingly), rapid desiccation mud crack development has been documented during humid, rainy conditions and on modern shorelines during very brief intertidal exposure. Even though they are probably rarer in the rock record than Flood critics admit, it also appears that true mud cracks could have formed during the Flood." (Whitmore 2009)

The articles he cited don't seem particularly relevant to Noah's flood. He cites a 1935 article by Paul Dimitri Krynine who reported mud cracks that developed over a brief time during a rainy season in Connecticut (Krynine 1935). Though they were preserved through several rains, they certainly are minor features compared to most reported ancient examples. The scale and depth do not compare. He also cites Jean-Claude Dionne's report of mudcracks that developed relatively quickly in tidal deposits in Canada.

> "Mud cracks and polygons form during summer in tidal flats of the south shore of the St. Lawrence Estuary. They occur near mean low water level at the top surface of ice push mud ridges formed during winter and break-up. They are a source of mud clasts which settle in the surroundings when carried away by waves and currents." (Dionne 1974)

It is not clear exactly how long it took for these reported mudcracks to develop but they seem to have at least lasted through the summer. These again seem to be relatively irrelevant to global flood hypotheses. The first quotes in this section from Snelling and Whitmore are accurate. For flood geology to be plausible, virtually all of the mudcracks reported in the rock record need to be explained to be something besides desiccation features.

Regarding the examples that we gave, Dr. Snelling wrote:

> "I have argued strongly already that "these cannot possibly be 'mud' cracks because these features are in a clay-poor sandstone, not mud. And as seen in [Hill and Moshier's] photograph[s] [their figures on pages 66 and 67 and Mitchell and Tillman's photograph (their Fig. 5)] of modern mud cracks, when the mud dries the polygonal shapes become concavely arched, whereas the claimed fossilized 'mud cracks' are flat." (Snelling 2026b)

Two points should be clarified. First, the modern example that we showed (Mitchell and Tillman 2024c) was deeply dried but did not show any significant concave arching, though perhaps precise testing would pick up some minor degree of this, but this would be equally possible for the Tapeats example in his Figure 4. Second, the clay content of the sandstone shown in our Figure 5 has not been demonstrated. Dr. Snelling sampled a limited set of beds in his study, and it remains unproven that his characteristics can be extrapolated throughout the Tapeats section, especially as we have agreed that some shale beds are found in the formation. As shown earlier, Myrow et al. (2025) reported increased shale content in their area and Hill (2016) did not identify where their photo was taken.

Dr. Snelling rejects mudcracks in the Muav Limestone, because they would not fit his hypotheses, though mudcracks in tidal settings in carbonates are common, both in modern and ancient sections. Robert B. Halley (1975) published a photograph of Cambrian-aged mudcracks in cross-sectional view from the Carrera Formation in California. In his Figure 32-8, he shows "vertical traces of upturned edges of polygonal mud cracks in dolomitic limestone". He interprets this portion of the Carrera Formation as ancient tidal sediments based on multiple criteria. The interpretation of the features as resulting from multiple phases of desiccation is very reasonable and hard to place as part of a cataclysmic flood deposit.

Are there criteria that we find in other ancient features interpreted as mudcracks that give reason to believe that they are valid? Dr. Steven Austin provided one such criteria. He provided sketches of two scenarios for cracks that resulted from the shrinkage of sediments, in this case, from the Permian aged Hermit Formation in the Grand Canyon. In the caption from the figure, he wrote:

> "Figure 3.17 Shrinkage cracks are shown in block diagrams, where sandy or silty laminae or beds have been injected into cracks in clay-rich layers.
>
> a. Shrinkage cracks seen in the Hermit Formation have both downward and upward penetration, and document the syneresis process, not shrinkage caused by drying.

b. Shrinkage cracks with only downward penetration would be expected to form in Hermit Formation if the clay-rich strata were subjected to drying before the overlying sandy or silty stratum was deposited. Such cracks are doubtful in the Hermit Formation." (Austin 1994)

We do not question that syneresis or diastasis cracks could be present through the rock record. It is also true that in most cases, we do not have the ability to see the bedding both

Figure 6 *Mud cracks from Cambrian Hickory Sandstone in Central Texas (Nielson and Barker 2013)*

Figure 7. *Multiple layers of mudcracks in cross-section view, Moenkopi Formation, Red Canyon, Glen Canyon National Recreation Area. At least 5 levels are visible. Notice that each thin downward from a surface. Photo from the National Park Service.*

above and below polygonal fractures as only one surface is revealed (**Figure 6)**. Usually, we recognize polygonal fractures while observing them on the top or base of a bed, but there are exceptions. One example, where the image is in the public domain. is shown in **Figure 7**. These are clearly multiple layers of actual mudcracks.

Plummer and Gostin (1981) named the presence of vertebrate tracks as one criteria for recognizing subaerial mudcracks. Dr. Snelling proposed that such tracks would fit in flood models.

"Supposed Cambrian mud cracks have been found with fossilized trilobite tracks, and Mesozoic rocks include dinosaur tracks on or associated with supposed mud cracks in many places around the world." (Snelling 2026b)

Snelling provided this explanation for animal tracks preserved in what he considers flood deposits:

> "However, **Flood geologists have repeatedly explained over decades that this pattern of fossils represents the burial order of the global Flood cataclysm**. Initially, bottom-dwelling shallow marine creatures were buried as the fountains of the great deep (ocean) opened up and tsunamis surged across the shallow ocean floor toward land. Only as the floodwaters eventually surged onto the land were land creatures then buried with marine creatures, although lowland land creatures (amphibians and reptiles such as dinosaurs) were buried before upland land creatures (other reptiles and mammals) were buried as the waters rose to their peak." (Snelling 2026) (*Emphasis in original*)

While we are unconvinced by this explanation for tracks in general, such as dinosaur tracks, it is not clear to us what this has to do with whether or not the polygonal features were subaerial desiccation cracks, which was the issue under discussion. **Figure 8** (Arizona Geological Survey 2021) shows an example from Arizona of mudcracks on a surface that is dominantly sandstone. Dinosaur tracks associated with units with interpreted mudcracks are common around the world, often directly on the same beds, as in **Figure 9.** In many cases, such desiccation features are identified on multiple levels. Dinosaur tracks associated with mudcracks are in Mesozoic sediments that most if not all flood geologists propose were deposited during Noah's flood. It is most reasonable to assume that the polygonal features were actual desiccation cracks, formed before the dinosaurs walked on them.

Figure 8. *Dinosaur tracks and mudcracks in the Moenkopi Formation, which is estimated to be early to middle Triassic in age (252 to 235 million years ago). This formation is younger than the Tonto units, but they serve to demonstrate that ancient mudcracks developed by exposure in the rock record just as they do today. (Arizona Geological Survey 2021)*

It remains true that we don't have additional photographic evidence and haven't conducted a personal examination of beds interpreted as mudcracks in the Tonto Group, including the one we showed in our article. Nevertheless, we consider the interpretation of subaerial mudcracks in these units quite reasonable.

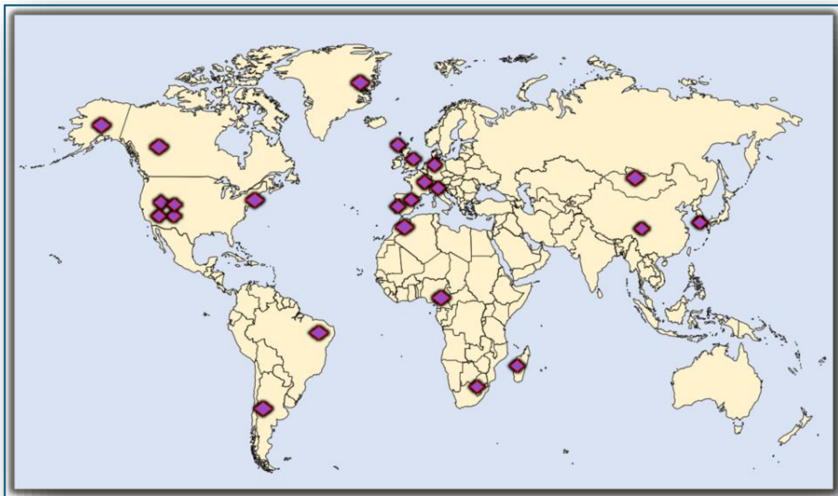

Figure 9. *Map showing locations of published accounts of dinosaur tracks associated with mudcracks.*

Trace fossils (Ichnology)

Why would we find horizons covered by the tracks and burrows of various animals if the formations were being deposited at rates of meters per day? In our article, we considered trace fossils to be inconsistent with flood geology. We wrote, "These were not some sort of death assemblage, transported into place, where a few survivors dug around before finally succumbing to the pressure of burial." (Mitchell and Tillman 2024c). Dr. Snelling, who says that we are not familiar with flood geology literature, wrote this:

> "No Flood geologist has argued that these were "some sort of death assemblage, transported into place, where a few survivors dug around before finally succumbing to the pressure of burial," (Snelling 2026b)

While our statement may have been a paraphrase of flood geology positions, this is essentially what flood geologist John Woodmorappe described in his article, "Are soft-sediment trace fossils (ichnofossils) a time problem for the Flood?" (Woodmorappe 2006). Here are quotes:

> "Furthermore, large and complex individual ichnofossils, including common ones such as Cruziana and less common but metre-sized ones visually reminiscent of washboard, can all form within strata." p. 115

> "One notable exception is the study of 'doomed pioneers'. According to this concept, it is believed that organisms washed downslope onto an inhospitable seafloor surface

can sometimes burrow for a short time before they die. Of especial relevance to Flood geology is the fact that numerous types of marine life are known to be capable of surviving transport, after which many of them will commence burrowing when deposited on or within a layer of sediment." p. 116

Although Snelling might describe it differently, something like this is also what he must rely on. What alternative does he have? There certainly would have been no time in his timeline for new generations of animals to grow to maturity, to later burrow or make other kinds of trace fossils. Burrows like we showed in our Figure 7 (Mitchell and Tillman 2024c) and Snelling showed in his Figure 10 (Snelling 2026b) don't appear overnight. They imply pauses in sedimentation for days, days flood geology models just don't allow for. They also imply an endless supply of burrowing animals – far too many for the planet to support all at once -- an issue which flood geologists ignore.

The example in **Figure 10** show trace fossils in a relatively sandy portion of the Bright Angel Formation (Santucci and Tweet 2020). Teichichnus trace fossils were made by animals that fed by burrowing along the water bottom (Baldwin et al. 2004). Notice that there are at least three surfaces along which these animals burrowed. The simplest explanation is that each of these was the water bottom for some period of time.

Figure 10. *Trace fossil, Teichichnus from the Bright Angel Formation. Red arrows highlight different horizons where the trace fossils are preserved. (Santucci and Tweet 2020)*

Time equivalent sediments in the Death Valley in the Great Basin in California provide more evidence that sedimentation paused repeatedly. Mata, et al. (2012) documented clear examples of trace fossils left by animals that lived like modern burrowing anemone. They wrote, "The lower Cambrian upper member of the Wood Canyon Formation in the Death Valley region, United States, preserves large vertical burrows up to 30 cm in length and 7 cm in diameter within oolitic and sandy dolostone and dolomitic sandstone beds" citing work by Corsetti and Hagdorn (2000). Think about this. Modern burrowing anemone live in a self-constructed wrinkled felt-like tube which was buried down in sand. When these Cambrian layers formed, ancient animals did just the same. All characteristics described in this formation are consistent with tidal deposition, including other sedimentary structures, such as herringbone cross-stratification. The burrows and other features are again inconsistent with a flood interpretation for the Cambrian section.

How could all of these trace fossils have been buried to be preserved? Do trace fossils make sense in deep time scenarios? Normal sedimentation processes, including storm and turbidity currents have covered tracks even in modern times. Vast numbers of such events would be expected to have occurred over millions of years. If it were a problem to preserve trace fossils with normal sedimentation processes as Dr. Snelling suggests, then we would expect very few trace fossils in units that he interprets as post-flood. That clearly is not the case. Trace fossils from mammal tracks to earthworm burrows (Verde et al. 2007; D'alessandro and Bromley 1986; Williamson and Lucas 1996) are common in Pleistocene sediments and other intervals that Snelling interprets as post-flood. Obviously, a global flood is not required for trace fossils to be preserved.

Carbonates

Regardless of the duration, pauses in sedimentation are indicated by beds covered with trace fossils. What kind of time duration is indicated by the other kinds of layers in the Tonto Group? Dr. Snelling correctly pointed out that some mud-sized material and some carbonate muds can be deposited relatively quickly. For flood geology to be a viable hypothesis, this must be true for every one of the shales and limestones through the intervals interpreted as flood deposits.

Snelling wrote:

> "However, it has been amply demonstrated by Flood geologists that ancient limestones are distinctly different from today's lime deposits that uniformitarians claim are their analogues." (Snelling 2026b)

He is correct in the sense that modern carbonate muds are dominantly of a different form of calcium carbonate than ancient limestones. Modern carbonate muds are dominantly composed of aragonite, while ancient limestones are dominantly calcite. Aragonite and calcite have the same chemical composition, but are stable over different temperature and pressure ranges. Geologists recognize that lime muds and fossils were typically originally deposited as aragonite but transformed by diagenesis to calcite. Relict aragonite structures have been observed in calcite dominated limestone (Lasemi and Sandberg 1984). Certainly not all of the details about how this occurred are understood, particularly given the variety of settings involved, but that it often occurred is not in doubt (Munnecke et al. 2023). In some cases, evidence suggests, for instance, that ancient ooids could have formed as calcite ooids instead of aragonite ooids because the chemistry of the ancient seas was different (Sandberg 1975).[10] We cannot assume that the past was exactly like the present. Diagenetic changes are ubiquitous in the rock record, however. In many cases, the aragonite was transformed further into dolomite. It is actually difficult to identify any scenarios whereby aragonite-dominated beds could be preserved as such, after even only shallow burial. It is also unlikely there were scenarios where regional carbonate diagenetic transformations could have occurred in the brief period proposed by flood geology.

Dr. Snelling declared,

> "They are also totally ignoring God's Word that describes the "fountains of the great deep" breaking up and remaining open for 150 days (Genesis 7:11, 24 and 8:2–3). As already explained by Flood geologists but ignored by Mitchell and Tillman, these superheated waters fountaining upward from the earth's mantle most likely were supersaturated with lime, silica, and various salts derived from breaking down mantle and crustal rocks at depth and during their upward passage. When that superheated steam mixed with the cold ocean waters, the sudden drop in temperature would drastically change the supersaturation conditions so that the contained salts were precipitated rapidly and even transported by the surging humungous tsunamis generated by the devastating earthquakes due to the catastrophic plate movements." (Snelling 2026b)

This is just an unsupported creative hypothesis based on an interpretation of Genesis that goes far beyond what the text actually says.

