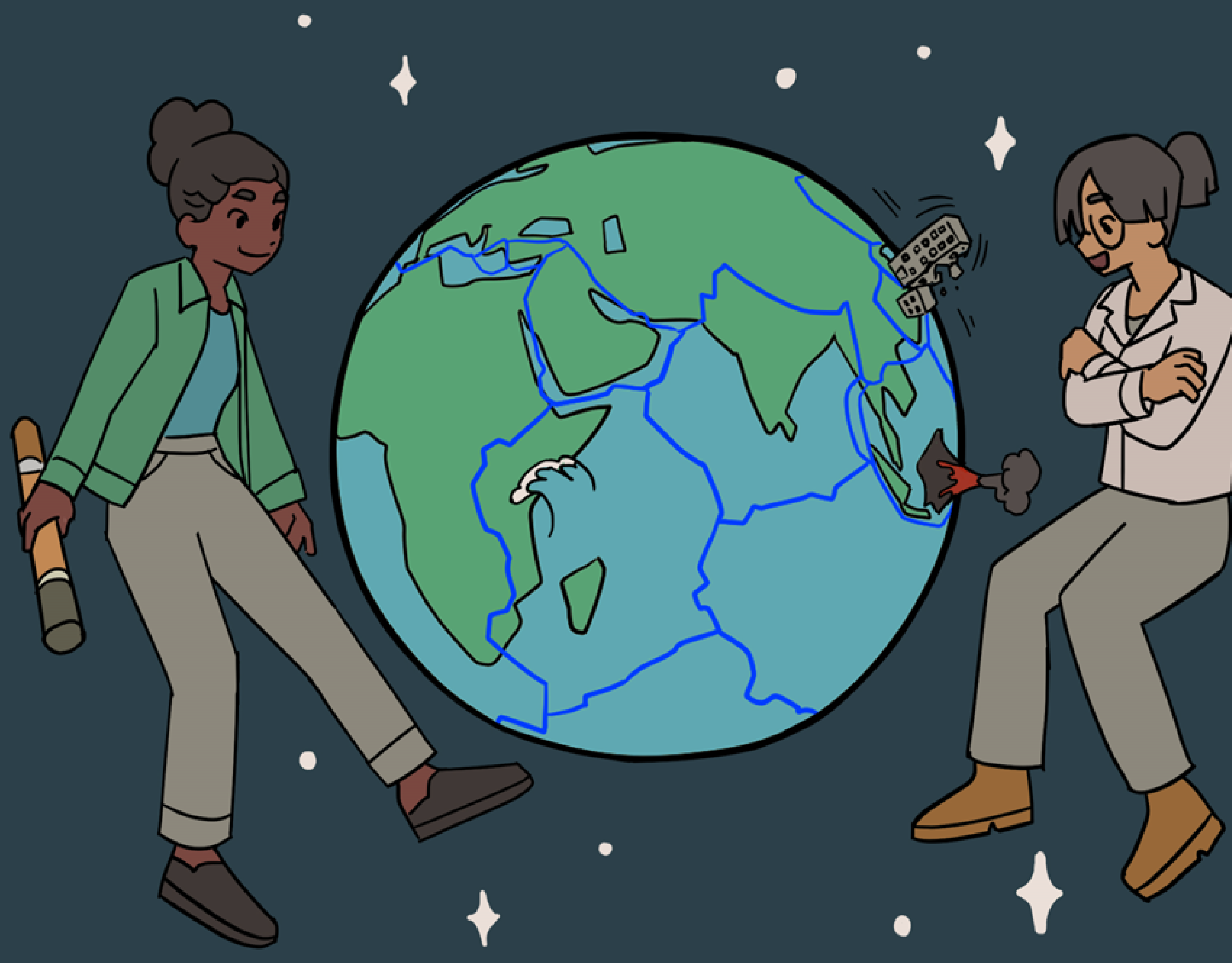
How To

READ A ROCK

Vol. 2

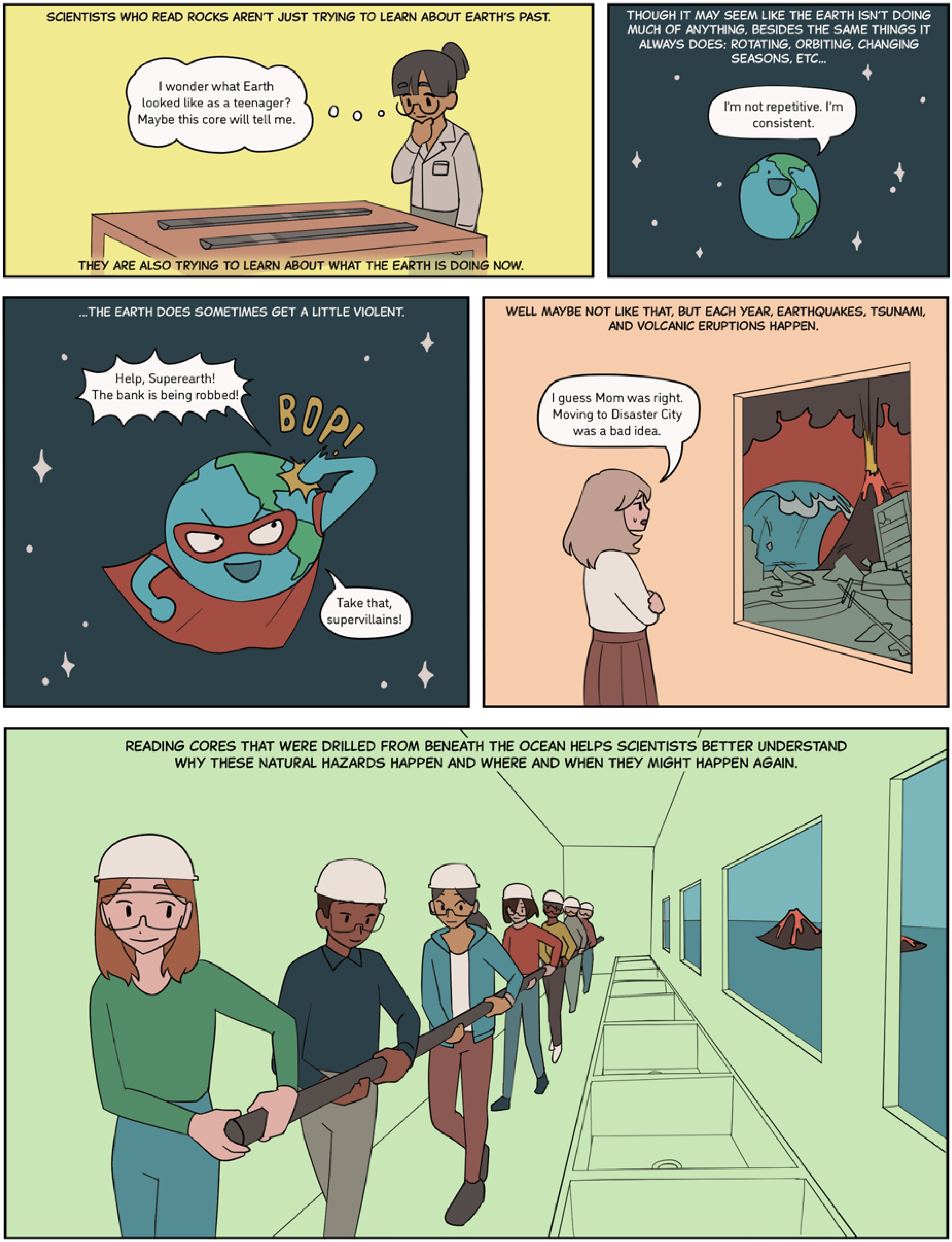


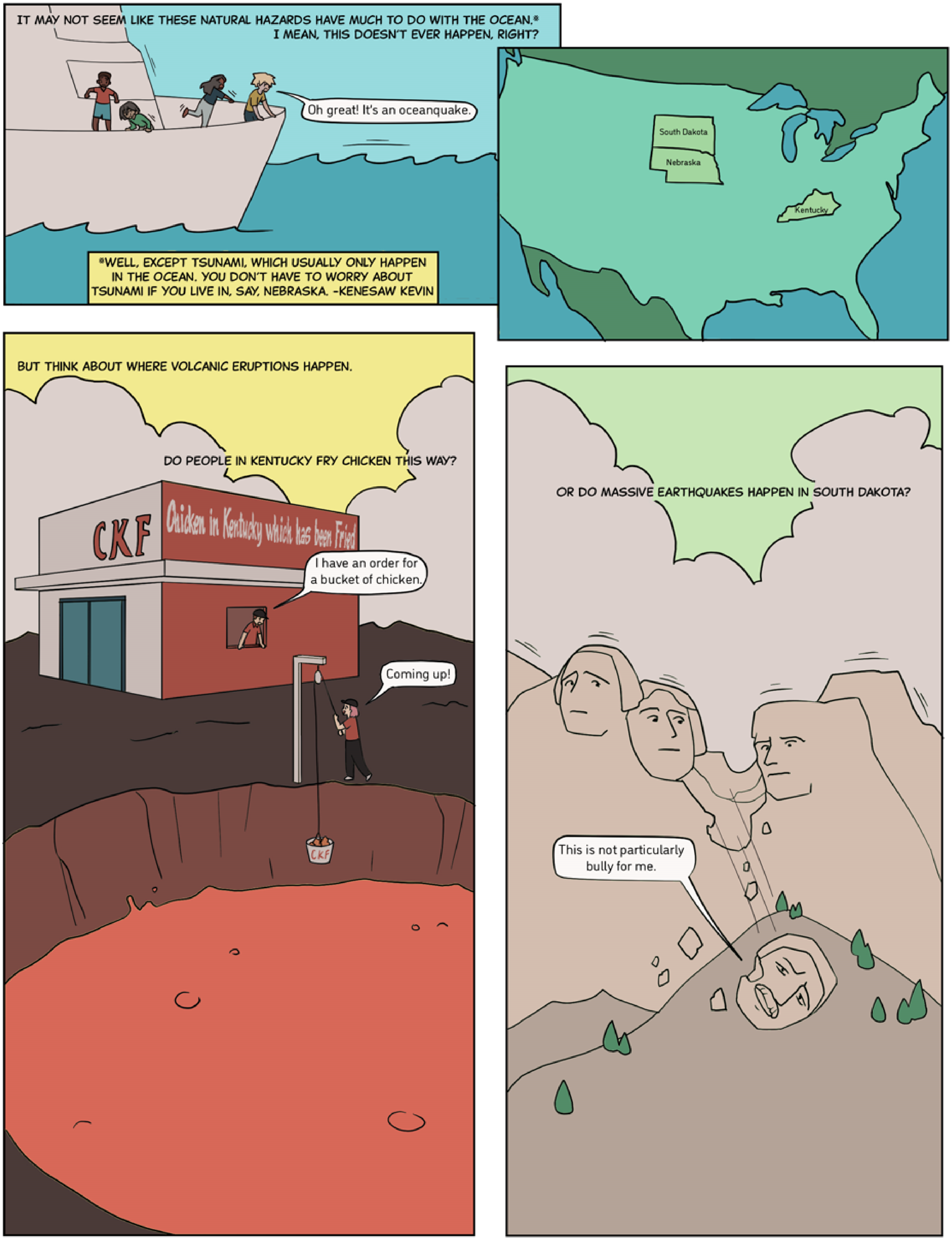
A Graphic Novel About Earthquakes, Tsunami, Volcanoes, Plate Tectonics, and the Scientists who Love Them

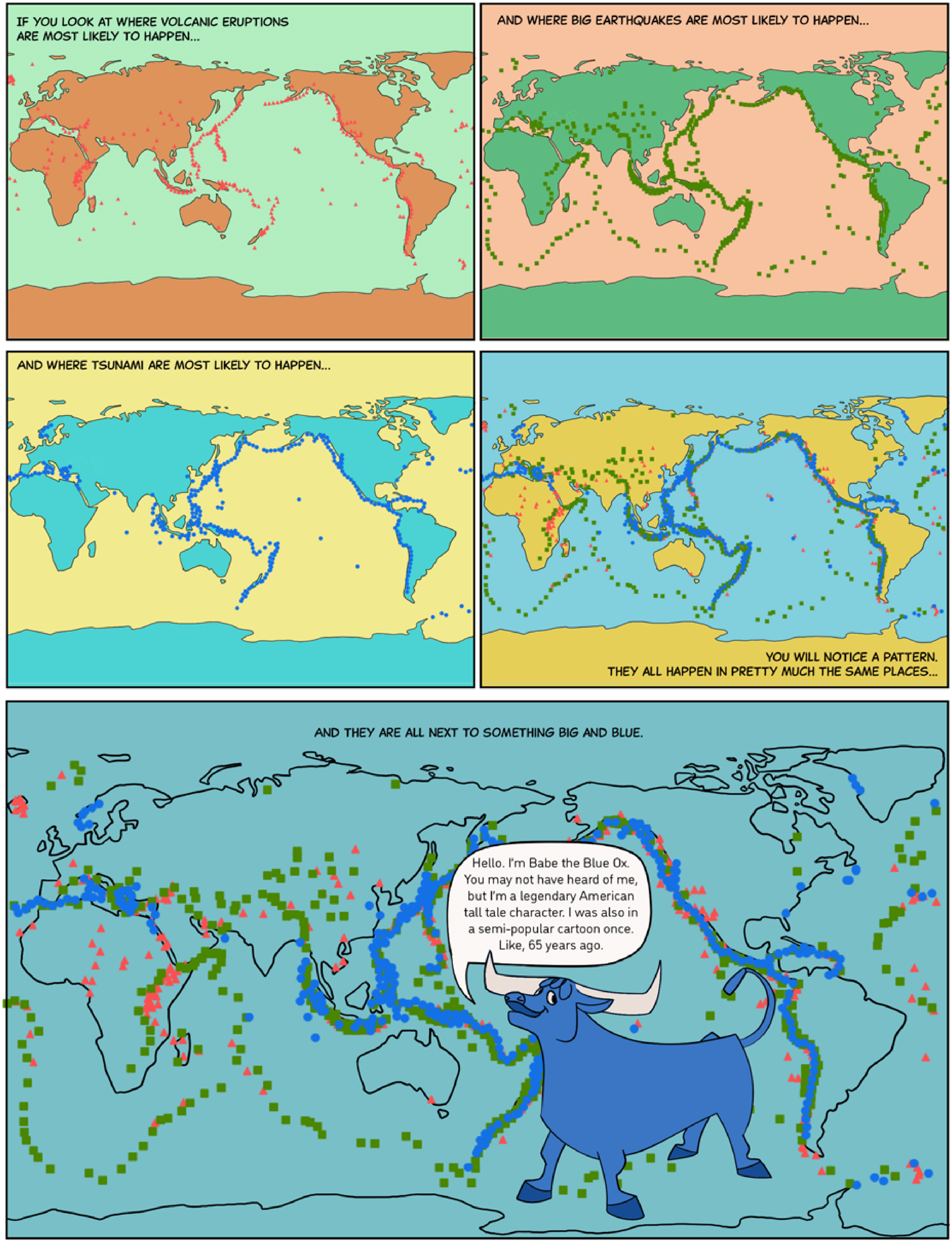
VOL. 2
AUG '23

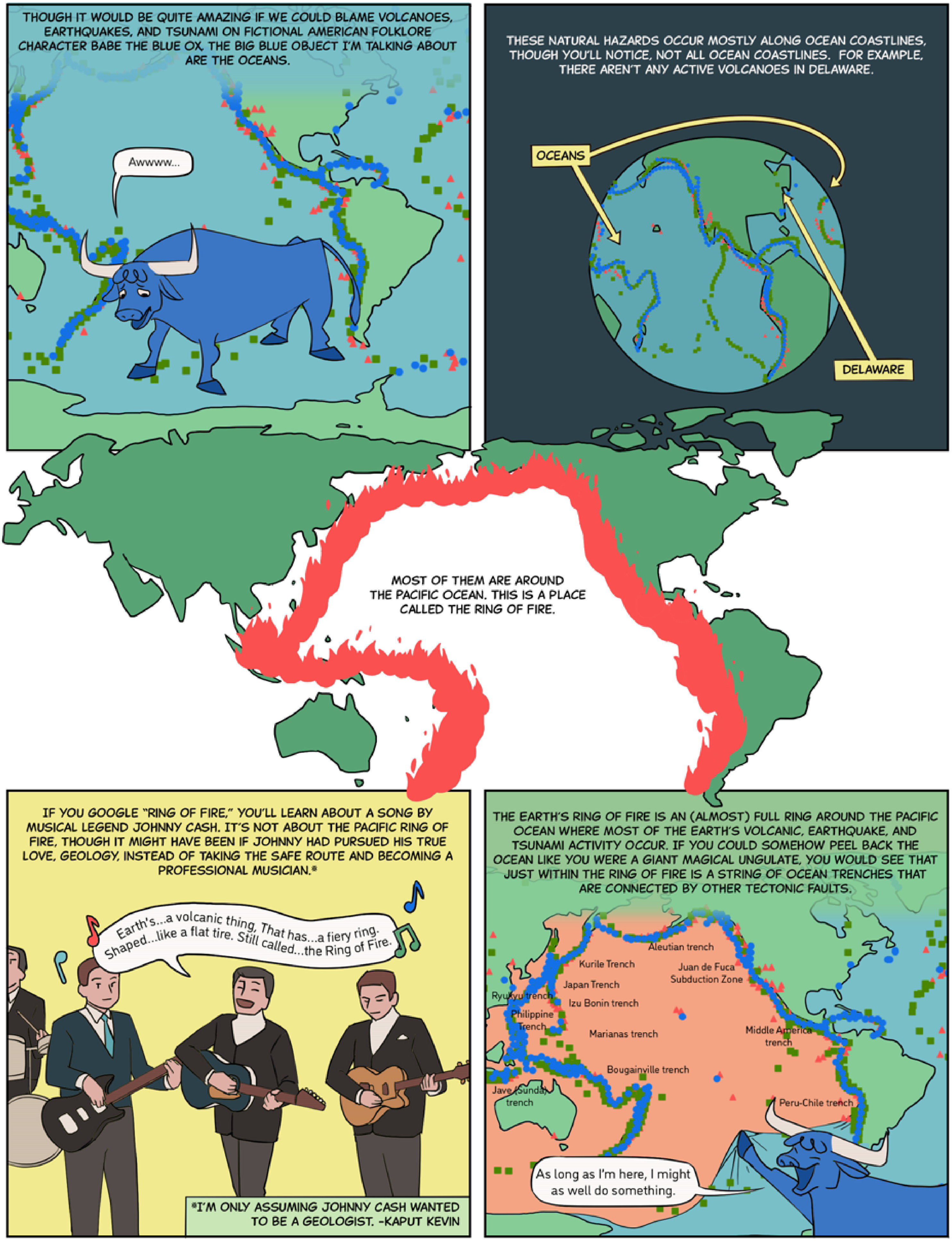
Written by Kevin Kurtz
Illustrated by Star Ren
Fact-checked by Dr. Patrick Fulton

