

Science AMA Series: We are Drs. Gulick, Morgan and Lowery. In spring we drilled into the Chicxulub impact crater. Now the whole science party has met for the first time to have a closer look at the cores. AMA!

Chicxulub<sub>Impact</sub><sup>1</sup>and<sub>r</sub>/ScienceAMAs<sup>1</sup>

<sup>1</sup>Affiliation not available

April 17, 2023

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### CORRESPONDENCE:

**DATE RECEIVED:**  
October 11, 2016

**DOI:**  
10.15200/winn.147610.03842

**ARCHIVED:**  
October 10, 2016

**CITATION:**  
Chicxulub\_Impact , r/Science ,  
Science AMA Series: We are  
Drs. Gulick, Morgan and  
Lowery. In spring we drilled into  
the Chicxulub impact crater.  
Now the whole science party  
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AMA!, *The Winnower*  
3:e147610.03842 , 2016 , DOI:  
[10.15200/winn.147610.03842](https://doi.org/10.15200/winn.147610.03842)

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Were there any technical challenges that laypeople may not realize with regard to the drilling?

[goodygood\\_274](#)

Oh man, so many technical challenges. Drilling is a tricky business, and even in a relatively shallow hole like ours there's lots of chances to get stuck or wear out the bit or have something break on the rig or what have you. A large part of why an expedition like this takes two months is it gives you time to deal with problems as they arise with drilling. Check out the operations chapter from the last time IODP used a lift boat like the Myrtle: [http://publications.iodp.org/proceedings/313/103/103\\_.htm](http://publications.iodp.org/proceedings/313/103/103_.htm) Mostly just a list of the technical challenges of drilling.

Were there any technical challenges that laypeople may not realize with regard to the drilling?

[goodygood\\_274](#)

There are always challenges in any major operation. For instance we spent nearly a week trying to get pipe into the hole to thread into each other when 200 m of pipe was dropped to the bottom of the first 500 m of hole and then we had to thread into it with the next 300 m. In the end it worked and we cored ahead another 830 m plus at the end could recover all of the pipe from the seafloor.

What will core samples tell us about how life was effected after the impact?

[Cg12341](#)

We will look for fossils, DNA, RNA and biosignatures in the crater rocks and in the sediments that cover the crater to tell us about ancient life (what was there 66 million years ago) and modern life (what is there now). We think that impact craters may provide habitats. And we will look at what species are in the earliest rocks above the impact. Are they unusual? Or does everything return to normal quite quickly?

Hi! I teach a high school astronomy course and I try to talk about impacts. I know that remote sensing is a huge addition to the field. How can I show this to students? Google Earth is great for some things, but I sure can't make out the Chicxulub crater. Any suggestions?

[ryeinn](#)

You are right - the crater is buried and there is not much of a signal at surface. That's why it took 10 years to find it. The gravity and magnetic data are fabulous - they show where the crater is very clearly. A google search will get images.

Hi! I teach a high school astronomy course and I try to talk about impacts. I know that remote sensing is a huge addition to the field. How can I show this to students? Google Earth is great for some things, but I sure can't make out the Chicxulub crater. Any suggestions?

[ryeinn](#)

In addition to the sink holes (cenotes) that line the inner rim of the cast which redherring2 mentioned, on gravity data you can see the low density rocks within the crater and on magnetic data your can see the manegtic melt sheet. Maybe those will work for a class

How big of a drill did you have to use/how deep did you core?

[Kehrnal](#)

pq plus and then dropped down to pq 1344.7 m (I think) it has all got a bit vague for me now.

Jo

Were pieces of Yucatan blown out and ejected to make any other smaller craters around the world? In other words, are there any confirmed SECONDARY CRATERS caused by the impact cratering event? Also, any hope of looking for TEKTITES generated from the structure you're documenting and studying? Rationale for these questions: I did my MS thesis in geology on an impact structure near the town of Hico, Texas that MIGHT have been produced by impacting ejecta from the Chicxulub event. Lots more field and geophysical study at the Texas crater needs to be done to pin this down, including a more definite age of origin. As well, Texas may have been littered far more recently with tektites from the Chesapeake Bay Impact crater event. Hico Crater references: [http://link.springer.com/chapter/10.1007%2F978-3-663-01889-6\\_7](http://link.springer.com/chapter/10.1007%2F978-3-663-01889-6_7) and <http://adsabs.harvard.edu/full/1982LPI....13..863W> Thanks.

