Bent Rock Layers and Deep Time

Stephen Mitchell

May 11, 2025

Email: Jesus.inHistandS@gmail.com

Sedimentary rocks are often “bent” (folded). If they were hard rocks at the time of the folding, then that folding must have happened over millions of years. If they were soft sediments at the time of deformation, then it could have happened more quickly. Do the rocks tell us that some deformation took millions of years to develop?

Plain Language Summary

Hardened sedimentary rocks that are “bent” or folded are found all around the world. Geologists all agree that this folding took place at rates that in some cases were rapid, occurring in minutes to 100s of years. Most geologists also recognize that In many cases, the folding took place very slowly, over 10s of thousands to

millions of years. Scientists have shown that even hardened rocks can be folded when stress is applied over long periods of time. Rapid deformation of hardened rocks occurs by faulting and fracturing and does not produce sinuous folds. If sediments were folded rapidly, that must have occurred when the sediments were soft (not strongly consolidated and lithified). YECs recognize this and therefore argue that all of the observed folding must have occurred when the sediments were still soft. If any of the folds in Phanerozoic sedimentary rocks (i.e., those interpreted by YEC to have been deposited during or after Noah's flood) were formed over millions of years, then the YEC interpretation of Earth history cannot be correct.

This article presents evidence of folding over deep time using examples of folds from two locations: 1) the Grand Canyon and 2) the Marathon fold belt in West Texas. In the Grand Canyon case, evidence indicating folding of hardened sedimentary rocks includes the shapes of the folds, the presence of fractures and faults that cross sedimentary layers and formed during folding, and fracturing/crushing of grains during folding (Mitchell and Tillman 2024b). *In the Marathon fold belt case, evidence indicating folding of lithified sediments includes very early internal fracturing of the Caballos Novaculite, the formation of pressure dissolution features known as styolites that are parallel to bedding, and the presence of fractures and faults that cross sedimentary layers and formed during folding. Both of these examples demonstrate that folding occurred after the sediments were lithified and therefore must have formed over deep time.*

Folded rock beds or "bent rocks" are often spectacular examples of the results of geologic processes. In this post, we will look at two examples, first the Cambrian aged Tonto Group in the Grand Canyon and then Devonian aged rocks in West Texas. While I often focus on stratigraphy examples that demonstrate problems for the young earth creation (YEC) timelines, this article will look at examples of rocks deformed by geologic processes studied in the field of structural geology. Figure 1 (above) shows a series of black chert beds in a roadcut near Marathon Texas. They were deposited as flat beds, but as you can see, they are now tightly folded. When did the folding take place? How long did it take? Could this have happened in just a few thousand years? In the Grand Canyon example, all of the observations found are well explained by rocks deforming slowly over millions of years. Some of the rocks in the West Texas example have clear evidence of deep time including features called “stylolites”. These features provide an important clue about how long ago these sediments became rock.

Often, order is important. Murder mysteries provide an example of this. Some begin with a body found in a swimming pool. People initially assume that the person slipped and fell into the pool, making it an accidental death. Everyone who watches this type of show knows that this might not have been the case. When the coroner examines the body, he may report that there was no water in the lungs, indicating that the body was dead before being put in the water. Many things may have happened to the body and the order in which they happened is critical. This is key to understanding what happened and identifying the murderer because on TV, it always was murder.

Folding in the Grand Canyon

Unraveling the story of a folded rock involves a bit of forensic study as well. We find many examples of folded rocks in the rock record. In this article, we will look at some particular folded rocks. In understanding how they formed, order is vital. YEC author, Dr. Andrew Snelling has written a series of articles in support of his claim that the folding of rocks in the Grand Canyon is consistent with “flood geology”, the interpretation that these rocks were deposited about 4000 years ago, during Noah’s flood. (Snelling 2021b; 2021a; 2022; 2023a; 2023b). In fact, he reports that this is #2 of his 10 “*Best Evidences from Science That Confirm a Young Earth*” (Snelling 2012). This particular article is titled: “Bent Rock Layers” As it is presented to be such a strong argument, it continues to be referenced online repeatedly. In order to make this claim, he recognized that order is important.

He recognized, as all geologists do, that hardened (lithified) sediments cannot be folded quickly. In order for his age model to be even considered, folding in rocks such as those in the Grand Canyon had to have happened while the sediments were still soft. This requires that they were later lithified very quickly and that all of the fracturing that is now apparent must have developed later, after this lithification.

The consensus of most geologists is that the rocks were deposited about 500 million years ago (Karlstrom et al. 2020). They were then buried deeply and as a result lithified over time. Later as the whole region, the Colorado Plateau, was uplifted, the rocks were then folded around 70 to 30 million years ago. Forty million years would easily allow hardened rocks to be folded. Determining which of these explanations is more correct involves piecing together the order of events.

Everyone recognizes that the rocks are quite hard now and, in this state, could not have been folded in a few hundred years or even thousands of years. Yet many rocks in the Grand Canyon have clearly been deformed from their original shape. There are two basic styles of sediment deformation: ductile and brittle deformation. Folds are examples of ductile behavior, while faults and fractures are examples of brittle behavior. Think of the difference between dropping a fresh rubber band vs. a piece of ordinary plate glass onto a hard surface. The rubber band will reshape and conform to the surface it lands on. If the fall is of a significant distance, the glass is history. It will deform by breaking into many pieces. Sediments can be deformed ductilely fairly quickly, more like the rubber band, if the sediments are not lithified. They also can be deformed ductilely, if the deformation takes place over millions of years, though at the microscopic scale, different mechanisms would be taking place.

Dr. Snelling sampled rocks from several folds in the Grand Canyon and made many good observations, both of the folds and of thin sections of samples collected from the folds (Snelling, Andrew A. 2021).[1] Mitchell and Tillman (2024b) showed that, at both the outcrop scale and at the microscopic scale, the folds are more consistent with the deformation