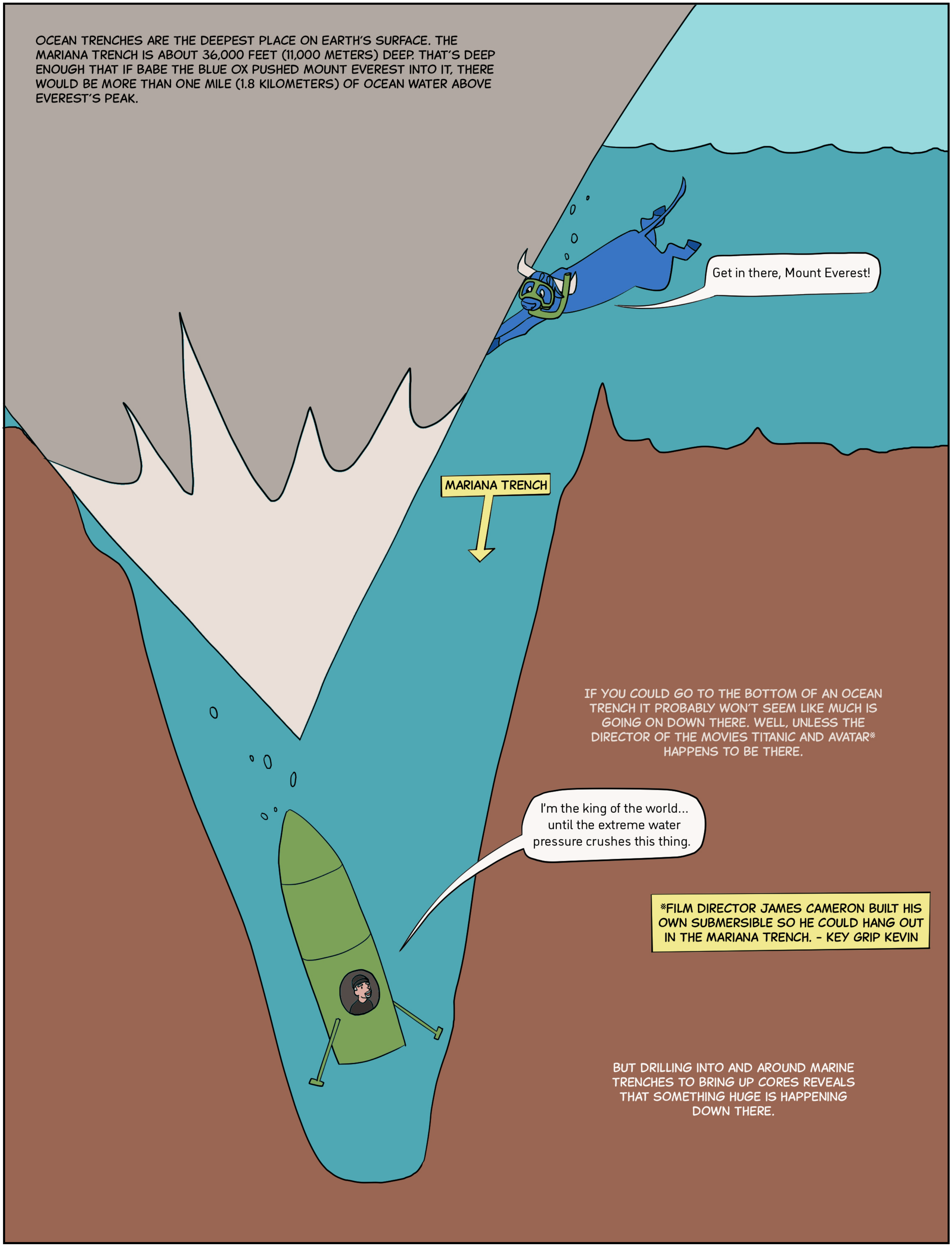
IODP INTERNATIONAL OCEAN DISCOVERY PROGRAM
NSF
IN SEARCH OF EARTH'S SECRETS

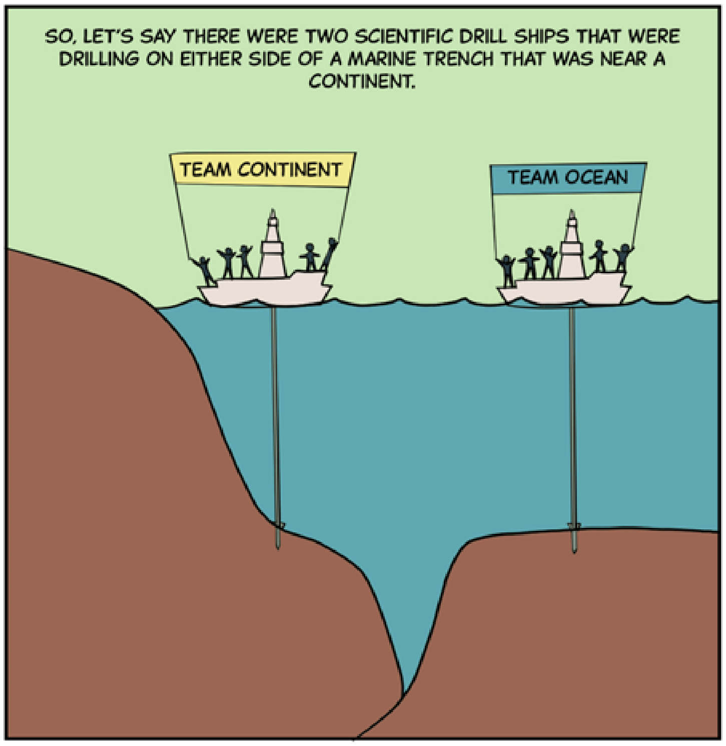

SCIENTISTS WHO READ ROCKS AREN'T JUST TRYING TO LEARN ABOUT EARTH'S PAST.
I wonder what Earth looked like as a teenager? Maybe this core will tell me.
THEY ARE ALSO TRYING TO LEARN ABOUT WHAT THE EARTH IS DOING NOW.
THOUGH IT MAY SEEM LIKE THE EARTH ISN'T DOING MUCH OF ANYTHING, BESIDES THE SAME THINGS IT ALWAYS DOES: ROTATING, ORBITING, CHANGING SEASONS, ETC...
I'm not repetitive. I'm consistent.
...THE EARTH DOES SOMETIMES GET A LITTLE VIOLENT.
Help, Superearth! The bank is being robbed!
BOP!
Take that, supervillains!
WELL MAYBE NOT LIKE THAT, BUT EACH YEAR, EARTHQUAKES, TSUNAMI, AND VOLCANIC ERUPTIONS HAPPEN.
I guess Mom was right. Moving to Disaster City was a bad idea.
READING CORES THAT WERE DRILLED FROM BENEATH THE OCEAN HELPS SCIENTISTS BETTER UNDERSTAND WHY THESE NATURAL HAZARDS HAPPEN AND WHERE AND WHEN THEY MIGHT HAPPEN AGAIN.

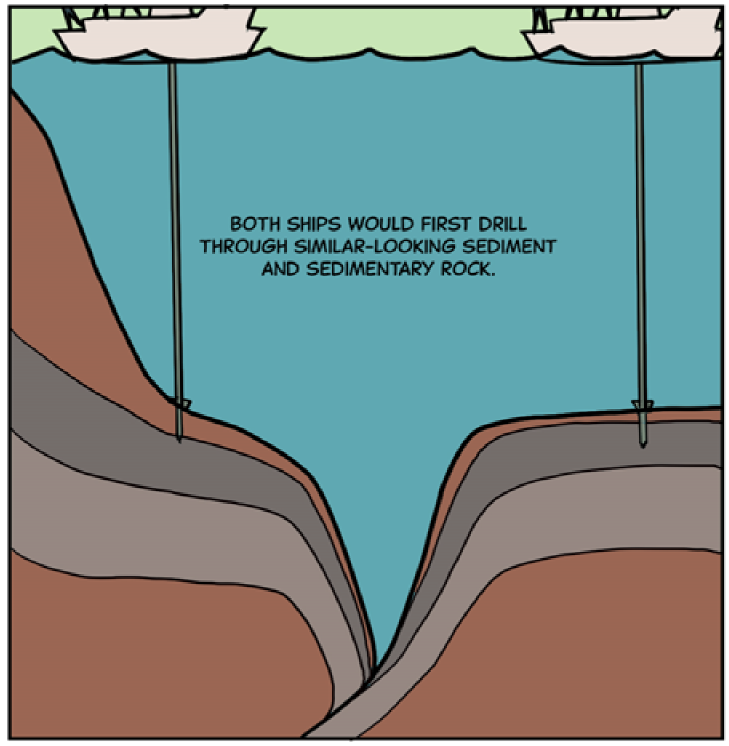

IT MAY NOT SEEM LIKE THESE NATURAL HAZARDS HAVE MUCH TO DO WITH THE OCEAN.*
I MEAN, THIS DOESN'T EVER HAPPEN, RIGHT?
Oh great! It's an oceanquake.
*WELL, EXCEPT TSUNAMI, WHICH USUALLY ONLY HAPPEN IN THE OCEAN. YOU DON'T HAVE TO WORRY ABOUT TSUNAMI IF YOU LIVE IN, SAY, NEBRASKA. -KENESAW KEVIN
South Dakota
Nebraska
Kentucky
BUT THINK ABOUT WHERE VOLCANIC ERUPTIONS HAPPEN.
DO PEOPLE IN KENTUCKY FRY CHICKEN THIS WAY?
CKF
Chicken in Kentucky which has been Fried
I have an order for a bucket of chicken.
Coming up!
CKF
OR DO MASSIVE EARTHQUAKES HAPPEN IN SOUTH DAKOTA?
This is not particularly bully for me.

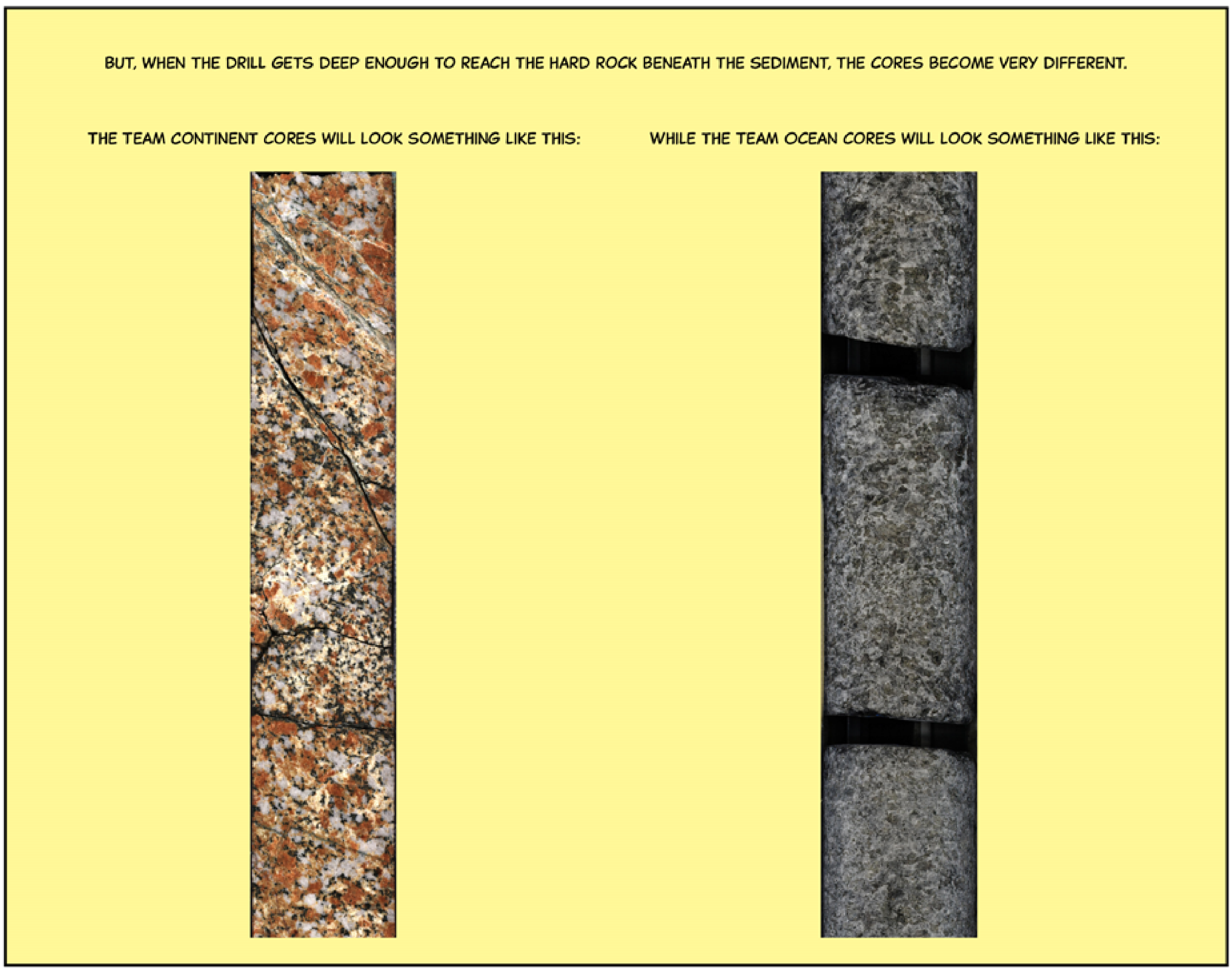

IF YOU LOOK AT WHERE VOLCANIC ERUPTIONS ARE MOST LIKELY TO HAPPEN...
AND WHERE BIG EARTHQUAKES ARE MOST LIKELY TO HAPPEN...
AND WHERE TSUNAMI ARE MOST LIKELY TO HAPPEN...
YOU WILL NOTICE A PATTERN. THEY ALL HAPPEN IN PRETTY MUCH THE SAME PLACES...
AND THEY ARE ALL NEXT TO SOMETHING BIG AND BLUE.
Hello. I'm Babe the Blue Ox. You may not have heard of me, but I'm a legendary American tall tale character. I was also in a semi-popular cartoon once. Like, 65 years ago.

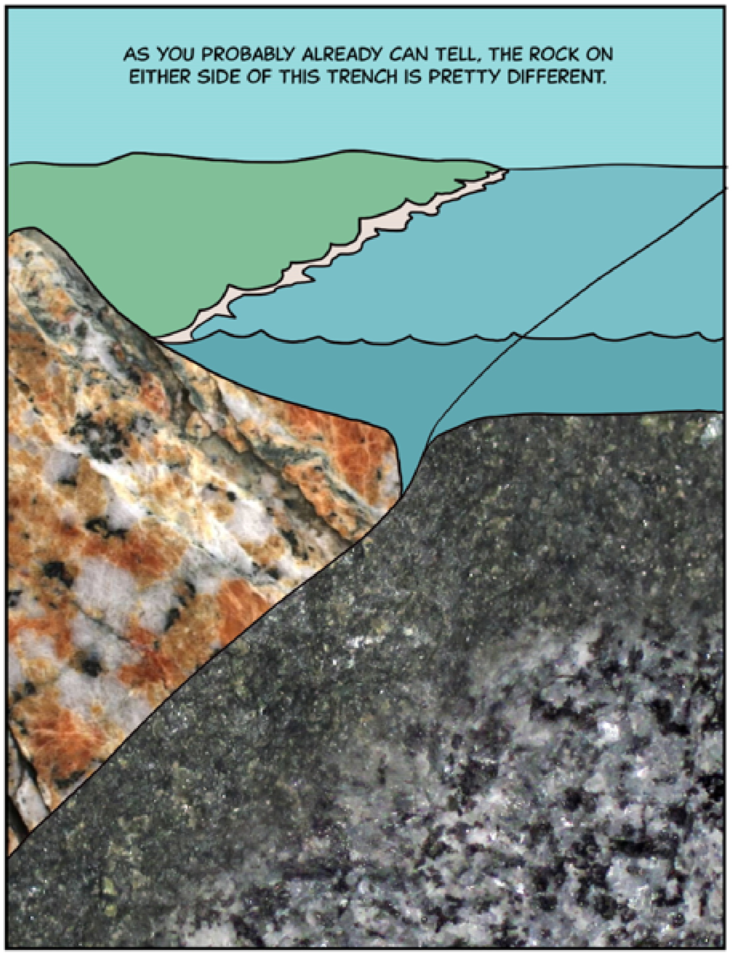

THOUGH IT WOULD BE QUITE AMAZING IF WE COULD BLAME VOLCANOES, EARTHQUAKES, AND TSUNAMI ON FICTIONAL AMERICAN FOLKLORE CHARACTER BABE THE BLUE OX, THE BIG BLUE OBJECT I'M TALKING ABOUT ARE THE OCEANS.
Awwww...
THESE NATURAL HAZARDS OCCUR MOSTLY ALONG OCEAN COASTLINES, THOUGH YOU'LL NOTICE, NOT ALL OCEAN COASTLINES. FOR EXAMPLE, THERE AREN'T ANY ACTIVE VOLCANOES IN DELAWARE.
OCEANS
DELAWARE
MOST OF THEM ARE AROUND THE PACIFIC OCEAN. THIS IS A PLACE CALLED THE RING OF FIRE.
IF YOU GOOGLE "RING OF FIRE," YOU'LL LEARN ABOUT A SONG BY MUSICAL LEGEND JOHNNY CASH. IT'S NOT ABOUT THE PACIFIC RING OF FIRE, THOUGH IT MIGHT HAVE BEEN IF JOHNNY HAD PURSUED HIS TRUE LOVE, GEOLOGY, INSTEAD OF TAKING THE SAFE ROUTE AND BECOMING A PROFESSIONAL MUSICIAN.*
Earth's...a volcanic thing, That has...a fiery ring. Shaped...like a flat tire. Still called...the Ring of Fire.
*I'M ONLY ASSUMING JOHNNY CASH WANTED TO BE A GEOLOGIST. -KAPUT KEVIN
THE EARTH'S RING OF FIRE IS AN (ALMOST) FULL RING AROUND THE PACIFIC OCEAN WHERE MOST OF THE EARTH'S VOLCANIC, EARTHQUAKE, AND TSUNAMI ACTIVITY OCCUR. IF YOU COULD SOMEHOW PEEL BACK THE OCEAN LIKE YOU WERE A GIANT MAGICAL UNGULATE, YOU WOULD SEE THAT JUST WITHIN THE RING OF FIRE IS A STRING OF OCEAN TRENCHES THAT ARE CONNECTED BY OTHER TECTONIC FAULTS.
Aleutian trench
Kurile Trench
Juan de Fuca Subduction Zone
Japan Trench
Ryukyu trench
Izu Bonin trench
Philippine Trench
Marianas trench
Middle America trench
Bougainville trench
Java (Sunda) trench
Peru-Chile trench
As long as I'm here, I might as well do something.

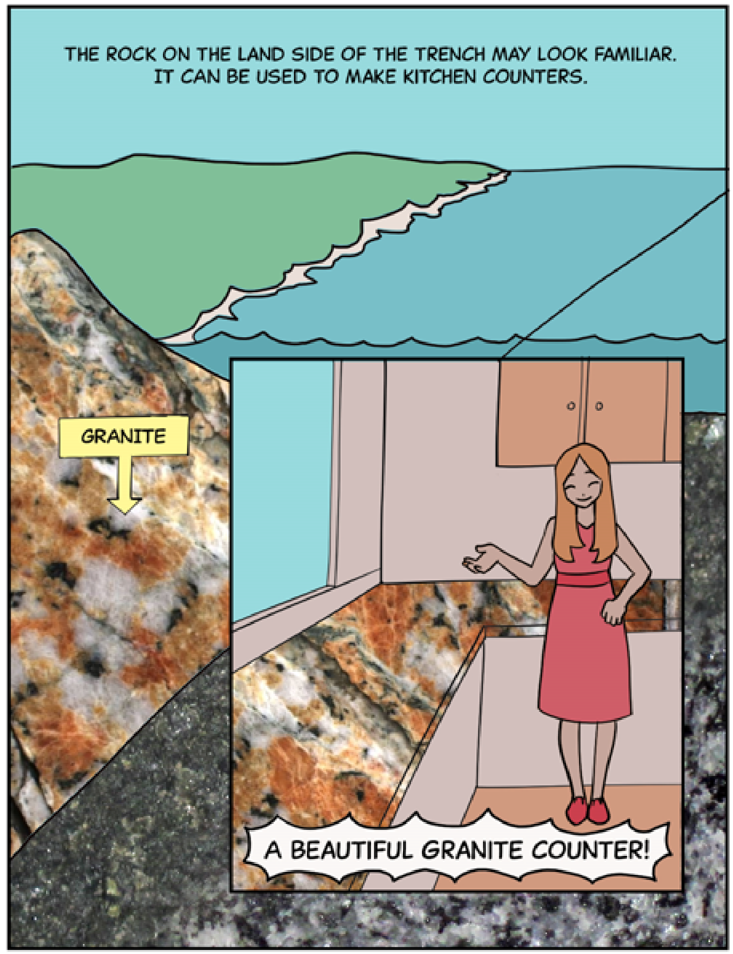

OCEAN TRENCHES ARE THE DEEPEST PLACE ON EARTH'S SURFACE. THE MARIANA TRENCH IS ABOUT 36,000 FEET (11,000 METERS) DEEP. THAT'S DEEP ENOUGH THAT IF BABE THE BLUE OX PUSHED MOUNT EVEREST INTO IT, THERE WOULD BE MORE THAN ONE MILE (1.8 KILOMETERS) OF OCEAN WATER ABOVE EVEREST'S PEAK.
Get in there, Mount Everest!
MARIANA TRENCH
IF YOU COULD GO TO THE BOTTOM OF AN OCEAN TRENCH IT PROBABLY WON'T SEEM LIKE MUCH IS GOING ON DOWN THERE. WELL, UNLESS THE DIRECTOR OF THE MOVIES TITANIC AND AVATAR* HAPPENS TO BE THERE.
I'm the king of the world... until the extreme water pressure crushes this thing.
*FILM DIRECTOR JAMES CAMERON BUILT HIS OWN SUBMERSIBLE SO HE COULD HANG OUT IN THE MARIANA TRENCH. - KEY GRIP KEVIN
BUT DRILLING INTO AND AROUND MARINE TRENCHES TO BRING UP CORES REVEALS THAT SOMETHING HUGE IS HAPPENING DOWN THERE.

