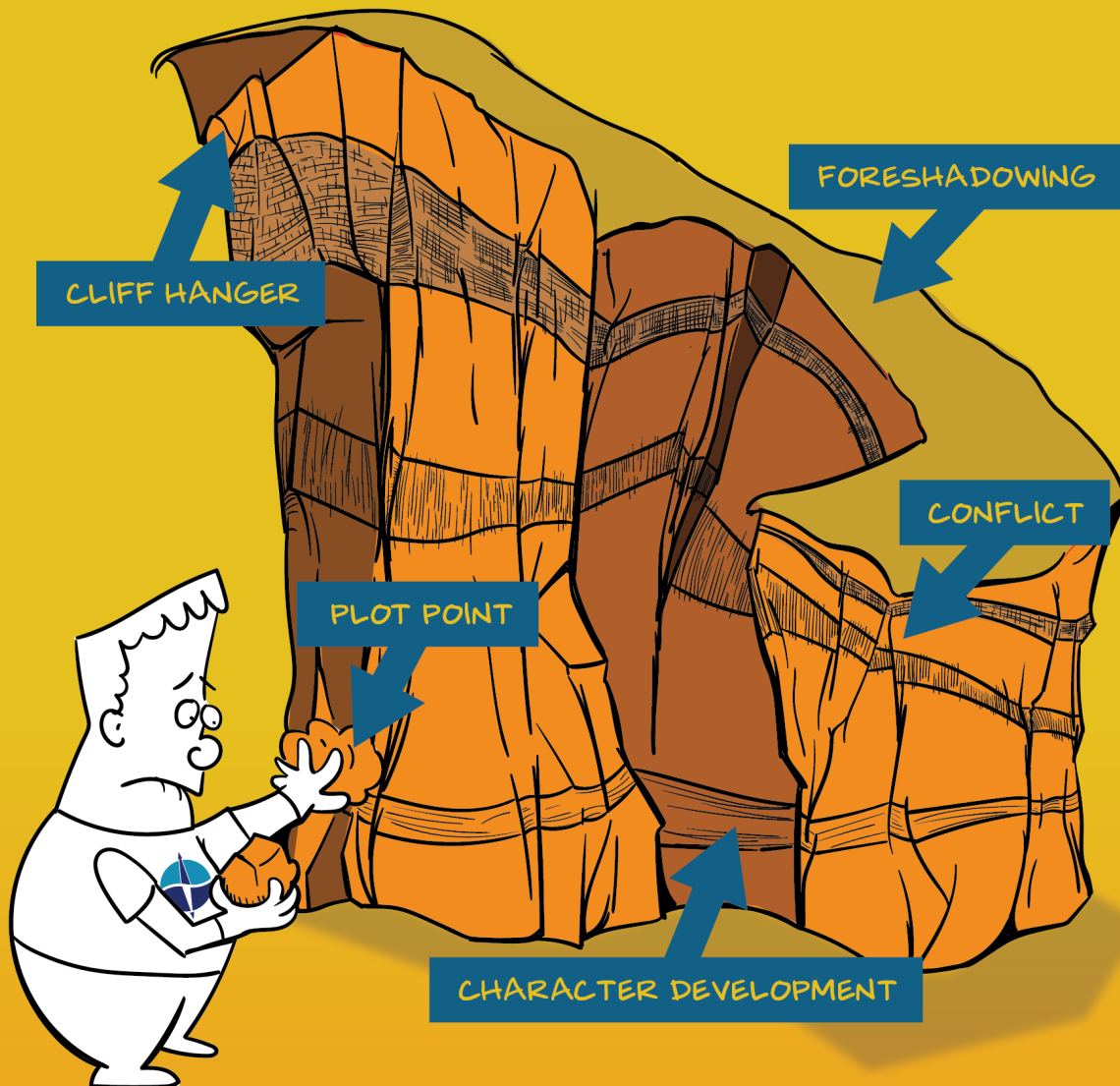


How To READ A ROCK

A Graphic Novel on Ocean Science



VOL. 1

JUL '22

Written by Kevin Kurtz

Illustrated by Nicole Kurtz (No relation, seriously)

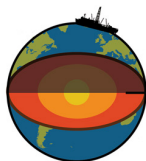
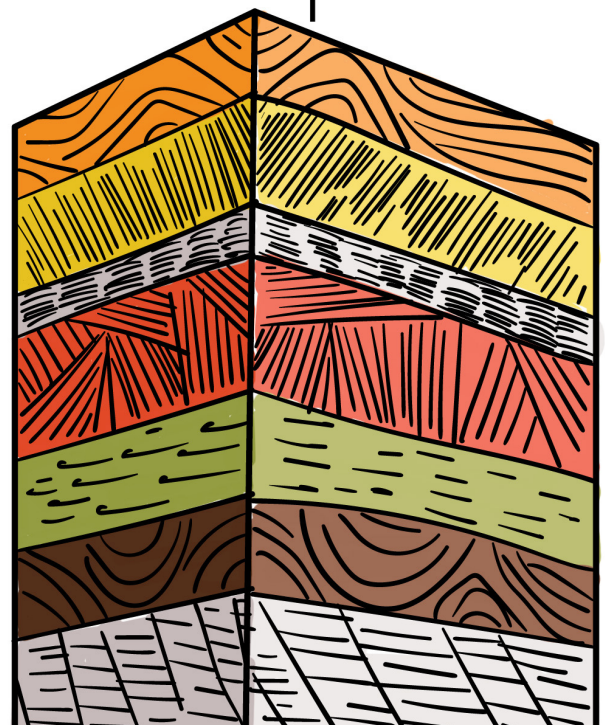
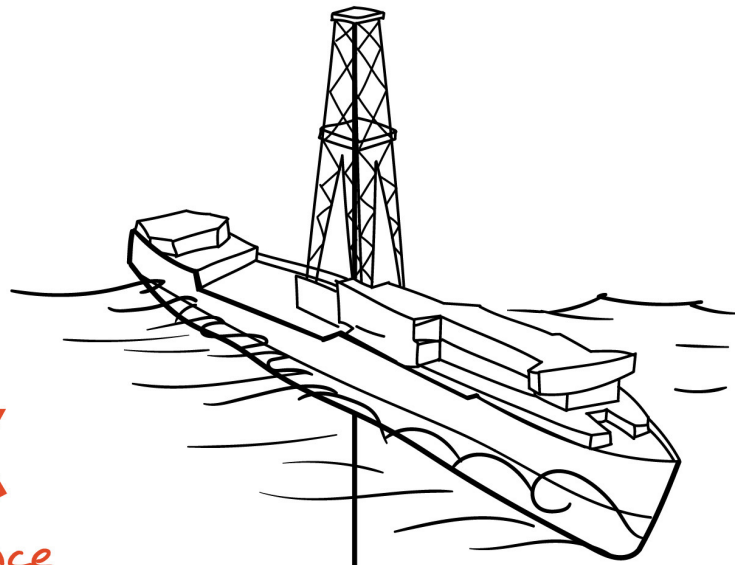
Fact-checked by Dr. Patrick Fulton



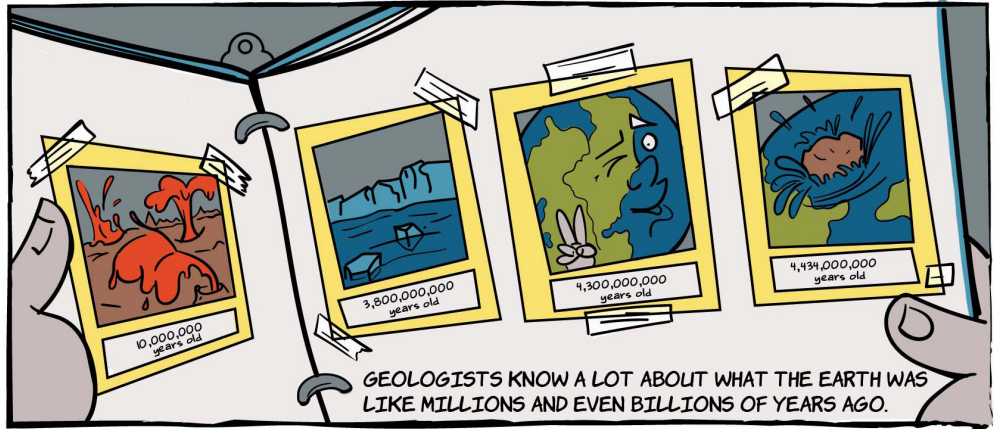
How To READ A ROCK

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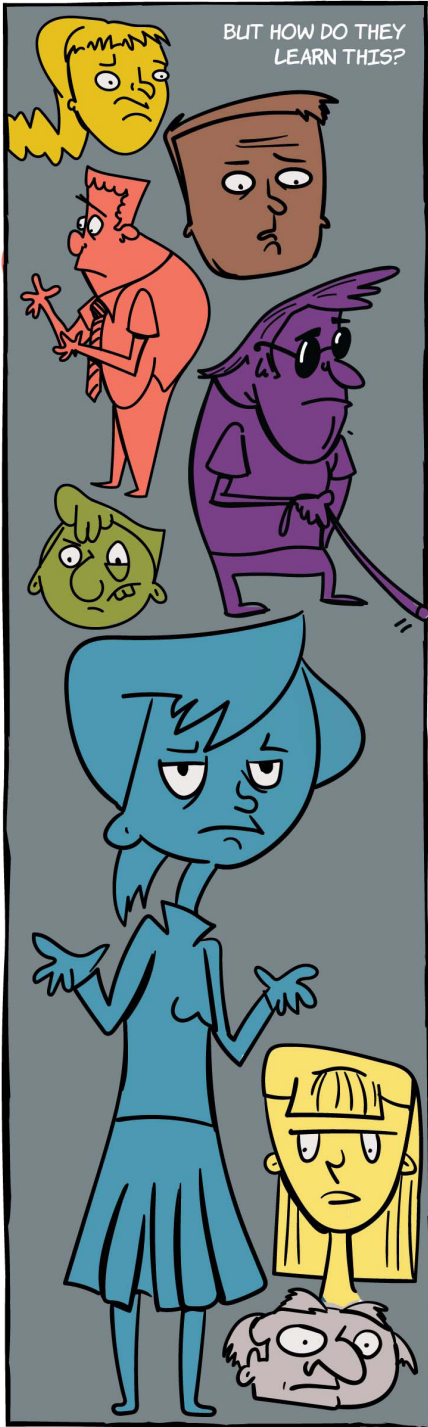
Kevin Kurtz
Nicole Kurtz
Patrick Fulton
2022



**IN SEARCH OF
EARTH'S SECRETS**



GEOLOGISTS KNOW A LOT ABOUT WHAT THE EARTH WAS LIKE MILLIONS AND EVEN BILLIONS OF YEARS AGO.



BUT HOW DO THEY LEARN THIS?

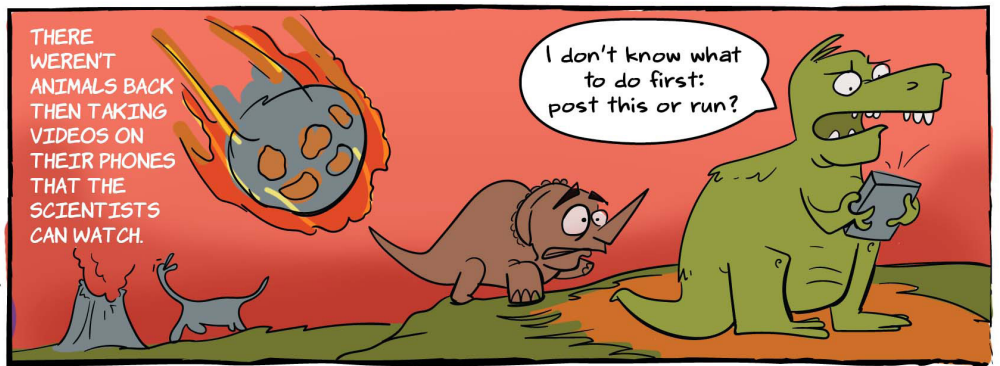


Ugh! The Prehistoritron broke down.

How am I going to get to the Paleocene?

Try Uber.

THEY DON'T HAVE TIME MACHINES.



THERE WEREN'T ANIMALS BACK THEN TAKING VIDEOS ON THEIR PHONES THAT THE SCIENTISTS CAN WATCH.

I don't know what to do first: post this or run?



AND THERE DEFINITELY AREN'T ANY GEOLOGISTS WHO ARE THAT OLD.

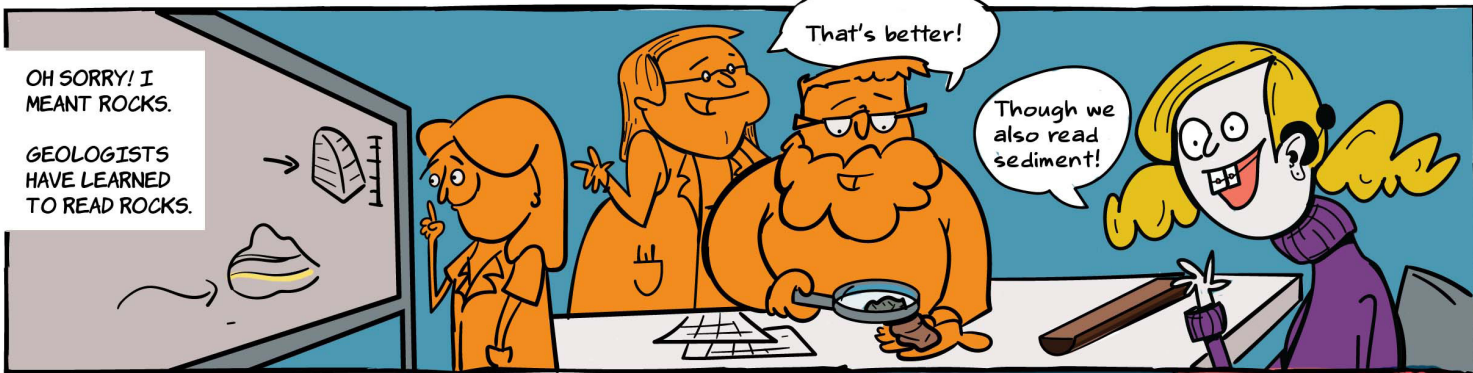
Did I ever tell you kids about the time I met a trilobite?

Yes, Great (1.84 x 10⁶) - Grandpa.



INSTEAD, GEOLOGISTS HAVE DISCOVERED A LOT ABOUT EARTH'S ANCIENT PAST BECAUSE THEY HAVE LEARNED HOW TO READ SOCKS.

Socks?!?!



OH SORRY! I MEANT ROCKS.
GEOLOGISTS HAVE LEARNED TO READ ROCKS.

That's better!

Though we also read sediment!

READING ROCKS AND SEDIMENT MAY SOUND AS GOOFY AS READING SOCKS...



Children of Mud and Stone

Barry Potter and the Geologist's Stone



...BUT THIS SKILL HAS REVEALED EARTH'S AMAZING PAST TO US.



To Kill a Rockingbird

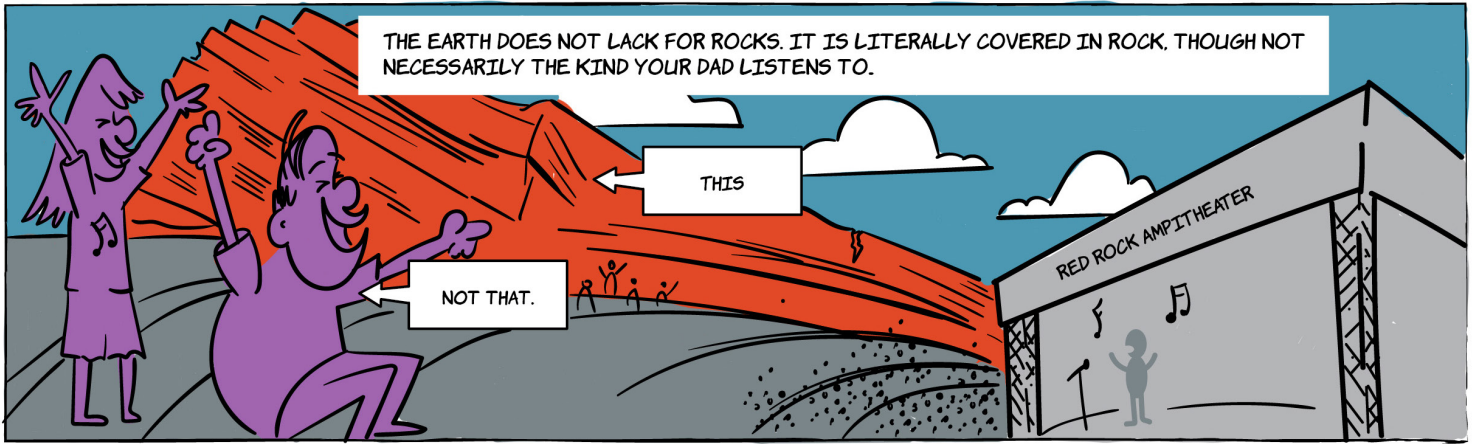
The Earthquake Faults Within Our Stars



IT'S NOT THAT THERE'S ACTUAL WRITING ON THE ROCKS.



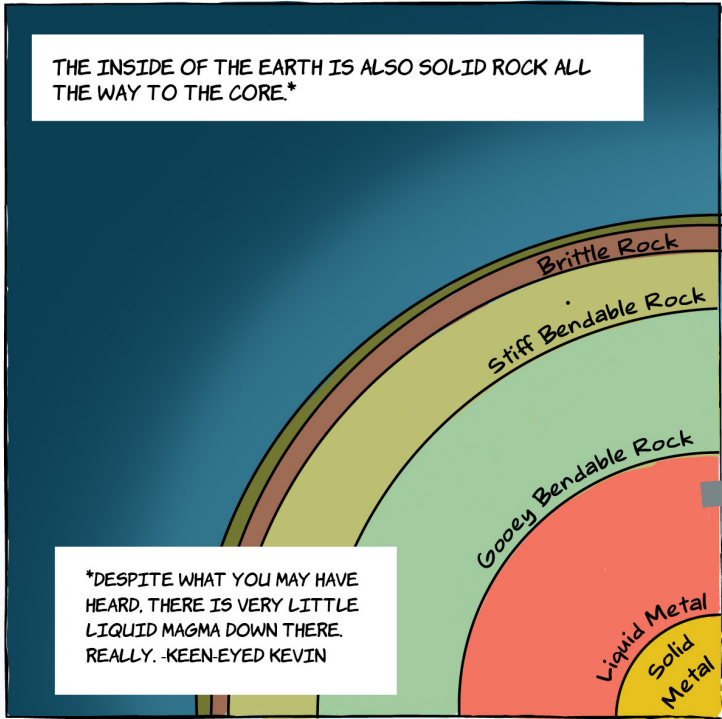
BUT THERE IS A LOT OF INFORMATION IN THE LAYERS, THE MINERALS, AND ANY FOSSILS THAT ARE IN THE ROCKS AND SEDIMENT, THAT SCIENTISTS CAN LEARN FROM.



THE EARTH DOES NOT LACK FOR ROCKS. IT IS LITERALLY COVERED IN ROCK, THOUGH NOT NECESSARILY THE KIND YOUR DAD LISTENS TO.

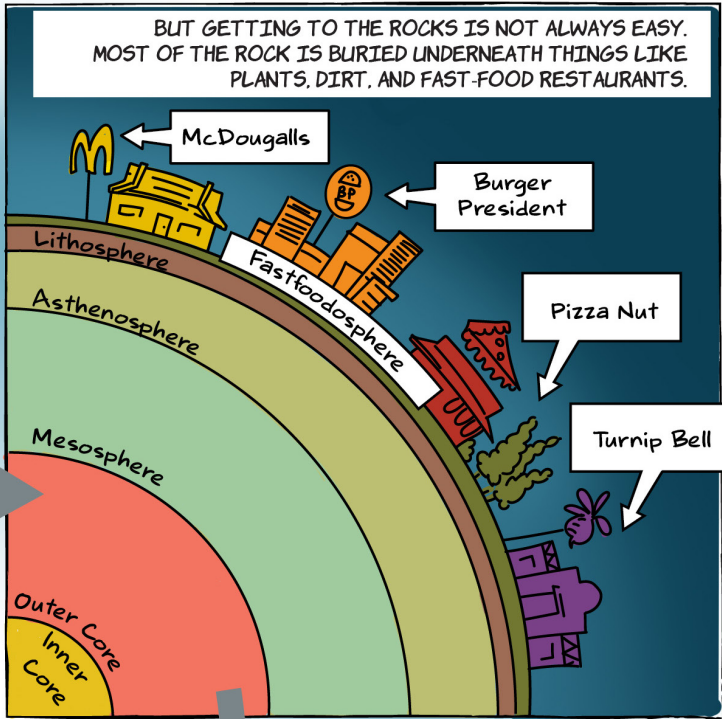
THIS

NOT THAT.

