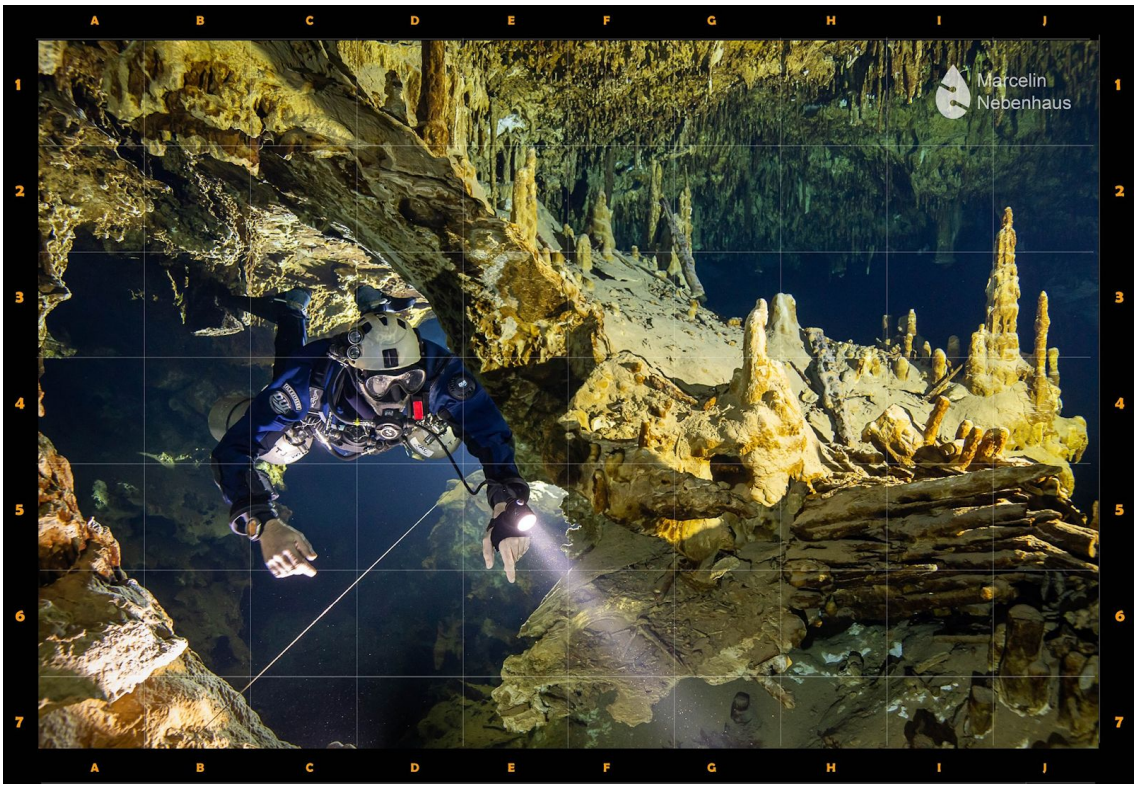
Under the Jungle - Geo Karst challenge - Sunday July 26
Explain the history of Minotauro - in geological time!



Nat point to - **The iconic arch in CENOTE MINOTAURO**, right next to the double arrow jump. WHAT ORDER DID ALL THESE FEATURES FORM IN? There are sideways stalactites fused onto the rock, some of the fomations are golden, others are black. There's layers and layers of rock in the arch itself, but why is there even an arch that Vince can swim through? Is it dissolved out, or is it a piece of rock that just fell over. Did that show up before or after the formations on top? Did sea levels affect this? Rainfall? Earthquakes? I don't even know where to start!

Lets see if we can all understand what story the earth can tell us in this gorgeous site.

Step 1 - There is a cave. We know that the halocline is particularly good at making cave, so most likely this cave formed at the halocline. This is only possible at high water levels, so **high sea level**.

For the cave to form that high up in the geology, then the water table was high - and so therefore this had to be during an inter-glacial - one of the past high sea levels.