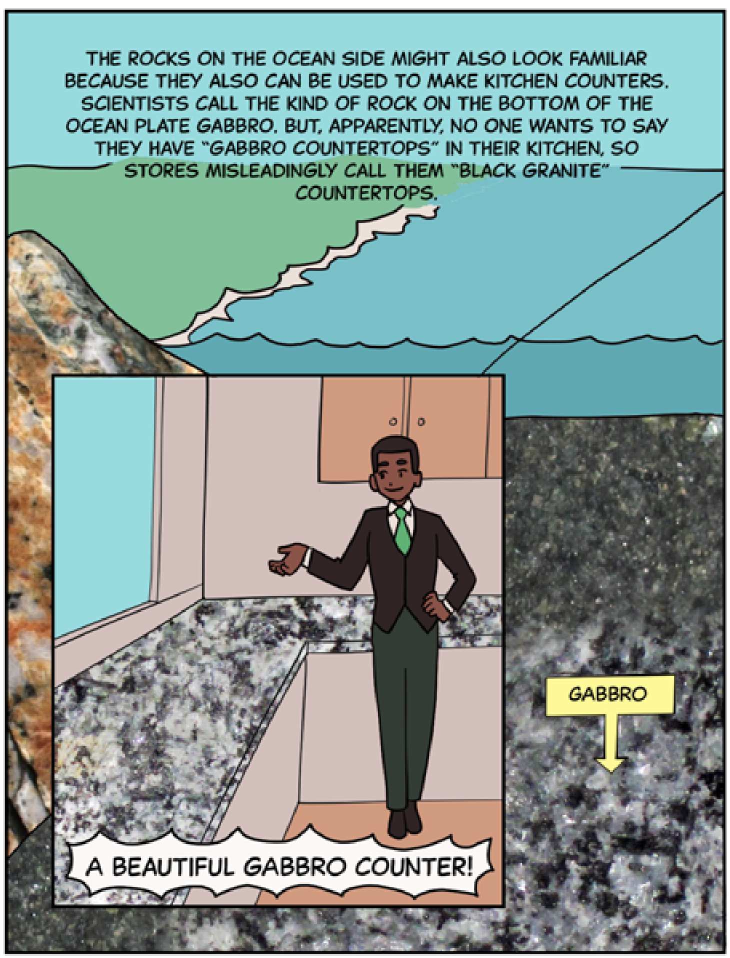

SO, LET'S SAY THERE WERE TWO SCIENTIFIC DRILL SHIPS THAT WERE DRILLING ON EITHER SIDE OF A MARINE TRENCH THAT WAS NEAR A CONTINENT.
TEAM CONTINENT
TEAM OCEAN

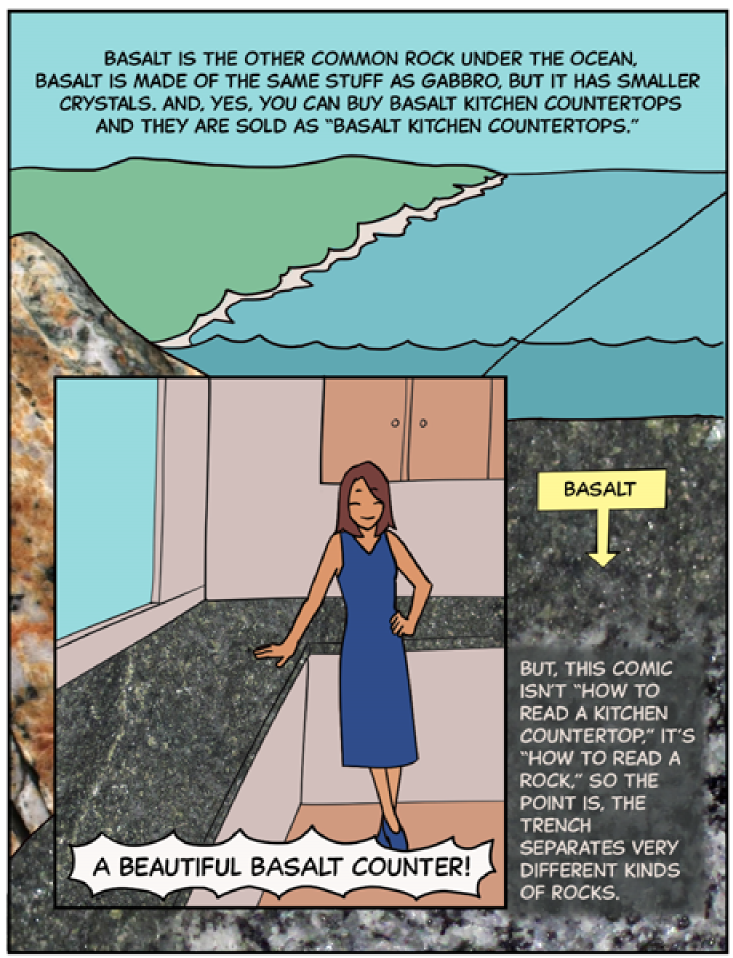

BOTH SHIPS WOULD FIRST DRILL THROUGH SIMILAR-LOOKING SEDIMENT AND SEDIMENTARY ROCK.

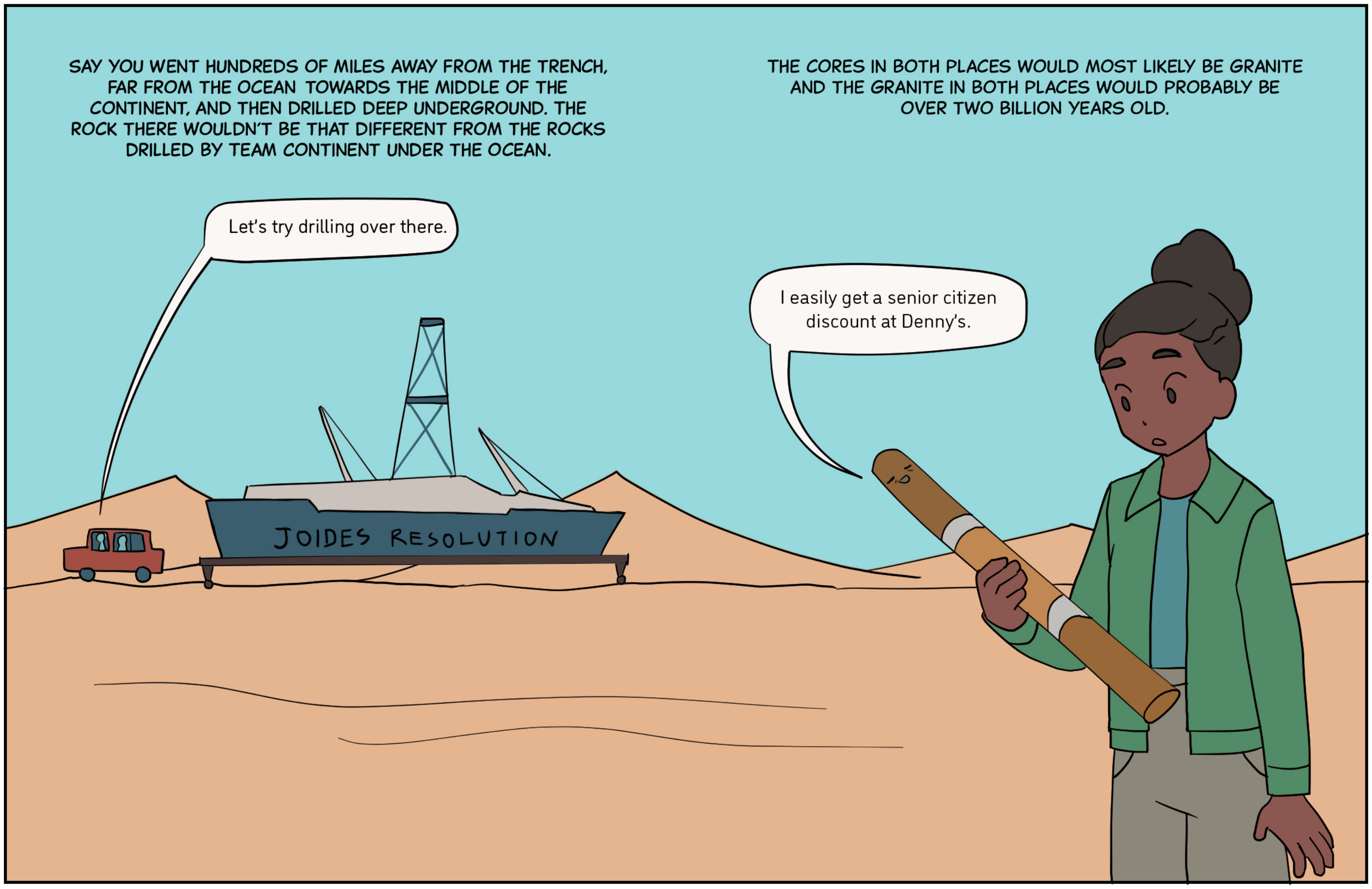

BUT, WHEN THE DRILL GETS DEEP ENOUGH TO REACH THE HARD ROCK BENEATH THE SEDIMENT, THE CORES BECOME VERY DIFFERENT.
THE TEAM CONTINENT CORES WILL LOOK SOMETHING LIKE THIS:
WHILE THE TEAM OCEAN CORES WILL LOOK SOMETHING LIKE THIS:

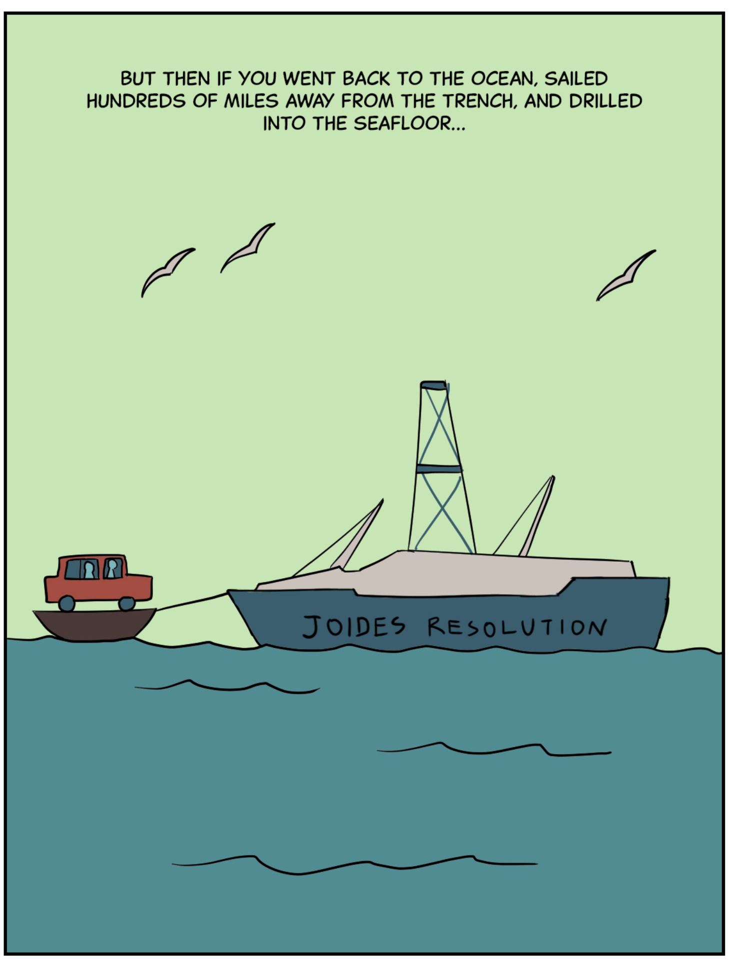

AS YOU PROBABLY ALREADY CAN TELL, THE ROCK ON EITHER SIDE OF THIS TRENCH IS PRETTY DIFFERENT.

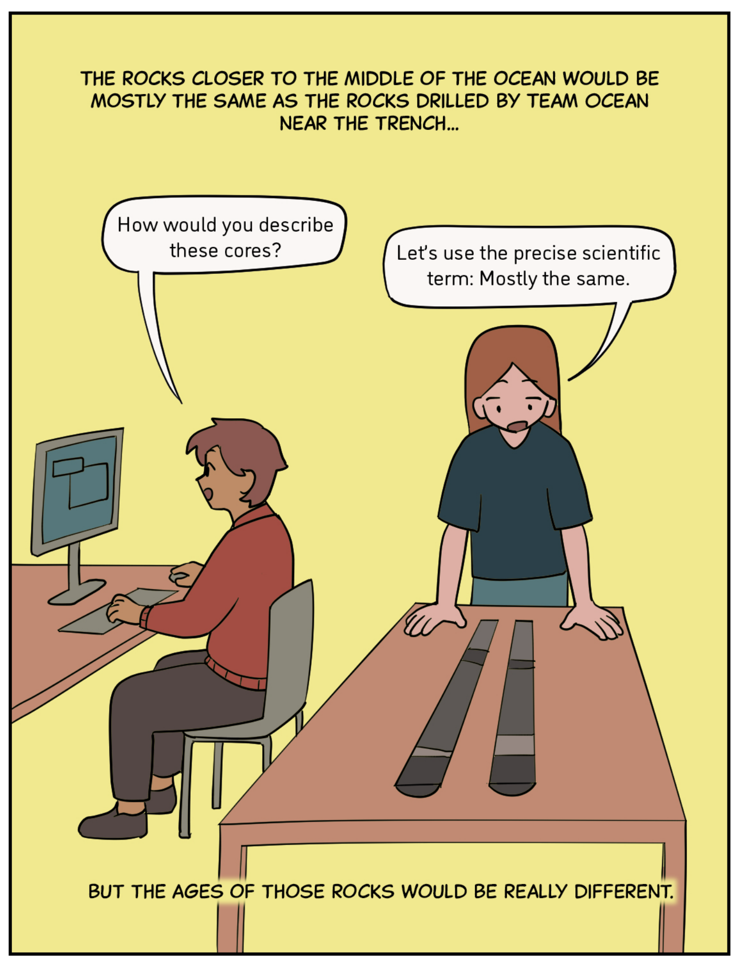

THE ROCK ON THE LAND SIDE OF THE TRENCH MAY LOOK FAMILIAR. IT CAN BE USED TO MAKE KITCHEN COUNTERS.
GRANITE
A BEAUTIFUL GRANITE COUNTER!

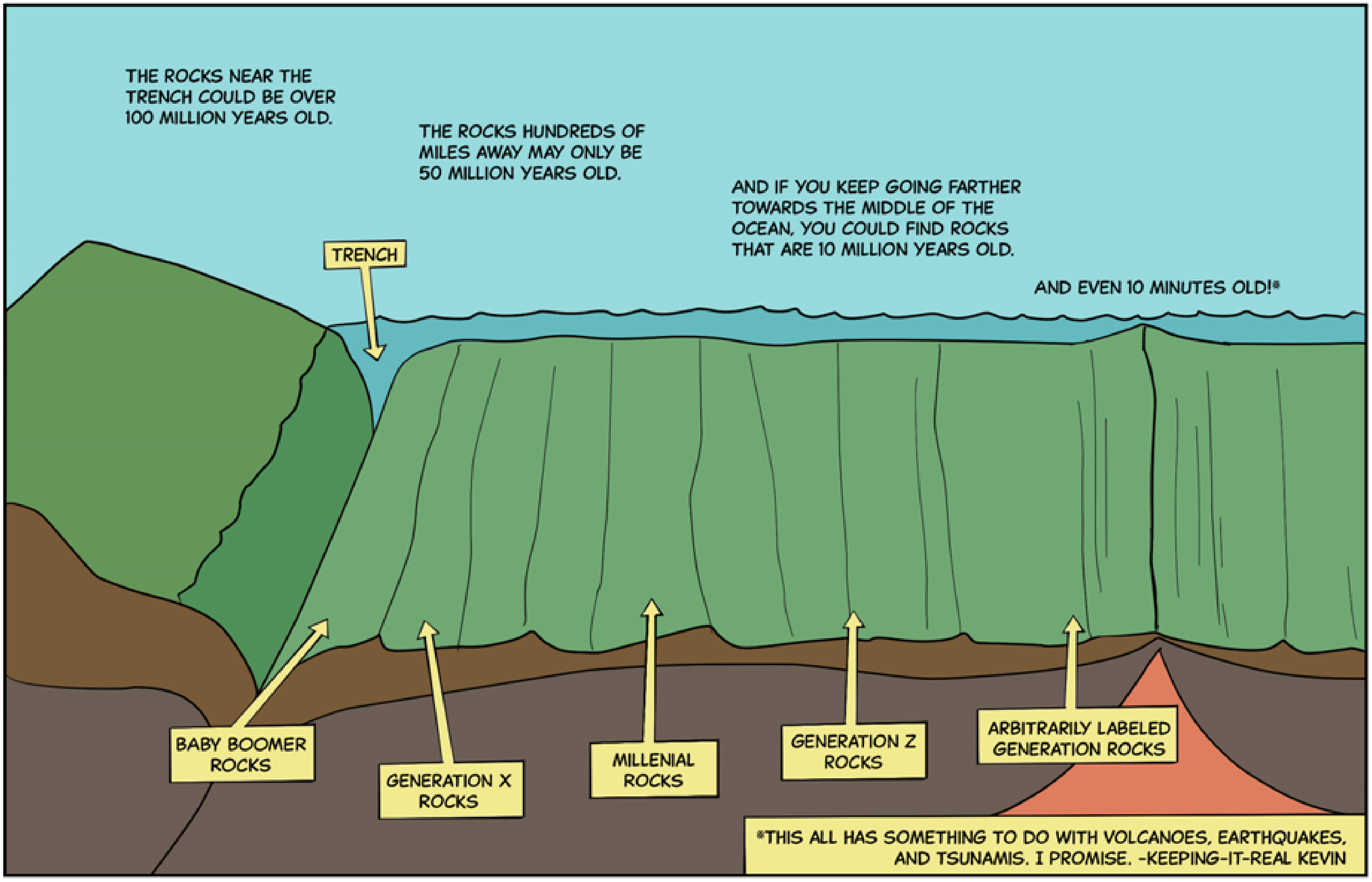

THE ROCKS ON THE OCEAN SIDE MIGHT ALSO LOOK FAMILIAR BECAUSE THEY ALSO CAN BE USED TO MAKE KITCHEN COUNTERS. SCIENTISTS CALL THE KIND OF ROCK ON THE BOTTOM OF THE OCEAN PLATE GABBRO. BUT, APPARENTLY, NO ONE WANTS TO SAY THEY HAVE "GABBRO COUNTERTOPS" IN THEIR KITCHEN, SO STORES MISLEADINGLY CALL THEM "BLACK GRANITE" COUNTERTOPS.
GABBRO
A BEAUTIFUL GABBRO COUNTER!

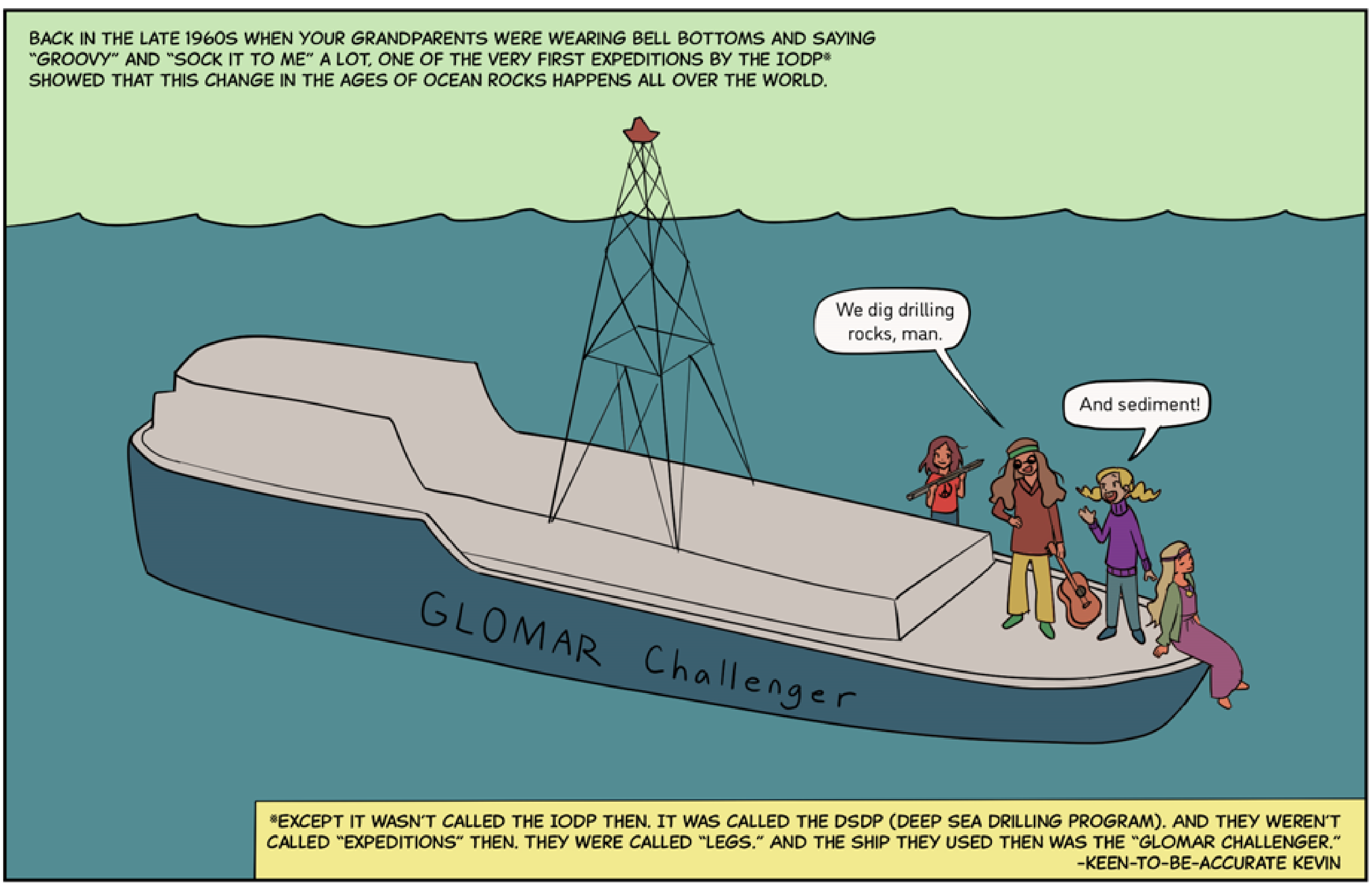

BASALT IS THE OTHER COMMON ROCK UNDER THE OCEAN. BASALT IS MADE OF THE SAME STUFF AS GABBRO, BUT IT HAS SMALLER CRYSTALS. AND, YES, YOU CAN BUY BASALT KITCHEN COUNTERTOPS AND THEY ARE SOLD AS "BASALT KITCHEN COUNTERTOPS."
BASALT
A BEAUTIFUL BASALT COUNTER!
BUT, THIS COMIC ISN'T "HOW TO READ A KITCHEN COUNTERTOP," IT'S "HOW TO READ A ROCK," SO THE POINT IS, THE TRENCH SEPARATES VERY DIFFERENT KINDS OF ROCKS.