Algal Mats (Stromatolites) and other reef deposits

Reefs are common features of ancient sediments and modern marine shelves. We find them in every time period from the Proterozoic to the present. The cast of characters changed through time, but the features are recognizable and provide challenges for any flood interpretation.[11] In our opinion, no other single characteristic of the rock record is easier to document and more difficult to reconcile with flood geology processes and timelines. In these discussions, we focus on Cambrian examples.

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[10] Ooids are round grains of sand that formed as minerals precipitated around a nucleus that rolled around, agitated by waves or shallow water currents, usually in warm water. Today they are dominantly calcium carbonate, but in the Cambrian, glauconite and hematite ooids also formed. In the laboratory, calcium carbonate in the form of aragonite forms them over weeks (Davies et al. 1978). They are found in thousands of beds in the rock record. How could they have formed during a flood?

[11] Further discussions of the issues that reefs pose for flood geology are here: Ancient Reefs confirm Deep Time and sink Flood Geology and Issue #1: Ancient and Modern Reefs

Given the different ways the term reef has been used, it is worth documenting what we mean by "reef". Here is the definition that Steve published (Mitchell 2018) specifically for distinguishing features that impact flood geologic interpretations.

1. A reef represents a concentrated organic accumulation: Many ancient and modern lifeforms, both animals and plants, have left accumulations of lime skeletons. Examples here include algae, corals, rudists, and other ancient animals.

2. A reef is a build-up or mound: Reef will be used for accumulations that had positive bathymetric relief. Other organic lime accumulations also took long times to form but would not here be referred to as reefs.

3. A reef is locally derived and includes some preserved lifeforms that grew in place: Modern coral reef deposits include some coral that grew in place, but much is broken and much ends up having been eaten by various animals. Even so, the reefs considered here all have some species that are found in their growth position.

4. A reef has associated facies are consistent with modern reef settings: In each of the cases that we describe as reefs, internal facies of the reefs have been mapped in as much detail as the deposits will allow and they are consistent with modern reefs and the facies that surround modern reefs.

Features that meet these criteria all developed over time durations that significantly extended beyond the one-year long period hypothesized for a global flood. In Cambrian rocks, two main types of deposits are characterized as reefs: archaeocyatha and stromatolites. **Archaeocyatha** were a type of calcareous sponge that attached to the water bottom and grew together to form ancient reefs (S. Pruss, n.d.; S. B. Pruss et al. 2019, 2021). (**Figure 11**) They appeared and disappeared in the Cambrian period. Most of the archaeocyatha reefs that have been identified are relatively small, but still reflect growth over a period of years. The general location of key published archaeocyatha reefs in southern

Figure 11. *Branching form of archaeocyath from Rowland's Reef in Nevada. Image from Wikipedia: Killamator, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons*

Nevada is shown on **Figure 12** (Figure 8 in Mitchell and Tillman 2024c). Notice that they were not far from the Grand Canyon. Such reefs did not exist in flood geology models.

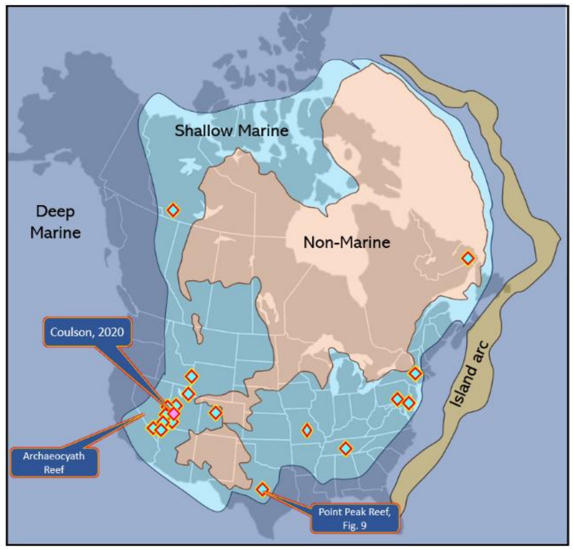

Figure 12. *Simplified Late Cambrian paleogeography from Blakely's "Key Time Slices of North America" (2013), with locations of "apparent in-situ" stromatolitic reefs from Coulson (2021). Notice that the occurrences fall within shallow marine regions on the map. The recognition of in-situ stromatolites that developed after the GU is not reconcilable with most FG models and this issue appears repeatedly in the Cambrian record. In addition, the figure locates another form of Cambrian reefs from an ancient sponge, archaeocyaths. This also would not fit FG models.*

The earliest and most prominent reefs in the Cambrian period were **stromatolite reefs**. Stromatolites represent stacked layers of biogenic deposits and are a particular form of features known as microbialites or microbially induced sedimentary structures (MISS). The following is a good description of these features.

> "Benthic microorganisms form highly organized communities called "biofilms." A biofilm consists of the individual cells plus their extracellular polymeric substances (EPS). In marine and non-marine environments, benthic microbial communities interact with the physical sediment dynamics and other factors in the environment in order to survive. This interaction can produce distinctive sedimentary structures called microbialites. Binding, biostabilization, baffling, and trapping of sediment particles by microorganisms result in the formation of **microbially induced sedimentary structures (MISS)**; however, if carbonate precipitation occurs in EPS, and these processes happen in a repetitive manner, a multilayered build-up can form—**stromatolites**." (N. Noffke and Awramik 2013) Emphasis added.

Many such microbial features are noted in Cambrian strata (Nora Noffke and Gass 2026). Such features are found in rocks and sediments from the Archean and Proterozoic eras all the way to recent (Chivas et al. 1990; Vahrenkamp et al. 2024; Macintyre et al. 1996). Stacks of sediment formed by biofilms that trapped sediments and enable their preservation are categorically not part of any cataclysmic flood deposit. Modern laminations have been measured to grow at rates of 1.6 to 5.6 years per lamination (Petryshyn 2013). Figure 10 showed many places where Cambrian stromatolitic reefs have been recognized. **Figure 13** is one example from central Texas where many small patch reefs are exposed. (Ahr 1971; Chafetz 1973; Nielson and Barker 2016; Khanna et al. 2020, 2020).

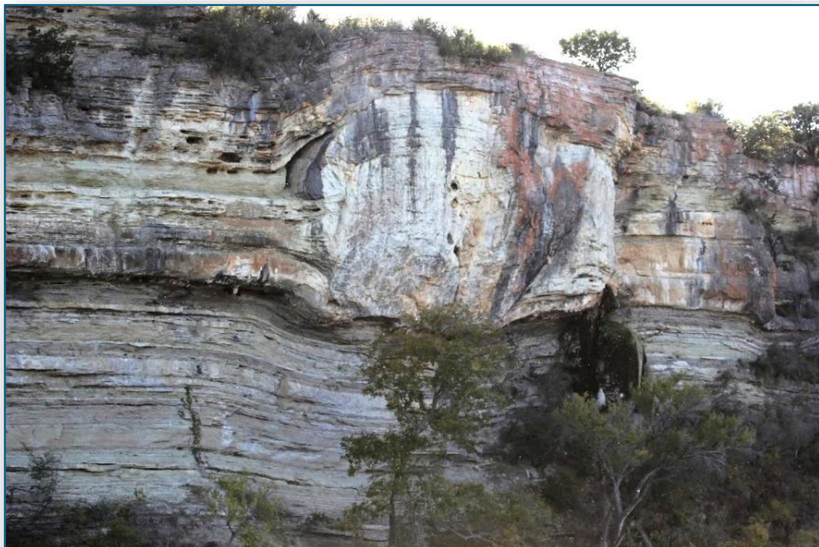

Figure 13*. One of a set of algal stromatolite reefs or bioherms from Point Peak Formation (Cambrian) in central Texas (Ahr 1971; Chafetz 1973; Nielson and Barker 2016; Khanna et al. 2020; Hopson et al. 2025).*

Stromatolites in the Muav Formation in the Grand Canyon area have been reported by several investigators, as we pointed out in our article (Resser 1945; Hardy 1986; Korolev 1997; Wanless 1973; Mitchell and Tillman 2024c). Stromatolites are clearly problematic for flood geology and Dr. Snelling fully recognized the issue as he wrote:

> "Mitchell and Tillman are correct in asserting that true stromatolites "demonstrate alternate periods of flooding and exposure, typically by tides," as seen for example in Hamlin Pool in Shark Bay, Western Australia today. And it is true that **genuine stromatolites in the Muav Formation would be a challenge for the biblical global Flood cataclysm interpretation**." (Snelling 2026b) Emphasis added.

Thick accumulations of tidal layers just could not have been formed as tiny parts of a one-year cataclysmic flood deposit. The first rescuing proposal is: maybe they aren't really algal:

> "However, microscopic examination of both today's stromatolites and many of the fossilized stromatolites reveals the algae and fossilized algae are responsible for building the stromatolites. **No one has checked under a microscope that these**

> **banded units that have been *interpreted* as stromatolites to confirm whether any fossilized algae are present.** So should we doubt the reports of stromatolites in the Muav Formation until this work is done? Absolutely! Until that is done, these banded units cannot be claimed to be stromatolites. Besides, the stromatolites being built by cyanobacteria today are mounds and not banded units built by algal mats." (Snelling 2026b) Emphasis in original.

Yet as we examine Snelling and his co-author's statement in a fairly recent paper, he admits that such bacterial structures are likely to be rare in ancient authentic biogenic features:

> "Since precipitation and mineralization are not directly associated with bacterial structures (such as cyanobacterial sheaths) it may greatly diminish the number of microfossils associated with fossil stromatolites. Therefore, the absence of microfossils in fossil stromatolites is not necessarily an indicator that abiogenic processes formed them." (Purdom and Snelling 2020)

Are the examples in the Muav valid biogenic stromatolites? Look at what the paleontologist Charles E. Resser wrote and showed in 1945.

> "The small nodules with concentric structures in certain parts of the Muav limestone are considered to be algal deposits, and resemble the type usually referred to as Girvanella. The structure in well preserved specimens is similar to that which is characteristically developed by this plant through the concentric disposition of its tubes." (Resser 1945)

Resser showed two examples in his Plate 17 (28 and 29) (**Figure 14**). These certainly seem to be diagnostic fossils identified by an expert paleontologist. It is unclear what other options would be. Ressner and McKee reported several types of occurrences for these features. (Resser 1945; McKee 1945)

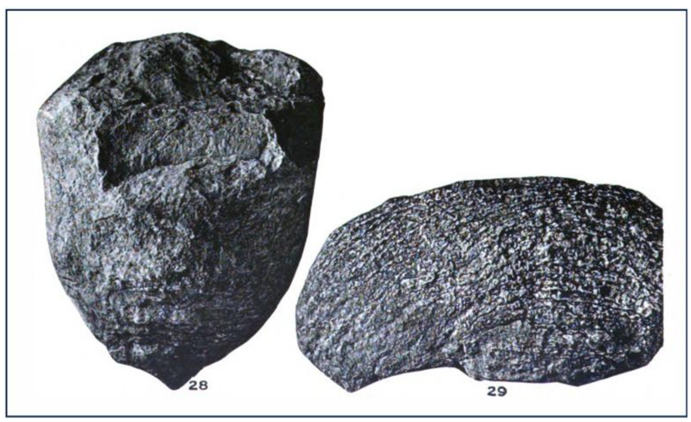

Figure 14. *Algal stromatolites called Girvanella from Resser 1945.*

The presence of stromatolites in the Tonto Group was also published recently in the French Mountain Dolostone (Rowland et al. 2023). The Frenchman Mountain overlies the Muav Formation and was added to the Tonto Group by Karlstrom, et al. (2020). (Snelling 2021b). They are recorded in multiple beds in several measured sections.

It is very significant that several workers documented stromatolites in the Upper Cambrian above the Muav. One can't have early flood deposits in the Tonto, covered by non-flood deposits in the Upper Cambrian and then go back into flood deposits. Some of those documenting such deposits in just the USA include: (Ahr 1971; Palmer and Halley 1954; K. P. Coulson 2021; K. Coulson 2016; Khanna et al. 2020; Retallack 2025). Khanna et al. (2020) and Hopson (2025) are two recent studies that describe the stromatolitic mounds in Mason County, Texas, one example of which was shown in Figure 13. They show that many mounds are preserved and about how they developed.

Dr. Snelling's suggestion that these features, which grew in such prolific numbers, are not biogenic growth features, reefs as most geologists would recognize them, is showing desperation. No one should dispute that there are stromatolitic reefs in the Cambrian. If flood geologists have to recognize that Cambrian reef deposits exist, is that the end of their story? Dr. Snelling proposed another rescue mechanism, in case the first one didn't work:

> "Flood geologist Coulson certainly has "documented Late Cambrian stromatolitic reefs in the Notch Peak Formation in Utah in great detail." But those thick intervals of "stromatolitic reefs" that are stratigraphically younger than the Muav Limestone and well above the Great Unconformity may not have grown in place as no geologist observed them growing." (Snelling 2026b)

Here we go again. No geologist saw them. We have to trust that God has not deceived us. Were all of these rocks transported into place? No one has proposed how this might have taken place or showed any evidence that it occurred. How far could one transport large bodies of rock with stromatolites apparently in growth position?

Young Earth Creationist, Dr. Ken Coulson (2021) explained the issue that stromatolites cause for flood geology here:

> "The crux of the issue is not biotic vs abiotic, it is time (Purdom and Snelling 2013). In bed 9, for example, time-dependent processes were responsible for microbialite coalescence and elongation (K. P. Coulson et al. 2016). In bed 11, encrusting sponges constructed 30 – 70 cm-high microbialites one lamination at a time."

This process does not fit inside a one-year long cataclysmic flood. Coulson recognizes that if a global flood occurred, far less sediments resulted from it than many flood geologists claim. Coulson's conclusions should be significant to YEC, because he did not start out trying to force these into any old earth model. They are also significant because his thesis advisors were Dr. Leonard Brand of Loma Linda University and Art Chadwick of Southwestern Adventist University, both prominent flood geology authors. Coulson even noted apparent herringbone cross-stratification as further verification that the stromatolites were from an intertidal zone.

Responding to our claim that reefs are found throughout the geologic column and that we find no place to put a flood, Dr. Snelling (2026b) writes "However, in making that claim, they ignored several robust responses to such claims." We have read each of the articles that he sites and have not found them robust. The claims can be summarized just like those he gave for the Cambrian example. Either they were not a reef or they were transported. References in Steve's website were cited in a footnote earlier. They require one to start with the assumption that the rocks were formed during Noah's flood and then try to force the data into this proposition.

Part 2 Conclusions

When we wrote our response to the Snelling papers on the petrology of the Tonto units and their interpretation of the duration over which they were deposited, we knew that these would not be acceptable to Dr. Snelling or other flood geologists. Our claim was that the features in these rocks and other time equivalent units are incompatible with the flood geology timeline and the processes that it demands. Dr. Snelling responded by pointing out that we weren't there and by claiming that our bias from our geological training and experience makes our points invalid. He rejected the evidence that we presented, and this was not surprising for him, given that he will continue to claim that the data in the rock record support the flood geology proposed interpretations. In this portion of our reply, we have expanded our description of some units and the YEC literature we consider pertinent.