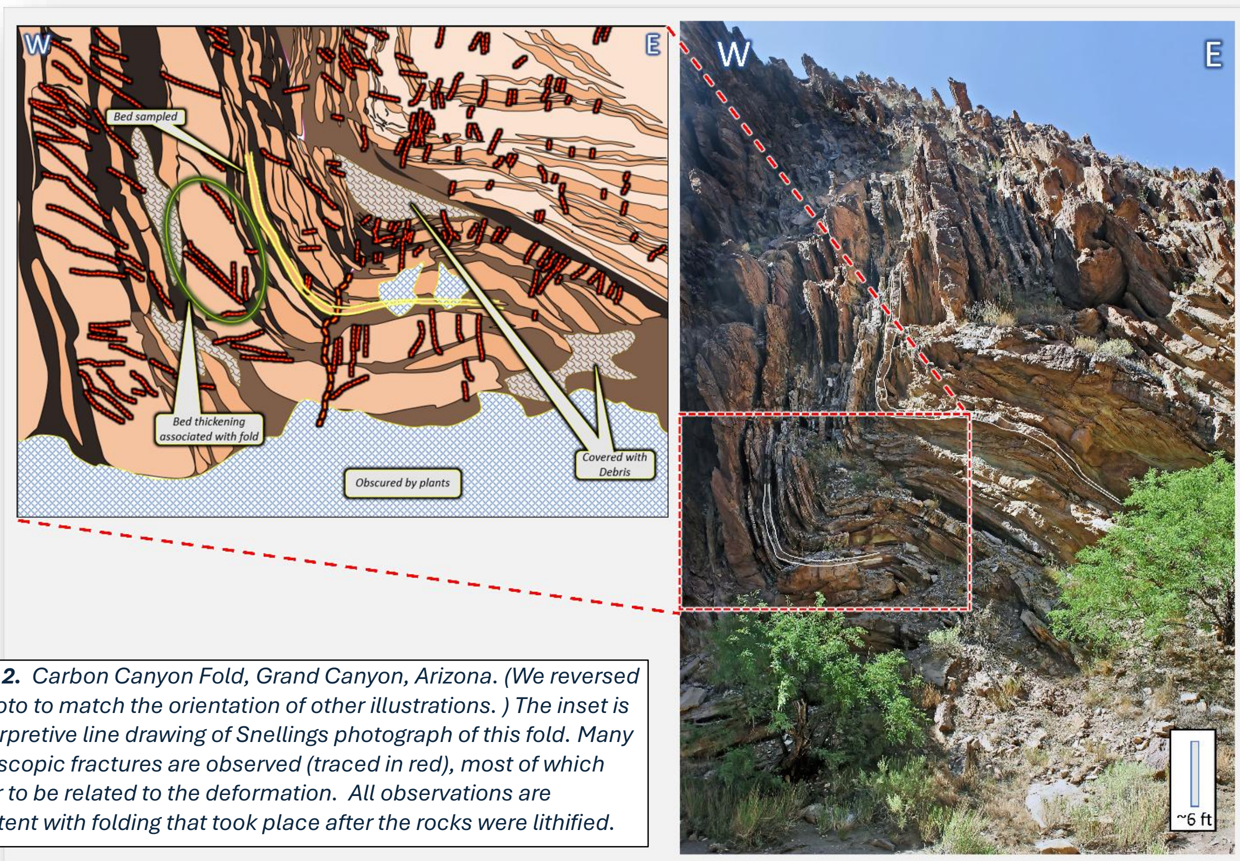

Figure 2. *Carbon Canyon Fold, Grand Canyon, Arizona. (We reversed the photo to match the orientation of other illustrations.) The inset is an interpretive line drawing of Snellings photograph of this fold. Many macroscopic fractures are observed (traced in red), most of which appear to be related to the deformation. All observations are consistent with folding that took place after the rocks were lithified.*

[1] Thin sections in geology are thin slices of rock cut and mounted on a glass slide. They are then ground and polished to 30 microns in thickness so they can be examined under a polarizing light microscope.

having taken place after the rocks were lithified. Order is important. **Figures 2** and **3** are from our paper.

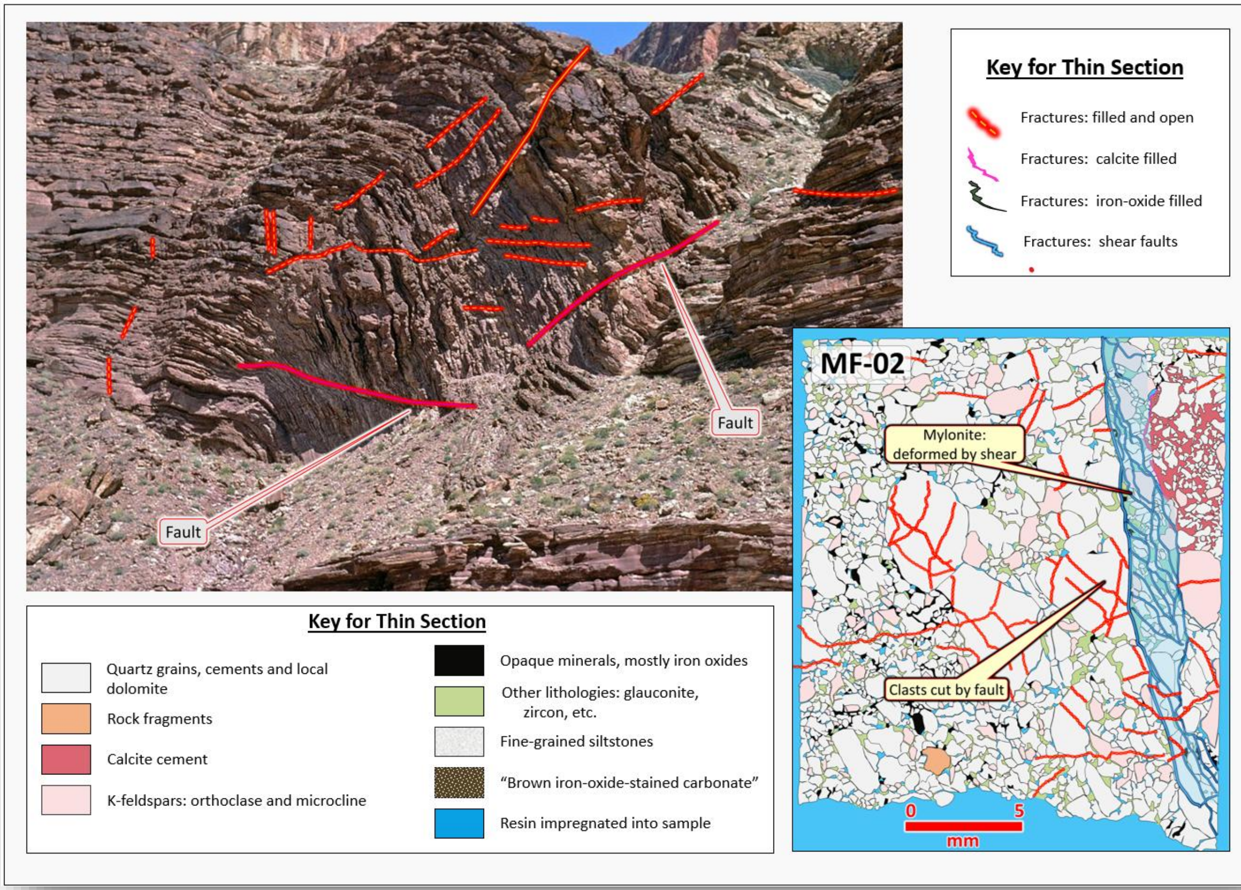

Figure 3. *Monument Fold with interpreted faults and fractures traced in red. Relatively straight (planar) fault limbs are evident. Faults and fractures are consistent with lithified rocks that are folded. The inset is an interpretive line drawing of Snelling's thin section photograph taken from a sample of the fold. It shows a deformed zone with that resulted from tectonic shearing. Many fractures are present (traced in red). Grains are also fractured outside of the sheared zone and the shear faulting through both quartz and K-feldspar clasts. (Snelling, 2021: Appendix D – Locations and Petrographic Descriptions of Tapeats Sandstone Samples).*

Here are some of the key observations from that report.

- All of the described folds are fractured and many of the fractures appear to be related to the folding episode. As we noted in the article, further work could be done that would help evaluate the fracturing, but many observed fractures are convincingly associated with the folding episode.
- The folds include limbs that are relatively straight. Such planar fault limbs indicate that the sediments had at least some lithification, not like the "soupy" behavior of folded soft sediments.
- We see evidence of thinning of some of the more easily deformed (less competent) beds. This again is consistent with the deformation of lithified rocks.
- Fractures can cut through sands as soft sediments, but when they do, they don't go through the grains. The slides show many examples where the fracturing goes through the grains. In at least one case, as shown in Figure 3, there is clear evidence of shear in which grains were crushed, inconsistent with soft sediment deformation.
- The more heavily deformed areas are often more heavily fractured, again supporting the interpretation that the fracturing was not a later post-folding feature.

In the examples from the Grand Canyon, we found the folding as best explained as having taken place over deep time. Evidence such as the fold shapes, fracture development and grains that have been cut by fractures are strong evidence that the order in this case was lithification first and then folding and fracturing.

