***Figure 1***. *Red Rock Canyon, Nevada*

# Dinosaur Tracks in Sand Dunes … under the Sea?

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There are many reasons to go to Las Vegas, Nevada. One reason is to see some spectacular ancient sand dune deposits. Young Earth Creationists (YEC), who try to explain much of the geologic record as deposits from Noah's flood, interpret these to have been deposited underwater during a global catastrophic flood. An interesting complication for this interpretation is the fact that dinosaur tracks are found in these ancient dune fields.

First, I need to describe the rock formation that we are looking at. The formation is the Aztec Sandstone. It is Jurassic in age regardless of how long ago that was or how it formed. Here is a description of the unit from the website for the Red Rock Canyon State Park in Nevada:

> *"The great sandstone cliffs at Red Rock, thousands of feet high, are made up of the Aztec Sandstone. This formation, about 180 - 190 million years old, is comprised of lithified sand dunes that formed in a vast desert that covered a large part of the southwestern United*

> *States during the Jurassic time. Lithification is the process of changing unconsolidated sediment into sedimentary rock. Massive cross-bedding, typical of aeolian (wind) deposits, is a result of the shifting wind direction across the Jurassic dune field and is seen in the Aztec Sandstone rock outcrops."* (Southern Nevada Conservancy 2024)

This contrasts with YEC explanations in several ways. YEC authors interpret these Jurassic sandstones to have been deposited by the flood and if this were true, a number of observed features would need to be explained, including those dinosaur tracks right in what were ancient sand dunes. Maybe those ancient dunes were not formed by wind. This article will compare conventional models with the flood geology proposal. Before looking at the dinosaur tracks, we need to understand a bit about the sandstones and compare them using other characteristics.

## Visiting Red Rock Canyon,

Let's look at the Aztec formation in Red Rock Canyon, near Las Vegas, Nevada. I spent a great afternoon there in 2020 guided by my nephew, Paul Dunsworth. This was just before the covid-19 pandemic shut the country down. Here is what happened. In January of 2020, my wife and I decided to meet Paul in Las Vegas where he lives and then go down together to visit my brother who lives in Yuma, Arizona. January is a much better time of year to visit both of these places than say, August. We flew in on a Sunday morning, rented a car and drove to Paul's apartment. I suspect that many of the people on the plane with us hurried to the never stopping excitement of the Las Vegas Strip.

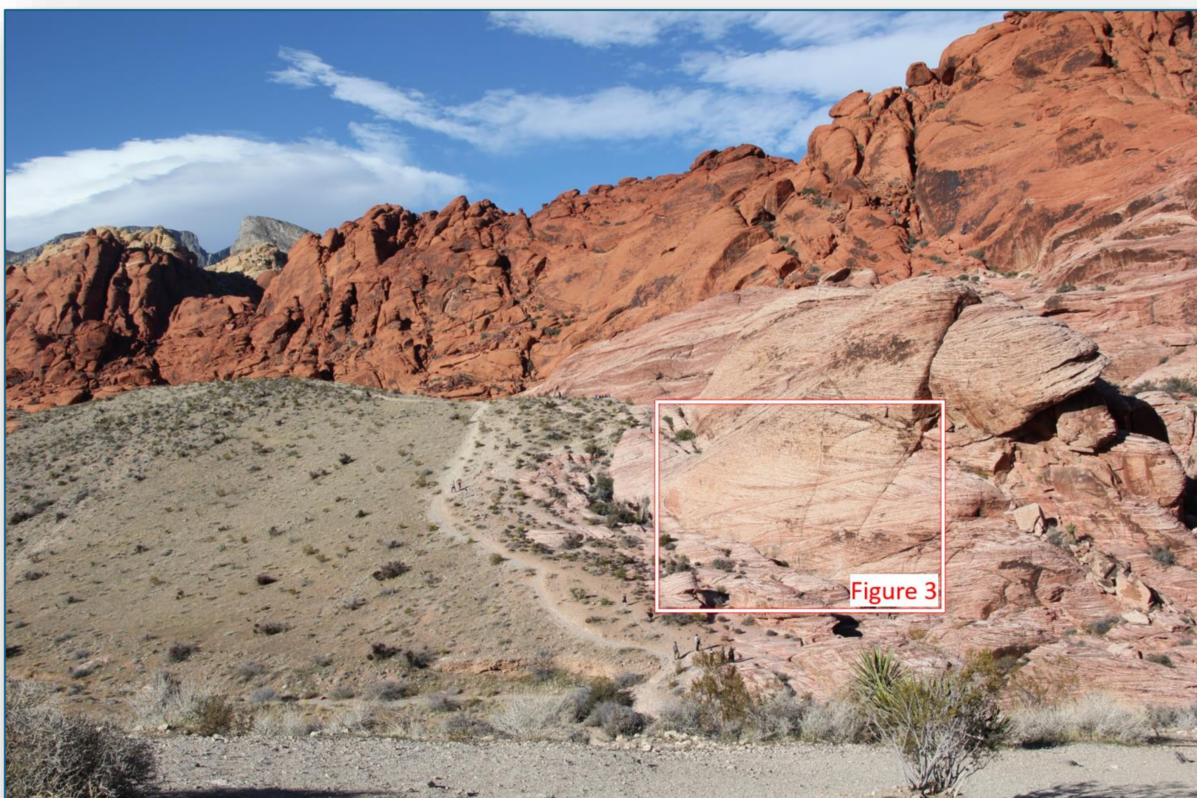


***Figure 2**. Aztec Sandstone, Red Rock Canyon, Nevada*

Paul knew that was really not our scene. Instead, he took us to see rocks. That was exciting. Thankfully, my wife is quite patient with my passion for geology and rocks and she also loves natural beauty. It was a gorgeous sunny afternoon and many people were out to experience the Red Rock Canyon. We stopped at the visitor center and then drove up to the beautiful red rocks. Walking up to them, I was amazed by the number of small figures moving all over them. This is a spectacular place for rock climbing for those who are younger, more agile and perhaps a bit braver than I. You will see climbers in some of the images that I am including. Geologists like to include people in their slides to provide approximate scales to appreciate the sizes of the features. In many cases, it is difficult to find someone willing to put in the hiking and effort to be a scale in many areas, but these climbers provided great scales without even knowing that was their purpose.

**Figure 1**, taken from the visitor center, shows the spectacular red and yellow sandstones of the Aztec faulted down below the much older Cambrian limestones in the background. The sandstones are not just horizontal parallel bedded such as form in many settings. When laminations and beds formed in non-parallel fashion they are referred to as cross-bedded and the cross-bedding in the Aztec is spectacular. (**Figure 2, 3 and 4**).

***Figure 3***. *Cross-bedding in the Aztec Sandstone that formed as dunes migrated.*


***Figure 4.*** *Cross-bedding in Aztec Sandstone with various sized humans for scale. Notice that in addition to depositional cross-beds, there are other bands that were formed by ground water, known as Liesegang bands. These are common in this unit.*

## Forming Sand Dunes

How did these sand bodies form? Think about what we observe: thick units of sandstones with many large stacked sets of cross-bedded sandstone. Contemporaneous similar sand deposition took place over a very large area (**Figure 5**) (Wilkens 2008). The options for depositing large scale cross-beds like this are limited. They aren't formed by rivers or as normal beach deposits. This scale of cross-beds indicates dune deposition and really only two basic possibilities can be considered. Large dunes could have formed either subaerially as wind-blown sand dunes or in a subaqueous setting. Note that no marine flora or fauna are present in these formations. Fossils are from terrestrial environments or fresh water settings like small ponds. Most geologists quickly opt for subaerial dunes. The concept would be that Red Rock Canyon had dune field similar to the one in **Figure 6**. If we could cut a profile through the dunes in the Colorado example many similar features would be evident. Geologists describe the processes and features laid down by wind as "eolian" (also spelled "aeolian") features. Check out the animations and terminology for sand dunes here: ["Aeolian Dunes and Sandstone: Overview and Terminology"](#).