We pointed to a number of characteristics that one should expect in a deposit from a global cataclysmic flood deposit where sediment was moving at very, very high rates and depositing at enormous rates. Chaos and mixing of sediment, comminuted grains should dominate most units, but they don't. The fossil record should be mixed as well, but it is not so. Flood geologist's explanations could be reasonable to explain local anomalies but are inadequate for the overall pattern.

We also went through his explanations and arguments against the features that we reported as inconsistent with flood geology. Such evidence includes sedimentary structures that classically are seen as indicative of normal sedimentation, such as tidal deposits, including herringbone cross-stratification. It is highly unlikely that we could ever convince him that the mudcracks reported in the Tonto units are desiccation features, but other examples through his flood interval are common and we showed a number that are strongly indicative of subaerial desiccation. Arguments by Snelling (Snelling 2026b) and Austin (Austin 1994) fall flat when they claim that environments interpreted by most carbonate stratigraphers are somehow invalid because the limestones are calcite dominated, rather than aragonite. They fail because such diagenetic changes are well documented in geologic literature and should be expected.

Finally, we came to the stromatolitic reefs. By faith in his model, Dr. Snelling suggests that they must not be stromatolites or if they are, they must have been transported. We showed conclusively that these are algal stromatolites and that even if some were not algal, he still has no option for the layer-by-layer deposition that they record. Moving them as large bodies of rock is not feasible and no mechanism is suggested by Dr. Snelling or any other flood geologist. We continue to be comfortable with the green dots and red dots that we placed in our Table 1.

Reply to Part 3

The Tonto Deformation: Responding Again to "Peaceful Science" Critics

Since at least 2009, Dr. Snelling has been publishing that the folding of the Tonto Group, particularly the Carbon Canyon Fold, occurred while the sediments were soft and pliable, and that this proves that this deformation did not occur millions of years ago (Snelling 2009b). It is important to note that we and Dr. Snelling agree on some aspects of the Tonto deformation. For instance, we agree that the sampled folds in the Tonto Group all formed as a part of a major mountain forming event, known as the Laramide Orogeny. We agree that the folding in the Grand Canyon area involved older Precambrian normal faults. Regional compression caused large-scale reverse movement on them, as monoclines developed and the Colorado Plateau was uplifted. We agree that the folding took place after the deposition of thousands of feet of sediment above the Tonto Group. We also agree that the folding did not involve metamorphism.

We both also recognize that sediments can be folded both by soft-sediment deformation and by slow deformation of lithified sediments. Dr. Snelling recognized the slow alternative but stated, "Incremental strain over sustained periods of time is harder to differentiate. As noted above, it can also result in ductile deformation" (Snelling 2023c). Part of the challenge in classifying incremental strain is that we must all recognize that there is a continuum between soft sediment deformation and high pressure / high temperature metamorphic deformation. The evidence, in our view, is consistent with the Tonto deformation reflecting incremental strain over deep time at relatively low temperatures and pressures. Dr. Snelling has correctly pointed out that the units do not show significant evidence of features such as sub-grains, undulose extinction, deformation lamellae and deformation kink bands, all associated with higher grades of temperature and pressure, but he has not dealt with explaining when such features begin to develop along the continuum. **The Tonto deformation, where sampled by Dr. Snelling, just did not reach the necessary temperatures and pressures for these to develop.**

Dr. Snelling has built the case that, regardless of other characteristics that are found, only examination under the microscope can be used to distinguish between soft-sediment deformation vs. slow deformation of lithified sediments.

> ”However, field examination of these folds is insufficient to determine whether they were due to such ductile behavior of the lithified rocks under much later prolonged stress or due to soft sediment deformation soon after deposition. **Detailed microscopic examination is thus absolutely necessary** to document the character of the sandstone, specifically, the textural relationships between the constituent grains and the timing of the formation of the cement (lithification).” (Snelling 2023b, 3) Emphasis added.

In this light, it is interesting that Snelling published in 2009, as a fact, that in particular the Carbon Canyon Fold, was formed by soft-sediment deformation *before* he had examined any of the microscopic evidence that he now has.

Dr. Snelling’s 2026 response to our article on the Tonto deformation brings in familiar themes.

> “They make this claim although no geologist has observed such claimed long-timescale folding. The long timescale has only been inferred based on uniformitarian assumptions. On the other hand, it should be emphasized that the folding of soft sediments has been observed in laboratory experiments, and those experiments demonstrate that fracturing can occur in soft-sediment deformation.” (Snelling 2026a)

Again, It is still true that none of us were there. As noted earlier, Dr. Snelling went looking for data that would support his particular interpretation of scripture. It is fair to say that my co-author and I were skeptical of his conclusions from the start, but we have tried to evaluate his data fairly to see if it proves his conclusions. Since we all bring in biases, we must assume that these do not invalidate the actual data that we consider. We tried to interpret all of the data available that has bearing on the questions at hand.

It is evident that this study was primarily designed to address the question of whether or not the Tonto units were metamorphosed. He didn’t systematically sample depositional facies or map bedding geometries, etc. to determine depositional environments. He also did not map fractures or faults that are evident in the outcrops. These aspects just were not a focus for him. He seems to remain convinced that rock deformation in lithified sediments could only be associated with metamorphism. Hence, he argues that if the Tonto Group had been lithified before the folding took place in the sampled folds, the rocks must, in his view, have been significantly metamorphosed if they were not folded while still soft.

Dr. Snelling is using a strawman argument because no one has argued that these rocks were metamorphosed in the Grand Canyon. Snelling can defeat the argument that the Tonto units were metamorphosed but that is not really at issue. No one argues that the rocks were buried and deformed by any combination of high temperature and pressure.

Why do geologists agree that the Tonto units were never hot enough or under enough pressure for metamorphism? Several tools have been used to develop a history of temperature, the thermochronology, of the Grand Canyon. These include Zhe, a methodology that uses rations of uranium (^{238}U, ^{235}U) and thorium (^{232}Th) vs. helium in zircon and other techniques such as apatite fission track measurement. Several estimates of the temperature history for the Paleozoic rocks of the Grand Canyon have been made. Here is one of the most recent:

> "Good paths suggest that maximum Laramide reheating as high as 140 °C was achieved by ca. 80 Ma, followed by rapid cooling to ~90 °C by 55 Ma, slow cooling from 55 to 20 Ma, and rapid cooling to near surface temperatures after 20–10 Ma" (Thurston et al. 2021)

Dr. Snelling also provided estimates in the following description:

> "In conclusion, therefore, the consensus from all these estimation methods is that the Tapeats Sandstone prior to the Laramide deformation responsible for the Carbon Canyon fold would have been subjected to a burial temperature of 110–130°C. Then during the Kaibab uplift erosion caused the temperatures within the Tapeats Sandstone to decrease to <70°C." (Snelling 2023b)

Figure 15 shows the temperature and pressure range estimates for various forms of metamorphism that can be distinguished by their mineralogy (Zou 2013). The box shows the range over which quartz cementation would have formed in the Tonto. The right bottom corner represents the hottest and highest pressure experienced, just before the rocks were uplifted by the Laramide Orogeny and the uplift of the Colorado Plateau. Notice that the temperatures and pressures are all in the diagenetic domain, never reaching low grade metamorphism. It is worth noting that the P-T ranges for the various metamorphism grades are not uniform as different investigations use different ranges, but regardless, we did not identify any that would consider the range from the Tonto Group as being within even the low-grade region.

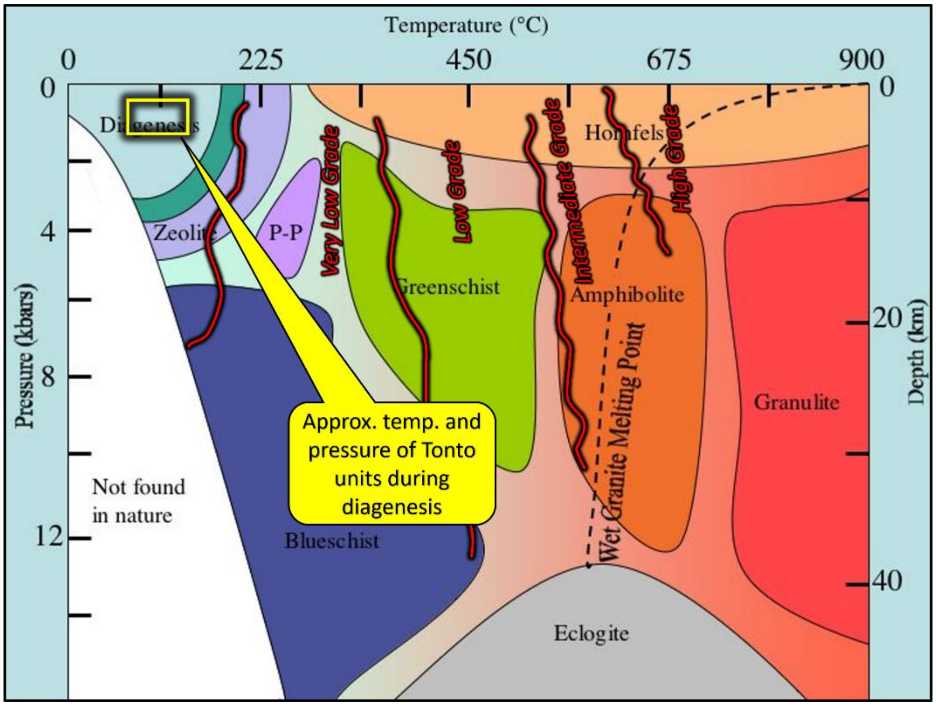

Figure 15. *Diagram of metamorphic facies in regard to temperature and pressure. The labeled box shows approximately where the Tonto units would have fallen based on both hydrostatic and lithostatic pressures. The box partially obscures the word "Diagenetic". Base figure: David Magrass, Public domain, via Wikimedia Commons; Metamorphic grades from: Regional Metamorphism by Zao, 2013.*

We would conclude that the temperature / pressure data, folding styles and thin sections agree that this deformation did not involve metamorphism. That does not mean that the rocks were deformed by soft-sediment deformation. The deformation here involved incremental strain over long periods of time. In addressing Dr. Snelling's Part 3 response in more detail, first, we will address some of the specific statements that Dr. Snelling made that deserve replies. Some were addressed earlier in the introductory section, but need to be responded to more specifically here.

Images used

One concern that Dr. Snelling points to is our use of figures. We presume that he provided the set of images of all of his slides to allow his work to be examined and potentially critiqued. As pointed out earlier, we were not free to use his images without his permission, and he did not respond to our request for permission. Many of his claims needed to be addressed by referring directly to his images. We had hoped to be able to show uninterpreted and interpreted versions adjacent to one another. Fortunately, we found images of some of the outcrops with folds that we were able to use, such as from USGS images which are in the public domain. In some cases, we did not find images that we could use online or in other literature. For example, on the Whitmore Helipad Fold and the

Matkatamiba Fold, the only photographic images we found were in his reports. In these cases, we chose to present interpretations of his photographs. These were clearly labeled as interpretive line drawings. While Snelling may not have agreed with our interpretations, this was the only way to appropriately show the features that we recognized in the folds. We would encourage him to present his own interpretations of the fault and fracture patterns, perhaps classifying them in terms of those associated with the Laramide deformation vs. other causes.

Thin section images were more difficult, but given the interpretation presented by Dr. Snelling and his stated position that thin sections were the only means of distinguishing the timing of the lithification, these were critical. Simply describing slides as fractured would hardly have substituted. We again would encourage him to present his interpretation of the fracturing in his slides. No doubt he would have different interpretations, but we are comfortable with the interpretations that we presented. We examined all of his slides in all of the detail that we could, but could only give a few examples, those essential to making our points.

Dr. Snelling pointedly accused us of deceit on our Figure 24. Again, we find ours to be a reasonable interpretation. He wrote:

> "The degree to which fractures cut through grains is also particularly difficult to observe in fine-grained rocks. Even so, Mitchell and Tillman feature the thin section shown in their Fig. 24, in which they highlight the dark rounded areas that they claim "were cemented before being cut by fractures with small amounts of offset."129 However, the prominent offset along an interpreted fracture in their Fig. 24 was manufactured deceitfully by Mitchell and Tillman, as unsuspecting readers did not have my original photomicrograph of the actual thin section for comparison. So it is presented in my Fig. 13 here, which conclusively shows absolutely no offset of the sample along a fracture. If the fracture were there, it would be highlighted by the same blue-dye-colored epoxy resin that is evident in fractures in other photomicrographs, such as in my Fig. 12 (left) above and in the sample-preparation-induced wide fracture near the top of the photomicrograph in my Fig. 13. How can any of Mitchell and Tillman's claims be trusted when such deceit is plainly evident?" (Snelling 2026a)

First, recognize that we did not claim that this is an open fracture. We see this as a linear healed zone of deformation. The dark rounded areas that we suggest could be concretions clearly have abrupt flat sides. These flat sides are bounded by a linear zone of fine-grained rock with what we recognize as a different texture than is found in most of the sample. The displacement that we suggested is probably just a few millimeters in strain, but still was the result of deformation. We would certainly have preferred to have had the ability to present the actual slide image with it, but that was not an option, since he did not respond to our request. In any case, we certainly engaged in no deliberate deceit!

Dr. Snelling criticized our interpretative line drawing of his slide MF-02 in our Figure 25 (Snelling 2026a). We all recognize that the blue tint along the slide is dye from the resin injection, but continue to interpret this as reflecting fine-scale deformation along a shear zone. His photograph shown of the location certainly appears to show deformation consistent with shearing, particularly the dark bed beneath the sampled bed that thickens and thins consistent with this (Snelling 2023a). His description of this slide includes the following:

> "Some quartz grains exhibit **undulose extinction**. Along the edges of two huge (4.69 and 6.14 mm, ϕ = -2.12 and -2.36) quartz grains is what appears to be a **zone of crushed and/or sheared quartz like "mylonite" made up of tiny-small irregular quartz fragments with different extinction angles** but "blend" into one another as a cemented mass, that on their other sides also cuts off the corners of former K-feldspar laths. The same wide crushed quartz "mylonite" zone elsewhere cuts between two very large K-feldspar laths, cuts the edges of other quartz grains, or even includes an altered elongated K-feldspar grain, and a sheared "island" medium quartz grain with stress twinning in crossed polars and with an included long, thick, altered edge-on muscovite flake with frayed ends." (Snelling 2023a) Emphasis added.

Snelling's description seems quite consistent with moderate deformation at low temperature of sandstone that was at least partially lithified.

Sampling for structural analysis

In our critique of Dr. Snelling's Tonto work, we suggested that the sampling and analysis were not really adequate to address some of the questions that need to be answered. This does not mean that the sampling was bad, but, as mentioned earlier, his study was not really designed to provide a structural analysis in any detail or to address other folding options. A study designed to address the possibility that the Tonto units were metamorphosed would not be expected to, for instance, explain the pattern and origin of fracture sets in the units.