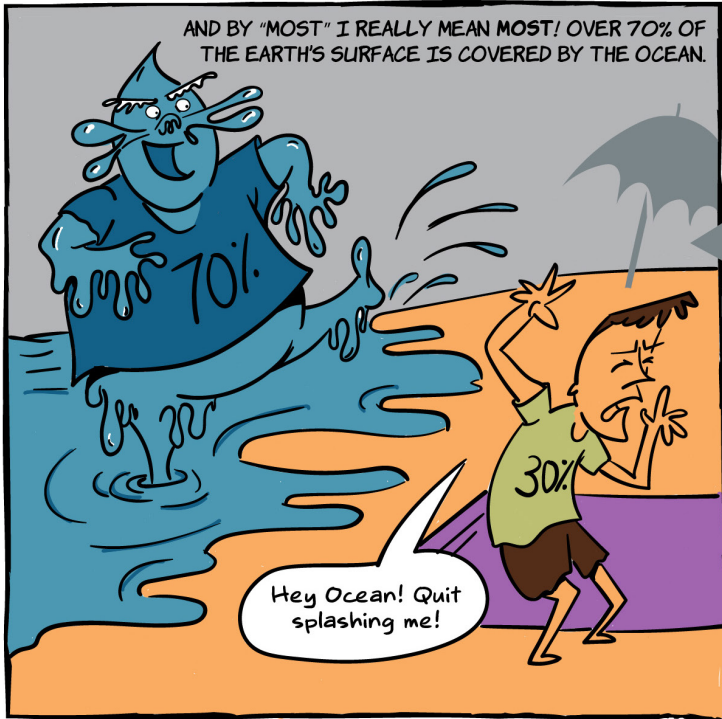


THE INSIDE OF THE EARTH IS ALSO SOLID ROCK ALL THE WAY TO THE CORE.*

*DESPITE WHAT YOU MAY HAVE HEARD, THERE IS VERY LITTLE LIQUID MAGMA DOWN THERE. REALLY. -KEEN-EYED KEVIN

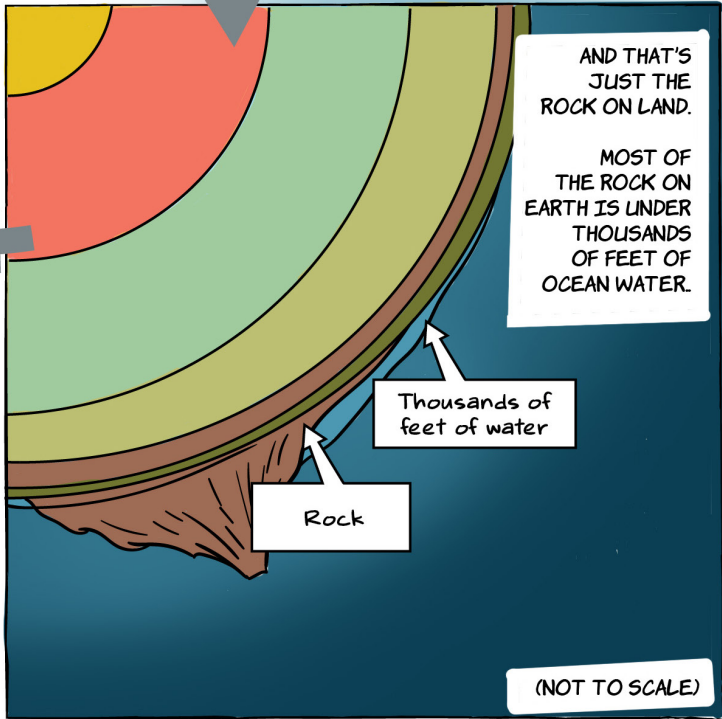


BUT GETTING TO THE ROCKS IS NOT ALWAYS EASY. MOST OF THE ROCK IS BURIED UNDERNEATH THINGS LIKE PLANTS, DIRT, AND FAST-FOOD RESTAURANTS.



AND BY "MOST" I REALLY MEAN MOST! OVER 70% OF THE EARTH'S SURFACE IS COVERED BY THE OCEAN.

Hey Ocean! Quit splashing me!



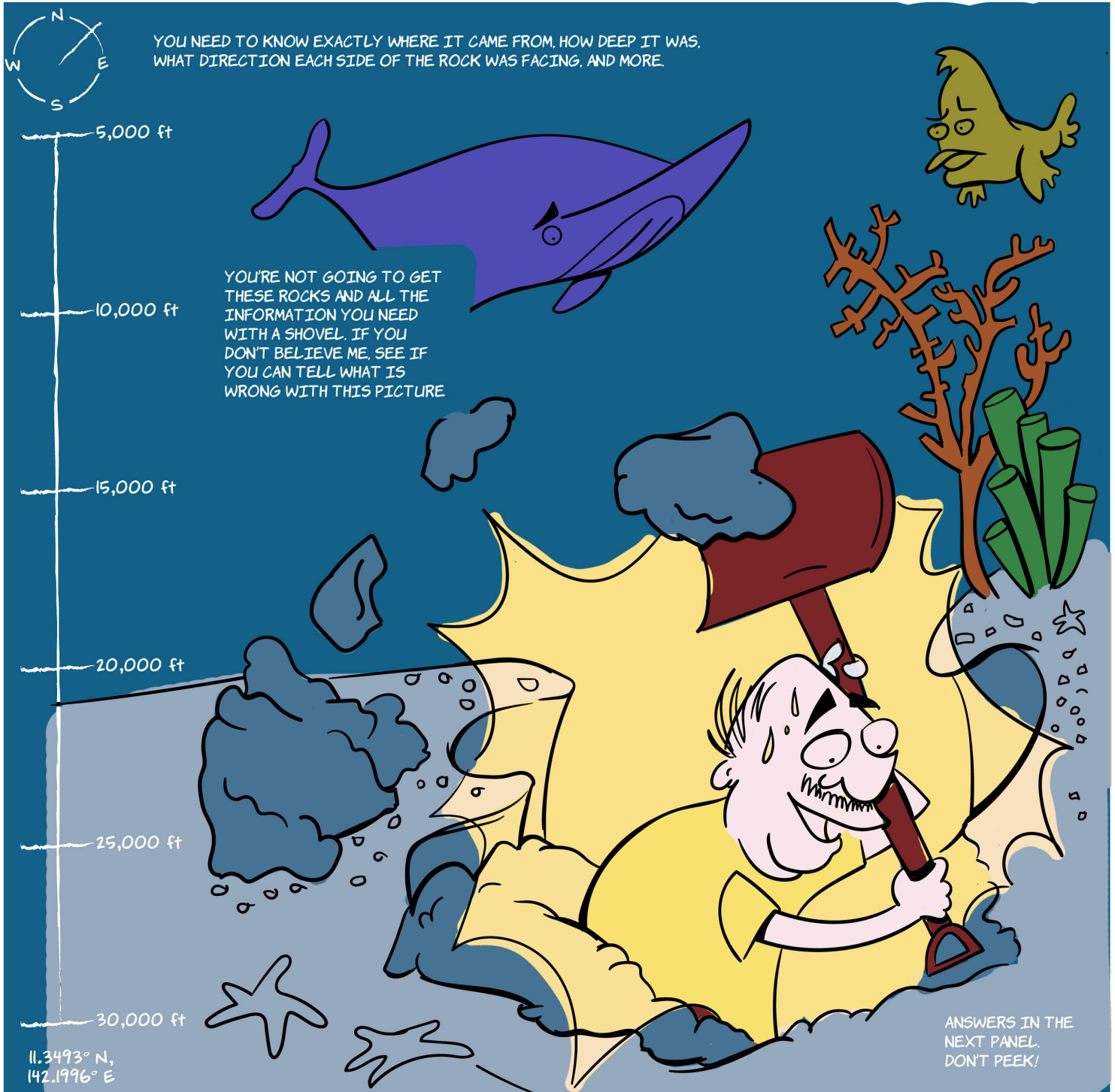
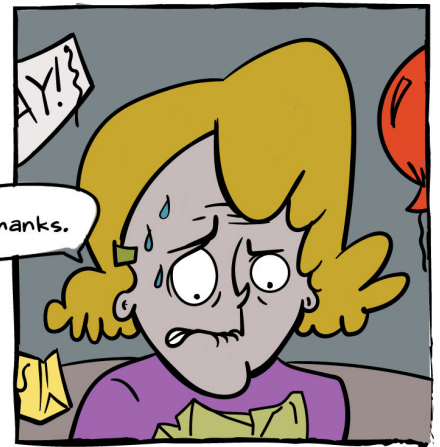
AND THAT'S JUST THE ROCK ON LAND.

MOST OF THE ROCK ON EARTH IS UNDER THOUSANDS OF FEET OF OCEAN WATER.

Thousands of feet of water

Rock

(NOT TO SCALE)



IT'S PITCH BLACK
DOWN THERE!

AT THIS DEPTH, THE WATER
PRESSURE WOULD CRUSH A PERSON.

PEOPLE CAN'T
BREATHE
UNDER WATER.

PEOPLE ARE
FLOATERS.

THE SEDIMENT ABOVE THE
SEAFLOOR ROCK CAN BE
HUNDREDS AND EVEN
THOUSANDS OF FEET THICK.

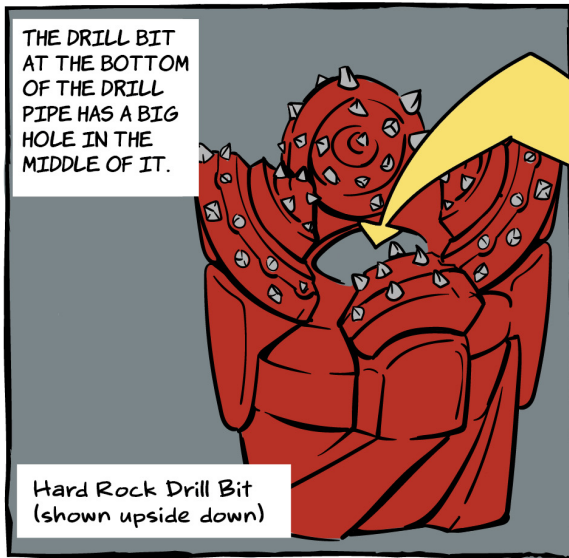
HAVE YOU EVER TRIED TO CUT A ROCK WITH
A SHOVEL? WELL, DONT! IT'S A BAD IDEA.

BUT THERE IS A
WAY TO
COLLECT THE
ROCKS BENEATH
THE SEAFLOOR,
WHILE ALSO
PROVIDING ALL
THE OTHER
INFORMATION
YOU NEED.

From 12,000
feet below the
ocean surface.

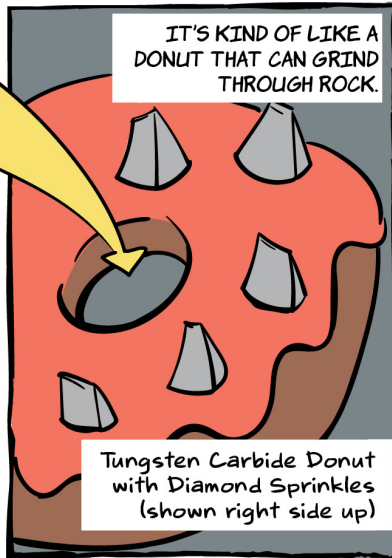
SCIENTISTS AND
ENGINEERS HAVE
DEVELOPED DRILLS
THAT CAN CUT DOWN
THROUGH SEDIMENT AND
ROCK TO REACH DEPTHS
THOUSANDS OF FEET
BELOW THE SURFACE,
AND SHIPS THAT CAN
OPERATE THEM.

The JOIDES Resolution,
a scientific research
ocean drilling ship.



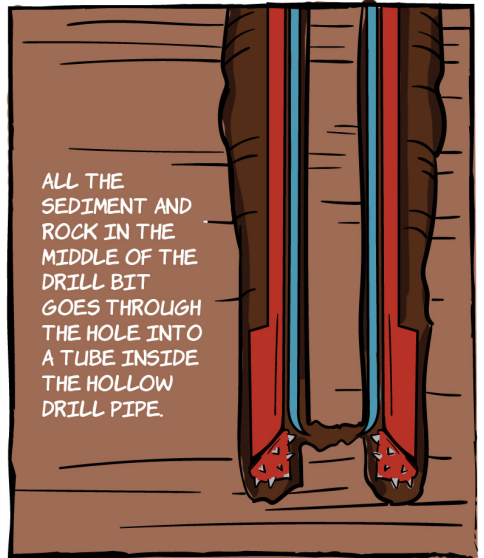
THE DRILL BIT AT THE BOTTOM OF THE DRILL PIPE HAS A BIG HOLE IN THE MIDDLE OF IT.

Hard Rock Drill Bit (shown upside down)

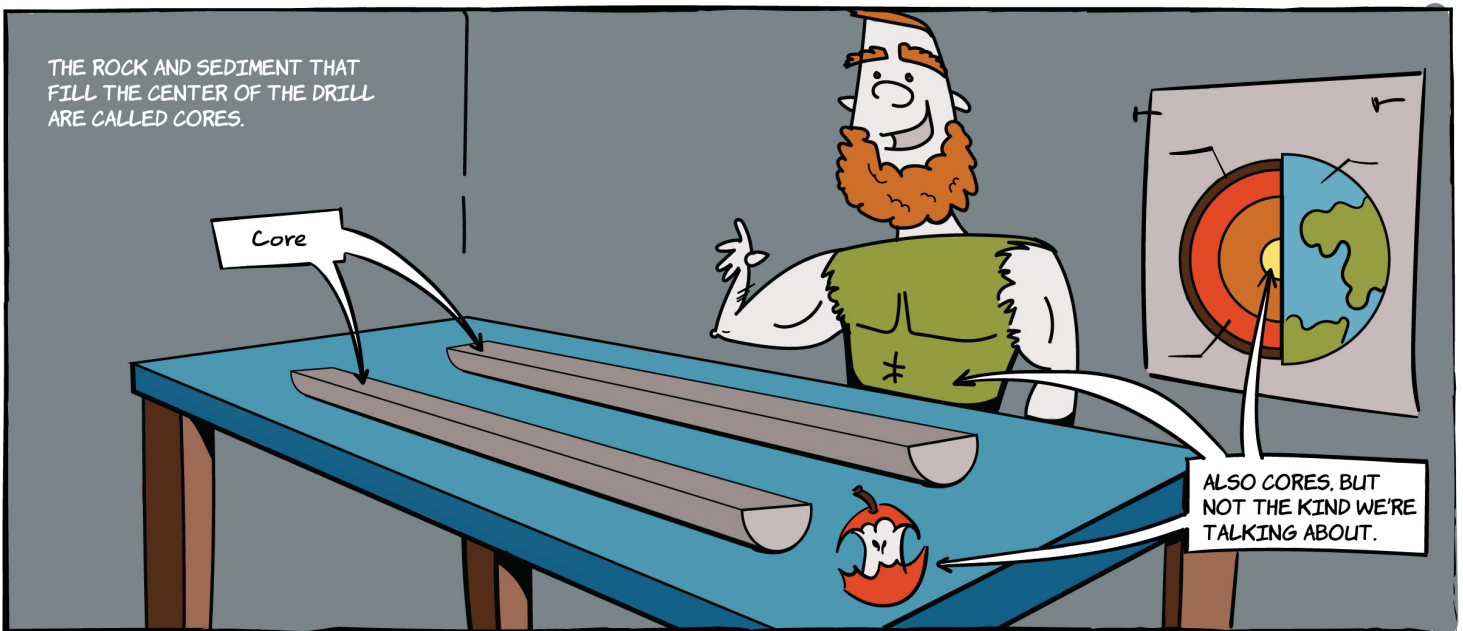


IT'S KIND OF LIKE A DONUT THAT CAN GRIND THROUGH ROCK.

Tungsten Carbide Donut with Diamond Sprinkles (shown right side up)



ALL THE SEDIMENT AND ROCK IN THE MIDDLE OF THE DRILL BIT GOES THROUGH THE HOLE INTO A TUBE INSIDE THE HOLLOW DRILL PIPE.



THE ROCK AND SEDIMENT THAT FILL THE CENTER OF THE DRILL ARE CALLED CORES.

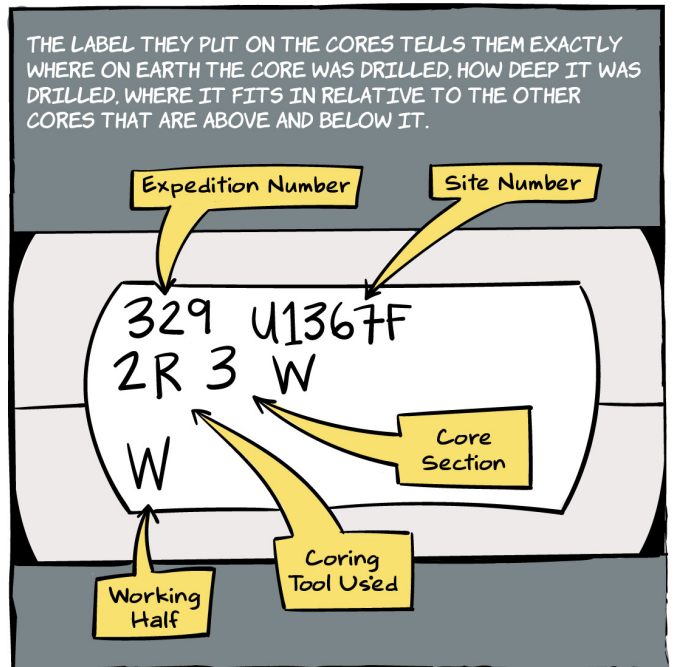
Core

ALSO CORES. BUT NOT THE KIND WE'RE TALKING ABOUT.



AS SOON AS A CORE IS BROUGHT TO THE SURFACE, SCIENTISTS PUT A LABEL ON IT.

NOT LIKE THAT!



THE LABEL THEY PUT ON THE CORES TELLS THEM EXACTLY WHERE ON EARTH THE CORE WAS DRILLED, HOW DEEP IT WAS DRILLED, WHERE IT FITS IN RELATIVE TO THE OTHER CORES THAT ARE ABOVE AND BELOW IT.