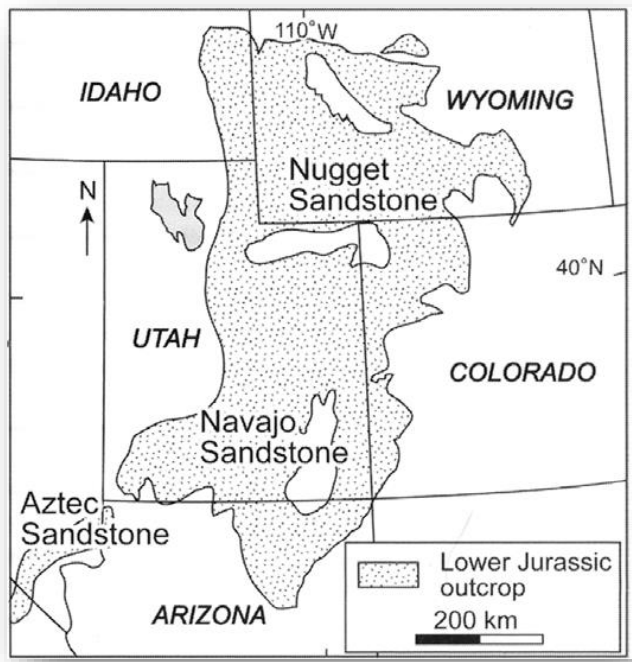


***Figure 5.*** *Map of preserved distribution of Jurassic sandstone units deposited at approximately the same time.*

The name for a large area of desert covered in wind-swept sand that forms various dune shapes is an *erg*. Certainly, we have many modern examples to compare the Jurassic sandstones with. It is also true that they clearly share many characteristics. One comparison would be the overall scale of depositional packages. If the ancient units were much larger than modern examples that would be a possible concern. **Figure 7** shows that the Jurassic extent of the outcrops that we have today may seem large, but it is not particularly large when compared to modern deserts. Just as the Sahara Desert does not have continuous sand dune fields that stretch across it, there would have been considerable variability in the Jurassic erg. In fact, the Sahara and Arabian deserts can each be divided up into a number of ergs but the overall desert is huge. It is also true that we are looking at a snapshot in time with modern deserts, while we are looking in the ancient rocks at what was preserved over considerable lengths of time. In the Sahara Desert, much of today's shape and thickness developed over the last 12,000 years, even though the area may have been dry for a longer time. The ANN deposits are much thicker, but consensus view would have it to have developed over a much longer time.

***Figure 6.*** *Great Sand Dunes National Park, Colorado (photo by National Park Service)*

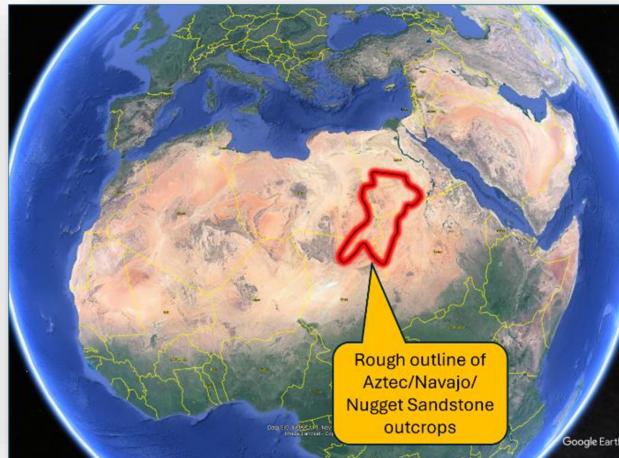


***Figure 7*** *Comparison of the outcrops of the exposures of the Jurassic sandstones. The Aztec, Navajo and Nugget Sandstones (**ANN**) were contemporaneous. Here you can compare their extent with the modern Sahara and Arabian Deserts using a Google Earth image.*

At a large scale, the Red Rock Canyon examples would fit well as part of a desert erg. How about really zoomed up and looking at the fine details? Unfortunately, I wasn't able to get samples to examine the sand grains from the state park. However, if these are similar to the only detailed descriptions that I have found from the Aztec Formation in California, then we can make some comparisons. Evans described them this way:

> "Constituent grains of the sandstone are well-rounded, have a high degree of spericity and are well-sorted. Most of the unit is composed of pitted quartz grains that are frosted or dull. A few percent of feldspar and magnetite are present. Grains are well-cemented by silica and locally by hematite." (Evans 1971)

This would seem to be a textbook description for eolian or wind-blown sands. Frosted and pitted quartz grains are typically considered diagnostic. That said, some Navajo Sandstone frosted grains have been attributed to later diagenesis (Marzolf 1976). We need to keep looking.

## Flood Geology Explanations

I read three short articles written from a YEC perspective: "Eroded Appalachian Mountain siliciclastics as a source for the Navajo Sandstone" by Carl Froede (Froede 2004), "Dancing Dinosaurs? Stony footprints point to something more serious" by Michael Oard (Oard 2008) and "Valley of Fire: Explained by the geological proceses of Noah's Flood" by Dr. "Tas" Walker (Walker, n.d.). These are all brief articles that do not propose to explain many details of the formations.

Perhaps the most extensive study from a YEC perspective of ancient deposits generally attributed to eolian deposits was the 2018 study: "The Coconino Sandstone (Permian, Arizona, USA): Implications for the Origin of Ancient Cross-bedded Sandstones" by John Whitmore and Paul Garner (2018, 581). A lot of effort went into this study. Why? In their own words:

> "The Coconino is thought to have been deposited during Noah's Flood by most Flood geologists because it is bounded by widespread Paleozoic marine deposits, which occur both below, and above the Coconino; and **of course you cannot have major windblown dune sands in the middle of worldwide Flood deposits**" (Whitmore and Garner 2018, 582) (emphasis added).

They collected data, did some good petrographic studies and made a number of good observations. Here are some of the observations that they conclude support an aqueous origin for the Coconino Sandstone:

1. *Extensive mica and dolomite*
2. *Large parabolic folds (7 m high example shown)*
3. *Extensive current lineation*
4. *Planar beds*
5. *Poor Sorting and roundness of grains*
6. *Cross-bed dips averaging about 20 degrees*
7. *Similarity of vertebrate trackways to those made underwater*
8. *Sand injectites*

I cannot comment in detail on all of these with regards to the younger ANN Sandstones but some certainly bear comment. Dr. Lorence Colins and Tim Helbe have authored articles that provide good direct responses to Whitcomb and Garner's paper. Dr. Collins, in his paper, "Eolian or Water Deposition of the Coconino Sandstone" (Collins 2022), among other things, points out that the proposal that the Coconino Sandstone was deposited by hurricane waves would not be valid regardless of the size of the storm because hurricanes just don't interact with the waterbottom except right at the coastline. Another question that he raises is where did the sand come from. We understand where such sand could come from if it began as quartz and feldspar in granites, but if the Earth is 5350 years to generate sand from that source. I would argue that if the model is that the flood was about 2350 BC as it is commonly dated by YEC and creation took place at approximately 4000 BC, then their models allow even less time.