Folding in the Marathon Fold Belt

Evidence, such as was seen in the Grand Canyon, is not the only type of evidence that can help show the timing of hardening. We find a different type of evidence in the Marathon Basin in West Texas. Here the rocks were buried and the weight of the overburden put great pressure on the sediments, lithifying them. The continued pressure caused the development of features called stylolites. Before describing them in detail though, let's look briefly at the Marathon Basin (**Figure 4**). (E. F. McBride and Folk 1977; Hickman, Varga, and Altany 2009). This is part of a deformation belt that stretches from Mexico, across Texas and ultimately across part of Oklahoma and Arkansas. What was originally a deepwater basin was crumpled up and shoved northward when South American plates

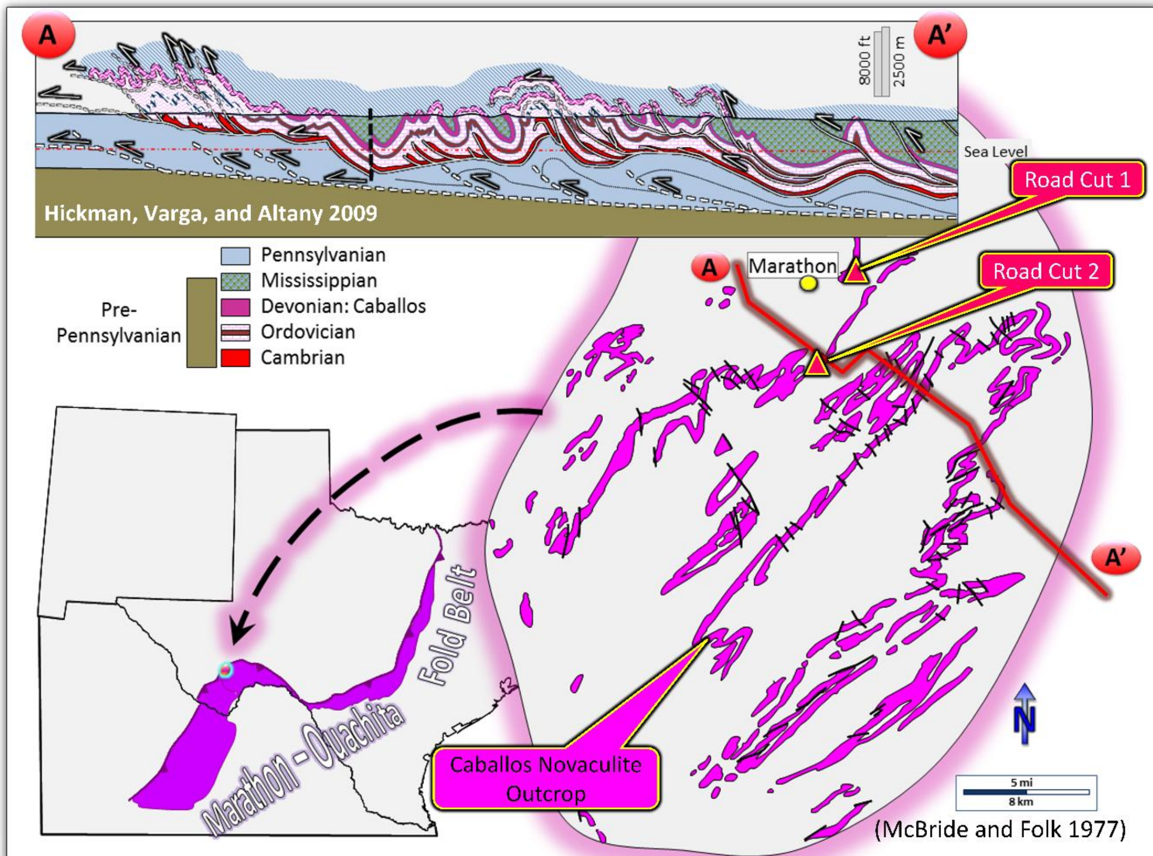

Figure 4. *Location of Marathon Basin and features discussed. Lower left map shows the Marathon-Ouachita fold belt that stretches from Mexico across Texas and shows the area of the next map. That map, adapted from McBride and Folk 1977 shows the outcrop pattern for the Caballos Novaculite. Cross-section A-A' from Hickman, Varga, and Altany 2009 interprets both the subsurface rocks and those that have now been eroded away.*

collided with North America. The section has low angle thrust faults[2] and highly folded

[2] A thrust fault is a fault that result older rocks are pushed on top of younger rocks. It is at an angle of less than 45 degrees.

sections. The folding took place in the Late Pennsylvanian Period, regardless of how long ago that was. The Marathon folds were heavily eroded, and an angular unconformity separates them from the sediments of the next period, the Permian Period. In much of this area, the Permian sediments are eroded away and Cretaceous sediments were deposited over this later additional unconformity surface.[3] Fortunately in the area south of Marathon, Texas, the Cretaceous sedimentary rocks have also been eroded away, exposing the fold belt for us to study at the surface.

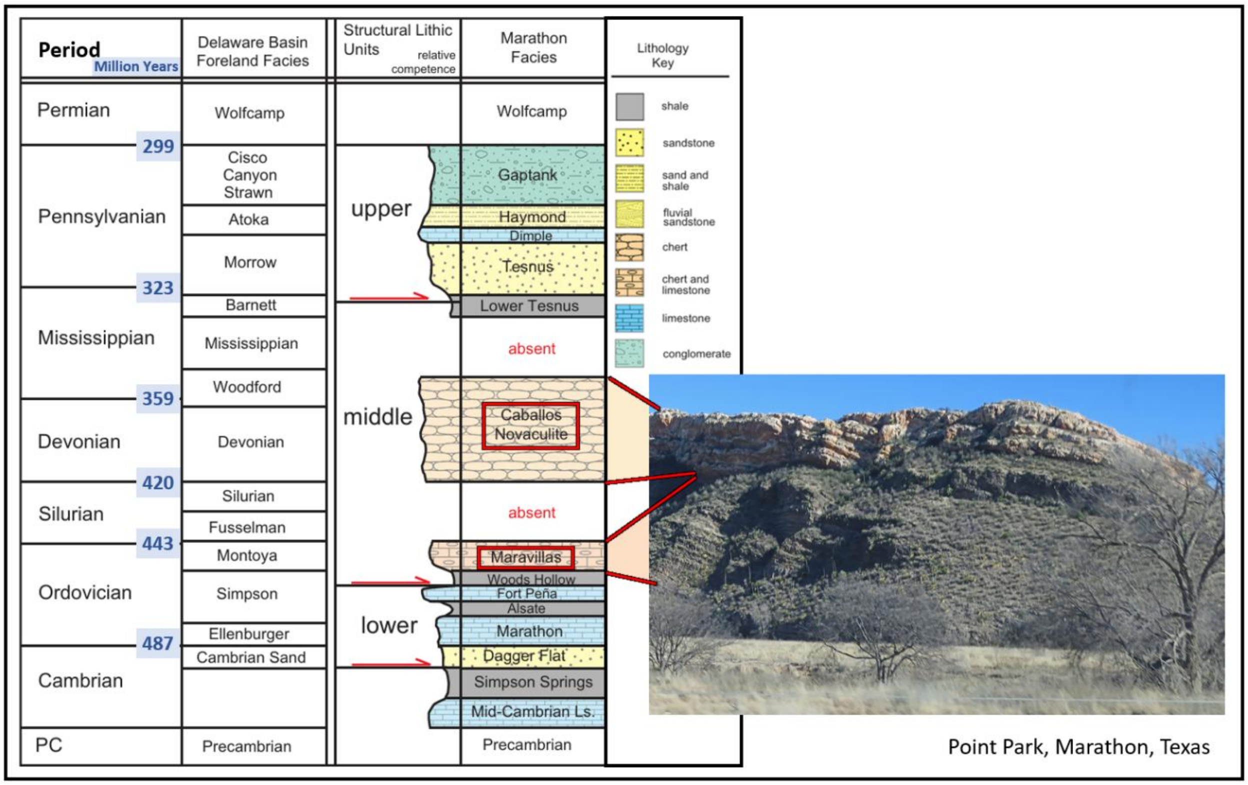

Figure 5. *Marathon Basin Stratigraphy from Chapman and McCarty, 2013 with the accepted geological ages from the International Stratigraphic Commission. The relative thicknesses are based approximately to the relative times involved in their deposition, not the thicknesses. The photograph is from near Point Park, near Marathon, Texas.*