Expedition Number

Site Number

Core Section

Coring Tool Used

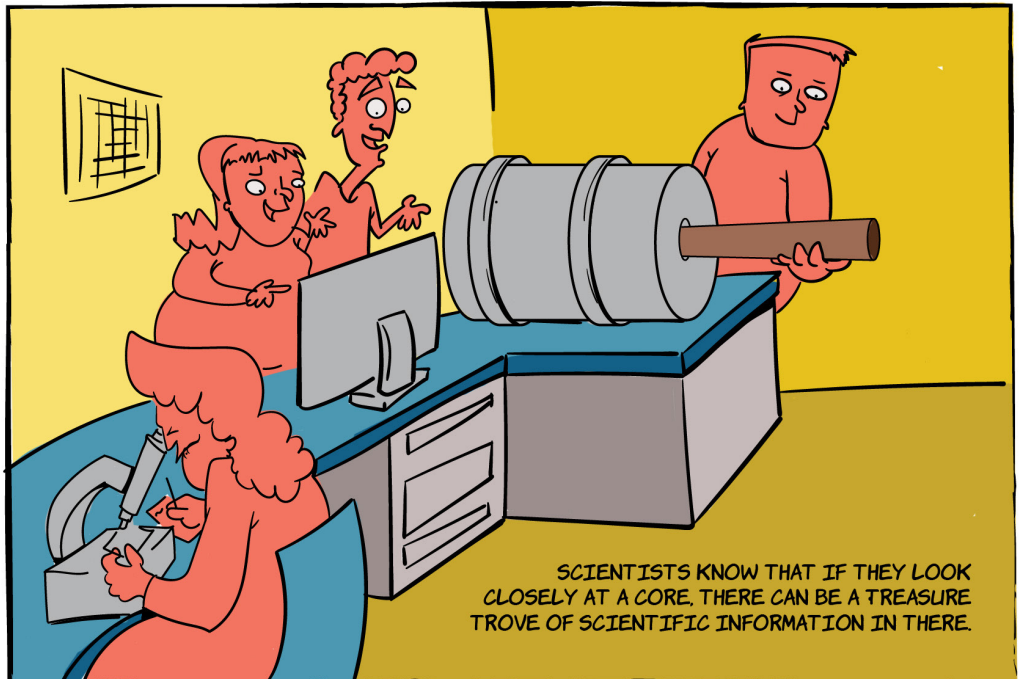
Working Half

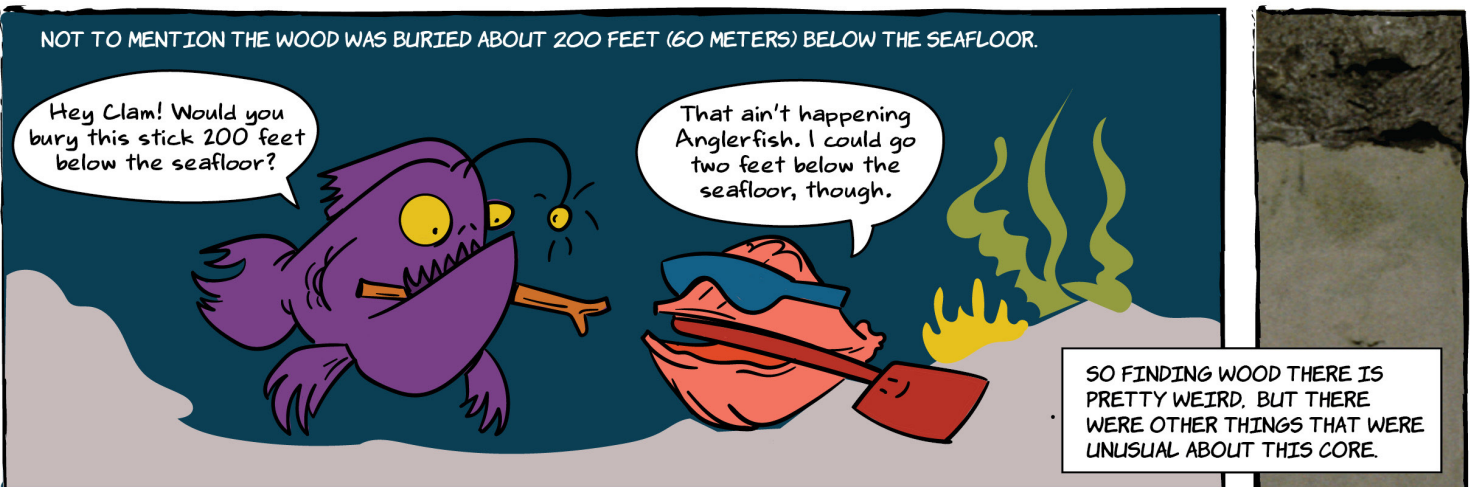
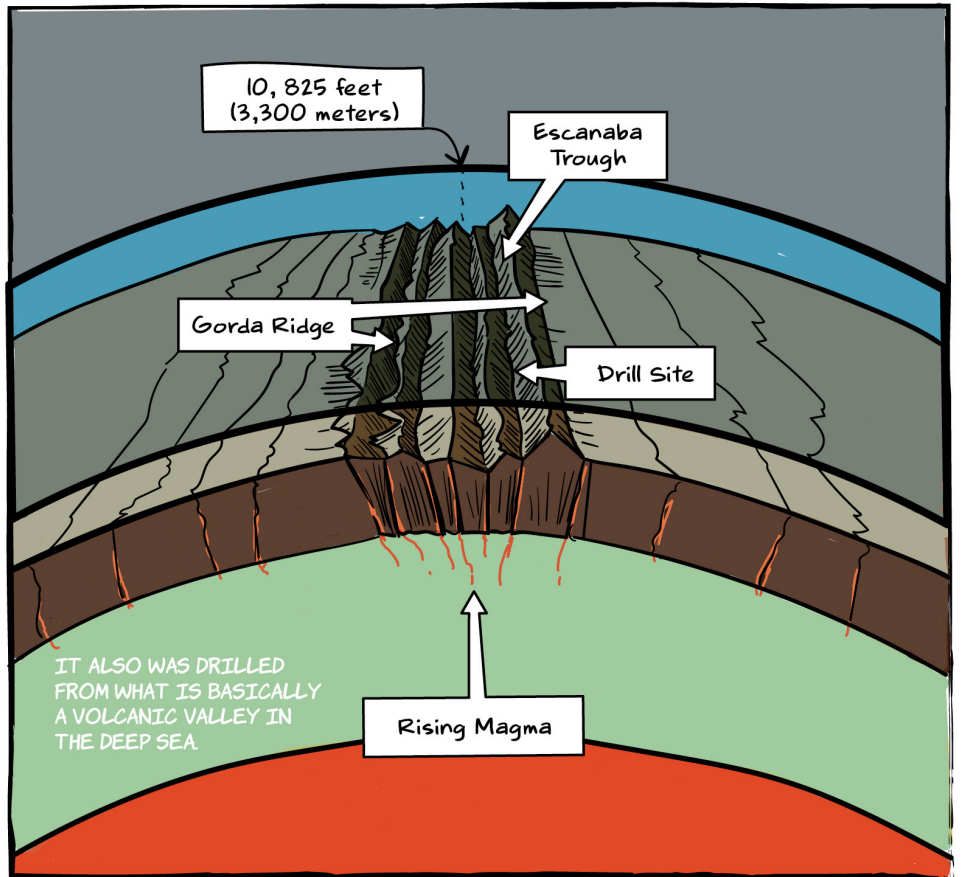
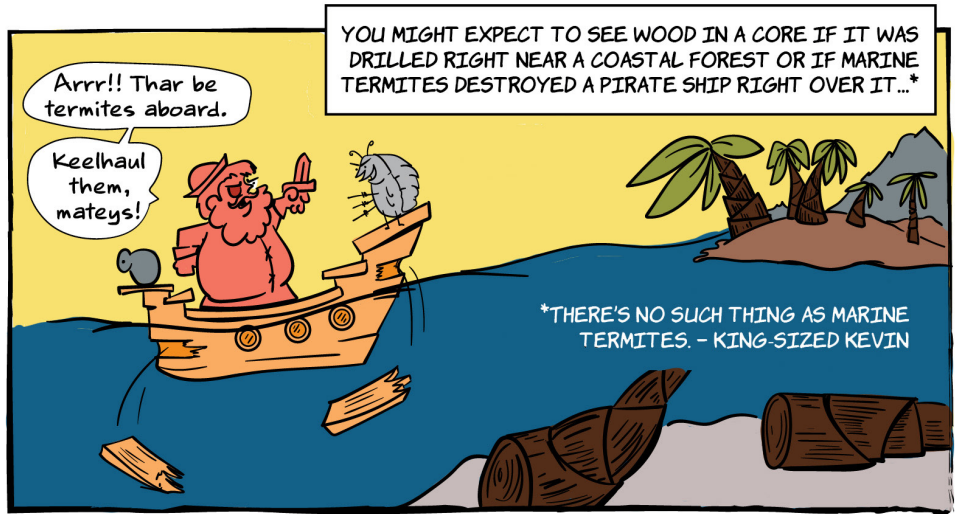
THIS ATTENTION TO DETAIL IS NECESSARY FOR SCIENTISTS TO LEARN THE AMAZING THINGS THEY DISCOVER

FOR INSTANCE, TAKE A LOOK AT THIS CORE OF SEDIMENT THAT WAS DRILLED BY THE JOIDES RESOLUTION.

3 INCHES (76 CM) WIDE

59 INCHES (150 CM) LONG





THE CORE WAS PART OF A MUCH LARGER LAYER OF SAND UNDER THE SEAFLOOR.

Here's where the core used to be

IN THIS LAYER, THE TINIEST SAND GRAINS...

Hold on! This is, Gertie, the narrator's cat.

Yes, you heard right. I'm a cat.

I've heard a lot about ocean cores over the years, and I think there is some stuff you should know about the layers in the seafloor before we start talking about sand grains.

RANGES FROM 6 TO 60 MILES (10 TO 100 KILOMETERS) THICK

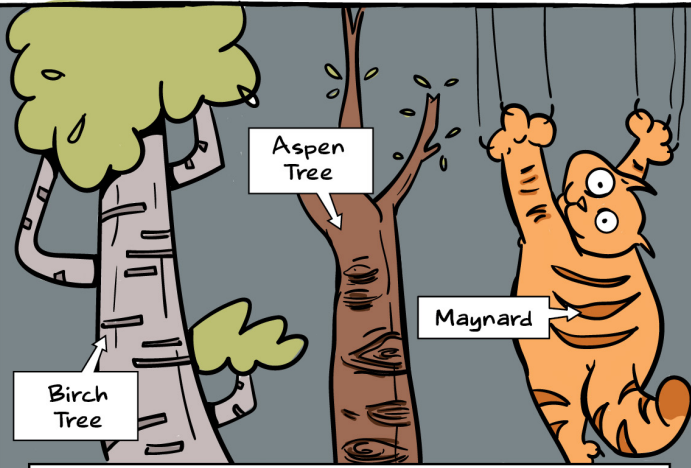
The sediments and rock under the seafloor aren't one solid piece of sameness.

Anywhere you drill, there are going to be layers. Each layer has things that make it different from the layers above and beneath it.

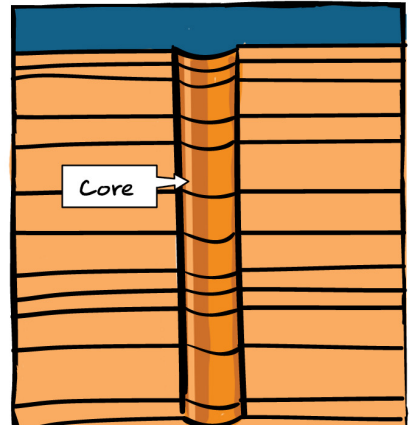
YOU PARTICULARLY SEE THIS IN SEDIMENT.

FOR EXAMPLE, LOOK AT THIS CORE DRILLED BY THE JOIDES RESOLUTION DURING EXPEDITION 363 IN THE PACIFIC, NORTH OF PAPUA NEW GUINEA.

Core



NOTICE THIS CORE LOOKS KIND OF LIKE A BIRCH TREE OR AN ASPEN TREE. OR MY BROTHER MAYNARD'S BACK.



THOSE STRIPES ARE LAYERS. THE LAYERS DON'T JUST EXIST IN THE CORE. THEY EXTEND INTO THE SEAFLOOR AROUND IT.

THESE LAYERS ARE FORMED BY THE STUFF THAT IS CONSTANTLY DRIFTING DOWN THROUGH THE OCEAN TO PILE UP ON THE SEAFLOOR.

THIS STUFF CAN BE MADE OF A VARIETY OF THINGS. WHAT YOU SEE DEPENDS ON WHERE AND WHEN YOU ARE IN THE OCEAN.

Gimme that shell!

I saw it first!

IN THE MIDDLE OF THE OCEAN, MOST OF THE SEDIMENT COMES FROM THE SHELLS OF LIVING THINGS, THOUGH NOT THE KIND OF SHELLS THAT MAKE TOURISTS BREAK OUT IN FISTFIGHTS.

THE TINY SHELLS IN OCEAN SEDIMENT LAYERS COME FROM TINY SINGLE-CELLED PLANKTON DRIFTING THROUGHOUT THE WATER COLUMN.

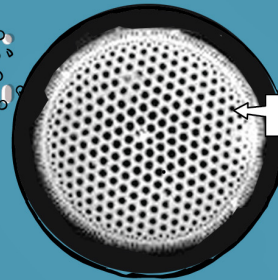
THIS SAND GRAIN IS DRAWN TO SCALE TO SHOW YOU THAT THESE SHELLS REALLY ARE TINY.



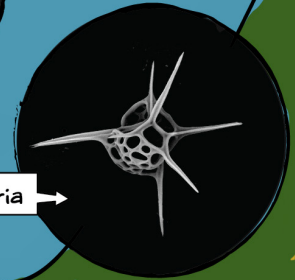
Foraminifera



Coccolithophores

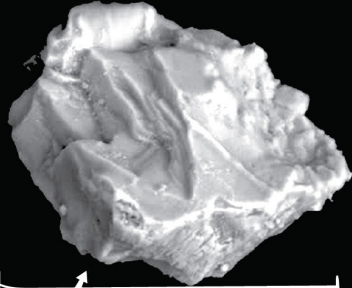


Diatoms



Radiolaria

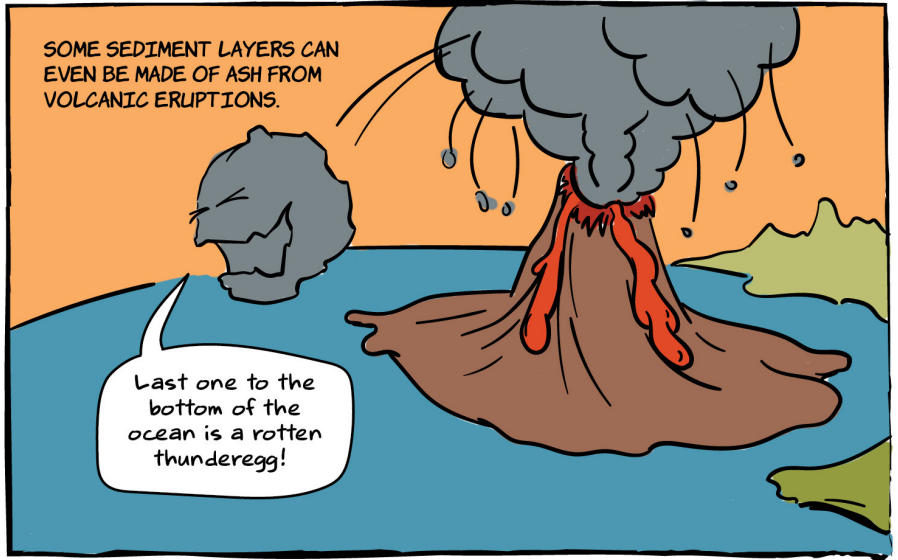
SEDIMENT LAYERS NEAR LAND ARE MORE LIKELY TO HAVE LITTLE BITS OF ROCK AND MUD IN THEM, LIKE THE SAND GRAIN IN THE LAST PANEL.



90 μm (MICRONS IN DIAMETER)

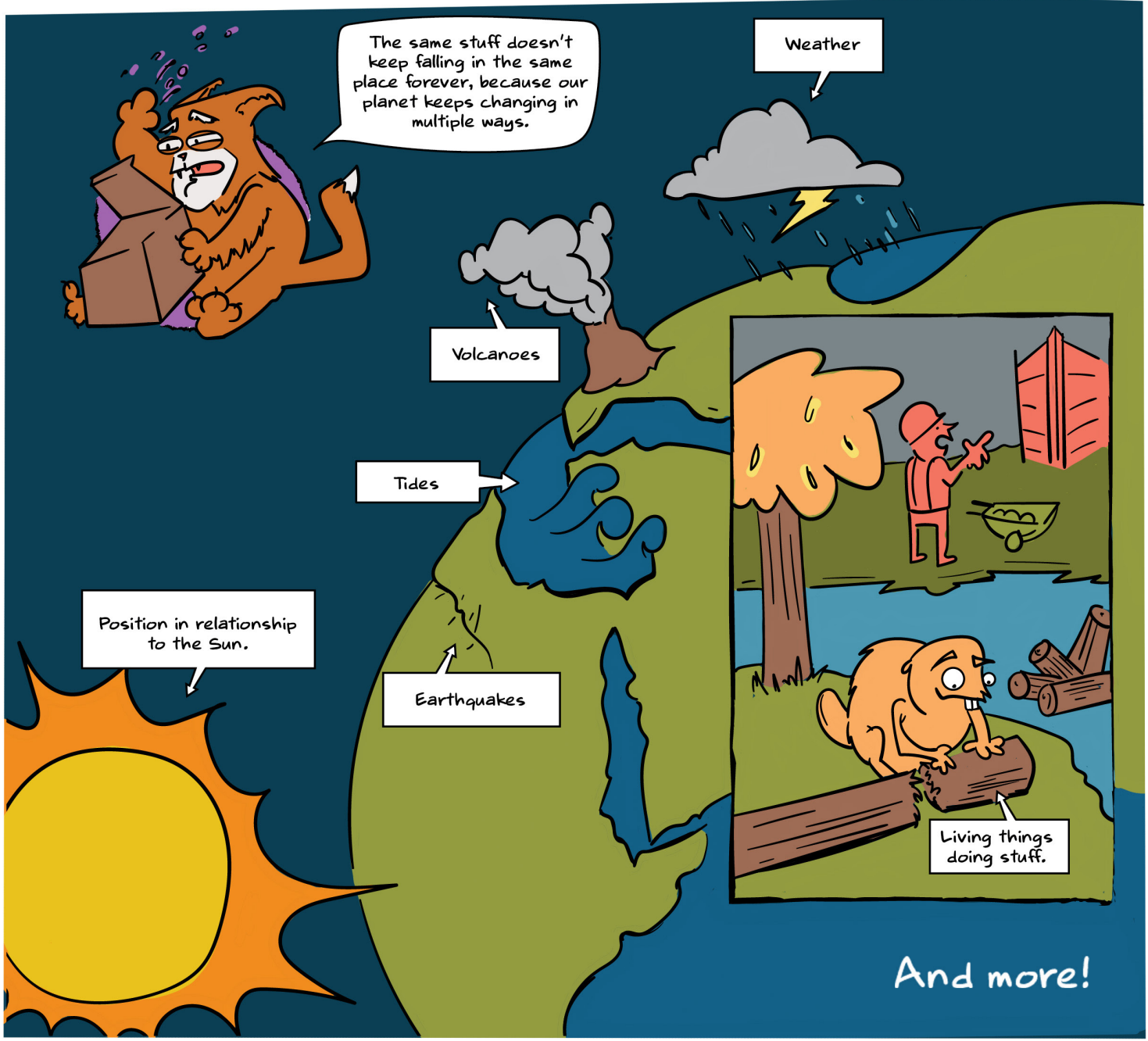
This sand grain was knocked off a land rock and carried to the ocean by wind and water.

SOME SEDIMENT LAYERS CAN EVEN BE MADE OF ASH FROM VOLCANIC ERUPTIONS.



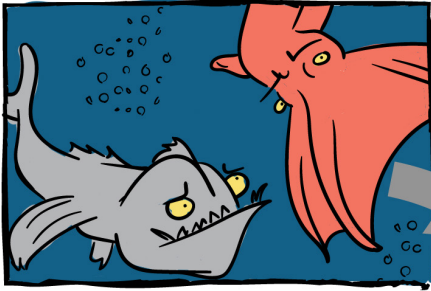
Last one to the bottom of the ocean is a rotten thunderegg!

The same stuff doesn't keep falling in the same place forever, because our planet keeps changing in multiple ways.

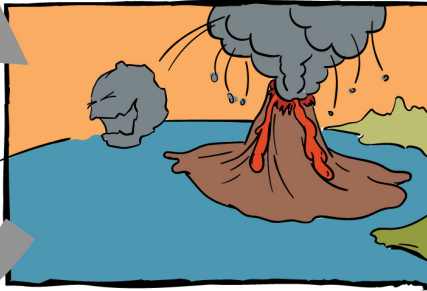


And more!

Because changes like these keep happening, the layers under the seafloor change too. One layer may have been created when the ocean here was filled with tons of foraminifera. Their shells kept covering the seafloor for thousands of years.



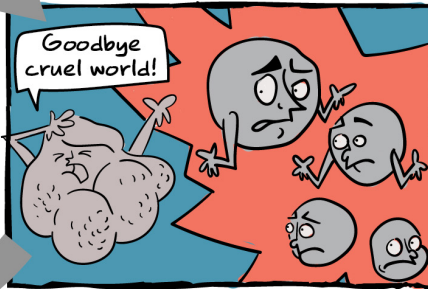
A. 10000 YEARS OF FORAM SHELL ACCUMULATION



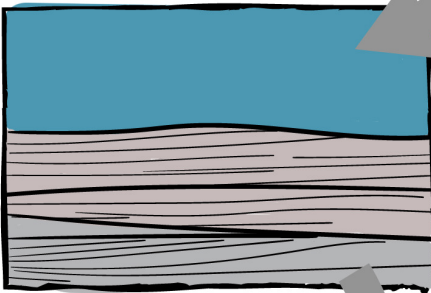
B. BUT THEN A BIG VOLCANIC ERUPTION HAPPENED NEARBY, AND LOTS OF VOLCANIC ASH COVERED THE SEAFLOOR.