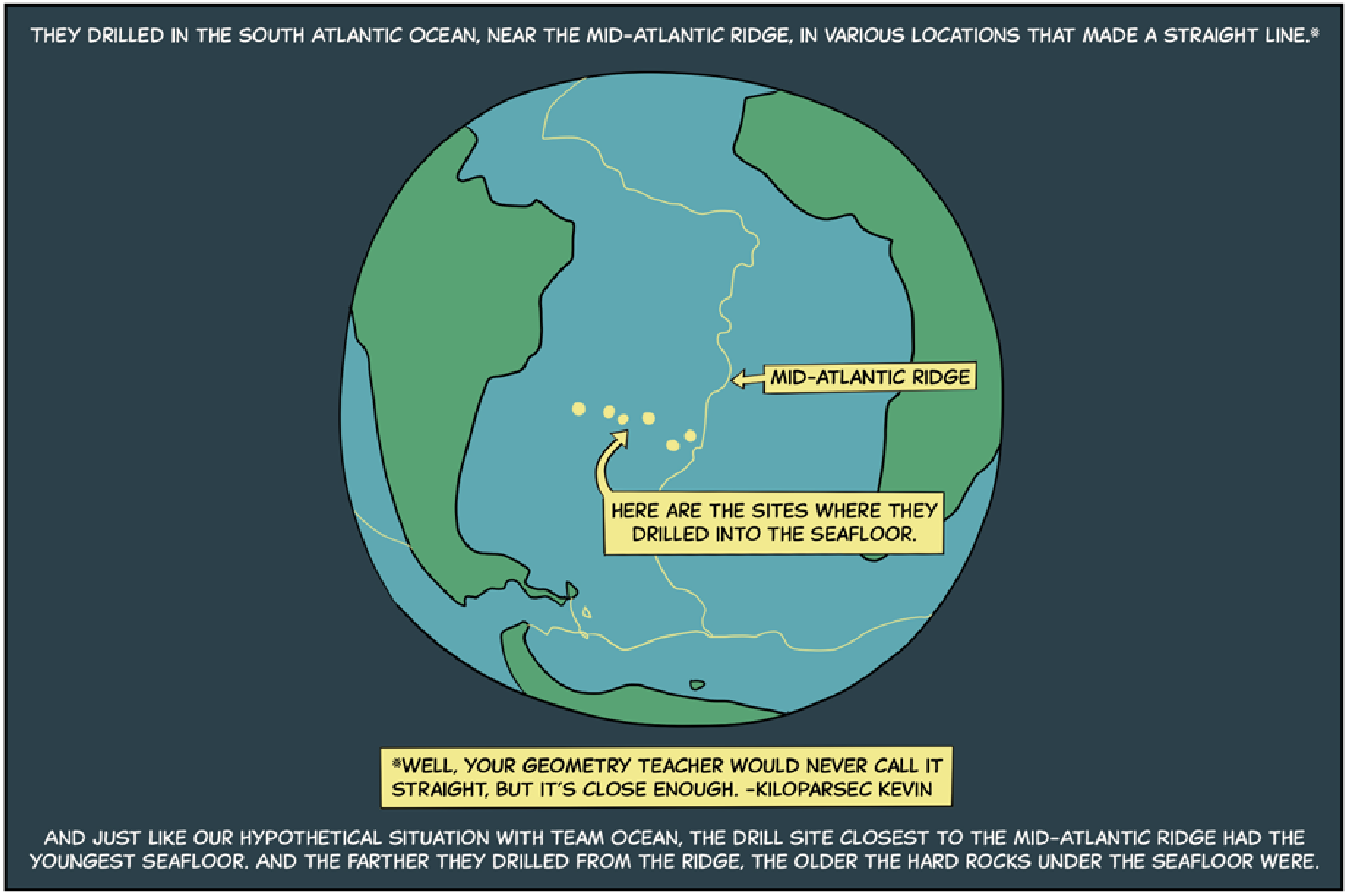

SAY YOU WENT HUNDREDS OF MILES AWAY FROM THE TRENCH, FAR FROM THE OCEAN TOWARDS THE MIDDLE OF THE CONTINENT, AND THEN DRILLED DEEP UNDERGROUND. THE ROCK THERE WOULDN'T BE THAT DIFFERENT FROM THE ROCKS DRILLED BY TEAM CONTINENT UNDER THE OCEAN.
Let's try drilling over there.
JOIDES RESOLUTION
THE CORES IN BOTH PLACES WOULD MOST LIKELY BE GRANITE AND THE GRANITE IN BOTH PLACES WOULD PROBABLY BE OVER TWO BILLION YEARS OLD.
I easily get a senior citizen discount at Denny's.

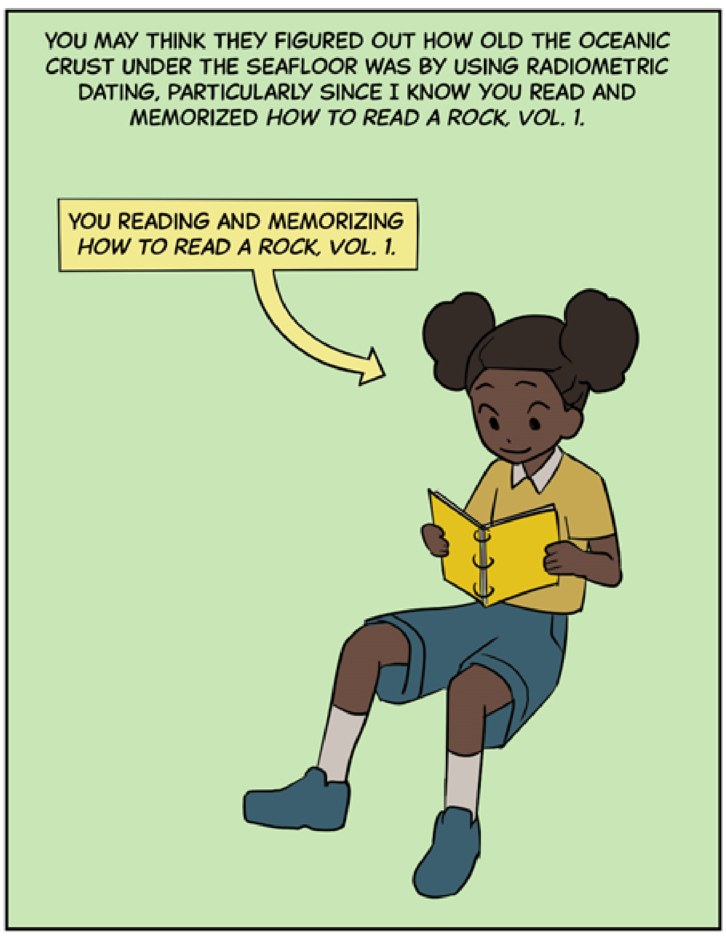

BUT THEN IF YOU WENT BACK TO THE OCEAN, SAILED HUNDREDS OF MILES AWAY FROM THE TRENCH, AND DRILLED INTO THE SEAFLOOR...
JOIDES RESOLUTION


THE ROCKS CLOSER TO THE MIDDLE OF THE OCEAN WOULD BE MOSTLY THE SAME AS THE ROCKS DRILLED BY TEAM OCEAN NEAR THE TRENCH...
How would you describe these cores?
Let's use the precise scientific term: Mostly the same.
BUT THE AGES OF THOSE ROCKS WOULD BE REALLY DIFFERENT.

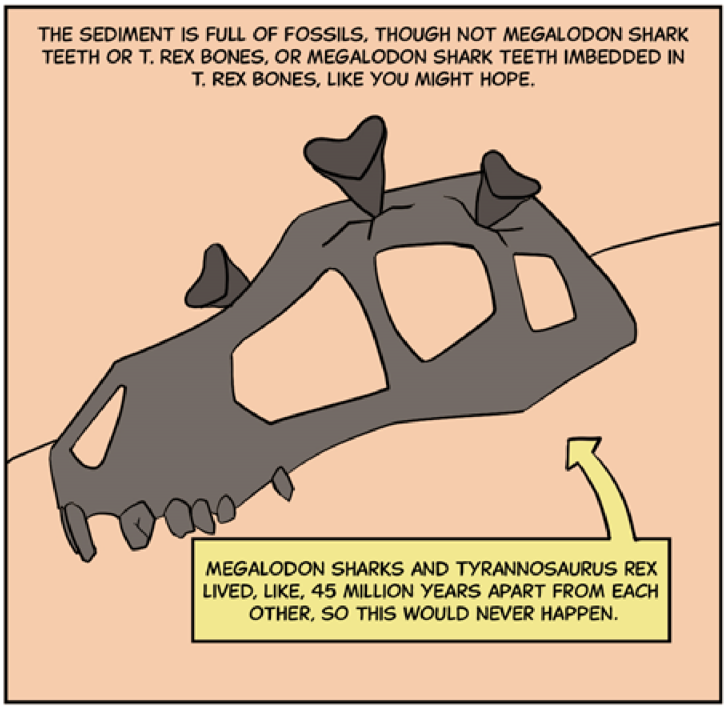

THE ROCKS NEAR THE TRENCH COULD BE OVER 100 MILLION YEARS OLD.
THE ROCKS HUNDREDS OF MILES AWAY MAY ONLY BE 50 MILLION YEARS OLD.
AND IF YOU KEEP GOING FARTHER TOWARDS THE MIDDLE OF THE OCEAN, YOU COULD FIND ROCKS THAT ARE 10 MILLION YEARS OLD.
AND EVEN 10 MINUTES OLD!*
TRENCH
BABY BOOMER ROCKS
GENERATION X ROCKS
MILLENIAL ROCKS
GENERATION Z ROCKS
ARBITRARILY LABELED GENERATION ROCKS
*THIS ALL HAS SOMETHING TO DO WITH VOLCANOES, EARTHQUAKES, AND TSUNAMIS. I PROMISE. -KEEPING-IT-REAL KEVIN

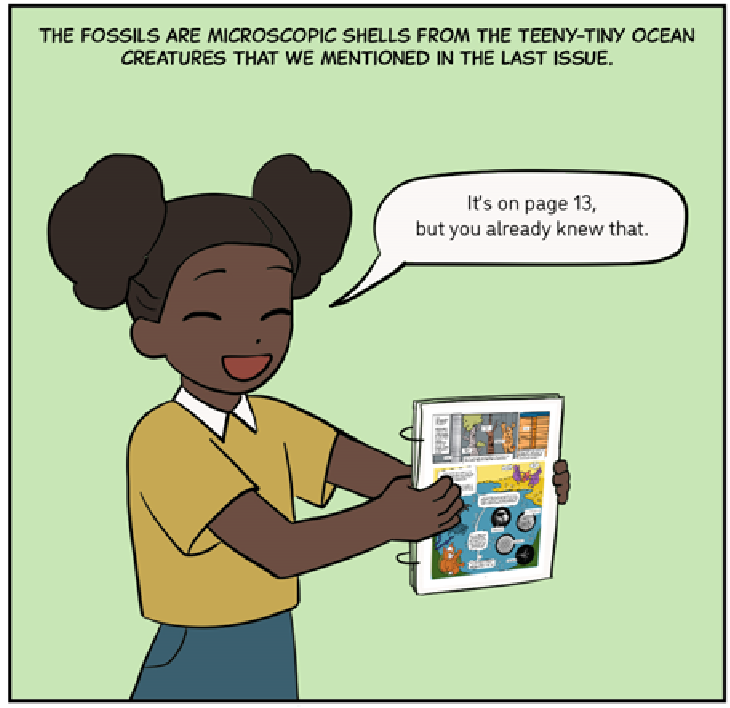

BACK IN THE LATE 1960S WHEN YOUR GRANDPARENTS WERE WEARING BELL BOTTOMS AND SAYING "GROOVY" AND "SOCK IT TO ME" A LOT, ONE OF THE VERY FIRST EXPEDITIONS BY THE IODP* SHOWED THAT THIS CHANGE IN THE AGES OF OCEAN ROCKS HAPPENS ALL OVER THE WORLD.
We dig drilling rocks, man.
And sediment!
GLOMAR Challenger
*EXCEPT IT WASN'T CALLED THE IODP THEN. IT WAS CALLED THE DSDP (DEEP SEA DRILLING PROGRAM). AND THEY WEREN'T CALLED "EXPEDITIONS" THEN. THEY WERE CALLED "LEGS." AND THE SHIP THEY USED THEN WAS THE "GLOMAR CHALLENGER." -KEEN-TO-BE-ACCURATE KEVIN

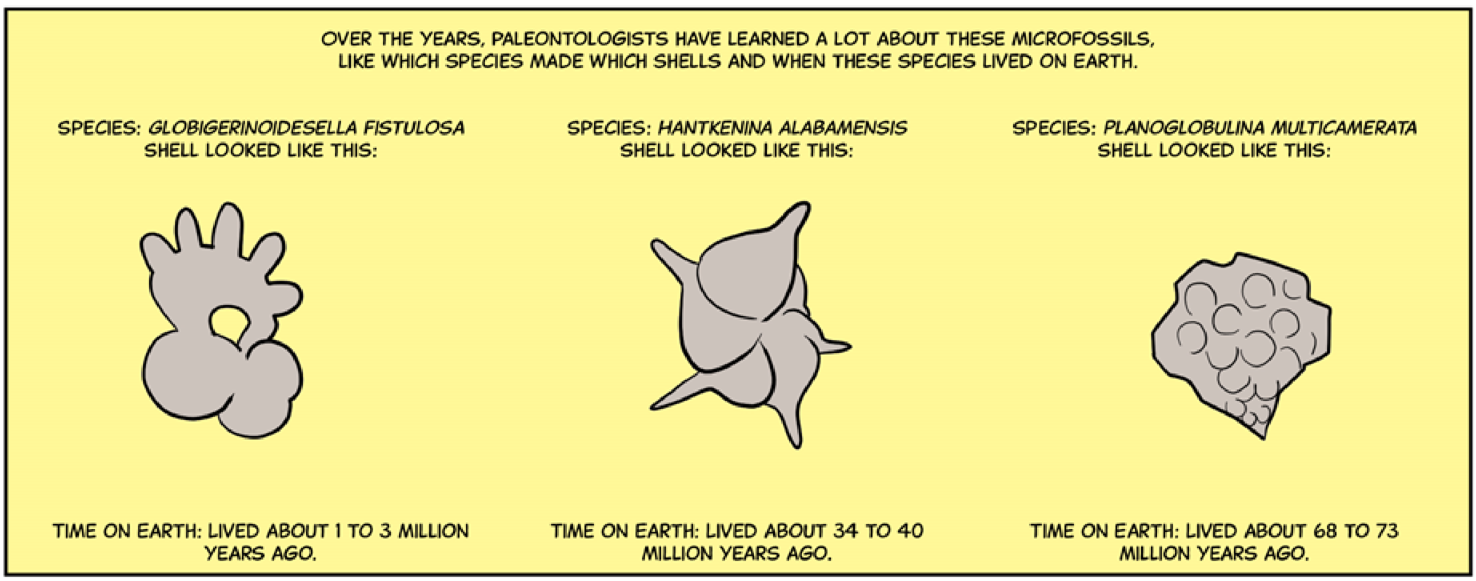

THEY DRILLED IN THE SOUTH ATLANTIC OCEAN, NEAR THE MID-ATLANTIC RIDGE, IN VARIOUS LOCATIONS THAT MADE A STRAIGHT LINE.*
MID-ATLANTIC RIDGE
HERE ARE THE SITES WHERE THEY DRILLED INTO THE SEAFLOOR.
*WELL, YOUR GEOMETRY TEACHER WOULD NEVER CALL IT STRAIGHT, BUT IT'S CLOSE ENOUGH. -KILOPARSEC KEVIN
AND JUST LIKE OUR HYPOTHETICAL SITUATION WITH TEAM OCEAN, THE DRILL SITE CLOSEST TO THE MID-ATLANTIC RIDGE HAD THE YOUNGEST SEAFLOOR. AND THE FARTHER THEY DRILLED FROM THE RIDGE, THE OLDER THE HARD ROCKS UNDER THE SEAFLOOR WERE.


YOU MAY THINK THEY FIGURED OUT HOW OLD THE OCEANIC CRUST UNDER THE SEAFLOOR WAS BY USING RADIOMETRIC DATING, PARTICULARLY SINCE I KNOW YOU READ AND MEMORIZED *HOW TO READ A ROCK, VOL. 1.*
YOU READING AND MEMORIZING *HOW TO READ A ROCK, VOL. 1.*

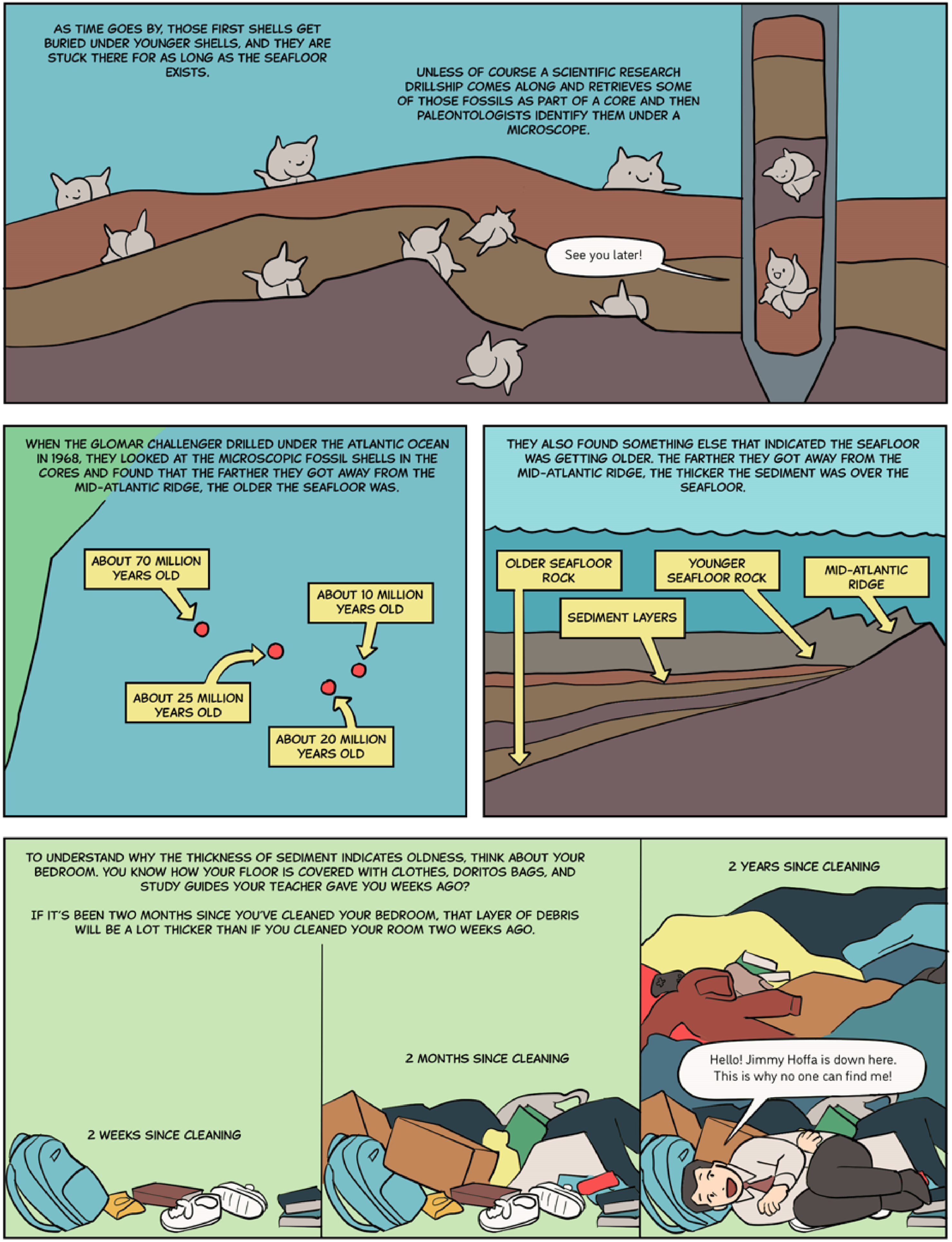

BUT THEY FIGURED OUT THE AGE DIFFERENCES BY LOOKING CLOSELY AT OTHER THINGS IN THE SEDIMENT THEY DRILLED.
Yay, sediment!