In the exposed portion of the Marathon Basin, much of the original folded rock has also now been eroded away, as shown in the restored cross-section in Figure 4. Rocks that were easier to erode away today form valleys in the area, while those more resistant to erosion form ridges. In particular, the Caballos Novaculite forms distinct ridges through the area.

---

[3] Erosion of the mountains that were formed during the Pennsylvanian Period is described in more detail here: https://jesusinhistoryandscience.com/?p=2744 In this article, we find over a mile of sedimentary rock eroded away. Along this unconformity are eroded beach rocks from the Devonian equivalent of the Caballos Novaculite. Soft sediments do not wear into beach rock.

Much of the basin's history involves how the sediments were laid down, but that is another story. Even so, understanding the stratigraphy is important. **Figure 5** shows the basic stratigraphic column from the Marathon Basin for the Paleozoic rocks. (Chapman and McCarty 2013; Hickman, Varga, and Altany 2009; Cohen et al. 2013). While YEC will not agree with the ages assigned by most geologists, the order in which the rocks were laid down would not be disputed. The rock formations that this article are primarily concerned with are the *Maravillas Chert* and the *Caballos Novaculite*. These sedimentary rocks are both forms of chert, a rock that might be considered similar to limestone, but instead of being composed of calcium carbonate, these rocks are composed of silicon dioxide or quartz in a microcrystalline form. They were first laid down as lime mud that was chemically replaced by silica. This made them stronger (more competent) during the folding and also made them very resistant to erosion. The Maravillas Formation is composed of relatively thin-bedded black chert, limestones and shale. (Earle F. McBride 1970). The Caballos Novaculite is a formation composed largely of a form of chert known as novaculite. Novaculite is a high-purity siliceous rock, containing over 99% silica. Novaculite is famous for its use as a whetstone, such as from a formation of the same age named the Arkansas Novaculite from that state. The Caballos Novaculite is typically far too fractured to use for whetstones.

Low angle thrust faults cut through the least competent beds. Units like the Maravillas, whose beds are thinner and had more variable lithology, as a result were often tightly folded, as shown in Figure 6. (This folding is at a finer scale than that shown on the regional section in Figure 4.) The Caballos Novaculite is made up of thicker units, some of which are composed of essentially 100% novaculite. It is also folded, as shown in Figure 4, but its greater strength meant that the folds were larger scaled. Today it is very highly fractured as well.

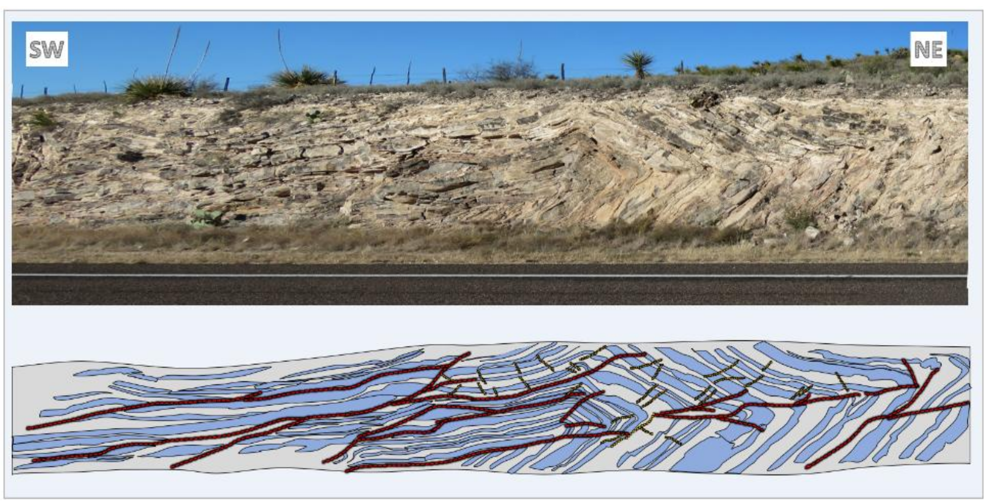

Figure 6. *Folding in the Maravillas Chert at Outcrop 1 location. A portion of this fold was shown in Figure 1. This is roadcut is oblique to the structure but shows how the beds of chert, with even thin beds of shale, was tightly folded.*

Lithification

Order is important. Today, we observe very hard rocks that are folded and highly fractured. They were not formed that way. What do we know about their history? There are different opinions about what the water depth was when the sediments were laid down that became the Caballos Novaculite, but all recognize that the sediment was first a lime mud that was replaced by silica (Folk and McBride 1976; E. F. McBride and Folk 1977; Webb 1975). Processes that take place in sediments after their deposition are collectively called diagenesis. At some point an important diagenetic change took place in the sediments that became the Caballos Novaculite. Silica replaced the original calcium carbonate mud. This siliceous ooze was later hardened to chert as another diagenetic change. Its purity allowed it to develop into a novaculite. The question to consider is: did the rocks, including the novaculite lithify before the tectonic folding took place? If this lithification took place before the folding, then the folding must have taken place over millions of years.

Determining this timing requires looking for clues. Dr. Robert Folk and Dr. Earle McBride published photographs of brecciated novaculite. Breccias are composed of angular fragments cemented together to form a rock. In this case, the pattern shows that some of the breccias formed very locally and early. The pieces could be re-assembled, if the black, very fine-grained rock were taken out from between them (**Figure 7** (Folk and McBride 1976)). The pictures they published look a bit like a piece of glass that has been shattered and then black mud poured into the open gaps. Although these breccias are not found throughout the formation, they demonstrate conclusively that at a minimum, some of the novaculite was lithified early.

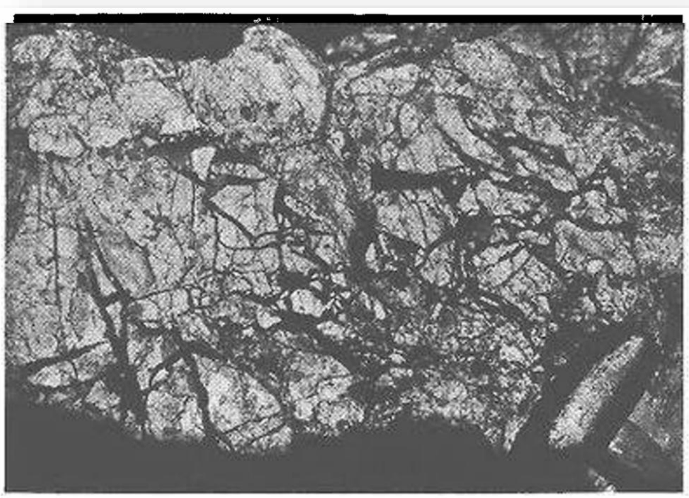

FIG. 6.—Outcrop photograph of black/white breccia. Note blocks fit together if slightly moved. Hammerhead is 13 cm long.