Referring to our pointing out that his study did not collect the data required to answer our additional questions, Dr. Snelling described us as "pontificating" (Snelling 2026a). He is welcome to his opinion, but if he had wanted to deal in any detail with the fracturing that we all recognize to be present, he would have collected other data. The data available just do not allow us to separate fractures into different sets that might have been associated with deformation vs. compaction vs unroofing. Capturing all of the data desired would involve considerable time and effort, but it would allow the various fracture systems to be understood. An example of such work was published in a recent article by Dr. Xiaolong Sun, et al, where they were able to document four different fracture sets through rocks in Spain. (Sun et al. 2021). Similarly, such data could be collected for the Grand Canyon folds.

We pointed out that Dr. Snelling did not provide his own cross-sections. He rejected this, apparently misunderstanding what was meant by a cross-section. Neither his photographs, nor our interpretive line drawings constitute cross-sections. Projecting onto a single plane along a well-oriented line shows the bed interpretation and their structural relationships. By including faults and key fractures, a clear picture is communicated that shows what the interpreter believes to be the geologic picture. Zooming out enough to show the relationship with the key monoclinal faults, would clarify the timing and help explain how these sampled folds developed. Many examples are available, such as in Reches and Matthews (1978. p. 244, 245, and 248). Karlstrom and Timmons (2012, p. 105) show examples of interpretation over a photograph. Of course, if one doesn't provide such basic displays, it could imply either a lack of understanding of the features or unwillingness to present data that might open up other interpretations. It is interesting that Snelling complains when the figures of the Carbon Canyon fold have been reversed, so as to orient them in the same direction that the vast majority of Colorado Plateau monocline cross-sections are drawn, including the one he included as Figure 4 in his Carbon Canyon Fold article (Snelling 2023b). The orientation we went with was clearly labeled on the figures.

Reference to the Palisades Fault

We included some discussion of the Palisades fault, because it provides additional data to help understand the deformation along the monoclines. The objection from Dr. Snelling is really surprising. He wrote,

> "However, as I emphasized previously, what happened on the Palisades Fault is not relevant to the Carbon Canyon fold adjacent to the Butte Fault. In any case, **the issue even with respect to the Palisades Fault is not the fault itself, but what happened adjacent to it**." (Snelling 2026a) Emphasis in original

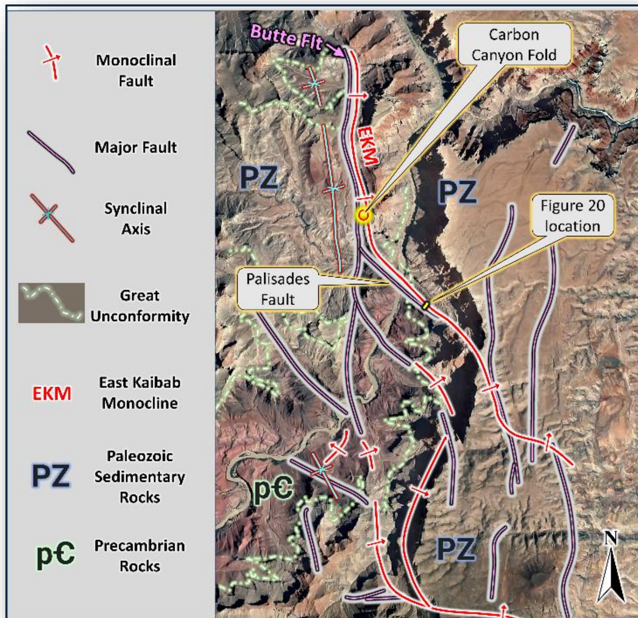

Figure 16. *Location of Palisades fault relative to the Butte Fault and the Carbon Canyon Fold. (faulting from Reches and Matthews, 1978 over Google Maps image)*

This might sound like a serious objection, unless you understand where the Palisades fault is with respect to the Carbon Canyon fold. **Figure 16** should clarify this. The Palisade fault is a branch of the same fault that the Carbon Canyon fold is developed along. Deformation along the same fault from the same overall forces is clearly relevant, especially when they relate to the same rock units.

How does this help? Here are a few quotes from Reches and Matthews, 1978:

> "The lowest structural level of the Palisades monocline is composed of both flexuring and faulting **within the Dox Formation and the Tapeats Sandstone**." (Reches and Matthews 1978) Emphasis added.

> "The monocline includes a sharp anticlinal bend with a radius of curvature of about 10 m (Fig. 11) [our figure 2] and a relatively open synclinal bend with a radius of curvature of about 150 m. **The rocks in the anticlinal bend are intensely fractured**, but the apparent displacements are small. The steeply dipping beds of the Bright Angel Shale and the overlying Muav Limestone are disturbed by small faults, by joints, and by small folds. The structural throw of the monocline is about 150 m." (Reches and Matthews 1978) Emphasis added.

> "Figure 11. The continuous anticlinal bend in the sandstone layers of the upper member of Tapeats Sandstone (sec. b-b, Fig. 12). Radius of curvature is 10 to 15 m. The rocks are brecciated, but the layers are continuous. The termination of the Palisades fault is about 10 to 15 m below this exposure." (Reches and Matthews 1978)

What does this tell us? Here are three important observations.

1. Both the Dox Formation and Tapeats Sandstone were involved in the flexuring.

Since Dr. Snelling agrees that Precambrian sedimentary layers were lithified prior to the Tapeats deposition, this means that the Precambrian lithified sediments were folded during the same Laramide event that caused all of the sampled folds. This was a process that did not happen over one year. (Snelling 2026a)

2. The Tapeats formation was brecciated during the faulting and folding.

This means that it was lithified at least to some degree at the time. We don't have exposure of the Butte fault zone adjacent to the Carbon Canyon fold, but it may have had the same brecciation. Regardless, for the Tapeats, this demonstrates that in at least some areas in the Grand Canyon region, it was not soft sediment during the Laramide deformation.

3. Samples of calcite twinning were examined from the Muav Limestone.

Samples taken from close to the flexure had more twinning than those away from it. This is consistent with deformation of the whole area with uplift, but more intense stress closer to the fault zone. Calcite twinning occurs in the deformation of lithified limestones, not lime mud.

These three observations are all consistent with deformation of lithified Dox and Tonto units in the Palisade fault region.

Dr. Snelling described what would indicate that the Tapeats Sandstone was lithified at the time of deformation. He wrote, "These rock layers should have broken and shattered during the folding, unless the sediment was still relatively soft and pliable." (Snelling 2009a). Breaking and shattering is exactly what is demonstrated at the Palisades fault. Brecciation has not been documented at Carbon Canyon, but the actual Butte fault zone is not exposed at this location. These observations from the Palisade fault are consistent with at least partially lithified sediments folded over deep time under varying stress conditions and this is reasonable for the Carbon Canyon Fold as well.

Fold morphology vs. modeling of soft-sediment deformation

In describing soft-sediment deformation in our article, we wrote, "The resulting folds commonly have a "*soupy*" appearance such as might develop in folding damp clay or mud with significant thickness changes and varying fold amplitudes and wavelengths." We contrasted the "relatively planar limbs and fairly sharp hinges", particularly evident in the Monument fold and the nearby kink fold, with the more fluid appearance so common in soft sediment deformation. Dr. Snelling responded:

> "Of course, the sediment layers in these Grand Canyon folds obviously do not have a "soupy" appearance. But their morphology instead does match the features observed in laboratory-scale, experimental, soft-sediment-deformation simulations, including the relatively planar limbs and fairly sharp hinges seen in all four folds documented in my papers." (Snelling 2026a)

This is a bold statement. It is worth looking at the studies that he says document this. He describes these here:

> "Some excellent relevant examples are the simulation experiments of **Rettger (1935), Handin et al. (1976), Friedman et al. (1976), Weinberg (1979), and Friedman, Hugman and Handin (1980)**. These and other experiments involved confining pressures, and yet the dampened sand and/or clay layers when compressionally folded would appear to have faithfully simulated soft sediment deformation to produce folds similar and identical to those observed and classified as folding due to soft-sediment deformation in exposed outcrops of now lithified sedimentary layers elsewhere (for example, Waldron and Gagnon 2011, and Alsop et al. 2019). Even the folding of these Tapeats Sandstone beds have been simulated in these soft-sediment deformation experiments (fig. 10), along with the accompanying minor faulting, and the fractures and joints." (Snelling 2023c) Emphasis added.

Are these simulation experiments really demonstrating what Snelling believes they are? Let's look at each of the five modeling papers:

Perhaps R.E. Rettger's paper (1935), "*Experiments on Soft-Rock Deformation*" provides the most support. Rettger used physical modeling to deform sands and clays that he developed into layers. Interestingly, most of the deformation models do have the changes in thickness that we have described as "soupy". Perhaps his Figure 13 shows something similar to a kink fold. It was formed by compressing dried sands that showed some strength as a result. Here are some observations that Rettger reported that can be useful in recognizing soft-sediment deformation.

1. “Clays and sands which were deformed under water, or while still damp, never showed clean knife-edge breaks.” Certainly, at the outcrop scale, the Tonto photos show abrupt edges to faults.

2. “It was further noticed that no cavities were produced which might later be filled with cementing material. In some cases, the sediment adjacent to the fault plane became considerably disrupted, forming something like fault-plane filling. This filling, however, usually showed blurred edges and some connection with the side-wall material.” Such filling is not noted in the Tonto folding.

3. “Another point which might be mentioned as showing the condition of the rock at the time of deformation is the non-uniformity of the positions of the faults and the movements along them. Some of the faults show a displacement in one direction, while others show an opposite movement.” These type of faults and folds have not been noted in the Tonto group.

The second paper Snelling referenced is “*Experimental folding of rocks under confining pressure: Part II. Buckling of multilayered rock beams.*” It was published in 1976 by John Handin and other structural geologists (Handin et al. 1976). They describe their modeling: “Specimens composed of as many as five layers of various combinations of dry Coconino Sandstone (brittle) and Indiana Limestone (ductile) are folded at 1-kb confining pressure.” This is an important modeling paper, but it demonstrates deformation of lithified sediments of different strengths, not soft-sediment deformation.

The third paper cited is “*Experimental folding of rocks under confining pressure: Part III. Faulted drape folds in multilithologic layered specimen*”, published by Friedman (Friedman et al. 1976). Again, their physical modeling used lithified stone: limestone, sandstone, and rock salt. Their modeling says nothing about soft-sediment deformation.

The fourth paper continues this theme. In 1979, David Weinberg wrote “*Experimental folding of rocks under confining pressure: Part VII, Partially scaled models of drape folds*” (Weinberg 1979). Their physical modelling worked with chalk, dolomite, lead, limestone and sandstone. This allowed Weinberg to demonstrate ways that variable lithologies would impact deformation. The materials used were rocks and soft metal, not soft-sediment.

The last paper is “*Experimental folding of rocks under confining pressure, Part VIII — Forced folding of unconsolidated sand and of lubricated layers of limestone and sandstone*” by Dr. Melvin Friedman and two others, including John Handin (Friedman et al. 1980). As the title suggests, this paper does have some bearing on the deformation of unconsolidated sand, and it makes some useful observations regarding fractures in unconsolidated sediments. They reported,

> "The deformed sand veneers clearly demonstrate that unconsolidated sand under confining pressure behaves in many respects like indurated sandstone. The microfracture patterns, which become more ordered with increasing confining pressure, show the same general stress trajectories as do similarly deformed indurated sandstones." (Friedman et al. 1980)

Even if this is true, it is not clear from Friedman et al.'s text or their models that there are indications of relatively planar limbs or fairly sharp hinges being supported by their modeling. Dr. Snelling appears to be trying to stretch Friedman et al.'s findings beyond what they intended.

Dr. Snelling wrote, "Nabavi and Fossen (2021) have reviewed the history of such experiments, primarily undertaken in squeeze boxes with layers of dampened sand and/or clay, glass sides to the box and a crank handle for moving one end inwards towards the other fixed end so that the compressional folding of the dampened sediment layers can be simulated." Nabavi and Fossen (2021) is a fine article on folding, but it really deals very little with physical modeling. They show one line drawing as an example of soft-sediment deformation and it clearly has what we would describe as a soupy appearance, without planar limps or sharp hinges. The figure is taken from "*Folding during soft-sediment deformation"* by G.I. Alsop, et al, (2020). The paper shows many examples from Israel of soft-sediment deformation, all with soupy appearance. We would argue that the figures in Waldron and Gagnon (2011) all show "soupy" deformation, not planar limbs and sharp hinges.

Davis (1978) did a great job of modeling monoclines similar to those on the Colorado Plateau. He used kaolinite and modeling clay but apparently did not try to use materials with characteristics that were scaled to represent what either lithified or non-lithified materials would have had. This just was not the focus of his work.

To summarize, Dr. Snelling's objection that "laboratory-scale, experimental, soft-sediment-deformation simulations" show the planar limbs and sharp hinges has not been demonstrated. We are still quite comfortable that the regional and outcrop scale observations of the Tonto folds are best explained by deformation of at least partially lithified sediments over deep time.

Ubiquitous deformation at microscopic scale

If the Tonto units had been metamorphosed by temperature increases from deep burial and pressure, the samples collected would have documented this, but no one would have expected this. Dr. Snelling spent considerable effort in each of his reports describing microstructures that provide information about the deformation of sedimentary rocks. He describes features like kink bands, deformation lamellae, deformation bands and undulose extinction. We would not have been surprised to have seen more examples of such microstructures in Snelling's slides. By the same token, the lack of these is not troubling.

Why would that be? We supplied at least a major part of the answer in our article quoted here:

> "Folding of lithified sediments, in contrast, takes hundreds of thousands to millions of years. Of course, unlithified and well lithified sediments are end members on a continuum and deformation rates and mechanisms will depend on the lithologies involved and the degree of lithification. For simplicity, let's first consider these end members, but recognize that the Tonto units are not at the extremes, either in terms of the degree of lithification or the amount of deformation evidenced." (Mitchell and Tillman 2024b)

This means that the range of microstructural features that result from this deformation would not all be present. The degree to which they should be expected depends on several factors, including: the degree of lithification (at the time of the deformation), the amount of deformation, and the rate it occurs at. First, we should agree that these are not as tightly folded as many sediments are, such as in orogenic belts. Folding is often much more intense in the cores of mountain ranges. These are not even as intensely deformed as rocks along the Palisades fault as evidenced by the amount of brecciation there. (Reches and Matthews 1978; Orofino 2005) .

Dr. Snelling reported, "Thus, the only definitive method for distinguishing between slow ductile deformation of lithified sandstone layers and soft-sediment deformation of unlithified sandstone layers is microscopic examination of the minerals and textures within those sandstone layers, which is exactly what was done in my investigations." (Snelling 2026a) Notice that he describes this as a discrete, all-or-nothing situation, without dealing with the reality of the continuum that we know exists in nature. His response to us never really dealt with at what point along the continuum, microstructural features appear.