THE SEDIMENT IS FULL OF FOSSILS, THOUGH NOT MEGALODON SHARK TEETH OR T. REX BONES, OR MEGALODON SHARK TEETH IMBEDDED IN T. REX BONES, LIKE YOU MIGHT HOPE.
MEGALODON SHARKS AND TYRANNOSAURUS REX LIVED, LIKE, 45 MILLION YEARS APART FROM EACH OTHER, SO THIS WOULD NEVER HAPPEN.

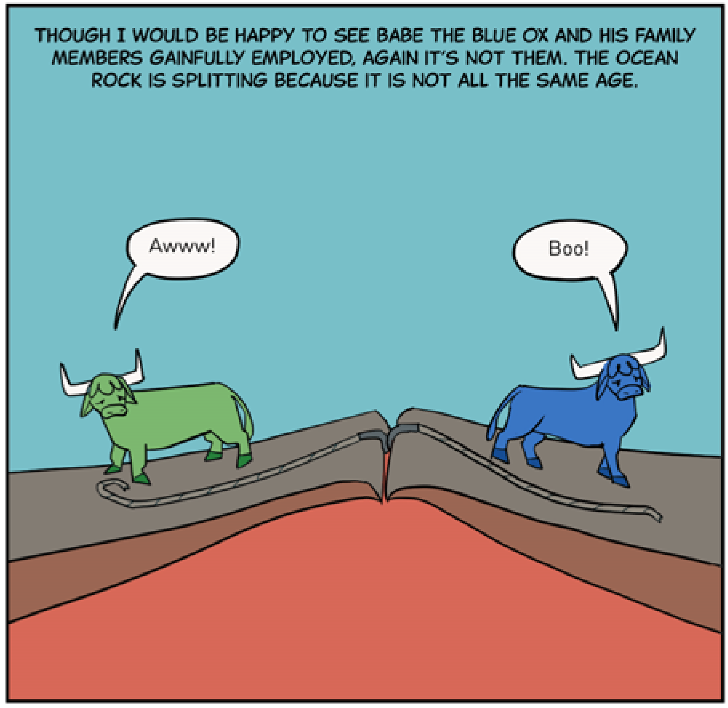

THE FOSSILS ARE MICROSCOPIC SHELLS FROM THE TEENY-TINY OCEAN CREATURES THAT WE MENTIONED IN THE LAST ISSUE.
It's on page 13, but you already knew that.

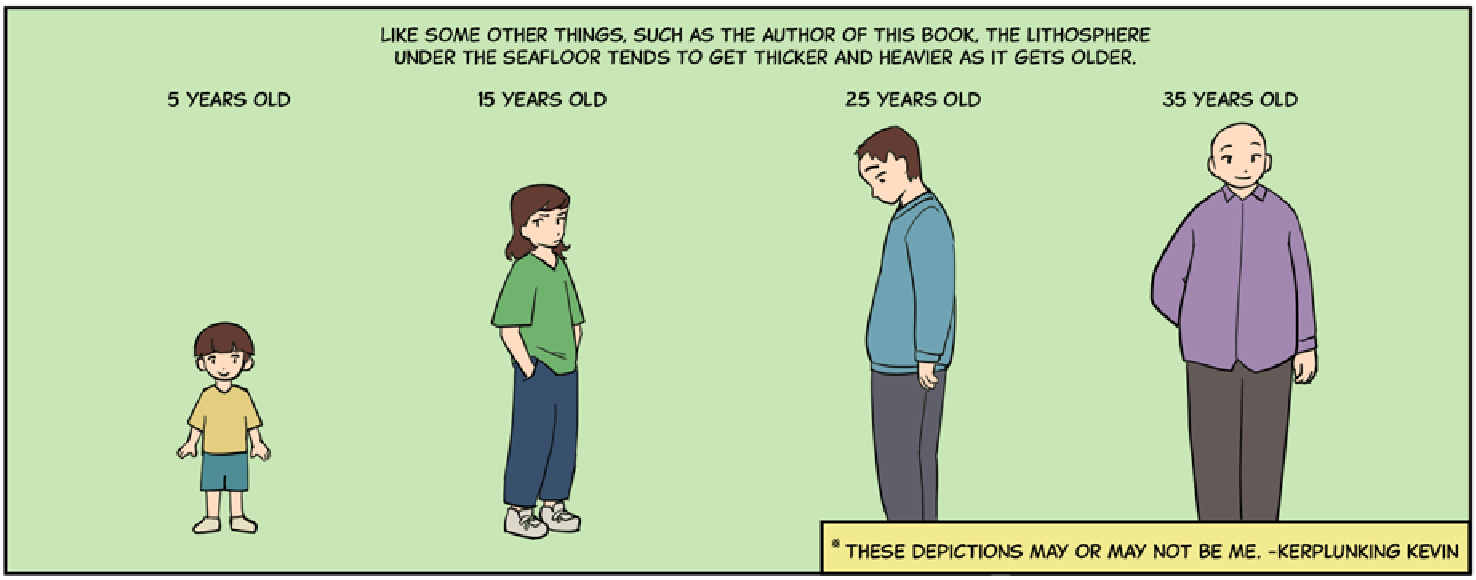

OVER THE YEARS, PALEONTOLOGISTS HAVE LEARNED A LOT ABOUT THESE MICROFOSSILS, LIKE WHICH SPECIES MADE WHICH SHELLS AND WHEN THESE SPECIES LIVED ON EARTH.
SPECIES: *GLOBIGERINOIDESELLA FISTULOSA* SHELL LOOKED LIKE THIS:
TIME ON EARTH: LIVED ABOUT 1 TO 3 MILLION YEARS AGO.
SPECIES: *HANTKENINA ALABAMENSIS* SHELL LOOKED LIKE THIS:
TIME ON EARTH: LIVED ABOUT 34 TO 40 MILLION YEARS AGO.
SPECIES: *PLANOGLOBULINA MULTICAMERATA* SHELL LOOKED LIKE THIS:
TIME ON EARTH: LIVED ABOUT 68 TO 73 MILLION YEARS AGO.

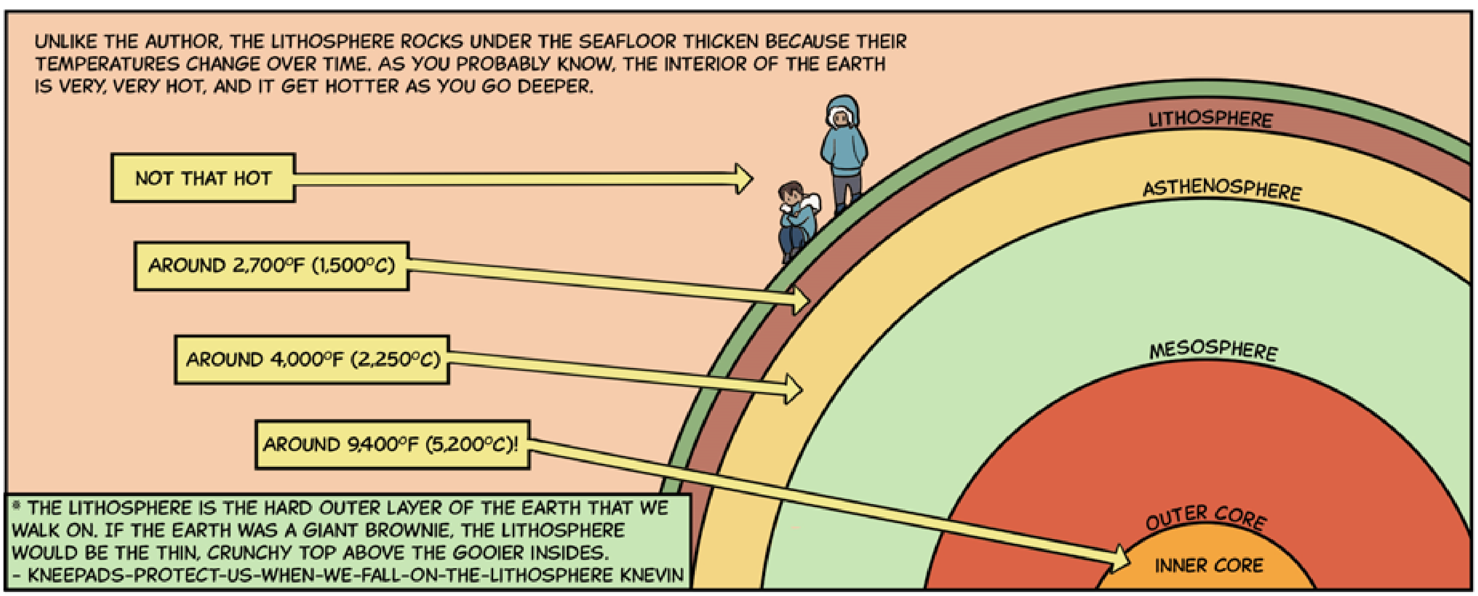

THE FIRST SHELLS THAT FALL ON BRAND NEW SEAFLOOR HELP US FIGURE OUT HOW OLD IT IS, BECAUSE THE SHELLS CAN ONLY BE FROM SPECIES THAT WERE ALIVE AT THAT TIME.
BRAND NEW SEAFLOOR ROCK
A BUNCH OF *HANTKENINA ALABAMENSIS* FOSSILS
SO MUST BE 34 TO 40 MILLION YEARS OLD

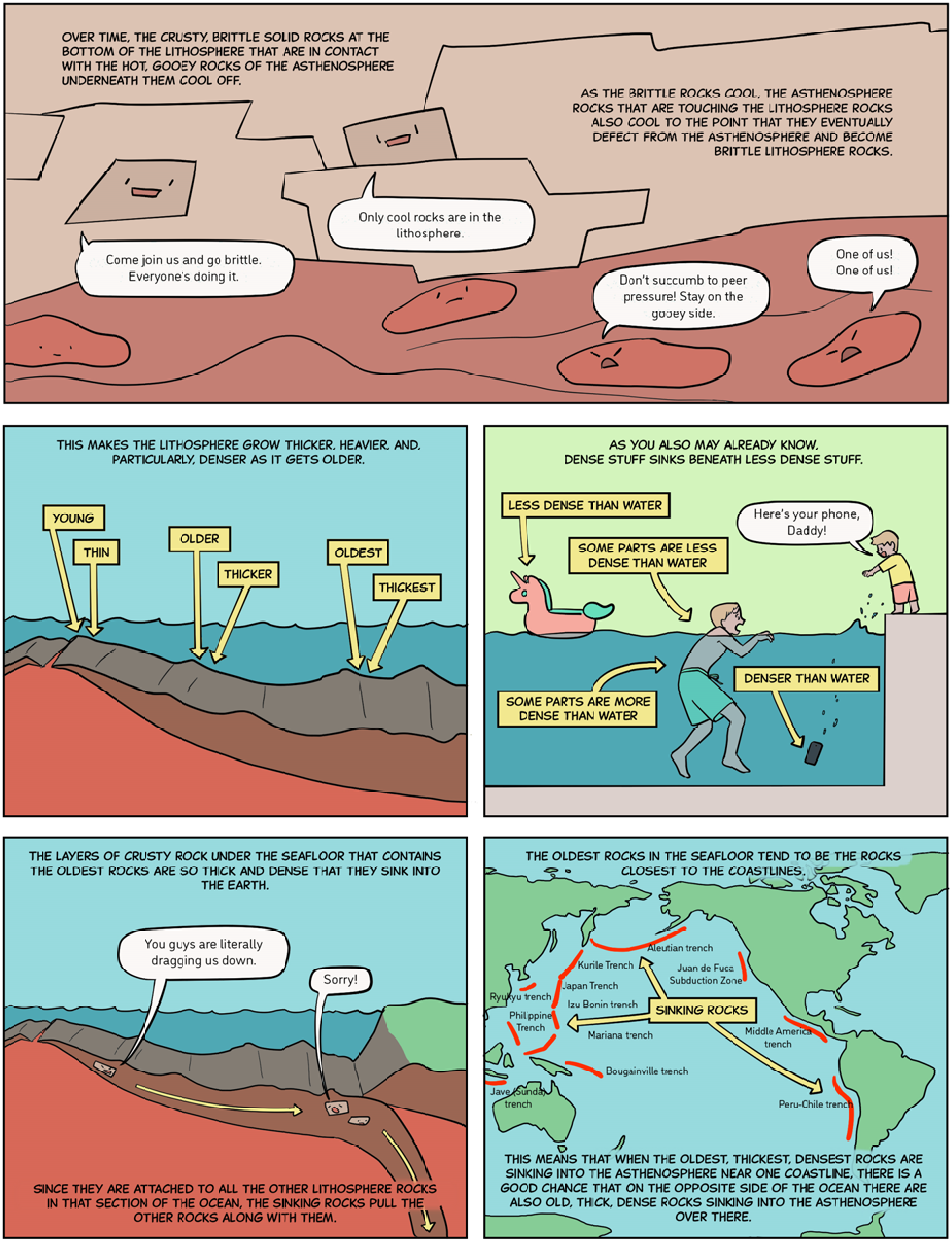

AS TIME GOES BY, THOSE FIRST SHELLS GET BURIED UNDER YOUNGER SHELLS, AND THEY ARE STUCK THERE FOR AS LONG AS THE SEAFLOOR EXISTS.
UNLESS OF COURSE A SCIENTIFIC RESEARCH DRILLSHIP COMES ALONG AND RETRIEVES SOME OF THOSE FOSSILS AS PART OF A CORE AND THEN PALEONTOLOGISTS IDENTIFY THEM UNDER A MICROSCOPE.
See you later!
WHEN THE GLOMAR CHALLENGER DRILLED UNDER THE ATLANTIC OCEAN IN 1968, THEY LOOKED AT THE MICROSCOPIC FOSSIL SHELLS IN THE CORES AND FOUND THAT THE FARTHER THEY GOT AWAY FROM THE MID-ATLANTIC RIDGE, THE OLDER THE SEAFLOOR WAS.
ABOUT 70 MILLION YEARS OLD
ABOUT 10 MILLION YEARS OLD
ABOUT 25 MILLION YEARS OLD
ABOUT 20 MILLION YEARS OLD
THEY ALSO FOUND SOMETHING ELSE THAT INDICATED THE SEAFLOOR WAS GETTING OLDER. THE FARTHER THEY GOT AWAY FROM THE MID-ATLANTIC RIDGE, THE THICKER THE SEDIMENT WAS OVER THE SEAFLOOR.
OLDER SEAFLOOR ROCK
YOUNGER SEAFLOOR ROCK
MID-ATLANTIC RIDGE
SEDIMENT LAYERS
TO UNDERSTAND WHY THE THICKNESS OF SEDIMENT INDICATES OLDNESS, THINK ABOUT YOUR BEDROOM. YOU KNOW HOW YOUR FLOOR IS COVERED WITH CLOTHES, DORITOS BAGS, AND STUDY GUIDES YOUR TEACHER GAVE YOU WEEKS AGO?
IF IT'S BEEN TWO MONTHS SINCE YOU'VE CLEANED YOUR BEDROOM, THAT LAYER OF DEBRIS WILL BE A LOT THICKER THAN IF YOU CLEANED YOUR ROOM TWO WEEKS AGO.
2 WEEKS SINCE CLEANING
2 MONTHS SINCE CLEANING
2 YEARS SINCE CLEANING
Hello! Jimmy Hoffa is down here. This is why no one can find me!


THE REASON THE SEAFLOOR ROCK GETS OLDER THE FARTHER YOU MOVE AWAY FROM A MID-OCEAN RIDGE IS BECAUSE THE OCEAN CRUST ON EITHER SIDE OF THE RIDGE IS BEING PULLED APART.
That's my cousin, Gabe the Green Ox.

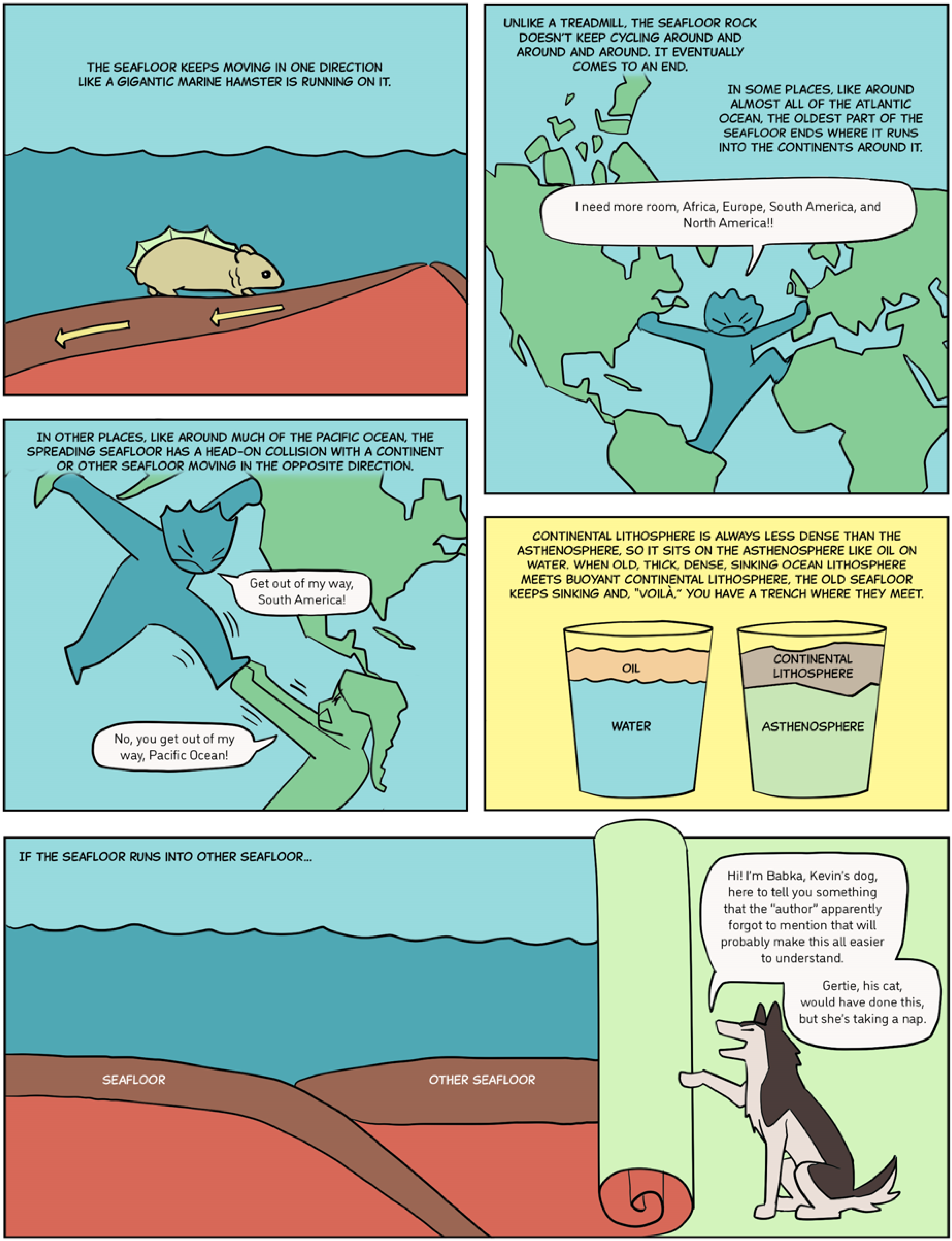

THOUGH I WOULD BE HAPPY TO SEE BABE THE BLUE OX AND HIS FAMILY MEMBERS GAINFULLY EMPLOYED, AGAIN IT'S NOT THEM. THE OCEAN ROCK IS SPLITTING BECAUSE IT IS NOT ALL THE SAME AGE.
Awww!
Boo!