Tim Helbe had an article very recently published in "Perspectives on Science and Christian Faith" titled "Flood Geology and Conventional Geology Face Off Over the Coconino Sandstone". (Helble 2024) This article provides a great short description of how the consensus of modern geologists view the deposition of the Coconino Sandstone. He goes carefully through some of the disagreements between the two views.

*1. Extensive mica and dolomite.*

I have not found any note of mica from the ANN sands but they may contain trace amounts such as are found in the Coconino. Calcareous beds including dolomite are found in the ANN and typically interpreted as lacustrine deposits such as one would expect in interdune areas. Interdune areas in modern ergs often have ponds and oases and carbonates such as limestone and dolomite would have be deposited in such settings.

Mica can be transported a long distance. Eolian mica is reported in soils in Hawaii (Dymond, Biscave, and Rex 1974) and Japan (Mizota and Takahashi 1982). Such micas are clearly not locally derived and eolian transport seems the only logical mechanism. One would not expect mica to remain in more than very low percentages in eolian sands, but they are reported in modern eolian sands in some cases, such as in the Hexi Corridor in China (Zhu, Zhang, and Sun 2021). Helbe (2024) showed that the mica in the Coconino Sandstone fits well with the results of YEC testing with modern sands (Helble 2024; Anderson et al. 2013).

*2. Large parabolic folds*

Folded beds are not uncommon in the ANN. One example is shown in **Figure 8**. Many soft-sediment deformation features are documented by Dr. Gerald Bryant in his doctoral dissertation: “Outcrop Studies of Soft-sediment Deformation Features in the Navajo Sandstone” (Bryant 2011). He shows many complex features of various sizes and shows that they are often associated with sand injections. While Bryant notes that similar scaled modern analogs are difficult to find, the model proposed by Colby Ford for such folding in the Navajo Sandstone in Zion National Park seems to explain how dune collapse could account for such features (Ford 2015). Whitmore and Garner give no reason that such could not be associated with eolian sedimentation so perhaps this objection collapses.

***Figure 8.*** *Folded dune sands, zoom in on portion of Figure 4.*

3. Extensive current lineation:

I did not observe surfaces such as are reported in the Coconino.

*4, Planar beds:*

It is not clear what Whitmore and Garner are describing in this objection. Planar beds are common in the Coconino Sandstone, ANN formations and modern dunes (McKee 1979). Horizontal planar beds also occur. This should be expected given the variety of different depositional settings that would have existed across an erg.

*5. Poor Sorting and roundness of grains:*

I did not sample the Aztec in the state park but the reports that I have seen do not show any issue here. **Figure 9** shows that at least published examples of Aztec sand are similar to published examples of dune sand from the Sahara Desert (Eichhubl et al. 2004; Pastore et al. 2021). While I do not have quantitative data from the Aztec Formation, the sorting and rounding seem similar. An image of a slide from the Navajo Sandstone in Utah was published in a MS Thesis and it appears similar but less magnification was used (Hansen 2007).

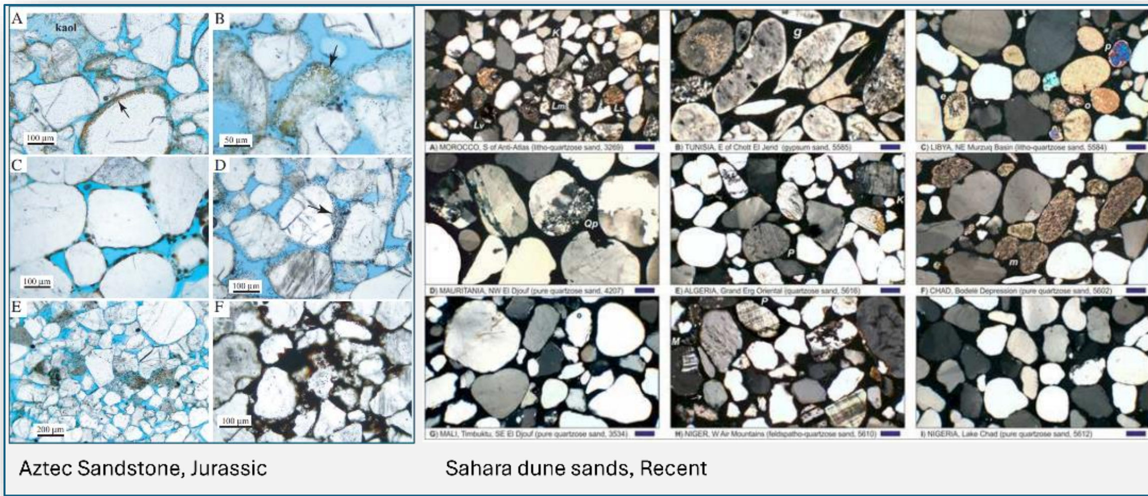


***Figure 9.*** *Comparison of sands from the Navajo SS from the Valley of Fire, Nevada published by Eichhubl, et al., 2004 with uncemented sands from the Sahara Desert published by Pastore et al, 2021. (I am assuming fair use to post these.)*

*6. Cross-bed dips averaging about 20 degrees*

Certainly, the foresets of the Aztec are variable and I do not have measurements of their distribution. Is this a criteria that can be used to distinguish dunes that were formed by wind vs. water. Whitmore and Garner state:

> *"The average dip of the cross-bed foresets in the Coconino (based on hundreds of measurements by us and others) is about 20°. Modern eolian dunes have foreset dips at the angle of repose (~33°) and modern sand waves have dips ranging from 1 to 35° with an average of 15°. Ancient cross-beds may become compacted during burial, but our work (theoretical and petrographic) shows this can only account for several degrees of dip decrease in the Coconino."* (Whitmore and Garner 2018)

One detailed study of the Navajo SS in Utah measured dips of 28° (Allen, Lee, and Potter-McIntyre 2013). Looking at the Aztec, many dips are clearly above 30° (**Figures 10, 11 and 12)**. If the angles were corrected for structural dip, one could demonstrate increased dip. Many dips are less. Some of that is because the outcrop shows only apparent dip. The depositional dip, if it were possible to measure it would be perpendicular to the original slipface and angles would be higher. Another example from the ANN, this time from the Navajo Sandstone is shown in **Figure 13**. Additional striking photos of "The Wave" can be found here: https://theblondecoyote.com/2018/07/16/aerial-geology-the-wave/. At "The Wave", again the foresets are at high angles. Notice that there are multiple sets separated by deflation surfaces that existed long enough to have horizontal beds deposited over them. Notice that the light and dark beds have a cyclicity to them. One would have to wonder what would drive this cyclicity in a global flood.

The technical term for the steepest angle that loose sediment can be piled without slumping is the "angle of repose". Would a cross-bed set of 20-28° be marine? General values for the angle of repose are given as follows: Sand (dry) 34°; Sand (water filled) 15–30°; Sand (wet) 45° (Beakawi Al-Hashemi and Baghabra Al-Amoudi 2018). In more detail, the angle of repose depends on many factors including moisture content, sorting of the sand, roundness and sphericity of the grains. Well-rounded and more spherical grains will tend to have lower angles of repose than rougher, less spherical grains.