Step 2 - There is speleothem in the cave - with stalagmites, stalactites, and flowstones. Those can only form when the cave is air filled. That is only possible at low water table - so **low sea level**.

Step 3 - There used to be alot of sediment in this cave, since flowstone forms on flat surfaces like rock or sediment banks. Indeed - these arches and pendants are mostly near the ceiling…. Which

means the sediment reached very high close to the ceiling. The cave used to be mostly filled up with sediment!!!!

Since some of the sediment really looks like layers of calcite rafts - see the picture of the “pancake” pendent near the Arch - the water table had to be close to the ceiling to get calcite raft at that level. However - not high enough to flood the whole cave since some air is needed to form the rafts. So that means another high water level and **high’ish sea level**.

If the water table was running through the cave, but not fully to the ceiling, that makes great conditions for abundant formation fo rafts.

Step 4 - But some of the rafts and sediments are still cemented to the bottoms of the pendent…. So the water table dropped and dripping water then got into the sediments and formed cements, gluing it all together. That would require for the sediments to not be waterlogged, so back to a low water table and **low sea level**.

Step 5 - The massive amounts of sediment are washed out. Whoosh. High water table so **high sea level** again.

So much of the speleothem was formed on top of, or in some way connected to the sediments, that alot of the speleothems fell over, most likely underwater.

Adam - I know that the fallen over stal are of great interest - it does look like most of them fell over from the flowstone/sediment underneath being removed. They were simply destabilized.

Step 6 + 7 However we have 3 most critical observations

Adam Hanlon shared that some stal are cemented in place! Which is only possible if water is dripping on them and precipitating calcite...

We also have comments from Roger Williams that he sometimes sees new speleothems forming under the pendents/arches… which means water flowed through them and made new younger stal.

In all cases - both Adam and Roger’s observations then require **ANOTHER low-then-high sea level cycle.**

Indeed - Kyle Horn photo of a pendant seems to show stalactites on the underside!

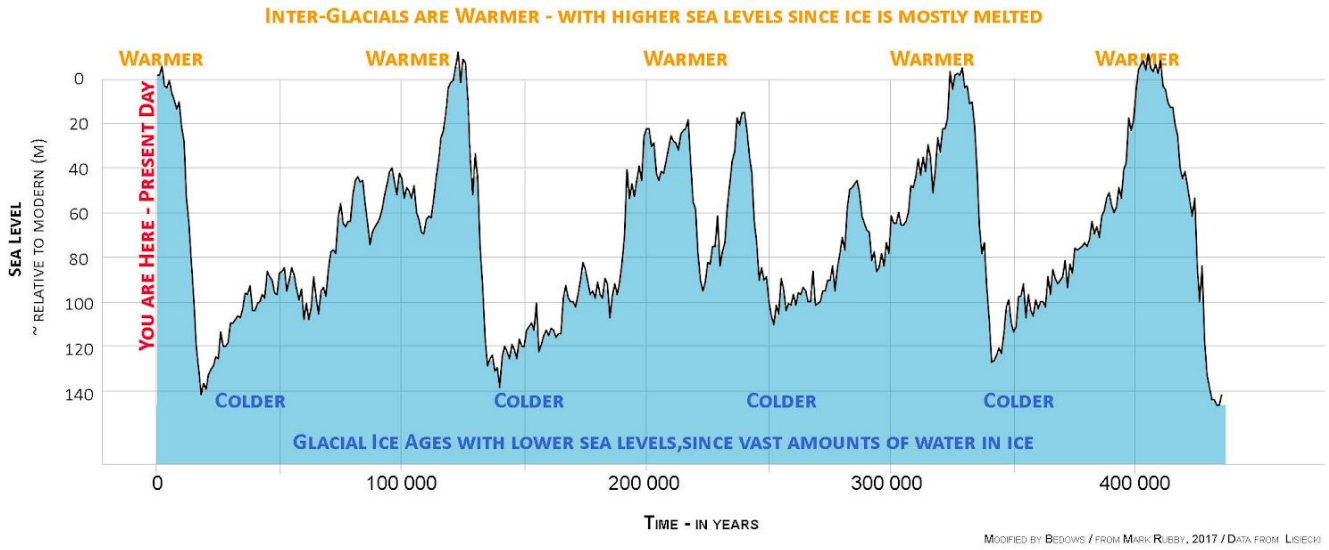
What is the timeline required for all this? How old are the caves - based on what we can see in these pictures?