[craterlady](#)

To date there are no confirmed secondary crater from the Chicxulub event. All the candidates that have been studied as possible ones so far have turned out to be of a different age and thus a different impact. - Sean

Is the iridium layer the true marker bed for the K-T boundary or are there other indications?

[arithmeticulous](#)

The layer was identified using iridium. But there are other markers. The shocked minerals are the most beautiful. There are pieces of shocked quartz, feldspar and zircon in the layer. These are minerals from the Chicxulub impact site that have been shocked to pressures above ~10 GP, and are found all around the world. You only see these features at impact craters and nuclear test sites. There are also nickel-rich spinels that are condensates from the impact plume.

How much of the core is directly related to the impact? What sort of structures and rock types/minerals does the impact produce?

Also, are you keeping a piece of it to use as bookends? Because I totally would.

[sailhetethys](#)

re, bookends: don't tell anyone, but yes.

PS - we're supposed to be signing these. This is Chris. Hello. Don't tell anyone about the core bookends.

How much of the core is directly related to the impact? What sort of structures and rock types/minerals does the impact produce?

Also, are you keeping a piece of it to use as bookends? Because I totally would.

[sailhetethys](#)

Actually all of the core below the limestones that bury come from rocks directly influenced by the impact. These include broken and melted rocks (breccia) as well as uplifted deep rocks that show evidence of experiencing enormous pressures during the event. In effect of the 830 meters of core 600 m at least was directly impact related or affected, plus the sediments above record the history of life coming back at ground zero.

How much of the core is directly related to the impact? What sort of structures and rock types/minerals does the impact produce?

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[sailhetethys](#)

We have 120 m of rock that covered the crater, and over 700 m of rocks from the crater itself. It consists of impact breccias (mixed pieces of sediment and basement and melt rock) and fractured, shocked, basement rocks.

I have a few bookends - but don't tell anyone else.

Jo

So how long will it be until we get to here some definite results and findings?

[finsky](#)

We think we have our first paper coming out shortly - a revised manuscript is being considered by the editor at the moment. And we have made a number of exciting observations that will be written up in

the next few months.

If I were standing at the antipode (directly opposite side of the Earth) of the impact at the time of the event, what would I have felt, heard or even seen?

[TBra](#)

Probably too far to feel the earthquakes, if coastal then certainly the tsunami waves might be observed, but the biggest effect on the other side of the world would have been the atmospheric phenomena including likely a glow from the impact and a darkening of the skies from dust and ejecta and there would have been heating at the ground level from material raining back down...exactly how hot in that exact spot we don't know as it would depend on direction and angle of the impact - Sean

If I were standing at the antipode (directly opposite side of the Earth) of the impact at the time of the event, what would I have felt, heard or even seen?

[TBra](#)

check out: <http://impact.ese.ic.ac.uk/ImpactEffects/> and use a 45 degree impact angle and 14.5 km diameter asteroid. There would have been detectable earthquakes on a seismometer and the sky would gradually get dark, but with bright radiating ejecta particles coming towards you.

Why has it taken this long to drill?

[Nyxtia](#)

Scientific Ocean Drilling has been going on for 40+ years now, and there is a huge amount of questions that have been answered about the nature of the history of the earth and its processes in that time. This crater (which was only discovered in the early 90s, remember) was on a long list of important stuff that we needed to check out.

What has been the most interesting finding or fact that has come out of this drilling to date?

[RickGrimesBeard23](#)

We have learned some amazing things such as how impact cratering works as a physical process - finding basement rocks within the ring of mountains (peak ring) confirmed that; also we have an incredibly thick layer of broken and melted rocks that lie over this peak ring that speak for material falling back into the crater and mixing with melt as well as tsunami

Hi, I was wondering if the asteroid made a crater, where do the remnants go? Does it break apart into uncountable pieces upon impact onto the earth? Also how does analysing rock look further into how life survived after the event?

Sorry if I sound ignorant as I do not study geology and English is my second language

[Fitri\\_\\_](#)

The asteroid was largely vaporized and is the reason for Iridium being found at the end Cretaceous sediment layer all over the world. However one of our goals is to carefully examine all the cores we

collected to see if any trace of the impactor remained in the crater or was transported back to the crater. -Sean

Thanks for taking time to follow up for more questions on this interesting project.

What would you say was the most surprising difference between what was inferred from the seismic survey and what was observed in the cores?