***Figure 10.*** *Cross-bed sets in the Aztec SS in Red Rock Canyon. White lines show angle of 30 degrees. Many beds exceed this and if they were corrected for the regional dip, the depositional dip along the leeward slipface or foreset would be higher. The red circled area is the folded area shown in Figure 8.*

***Figure 11****. Cross-bed sets in the Aztec SS in Red Rock Canyon. Again, white lines show 30 degrees of dip. The leeward foresets shown have dips approximately this.*

***Figure 12 .*** *Cross-bed sets in the Aztec SS in Red Rock Canyon. Here three of the sets have had the uppermost and steepest parts of the beds truncated by the boundary of the next sets.*

An example from modern dunes is useful. **Figure 14** shows an example of a recent dune where most of the cross-bed angles are significantly less than 30-35 $^{o}$ [1]. (McKee 1979) Some

***Figure 13.*** *The Wave, located along the Utah-Arizona border shows beautiful high-angle cross-beds in the Navajo Sandstone.*

*(photo from Wikipedia)*

actually are present that are higher, but most are not. McKee's USGS Professional paper, A Study of Global Sand Seas includes tracings of several dune styles around the world and many show bedding at lower angles than the ultimate original angle of repose, similar to those in the ANN and Coconino Sandstones. A similar direct comparison between the Navajo Sandstone cross-beds and barchan dunes in White Sands, New Mexico was shown by Prothero and Schwab as a literal

[1] Dunes from the White Sands National Park are composed of gypsum sand, rather than quartz sand that dominates most dunes. The angle of repose for gypsum sands is 35$^{o}$, much like that of quartz sand (Monolithic Dome Institute 2023).

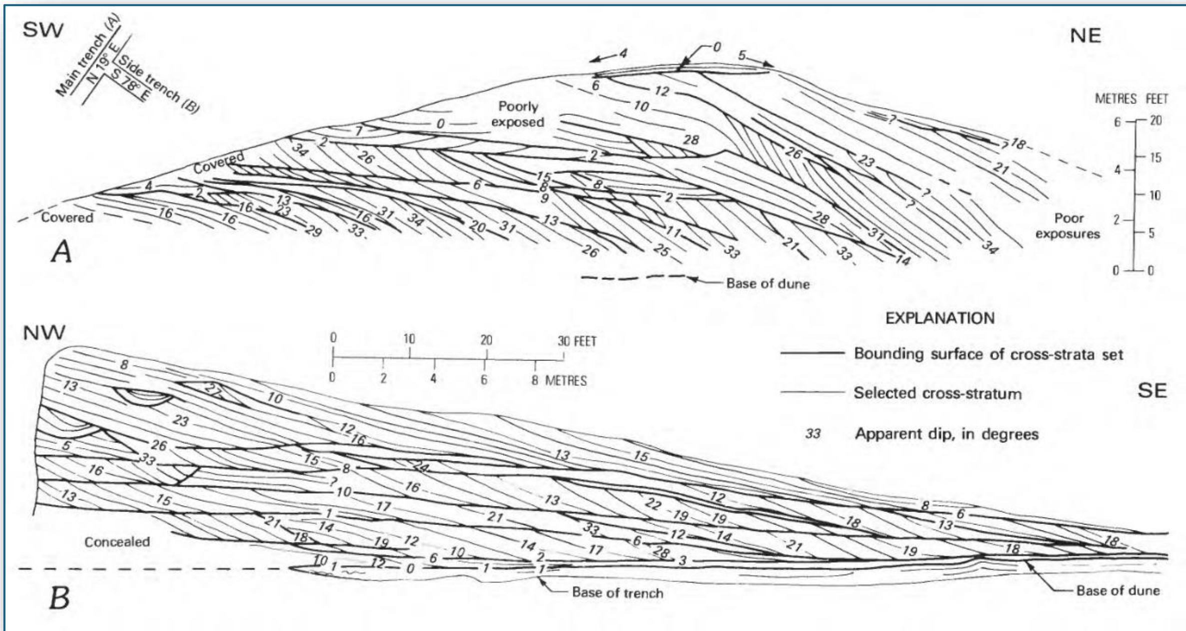


***Figure 14*** *Tracings of cross-beds made from trenching a barchan dune in White Sands National Park, New Mexico*

"textbook example", (Prothero and Schwab 2013) The cross-bed angles support a wind-blown eolian origin, though perhaps by themselves do not entirely rule out some sort of underwater origin.

6. *Similarity of vertebrate trackways to those made underwater*

YEC biologist, Dr Leonard R. Brand has published experiments to examine tracks formed by lizards and salamanders under various conditions. (L. R. Brand 1978; L. Brand and Tang 1991). He examined tracks on 1) dry sand, 2) moist sand, 3. wet sand, 4. underwater sand and included different slopes. He concluded that the tracks from the Coconino were most like those from underwater sand. Brand and Tang (1991) argued that these trackways were made by animals that were partially buoyant in water and drifting with currents. I don't know the settings for the tracks in the Coconino Sandstone. It is not difficult to believe that at times portions of an erg would have had small streams. Recognize that paleontologists studying tracks often recognize tracks that actually were made in shallow water (references).

It is evident however that the conditions that Dr. Brand tested are very different than the proposed conditions for Noah's flood. He tested small animals in 4 cm of slow moving water. (~8 cm/s). The rates of water movement demanded by the proposals for flood waters were often over an order of magnitude faster (Snelling 2021). The limited time of Noah's flood (1 year) with the amount of sediment deposited demands that rates have been very high with very, very little time for pauses or slow moving water. (Mitchell 2018; Mitchell and Tilman 2024). It takes some strong faith to believe that the ancient small animals that left tracks in the Coconino Sandstone would have left such tracks during a catastrophic flood. It is also important that Brand's testing is not likely to be valid for dinosaurs. More on this later.

7. *Sand injectites - discussed with parabolic folds and not repeated here.*

The concerns that Whitmore and Garner (2018) raised for the Permian Coconino Sandstone don't seem to be relevant for the Jurassic ANN formations regardless of their validity in the Coconino. We have a series of dune deposits in units where all of the fossils are consistent with terrestrial environments. The high angle cross-beds are consistent with subaerial dunes. Sand grain information available is consistent with subaerial dunes. Published slides of the sand grains are similar to modern dune sands. If we stopped there, subaerial dunes would be a logical conclusion, but there is much more.

## Dinosaur Tracks in the Sands

As the title of this post suggests, there is another important type of data to reconcile. Any explanation for the units must account for the dinosaur tracks. Were the dinosaurs living and hunting through an ancient desert region or were they dealing with a global catastrophic flood?

