Under the Jungle - Geo Karst challenge - Sunday September 20

How old are the caves / how fast do they form?

Kyle Horn asks - "**What about those saltwater passages that are almost completely barren of formations, yet so close to decorated freshwater passages? ARE SHALLOW CAVES WITHOUT SPELEOTHEMS JUST VERY YOUNG? Were they not dry long enough for speleothems to form, or are they just very young caves that haven't had time for formations to grow?"** Some of these undecorated caves and karst features are enormous like the Caleta Xel Ha – were they created recently by sudden collapse, or is something else happening? How long does it take a big feature like Xel Ha to form? Let's get a conversation started, take a guess and share your observations and photos.

Shallow fresh - no speleothem….

Deep saline - no speleothem….

#1 - There has to be land…. So sea level has to be low "enough".

You may be surprised to learn that most of the geological time back to 65 million years ago - sea level was +100 to +200 m HIGHER then present…. It is only about 10 million years ago that ocean basins were big enough and deep enough to hold water creating more land. With the Yucatan Peninsula in its position and approximately at the same level - that means that the earliest time that ANY underground river caves could have formed was when there was land, with rainfall infiltrating to create a fresh water lens, with vegetation and soil to give the CO_2 boost, and the gravity drive to push water through the system to the coastal margins.

MAX IS 10 MILLION YEARS - even in the inland older rocks like the Mio-Pliocene that are ~25 million years old. And yes - there would have been caves forming in that older rock… nothing stopping it… but only after ~10 million years ago.

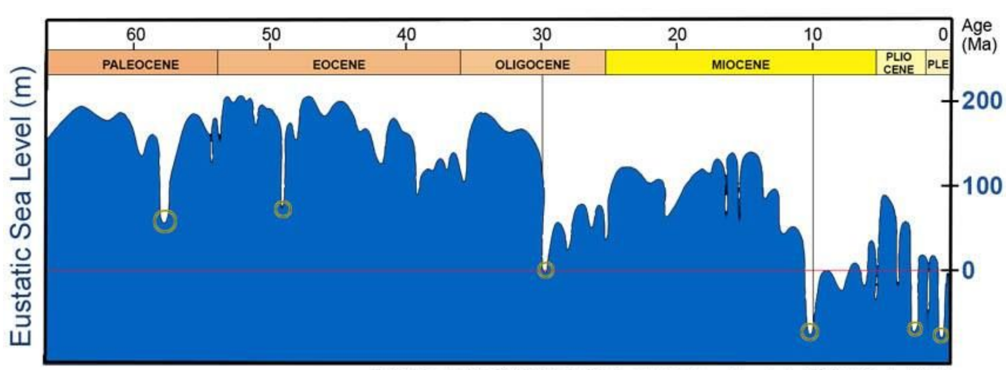


FIGURE PREPARED BY MONROY-RIOS. Modified from Haq et. al. (1987) & Savin (1977)

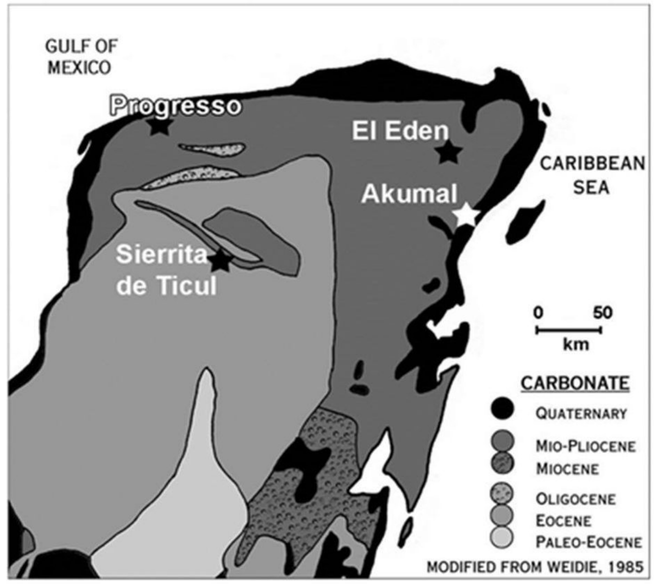
#2 - the caves have to be younger than the rock they are in…

The Yucatan Peninsula has off-lapping aprons of progressively younger rock - out to a ~ 10 km wide coastal Quaternary boundary. The Quaternary started ~2.5 million years ago.