A critical component of this understanding is the timing of diagenesis and that will be discussed next. For now, it is enough to recognize that we don't know the exact timing of the quartz cementation that is so extensive today.

We described the sediments as having been pervasively deformed, as that is what folding does. The rocks did not simply slide along brittle faults, but every portion experienced some deformation, though clearly not all experienced equal amounts. We see that in the fracturing in the slides that Snelling prepared. The grain scale deformation is dependent on factors that include the strength and thickness of the beds, the temperature, the rate of deformation and the specific geometries involved. Laboratories have certainly been able to reproduce the various deformational features that Snelling described, but we simply don't know when they would have begun and how extensive they would have been, particularly in specific settings, such as in the Grand Canyon folds.

Dr. Snelling accused us of "cherry picking" the slides that we used in our article. (Snelling 2026a) We obviously wanted to show important features and selected examples that reflected points that we wanted to illustrate. Extensive fracturing often cuts through quartz grains. This is particularly evident in the Monument fold samples where we saw this in virtually every slide. It is likely that this degree of fracturing and almost brecciation is related to the observation that the weaker recessive beds are thinner on this fold than on the Carbon Canyon fold. The finer grained Bright Angel shale also shows evidence of deformation at the scale of thin sections (Snelling 2021a). We interpret some of the deformation to show as thin zones of disturbed grains, though as Snelling observed, "The degree to which fractures cut through grains is also particularly difficult to observe in fine-grained rocks" (Snelling 2026a). Fracturing is evident in the Muav samples, particularly MFML-05, as is also evident in the photo of the sample location (Snelling 2024a). In many cases, the most heavily fractured slides were made from samples in the most heavily deformed portions of the folds. Perhaps more extensive sampling, including looking at cuts in different direction would show areas that show more extensive grain deformation. Nevertheless, grain deformation is observed in the thin section slides and it impacted fracture development.

Diagenesis

Both we and Dr. Snelling agree that the folding found in the Tonto formations could not have happened since Noah's flood if the rocks were as cemented and hardened as they are today. The processes that occurred to transform loose sands, mud and lime into various sandstones, shales and limestones are called "diagenesis". As we noted in our article, it is difficult to determine when the quartz cementation took place that lends most of the strength to the rocks that we see today. We cannot radiometrically date it and Dr. Snelling would not accept the results if we could.

Snelling's timeline demands that quartz cementation took place very rapidly.

> "Yet they persist in claiming without justification that "these temperatures will not allow noticeable cementation in a few hundred years." This claim is entirely refuted by observational and experimental evidence." (Snelling 2026a)

Temperature is just one problem. It is a misconception that just a small amount of water passing through the pore space between sediment particles is needed to cement the grains together.

To support his claim of rapid quartz cementation, Dr. Snelling cites an article by Akahane, et al. (2004) where these authors describe relatively rapid precipitation of opal on wood in hot springs. Opal is hydrated silicon dioxide, not crystalline quartz, and its precipitation on wood is very different than that of quartz from connate waters in sedimentary rocks. Even if opal were somehow rapidly precipitated through the Grand Canyon formations regionally, the opal would still have to be very rapidly converted to the crystalline quartz we see today.

In the abstracts for each of his Tonto structural articles, Dr. Snelling makes this type of statement: "However, if the Tapeats Sandstone had been deposited at 507–508 Ma, after ~450 million years it should have been fully cemented and lithified." (Snelling 2023b, 2023c, 2024c, 2024b). While we certainly agree that the lapsed time provided by deep time models allowed adequate time for quartz cementation, this is not the only requirement. Other requirements include that rocks were heated to adequate temperatures and that significant fluid movement took place to deliver enough cementing silica ions.[12] Were these

[12] Can we find an example where sand was deposited but not extensively cemented, despite burial for a very long period of time? One example is the Cambrian Hickory Sandstone that was deposited on the Great Unconformity in what is now Central Texas. Dr. McBride wrote:

> "Despite its great age, the Hickory remains friable where it was never buried more than 1500 ft (~1 km), notably along the flanks of the Llano Uplift. The slight induration shown by most beds is the product of incipient quartz overgrowth development plus trivial suturing of grains at pressure solution contacts. Because of its poorly cemented nature, the Hickory has been a source of industrial sand for several decades." (McBride 2013)

This is further documented in McBride et al. (2002) and Kyle and McBride (2014). Recognize that where the Hickory Sandstone was buried deeper, more lithification took place. Diagenesis was not uniform and different regions could have been affected differently in the Grand Canyon units as well. The Hickory Sandstone shows how important temperature history is in diagenesis. In the Hickory Sandstone example, a history of shallow burial would have been important if quartz overgrowth development was limited. How hot did the Hickory get? Estimates vary. McBride wrote:

requirements met in the Tonto units? The burial history with the extrapolated thicknesses of section that are now eroded should have provided for the temperature increase required for quartz cementation over deep time. The box in Figure 15 shows the P/T range over which the sediments would have passed during quartz pore filling diagenesis. Assuming a maximum depth of burial of 15,000 ft., as both we and Dr. Snelling have seen as reasonable, two different pressures are relevant. The lithostatic pressure, that pressure due to the overburden of the rocks plus fluids above the Tonto, is estimated to be 1.034 kbar (15,000 psi). This pressure is relevant to the compaction of the units. Snelling estimated that the hydrostatic pressure, the pressure due to the connected fluid column, would be ~0.3–0.4 kbar (~4,300–5,900 psi) (Snelling 2026a). This would be the pressure more relevant to the chemical reactions during diagenesis. Over time, the section would have progressed from the cooler, upper left corner of Figure 15 to the bottom right corner, at which point it began to cool because the Colorado Plateau was uplifted.

The temperatures and pressures present in these figures would have permitted quartz cementation and other diagenetic effects over deep time. What about in just a few hundred years? The temperatures do limit the amount of quartz that can be deposited in a short

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"The thermal history of the Hickory and overlying rocks is controversial. According to the burial history shown in figure 8 and assuming a geothermal gradient of 30° C/km, basal Hickory beds in shallow cores did not exceed **50° C**. Beds in deep cores reached at least 84° C and probably reached 95°C. Sparse vitrinite-reflectance data from overlying Pennsylvanian shale (Ro ~0.3 to 0.5 = ~45° to 65° C; Wiggins (1982)) agree with the low temperature estimate. Much higher temperatures (**to 210° C**) were reported for homogenization temperatures of fluid inclusions from overlying Ordovician and Carboniferous carbonate rocks (Young and Jackson, 1981) and from sulfur isotopes in the Cap Mountain Limestone (70° to 200° C. Smith (1981)." (McBride et al. 2002) Emphasis added.

As you can tell, there is a range in uncertainty for the Hickory Sandstone, but relatively low temperatures are consistent with the low degree of cementation present. Thus analogously, for the Tonto folds, even if the Cambrian folds had demanded far less cemented sands, that still would not negate deep time options. If the units had been less cemented at the time of deformation, further cementation could have taken place over the next 44 to 64 million years, before the carving of the Grand Canyon about 6 million years ago, or even later by the time the Tapeats would have been exposed with erosion by the Colorado River. That also would have been enough time for upwelling of meteoric waters to cool and deposit further quartz.

time. Dr. Earle McBride, a well-respected petrologist, summarizes the conclusions of research on quartz cementation:

> "In rapidly subsiding basins, like the Gulf Coast and North Sea basins, most quartz cement is precipitated by cooling, ascending formation water at burial depths of several kilometers where temperatures range from 60º to 100º C. **Cementation proceeds over millions of years, often under changing fluid compositions and temperatures**. Sandstones with more than 10% imported quartz cement pose special problems of fluid flux and silica transport. If silica is transported entirely as H_4SiO_4, convective recycling of formation water seems to be essential to explain the volume of cement present in most sandstones. Precipitation from single-cycle, upward-migrating formation water is adequate to provide the volume of cement only if significant volumes of silica are transported in unidentified complexes. Modeling suggests that quartz cementation of sandstones in intracratonic basins is effected by advecting meteoric water, although independent petrographic, isotopic or fluid inclusion data are lacking." (McBride 1989) Emphasis added.

Notice that Dr. McBride pointed out that the silica within the original pores would not have been adequate to account for heavily cemented sandstones. He states: "Most calculations yield values in the range of 10^4 to 10^5 pore volumes (i.e., pre-cement pore volumes) of water necessary to introduce 5 to 15% cement in each cubic centimeter of rock". Sources can be postulated without resorting to any cataclysmic processes. Over deep time, there is no reason to resort to cataclysmic or miraculous processes, but this would not be true for cementation over a few years. Dr. Snelling would probably say that McBride is biased by his "uniformitarian geology", but the proposals by Snelling are short of support. He proposed that hyper-rapid cementation can occur regionally at the temperatures that he provides but so far has not given evidence of this.

It is reasonable to hypothesize that some quartz cementation took place over the 44 to 64 million years that elapsed after the Laramide folding and before erosion exposed the Tonto Group. The SEM images shown by Dr. Snelling can be interpreted to support this hypothesis. We agree that they do not demonstrate deformation prior to the formation of quartz crystal faces, though such deformation need not have been ubiquitous over all regions. The photograph in his Figure 9d (Snelling 2026a) is much like that in Figure 41 in McBride et al (2002) described as "incipient overgrowths of quartz". This is consistent with diagenesis that continued after the folding event.

It is interesting that Dr. Snelling rejected the paragenesis (the order in which minerals were formed) in the Muav limestone that we outlined from our interpretation of his slides and his descriptions, without providing any other interpretation. The order we outlined was based on cross-cutting relationships that are evident in slides like MFML-05, our Figure 22.

What do we conclude about diagenesis? We find it consistent that much cementation took place before the Laramide event when the rocks were heated to their maximum temperature. Cementation may have continued after the deformation, but that is uncertain. However, we do not see a scenario where the regional quartz cementation could have occurred in the extremely short timeframe proposed by Dr. Snelling.

Carving the Grand Canyon

It is important to contrast the timing of the diagenesis that we suggest with the proposals that Dr. Snelling makes for the Grand Canyon rocks. He views the carving of the Grand Canyon to have occurred over a few hundred years following Noah's flood and yet after the lithification of the units by some hyper-fast process that occurred after the flood. Dr. Snelling at times reported that his interpretation of geologic events, such as diagenesis, represents those of all flood geologists, but we have not found that to be the case. For instance, Snelling wrote:

> "However, that is a proverbial red herring because **no creationist geologist** claims the Precambrian sedimentary layers were unlithified at the time of Laramide folding. If Mitchell and Tillman had read my paper on the Tapeats Sandstone, they would know that creationist geologists agree the Precambrian sedimentary layers were lithified when they were eroded before the Tapeats Sandstone was unconformably deposited on them, well before the Laramide folding." (Snelling 2026a) Emphasis added.

Perhaps it is true that most flood geologists consider the Precambrian rocks *in the Grand Canyon* to have been lithified prior to the flood, but it is not true that Precambrian rocks are globally considered pre-flood and potentially lithified. For instance, Dr. Tas Walker published a geological column that shows early flood deposits going back through the Proterozoic and possibly into the Archean. (T. Walker 2020). Michael Oard, the person most young earth leaders (including those at Answers in Genesis) cite as their expert on a post-Flood ice age, classified Precambrian sedimentary rocks like the Grand Canyon Supergroup as Flood deposits (Oard and Froede Jr 2008). We are not "lampooning" YEC, but recognizing that there are different opinions among leading flood geology authors and we are not assuming that Dr. Snelling speaks for all of them.

By the same token, Dr. Snelling writes as if flood geology presents the united view that the Grand Canyon was carved after the flood through hardened rocks. While this does represent the view of many flood geologists, others present the view that the canyon was carved largely during the late stages of the flood. (Scheele 2010; Oard 2021; T. Walker 2012; Clarey 2026)

What carved the Grand Canyon? Dr. Snelling wrote,

> "The Colorado River carved the present-day Grand Canyon through the hard lithified strata. [Actually, there are also secular uniformitarian geologists who agree with Flood geologists that the Colorado River did not carve the Grand Canyon. Instead, the uplifted Kaibab Plateau impounded a system of huge lakes that catastrophically breached that dam and rapidly carved the canyon within days." (Snelling 2026a)

This is partially true. While there are several proposals for how the Grand Canyon reached its depth today, it is doubtful that many, if any, non-flood geologists believe that the canyon was carved within days or even a few hundred years. Most would support Dr. Karl Karlstrom's conclusion that, while the Grand Canyon may have had precursors, it was largely integrated and carved over the last 5-6 million years (Karl E. Karlstrom et al. 2014). It is also true however that a recent report used radiometric dating of zircons to support the proposal that spillover from a large lake in the Bidahochi basin was important in erosion of the Grand Canyon. This erosion began around 6.6 million years ago (He et al. 2026). Predictably, flood geologists see this as support for their version of the spillover hypothesis (Clarey 2026). Given that He et al.'s support for the hypothesis is radiometric dating, this would be problematic (Duff 2026). Using data that you don't support to support your model is contradictory. He, et al. proposes that the spillover could explain how the Colorado River came to be integrated, but does not suggest any cataclysmic carving episode.

Casting further doubt on the lake spillover hypothesis misused by Dr. Snelling is a new paper by Karlstrom et al. (2026). The authors of the new study argue that detrital sanidine tracer grains and fish phylogeny data indicates that "…multiscale mantle-driven uplift, rather than lake spillover, was the primary driver for integration of the proto-Colorado River through Grand Canyon." No doubt work will continue understanding canyon development over the last few million years.

Dr. Snelling continues to believe that "Diagenesis would have to occur within a few decades to a few hundred years" (Snelling 2026a). He is right that our article did not go through his explanations for how that might have taken place. It is also true, as he wrote, "few if any petrologists would support the time frame reported in my quoted comments" (Snelling 2026a) He writes:

> "However, in their abbreviated version of my hypothesis, they neglected to explain the Flood geology model in which much of the waters for the biblical global Flood cataclysm were expelled from the upper mantle as mineral-laden superheated steam

> (when "the fountains of the great deep burst forth" [Genesis 7:11]). Then, during subsequent deposition of the sediment layers right across the continents over thousands of square miles, those mineral-laden hot waters would have become trapped in the pore spaces within the sediments where the minerals would have precipitated as the pore waters rapidly cooled, thus achieving lithification rapidly. Furthermore, many observational data have been presented to support this Flood geology model, including support from the secular uniformitarian literature." (Snelling 2026a)

We are not sure what he considers his support from secular literature. His proposal of superheated steam is interesting. Perhaps this is why he proposes that "the beds dried and were cemented and lithified to sandstone" (Snelling 2023b). Why would the rocks have dried out? The pore space in buried rocks is typically filled with interstitial water until exposed to air, such as the exposure due to carving by a canyon. It is hard to understand where the water would have gone. It would not have evaporated away. Wouldn't superheated steam have heated the sands higher than what Dr. Snelling says the rocks were heated to?