Many dinosaur tracks have been found and studied in the ANN (Bonde et al. 2008; 2012; D. B. Loope 2006; David B. Loope and Rowe 2003; Minter, n.d.; Rowland and Mercadante 2014; Rowland et al. 2014; Stoller 2011; Wilkens 2008; Reynolds 2006). Many types are found along with the tracks and trails of many other types of animals. At one time, it seemed that dinosaur tracks in southern Nevada were anomalously scarce. That changed when Dr. Stephen Rowland, professor emeritus from the University of Nevada at Las Vegas and others in 2014 published this report: "First Report of Dinosaur, Synapsid, and Arthropod Tracks in the Aztec Sandstone (Lower-Middle Jurassic) of Red Rock Canyon National Conservation Area, Southern Nevada" Here are a few points from this report:

He documents "tridactyl, grallatoroid dinosaur tracks up to 14 cm long" at 3 sites in the Red Rock Canyon National Conservation Area. One of the tracks is particularly well preserved, (**Figure 15**) (Rowland et al. 2014). Other sites have more tracks but not as well preserved (**Figure 16**) (Rowland et al. 2014). The authors also make a significant interpretation of the state of the dunes at the time the dinosaurs traversed it. Here I quote:

> *"We can also say something about the moisture content of the sand. Neoichnological experiments with dry, moist, and saturated sand have shown that recognizable tracks can form only when the moisture content of the sand is in the range of 2-24% by weight (Manning, 2004). Below 2% moisture, the sand is not sufficiently cohesive for distinct tracks to form, and above 24% the sand flows under its own weight, also preventing the development of tracks. In the case of the track at Tracksite UNLV-AZ-005, the moisture content was probably toward the upper end of that range. Clearly, the sand was cohesive enough to preserve the track and also for brittle failure to occur. Moreover, it contained sufficient moisture that the increase in pore pressure, caused by the penetration of the dinosaur's foot into the sand, permitted the sand to flow, thus creating the 7-mm displacement bulge."* (Rowland et al. 2014).

Neoichnology is the study of the tracks of animals from today and Dr. Brand is not the only one to have investigated tracks using living animals.[2] Several important studies have been published including some in the Navajo Sandstone. (D. B. Loope 2006; Manning 2004; Falkingham and Gatesy 2014). Notice that Rowland and his co-authors believe that they can not only determine that the tracks were made under subaerial conditions but recognize the moisture content of the sands. That is cool.

One thing that is true in the ANN Sandstones, as in many other units with dinosaur tracks, is that the fossils go in many directions, as you can see in **Figure 16**. Some YEC in the past hypothesized that dinosaur tracks formed as the dinosaurs were running away from the flood. If so, they couldn't agree which way to go. It is interesting that many of the tracks found in the ANN formations are found on the steeper side of the dunes. I observed similar tracks in the sand dunes of the White Sands National Park (**Figure 17**). I am not sure what made them, but I am pretty sure that it wasn't dinosaurs. At White Sands, we saw many types of tracks, including those from mammals, birds and insects. In the Aztec Sandstone, there also were a variety of animals ranging from dinosaurs to spiders to scorpion like creatures and even mammal-like animals (Reynolds 2006; Rowland et al. 2014). Many levels were bioturbated, that is chewed up by animals below the surface, probably including worms. One trace fossil has been recognized that has been attributed as possibly formed by "burrowing colonial insects" (Stoller 2011) (Fig. 6). "These consist of a network of variously oriented, tubular, sand-filled burrows, round in cross-section, and about 8 mm in diameter". Today that would probably mean ants.

[2] Concerning the Coconino Sandstone, this quote reflects
"The DeChelly study indicates an erg environment in which the foresets of dunes provided a substrate for the passage of numerous presumed synapsids (Laoporus trackmaker), rare diapsids/areaoscelids (Dromopus sp.), spiders (Octopodichnus trackmaker), scorpionoids (Paleohelcura trackmaker) and other arthropods. These surfaces were also swept by winds that produced eddies and wind ripples on the lee or avalanche slopes. Such evidence provides definitive proof of a sub-aerial depositional environment, not a subaqueous setting as proposed by Brand and Tang (1992). For this reason we are dubious about the interpretation of tracks made by animals with "aquatic adaptations" in similar facies (Cornberger Sandstone) of Europe (Fichter, 1994).
In addition to straight-line Laoporus trackways with normal alternating gait, these surfaces reveal various oblique and zig-zag trackway configurations, of the type noted and attributed to swimming by Brand and Tang (1991). Such evidence provides definitive evidence that such trackways can be produced in sub-aerial settings (cf. McKee, 1944, 1979), and that explanations for such unusual configurations must be sought through an analysis of terrestrial locomotion on sloping substrates." (M. G. Lockley et al. 1995) The trace fossils strongly support subaerial deposition of the Coconino Sandstone.

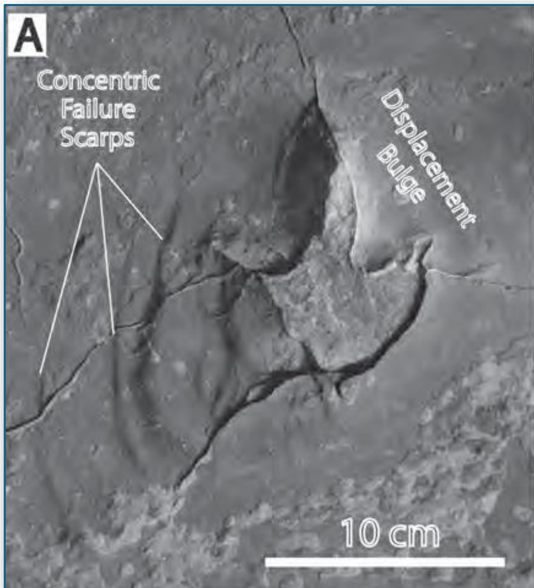


***Figure15.*** *Solitary tridactyl track from Red Rock Canyon . Interpreted as the right foot that entered sand approximately perpendicular to the surface and exited obliquely. The authors interpret the dinosaur to have been walking on a slope.*


***Figure 16.*** *Map generated by photogrammetric data of tracks from one bed in the Red Rock Canyon area. The authors note that more than 50 tracks are found with various states of preservation. The data suggest that the animals were walking diagonally up a slope.*

*__Figure 17.__ Animal track on the leeward side of dunes in White Sands National Park, New Mexico. These dunes are composed of gypsum grains but even so, the setting would have been similar in ergs dominated by quartz sand. The bulge on the downslope side of the tracks is evident.*

Dinosaur tracks in many places are associated with another sedimentary structure that develops in terrestrial settings. These have been recognized in many parts of the ANN units. For example, (Bryant 2011; Graham 2016; Hassan 2015; Parrish and Falcon-Lang 2007; Wilkens 2008) reported mudcracks in the ANN. Such desiccation features form when muds and muddy sands are exposed and dry out. The mudcracks in the ANN are found in sediments that are interpreted as interdune deposits that formed between the ancient dunes. YEC have long recognized this challenge. Exposure and periods of drying don't fit in a one-year long flood event. They often claim features called mudcracks have been incorrectly identified and were actually formed in subaqueous settings. A few propose that mudcracks could have developed in a few hours and then be buried.

Whitmore and Garner (2018) interpreted features to be misidentified as mudcracks because "the cracks penetrate both downward and upward about 15 cm from bounding surfaces." It is likely that some features such as fluid injected sands have been misidentified as mudcracks. Most often we find mudcracks along an exposed surface and since the rocks that were above them are gone, it is impossible to rule out that the cracks originally extended above the surface. Although the photo in **Figure 18** (Graham 2016) is from Triassic formations and thus older than the ANN sands, it does demonstrate that valid desiccation cracks are found in the geologic record in this region. It also demonstrates that they did not form in a few hours and then were covered by the flood. Multiple layers are present, hence demonstrating multiple wet periods and multiple periods of drying.