Therefore all the caves along the Caribbean coast can only be an EXTREME MAXIMUM of 2.5 million years old…. However we need a chunk of time for the Quaternary sediments to be lithified/cemented into rocks - so lets take 0.5 million years for that = max age of caves = **2 million years old**.

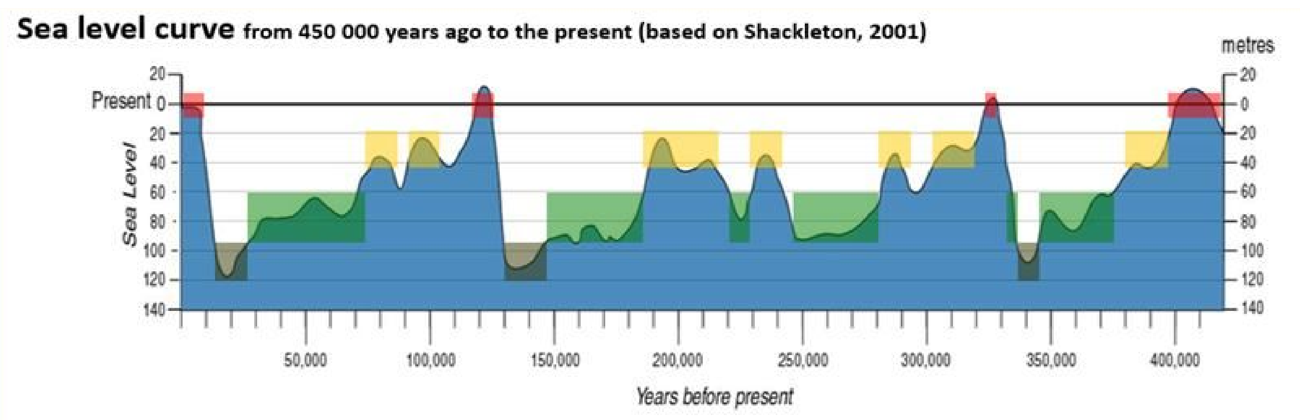
Any caves that formed starting ~10 million years ago in the older Mio-Pliocene rocks > 10 km from the coast would have run to the paleo coastline - which then got buried by the younger Quaternary sediments.

And - I suggest there is little reason the Mio-Pliocene caves need to connect to the caves in the Quaternary rock - likely just totally separate.



#3 - But sea level has been going up and down

Once we only consider our most recent geology history - yes it is correct that our CURRENT cycles of glacial/interglacial make sea level go up and down in neat repeating patterns. That is all dependent on the continents being where they are, the earth orbit having its current wobble/tilt/non-circular pattern.



You can see that we have had 4 cycles in the last 450 000 years, but with only 3 of them (grey blocks) reaching to 100-120 m below present.

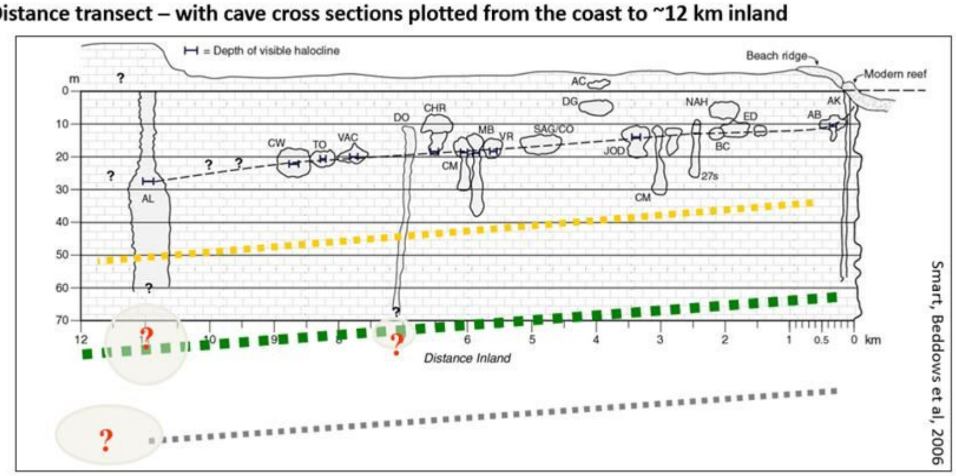
If the current caves are forming along the halocline (more on that below) which is mostly ~ 20 m below current water table