[Wrathchilde](#)

We knew from the seismic survey that there was a buried peak ring and that it had low velocity (also low density) material within it. We however had no idea what it was made of. We now know how incredibly damaged these rocks are how far they traveled and we are just investigating what the crater environment right after the impact. - Sean

I have heard theory of death of all of the dinosaurs taking place in hours after the impact. Is this really possible?

The theory I heard was from Dr. Jay Melosh from Purdue university. The theory stated that the ejected gas and dust from the strike came raining down and heated the earth up to 1000 degrees in a matter of 2 hours.

<http://www.radiolab.org/story/dinopocalypse/>

Thanks!

[Jimboyeah](#)

Yeah, I think there's been some other work done that suggest the ejecta coming back into the atmosphere wouldn't create conditions hot enough for forest fires/instant death once you reach a certain distance from the crater. Also, if you heated the earth up to 1000 degrees, I don't think that much of anything would have survived (especially avian dinosaurs).

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<http://www.radiolab.org/story/dinopocalypse/>

Thanks!

[Jimboyeah](#)

Only the flora/fauna within about 1500 km of Chicxulub received lethal thermal radiation directly from the hot plume (much like from a nuclear explosion). The effects further away, from the re-entering ejecta, are much less devastating, and would depend on where on earth you were. Jo

Thank you for doing this AMA! Apart from its size, can you tell if there is anything unusual about the composition of the impactor? If so, what is it and did the location of the strike have anything to do with

the severity of the fallout?

[ThatChap](#)

It was probably a carbonaceous chondrite - so not unusual. The impact site had ~3-km of sediments - which likely led to large volumes of dust and sulphur being sent around the globe, both of which reduced light levels and led to cooling.

What methods are you using on the core? Mass spec?

What hypotheses do you have for what you will or will not find?

How far would you like to drill into the crater? How far did you get this time? How many more sites would you like to core?

The oil industry has huge experience drilling kilometres into sea bed - are the same platforms tools and techniques applicable?

SO MANY QUESTIONS!

[ChazR](#)

-We are using a ton of methods on the core: visual core description, micropaleontology, major and minor elemental analysis; we took CT scans of the whole core, etc. And that's just standard IODP "shipboard measurements" We're in a building in Germany but whatever; usually this is shipboard stuff we just used a special ship that was too small). Once we all get home with all our samples back to our individual labs, we'll probably run basically every modern analysis we can on these things.

-I would love to drill further into the crater, but with 2 months and ~\$10 million dollars I think we got a great core from this site. It would be great to offset and drill another hole in the annular trough, where it's deeper, to see how it's different from the peak ring rocks

-The scientific ocean drilling community also has a lot of experience drilling kilometers into the seafloor, and actually, while a lot of our techniques are similar to the oil and gas industry, a lot of them are different, too. We take continuous cores in the holes we drill, while usually the oil industry just cuts through the rock without taking a core (because this is quicker and cheaper). We also avoid places where oil and gas might be, and so don't have the same challenges they do.

Is it possible to use the data from this excavation, to model if the impact also triggered the release of Lava in the Deccan Traps?

By that I mean, if the impact was large enough that the energy traveled through the magma and triggered the release of lava from the Deccan Traps if that area was already kinda weak? Also did it have any impact in the nearby Yellowstone Cauldron?

[Ignatius Reilly 67](#)

The Yellowstone Caldera is much younger. As for the Deccan Traps, I'm familiar with the hypothesis that the Chicxulub Impact invigorated Deccan volcanism. It's, uh, an interesting idea. I think the problem is that the timing of Deccan volcanism (i.e., when were the major flows?) fairly poorly constrained relative to the KPg impact, and to show a causal relationship you'd really need to show that the volcanoes starting erupting basically at the same time the asteroid hit. I don't think we can do that right now.

-Chris

What life forms survived?

[medicoanonimo](#)

Mostly stuff that was small and wasn't picky about what it ate. For example, 90% of foraminifera (the microfossil group that I study) went extinct at the end of the Cretaceous. The ones that went extinct were the big (for microfossils; still sand-sized) specialized ones that had particular ecological niches that they filled. The ones that survived were the generalists who were good at eking out a living where the species couldn't.

Anything new and exciting regarding what is contained in the core layers and potential correlations to remote geographies?