***Figure 18.*** *Multiple layers of mudcracks in cross-section view, Moenkopi Formation, Red Canyon, Glen Canyon National Recreation Area. At least 5 levels are visible. Photo from the National Park Service.*

When we find apparent mudcracks associated with other features that are common today in tidal environments or other settings where sediment might dry out, it is very convincing that they really were formed by desiccation. When we find dinosaur tracks associated with mudcracks, this is strong evidence of exposure and desiccation and is inconsistent with a flood origin. (**Figure 19**)("Fossil Trackway, Moenkopi Formation – Flagstaff, Arizona | e-Magazine of the AZ Geological Survey" 2021) Examples are found literally all around the world, such as: New Mexico (personal information), Utah (Balsley 1980), Connecticut (Getty et al. 2017), Colorado (Noffke, Hagadorn, and Bartlett 2019), Korea (Paik et al. 2006), Italy (Avanzini et al. 1997), France (Le Loeuff et al. 2006), Germany (Fischer et al. 2021; Lallensack et al. 2015), Madagascar (Wagensommer et al. 2012), Spain (López-Martínez, Moratalla, and Sanz 2000), Portugal (Henriques and Ramalho 2005), South Africa (Sciscio et al. 2016), UK (Whyte and Romano 2008). (**Figure 20**) In many of these locations,

*Figure 19. 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 older than the ANN units, but they serve to demonstrate that ancient mudcracks developed by exposure in the rock record just as they do today.*

the tracks are directly on mudcracked surfaces and many have nearby beds with paleosols with abundant rooted zones.

Trace fossils such as dinosaur tracks are not the only type of fossils found in the ANN. In the Valley of Fire State Park in Nevada, occasionally petrified logs are found. These logs are not in growth position and so could have been transported there, though they are associated with rocks that would be interpreted as interdune, not on the sand dunes. There are exceptions to this in the Navajo Sandstone. Parrish and Falcon-Lang (2007) describe trees in growth position in the ANN (Parrish and Falcon-Lang 2007). They studied interdune areas that, just as we find today apparently developed lakes. Carbonate mounds are found that they propose developed as ancient springs fed into the area. In a few cases, they found where the carbonate developed around trees trunks. They describe the trees as coniferous. They report:

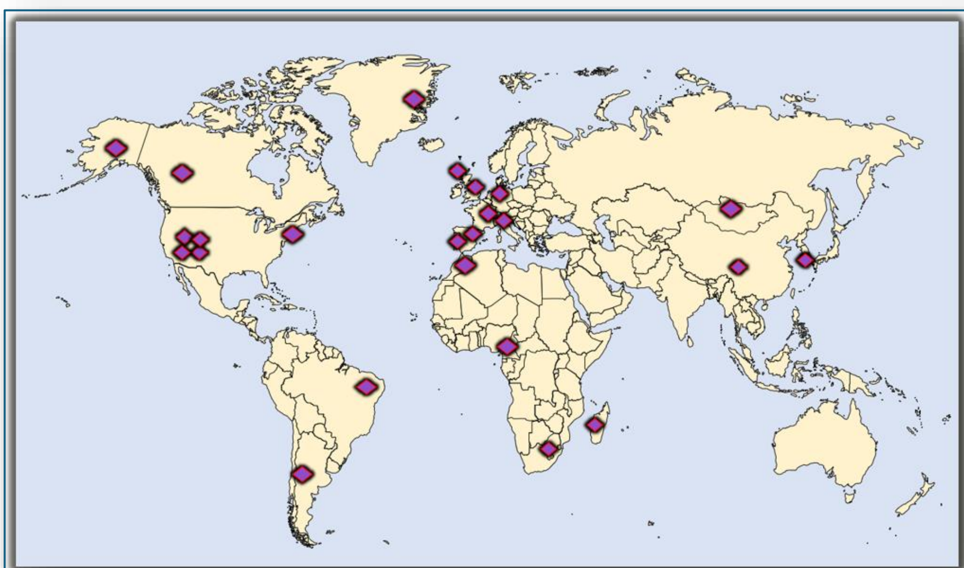

*Figure 20. Map showing locations of published accounts of dinosaur tracks associated with mudcracks*

*"A few stumps preserved in growth position are rooted in eolian sandstone immediately below the lake deposits, and evidently established on interdune soils in response to a rising water table. Following at least several decades of growth, trees were killed as the water table continued to rise forming shallow lakes containing ostracods."*

Clearly this would be impossible in a flood deposit. A deposit made in a few days would not have given the opportunity for trees to grow.

I want to show one more example of a Jurassic feature that is difficult to imagine in anything but an eolian setting. The crescent shaped marks shown in **Figure 21 ((**Kirkland and Milner 2006) developed as wind blew a plant around. Both pictured examples reflect this. The left example shows that during the Jurassic in what is now Utah, depositional processes stopped long enough for a small plant to grow. Wind then blew it around, leaving us evidence to find.

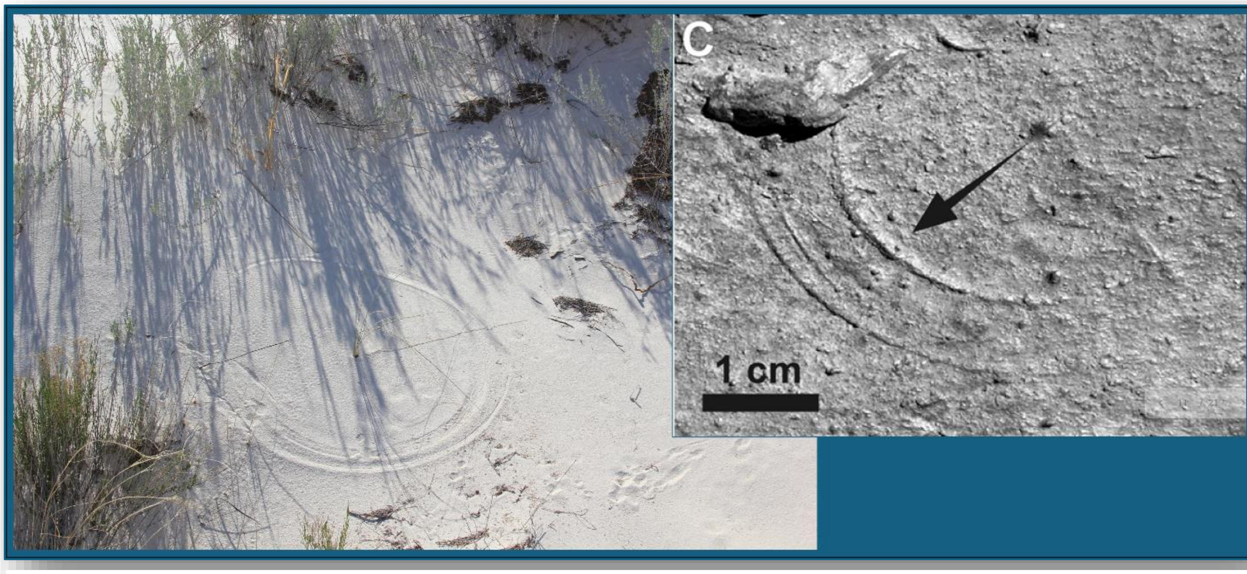


***Figure 21**. Examples of near circular and cresent shaped marks left by plants blown by wind. The left photo is from White Sands National Park in New Mexico. The right photo is of a smaller feature that formed the same way from the Upper Jurassic Moenave Formation in southwest Utah.*

## Discussion and Implications

The ANN formations have been interpreted to be from eolian settings for very good reasons. We have seen that the complex sets of cross-beds are consistent with dune sands that covered areas similar to large deserts of today. We saw a number of features that fit that general depositional environment including: high angle cross-beds that are at times "gigantic scale" (McKee 1979), cycles within the cross-beds consistent with annual climate variations (D. B. Loope 2006), often well rounded and well sorted sand grains, sediments consistent with interdune deposition, paleosols, dinosaur tracks that are indicative of moist to dry sand tracks, other trace fossils consistent with an arid or semi-arid setting, petrified wood even occasionally in growth position and mudcracks that indicate desiccation over some period of time.