Then most of the caves we are diving formed when sea level was at near modern….

That means that most of the caves we dive formed during just these tiny RED BLOCKS of time.

It follows that they must form very fast…. Whoaa

Distance transect – with cave cross sections plotted from the coast to ~12 km inland



#4 - How fast can caves form?

The rock has to be dissolved, and that happens from water that is under-saturated with respect to carbonate.

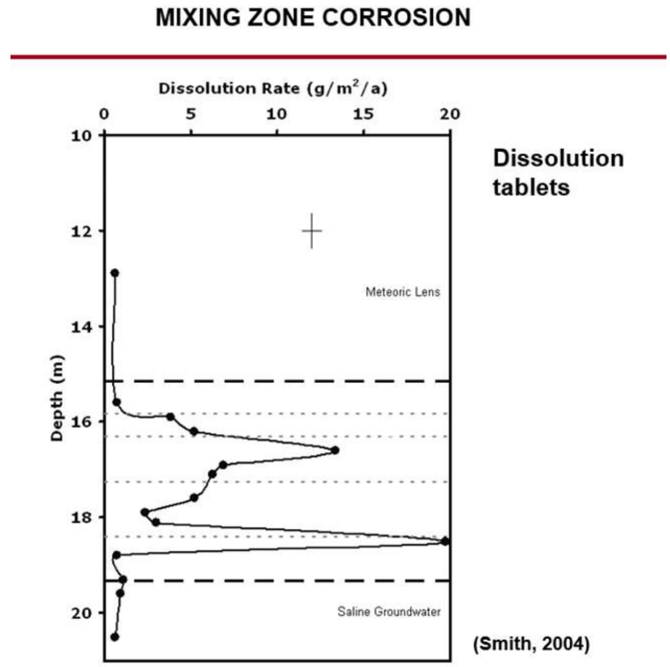
If you have two water - both saturated with carbonate - but they mix…. Then the solution can be undersatured….

With fresh-saline mixing at the halocline - the under-saturation can be very impressive with 5-20 g / m2/ year in the B tunnel of Maya Blue for example, as measured by blocks of carbonate allowed to slowly dissolve over two years.

FYI - you can also get mixing corrosion where any two waters meet - where two cave passages flow into each other, where rainwater mixes with the groundwater at the water table.

You can also have additional under-saturation where microbes digest organic matter also common in the halocline - since microbial respiration gives off CO2 which also creates under-saturation.

But really - yes - you get a very effective chemical drill with two salinities, two temperatures, two waters of a wide range of contrasting physical-chemical conditions.



Some of the rock strata though are resistant to dissolution, and some of the sedimentary beds though are just super at dissolving out - creating what we call the "bedding plane passages" although that is a mis-nomer since it is often the whole actual bed that dissolves out.

However a big caveat here - it would be too simple to take this 5-20 g/m2/year and multiply it out… since these tablets were hanging in the middle of the passage where mixing would be maximum - but that also contact with wall rock would be minimum. So these numbers should be considered extreme end members, but still illustrative that extreme dissolution potential is generated, although maybe 1/10th of it is realized.

#5 - Are we talking 1 000, 10 000, or a million years…

Most of the caves we dived were likely carved out in some thousands of years - VERY fast.

However - with sea level going up and down all the time…. There are only little windows of time that they form, before they are either drained and decorated…. Or just end up in the wrong place like the middle of the fresh water lens or the saline water where not much is happening.