[tpchnmy](#)

If you mean can we link findings in the crater with deposits in the global boundary layer, then yes. In fact some of that work has already been done in the past. However we are interested in searching the cores we recovered for evidence of the asteroid within the crater, as well as for understanding the energy released, possible kill mechanisms and whether microbial life occupied with fracture rock of the impact site after the event. - Sean

Hi! Exciting work, thanks for the AMA. Will you be using this core to put additional constraints on the gravitational and seismic models of the crater? Do you expect those models to be significantly improved as a result? What additional insight into the nature of the impact do you hope to find?

[gunishment](#)

The drill core will be used to calibrate the seismic reflection data and ground truth all the other geophysical data. This means we can better model crater structure away from the drill hole, and onshore in particular. Personally, I hope to be able to better constrain the angle and direction of impact. Jo

Is there any relationship between impacts like this and the formation of oil and gas reservoirs?

[PerilousAll](#)

uhhhh, not that I know of? Petroleum systems require a source rock for the oil to come from, so while the structure of a crater might make a great trap, the impact would obliterate any oil/gas that might have filled up that trap.

Other than the initial impact structure, how does an event of this size affect the regional / long term geology? Is the original paleomagnetism erased? Can fractures and faults caused by the impact make the area more earthquake prone in the future?

[joshwoos](#)

Some of the original paleomag is likely to be erased, and some rocks will become magnetized by the passage of the shock wave and/or heating.

They won't be more earthquake prone as such- it will just mean that when tectonic plates move (the cause of earthquakes), the motions may be accommodated along the faults/fractures. Jo

Why are you only looking at 800 meters of core when you drilled over 1200 meters deep?

[redherring2](#)

We only had a \$10 million budget and therefore decided to not core the first 500 m or the last 50 million years of time (we just drilled a hole during that interval), and then started core from 50 million years (500 m down) to the impact event itself and then impact rocks and then into the damaged target rock. We reached the end of our funds at 1334.7 m.

How big was the meteor in a eli5 relative size.

[Phonda](#)

actually - more likely to be closer to 14.5 km wide. 10 km is for a vertical impact - and the most likely impact angle is 45 degrees.

[deleted]

[\[deleted\]](#)

That some people think jalapeno poppers are an acceptable breakfast food.

-Chris

Do your researches find a link between Chicxulub accident and the period of heavy volcano activities?

[lerouke](#)

No. We don't think there is any connection. The volcanic activity started before and ended after the Chicxulub impact. Although seismicity can enhance volcanic activity - the effects would be minor compared to the impact itself.

Will the core samples give us details as to how bad conditions on Earth got directly, and several years after the initial impact?

[FuckyesMcHellyeah](#)

We plan to look at the fossils and the geochemistry of the sediments deposited in the crater following the impact to try to understand how life was effected locally and how the types of rocks that the asteroid hit (and make up some of the debris that fills the crater) might have contributed to the extinction when they got pulverized and flung into the atmosphere.

Can you give us any idea of what has/will be learned from studying the crater? Can we be certain now that this is what killed off the dinosaurs and other species of the time?

[jagonguy](#)

We're already certain that this is what killed the dinosaurs. We've been sure for a while, actually, because the timing of the impact and the extinction level are so close. The Deccan Traps erupted for millions of year before and after the mass extinction, but everything went extinct the exact same time, in the same layer we find all the impact debris.

What will we learn from the crater? We'll learn a lot about how craters form, and also how the formation of the crater might have effected the way that everything died.

-Chris

Did you encounter any unexpected drilling issues? If so how did you overcome them?

Was core recovery generally good or did you have intervals with poor recovery?

[theladygeologist](#)

There were lots of issues - dropping the casing in the hole, having a drill bit destroyed and then having to drill through pieces of it, and losing drilling mud into large cavities. And logging tools not working. Recovery was close to 100 %.

Jo

Did you encounter any unexpected drilling issues? If so how did you overcome them?

Was core recovery generally good or did you have intervals with poor recovery?

[theladygeologist](#)

Define "unexpected"? You never expect any particular issue, but there is a range of things that can go wrong that the drillers were well prepared to deal with. Complications are part of any drilling project. I'm actually not aware of any coring operation where everything went right and there were no problems.

Core recovery was great. 100% (or more!) in nearly every core.

Does evidence from different periods show up more or less chronologically in a linear way along the core samples length, if not, how did the old planet mix things up, or has that even been looked at?