Next, let's consider the observations that suggest an aquatic or submarine dune setting. The main arguments presented seem dominantly to be providing possible alternative explanations for the features above. In terms of features that are directly indicative of a subaqueous setting, I have not identified any. It has been suggested that we might expect to find more ripple marks (McKee 1979), though they are not uncommon. Helbe, (2024 92) showed that rippled beds in the Coconino Sandstone fit well with eolian characteristics. This would be good data to collect in the ANN Perhaps the strongest argument for deposition by moving water is that it fits the YEC model, while a non-aquatic model would not. Perhaps the comment on the Coconino would need to be applied for the ANN units: "It is likely the Coconino was deposited during the Flood by depositional processes operating at rates that we have not yet been able to model in the laboratory or with the computer." (Whitmore and Garner 2018, 618).

Dinosaur tracks add a real complication for the moving water interpretation. If the dunes were deposited in moving water, then we should be able to tell some things about the water by knowing the sand size. Larger sand grains require more energy and hence faster moving water to move. **Figure 22** (Lewis 1984) is one version of a commonly used summary chart used to characterize the bedforms or sedimentary structures that develop with moving water of different velocities vs. sediment grain sizes. It has been cited many times and one version was used by YEC flood geologist, Dr. Andrew Snelling (Snelling 2022, 241). Dunes require relatively high velocity moving water down at the sediment-water interface where actual deposition takes place. Above this interface, water would have been moving more rapidly. This tells us something about what had to be happening when footprints were made if the ANN dunes were deposited underwater.

We have modern examples of underwater dunes, termed "aqueous dunes" They can even involve gravels moved by catastrophic floods apparently due to glacial outflows. (Carling 1996). They also form with up to medium sands (Reeder 2011). Most are in fairly deep water. As Brian Romans observed, "*Sand dunes observed in water are typically smaller than their eolian cousins (some wind-blown dunes are hundreds of feet tall) because the height of dunes scale to the height of the current that creates them. The taller the current, the taller the dunes*"(Romans 2018). If the ANN dunes were as tall as they apparently were, the currents would have needed to be thick. Modern subaqueous dunes are reported with heights of 1.5 to 20 m (5-90 ft) in water depths of 100-830 m

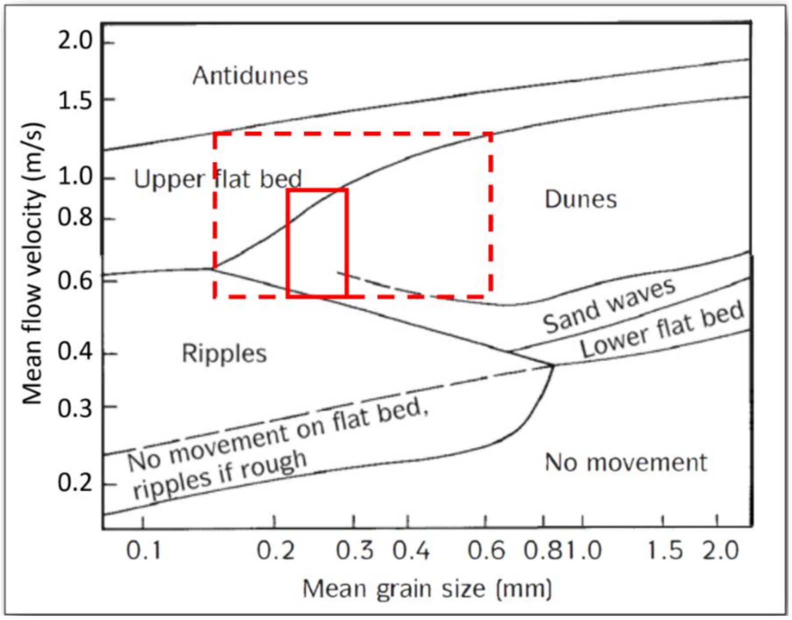


***Figure 23**. Relationship between sediment size, velocity and bedforms from physical model studies known as flume experiments. Distinctive bedding and cross-beddings result. Antidunes and upper flat bed features are characterized as "upper flow regime" bedding forms while the others are characterized as "lower flow regime" characteristics (https://www.geological-digressions.com/the-hydraulics-of-sedimentation-flow-regime/ . (Lewis, 1984) The red box shows the range for most of the ANN sand, while the dashed shows the total range. Range taken from*

(328-2700 ft) (Geng et al. 2024; Romans 2018; Reeder 2011; Carling 1996; Flemming 2000). It seems clear that the ANN dunes were larger and thus by implication in at least similar water depths.

Now picture dinosaurs walking up the slipface of a subaqueous dune in hundreds of feet of water. **Figure 24** shows my poor attempt to draw a picture of what this would have looked like. Despite the artist's obvious limitations in the drawing, you can see that it takes a determined faith to believe that dinosaurs were climbing submarine dunes. In an underwater setting with a strong current flowing, picture several types of dinosaurs, small mammals or mammal-like animals walking on the dunes. It is not even as if the tracks were just on one bed at each site, but they are preserved on many different beds, sometimes at the same site. Picture trees growing under the water. Remember that the trees that grew in-place are not setting on pre-flood sediments in the YEC models. There are thousands of feet of flood sediment below and above them.

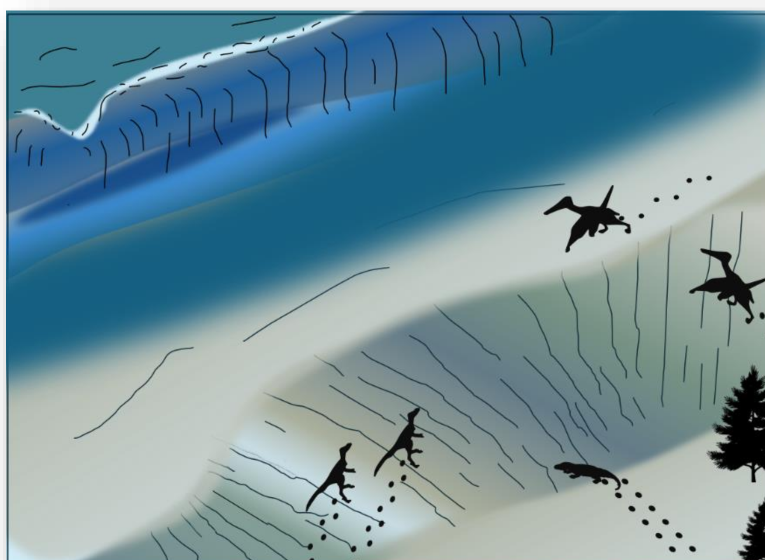

***Figure 24.** Illustration intended to show an underwater setting subaqueous dune with track forming animals walking around and conifer trees growing in the interdune area. Remember that the current must have been flowing rapidly.*

One other ancient animal is represented in the Jurassic in the same area: pterosaurs – winged reptiles (Bilbey et al. 2004). Pterosaur tracks are also reported in the Navajo and Aztec formations, but these are too poorly preserved to be verified (M. Lockley, Harris, and

Mitchell 2008). Why would they not have flown away instead of walking around under the sea? In the FG explanation, these bird-like creatures were walking underwater.