Figure 7. *Example of early brecciated Caballos Novaculite from Folk and McBride 1976*

Stylolites

This brings us to another clue regarding the lithification: ***stylolites***. The weight of the overburden with burial and the pressure from tectonic forces puts a large amount to stress on sediments. This can lead to parts of the rock being locally dissolved and then the re-precipitation of that material elsewhere, and the formation of features known as styolites. The surface along which the material was dissolved over is normally jagged because tiny irregularities in the original rock made the dissolution uneven. Most commonly these are associated with limestone, but they can be found in sandstones and as in this case, in chert. In the Caballos Novaculite, all of the apparent bedding surfaces are actually stylolites (Earle F. McBride 1988; Cox and Whitford-Stark 1987) (**Figures 8-11**). Stylolites concentrate small amounts of impurities from the host rock along them. In this case, that takes the form of iron oxides. That is the origin of the red staining, both along the stylolites and along many fracture surfaces. In describing stylolites in novaculite in China, Zhaoliang Hou, et al (2024) described how dissolution began with micro-cracks that were extended to form stylolites, and this provided avenues for fluid migration. This is how styolites would have begun in the Caballos.

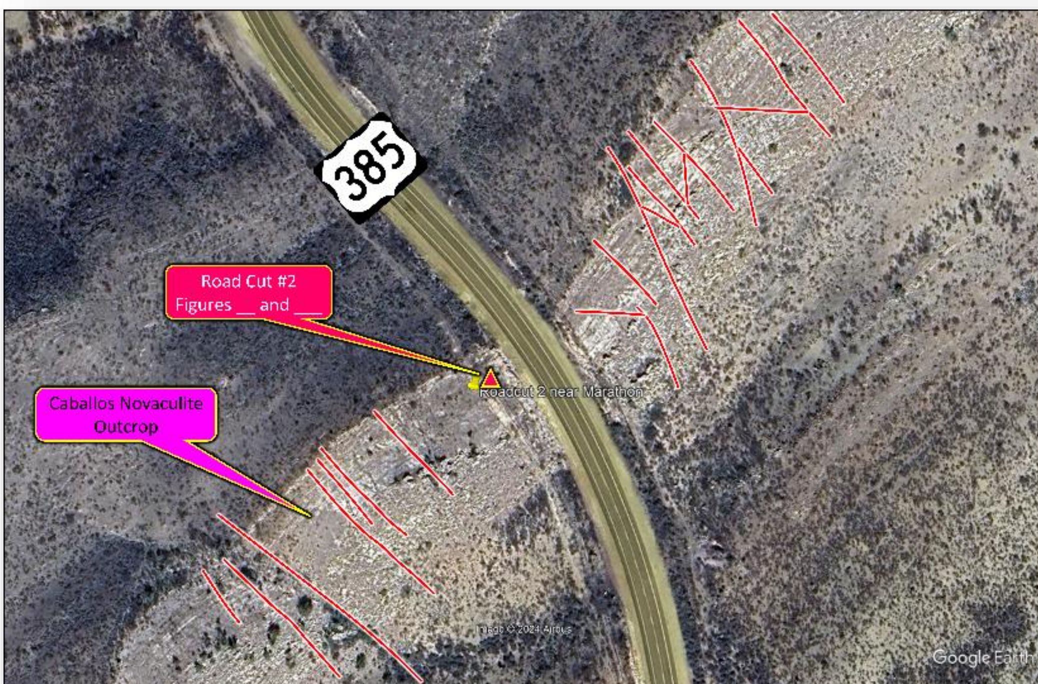

Figure 8. *Google Earth view of Roadcut 2. Many of the faults and fractures that are evident on the photo are highlighted in red. Many more could have been included.*

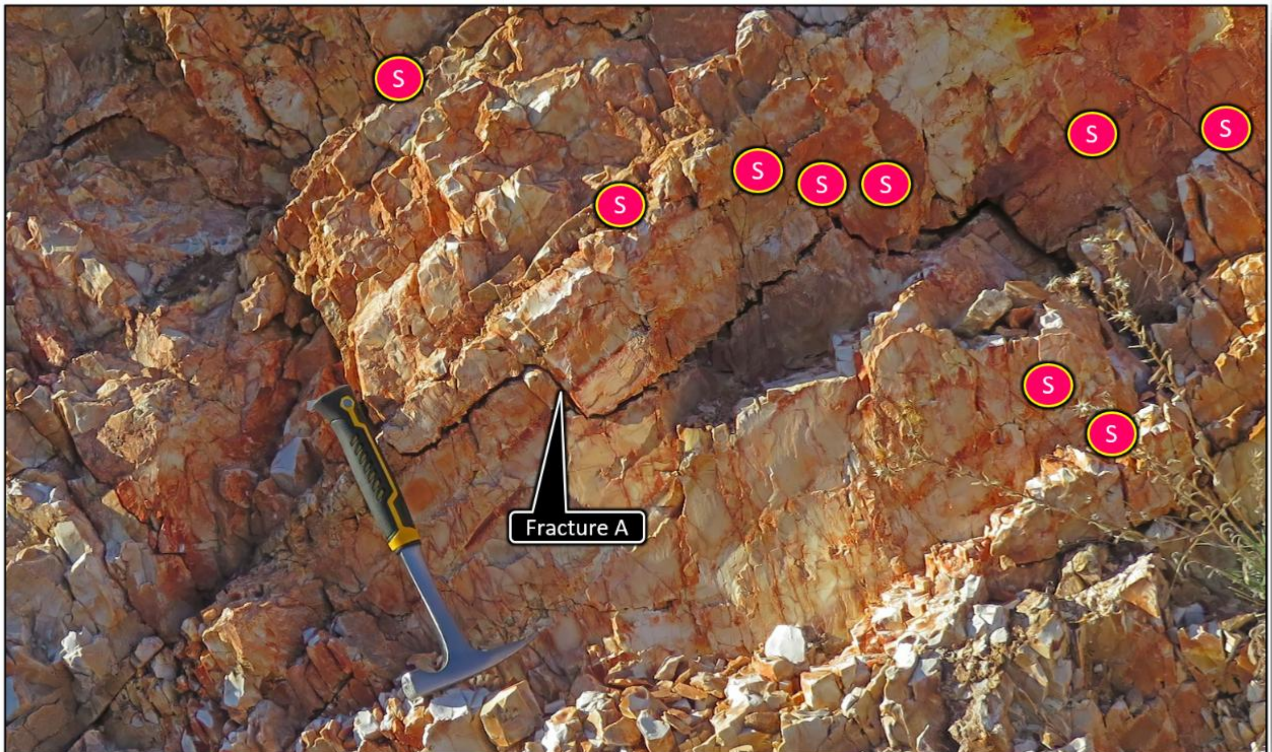

Figure 9. *Major styolites (Red S circles) from the Roadcut 2. (Figure 2). Many fractures are evident as well, including Fracture A that follows styolites in some portions.*

Figure 10. *Styolite surface from Roadcut 2 showing irregularities along it.*

Significantly, the Caballos stylolites developed parallel to the base and top of the unit. This is important because it shows that they formed as a result of overburden pressure from the sediment load above them and hence can be termed “sedimentary stylolites” (Toussaint et al. 2018). Stylolites are great indicators of the direction of the stress that the rocks were under when the styolites formed. Here, they are a valuable clue in determining the order of events. If the stylolites had formed later with the deformation, they would have been orthogonal to the strain direction in the folds (Fossen 2010) p.122. The stress in this case was downward due to the overburden and hence was prior to the folding