[skinisblackmetallic](#)

Yes. [https://en.wikipedia.org/wiki/Law\\_of\\_superposition](https://en.wikipedia.org/wiki/Law_of_superposition)

If you're asking if there was any slumping or post-depositional deformation, no, not really. not on a large scale.

Did you hit the central uplift? If so, did your core record any faults and is there any physical evidence of the velocity in which the peak may have been uplifted (I.e. glass)? With an impactor of this size I'm sure impact melt was created, but have any high-P mineral polymorphs been found in the suite? Congrats on your success!

[Cistum](#)

We drilled into structurally uplifted material. Lots of faults and fractures. Lots of shock metamorphism. And impact melt rock. Thanks for the congrats. Jo

Did you hit the central uplift? If so, did your core record any faults and is there any physical evidence of the velocity in which the peak may have been uplifted (I.e. glass)? With an impactor of this size I'm sure impact melt was created, but have any high-P mineral polymorphs been found in the suite? Congrats on your success!

[Cistum](#)

Actually instead of targeting the central uplift which in a multi-ring impact basin like Chicxulub is actually buried beneath a melt sheet in the center of the crater, we instead targeted the peak ring that surrounds the center and is now buried within the younger sediments. We did core into the peak ring for hundreds of meters which is cool as these are the first samples from a peak ring. We are very interested in looking for all the ranges of evidence that help us understand impact processes. For instance studying the cores for evidence of shock since impacts can produce 10s of Gigapascals of pressure. The melt itself in fact likely felt pressures close to 60 GPa. Additionally we are very interested in understand how a peak ring is emplaced and so are measuring diligently every fault we find! - Sean

Is it chick-su-lub? or do you all just refer to it as the hole or the pit or something?

[kharneyFF](#)

Hole M0077A.

How is it known that this crater is directly linked to the mass extinction event, and when was this found out? I always thought this was just a theory, and am very interested

[jackflaners](#)

I always enjoy such a phrased question :-). In the world of science, a theory is as good as it gets. Something only reaches the level of theory when there is evidence from numerous sources that a repeatable and testable so that the original hypothesis can then be elevated to a theory. For instance the Theory of Evolution. Or the Asteroid Impact Theory for the end of the Cretaceous. Having said that, yes the evidence that the Chicxulub impact was exactly timed to the end of the Cretaceous mass extinction event is robust and global. Every preserved layer of rock from that exact time have the evidence of the asteroid within the boundary and studies of total productivity of life on Earth show a precipitous crash right at this event 66 million years ago. So the new aspect to study is why was it a mass extinction event...what were the kill mechanisms and how to impacts work as a process anyways? These are aspects we are now studying :-). -Sean

Is there ANY remaining portion of the meteor embedded in the earth's crust? Was it truly 100% vaporized? I know it isn't recoverable, but is it detectable?

Was all of the meteor material truly distributed across the planet? (I am thinking mainly of the iridium)

What portion of the meteor was ejected beyond earth's orbit?

[BookEight](#)

The asteroid did vaporize when it hit and is spread all over the Earth to be found in any well preserved 66

Million year old rocks; this includes the Iridium and also material that condensed within the vapor plume such as spherules. However we are actually searching our cores to see if there is any trace of the meteor in the broken or melted rocks or sediments that deposited immediately after the event. -Sean

What questions do you hope to answer with these cores?

[ddollarsign](#)

1. How are impacts formed and what makes a peak ring? How are rocks weakened such that during an impact they can flow?
2. What insights into the mass extinction event can we learn from the recovery of life in the crater?
3. How did the impact influence the subsurface biosphere? Can impacts be a haven for chemosynthetic life?

-Sean

How fast was the object that caused the crater traveling before impact?

[DancingFurniture](#)

The most likely speed was 18 kilometers per second... -Sean

Is there anything left of the impactor?

[darthgarlic](#)

Absolutely! It is spread around the world with the global eject layer in any preserved rocks from 66 million years ago. However we don't know yet whether any of it is preserved within the crater but will analyze the cores carefully to see if we can find a trace or it. - Sean

Could the Chicxulub impact have ejected organic matter into **outer\*** space? (Near the impact location, or the anti-podal location on the planet?)

\*I think low Earth orbit is a given on this, but I'm trying to figure out if any organic matter from Earth would have potentially landed on other celestial bodies in our solar neighborhood.