C. THEN, AFTER THE ASH HAD ALL FALLEN, FORAM SHELLS CONTINUED TO FALL TO THE SEAFLOOR FOR MANY MORE CENTURIES.



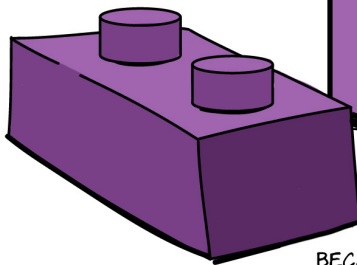
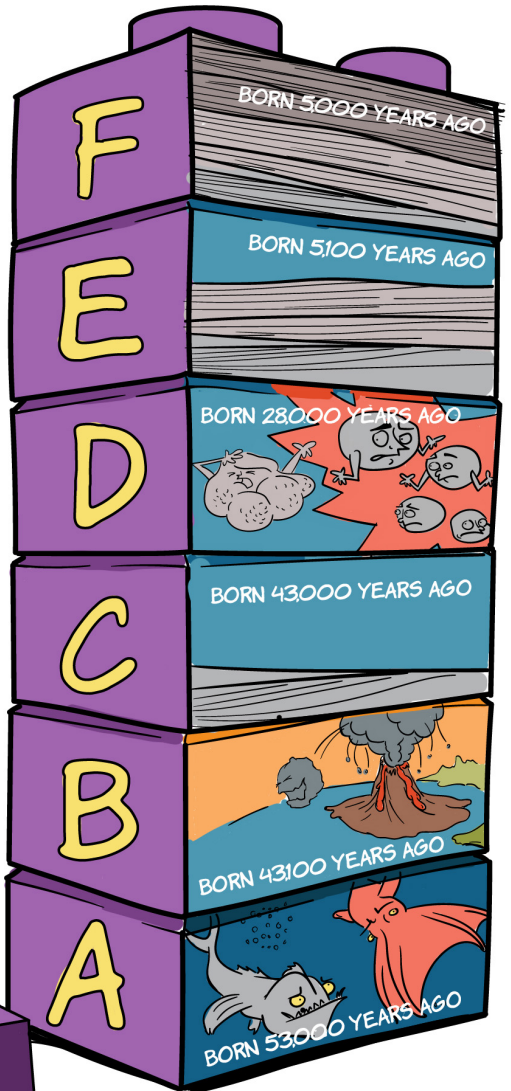
D. THEN SOMETHING HAPPENS THAT CHANGED THE OCEAN ENVIRONMENT. MOST FORAMS COULD NO LONGER SURVIVE IN THESE NEW CONDITIONS, BUT DIATOMS WERE ABLE TO THRIVE. THEY DROPPED THEIR GLASSY SHELLS THERE FOR THOUSANDS OF YEARS.



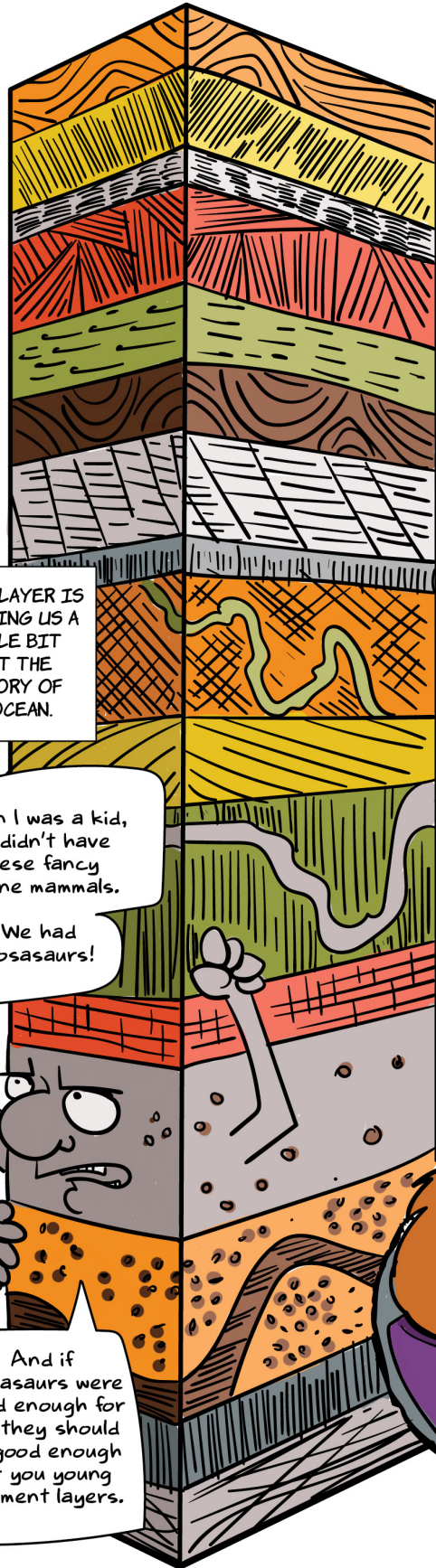
E. AND SO ON.



F AND SO ON.



BECAUSE NEW SEDIMENT FALLS ON OLDER SEDIMENT, THE TOP LAYER TENDS TO BE THE YOUNGEST. AND THE DEEPER YOU GO, THE FARTHER BACK IN TIME THE LAYER WAS MADE.

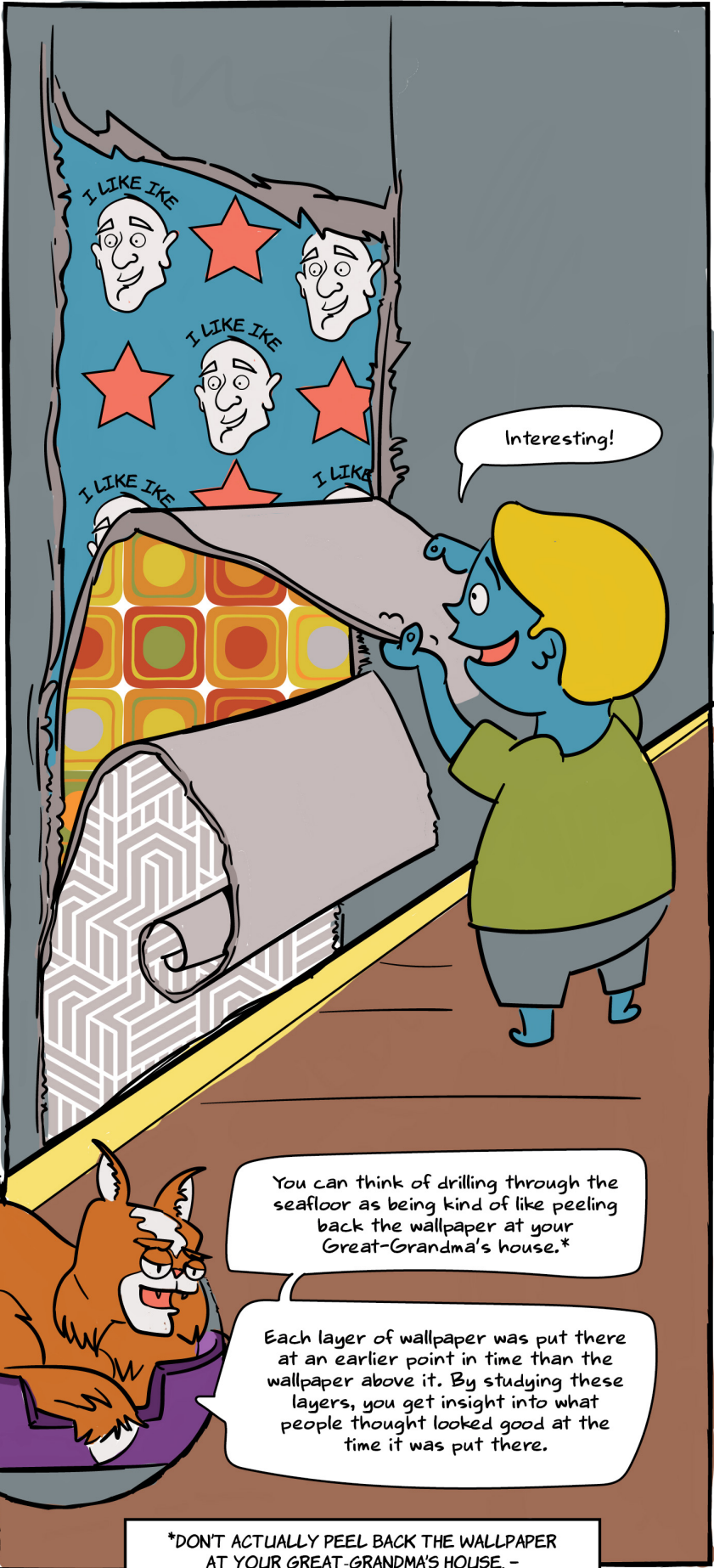


EACH LAYER IS TELLING US A LITTLE BIT ABOUT THE HISTORY OF THE OCEAN.

When I was a kid, we didn't have these fancy marine mammals.

We had mosasaurs!

And if mosasaurs were good enough for us, they should be good enough for you young sediment layers.



Interesting!

You can think of drilling through the seafloor as being kind of like peeling back the wallpaper at your Great-Grandma's house.*

Each layer of wallpaper was put there at an earlier point in time than the wallpaper above it. By studying these layers, you get insight into what people thought looked good at the time it was put there.

*DON'T ACTUALLY PEEL BACK THE WALLPAPER AT YOUR GREAT-GRANDMA'S HOUSE. - KINDHEARTED KEVIN

So, if you can remember six pages back when the narrator guy who I live with was talking about that layer with the wood in it, keep in mind that sediment layer above it is younger and the layer below it is older.

Got it? All right, I'll let him start talking again then. Bye!

And remember, cats rule, dogs drool.



IN THIS LAYER, THE TINIEST SAND GRAINS WERE...

IN THIS LAYER, THE TINIEST SAND GRAINS WERE AT THE TOP, CLOSEST TO THE SEAFLOOR.

AND THE BIGGEST SAND GRAINS WERE THE DEEPEST.

About 135 feet (41 meters) below the seafloor

About 135 feet (41 meters) below the seafloor

THE FACT THAT THEY WERE SORTED FROM TINIEST TO BIGGEST COULD BE EVIDENCE THAT SOMETHING DRAMATIC HAPPENED HERE.*

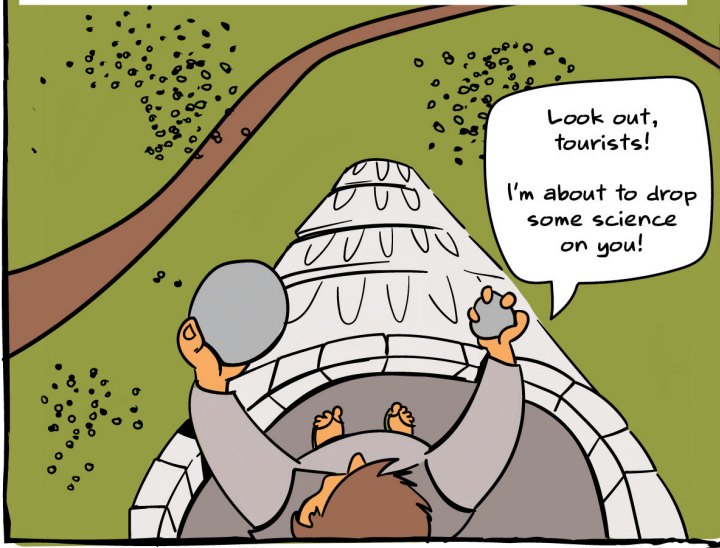
"Forameo. Forameo. Wherefore art thou, Formaeo?"

*DRAMATIC NOT IN THE SENSE THAT THESE SAND GRAINS PERFORMED ROMEO AND JULIET, BUT THAT SOMETHING HAPPENED QUICKLY AND KIND OF VIOLENTLY. -KINETIC KEVIN

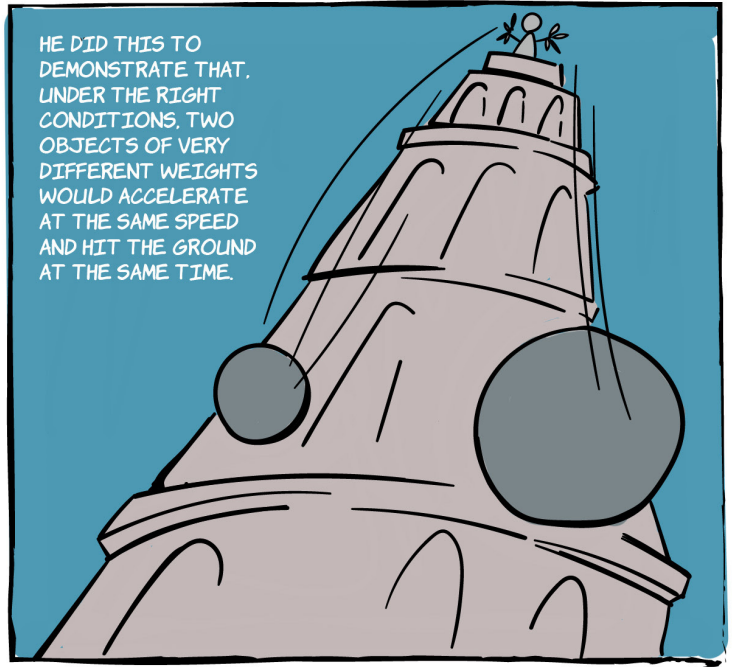
TO UNDERSTAND WHY, LET'S TALK ABOUT GALILEI GALILEO FOR A MINUTE.

Hi, I'm scientist Galilei Galileo.

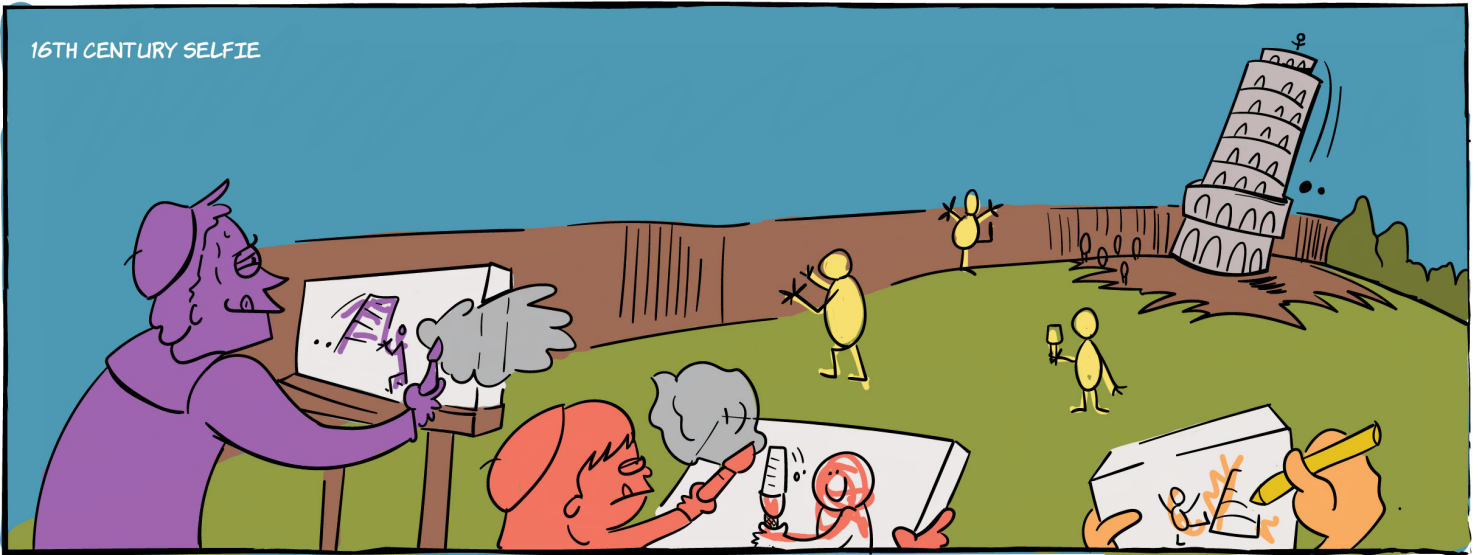
ACCORDING TO AN EARLY BIOGRAPHER, GALILEO ONCE WENT TO THE TOP OF THE LEANING TOWER OF PISA AND DROPPED A HEAVY BALL AND A NOT-SO-HEAVY BALL FROM IT.



HE DID THIS TO DEMONSTRATE THAT, UNDER THE RIGHT CONDITIONS, TWO OBJECTS OF VERY DIFFERENT WEIGHTS WOULD ACCELERATE AT THE SAME SPEED AND HIT THE GROUND AT THE SAME TIME.



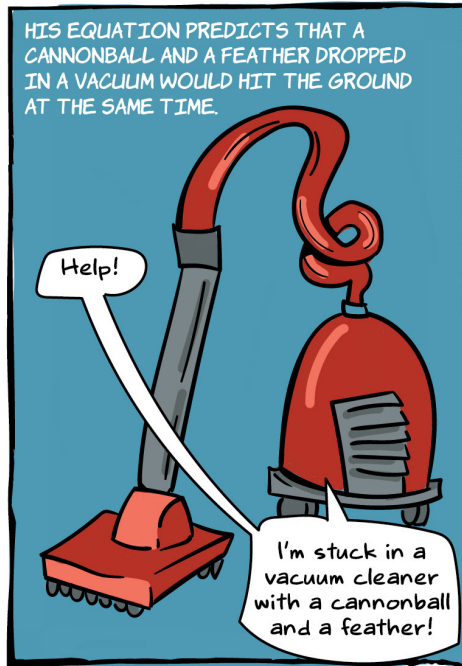
16TH CENTURY SELFIE



GALILEO WASN'T THE FIRST PERSON TO DEMONSTRATE THIS HAPPENS, BUT HE WAS THE FIRST PERSON TO FIGURE OUT THE MATHEMATICAL EQUATIONS THAT EXPLAIN WHY THIS HAPPENS.



HIS EQUATION PREDICTS THAT A CANNONBALL AND A FEATHER DROPPED IN A VACUUM WOULD HIT THE GROUND AT THE SAME TIME.

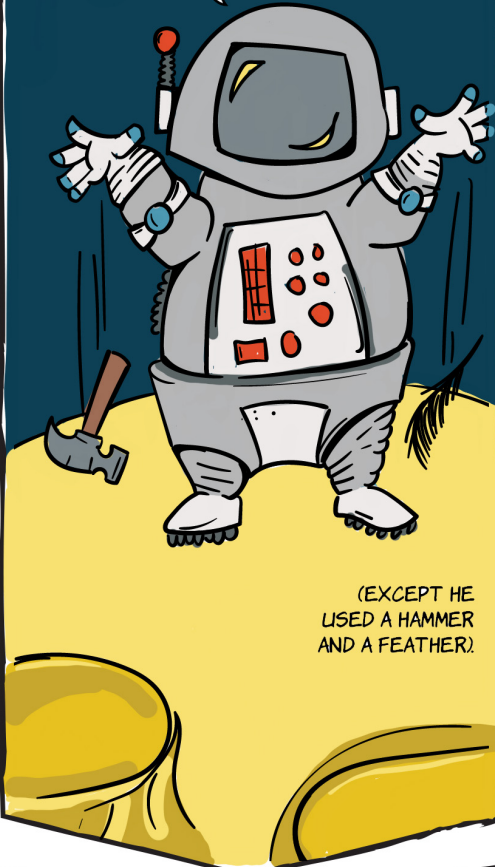


NOT THAT KIND OF VACUUM! A VACUUM IS A SPACE THAT HAS NOTHING IN IT.

No molecules.
No atoms.
No nothing.