***Figure 11**. Styolite separating surfaces in the Caballos formation. They parallel the lower stratigraphy and were formed before the rocks were deformed by the folding episode.*

Stylolites within this unit are well developed, with average amplitudes ranging from 3.5mm to 10.98 mm (Cox and Whitford-Stark 1987). **Figures 12-15** show a sample, collected from Roadcut 2, that illustrates styolite and fracture characteristics in the Caballos. Many different types of fractures were observed and at many different scales. Numerous faults and fractures are evident on satellite images, such as the Google Earth image in Figure 8. Most fractures recognized at this scale are interpreted to have been related to the tectonic folding. These roughly parallel faults were part of the folding event. Smaller fractures, such as those labeled in Figures 9 and 12, cut through stylolites and also sometimes follow the stylolites. Obviously, these were cutting lithified sediments. In a highly fractured section such as this, it would take considerable time and effort to document the strike and dip of the many fractures, in order to clearly understand when and why they were formed. This is the same type of work that could have been done on the folds sampled in the Grand Canyon examples. It is entirely possible that the development of some of the fractures was related to the erosion of later rocks that once covered the region. After the folding, and prior to the uplift and erosion that exposes them today, the area was covered by 5000 to

7000 ft of Permian rocks and later up to 1000 ft of Cretaceous rock (DeCook 1961). As this rock was eroded away, it took a lot of weight off of the lower sediments and this would have induced some fractures and extended others.

Steve Webb studied cherts of equivalent age located north of the Marathon basin. He reported “Fractures commonly display intricate cross cutting relationships, some documenting no less than four generations of cementation.” (Webb 1975). While there is uncertainty in knowing which particular fractures were generated by the folding event, and it is likely that some fractures formed later, it is still very likely that some of the brittle fracturing took place during the Pennsylvanian Period. There also certainly may have been additional diagenetic processes that occurred later. However, Cox and Whitford-Stark (1987) reported, “Metamorphic temperature appears to have been an unimportant factor in stylolite genesis; the Caballos exhibits no evidence for thermal metamorphism.” There would be no basis to call on rapid deformation under high temperature – high pressure conditions.

In summary, I have presented three lines of evidence pointing to the interpretation that the Paleozoic formations, including the Maravillas Chert and the Caballos Novaculite were lithified prior to the folding that took place during the late Pennsylvanian Period. We recognized early brecciation of novaculite and the formation of stylolites. Both of these took place after the sediments had changed from siliceous muds, to hardened rock that deformed brittlely and before the folding associated with forming the fold belt. We saw fractures that developed associated with the tectonic folding, again telling us that the Caballos and Maravillas cherts were lithified.

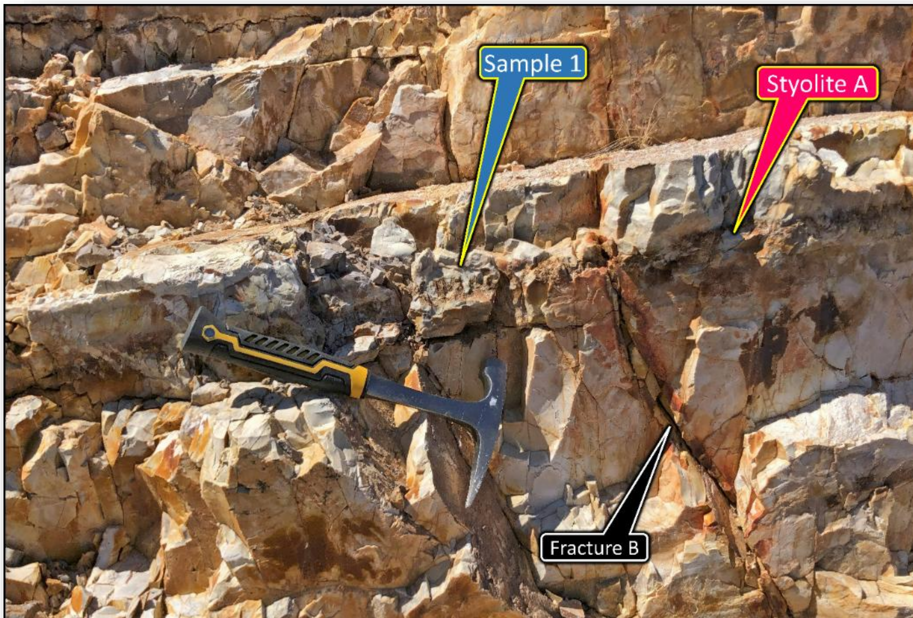

Figure 12. *Sample 1 at collected location at Roadcut 2. Notice that Fracture B goes directly through the styolites.*

Figure 13. *Close-up of Stylolite A on Sample 1. The irregularity of the surface is striking.*

Figure 14. *Sample 1 was sawed, sanded and then scanned. Styolites and fractures interpreted on the second image. Observe that there are small styolites (orange)and a later larger styolite, Styolite A (blue). This one cuts the earlier small ones and represents a larger amount of dissolution. Many fractures are highlighted in red. Beneath Styolite A are a series of fractures at high angles to the styolites. Similar fractures are not observed in the section above Styolite A. Above Styolite A, the novaculite presumably had slightly different properties in terms of its ability to transmit fractures.*

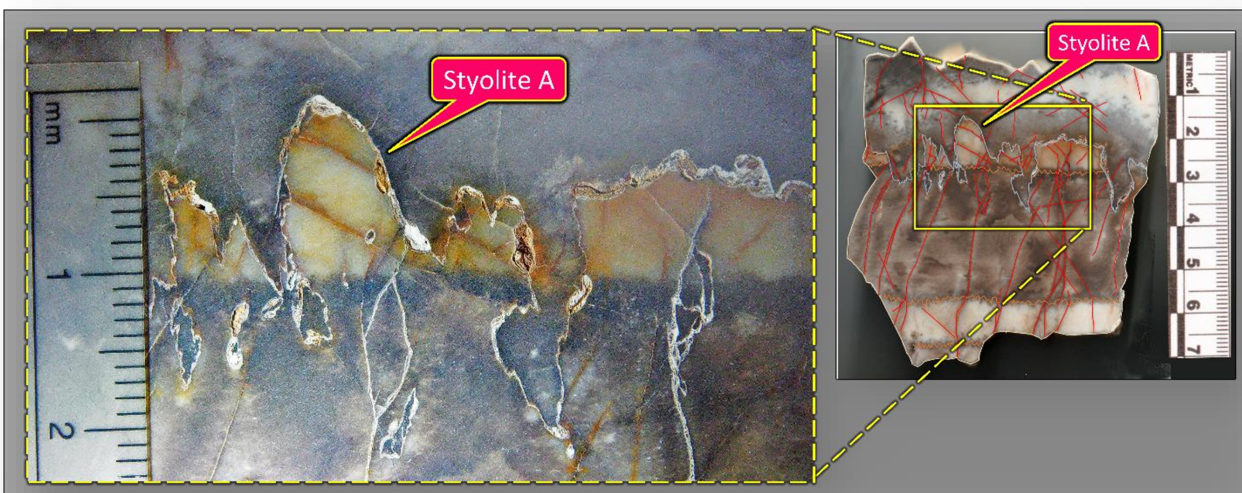

Figure 15. *Photomicrograph of Styolite A. Cox and Whitford-Stark (1987) reported a high value for the average stylolite of 10.98 mm, while this stylolite at this location is showing an amplitude of over 20 mm).*

Implications and discussion

This article began by describing the difference between flood geology timing vs. the timing recognized by most geologists. We agreed with YEC that it would have been impossible to fold lithified rocks in the time allowed by their proposed timelines. The question then considered was whether or not the sediments that they interpret to have been deposited by Noah's flood were actually soft sediment during the time over which many were "bent" (folded).