We need to work our way backwards.....

With #1 being the oldest.

7 = high 6 = low 5 = high 4 = low 3 = high'ish 2 = low 1 = high

Holy molly - that means we have to go all the way back to 340 000 years ago - just to account for what we can see in these pictures from Minotauro???? **Yes.**



Seriously - does this make sense.... Is the rock old enough to have caves this old?

Yes it does since the rock along the coastline is Quaternary - so 2+ million years. The rock is certainly old enough to have caves this old in them... and indeed the caves are likely older then that. We might even find evidence for even earlier phases of cave-sediment-excavation if we look at the geology more closely.

How can we test how old the caves are / if indeed these deposits date to the high/low sea levels inferred?

We are fortunate to have some much carbonate in the system, and we can use uranium-thorium radiogenic dating to get very good date on materials. The dating costs ~$1000 for each sample though, so it is worth taking the time to examine a cave geomorphology and sedimentology - to figure out what should be sampled and dated.

I am also pleased to share (quietly) that a paper is in the works that includes 400 000+ dates from speleothem material, which does indeed mean that the caves have to older then that.

Based on all that I know .... I would say that the caves overall are likely about ~1 000 000 years old +/- and of course that is a broad regionalization and may not apply to a given location. Some conduits near the coast have geomorphology/sediments that show them to be really quite young

and actively forming, which makes sense since they are in VERY young rock so that last 500 m to the coast is highly unstable in young rocks.

Kyle Horn also asked - "does the time that it takes the sea level to drop and rise between periods allow for dissolution in the deeper sections of karst or is it insignificant?"

Why yes!! When the water level and sea level are lower, then there is cave forming lower down.

In coastal karst, we have massive "overprinting" and we say the caves are POLYGENETIC since each passages has many phases of development.

An added complication is that the geology on the coastline is also changing - with more sediment/rock being laid down on the coast, or removed.

Our current model (ahem - soon to be questioned!) also assume that the platform is tectonically stable and has not moved vertical. .... Is that correct? :-)

In all cases though - the following graphic gives a good overview of caves forming, aging, and then growing some more over time. (from *Smart, Beddows et al, 2006).*