[Notabou](#)

Organic matter? uh, I dunno, probably? It definitely flung debris into space. I feel like any organic matter that was close enough to the impact to be flung into space would have also been incinerated on its way. Most of the stuff that left the earth was molten when it did. We find these things called spherules (glass balls that were ejected from the crater molten and cooled in the air into glass) all over the place. A lot of times they have bubbles in them, and when you drill into the bubble, there's no air in it. It's a vacuum! So this thing was flung into space, where it cooled, and then it brought a little bit of space back down with it to the earth, and then 66 million years later some guys with a drill ship (not us) dug it up and found some 66 million year old space.

A cool thing I learned the other day from my impact geology colleagues is that it's almost certain that there are spherules on the moon (the moon! How cool is that?).

-Chris

You say that the crater is directly linked to the extinction of the dinosaurs, but I have heard that their extinction cause is uncertain. Could you elaborate on this?

[boatymcboatface](#)

Nope. We're certain.

So, the other possible culprit is the Deccan Traps in India. But, Deccan volcanism occurred over the course of several million years (and the "main phase" started several hundred thousands years before the boundary and lasted several hundred thousand years after). If this were the reason for the mass extinction, you would expect to see a species go extinct in conjunction with this volcanism. AND, you expect to see certain groups go extinct. Life on the seafloor, for example, is usually strongly impacted (pun not intended) by large increases in CO<sub>2</sub>, as this drives ocean acidification. For example, 10 million years after the KPg Boundary, a massive release of carbon during what's known as the Paleocene-Eocene Thermal Maximum caused rapid global warming and a major extinction of life in the deep ocean.

At the KPg Boundary, we see everything go extinct at the exact same level, suggesting the cause of the extinction was much more rapid than volcanism. And, things that we would expect to be harmed by slow volcanism, like seafloor life, don't suffer a mass extinction. It's all organisms on land and in the shallow ocean.

This is a great review on the topic, if you have access to Science:

<http://science.sciencemag.org/content/327/5970/1214>

-Chris

How many attempts did it take for each of you to spell the crater name properly?

[mipe81](#)

Chicxulub

What has been your most important discovery about the crater?

[Malicaizer](#)

So far we have already submitted a paper to a high profile journal that will hopefully appear before the end of the year on how large impact craters take their shape and form features like a peak ring. Stay tuned! - Sean

What kind of statistical analysis do you use in your work? I'm a data analytics grad student very interested in prehistory, archeology and global cataclysm, especially impact events, and am currently reading VanPool's Quantitative Analysis in Archeology. It's fascinating but I'd love to know more about the analytical techniques you are using to understand natural events like the Chicxulub impact. Any book recommendations?

[hypersonic\\_platypus](#)

Impacts as a Geologic Process by Jay Melosh - Sean

I have to ask the obvious question: why so much drilling through granite? You said you were studying the recovery of life on earth after the impact, but wouldn't that be recorded in the overlying limestones and other sedimentary rocks, not granite.

[redherring2](#)

Impacts can produce habitats. The granite is highly fractured by the impact, and would have been warm for a long time, causing hydrothermal circulation for a few hundred thousand years. This hydrothermal activity may have provided nutrients for life. We see this at other craters - Haughton and Chesapeake. Jo

Hello. Is there any chance of negative/sideways results from the cores, such as discovering that it is not the crater in question, not a crater at all, or that is the crater but not the cause of the mass extinction after all? Thanks.

[kraygus](#)

So far all the evidence from the cores have if anything made it even more exciting in terms of understanding this large impact crater (evidence of the shock pressures it experienced for instance) and of understanding the mass extinction event (difference in recovery at the impact site of one type of marine organisms from another for instance). So lots of surprised but nothing sideways! - Sean

What sort of zones and boundaries (structural, textural, chemical, mineralogical, isotopic, etc.) have you found in the rock? Did you find rock that's unaltered by the impact?

[cv512hg](#)

To only rocks we cored that were not directly altered by the impact were the ones that buried the crater, the rest of the ~600 meter of core were fundamentally altered. We found amazing zones and boundaries throughout these rocks caused by the impact processes and the hydrothermal processes that followed. Even the rocks above the impact rocks were affected in that the fossils within them were fundamentally different due to the mass extinction event. \_ Sean

What percentage chance are you afraid that you'll unleash an alien shapeshifting creature like in The Thing? Even 1% chance it could happen? 0.01% chance?

[Bigliest](#)

A cold did pass through the science party...space flu?