Silica deposition from superheated, pressurized steam has been studied by Bordvik et al. (2023). It can be a real phenomenon but considering it a plausible scenario for regional diagenesis in 15,000 feet (or more) of Flood-deposited strata is not possible, even in Snelling's miracle-rich mode. Silica can be deposited, such as in pipes, from hydrothermal water supplies, as gas becomes supersaturated, precipitating due to a sudden drop in pressure. The deposits studied consisted of soft, porous deposits, that could be removed with compressed air, presumably composed of hydrated silica (opal-A). In tests across a number of pipes, they found that 74% of the silica formed solid particles by the second pipe. They observed precipitation beginning at 500º C! It is expected that such deposition would be found around hydrothermal vents, but not in the Tonto Group, especially at a basin scale. It is also important that, like in the opal described by Akahane, et al. (2004), opal would have to be converted to quartz to reflect the cementing agent in the Tonto Group. Applying this to regional columns of sediment, such as at the Grand Canyon, is not something that should be considered feasible. Even if such steam were generated, it would have deposited quickly in the first permeable layers the base of the Tapeats. In the Grand Canyon, quartz cementation needs to be explained up through the column, including higher levels, such as in the Coconino Sandstone. This would also mean that the silicic acid would have passed through the limestone units without leaving evidence. Genesis 7:11 refers to "the fountains of the great deep" (NASB), but it takes a lot of interpretation to transform this into mineral-laden superheated steam from the mantle. Such a hypothesis is interesting but can hardly be taken seriously.

Later Metamorphism in other areas

In our article on the deformation, we pointed out that Young Earth flood interpretations do not just have problems in the Grand Canyon. A global flood explanation for the rock record has to explain it all. One of the issues comes from the fact that late metamorphism is documented in many places in layers supposedly laid down after the Noah's flood, particularly given Snelling's interpretation of the top of the flood deposits. Here is Snelling's reference to an example we gave:

> "They also cited an example of a study of the deformation of Eocene and Oligocene sediments in the Taiwan fold-and-thrust Slate Belt. Thus, they state correctly that in 'Snelling's age model' these sediments 'would have been deposited about 4000 years ago over a period of at most a few hundred years' (actually, I would say over just a few decades). Yet in that Taiwan study, Tillman and Byrne supposedly documented that the sediments were lithified and metamorphosed as "lower greenschist facies" at relatively high temperatures, now demonstrated to have ranged from ~300–500°C. Of course, young-earth creationists agree that at those temperatures the rocks become plastic and are able to be readily deformed by ductile processes, which is also the case for the deformation observed in metamorphic rocks all around the globe. Thus, 'This deposition, burial, metamorphism, and erosion had to take place at incredible rates in any YEC model.' Precisely! But have they not read the young-earth n creationist literature that provides the details of how **these processes happened rapidly during the biblical global Flood cataclysm and its catastrophic aftermath,** with supporting documentation from the secular uniformitarian literature that Tillman and Mitchell are so fond of citing?" (Snelling 2026a) Emphasis added

The geologic descriptions of the deformation of the Taiwan Slate Belt have been documented several times. (Mitchell and Tillman 2024b; Sibuet and Hsu 2004; Chen et al. 2019). It is interesting to see that he confirms the incredible timeline that this requires for flood geology. He says that "processes happened rapidly during the global flood cataclysm and its catastrophic aftermath", but the flood geology scenario really can't apply to features like this. In the Dr. Snelling timeline, this is all taking place after the flood. First, we know that in this area, sedimentary rocks were deposited on top of layers that were supposedly flood layers. Dr. Snelling obviously has no problem seeing these rocks deposited in a few days after the flood, but can't use cataclysmic flood deposition to do so. Many events are recorded globally during the Eocene and Oligocene epochs. For example, in the Gulf of Mexico, we find deltas, thick slope deposits, and even small reefs. (see this article for more information: What happened geologically between Noah's flood and Abraham?) This deposition took far longer than the entire time that Dr. Snelling suggests for all of the events. Depositing the Eocene to Oligocene sediments that were metamorphosed is just a small part of the issue though. In order to metamorphose the shales to slate, another eight km or more of sediments had to have buried the Pilushan Formation that is slate today. We can't use internal clues to quantify how long it took for the rocks to be deformed into the folds that we find today. The limiting factor would have been the rate at which plates were moving, rather than the viscosity of the heated rocks. Flood geologists must remember that calling on miraculous rates of plate movement might be a hypothesis for during the flood, but this happened later. Additional deformation was required to bring the deeply buried rocks up from the great depths to the surface and into today's mountains. The rocks that covered them had to be eroded away and there is no justification to call on the cataclysmic earthquakes or tsunamis that were hypothesized for the early part of the Flood. Not surprisingly, flood geologists, such as Dr. Snelling, see these factors as not being a problem.

Taiwan is just one example of what Snelling would have as major post-flood deposition that was deeply buried, metamorphosed and then exposed by erosion. Others include the Alps (Engi et al. 2004; Vaughan-Hammon et al. 2022; Hoinkes et al. 1999) and the Zagros Mountains (Karim and Al-Bidry 2020; Boutoux et al. 2021).

Naturally, metamorphism and deformation of hardened rock examples can come from much closer to the Grand Canyon. In fact, we find clear evidence that metamorphic rocks were faulted and folded in the nearby Catalina metamorphic core complex, southeastern Arizona (Favorito and Seedorff 2021; Ducea et al. 2020; Spencer 2023; G. H. Davis 2025). Deformation there took place just south of the Colorado Plateau, during the Cenozoic Laramide Orogeny, approximately while the Grand Canyon monoclinal folding took place and also even later in the Cenozoic. In the Catalina complex, unlike in the Grand Canyon, rocks were deeply buried enough to be metamorphosed in some areas, as evidenced by strong foliation. Figure 6 of Favorito and Seedorff (2021) shows great examples. They report that the style is consistent with burial 6-8 km deep. Folded rocks extend from Precambrian to Cretaceous. We find sedimentary rocks, folded and metamorphosed. Also, igneous granites were emplaced during the period after Snelling interprets Noah's flood to have occurred. The granites and metamorphics cooled and solidified and later were uplifted and eroded. Dr. Snelling will say that he has explained these, but geologists find his evidence weak.

Dr. Snelling questioned our ability to provide examples where it is "well documented that the rocks were lithified at the time of deformation" (Snelling 2026a). He is quite right that most of the time, geologists working deformed rocks typically consider the reality of deep time settled science and don't really consider the idea that deeply buried sediments were folded as soft-sediment deformation. I (Steve) have published one particular example where the rocks provide a clear demonstration that they were lithified prior to a major folding event. In the Marathon fold belt in West Texas, the Caballos Novaculite contains clear evidence that it was lithified before folding. (See Bent Rock Layers and Deep Time). In this case, pressure dissolution features, called styolites, developed prior to the folding, parallel to the original bedding. Styolites in siliceous novaculite are definitive evidence that these were competent, lithified beds before they were folded over deep time.

We have cited examples of metamorphism, folding and igneous intrusions that occurred well after Dr. Snelling's proposed one year long global flood. Rock supposedly produced during the claimed global flood have already cooled and are often now exposed at the Earth' surface. The examples that we cited are younger and yet they also have cooled and been deeply eroded and are exposed at the surface. One possible answer would be that these rocks that are dated as younger were all dated wrong and the events all happened earlier, such as during the flood, but the relative dating of the events is, in most cases, well documented. Another idea would be that miraculous deformation continued around the world after the flood. If that were the case, then the question would be: when did all of these rapid paced effects cease? The Biblical record gives no hint that the world was geologically extremely violent after the flood. God's promise was: "*As long as the earth endures, seedtime and harvest, cold and heat, summer and winter, and day and night will not cease*." Genesis 8:22 CSB. This sounds as though the processes returned to normal over whatever area was affected by the flood. There is no Biblical reason to suggest that God chose to protect the area where Noah and his seed lived, while the rest of the earth was still being disturbed by the geologic chaos triggered by the flood.

Part 3 summary

We have read all of the articles by Dr. Snelling on the folds that he sampled in the Grand Canyon and, of course, his responses to our papers. We fully admit that we were not there when the folding occurred. We rely on physical evidence from this region and other areas to understand the processes and assess the timing. We find that the best explanation for all of the observations is that the rocks were at least partially lithified before the Laramide orogeny and were folded slowly during this event. We agree with Dr. Snelling that the Phanerozoic rocks in the Grand Canyon were not metamorphosed, though they were metamorphosed in the Catalina region, south of the Grand Canyon. The structural folding we observe in the Tonto Group (such as the Carbon Canyon Fold) is a direct result of the Laramide Orogeny, a massive mountain-building event caused by tectonic plate collisions. This was not a sudden, rapid squishing of soft mud during a flood year. Instead, just like the slow, grinding tectonic forces currently pushing up the Himalayas and the Alps, this continental collision slowly warped miles of solid, previously lithified rock. Snelling's hyper-compressed timeline simply does not allow for the millions of years of slow heat and immense, sustained pressure required to fold solid rock on a continental scale.

Some lithification of the Tonto is consistent with these observations:

1. Associated folding of Precambrian lithified units along the Palisades Fault. a fault that developed with the Butte fault along which the Carbon Canyon folding developed.

2. Brecciation of the Tonto units in the same area.

3. Planar limbs and sharp hinges in the Tonto folds, including the kink fold near the Monument fold

4. Fracturing associated with the folding, often cutting through grains and often most intense in the more tightly folded portions of the folds.

5. Timing of overall diagenesis, given the temperature and pressure constraints.

Dr. Snelling made the claim that the lithification of the sediments that are now stone in the Grand Canyon could have all taken place in a very brief time. His associated hypotheses just don’t have any technical support. They fail because they need to explain the diagenesis of vast volumes of sediment hardened by many different types of diagenesis. For example, euhedral quartz crystals forming in many different temperature and pressure situations speak to long time periods, time that just doesn’t fit the YEC model.

The entrenched meanders of the Colorado Plateau provide evidence of the gradual uplift of the region, especially given that we both agree that the sediments were lithified prior to the carving of the Grand Canyon. Rapid carving would not preserve the meandering morphology. It is entirely possible that some form of spillover contributed to the reorganization, but we see no data to support this having occurred over the timeframe that Dr. Snelling predicts.

Dr. Snelling seems to believe that if his proposal for soft-sediment deformation folding is true in the Grand Canyon, that would prove that flood geology is valid and that the Earth is young. We used a number of examples to point out that deformation over deep time is confirmed over and over. Much of the metamorphism would be considered post-flood in any published young earth model. It is not reasonable to propose that post-flood sediments were deposited, buried, metamorphosed and then uplifted and then much was eroded away in a few hundred years, after any of the YEC models for when Noah’s flood occurred.

Final Comments:

No, neither we nor Dr. Snelling were there when the Grand Canyons were there. In fact, neither was Moses. God was, but His account does not describe the geologic effects of Noah's flood, let alone in what is now the Grand Canyon region. YEC make their case based on three anchors:

1. The Bible can only be interpreted faithfully as demanding creation less than ten thousand years ago.

2. The abundant fossil record around the world has to be interpreted largely to be the result of a global cataclysmic flood a few thousand years ago.

3. The scientific data can and should be interpreted to fit these proposals.

Regarding the first anchor, we find that many Christians around the world seek to hold the Bible to be the inerrant Word of God, but do not believe that it teaches, much less demands that the Earth was created such a short time ago. It is far beyond the scope of our writings here to delve into how these views work and which are more correct, but suffice to say here, that we would urge grace as we deal with those who disagree with our interpretations.

Regarding the third anchor, YEC organizations, such as AIG, have devoted much effort and resources to attempt to demonstrate this point. We find that this has not been successful, and this study is a case in point.

This discussion revolves around the second anchor and its application to the Cambrian rocks in the Grand Canyon and largely in the American Southwest. Flood geology has a tremendous number of events to explain occurring within the one-year long event that they interpret to have been global.

Could the Cambrian sediments have been deposited within the early part of Noah's flood? We continue to find that there is no evidence to support this. If deposited by a cataclysmic flood, the Cambrian units should be dominated by thick chaotic units deposited by high velocity flows. We found beds that look very much like normal beds from modern day marine, tidal and fluvial processes. The timeline proposed by flood geology dictates that deposition was almost continuous through the flood, but we saw evidence of many pauses in sedimentation. There were many examples that could be pointed to, but the many layers of algal stromatolites that formed reefs in the Cambrian period are particularly clear.

All agree that if the sediments in the geologic record were hardened prior to the folding that is so common in rock formations, then more time was required than YEC proposals have for the entire of Earth's record. Dr. Snelling proposed that the folding developed in the

Grand Canyon provides an example where the folding interpreted as slow incremental strain over deep time can be conclusively demonstrated to have occurred within the one-year long flood interval, while the sediments were soft and pliable. We found that the characteristics here support folding over deep time. We also pointed out that the burial, metamorphism, subsequent exposure and erosion of many units of Cenozoic age which are typically characterized as "post-flood," also do not fit within flood geology timelines.

We can understand that many people will continue to hold their understandings of a young earth and a global flood. Some will hold to this, believing that someday, explanations will be found that support these positions. That is a faith decision and can be respected as such. That is quite different than claiming that today's evidence and current findings support positions, when in fact they do not.

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Plate Descriptions

This section presents a set of plates (I to XI) featuring photographs Steve took during a trip in April 2026 and one additional plate (XII). Steve's visit provided a better opportunity than any of his earlier trips to focus on the Cambrian section. Although the plates support useful observations, they are not part of a systematic study and should not be treated as a substitute for one. The plates start with broader regional views and progress to increasingly detailed images. He did not have permission to collect samples and was also unable to observe any Laramide folding, including the ones that Dr. Snelling sampled.

Plate XII was taken by Timothy K. Helble and used with his permission.

Plate XIII was taken by Dr. G.H. Billingsley of the USGS and as published on that website is available in the public domain.

Plate

Plate I.

Regional view from Navajo Point on the South Rim showing the Cambrian Strata. The angularity of the Great Unconformity is clear between the formations of the Precambrian Supergroup below and the Tapeats Sandstone above.

Plate II.

Regional view showing the formations of the Tonto Group separated from the Precambrian Vishnu Schist by the Great Unconformity.

Plate III.

Closer view of the Tapeats Sandstone over the Vishnu Schist. The zoom in shows more clearly the Tapeats onlapping a local paleohigh on the Great Unconformity.

Plate IV.

Tapeats Sandstone above the Dox Formation. In this area, the formation can be split into three units, a massive unit at the base, a thinner bedded middle package and a more massive unit at the top. The upper unit thins to the west. The Tapeats is cut by several small faults, the largest of which is labeled. The faults do not extend into the Bright Angel Formation very far, if at all. The Tapeats is also cut by vertical fractures (joints) as well.

Plates V, VI, and VII.