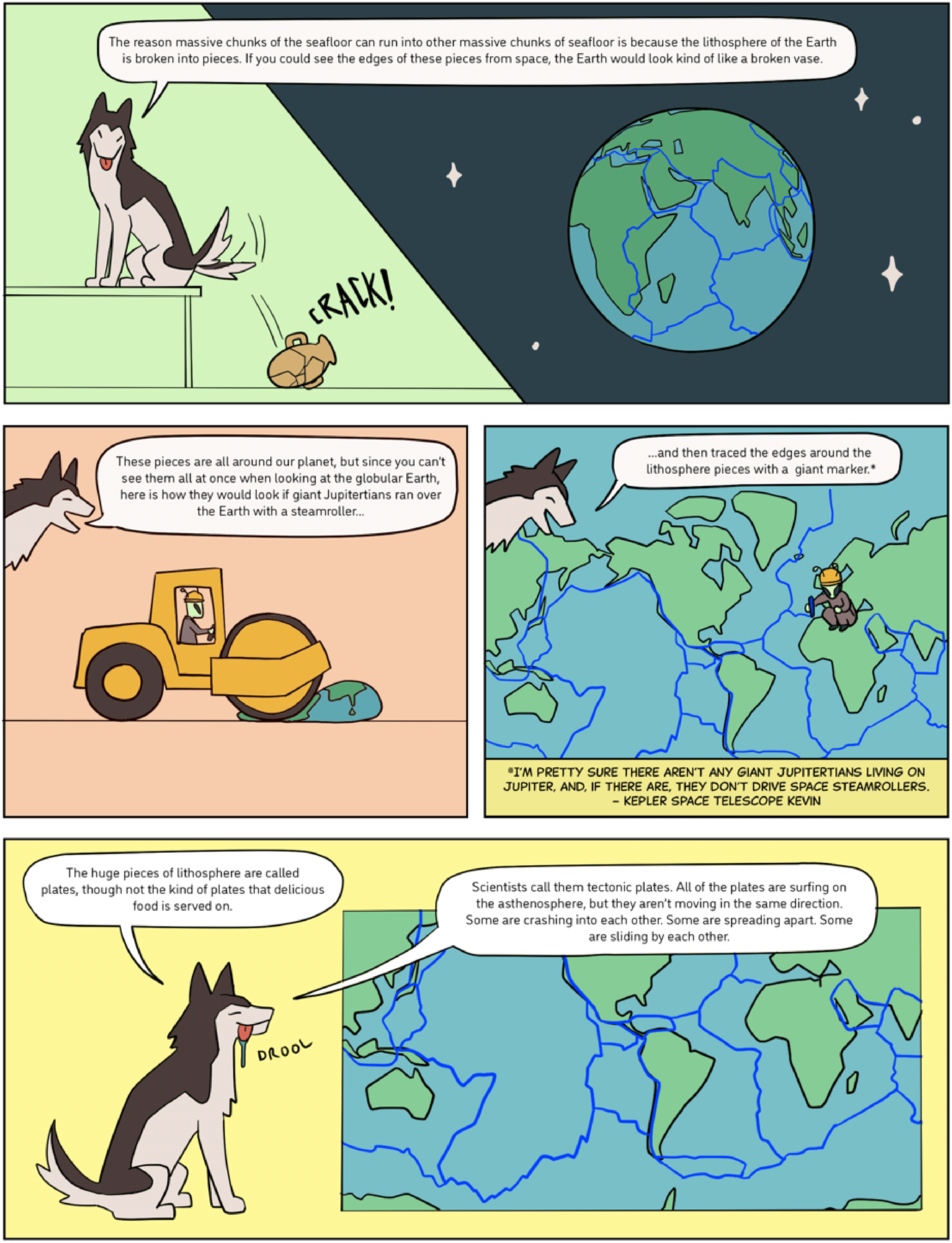

LIKE SOME OTHER THINGS, SUCH AS THE AUTHOR OF THIS BOOK, THE LITHOSPHERE UNDER THE SEAFLOOR TENDS TO GET THICKER AND HEAVIER AS IT GETS OLDER.
5 YEARS OLD
15 YEARS OLD
25 YEARS OLD
35 YEARS OLD
* THESE DEPICTIONS MAY OR MAY NOT BE ME. -KERPLUNKING KEVIN

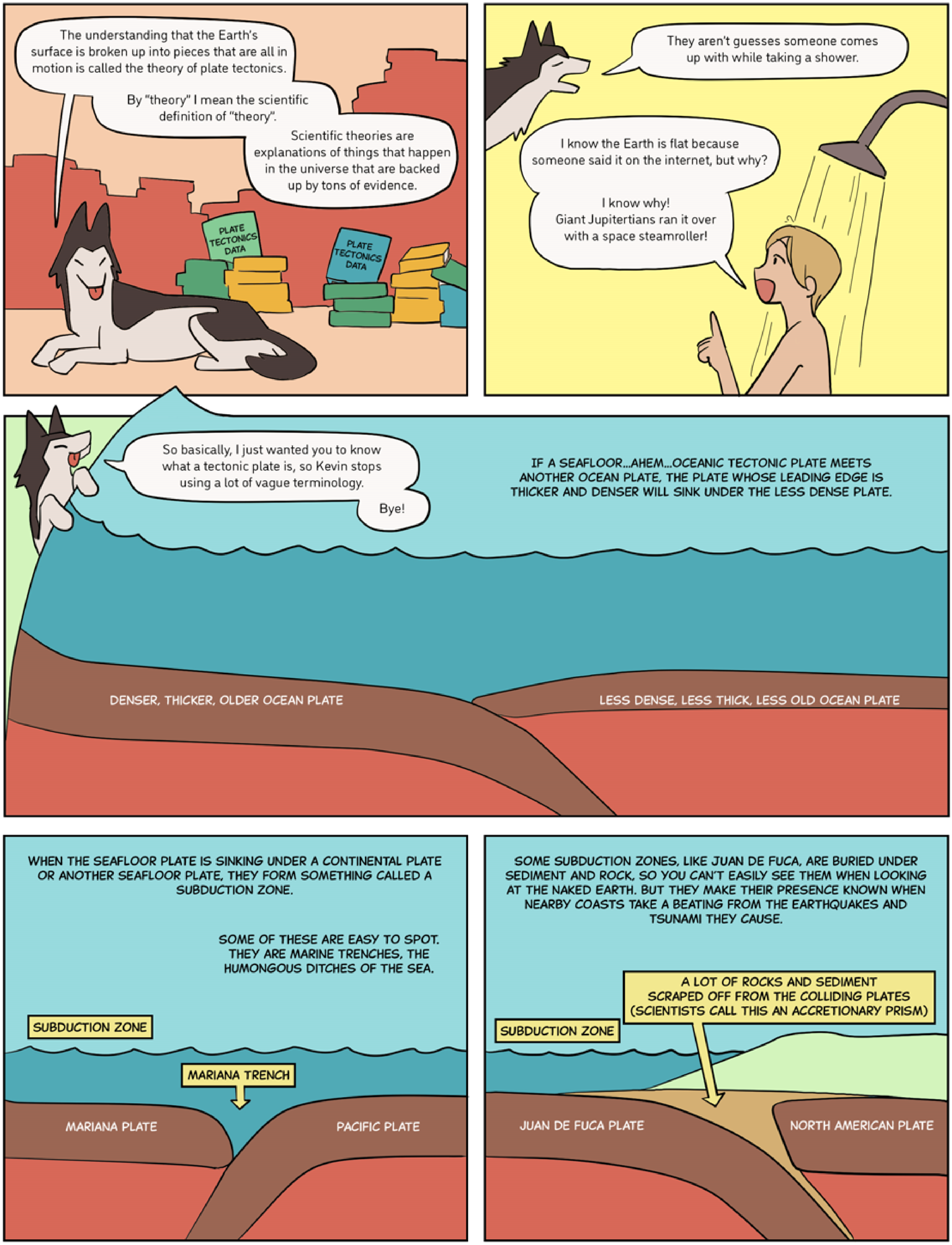

UNLIKE THE AUTHOR, THE LITHOSPHERE ROCKS UNDER THE SEAFLOOR THICKEN BECAUSE THEIR TEMPERATURES CHANGE OVER TIME. AS YOU PROBABLY KNOW, THE INTERIOR OF THE EARTH IS VERY, VERY HOT, AND IT GET HOTTER AS YOU GO DEEPER.
NOT THAT HOT
AROUND 2,700°F (1,500°C)
AROUND 4,000°F (2,250°C)
AROUND 9,400°F (5,200°C)!
LITHOSPHERE
ASTHENOSPHERE
MESOSPHERE
OUTER CORE
INNER CORE
* THE LITHOSPHERE IS THE HARD OUTER LAYER OF THE EARTH THAT WE WALK ON. IF THE EARTH WAS A GIANT BROWNIE, THE LITHOSPHERE WOULD BE THE THIN, CRUNCHY TOP ABOVE THE GOOIER INSIDES.
- KNEEPADS-PROTECT-US-WHEN-WE-FALL-ON-THE-LITHOSPHERE KNEVIN


OVER TIME, THE CRUSTY, BRITTLE SOLID ROCKS AT THE BOTTOM OF THE LITHOSPHERE THAT ARE IN CONTACT WITH THE HOT, GOOEY ROCKS OF THE ASTHENOSPHERE UNDERNEATH THEM COOL OFF.
AS THE BRITTLE ROCKS COOL, THE ASTHENOSPHERE ROCKS THAT ARE TOUCHING THE LITHOSPHERE ROCKS ALSO COOL TO THE POINT THAT THEY EVENTUALLY DEFECT FROM THE ASTHENOSPHERE AND BECOME BRITTLE LITHOSPHERE ROCKS.
Come join us and go brittle. Everyone's doing it.
Only cool rocks are in the lithosphere.
Don't succumb to peer pressure! Stay on the gooey side.
One of us! One of us!
THIS MAKES THE LITHOSPHERE GROW THICKER, HEAVIER, AND, PARTICULARLY, DENSER AS IT GETS OLDER.
YOUNG
THIN
OLDER
THICKER
OLDEST
THICKEST
AS YOU ALSO MAY ALREADY KNOW, DENSE STUFF SINKS BENEATH LESS DENSE STUFF.
LESS DENSE THAN WATER
SOME PARTS ARE LESS DENSE THAN WATER
Here's your phone, Daddy!
SOME PARTS ARE MORE DENSE THAN WATER
DENSER THAN WATER
THE LAYERS OF CRUSTY ROCK UNDER THE SEAFLOOR THAT CONTAINS THE OLDEST ROCKS ARE SO THICK AND DENSE THAT THEY SINK INTO THE EARTH.
You guys are literally dragging us down.
Sorry!
SINCE THEY ARE ATTACHED TO ALL THE OTHER LITHOSPHERE ROCKS IN THAT SECTION OF THE OCEAN, THE SINKING ROCKS PULL THE OTHER ROCKS ALONG WITH THEM.
THE OLDEST ROCKS IN THE SEAFLOOR TEND TO BE THE ROCKS CLOSEST TO THE COASTLINES.
Aleutian trench
Kurile Trench
Juan de Fuca Subduction Zone
Japan Trench
Ryukyu trench
Izu Bonin trench
SINKING ROCKS
Philippine Trench
Mariana trench
Middle America trench
Bougainville trench
Jave (Sunda) trench
Peru-Chile trench
THIS MEANS THAT WHEN THE OLDEST, THICKEST, DENSEST ROCKS ARE SINKING INTO THE ASTHENOSPHERE NEAR ONE COASTLINE, THERE IS A GOOD CHANCE THAT ON THE OPPOSITE SIDE OF THE OCEAN THERE ARE ALSO OLD, THICK, DENSE ROCKS SINKING INTO THE ASTHENOSPHERE OVER THERE.

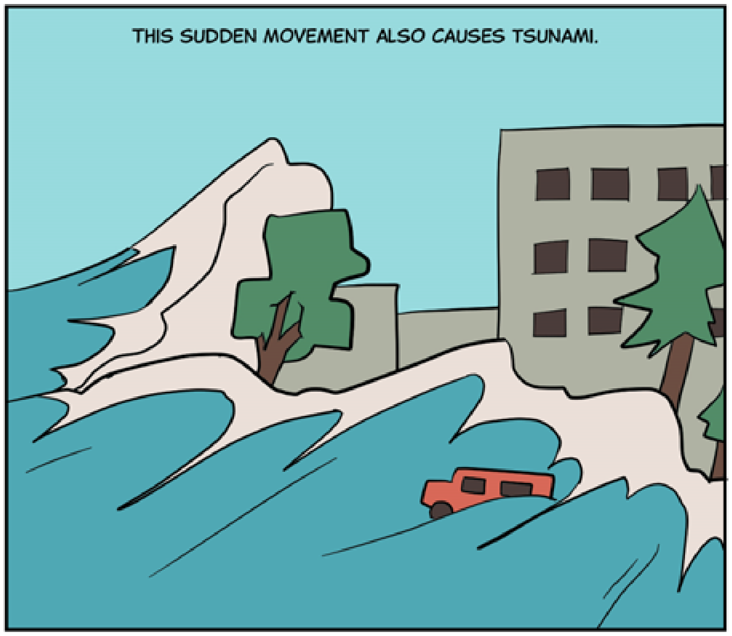

THESE SIDE-BY-SIDE, SINKING SLABS OF ROCK ARE TEARING THE OCEANS APART, LIKE TWO PUPPIES PLAYING TUG-OF-WAR WITH AN EXCESSIVELY CHEAP DOG TOY THAT LOOKS LIKE A DIAGRAM OF THE BOTTOM OF THE OCEAN.
RIPPPP
WHEN YOU SPLIT THE SEAFLOOR OPEN, IT'S KIND OF LIKE OPENING THE DOORS AT THE BEGINNING OF A BIG BLACK FRIDAY SALE, EXCEPT INSTEAD OF DESPERATE SHOPPERS HOPING TO GET A CHEAP TV FLOWING THROUGH, MAGMA IS FLOWING THROUGH THE OPENING IN THE SEAFLOOR.
STORE
MAGMA IS UNDERGROUND LIQUID ROCK, BUT THE ROCK UNDER THE LITHOSPHERE IS NORMALLY NOT MAGMA. IT STAYS SOLID UNTIL THAT OPENING APPEARS IN THE SEAFLOOR. THE OPENING TAKES THE PRESSURE OFF OF THE ROCK BENEATH IT, ALLOWING THE ROCK TO MELT INTO MAGMA.
LIQUID ROCK IS ONLY CALLED "MAGMA" WHEN IT IS UNDERGROUND. THE SECOND IT RISES ABOVE THE SURFACE, IT GETS CALLED LAVA. WHEN HOT LAVA TOUCHES COLD SEAWATER, IT IMMEDIATELY COOLS, SOLIDIFIES, AND BECOMES BRAND NEW SEAFLOOR ROCK.
WHICH IS WHY THE YOUNGEST SEAFLOOR IS THE CLOSEST TO THE MID-OCEAN RIDGE. IT WAS JUST CREATED.
THIS BRAND-NEW ROCK IS PART OF HOW THE SEAFLOOR SPREADS. WHEN I SAY, "SEAFLOOR SPREADING," IT MAY SOUND LIKE SOMEONE SPILLED SEAFLOOR ON THE FLOOR AND IT IS GOING ALL OVER THE PLACE.
Oops!
CLUNK!
SEAFLOOR
NOW WITH MORE BASALT!
GURGLE GURGLE GURGLE
BUT THE WAY THE SEAFLOOR SPREADS IS MORE LIKE THE WAY A TREADMILL MOVES, OR AT LEAST THE TOP PART OF A TREADMILL THAT YOU, OR, SAY, A HAMSTER, ARE RUNNING ON.
HAMSTERTON

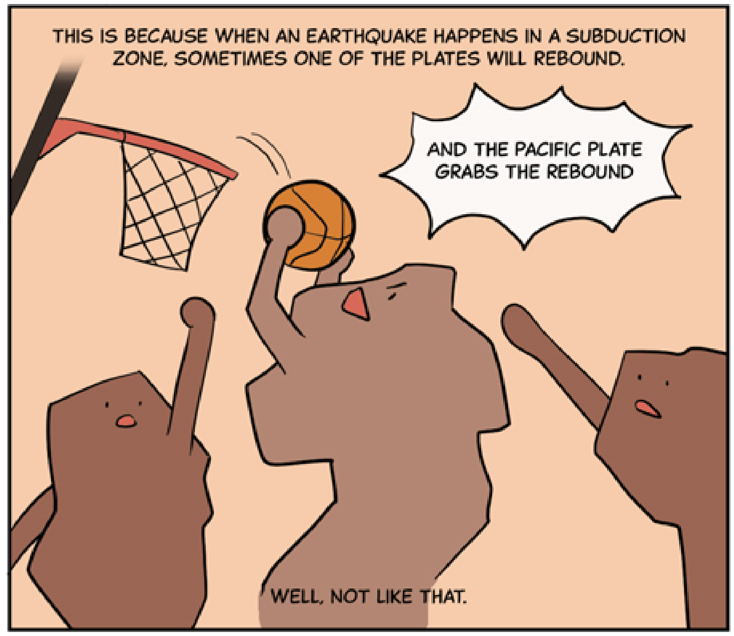

THE SEAFLOOR KEEPS MOVING IN ONE DIRECTION LIKE A GIGANTIC MARINE HAMSTER IS RUNNING ON IT.
UNLIKE A TREADMILL, THE SEAFLOOR ROCK DOESN'T KEEP CYCLING AROUND AND AROUND AND AROUND. IT EVENTUALLY COMES TO AN END.
IN SOME PLACES, LIKE AROUND ALMOST ALL OF THE ATLANTIC OCEAN, THE OLDEST PART OF THE SEAFLOOR ENDS WHERE IT RUNS INTO THE CONTINENTS AROUND IT.
I need more room, Africa, Europe, South America, and North America!!
IN OTHER PLACES, LIKE AROUND MUCH OF THE PACIFIC OCEAN, THE SPREADING SEAFLOOR HAS A HEAD-ON COLLISION WITH A CONTINENT OR OTHER SEAFLOOR MOVING IN THE OPPOSITE DIRECTION.
Get out of my way, South America!
No, you get out of my way, Pacific Ocean!
CONTINENTAL LITHOSPHERE IS ALWAYS LESS DENSE THAN THE ASTHENOSPHERE, SO IT SITS ON THE ASTHENOSPHERE LIKE OIL ON WATER. WHEN OLD, THICK, DENSE, SINKING OCEAN LITHOSPHERE MEETS BUOYANT CONTINENTAL LITHOSPHERE, THE OLD SEAFLOOR KEEPS SINKING AND, "VOILÀ," YOU HAVE A TRENCH WHERE THEY MEET.
OIL
WATER
CONTINENTAL LITHOSPHERE
ASTHENOSPHERE
IF THE SEAFLOOR RUNS INTO OTHER SEAFLOOR...
SEAFLOOR
OTHER SEAFLOOR
Hi! I'm Babka, Kevin's dog, here to tell you something that the "author" apparently forgot to mention that will probably make this all easier to understand.
Gertie, his cat, would have done this, but she's taking a nap.