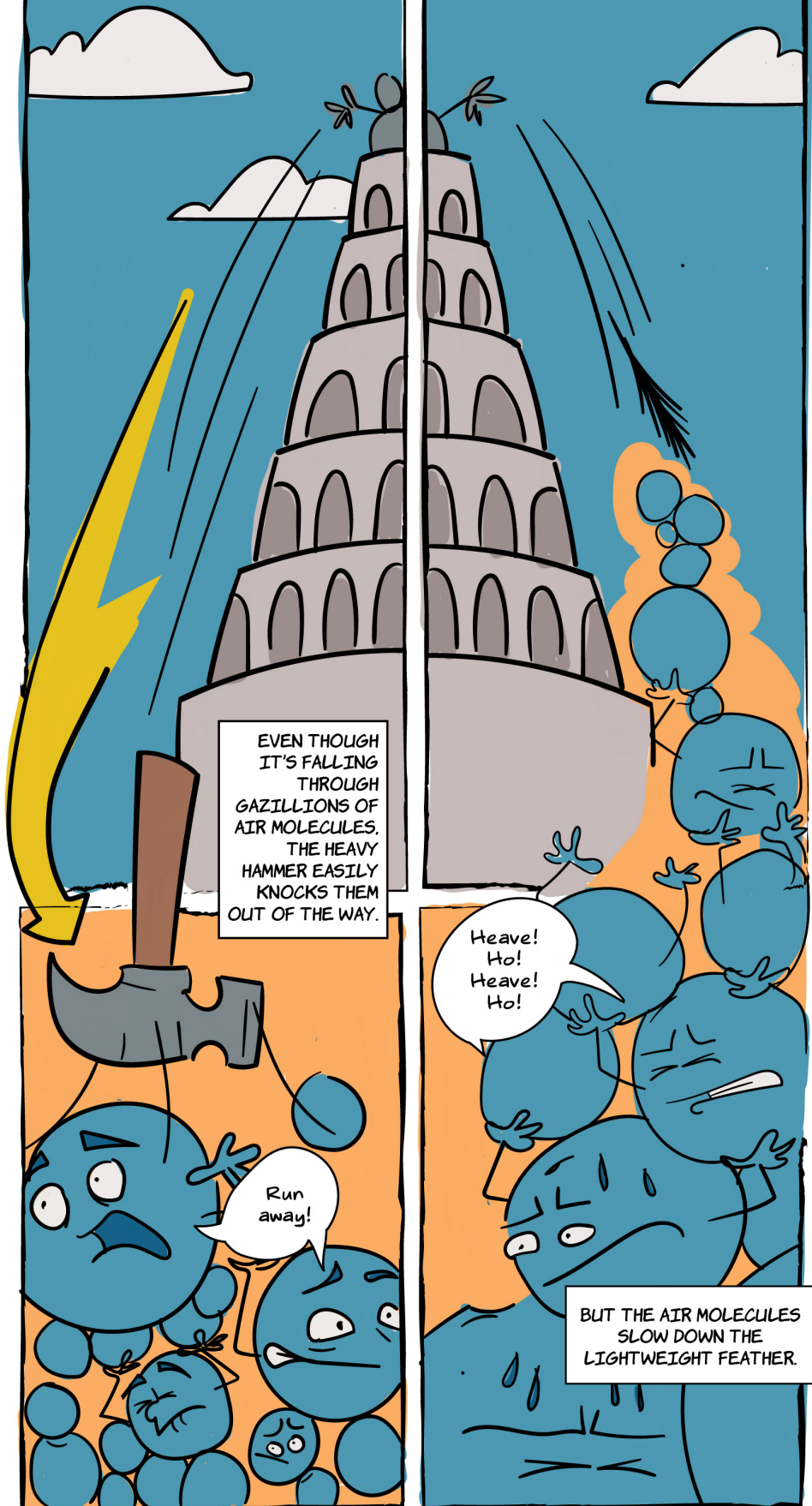
BECAUSE THE MOON BARELY HAS AN ATMOSPHERE, ITS SURFACE IS ALMOST A VACUUM. WHEN ASTRONAUT DAVID SCOTT WAS THERE, HE DEMONSTRATED GALILEO WAS RIGHT

Top that, Galileo!



(EXCEPT HE USED A HAMMER AND A FEATHER.)

IF YOU DROP A HAMMER AND A FEATHER ON EARTH, THOUGH, THE HAMMER PLUMMETS TO THE GROUND WHILE THE FEATHER GENTLY DRIFTS DOWNWARDS.



EVEN THOUGH IT'S FALLING THROUGH GAZILLIONS OF AIR MOLECULES, THE HEAVY HAMMER EASILY KNOCKS THEM OUT OF THE WAY.

Heave!
Ho!
Heave!
Ho!

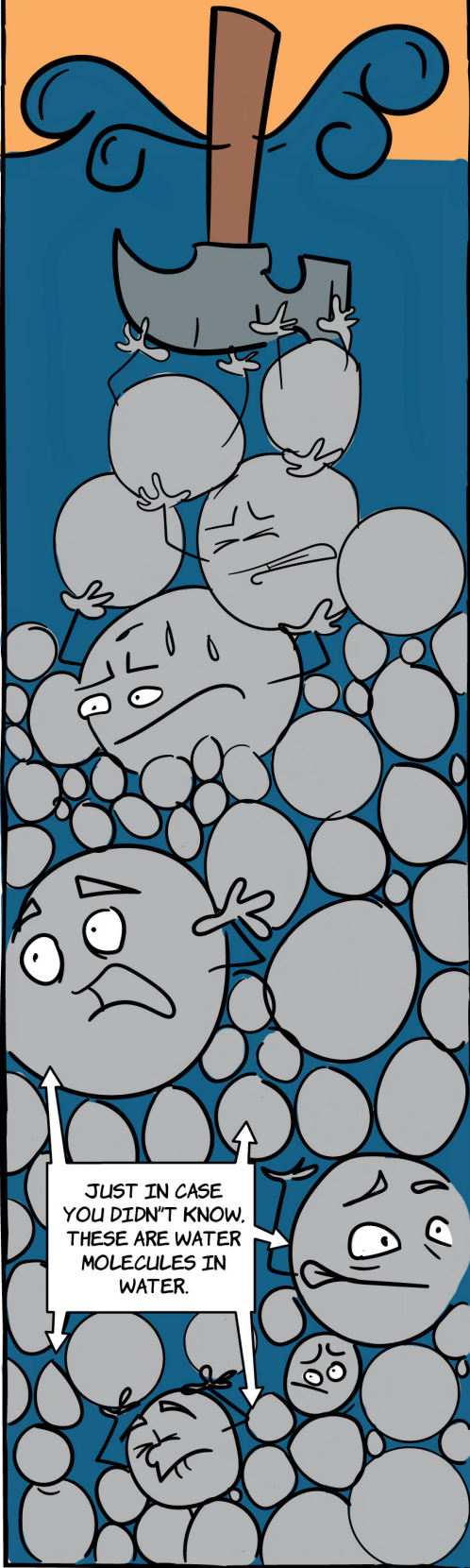
Run away!

BUT THE AIR MOLECULES SLOW DOWN THE LIGHTWEIGHT FEATHER.

THIS IS BECAUSE THE EARTH'S ATMOSPHERE IS FAR FROM BEING A VACUUM. THERE ARE SO MANY AIR MOLECULES IN THE ATMOSPHERE THAT YOU INHALE ABOUT 25 SEXTILLION AIR MOLECULES EVERY TIME YOU BREATHE.

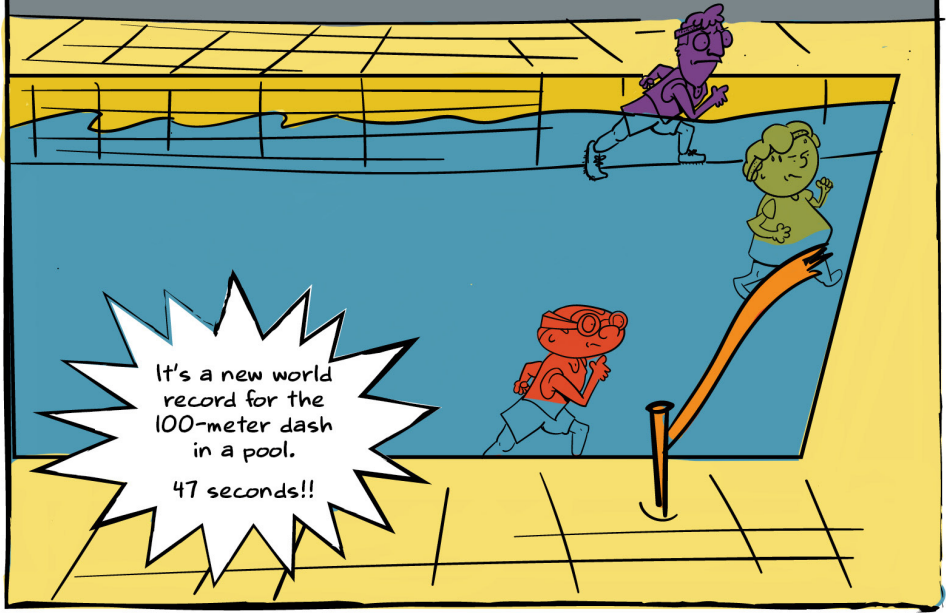
About 25 sextillion air molecules in there

IF YOU DROP A HAMMER IN WATER, IT WOULD NOT MOVE AS FAST AS IT DOES IN AIR, BECAUSE THERE ARE LOT MORE MOLECULES IN ITS WAY.



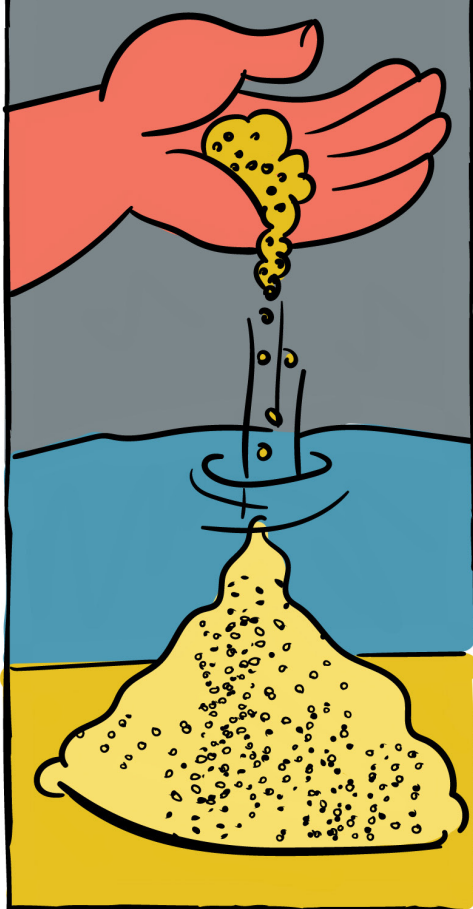
JUST IN CASE YOU DIDN'T KNOW, THESE ARE WATER MOLECULES IN WATER.

YOU MAY HAVE EXPERIENCED THIS YOURSELF IF YOU HAVE EVER TRIED TO HAVE A FOOTRACE IN A POOL. IT'S A LOT HARDER TO RUN THROUGH WATER THAN AIR.

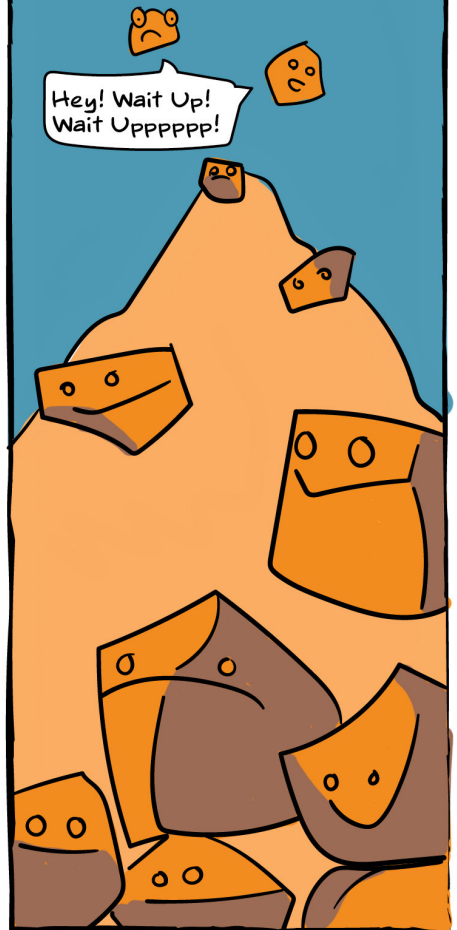


It's a new world record for the 100-meter dash in a pool. 47 seconds!!

SO, IMAGINE WHAT IT'S LIKE FOR SAND GRAINS. DROP A BUNCH OF SAND GRAINS IN WATER AND THEY ALL TRAVEL A LOT SLOWER THAN A HAMMER OR A SPRIINTER.



BUT THEY DON'T ALL TRAVEL AT THE SAME SPEED. THE BIGGEST ONES SINK FASTEST THROUGH THE WATER AND THE SMALLEST ONES ARE SLOWEST.



IF THE SAND GRAINS ARE DEPOSITED GRADUALLY OVER A LONG PERIOD OF TIME, THESE GRAIN SIZES WOULD ALL BE MIXED UP.



LIKE STORE-BOUGHT SNACK MIX.

THIS IS BECAUSE A LARGE SAND GRAIN THAT STARTED SINKING FIVE HOURS AGO CAN REACH THE SEAFLOOR AT THE SAME TIME AS A SMALLER SAND GRAIN THAT STARTED SINKING FIVE DAYS AGO.

It's a tie!

Next time you're not getting a 115-hour head start!



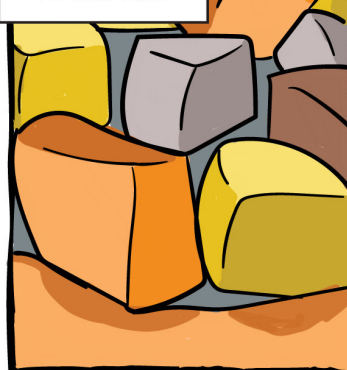
BUT IF A WHOLE BLUNCH OF SAND GRAINS ENTER THE OCEAN ALL AT THE EXACT SAME TIME,

THE WATER SORTS THEM SO THAT THE BIGGEST ONE SINKS FASTEST.

THE LESS BIGGER ONES ARE A LITTLE SLOWER AND THE TINIEST ONES ARE THE SLOWEST.

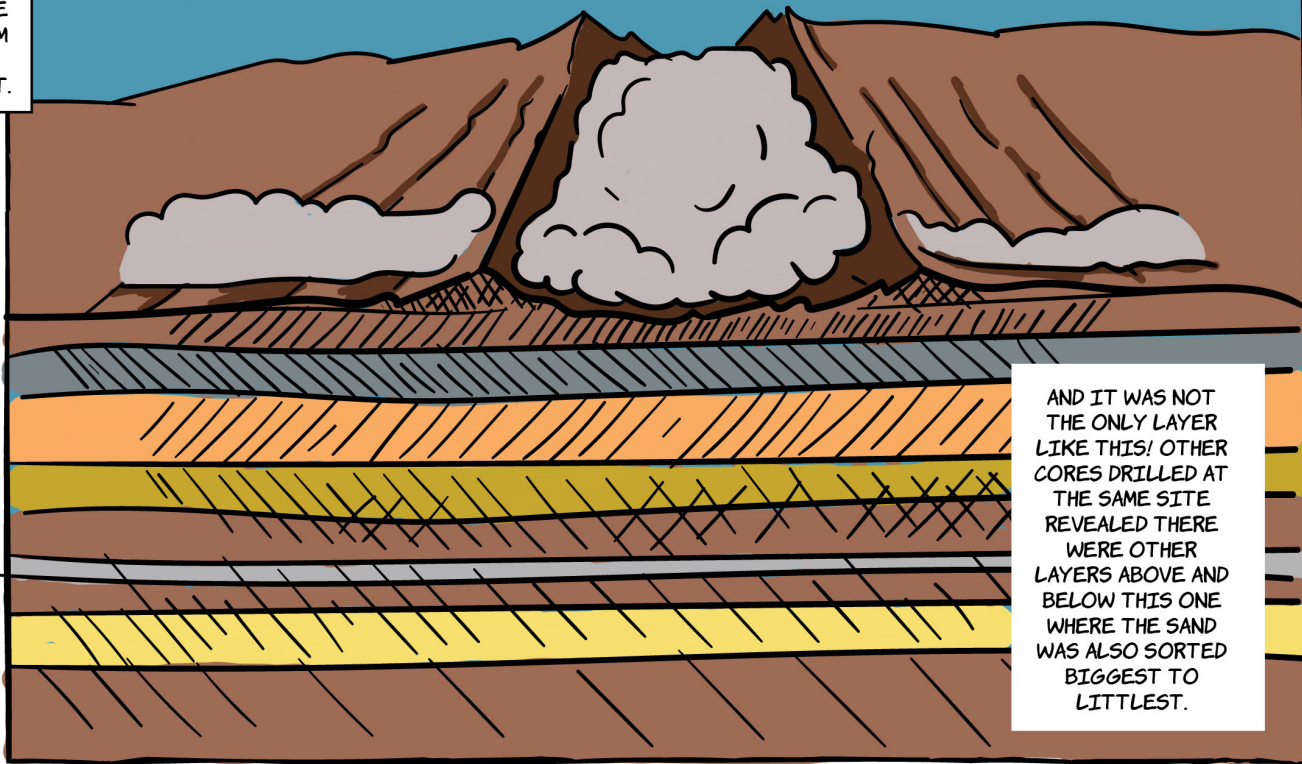


WHEN THESE GRAINS REACH THE SEAFLOOR, A LAYER FORMS WHERE THE GRAIN SIZES GET SMALLER AS YOU GO FROM BOTTOM TO THE TOP.



THE FACT THAT THIS LAYER IS ABOUT 65 FEET (20 METERS) THICK AND COVERS AN ENTIRE UNDERWATER VALLEY INDICATES THAT LITERALLY TONS AND TONS (AND TONS!) OF SAND SHOWED UP ALL AT ONCE.

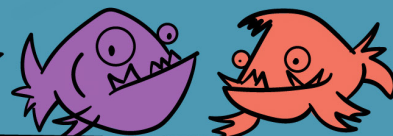
THIS CORE CAME FROM A LAYER LIKE THAT.



AND IT WAS NOT THE ONLY LAYER LIKE THIS! OTHER CORES DRILLED AT THE SAME SITE REVEALED THERE WERE OTHER LAYERS ABOVE AND BELOW THIS ONE WHERE THE SAND WAS ALSO SORTED BIGGEST TO LITTLEST.

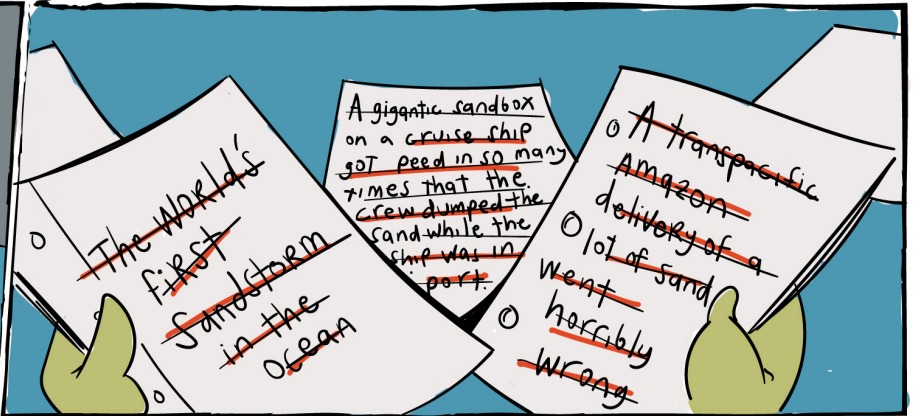
IT'S ANOTHER INDICATION SOMETHING FISHY IS GOING ON HERE.

He means that metaphorically. We had nothing to do with it.