Two examples were discussed. In the Cambrian aged Tonto Group in the Grand Canyon, we saw folded rocks whose morphology and internal characteristics are entirely consistent with moderate deformation at low temperatures. We relied largely on outcrop-scaled characteristics of the folds, and observations of thin-sections, published by YEC Andrew Snelling to evaluate whether or not the sediments were already lithified.

In the Marathon Basin, we saw direct evidence at the scale of hand samples of shattered solid novaculite that formed relatively soon after deposition. We also saw direct evidence of early lithification in the form of stylolites, both at the outcrop and hand sample scales. We recognized that the novaculite had already been heavily compacted by sediments above them. It happened to the degree that fluids were able dissolve away quartz, as the rock was compressed forming bedding-plane parallel stylolites. Fractures were recognized at a more regional scale and also at the outcrop and hand-sample scale. Many were likely formed during the compressional folding that created the Marathon Fold Belt.

The formation of stylolites in silica-based sediments is far less common than in carbonate rocks. A key reason for this is because quartz is far less reactive than carbonates. Stylolites in carbonates might have developed in a few years or perhaps even months. Toussaint et al. (2018) wrote that is has been "*suggested that stylolites in limestones can form very early in the diagenetic process, occurring at burial depths less than 100 m, where the normal stress is very small*."

At the microscopic scale, in the laboratory, even quartz can develop stylolites quickly. Gratier et al, (2005) reported:

> "*Experimental stylolites (in quartz) have been observed at stressed contacts between quartz grains loaded for a period of several months in the presence of aqueous silica solution, at 350°C under 50 MPa of differential stress*." ("in quartz" added)

In nature and particularly at the regional scale, it is a bit different. Other controls are involved. Toussaint et al. (2018) wrote:

> *"Assuming dissolution magnitude on each stylolite to be L=0.05 m, Angheluta et al.(2012) predicted that the time for its development is td = L/V_{sty}. Using V_{sty} for quartz as 10-3 m/Myr, they concluded that the $St_{ø}$ stylolites developed over td =50 million years. The prediction of such long time scales for quartz may also explain why*

stylolites in quartz are mainly found at depths exceeding 1.5 km burial (Tada and Siever, 1989). Observable teeth (i.e. L ~ 0.01 m) develop over at least 10 Myr, and, assuming a burial rate of 10 Myr/km, it provides an estimate for a minimum 38 observed depth for initial stylolitization in siliciclastic rocks."

What this means is that we should expect that the styolites in the Caballos Novaculite developed over millions of years. What possibly could have caused them to have developed over a few days such as YEC models would suggest? (**Figure 16**) (Clarey 2020; Mitchell 2018; Mitchell and Tillman 2024a; Snelling 2009; Vail, Mitchum Jr, and Thompson III 1977). The rocks show no evidence of exposure to extreme heat and pressure during their history or anything else that is particularly unusual.

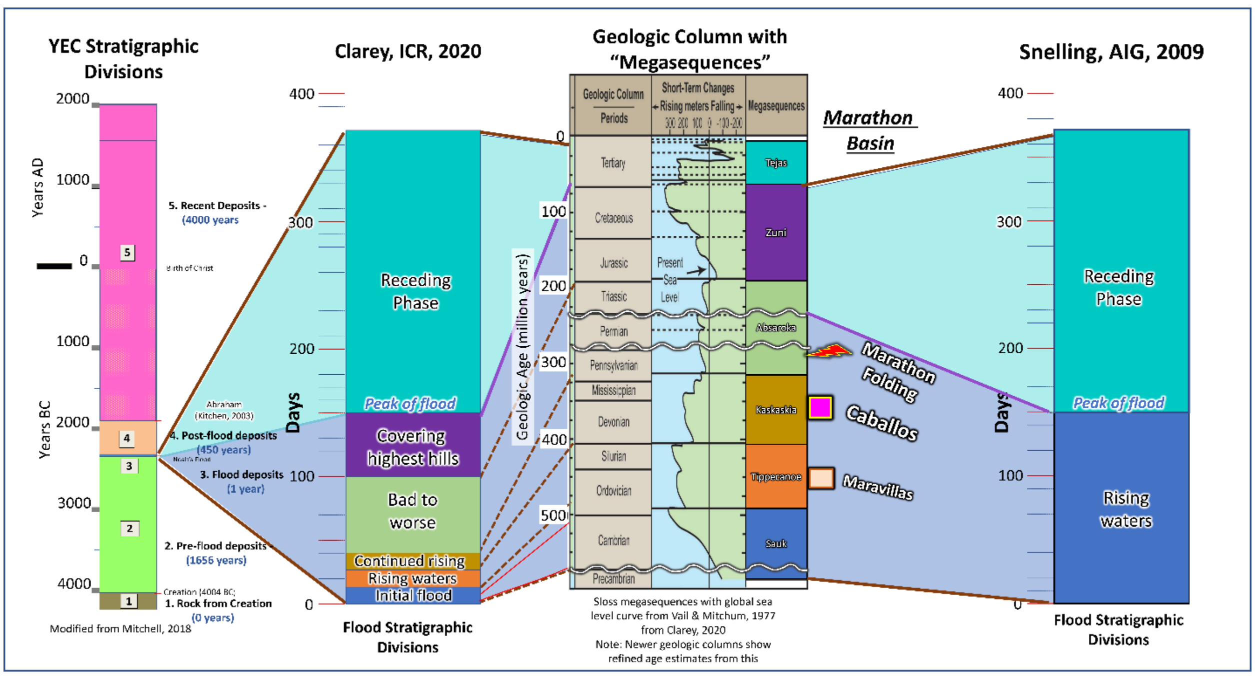

Figure 16. *YEC with any significant geologic training have recognized that the "Geologic Column" used by geologists over the last 200 years is a valid summary of thousands of observations, providing a framework to use to understand older vs. younger rocks. YEC have proposed different correlations of the relationship between the geologic column vs. their interpretations of the Earth's history. Two are shown in this figure. In Mitchell and Tillman (2024a) this was used to illustrate the timing demands of flood geology in the Tonto units of the Grand Canyon. This one illustrates those same demands as they relate to the units discussed from the Marathon Basin. The first column on the left in this figure shows the events that YEC recognize in the Earth's history that have geologic implications. The 3rd column shows the geologic column with the Eras, Periods and Epochs in the relative order that they are found around the world. The second and forth columns show interpretations as published by two leading YEC organizations. Notice that they are very different. The rocks discussed in this article are labeled next to the geologic column. Using this figure, one can estimate how long flood geologists are claiming it took to deposit various formations.*

Conclusions

Hard rocks can be bent, but that requires millions of years. Many rocks show clear evidence that this is exactly what happened. We can discern the order of the events. The evidence for this takes many different forms, just as the settings and types of rocks that were deformed by geologic processes around the world are widely variable.

Does this cause a problem for the Christian? The Bible does not tell us what the geologic effects of Noah's flood were. It does not tell us that rocks were deformed quickly and then hardened in a very brief time. It doesn't tell us that the hardened rocks that we have today, like the Caballos Novaculite, were eroded deeply in just a few years. God's view of days and times is different than ours.