These plates show various views of the Tapeats Sandstone outcrops showing the sand geometries. Observe bedding with alternating resistant and recessive beds. Individual resistant beds do not extend across the outcrop. They are consistent with small channel fills that at times amalgamated. Vertical fractures (joints) are again present, particularly evident on Plate V.

Plates VIII to XI

This series of photos show the upper part of the Tapeats Sandstone where it outcrops along the Bright Angel Trail, north of the Havasupai Gardens.

Plate VIII

Set of beds in the upper Tapeats Sandstone.

Unit A: Lower beds as seen in Plate VIIIb are poorly sorted, trough cross-stratified sands about 30 cm thick. The bed is actually an amalgamation of three different beds.

- Bed 1 is a reddish unit with trough cross-strata deposited from right to left. It had many clasts, presumably mudrock, that are now weathered out.
- Bed 2 is a trough cross-stratified, poorly sorted sandstone with the basal parts consisting of coarse-grained lags. The sandstone has fewer and smaller weathered clast holes. The unit cuts down into Bed 1 to the left.
- Bed 3 is a trough cross-stratified bed that thickens to the right. Cross-strata show deposition right to left.

To the right of the enlargement, this is part of a cut and fill package with trough cross-strata laterally accreted right to left. Thickening and thinning is indicative of some sinuosity in system.

Unit B: A set of compensationally-stacked sandstones. Resistant beds have cut and fill bases. Recessive beds are finer grained, including some black recessive beds presumably mudrock.

Unit C: Thicker fine-grained, recessive package that includes thin, black, finely laminated mudrock. (Plate VIIIa) This possibly fills in a shallow erosional channel. Discontinuous sand lenses separate some mudrock packages.

Unit D: Fine-grained sandy unit with irregular laminations and some coarser grains. (Plate VIIIa)

Unit E: On left of the outcrop two sand bodies are shown that amalgamate into one, as the upper one cut into the lower one (green line). The amalgamated sand is about 140 cm thick. The lower sand is cross stratified, filling to the left. The upper is one trough cross-stratified unit, filling and thickening to the right.

Plate IX: Closeup of trough cross-stratified sand showing coarser bases and mudrock clasts. It is worth noting that there are a few vertical fractures extending partially through the bed.

Plate X: Side view of outcrop shown in Plates VIII to XI.

Plate XI: Nearby top of weathered sandstone bed. With the finer grained material weathered away, the quartz pea-sized pebbles weathered out in relief. The quartz grains are well-rounded, milky "bull" quartz such as commonly weather out of granite and veins in igneous rocks. Such rounding and sorting is indicative of transport and abrasion by water transport. Such a process would have entailed at least thousands of years.

Plate XII: Tapeats Sandstone beds as seen in the south wall of Carbon Canyon, downstream from where the fold is located. The lower sandstone beds are often amalgamated.

As interpreted on the image below, a channel package is preserved. The erosional channel was filled with three smaller sand packages. Triangles show thinning upwards cycles (fining upwards?). 2The lowest unit is darker, possibly due to glauconite.

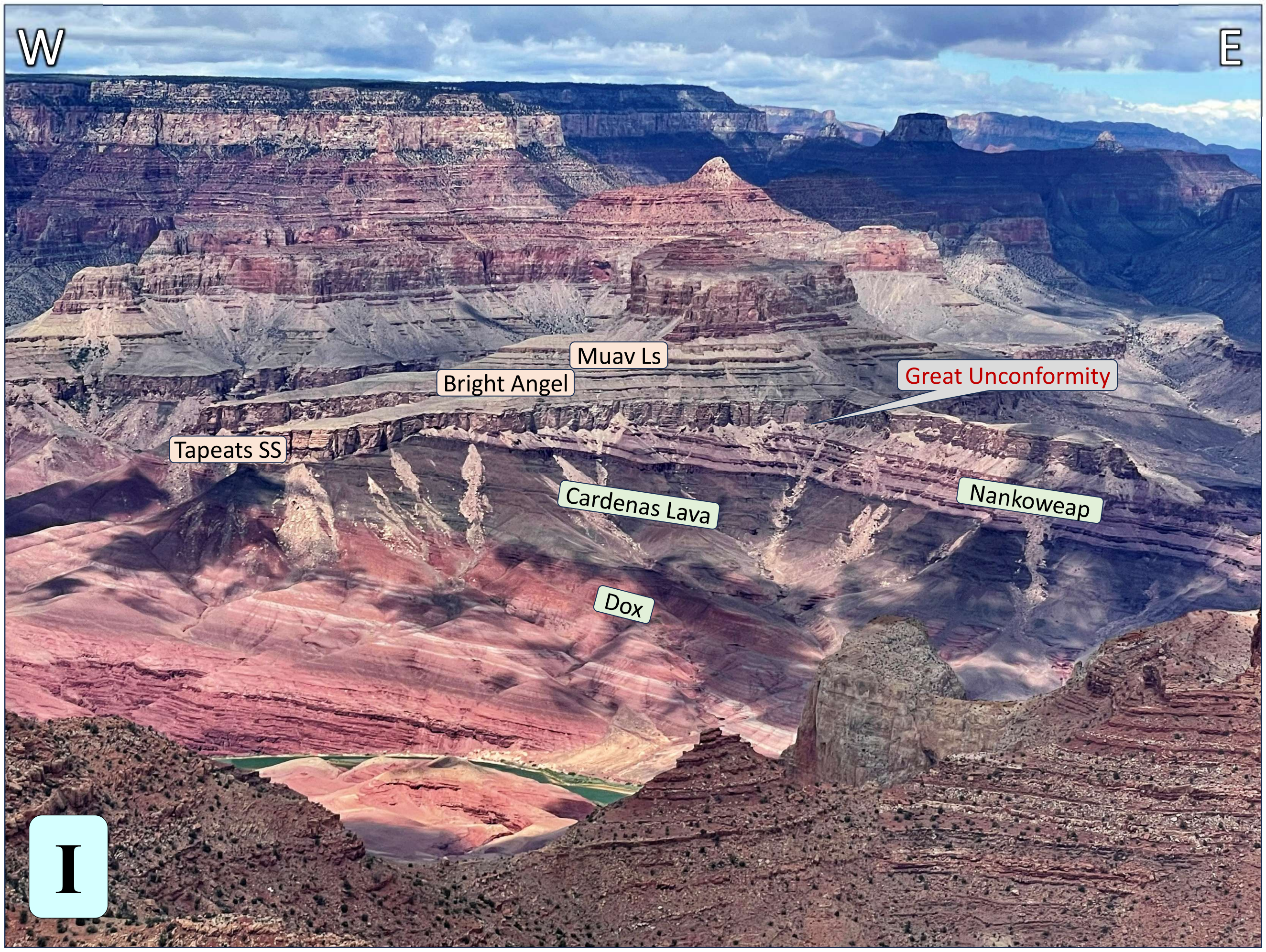
Photo from Timothy K. Helble.

Plate XII: Carbon Canyon Fold in Tapeats Sandstone on east side of Butte Fault (figure not reversed). Notice the different fold axis in the fold as highlighted by Tapp and Wolgemuth in Chapter 12 of "The Grand Canyon: Monument to an Ancient Earth", p. 125. Photo taken in 1989 by Dr. G.H. Billingsley of the USGS. (Billingsley, G.H., Goodwin, G., Nagorsen, S.E., Erdman, M.E., and Sherba, J.T., 2019, Geologic and related photographs of the Grand Canyon region (1967–2010): U.S. Geological Survey data release, accessed [Aug 05, 2026], at https://doi.org/10.5066/F7WS8SHW

Outcrop overall depositional observations:

- Poorly sorted, trough cross-bedded sandstones, often with coarse bottom lags.
- Cut and fill channel geometries of various
- Thinner mudrock beds
- Indications of sinuous bodies with lateral accretion filling.
- Rounding of quartz grains and pebbles
- Sand grains are moderately sorted.

All observations are consistent with fluvial deposition in a position not far from the source. The outcrop described from the Bright Angel Trail is from the upper part of the Tapeats. It compares well with Figure 3 published by Dr. Eben C. Rose in his 2006 paper, "*Nonmarine aspects of the Cambrian Tonto Group of the Grand Canyon, USA, and broader implications*". (Rose 2006). Plate V here also compares well, though his figure does not show the apparent grain size difference between the resistant vs. recessive beds that the photo highlights.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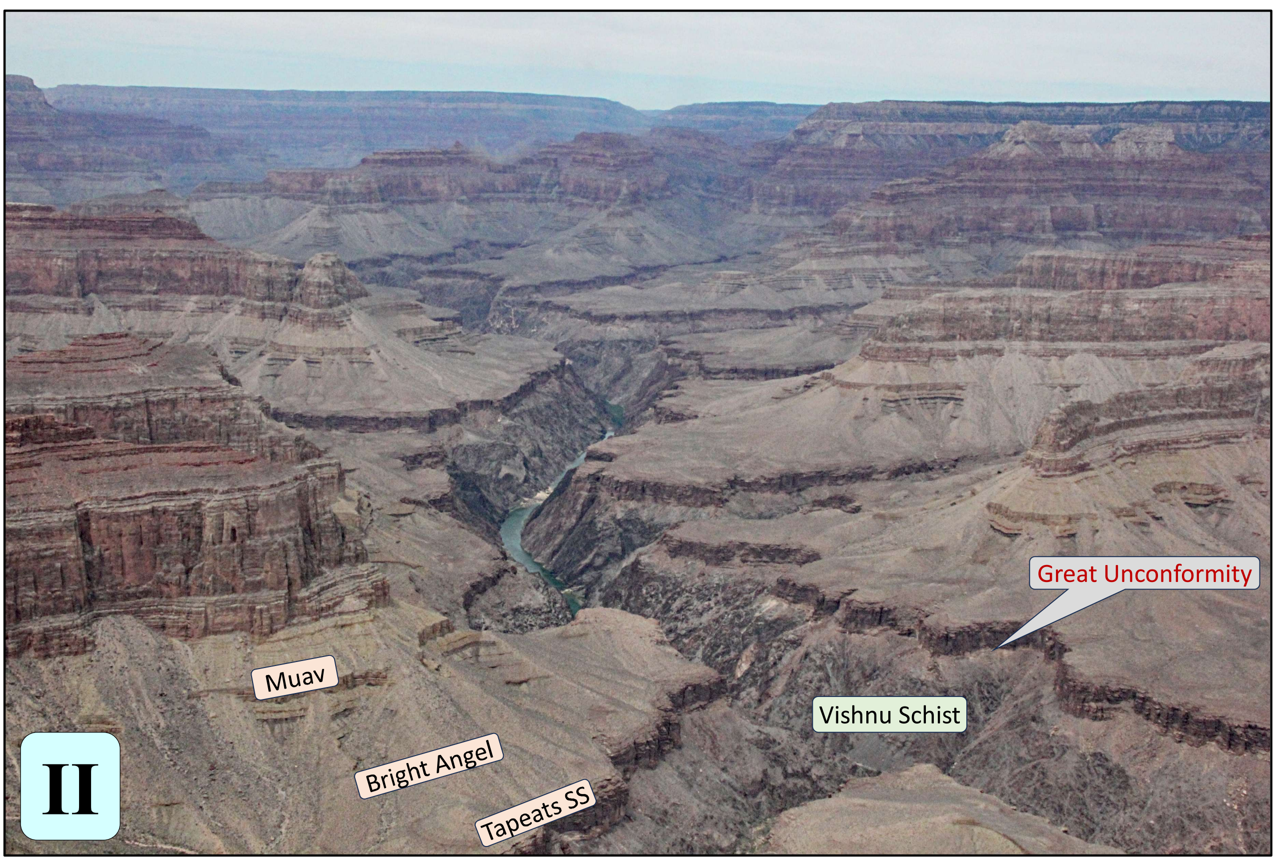
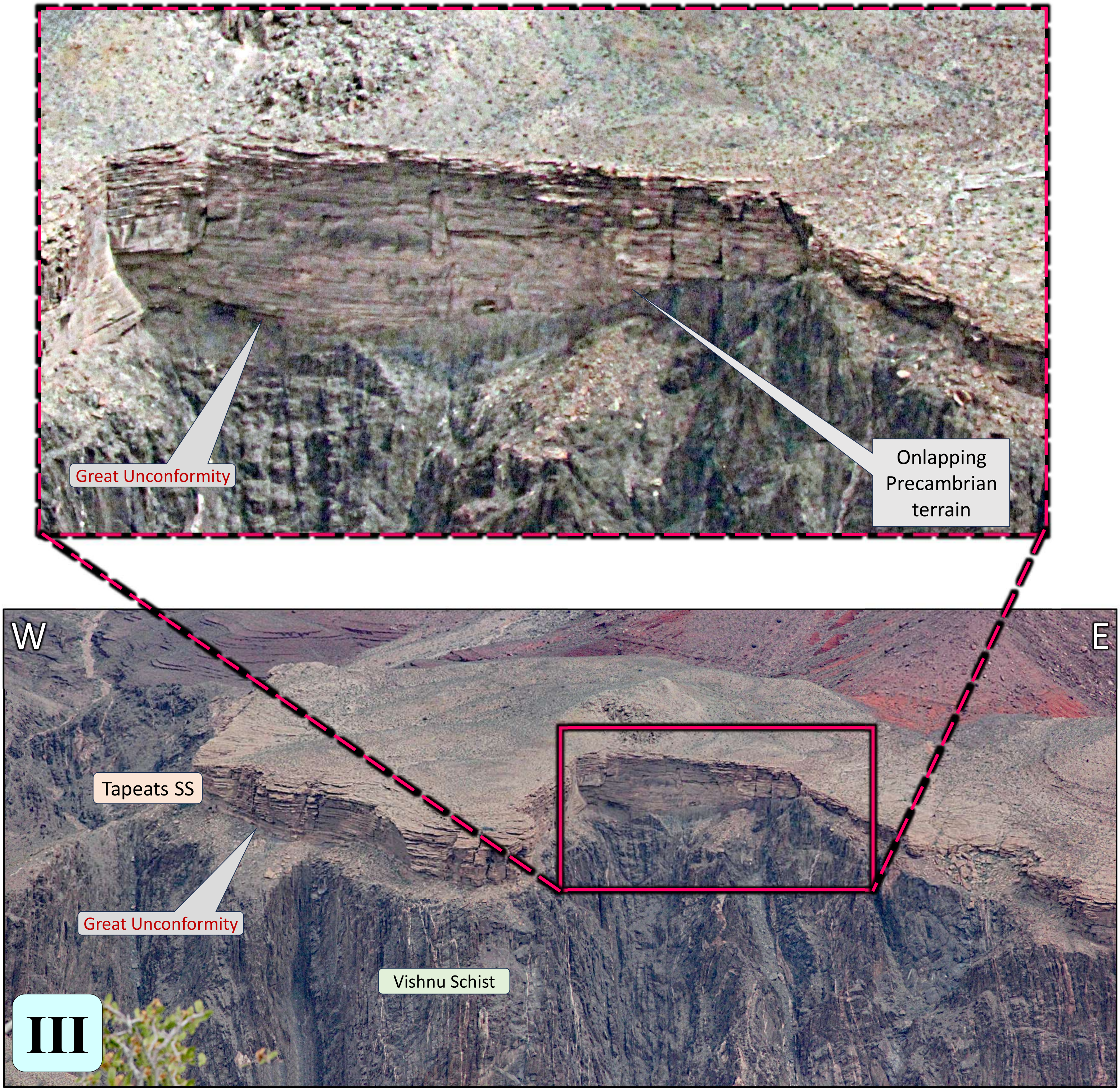
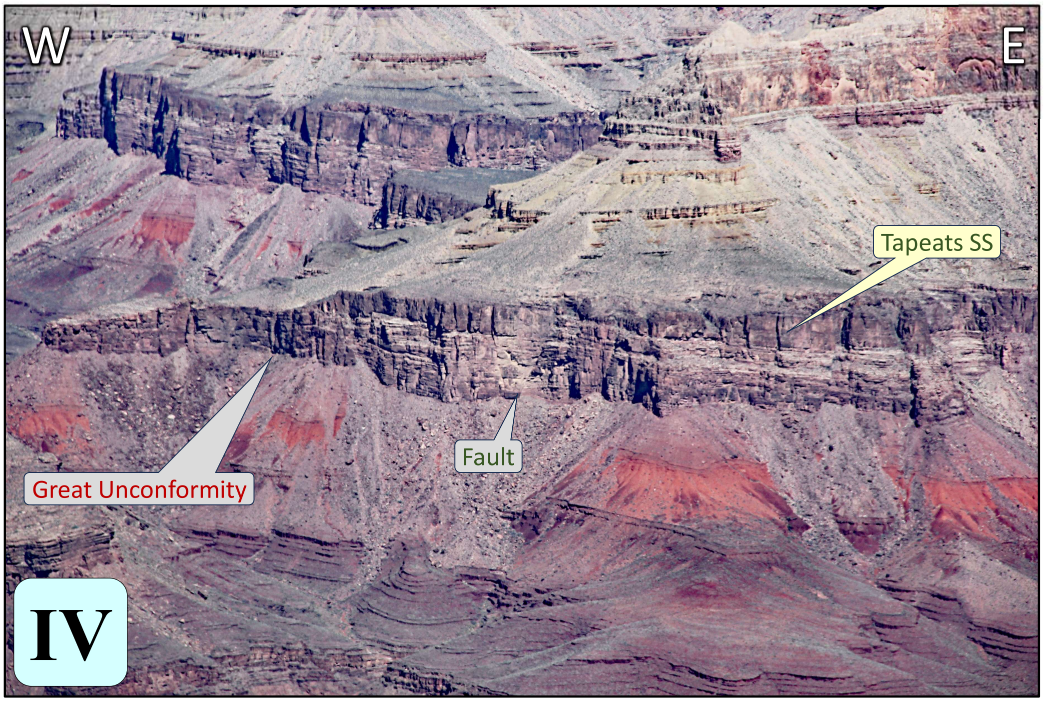