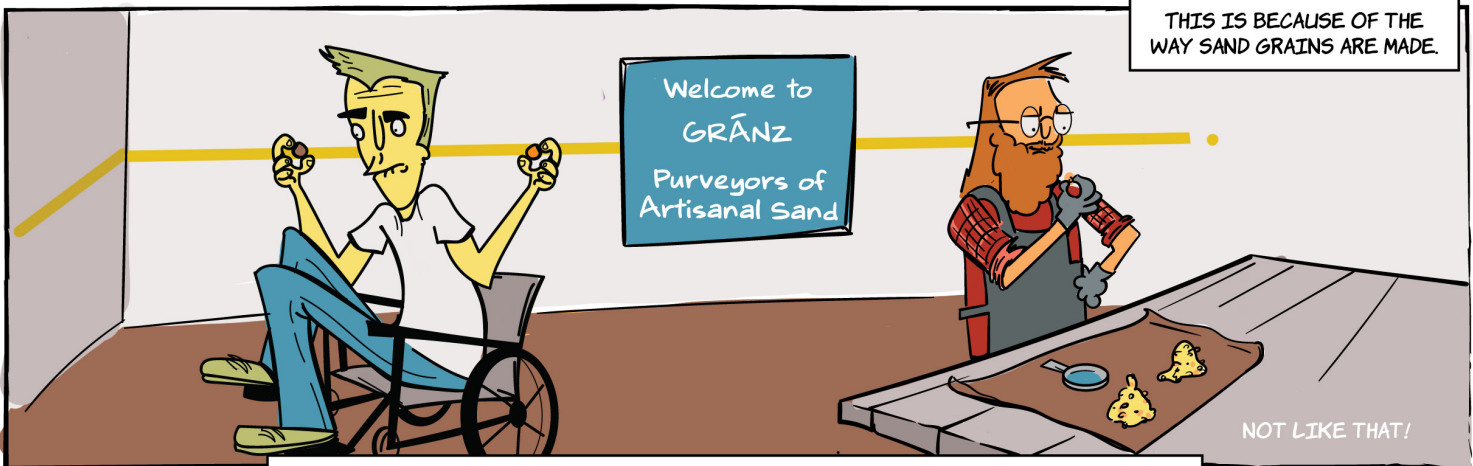
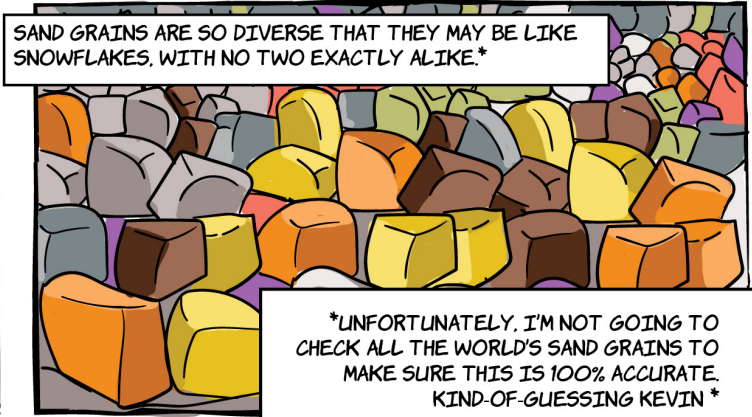




SO THE SAND SHOWED UP ALL AT ONCE, BUT WHERE DID IT COME FROM?

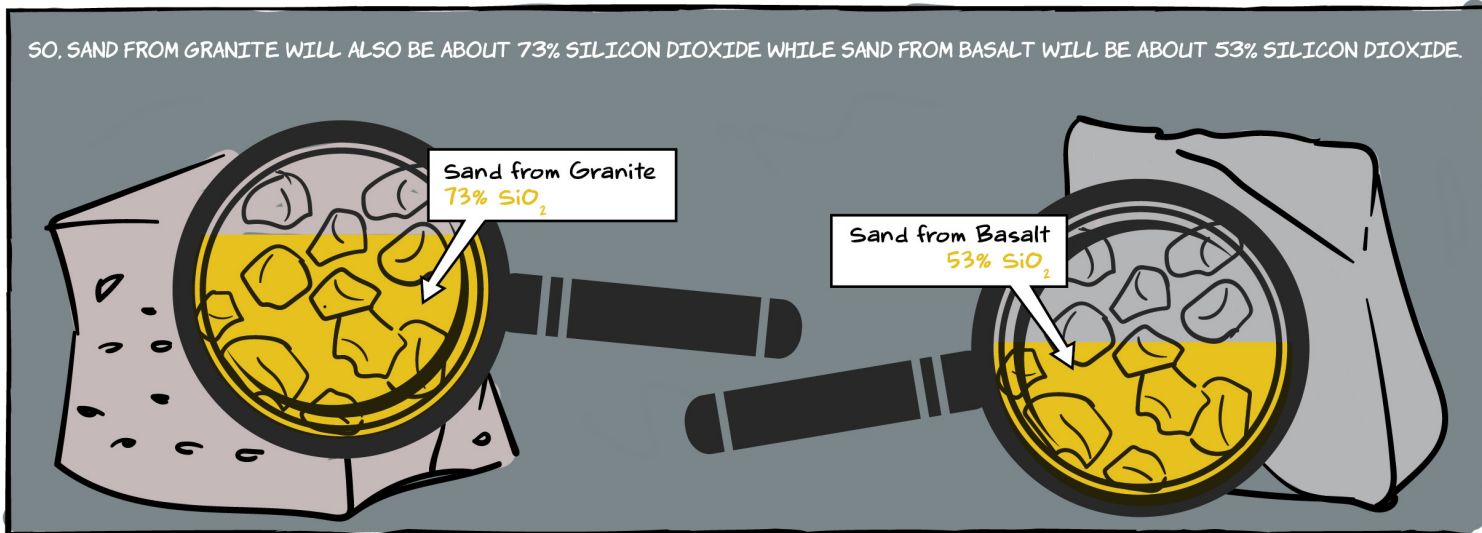
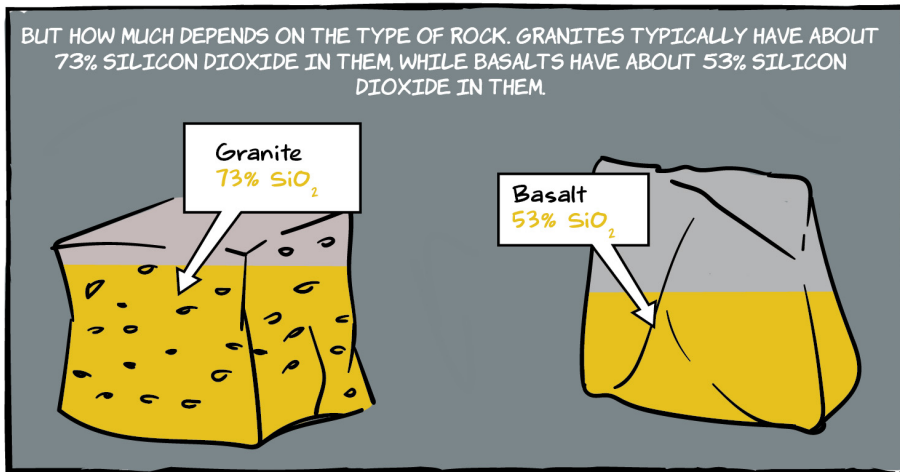
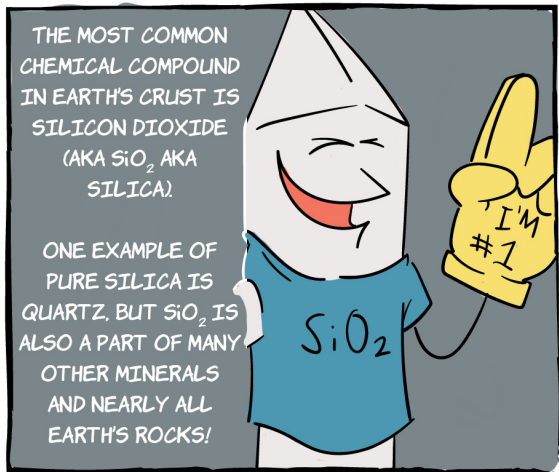


ONCE AGAIN, THE ANSWER WAS FOUND BY READING THE CORES. BUT THIS TIME, THEY WERE READING THE INGREDIENTS OF THE SAND GRAINS.



SAND GRAINS ARE MADE WHEN WEATHERING AND EROSION BREAK OFF BITS OF ROCKS.



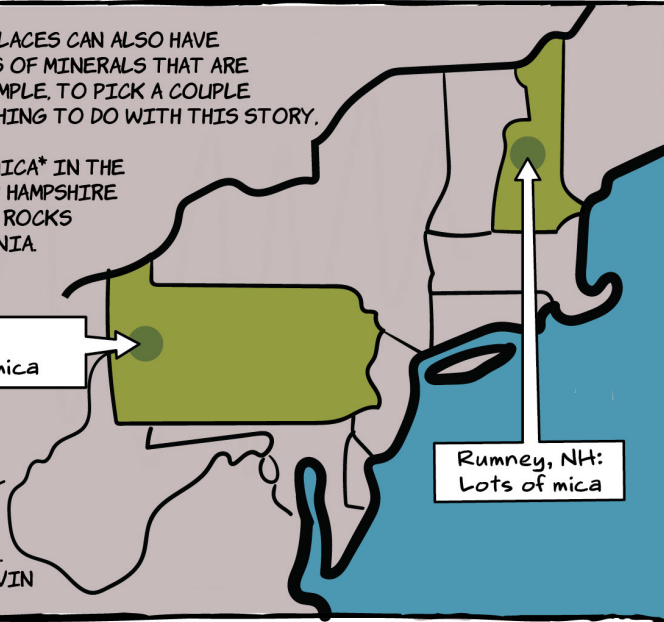


ROCKS IN DIFFERENT PLACES CAN ALSO HAVE SIGNIFICANT AMOUNTS OF MINERALS THAT ARE LESS COMMON. FOR EXAMPLE, TO PICK A COUPLE TOWNS THAT HAVE NOTHING TO DO WITH THIS STORY.

YOU WILL FIND MORE MICA* IN THE ROCKS OF RUMNEY, NEW HAMPSHIRE THAN YOU WILL IN THE ROCKS OF BUTLER, PENNSYLVANIA.

Butler, PA:
Not so much mica

*MICA IS THE MINERAL YOU CAN SLICE INTO THIN, SOMETIMES SEE-THROUGH, PIECES. KNOWLEDGEABLE KNEVIN



THE SAND GRAINS THAT WEAR OFF THE ROCKS IN RUMNEY WILL ALSO HAVE MORE MICA THAN THE SAND GRAINS FROM BUTLER. BECAUSE THE SAND MATCHES THE ROCKS' INGREDIENTS, IT BECOMES A FINGERPRINT FOR THE AREA.



AND IF THAT SAND TRAVELS A LONG DISTANCE, THE SAND'S INGREDIENTS CAN BE USED TO DETERMINE WHERE THE SAND ORIGINALLY CAME FROM.

The Butler town did it!



SO, THE SAND AND OTHER SEDIMENT IN THE CORE CONTAINED THE FINGERPRINT OF WHERE IT CAME FROM. THE GEOLOGISTS JUST NEEDED TO MATCH IT TO THE RIGHT PLACE.



THE GEOLOGISTS ALREADY KNEW THE SEDIMENT IN THE CORE LIKELY CAME FROM LAND, BECAUSE, IF YOU REMEMBER PAGE 11, IT HAD WOOD MIXED IN IT.

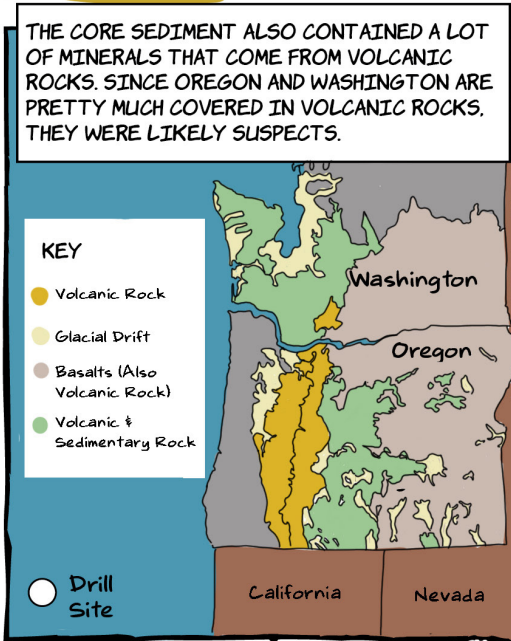




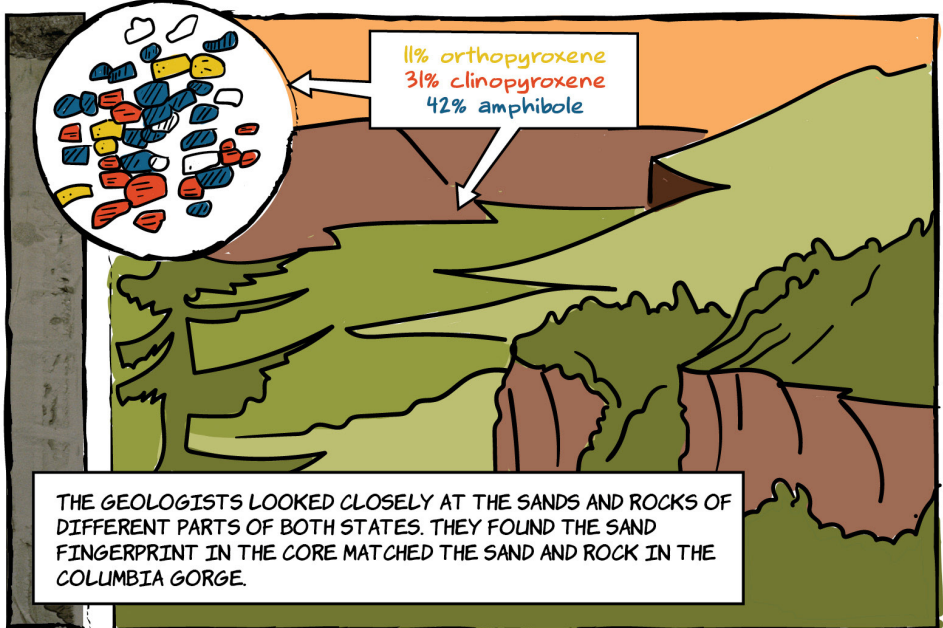
THEY ALSO KNEW THAT SAND DOES NOT COME IN MASS QUANTITIES FROM FARAWAY PLACES LIKE JAPAN OR ALASKA OR ECUADOR.

BECAUSE SAND DOESN'T, LIKE, CHARTER BOATS.

Bon Voyage, Sand!

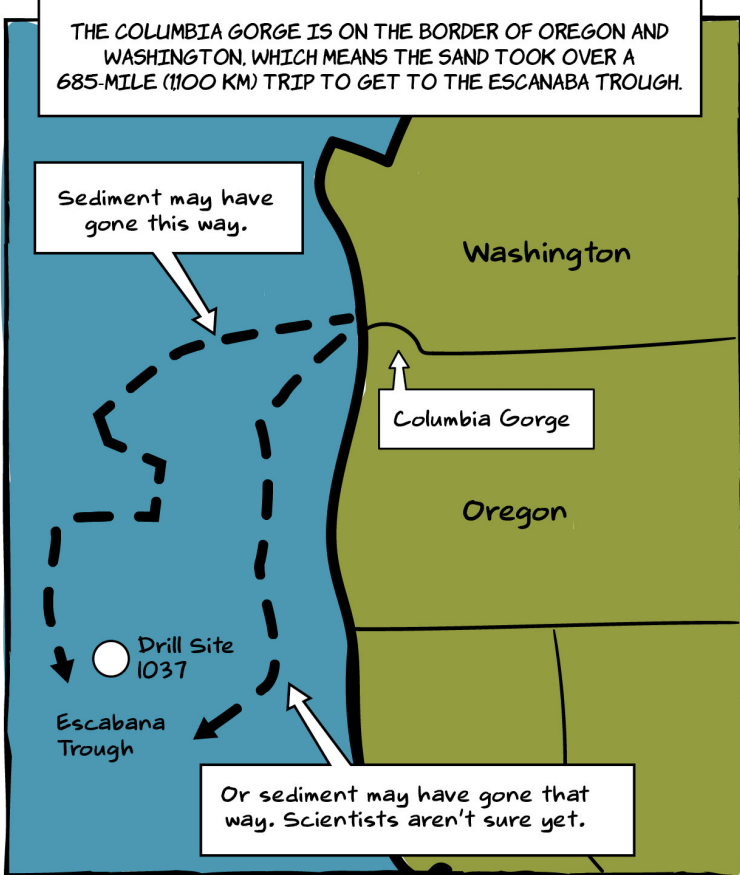


KEY
 ● Volcanic Rock
 ● Glacial Drift
 ● Basalts (Also Volcanic Rock)
 ● Volcanic & Sedimentary Rock
 ○ Drill Site



11% orthopyroxene
 31% clinopyroxene
 42% amphibole

THE GEOLOGISTS LOOKED CLOSELY AT THE SANDS AND ROCKS OF DIFFERENT PARTS OF BOTH STATES. THEY FOUND THE SAND FINGERPRINT IN THE CORE MATCHED THE SAND AND ROCK IN THE COLUMBIA GORGE.



THE COLUMBIA GORGE IS ON THE BORDER OF OREGON AND WASHINGTON, WHICH MEANS THE SAND TOOK OVER A 685-MILE (1100 KM) TRIP TO GET TO THE ESCANABA TROUGH.

Sediment may have gone this way.

Washington
 Columbia Gorge
 Oregon

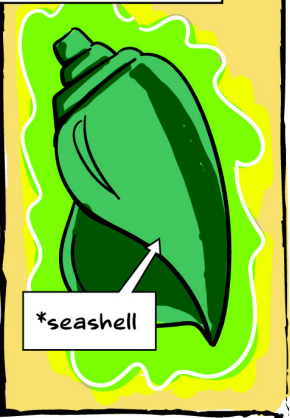
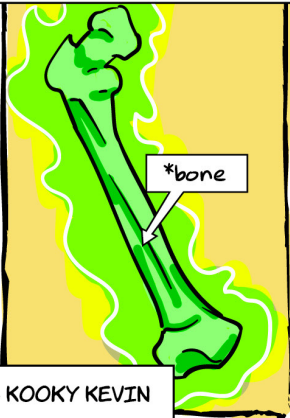
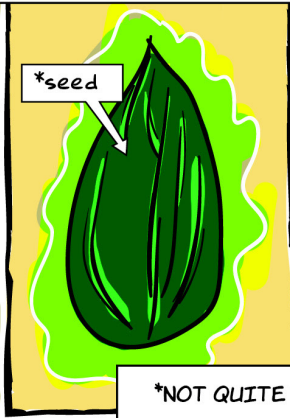
Or sediment may have gone that way. Scientists aren't sure yet.



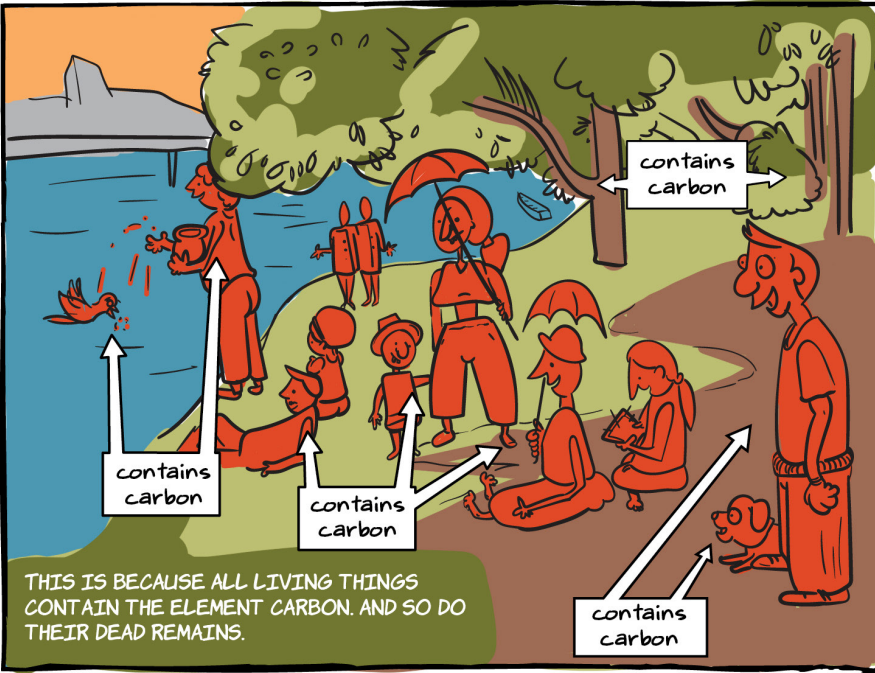
SO, THE CORES HAD TOLD WHERE THE SAND CAME FROM. THEY PROVIDED EVIDENCE THAT THE SAND CAME PRETTY QUICKLY. THE QUESTION NOW IS, WHEN DID IT HAPPEN?

And who are you wearing, Core?

THE ANSWER TO THIS WAS IN THE CORES TOO. THESE CORES CONTAINED THE REMAINS OF LIVING THINGS, AND THE REMAINS OF LIVING THINGS (LIKE THAT PIECE OF WOOD) CAN BE LIKE RADIOACTIVE STOPWATCHES.



*NOT QUITE THAT RADIOACTIVE, THOUGH - KOOKY KEVIN



THIS IS BECAUSE ALL LIVING THINGS CONTAIN THE ELEMENT CARBON. AND SO DO THEIR DEAD REMAINS.

THE VAST MAJORITY OF THE CARBON IN LIVING THINGS IS A TYPE CALLED CARBON¹² WHICH ISN'T RADIOACTIVE.