A given feature then may only take a short time to form, but it did so in little tiny time steps spanning much longer time.

#6 - Any way to ge an actual fix on how old?

Why yes - there is but it is not easy and it is expensive. We use uranium thorium dating to date materials like speleothems. Uranium is water soluble and there is actually quite alot in the Earth. When rain water infiltrates the rock, it dissolved out some uranium, and then that is locked in speleothems that form.

Thorium is not water soluble, so even though there is way more thorium globally - it does not get carried by the infiltrating rainwater and it not part of the initial speleothem.

Over time, the uranium decays to thorium…. Slowly… at a very fixed rate and we can use that as a geological clock.

Since we can measure the concentrations of the various types of uranium and thorium, we can tell how long the geological clock inside the speleothem has been running, and that is our super precise and accurate date.

The oldest piece of speleothem that we have is ~400 000 years old…. And that was from a shallow cave [paper in process of finalizing for publication :-)]

This reinforces the constraint that the caves of the Caribbean Yucatan are maximum 2 000 000 years old, if we managed to miraculously analyze a piece that was ~400 000+.

Even the sampling is tough - if you were to spend $2000 on dating a single marble sized piece of speleothem - which piece would you choose, from where, and why?

#7 - Just to make this more fun - let's consider the case of Xel Ha

Back in the 1970/1980 a group of intrepid geologists got into Xel Ha and did some great hydrogeochemistry work.

They calculated that from the measured concentration of carbonate in the water… the volume of water flowing through the site (in the few days there were there….), the volume of Xel Ha rock that got dissolved out - that **Xel Ha formed in 3000 years**.

I use this example as a thinking exercise for all my staring PhD students :-) but I'll give you the answer.

I put forward that Xel Ha is WAY OLDER than that….

They assumed that all the dissolved rock in the caleta water was from rock dissolved out locally.

Chemical mass-wasting of the northern Yucatan Peninsula by groundwater dissolution

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ABSTRACT

The northern part of the Yucatan Peninsula is a relatively flat, low-lying carbonate terrane with no geomorphic expressions of stream channels. It is estimated that mean annual recharge to the groundwater system is 150 mm. For the 65,500 km^2 study area, mean annual discharge (equivalent to recharge) is 9.8×10^9 m^3, or 8.6×10^6 m^3 for each 1 km of the 1,100-km-long coastline. In the interior of the peninsula, the recharging water annually dissolves about 37.5 t (metric tons) of calcite per 1 km^2. When the groundwater has become saturated with calcite, little additional water-rock interaction occurs until the active mixing (dispersion) zone is reached near the coastline.

Theoretical calculations and laboratory experiments have shown that when two waters, each calcite saturated and with different salinities, are mixed, the resulting solution generally becomes undersaturated with calcite and, therefore, is capable of dissolving additional calcite. On the basis of our study of the Xel Ha lagoon on the east coast of Yucatan, we calculate that as much as 1.2 mmol/L additional calcite can be dissolved in the brackish groundwater zone of dispersion. This indicates that if the total solution potential of the amount of water discharging at Xel Ha has focused within the lagoon area, the lagoon could be chemically incised in less than 3,000 yr. We postulate that chemical mass wasting by dissolution in the zone of groundwater mixing is an important geomorphic process in coastal areas of limestone terranes.

cal processes in landform evolution by investigating the groundwater hydrology and geochemistry and utilizing water balance and chemical mass transfer calculations.