It all is too difficult to reconcile for me. The YEC models actually limit God. God, as we see Him revealed in nature, works on a larger scale than we ever would have imagined before the discoveries in astronomy over the last century. He also works at a much finer scale than we would have considered before the discoveries of subatomic particles. We also have discovered that his time scale for creation was much longer than we are used to in our human lives. He created wonders such as dinosaurs, perhaps in part just because He gets joy from creating. He even shares them with us through their bones and footprints.

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It is likely the Coconino was deposited during the Flood by depositional processes operating at rates that we have not yet been able to model in the laboratory or with the computer. However, the Coconino does have many broad similarities to sand waves. Sand waves are very common bedforms in high-energy nearshore and shallow marine tidal environments (Garner and Whitmore 2011). They usually take the form of long parallel ridges transverse to the prevailing currents (Hulscher 1996), with crestlines ranging from straight to gently curved to sinuous. Most consist of quartz sand but they may also contain abundant biogenic material and/or gravel. Sand waves are typically 1 to 15 m high, with wavelengths between 100 and 500 m, although some are larger (e.g., the 24-m-high sand waves in the Irish Sea reported by Harvey 1966). In profile, they are most often asymmetrical (Allen 1980; Hulscher and Dohmen-Janssen 2005), with steeper faces pointing in the direction of the dominant currents, although symmetrical forms also occur. The dominant internal architecture, predicted by theoretical models (e.g., McCave 1971; Allen 1980) and confirmed by the available field data (e.g., Berné et al. 1988, 1991), consists of various forms of cross-stratification (Fig. 48). The most important factors promoting the formation of sand waves appear to be an abundant supply of sand and strong unidirectional or tidal currents (e.g., Terwindt 1971 on the sand waves of the North Sea). Sand waves typically develop where the most prevalent sediment size range is from 0.25 to 0.5 mm (2.0-1.0 ϕ) in diameter, and are absent where mud or silt comprises more than about 10-15% of the bottom sediment. Most sand waves occur in water less than 100 m deep, although much greater depths are occasionally recorded (e.g., the sand waves in 475-800 m depths in the Barents Sea described by King et al. 2014; Bøe et al. 2015). Morphodynamic models have shown that modern sand waves develop when the main oscillatory tidal current interacts with irregularities of the sea bottom, promoting crestward sediment transport, and they migrate in response to other harmonic components of the tidal flow (Hulscher and Dohmen-Janssen 2005; Besio et al. 2008a, 2008b).

Crescent-shaped ridges of sand

Z:\Documents\Steve\Bible Study\Creation\Geology\Texas Geology\Processes\Eolian Dune Desert

Allen 3D model of eolian Jurassic Navajo SS Utah.pdf

Bristow Eolian Landscapes Stratigraphy

Ford Soft-sediment Deformation and Dune Collapse in the Navajo Sandstone.pdf

Hansen Reservoir Characterization Outcrop Analogs Navajo Sandstone Utah.pdf

We think sand waves explain many features of the Coconino Sandstone that an eolian model does not explain. Sediment size, sorting and cross-bed style in sand waves, among other features, are similar to what is found in the Coconino. Seismic studies have shown that sand waves can have foreset lengths up to 50 m, more than twice the length of observed foresets in the Coconino. The average dip of the cross-bed foresets in the Coconino (based on hundreds of measurements by us and others) is about 20°. Modern eolian dunes have foreset dips at the angle of repose (~33°) and modern sand waves have dips ranging from 1 to 35° with an average of 15°. Ancient cross-beds may become compacted during burial, but our work (theoretical and petrographic) shows this can only account for several degrees of dip decrease in the Coconino. The Coconino reaches a maximum thickness of around 300 m in central Arizona. Modern ergs have average thicknesses about an order of magnitude less than this (Table 3). Sand sheet deposits like the Coconino are not unusual, and many of them have an average thickness many times that of modern ergs. The thickness of the Coconino and many other ancient sand sheets is suggestive of marine depositional processes, where thicker sheets of sand can potentially accumulate.

Sand dunes observed in water are typically smaller than their eolian cousins (some wind-blown dunes are hundreds of feet tall) because the height of dunes scale to the height of the current that creates them. The taller the current, the taller the dunes.  Romans

Two settings have been proposed.

Rowland

We describe and interpret a tracksite in the Lower Jurassic Aztec Sandstone in Valley of Fire State Park, southern Nevada. The site contains approximately one hundred tracks of the ichnogenus Brasilichnium, arranged in twelve subparallel trackways, all on the same bedding plane. The Brasilichnium trackmaker was most probably a fossorial, tritylodontid therapsid. Sedimentological analyses indicate that the trackway surface is a wind-ripple horizon with a primary dip of about 25 degrees, and that the animals climbed straight up the slip face of the dune. A combination of features leads us to conclude that the footprints were impressed into a crust of moist, cohesive sand, leaving two modes of preserved tracks: (1) shallow, well-defined tracks without associated sand crescents, and (2) deeper, less well-defined tracks with associated sand crescents. We interpret the assemblage of tracks to record gregarious behavior in a mixed-age group of tritylodontid therapsids. In the correlative Navajo Sandstone, other researchers have documented the presence of complex networks of burrows concentrated in elevated mounds, reminiscent of colonies of North American prairie dogs. The Brasilichnium trackmaker is a good candidate to have excavated the burrows. Although we cannot directly associated the Brasilichnium trackmaker with the burrow complexes, we hypothesize that these gregarious, fossorial animals lived in prairie-dog-town-like colonies. This study supports the aridity food-distribution hypothesis, which posits that the patchy distribution of food resources in arid environments creates selective pressure for colonial behavior.

In geology, an erg is a large area of desert covered in wind-swept sand that forms various dune shapes.

Evaporites… gypsum in Valley of Fire

> *The Aztec Sandstone is made up of two units. The lower resistant sandstone unit (100 metres (330 ft) thick) is tan to off-white in outcrops but pinkish in fresh exposures. Cross-bedded lenses can easily be observed. Frosted and pitted quartz grains well-cemented by silica are described by Evans in 1958 and 1971. The upper and less resistant unit (200m thick) consists of alternating white quartz arenites and red to brown silty sands.*

The Coconino is thought to have been deposited during Noah's Flood by most Flood geologists because it is bounded by widespread Paleozoic marine deposits, which occur both below, and above the Coconino; and of course you cannot have major windblown dune sands in the middle of worldwide Flood deposits. (Whitmore and Garner 2018)

*Figure 3  Modern mudcracks with dog tracks*

Reference Lorence Collins

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**Sedimentology of an ancient erg margin: the Lower Jurassic Aztec Sandstone, southern Nevada and southern California**

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