6 protons

6 neutrons

6 electrons

Carbon¹²

BUT THERE ALSO WILL BE A TINY BIT OF CARBON¹⁴ IN LIVING THINGS TOO.

6 protons

8 neutrons

6 electrons

Carbon¹⁴

CARBON¹⁴ IS CONSIDERED UNSTABLE BECAUSE IT CAN SUDDENLY GIVE OFF A BURST OF RADIATION AND THEN TRANSFORM INTO A NITROGEN¹⁴ ATOM.

Carbon¹⁴

POP

7 protons

7 neutrons

7 electrons

Nitrogen¹⁴

THIS ISN'T A TRANSFORMATION THAT HAPPENS AT A SET TIME. LIKE WHEN YOU TURN INTO A WEREWOLF.

Five seconds left until midnight, which means I'm going to turn into a werewolf

...nowoooooo
ooohhh!

IT'S MORE LIKE THE TRANSFORMATION OF CORN KERNELS INTO POPCORN. WHEN YOU COOK POPCORN KERNELS, YOU CAN'T PREDICT WHEN EACH INDIVIDUAL KERNEL IS GOING TO TRANSFORM.

You will change...Now!

I mean now!
Now!
Now!

BUT YOU CAN PREDICT THAT ALMOST ALL THE KERNELS WILL TRANSFORM INTO FLUFFY POPCORN WITHIN FOUR MINUTES.

YOU ALSO CAN'T PREDICT WHEN ONE CARBON¹⁴ ATOM IS GOING TO HAVE ITS RADIOACTIVE METAMORPHOSIS.

You will change...Now!

I mean now!
Now!
Now!

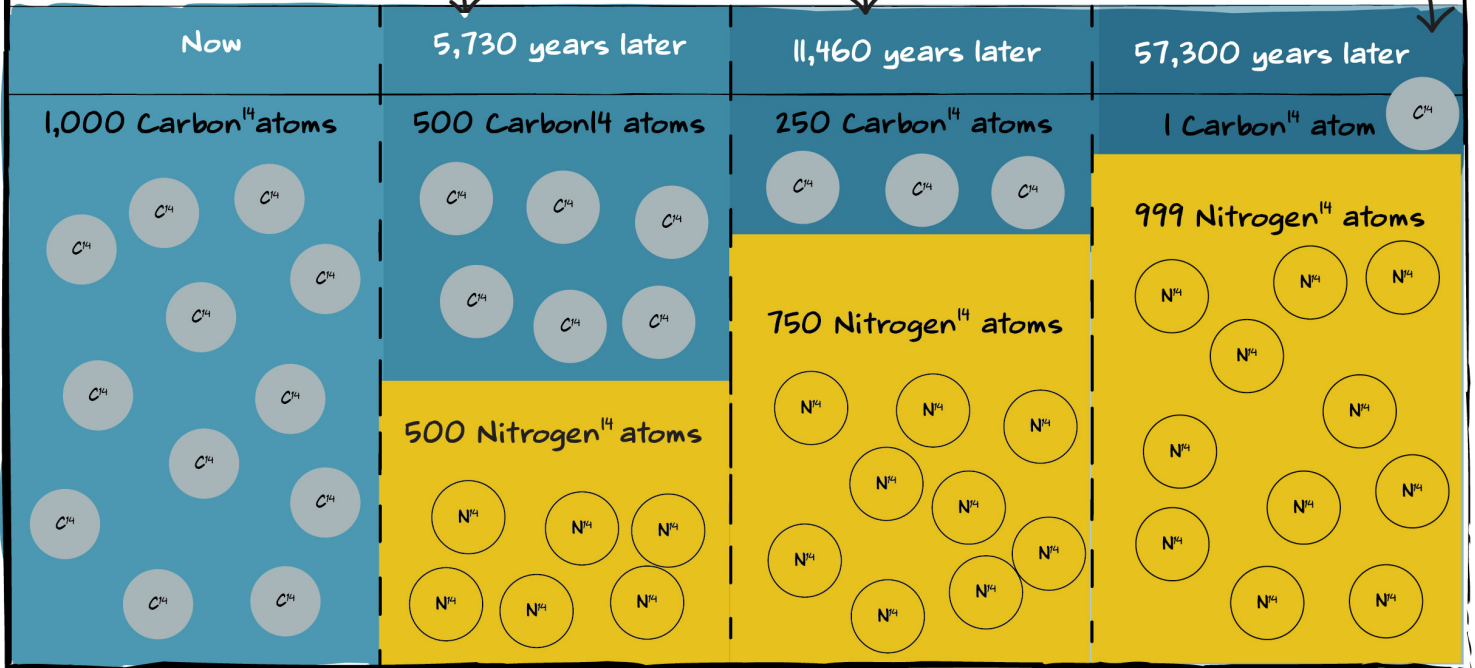
BUT YOU CAN PREDICT HOW LONG IT WILL TAKE HALF OF THE CARBON¹⁴ ATOMS TO TRANSFORM.

SCIENTISTS HAVE DETERMINED THAT THE HALF-LIFE OF CARBON¹⁴ ATOMS IS 5730 YEARS.

THIS MEANS, IF YOU HAVE A BUNCH OF CARBON¹⁴ ATOMS, HALF OF THEM WILL TURN INTO NITROGEN¹⁴ ATOMS WITHIN 5730 YEARS.

THEN OVER THE NEXT 5730 YEARS, HALF THE REMAINING CARBON¹⁴ ATOMS BECOME NITROGEN¹⁴ ATOMS (BECAUSE YOU WENT THROUGH ANOTHER HALF-LIFE).

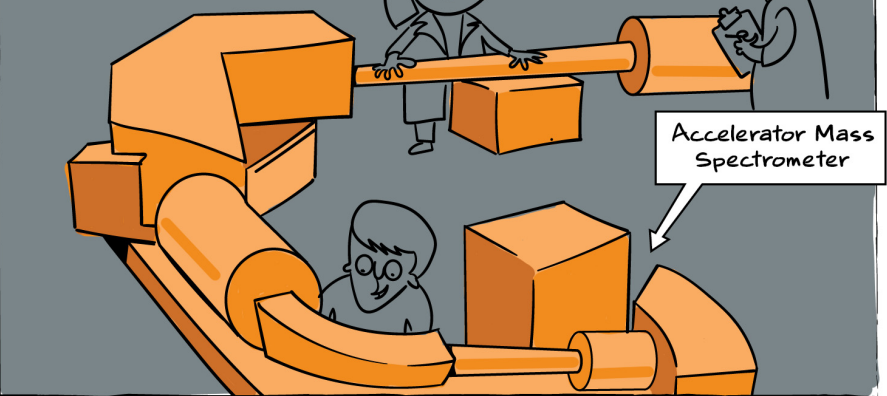
THE REMAINING CARBON¹⁴ ATOMS KEEP DECAYING AND GOING THROUGH HALF-LIVES. AFTER 10 HALF-LIVES (57300 YEARS), THE CARBON¹⁴ ATOMS ARE JUST ABOUT GONE, SO YOU CAN'T CARBON-DATE ANYTHING THAT OLD. THERE JUST AREN'T ENOUGH CARBON ATOMS LEFT.



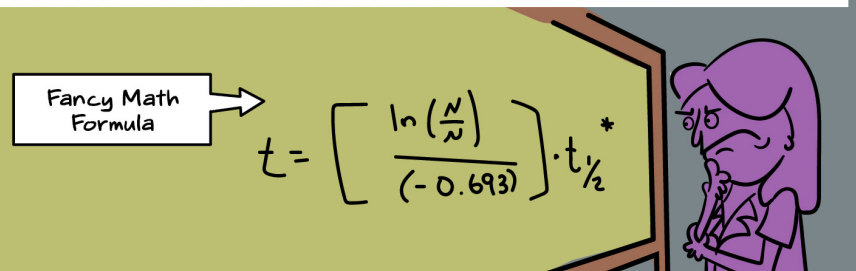
BECAUSE CARBON¹⁴ ATOMS DECAY IN THIS PREDICTABLE WAY, WHEN YOU HAVE THE REMAINS OF LIVING THINGS IN YOUR CORES, THEY ACT LIKE RADIOACTIVE STOPWATCHES.



SCIENTISTS USE SUPER SENSITIVE EQUIPMENT TO COUNT THE CARBON ATOMS THAT ARE LEFT IN THE REMAINS OF LIVING THINGS.

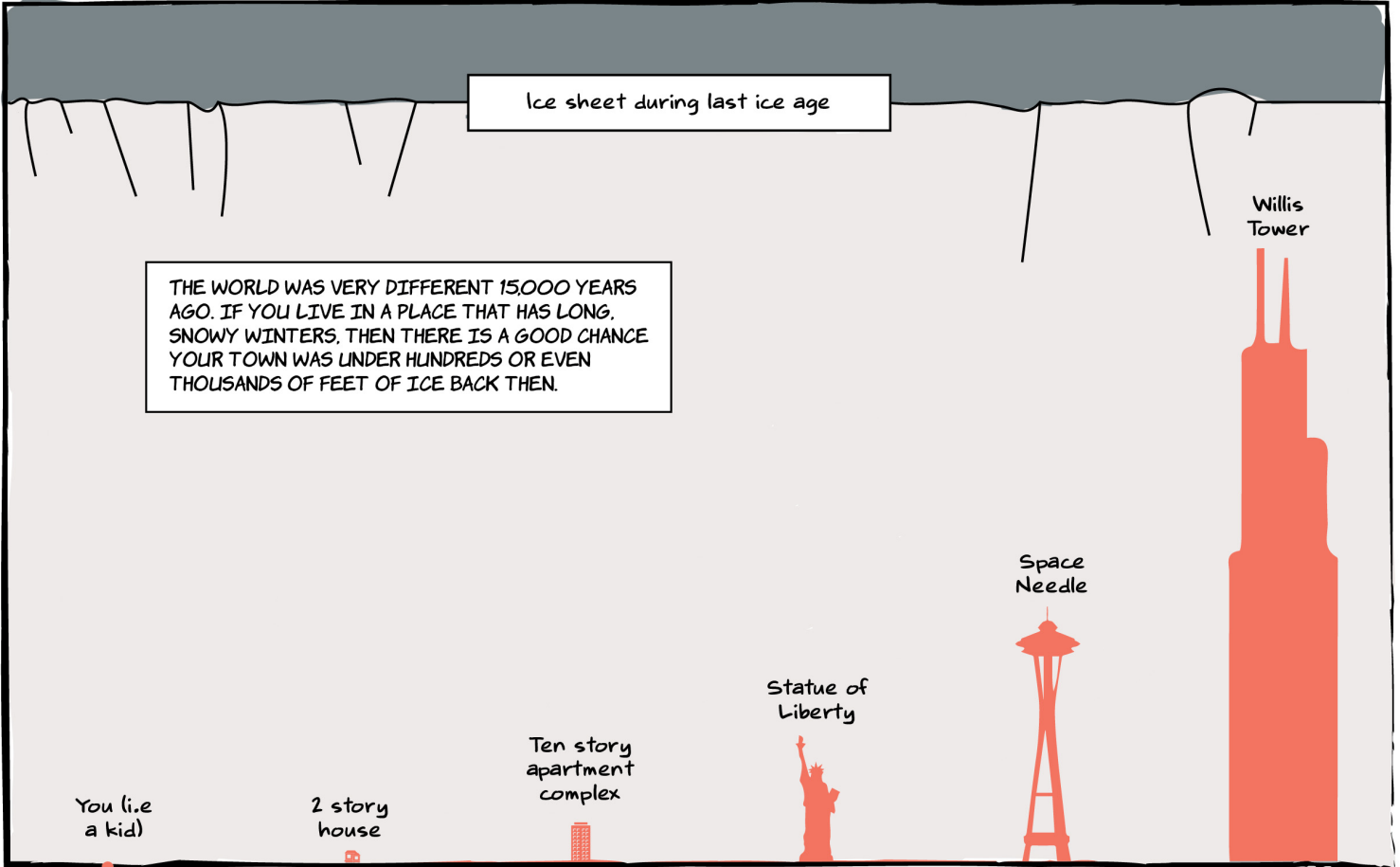
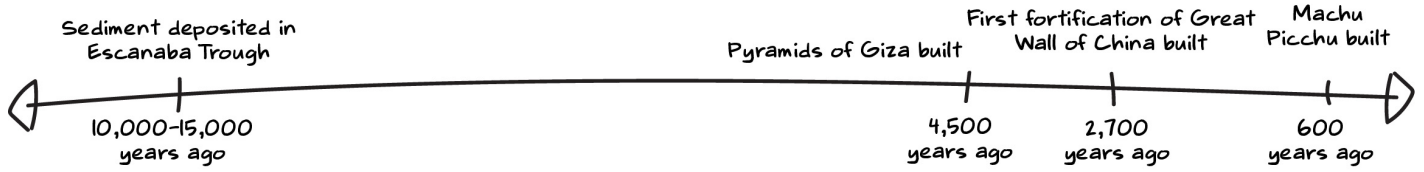


THEY CAN THEN PLUG THE NUMBERS OF ATOMS INTO A FANCY MATH FORMULA THAT WILL TELL THEM WHEN THE CARBON¹⁴ ATOMS STARTED DECAYING.

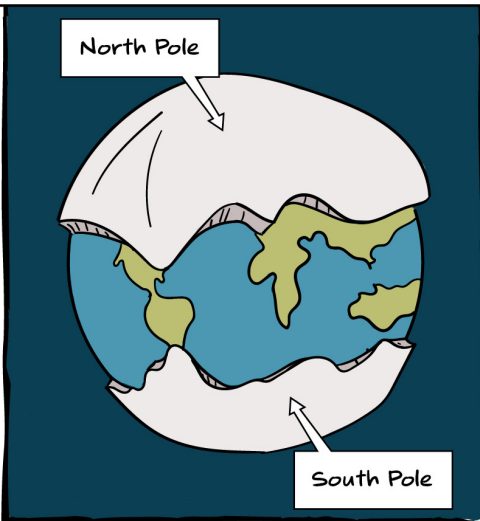


*I'D EXPLAIN WHAT THIS ALL MEANS, BUT I ONLY HAVE FIVE PAGES LEFT IN THIS ISSUE AND OTHER THINGS I NEED TO TELL YOU. PLUS, WHAT DO YOU THINK I DO? WRITE COMICS ALL DAY? - KNACKERED KEVIN

THIS PROCESS, CALLED RADIOCARBON DATING, REVEALED THE SEDIMENTS IN THESE CORES WERE DEPOSITED BETWEEN 10,000 AND 15,000 YEARS AGO.



THAT'S BECAUSE THE WORLD THEN WAS IN AN ICE AGE. AN ICE AGE IS A LONG PERIOD IN EARTH'S HISTORY WHEN THE SURFACE TEMPERATURE IS SO COLD THAT HUGE SHEETS OF ICE SPREAD OUT FROM THE POLES.



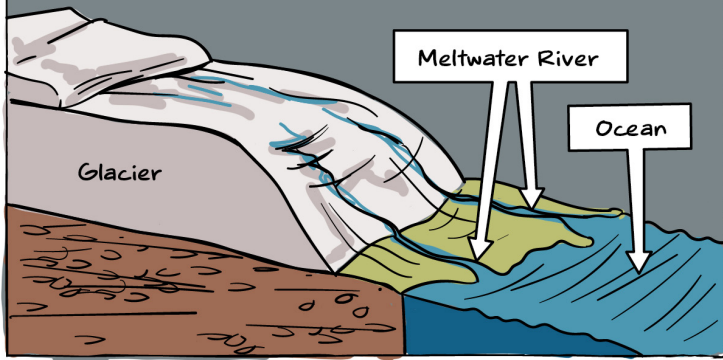
THE MOST RECENT ICE AGE STARTED ABOUT 26 MILLION YEARS AGO AND REACHED ITS COLDEST, ICIEST PEAK ABOUT 20,000 YEARS AGO.



AFTER THAT, THINGS STARTED WARMING UP AND KEPT WARMING FOR ABOUT 10,000 YEARS. AS YOU PROBABLY ALREADY KNOW, WARMING AIR MAKES SNOW AND ICE MELT.

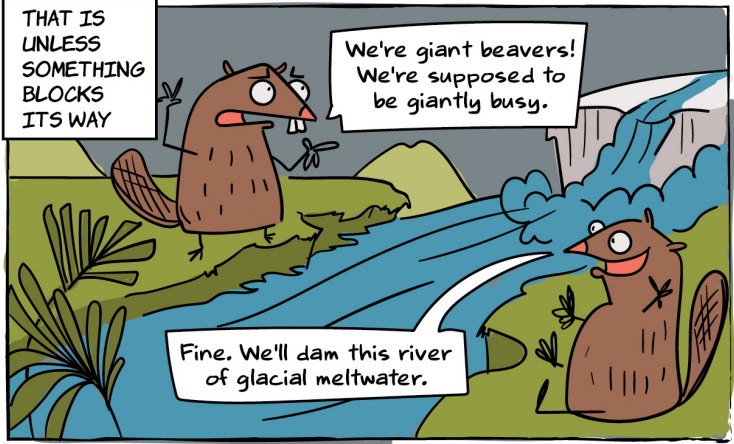


WHEN ICE SHEETS THAT COVER ENTIRE COUNTRIES MELT, A LOT OF EXTRA WATER STARTS FLOWING TO THE OCEAN.



THAT IS UNLESS SOMETHING BLOCKS ITS WAY

We're giant beavers! We're supposed to be giantly busy.



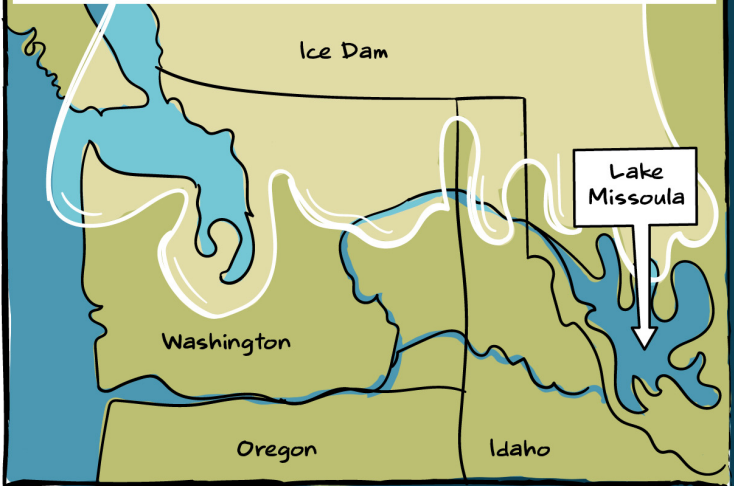
EVEN THOUGH THERE LITERALLY WERE GIANT BEAVERS ALIVE BACK THEN, THEY WEREN'T THE PROBLEM.

THE THING BLOCKING WATER DURING AN ICE AGE WAS... SEE IF YOU CAN GUESS IT...

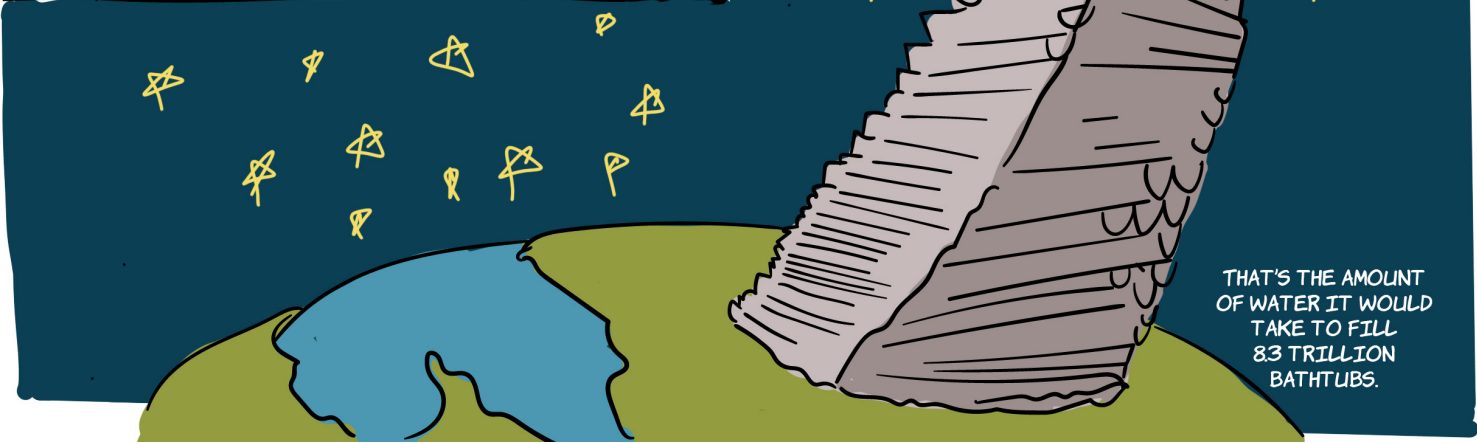


...ICE! EVEN THOUGH THE ICE SHEET WAS MELTING, IT DID NOT MELT ALL AT ONCE. IN SOME PLACES, LIKE WHAT IS TODAY CLARK FORD, IDAHO IN THE BITTERROOT MOUNTAINS, THICK ICE REMAINED TO BLOCK THE FLOW OF WATER.