HYDROGEOLOGIC SETTING

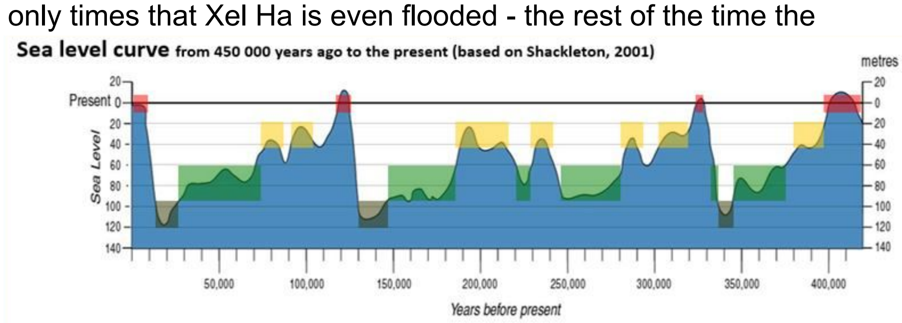
The northern part of the Yucatan Peninsula is characterized by a low-lying, nearly featureless microkarstic plain. The southwestern part of this plain is bounded by the Sierrita de Ticul, which extends from Polyuc to Maxcanu (Fig. 1) and functions as a groundwater divide that forms part of the southern hydrologic boundary. An arcuate trend of low-lying hills between Maxcanu and Campeche is also a groundwater divide, which separates the swampy coastal area from the higher interior southeast of the hills. Faulting between Polyuc and the eastern coast also represents a hydrologic boundary between the low-lying coastal area and the interior of the peninsula. The thin soil cover over the limestone, coupled with the extremely high permeability of the rock and the relatively featureless morphology of the

You - as a cave diver - know that the water runs for kilometers and really from the middle of the peninsula! Keep diving - keep exploring please.

The dissolved rock they measured did not all come from within the caleta - but over many kilometers of flow path. That alone multiplies the time needed by 100+ times longer….. Since the caleta is <1km long. That dissolved rock in the caleta water could have come from Chichen Itza….

At the time in the 1970's/1980s' they had no knowledge of the cave systems like we do today.

Another factor - is going back to this figure again. If you actually need 30 000 year to dissolve out Xel Ha - then how many of those short red squares do you need before you add up to 30 000 years…. And the answer is MANY. The red squares are the only times that Xel Ha is even flooded - the rest of the time the caleta is dray and drained at all other lower sea levels, and so there is definitely not any dissolution happening when it might be a beach or grassland….



REFERENCES YOU MAY LIKE

Chemical Mass Wasting - Xel Ha - https://northwestern.box.com/s/huxw7qfk63s0hvm4vgag0pmfkg2znx9g

Yucatan Cave Development - https://northwestern.box.com/s/01dr8lctl7pwx0dxv4rzvle1e6oxj6m1

Which FYI - there are some points in the Cave Development paper that I no longer consider quite correct … since you guys keep on finding new interesting cave to test ideas with!

(2 more below)

Post Script based on ongoing chatter…

Unfortunately I have not given a clear answer about why some shallow and deep passages are barren of stal. They just look young anc clean, and I do put some weight on Brian indication that dissolution have removed some speleothem.... but with speleothem being resistant to dissolution compared to the rock - I argue we should see some stal in those passages - if it was ever there.

WHAT ABOUT TECTONIC YOU SAY!

Another point of serious consideration, which is the tectonic stability. We have long considered the Yucatan Platform to be tectonically stable… but we are discovering not exactly.

Modern geodetic data shows falling Caribbean coast - which could be tied to the massive carbonate loading on the northern platfor that is presently pushing down … but that only happens at high sea level.

At more common lower levels - we see rising platform due to the denudation / slow dissolution and loss of mass. That is based on speleothem dates.

Both of these new contributions say the same thing - the platform is in vertical motion at a significant rate. It is moving. Under certain loading condition it goes does, and when mass loading is not happening then it rises up.

With OVERALL over 100 000's of years there is uplift - then another kicker is that our current upper level of caves formed much deeper… but over time have risen up and been occupied by the modern hydrogeology.

Two more refs for your consideration -

Monroy-Rios - Geodetic data -
https://gsa.confex.com/gsa/2018AM/webprogram/Handout/Paper320245/GSA2018_MonroyRios.pptx

Jenson - U/Th dates

https://gsa.confex.com/gsa/2018AM/webprogram/Handout/Paper318501/GSA%202018_POS%20in%20Quintana%20Roo_Jenson.pdf