The reason massive chunks of the seafloor can run into other massive chunks of seafloor is because the lithosphere of the Earth is broken into pieces. If you could see the edges of these pieces from space, the Earth would look kind of like a broken vase.
CRACK!
These pieces are all around our planet, but since you can't see them all at once when looking at the globular Earth, here is how they would look if giant Jupitertians ran over the Earth with a steamroller...
...and then traced the edges around the lithosphere pieces with a giant marker.*
*I'M PRETTY SURE THERE AREN'T ANY GIANT JUPITERTIANS LIVING ON JUPITER, AND, IF THERE ARE, THEY DON'T DRIVE SPACE STEAMROLLERS. – KEPLER SPACE TELESCOPE KEVIN
The huge pieces of lithosphere are called plates, though not the kind of plates that delicious food is served on.
Scientists call them tectonic plates. All of the plates are surfing on the asthenosphere, but they aren't moving in the same direction. Some are crashing into each other. Some are spreading apart. Some are sliding by each other.
DROOL

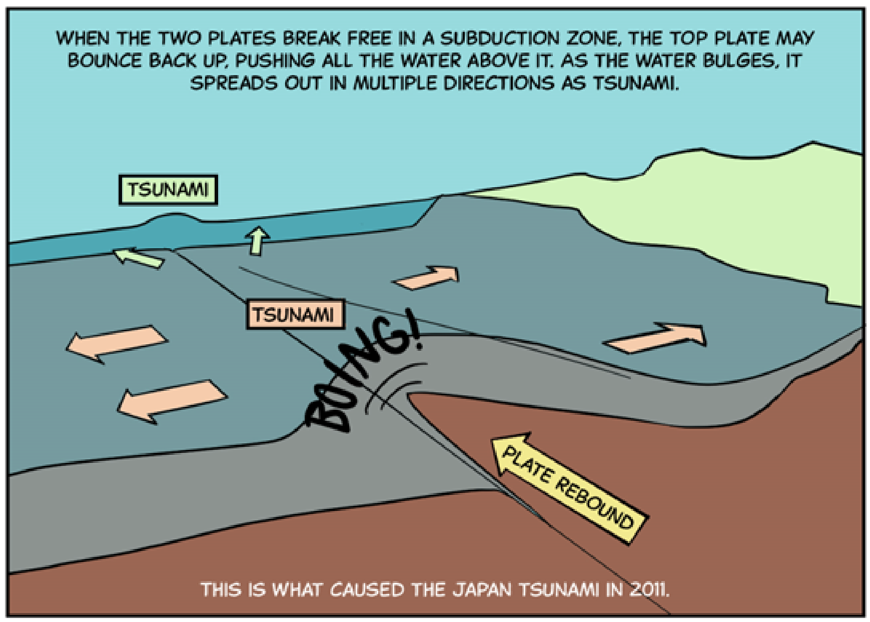

The understanding that the Earth's surface is broken up into pieces that are all in motion is called the theory of plate tectonics.
By "theory" I mean the scientific definition of "theory".
Scientific theories are explanations of things that happen in the universe that are backed up by tons of evidence.
PLATE TECTONICS DATA
PLATE TECTONICS DATA
They aren't guesses someone comes up with while taking a shower.
I know the Earth is flat because someone said it on the internet, but why?
I know why! Giant Jupitertians ran it over with a space steamroller!
So basically, I just wanted you to know what a tectonic plate is, so Kevin stops using a lot of vague terminology.
Bye!
IF A SEAFLOOR...AHEM...OCEANIC TECTONIC PLATE MEETS ANOTHER OCEAN PLATE, THE PLATE WHOSE LEADING EDGE IS THICKER AND DENSER WILL SINK UNDER THE LESS DENSE PLATE.
DENSER, THICKER, OLDER OCEAN PLATE
LESS DENSE, LESS THICK, LESS OLD OCEAN PLATE
WHEN THE SEAFLOOR PLATE IS SINKING UNDER A CONTINENTAL PLATE OR ANOTHER SEAFLOOR PLATE, THEY FORM SOMETHING CALLED A SUBDUCTION ZONE.
SOME OF THESE ARE EASY TO SPOT. THEY ARE MARINE TRENCHES, THE HUMONGOUS DITCHES OF THE SEA.
SUBDUCTION ZONE
MARIANA TRENCH
MARIANA PLATE
PACIFIC PLATE
SOME SUBDUCTION ZONES, LIKE JUAN DE FUCA, ARE BURIED UNDER SEDIMENT AND ROCK, SO YOU CAN'T EASILY SEE THEM WHEN LOOKING AT THE NAKED EARTH. BUT THEY MAKE THEIR PRESENCE KNOWN WHEN NEARBY COASTS TAKE A BEATING FROM THE EARTHQUAKES AND TSUNAMI THEY CAUSE.
A LOT OF ROCKS AND SEDIMENT SCRAPED OFF FROM THE COLLIDING PLATES (SCIENTISTS CALL THIS AN ACCRETIONARY PRISM)
SUBDUCTION ZONE
JUAN DE FUCA PLATE
NORTH AMERICAN PLATE

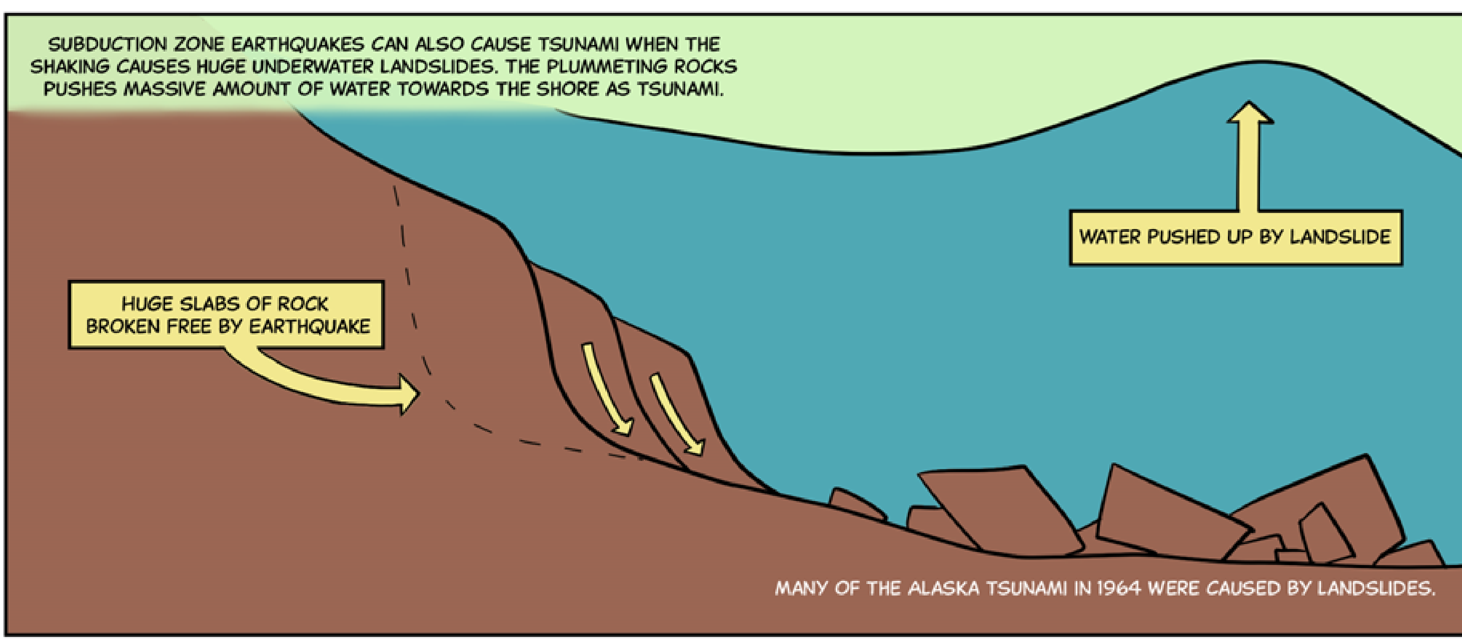

TECTONIC PLATES IN SUBDUCTION ZONES DON'T CAUSE EARTHQUAKES AND TSUNAMIS BECAUSE THEY ARE BIG MEANIES.
Hey Juan de Fuca plate! Want to help me give the Pacific Northwest coastal region a noogie?
I sure do, North American plate! Bwa! Ha! Ha!
THE PLATES THAT MEET AT SUBDUCTION ZONES ARE CONSTANTLY BEING PUSHED INTO EACH OTHER BY AGING, COOLING, AND THICKENING, AND EVEN THOUGH ONE PLATE IS SINKING BENEATH THE OTHER, THEY TEND TO GET STUCK.
IF THESE PLATES WERE MADE OF, SAY, EELS, THEY MIGHT SLIDE RIGHT BY EACH OTHER, BUT THEY ARE MADE OF ROCK, AND THE CRAGGY SURFACES OF TWO ROCKY PLATES RUBBING AGAINST EACH OTHER CAN MAKE MOVEMENT GRIND TO A HALT.
Wheee!!
Wheee!!
CRRRNCH
THE PUSHING DOESN'T STOP THOUGH, AND SO ENERGY KEEPS BUILDING UP IN THE SUBDUCTION ZONE, OFTEN FOR HUNDREDS OF YEARS, UNTIL THE STUCK PLATES EVENTUALLY BREAK FREE, AND THE PLATES MOVE PAST EACH OTHER.
THIS SUDDEN MOVEMENT OF HUGE PLATES IN SUBDUCTION ZONES RELEASES ALL THAT STORED ENERGY. THIS HAS CAUSED THE BIGGEST EARTHQUAKES IN RECORDED HISTORY.
In case you don't have access to the internet, here is a list of the five biggest earthquakes ever recorded by modern seismographs from about 1900 until the summer of 2023.
1. 1960. VALDIVIA, CHILE. MAGNITUDE 9.5.
2. 1964. ALASKA. MAGNITUDE 9.2.
3. 2004. INDIAN OCEAN. MAGNITUDE 9.2.
4. 2011. TOHOKU, JAPAN. MAGNITUDE 9.1.
5. 1952. SEVERO-KURILSK, RUSSIA. MAGNITUDE 9.0.
They all happened in subduction zones!!


THIS SUDDEN MOVEMENT ALSO CAUSES TSUNAMI.

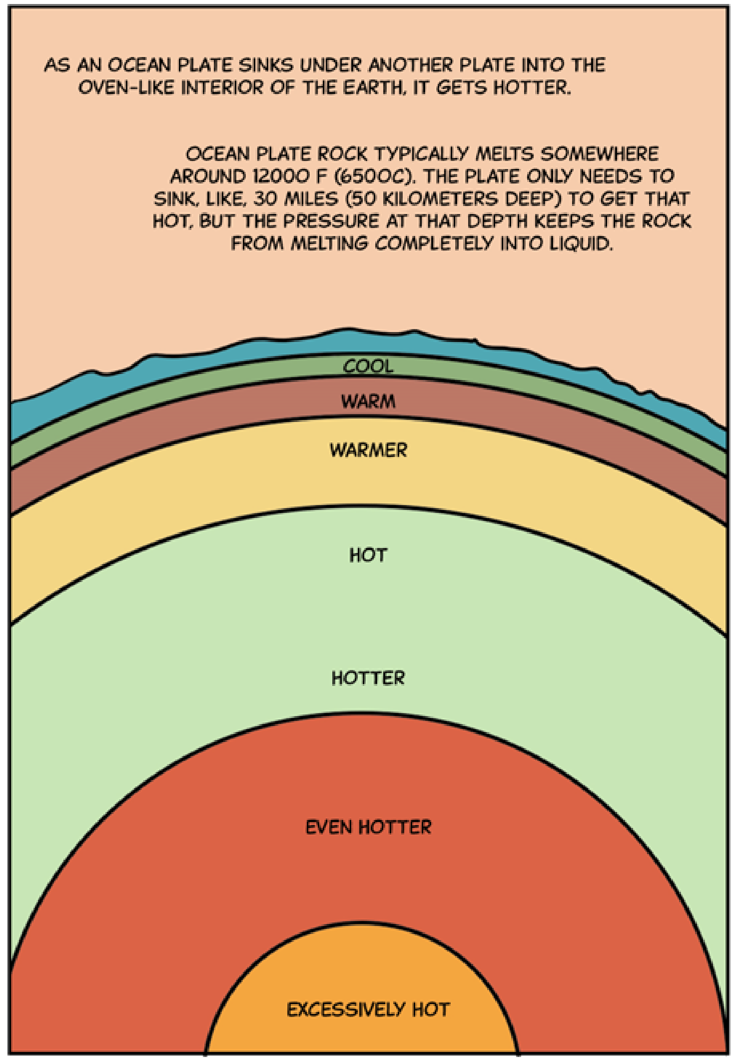

THIS IS BECAUSE WHEN AN EARTHQUAKE HAPPENS IN A SUBDUCTION ZONE, SOMETIMES ONE OF THE PLATES WILL REBOUND.
AND THE PACIFIC PLATE GRABS THE REBOUND
WELL, NOT LIKE THAT.

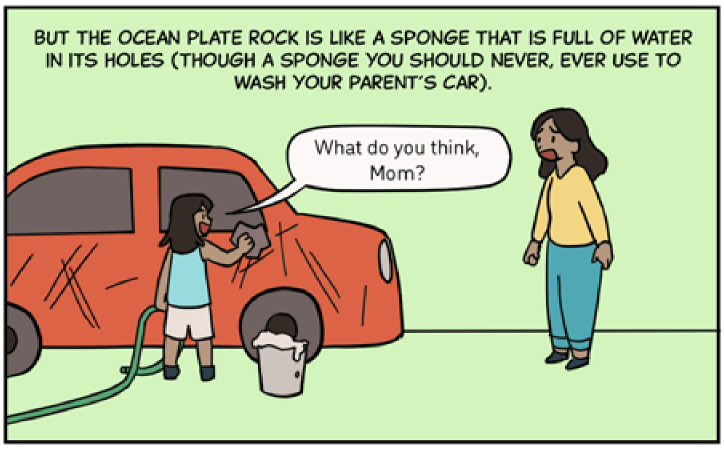

BUT IF YOU HAVE EVER PLAYED BASKETBALL WITH A RIM LOW ENOUGH TO BE ABLE TO DUNK THE BALL, YOU LIKELY PULLED THE RIM DOWN AFTER EACH SPECTACULAR SLAM DUNK. THEN WHEN YOU LET GO, IT BOUNCES BACK UP.

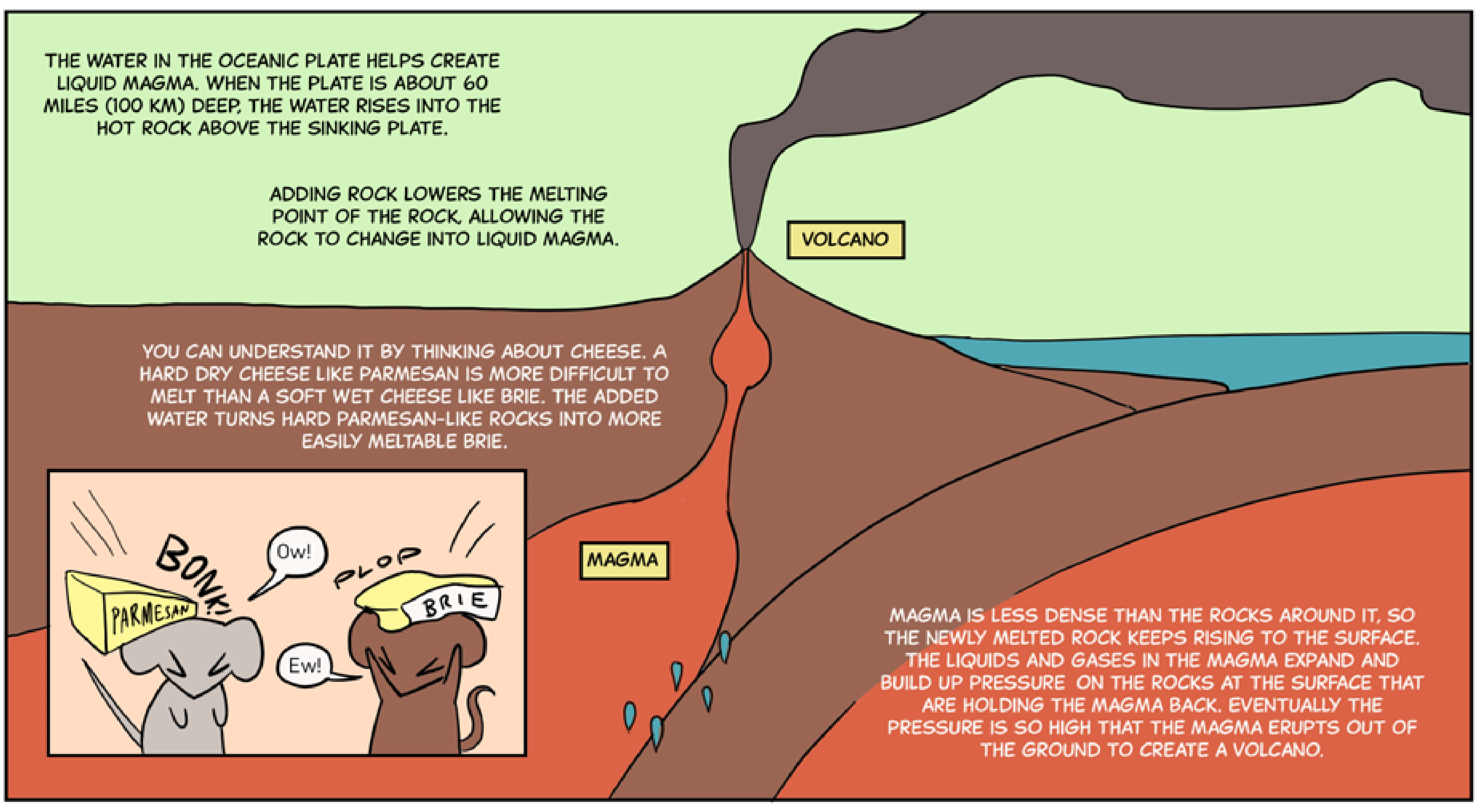

WHEN THE TWO PLATES BREAK FREE IN A SUBDUCTION ZONE, THE TOP PLATE MAY BOUNCE BACK UP, PUSHING ALL THE WATER ABOVE IT. AS THE WATER BULGES, IT SPREADS OUT IN MULTIPLE DIRECTIONS AS TSUNAMI.
TSUNAMI
TSUNAMI
BOING!
PLATE REBOUND
THIS IS WHAT CAUSED THE JAPAN TSUNAMI IN 2011.

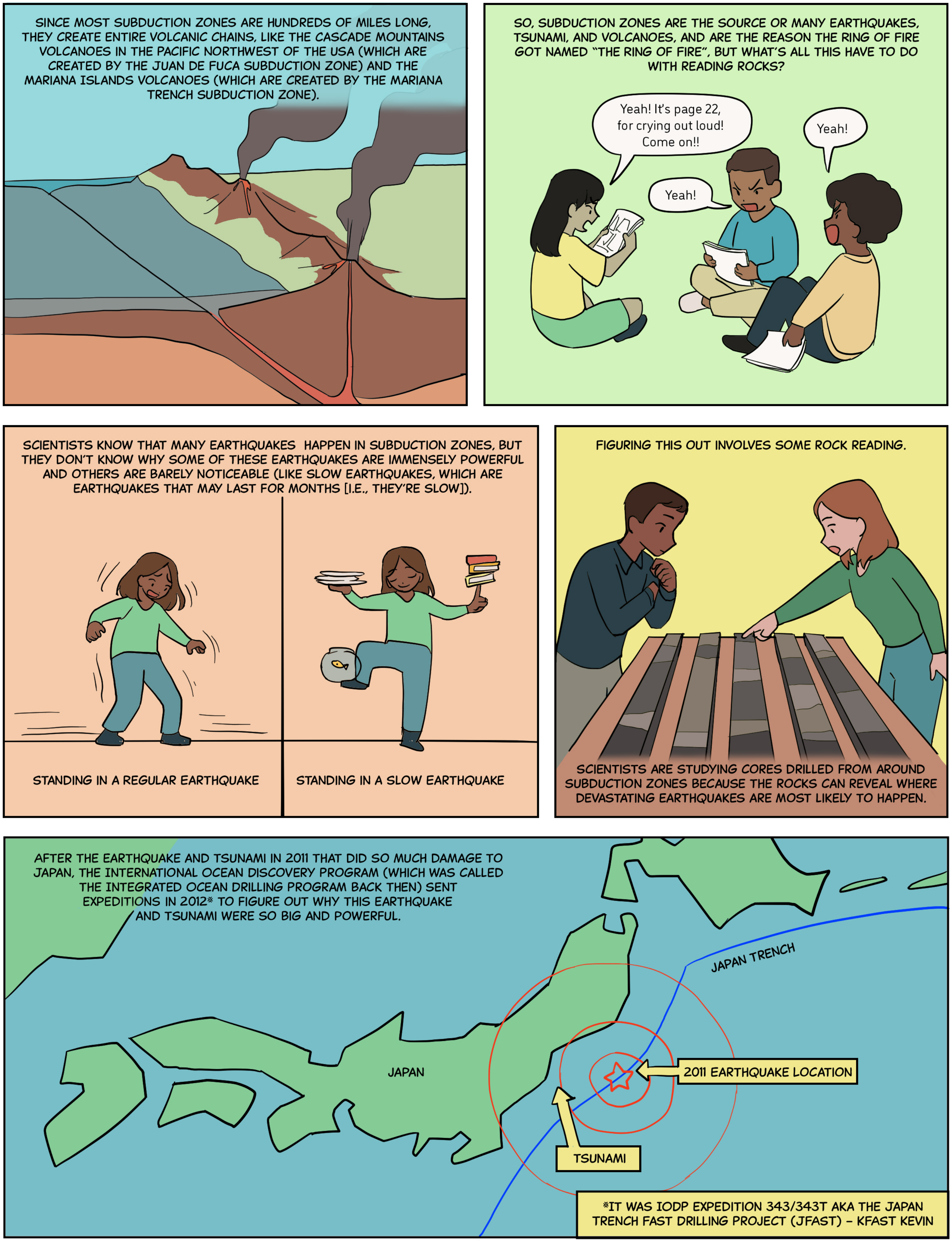

SUBDUCTION ZONE EARTHQUAKES CAN ALSO CAUSE TSUNAMI WHEN THE SHAKING CAUSES HUGE UNDERWATER LANDSLIDES. THE PLUMMETING ROCKS PUSHES MASSIVE AMOUNT OF WATER TOWARDS THE SHORE AS TSUNAMI.
WATER PUSHED UP BY LANDSLIDE
HUGE SLABS OF ROCK BROKEN FREE BY EARTHQUAKE
MANY OF THE ALASKA TSUNAMI IN 1964 WERE CAUSED BY LANDSLIDES.