THE MELTWATER KEPT COMING AND THE DAM KEPT BLOCKING IT, WHICH CREATED A HUGE LAKE OVER 200 MILES LONG. WE NAMED IT LAKE MISSOULA.



AT ITS BIGGEST SIZE, LAKE MISSOULA CONTAINED ABOUT 600 CUBIC MILES (2500 CUBIC KILOMETERS) OF WATER.



THAT'S THE AMOUNT OF WATER IT WOULD TAKE TO FILL 83 TRILLION BATHTUBS.

THE LAKE WAS ONLY TEMPORARY, THOUGH, BECAUSE OF SOMETHING WEIRD ABOUT WATER.

WATER IS ONE OF THE ONLY SUBSTANCES WHOSE SOLID STATE (ICE) FLOATS ON ITS LIQUID STATE (WATER).

Look familiar?



WHEN THE WATER IN LAKE MISSOULA GOT REALLY DEEP, THERE WAS ENOUGH WATER TO MAKE THE ICE DAM FLOAT.



THE LAKE WATER SURGED UNDER THE GLACIER WITH SO MUCH POWER, IT SMASHED THE ICE DAM TO PIECES.*



*THIS IS PROBABLY WHAT HAPPENED TO THE LAKE MISSOULA ICE DAM, BUT THERE ARE OTHER WAYS GLACIAL FLOODS, AKA JÖKULHLAUPS, CAN HAPPEN. - KNEE-KNOCKING KEVIN

THE GLACIAL FLOOD WAS HUNDREDS OF FEET HIGH AND TRAVELED AT SPEEDS OF 65 MILES (105 KILOMETERS) PER HOUR ACROSS IDAHO AND WASHINGTON.

AND THEN FOLLOWED THE COLUMBIA GORGE TO THE PACIFIC.

Ice dam was here

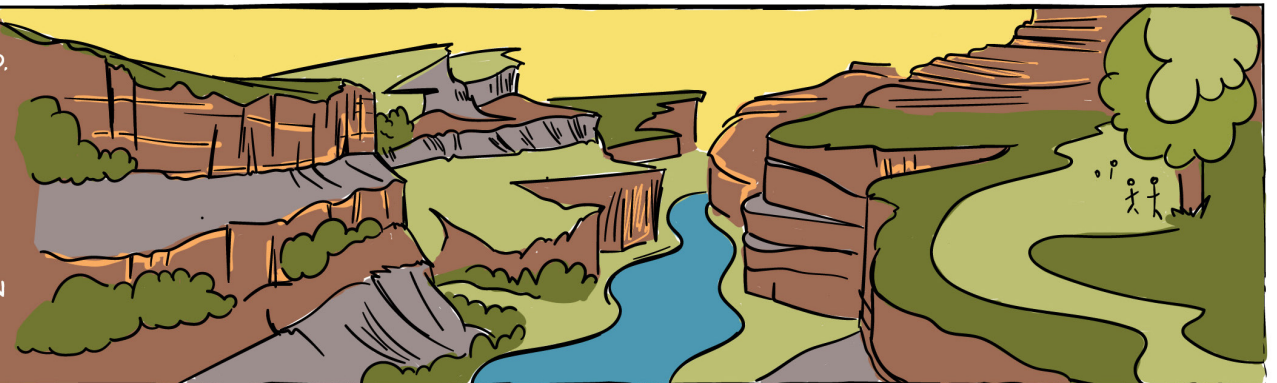


600 CUBIC MILES (2,500 CUBIC KILOMETERS) OF LAKE WATER RUSHED OUT.

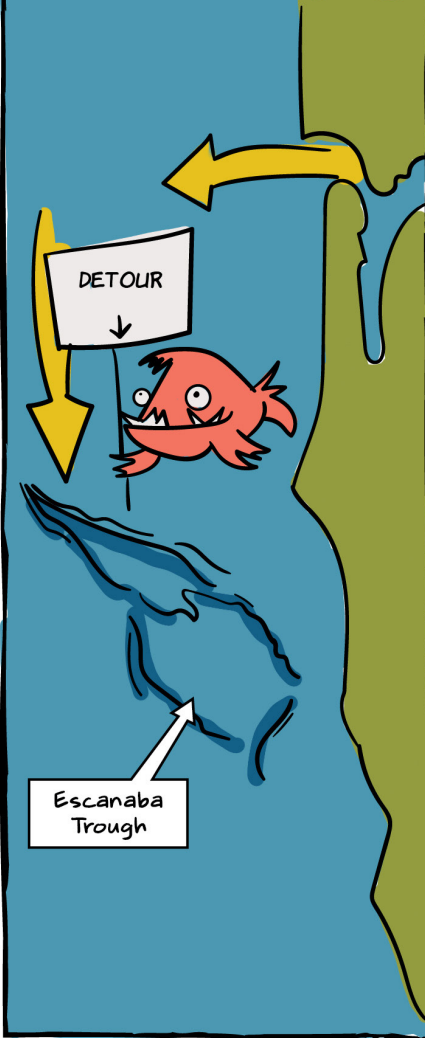
LIKE 67 TRILLION OF YOUR STRONGEST FRIENDS DUMPING 67 TRILLION BATHTUBS OF WATER DOWN THE WORLD'S BIGGEST WATERSLIDE AT THE SAME TIME.

AS IT TRAVELED, IT CARVED UP THE LANDSCAPE AND CARRIED HUGE AMOUNTS OF SEDIMENT.

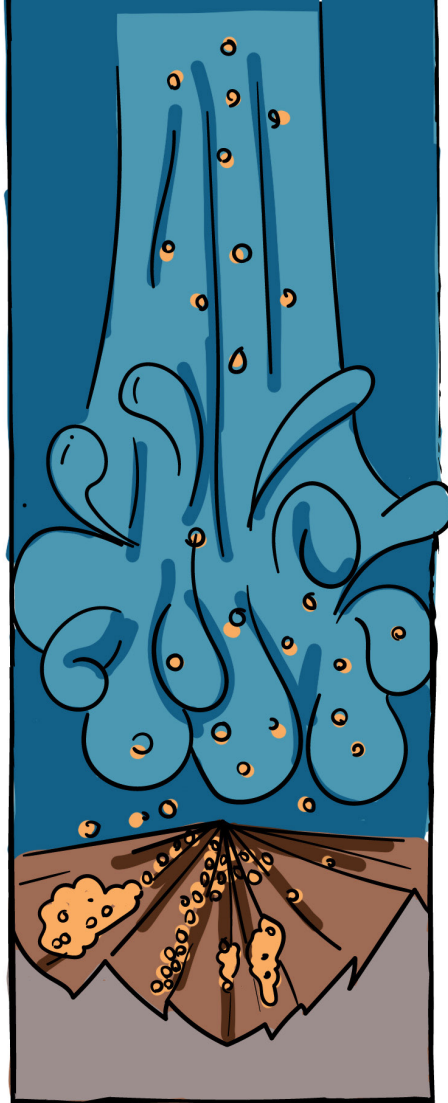
THE CANYONS AND COLLEES IT CREATED CAN STILL BE SEEN TODAY.



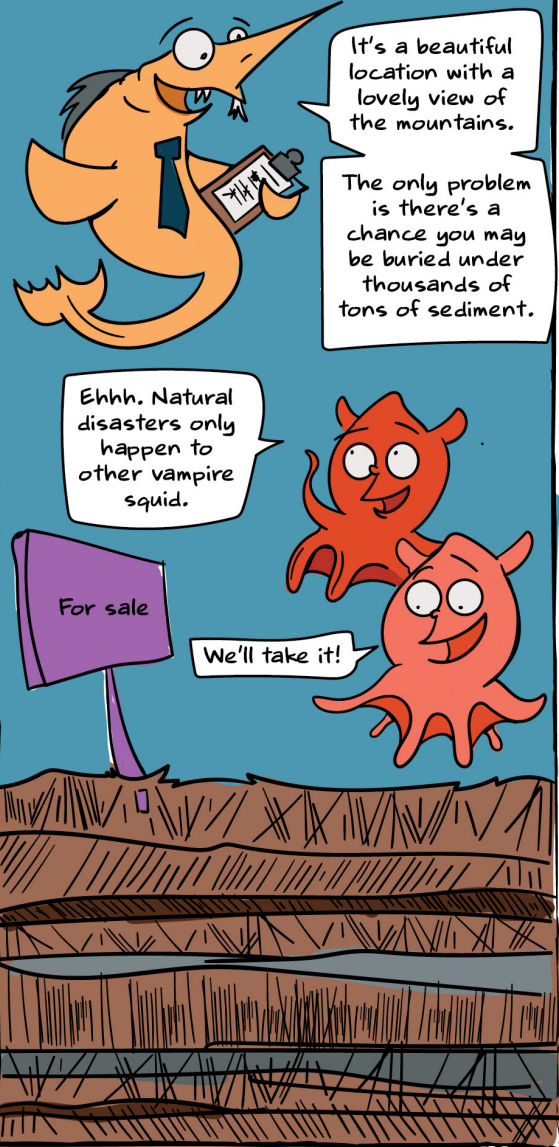
WHEN THE FLOOD REACHED THE PACIFIC, IT HAD ENOUGH POWER TO KEEP FLOWING FOR HUNDREDS OF MILES, THOUGH THE CHANNELS AND MOUNTAINS UNDERWATER CAUSED THE FLOOD TO MAKE A SHARP LEFT TURN AND HEAD SOUTH TO THE ESCANABA TROUGH.



THERE IT PETERED OUT ENOUGH TO DUMP A BUNCH OF ITS SEDIMENT ALL AT ONCE AND CREATED THE LAYER IN THE SEAFLOOR WHERE THE CORES CAME FROM.



AND THIS WASN'T A ONE-TIME DEAL. THERE WAS MORE THAN ONE LAYER IN THE ESCANABA TROUGH CREATED BY HUGE GLACIAL FLOODS.



It's a beautiful location with a lovely view of the mountains.

The only problem is there's a chance you may be buried under thousands of tons of sediment.

Ehhh. Natural disasters only happen to other vampire squid.

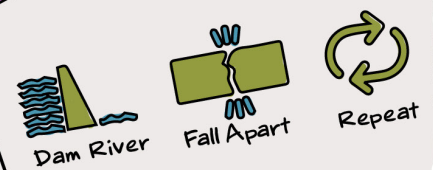
We'll take it!

For sale

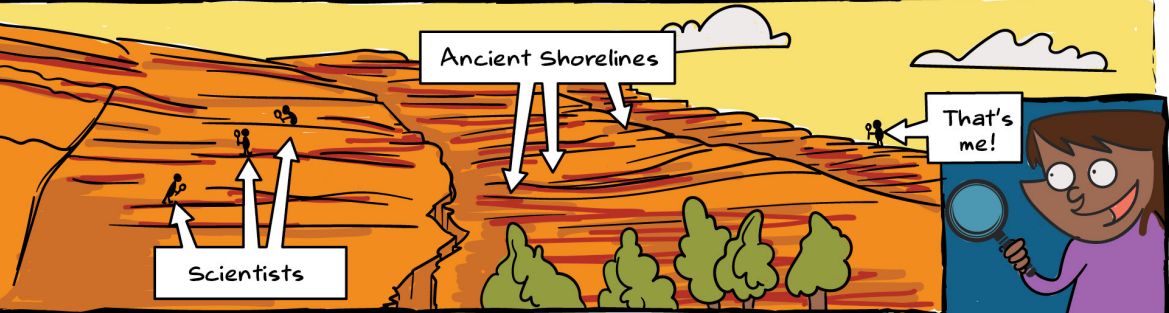
IT WAS STILL COLD ENOUGH THAT THE ICE DAM WOULD REFORM, LAKE MISSOULA WOULD REFILL, AND THEN THE DAM WOULD REBREAK, AND A FLOOD WOULD HAPPEN AGAIN. AND AGAIN. AND AGAIN.



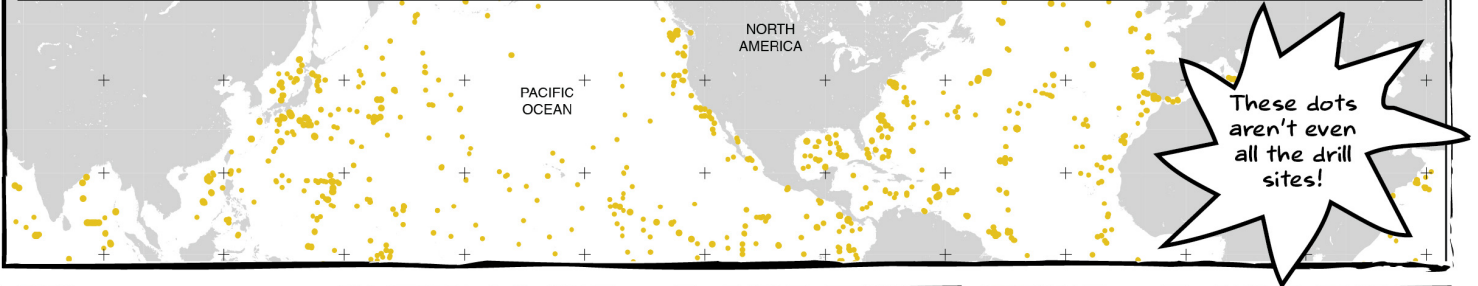
HOW TO CAUSE MULTIPLE MASSIVE FLOODS IN 3 EASY STEPS



READING THE CORES PROVIDED THE EVIDENCE OF THIS, BUT SO DID ROCKS AND SEDIMENT READ BY SCIENTISTS IN OTHER PLACES, SUCH AS THE SHORELINES OF LAKE MISSOULA VISIBLE IN THE MOUNTAINS ABOVE MISSOULA, MONTANA.



THESE CORES CAME FROM JUST ONE OF THE PLACES WHERE THE INTERNATIONAL OCEAN DISCOVERY PROGRAM'S RESEARCH SHIPS HAVE DRILLED THE SEAFLOOR.



AND THE CORES DON'T JUST TELL STORIES ABOUT GLACIAL FLOODS. THEY HAVE REVEALED STORIES ABOUT...

PAST CLIMATE CHANGE.



PAST MASS EXTINCTIONS



CREATURES LIVING INSIDE ROCKS AND SEDIMENT.



NEXT ISSUE: YOU'LL FIND OUT MORE CORE STORIES AND LEARN ANSWERS TO QUESTIONS LIKE:

WILL GERTIE THE NARRATOR'S CAT MAKE AN APPEARANCE. OR HAS FAME GONE TO HER HEAD?

IF YOU STOOD IN ONE PLACE ON THE SEAFLOOR FOR A LONG TIME, COULD YOU TRAVEL HUNDREDS OF MILES?

ARE MOST OF THE WORLD'S VOLCANOES UNDERWATER?

ARE TSUNAMIS CAUSED BY THE SEAFLOOR ACTING LIKE A DIVING BOARD?

SEE YOU THERE!

ABOUT THE AUTHOR

KEVIN KURTZ* IS AN AWARD-WINNING AUTHOR OF NONFICTION CHILDREN'S BOOKS ABOUT SCIENCE AND NATURE WHO ALSO LOVES COMICS. HE HAS ALSO BEEN AN EDUCATOR AT AN AQUARIUM, A SCIENCE MUSEUM, AND ON RESEARCH SHIPS WORKING WITH SCIENTISTS.

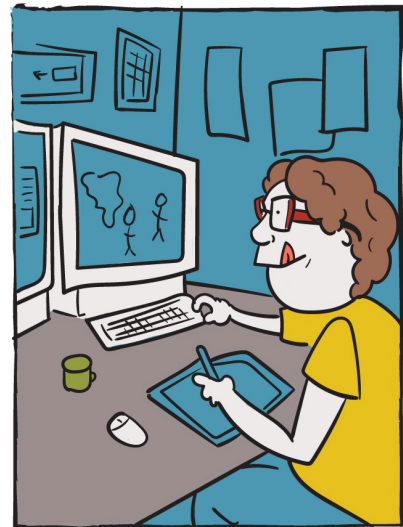
KEVIN LIVES IN ROCHESTER, NEW YORK, WHERE HE CONTINUES TO WRITE BOOKS AND DO PROGRAMS WITH SCHOOLS AROUND THE WORLD TO INTRODUCE CHILDREN TO THE WONDERS OF READING, WRITING, SCIENCE, AND NATURE. LEARN MORE ABOUT HIM AT HIS WEBSITE WWW.KEVKURTZ.COM.



ABOUT THE ILLUSTRATOR

NICOLE KURTZ* IS AN ARTIST DEDICATED TO USING HER SKILLS TO HELP OTHERS GET THE MOST OUT OF THEIR EDUCATION. SHE HAS WORKED AS AN EXHIBIT DESIGNER, FORENSIC ANIMATOR FOR THE COURTROOM, DEVELOPER OF CARD GAMES, AND AS A SCIENTIFIC ILLUSTRATOR ON RESEARCH SHIPS. HER PASSION LIES IN FIGURING OUT THE BEST WAY TO VISUALLY COMMUNICATE COMPLEX TOPICS WITH HUMOR.

NICOLE LIVES IN AUSTIN, TEXAS, WHERE SHE OPERATES HER BUSINESS AS AN INSTRUCTIONAL DESIGNER AND BRAND MARKETER FOR SERVICE SUPPORT INDUSTRIES. THIS WORK ALLOWS HER TO DEVELOP EDUCATIONAL TOOLS FOR BUSINESSES RANGING FROM HEALTHCARE PROVIDERS ASSISTING CHILDREN ON THE AUTISM SPECTRUM TO ORGANIZATIONS FOCUSED ON IMPROVING DIVERSITY IN THE CLASSROOM. LEARN MORE ABOUT NICOLE AND HER WORK AT ADUCATEDIGITAL.COM.



ABOUT THE SCIENCE ADVISOR

PATRICK FULTON IS AN ASSISTANT PROFESSOR OF EARTH AND ATMOSPHERIC SCIENCES AT CORNELL UNIVERSITY IN ITHACA, NEW YORK. AS A GEOSCIENTIST, PATRICK HAS SAILED ON SEVERAL SCIENTIFIC OCEAN DRILLING EXPEDITIONS OFF-SHORE NEW ZEALAND AND JAPAN AND IS PARTICULARLY INTERESTED IN UNDERSTANDING HOW EARTHQUAKES WORK AND HOW WATER FLOWS IN FAULTS AND FRACTURES UNDERGROUND.

A LOT OF WHAT HE HAS LEARNED FROM OCEAN DRILLING HE IS ALSO USING TO EXPLORE WAYS TO SUPPLY CLEAN RENEWABLE GEOTHERMAL HEAT ENERGY THROUGH DEEP BOREHOLES DRILLED ON LAND.



*Kevin and Nicole are seriously not related (they checked) and they're not married to one another either (they checked that too). Their love of science communication brought them individually to the International Ocean Discovery Program where they sailed as Outreach Officers on expeditions communicating the science onboard to classrooms around the world.

They've worked together since 2013 on a variety of animations, traveling exhibits, and award-winning comic books. Learn more about these other projects at JOIDESRESOLUTION.ORG - Kismet Kevin

How To READ A ROCK

A Graphic Novel on Ocean Science

HAVE YOU EVER WANTED TO READ A ROCK?

WE'RE GUESSING, PROBABLY NOT.

BUT AFTER READING THIS COMIC, YOU MAY
CHANGE YOUR MIND.

SCIENTISTS HAVE LEARNED A LOT ABOUT
THE EARTH THROUGH SCIENTIFIC OCEAN
DRILLING, WHERE THEY BRING UP ROCKS
FROM UNDER THE SEAFLOOR TO STUDY THEM.

THIS IS THE TRUE STORY,

TOLD IN THE GOOFIEST WAY POSSIBLE, OF
HOW SCIENTISTS READ ROCKS FROM UNDER
THE SEAFLOOR THAT HELPED TELL THE
STORY OF ONE OF THE MOST CATAclySMIC
EVENTS OF THE LAST 20,000 YEARS.