The psalmist wrote:

> 3 *For the LORD is a great God*
> *And a great King above all gods,*
>
> 4 *In whose hand are the depths of the earth,*
> *The peaks of the mountains are also His.*
>
> 5 *The sea is His, for it was He who made it,*
> *And His hands formed the dry land.*

Psalms 95:3-5 NASB

The Bible tells us that God formed the rocks in both the depths of the Earth and in the mountains. Regardless of what methods He chose to use or over what timespan, it is His work. As we study the geology of the Earth, we get glimpses of how He chose to work and we can recognize further what an amazing God He is.

Acknowledgments

Thank you to Dr. Kennen Tillman for his suggestions. His structural expertise has helped me grow in this area many times over the years.

References Cited:

Chapman, James B., and Reid S. McCarty. 2013. "Detachment Levels in the Marathon Fold and Thrust Belt, West Texas." *Journal of Structural Geology* 49 (April):23–34. https://doi.org/10.1016/j.jsg.2013.01.007.

Clarey, Dr Timothy. 2020. *Carved in Stone: Geologic Evidence of the Worldwide Flood*. ICR Institute for Creation Research.

Cohen, K.M., S.C. Finney, P.L. Gibbard, and J.-X. Fan. 2013. "The ICS International Chronostratigraphic Chart." International Stratigraphic Commission. http://www.episodes.org/journal/view.html?doi=10.18814/epiiugs/2013/v36i3/002.

Cox, Mark A., and J. L. Whitford-Stark. 1987. "Stylolites in the Caballos Novaculite, West Texas." *Geology* 15 (5): 439–42. https://doi.org/10.1130/0091-7613(1987)15<439:SITCNW>2.0.CO;2.

DeCook, K J. 1961. "A Reconnaissance of the Ground-Water Resources of the Marathon Area, Brewster County, Texas." https://www.twdb.texas.gov/publications/reports/bulletins/doc/B6111.pdf.

Folk, R. L., and E. F. McBride. 1976. "The Caballos Novaculite Revisited; Part I, Origin of Novaculite Members." *Journal of Sedimentary Research* 46 (3): 659–69. https://doi.org/10.1306/212F701D-2B24-11D7-8648000102C1865D.

Fossen, Haakon. 2010. *Structural Geology*. Cambridge UP, Hardcover.

Gratier, J. P., L. Muquet, R. Hassani, and F. Renard. 2005. "Experimental Microstylolites in Quartz and Modeled Application to Natural Stylolitic Structures." *Journal of Structural Geology* 27 (1): 89–100. https://doi.org/10.1016/j.jsg.2004.05.007.

Hickman, Robert G., Robert J. Varga, and Robert M. Altany. 2009. "Structural Style of the Marathon Thrust Belt, West Texas." *Journal of Structural Geology*, Nickelsen–Groshong volume: Low-temperature deformation mechanisms and their interpretation, 31 (9): 900–909. https://doi.org/10.1016/j.jsg.2008.02.016.

Hou, Zhaoliang, Kun-Feng Qiu, Anna Rogowitz, Richard A. Schultz, Hao-Cheng Yu, and Bernhard Grasemann. 2024. "Progressive Development of Stylolites in Cryptocrystalline Quartz." *GSA Bulletin* 136 (11–12): 4417–32. https://doi.org/10.1130/B37461.1.

Karlstrom, K. E., M. T. Mohr, M. D. Schmitz, F. A. Sundberg, S. M. Rowland, R. Blakey, J. R. Foster, L. J. Crossey, C. M. Dehler, and J. W. Hagadorn. 2020. "Redefining the Tonto Group of Grand Canyon and Recalibrating the Cambrian Time Scale." *Geology* 48 (5): 425–30.

McBride, E. F., and R. L. Folk. 1977. "The Caballos Novaculite Revisited; Part II, Chert and Shale Members and Synthesis." *Journal of Sedimentary Research* 47 (3): 1261–86. https://doi.org/10.1306/212F731A-2B24-11D7-8648000102C1865D.

McBride, Earle F. 1970. "Stratigraphy and Origin of Maravillas Formation (Upper Ordovician), West Texas1." *AAPG Bulletin* 54 (9): 1719–45. https://doi.org/10.1306/5D25CBE5-16C1-11D7-8645000102C1865D.

———. 1988. "Geology of the Marathon Uplift, West Texas." In *South-Central Section of the Geological Society of America*, edited by O. T. Hayward, 4:0. Geological Society of America. https://doi.org/10.1130/0-8137-5404-6.411.

Mitchell, Stephen. 2018. *A Texas- Sized Challenge to Young Earth Creation and Flood Geology: A Christian Geologist Looks for Answers*. Christian Faith Publishing, Inc.

Mitchell, Stephen, and Kennen S. Tillman. 2024a. “Examining Young Earth Creation Claims About the Grand Canyon.” *Peaceful Science*, August. https://doi.org/10.54739/tyet.

———. 2024b. “The Tonto Deformation.” *Peaceful Science*, August. https://doi.org/10.54739/k1y8.

Snelling, Andrew A. 2009. *Earth’s Catastrophic Past*. Institute for Creation Research. http://isgenesishistory.s3.amazonaws.com/digital%20downloads/earth-catastrophic-past-1-preview.pdf.

Snelling, Andrew A. 2012. “10 Best Evidences From Science That Confirm a Young Earth: #2 Bent Rock Layers.” Answers in Genesis. 2012. https://answersingenesis.org/geology/rock-layers/2-bent-rock-layers/.

Snelling, Andrew A. 2021. “The Fight for 53 Rocks.” Answers in Genesis. 2021. https://answersingenesis.org/geology/grand-canyon/fight-53-rocks/.

Snelling, Andrew A. 2021a. “The Petrology of the Bright Angel Formation, Tonto Group, Grand Canyon, Arizona.” *Answers Research Journal* 14:303–415.

Snelling, Andrew A. 2021b. “The Petrology of the Tapeats Sandstone, Tonto Group, Grand Canyon, Arizona.” *Answers Research Journal* 14. https://assets.answersingenesis.org/doc/articles/pdf-versions/arj/v14/petrology_tapeats_sandstone.pdf.

Snelling, Andrew A. 2022. “The Petrology of the Muav Formation, Tonto Group, Grand Canyon, Arizona.” *Answers Research Journal* 15:139–262.

Snelling, Andrew A. 2023a. “The Carbon Canyon Fold, Eastern Grand Canyon, Arizona.” *Answers Research Journal* 16. https://answersresearchjournal.org/geology/carbon-canyon-fold-arizona/.

———. 2023b. “The Monument Fold, Central Grand Canyon, Arizona.” *Answers Research Journal*, August. https://answersingenesis.org/geology/monument-fold-grand-canyon/.

Toussaint, R., E. Aharonov, D. Koehn, J. -P. Gratier, M. Ebner, P. Baud, A. Rolland, and F. Renard. 2018. “Stylolites: A Review.” *Journal of Structural Geology* 114 (September):163–95. https://doi.org/10.1016/j.jsg.2018.05.003.

Vail, Peter R., R. M. Mitchum Jr, and Sam Thompson III. 1977. “Seismic Stratigraphy and Global Changes of Sea Level: Part 4. Global Cycles of Relative Changes of Sea Level.: Section 2. Application of Seismic Reflection Configuration to Stratigraphic Interpretation.” https://archives.datapages.com/data/specpubs/seismic1/data/a165/a165/0001/0050/0083.htm.

Webb, Steven Ray. 1975. “A Subsurface Study on the Devonian Caballos Novaculite of the Tobosa Basin of West Texas.” Lubbock, Texas: Texas Tech University. http://hdl.handle.net/2346/20461.