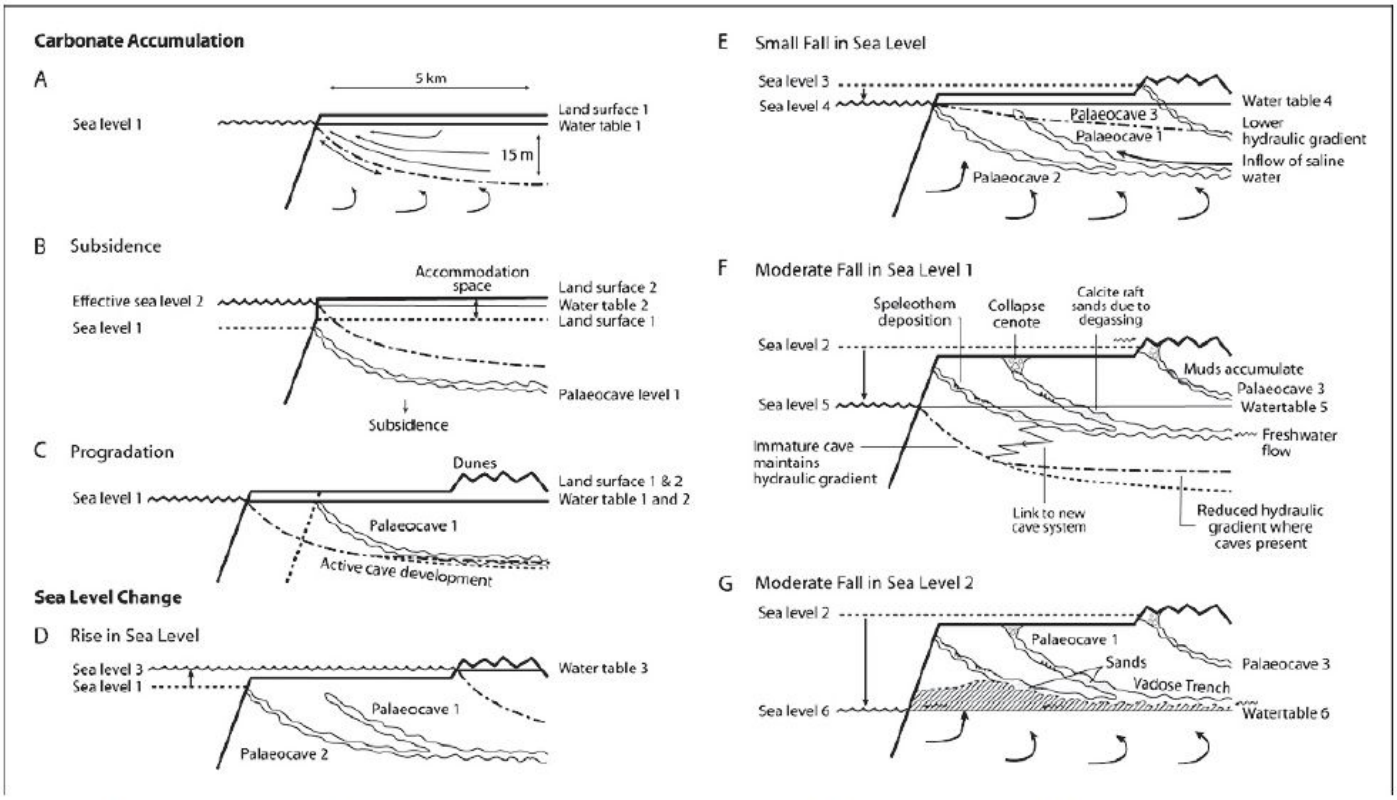


Figure 13. Response of Quintana Roo cave development to carbonate deposition and changes in sea level. Note that the cartoons have a large (~120×) vertical exaggeration, and for simplicity, the theoretical parabolic relationship between depth of mixing zone (shown as a sharp interface approximation) and distance from the coast for a porous media is used (but see Fig. 9). Chained line indicates locus of active carbonate dissolution in the mixing zone. (A) Groundwater flow and active cave development by mixing-zone dissolution. (B) Subsidence with constant sea level generates accommodation space, and carbonate sediment accumulates on the platform top. Earlier caves are abandoned (paleocave 1) as cave development occurs in a new shallower mixing zone. (C) Progradation of carbonate sediments with a constant sea level causes seaward extension of the cave system from A into the newly deposited carbonates, but within the platform, interior cave development continues in the existing caves. (D). A small rise in sea level may have a dramatic impact on position of the coast in the low-relief carbonates, shifting the locus of cave development. (E) A subsequent small fall in sea level exposes a large area of carbonates. Previous caves substantially increase the transmissivity of the platform, which results in a much lower gradient for the mixing zone. Consequently, the zone of active carbonate dissolution crosscuts earlier cavernous zones, only some of which are reactivated. (F) Further fall in sea level causes vadose conditions in the earlier caves with speleothem deposition, collapse, and accumulation of calcite raft sands and surface-derived sediments. A new, deeper level of cave development is initiated, and may link to existing passages, which continue to discharge fresh water from inland. (G) A similar moderate sea-level fall occurs, but input of saline water is sufficient to make the freshwater flow aggressive, developing a canyon passage, the gradient of which determines both the water table and mixing-zone position. Note: for B and C, cartoon A is the prior stage, but for D to G cartoon C is the prior stage.