Great Unconformity
Muav
Vishnu Schist
Bright Angel
Tapeats SS
II



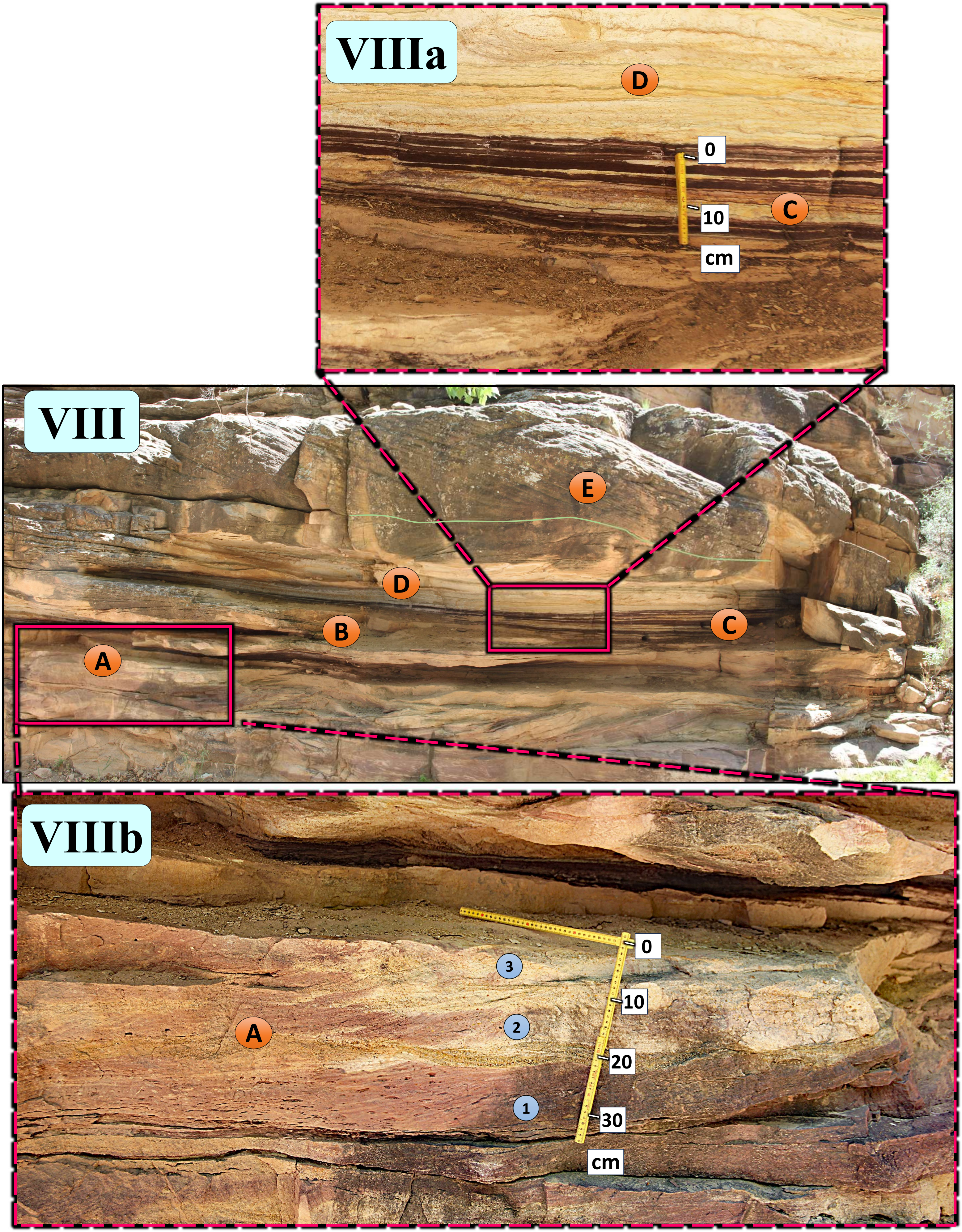
Great Unconformity
Onlapping Precambrian terrain
W
E
Tapeats SS
Great Unconformity
Vishnu Schist
III


W
E
Tapeats SS
Great Unconformity
Fault
IV


V


VI


VII


VIIIa
D
0
10
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C
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E
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A
VIIIb
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3
10
A
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30
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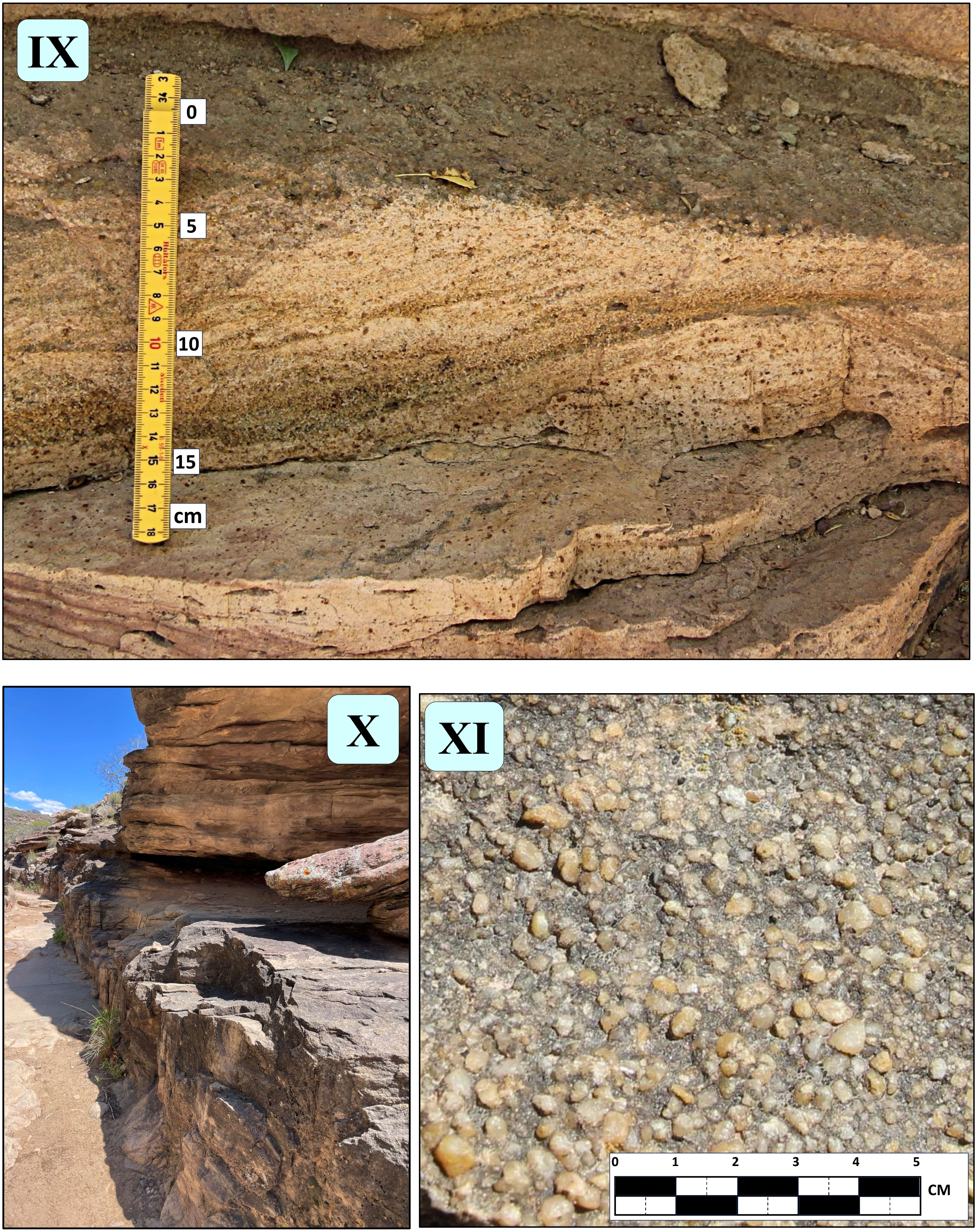
IX
0
5
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XI
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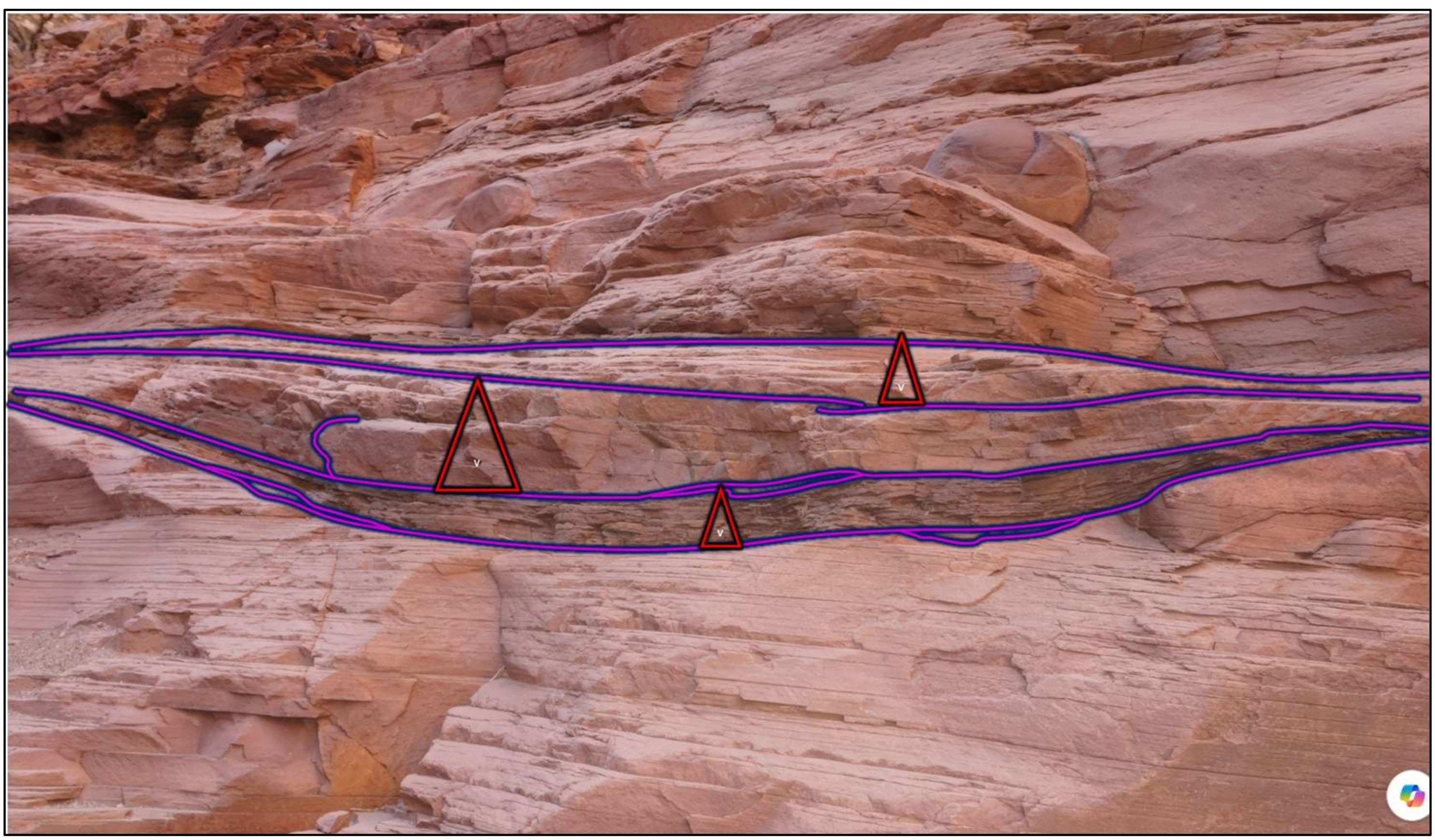
XII




XIII