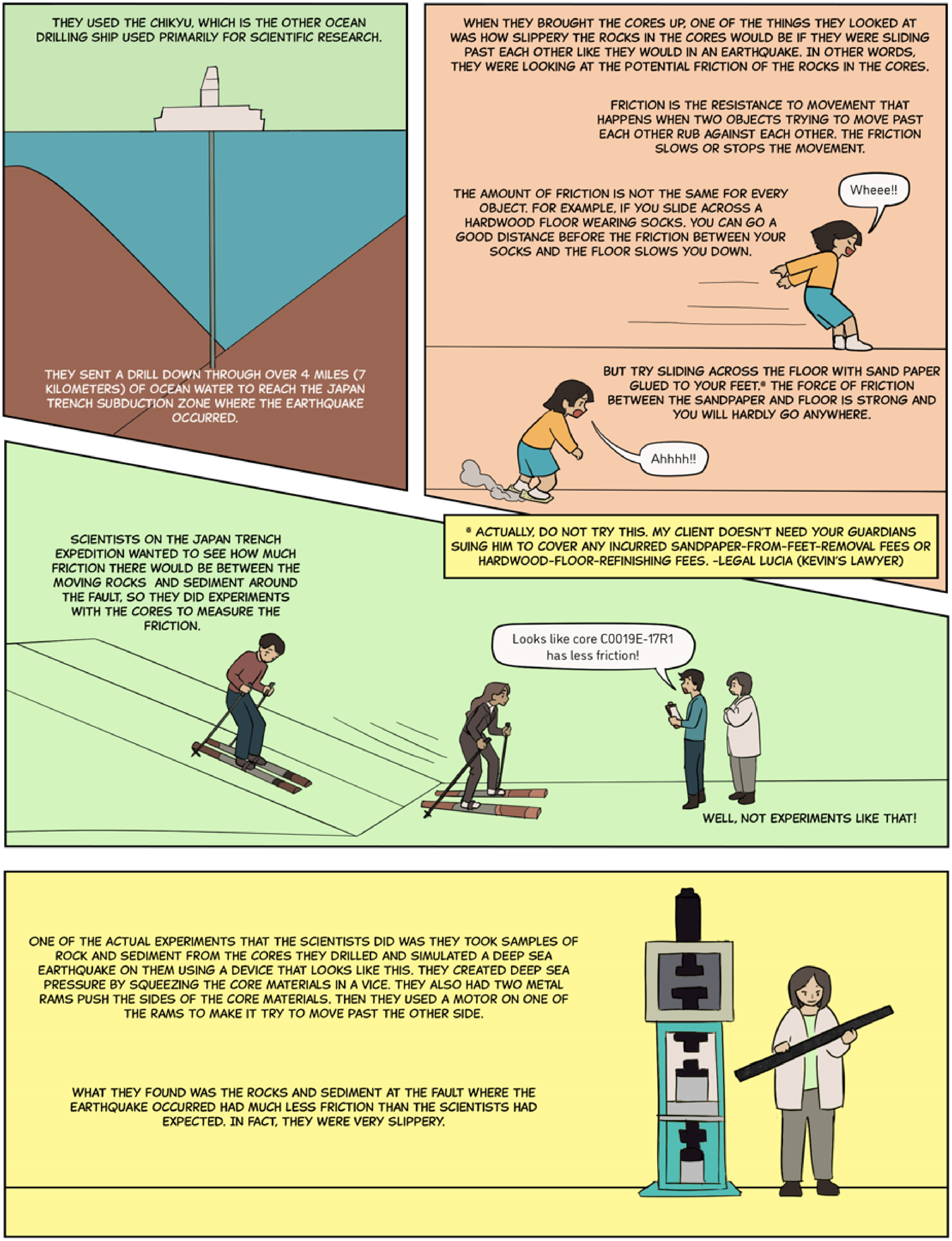

EARTHQUAKES AND TSUNAMI MAY SOUND LIKE ENOUGH SUBDUCTION ZONE-CAUSED DESTRUCTION. BUT THE MASSIVE MOVEMENT OF THE PLATES ALSO CAUSES VOLCANOES.
WANTED
THIS SUBDUCTION ZONE
BIG REWARD

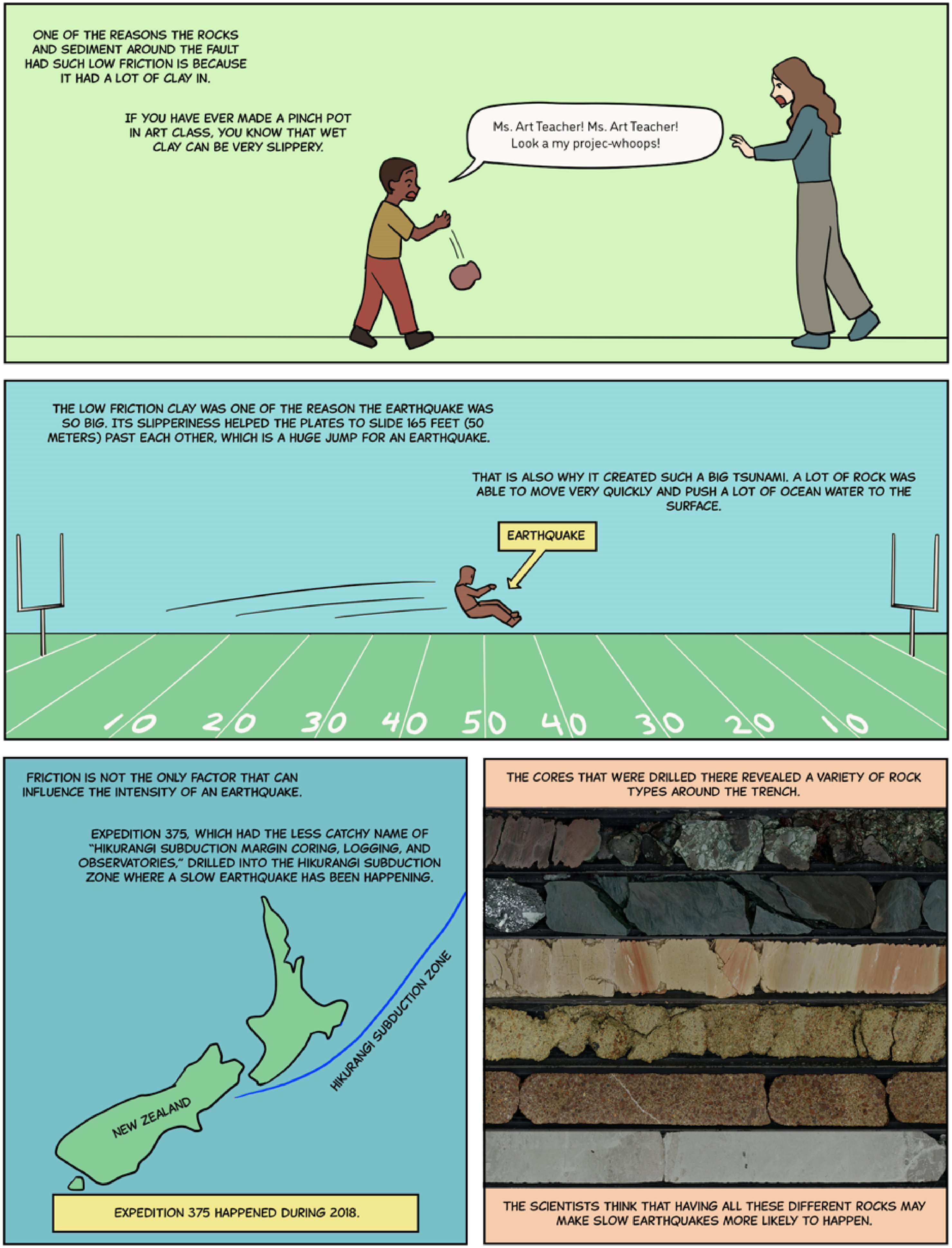

AS AN OCEAN PLATE SINKS UNDER ANOTHER PLATE INTO THE OVEN-LIKE INTERIOR OF THE EARTH, IT GETS HOTTER.
OCEAN PLATE ROCK TYPICALLY MELTS SOMEWHERE AROUND 12000 F (6500C). THE PLATE ONLY NEEDS TO SINK, LIKE, 30 MILES (50 KILOMETERS DEEP) TO GET THAT HOT, BUT THE PRESSURE AT THAT DEPTH KEEPS THE ROCK FROM MELTING COMPLETELY INTO LIQUID.
COOL
WARM
WARMER
HOT
HOTTER
EVEN HOTTER
EXCESSIVELY HOT

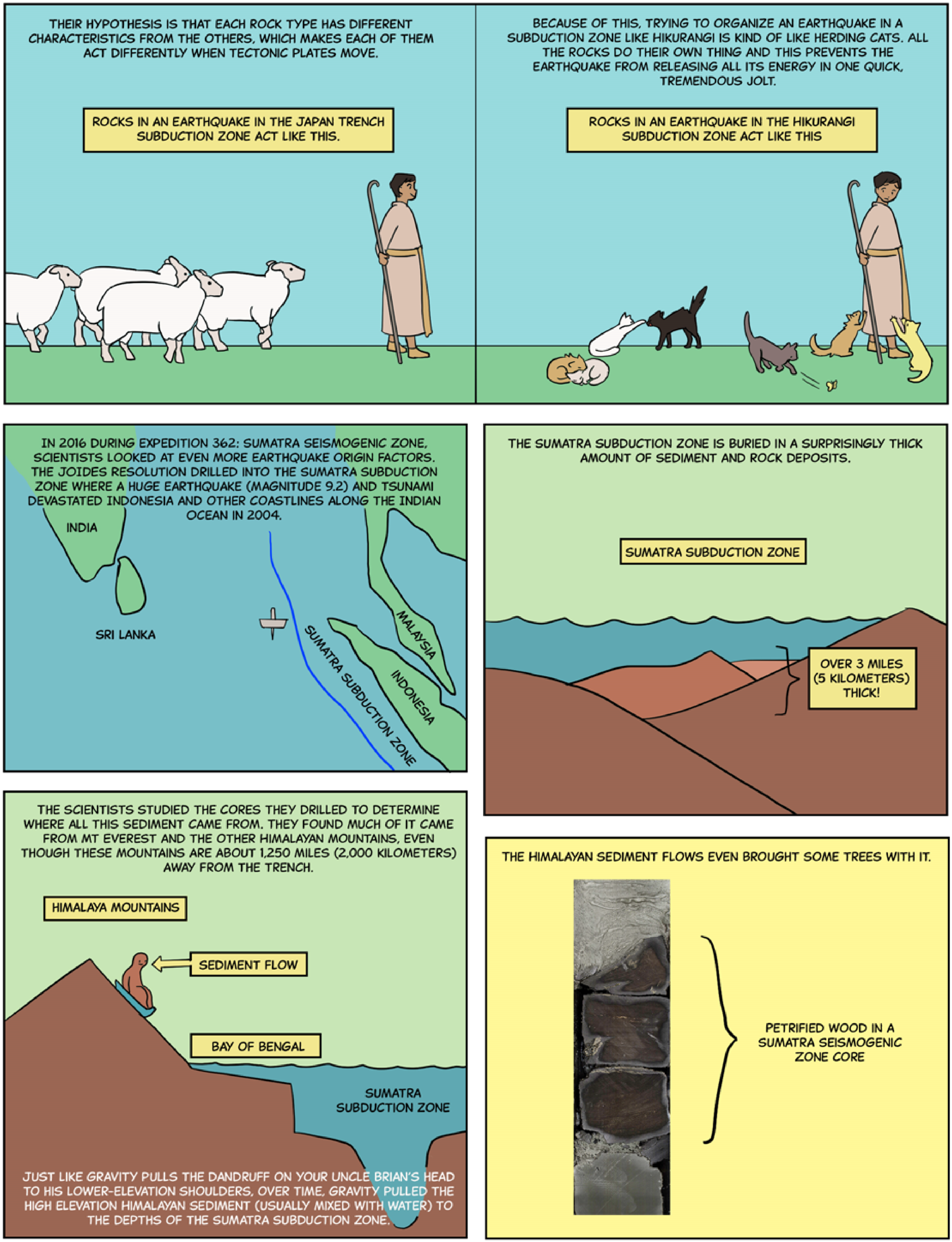

BUT THE OCEAN PLATE ROCK IS LIKE A SPONGE THAT IS FULL OF WATER IN ITS HOLES (THOUGH A SPONGE YOU SHOULD NEVER, EVER USE TO WASH YOUR PARENT'S CAR).
What do you think, Mom?

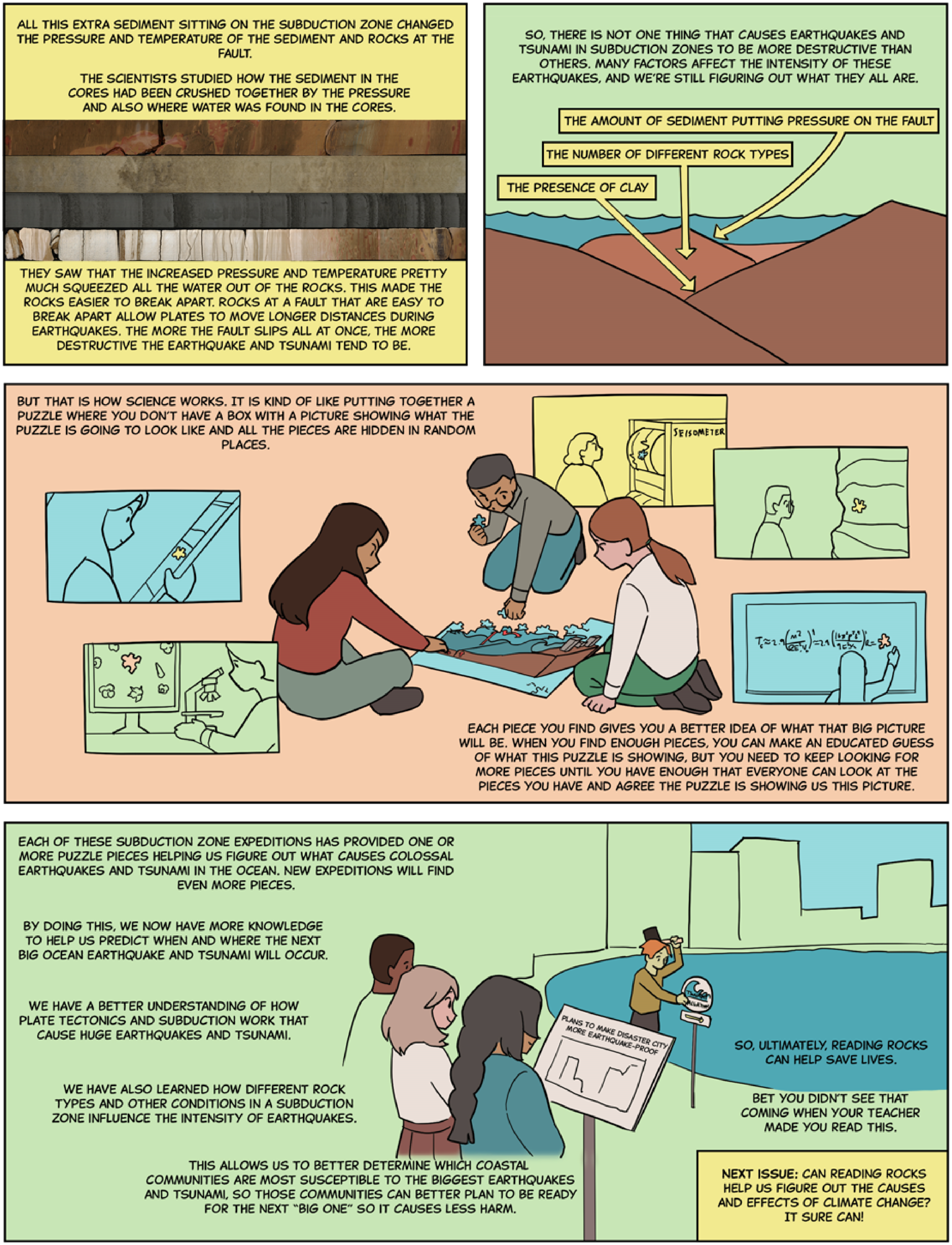

THE WATER IN THE OCEANIC PLATE HELPS CREATE LIQUID MAGMA. WHEN THE PLATE IS ABOUT 60 MILES (100 KM) DEEP, THE WATER RISES INTO THE HOT ROCK ABOVE THE SINKING PLATE.
ADDING ROCK LOWERS THE MELTING POINT OF THE ROCK, ALLOWING THE ROCK TO CHANGE INTO LIQUID MAGMA.
VOLCANO
YOU CAN UNDERSTAND IT BY THINKING ABOUT CHEESE. A HARD DRY CHEESE LIKE PARMESAN IS MORE DIFFICULT TO MELT THAN A SOFT WET CHEESE LIKE BRIE. THE ADDED WATER TURNS HARD PARMESAN-LIKE ROCKS INTO MORE EASILY MELTABLE BRIE.
BONK!
PARMESAN
Ow!
PLOP
BRIE
Ew!
MAGMA
MAGMA IS LESS DENSE THAN THE ROCKS AROUND IT, SO THE NEWLY MELTED ROCK KEEPS RISING TO THE SURFACE. THE LIQUIDS AND GASES IN THE MAGMA EXPAND AND BUILD UP PRESSURE ON THE ROCKS AT THE SURFACE THAT ARE HOLDING THE MAGMA BACK. EVENTUALLY THE PRESSURE IS SO HIGH THAT THE MAGMA ERUPTS OUT OF THE GROUND TO CREATE A VOLCANO.


SINCE MOST SUBDUCTION ZONES ARE HUNDREDS OF MILES LONG, THEY CREATE ENTIRE VOLCANIC CHAINS, LIKE THE CASCADE MOUNTAINS VOLCANOES IN THE PACIFIC NORTHWEST OF THE USA (WHICH ARE CREATED BY THE JUAN DE FUCA SUBDUCTION ZONE) AND THE MARIANA ISLANDS VOLCANOES (WHICH ARE CREATED BY THE MARIANA TRENCH SUBDUCTION ZONE).
SO, SUBDUCTION ZONES ARE THE SOURCE OR MANY EARTHQUAKES, TSUNAMI, AND VOLCANOES, AND ARE THE REASON THE RING OF FIRE GOT NAMED "THE RING OF FIRE", BUT WHAT'S ALL THIS HAVE TO DO WITH READING ROCKS?
Yeah! It's page 22, for crying out loud! Come on!!
Yeah!
Yeah!
SCIENTISTS KNOW THAT MANY EARTHQUAKES HAPPEN IN SUBDUCTION ZONES, BUT THEY DON'T KNOW WHY SOME OF THESE EARTHQUAKES ARE IMMENSELY POWERFUL AND OTHERS ARE BARELY NOTICEABLE (LIKE SLOW EARTHQUAKES, WHICH ARE EARTHQUAKES THAT MAY LAST FOR MONTHS [I.E., THEY'RE SLOW]).
STANDING IN A REGULAR EARTHQUAKE
STANDING IN A SLOW EARTHQUAKE
FIGURING THIS OUT INVOLVES SOME ROCK READING.
SCIENTISTS ARE STUDYING CORES DRILLED FROM AROUND SUBDUCTION ZONES BECAUSE THE ROCKS CAN REVEAL WHERE DEVASTATING EARTHQUAKES ARE MOST LIKELY TO HAPPEN.
AFTER THE EARTHQUAKE AND TSUNAMI IN 2011 THAT DID SO MUCH DAMAGE TO JAPAN, THE INTERNATIONAL OCEAN DISCOVERY PROGRAM (WHICH WAS CALLED THE INTEGRATED OCEAN DRILLING PROGRAM BACK THEN) SENT EXPEDITIONS IN 2012* TO FIGURE OUT WHY THIS EARTHQUAKE AND TSUNAMI WERE SO BIG AND POWERFUL.
JAPAN TRENCH
JAPAN
2011 EARTHQUAKE LOCATION
TSUNAMI
*IT WAS IODP EXPEDITION 343/343T AKA THE JAPAN TRENCH FAST DRILLING PROJECT (JFAST) – KFAST KEVIN


THEY USED THE CHIKYU, WHICH IS THE OTHER OCEAN DRILLING SHIP USED PRIMARILY FOR SCIENTIFIC RESEARCH.
THEY SENT A DRILL DOWN THROUGH OVER 4 MILES (7 KILOMETERS) OF OCEAN WATER TO REACH THE JAPAN TRENCH SUBDUCTION ZONE WHERE THE EARTHQUAKE OCCURRED.
WHEN THEY BROUGHT THE CORES UP, ONE OF THE THINGS THEY LOOKED AT WAS HOW SLIPPERY THE ROCKS IN THE CORES WOULD BE IF THEY WERE SLIDING PAST EACH OTHER LIKE THEY WOULD IN AN EARTHQUAKE. IN OTHER WORDS, THEY WERE LOOKING AT THE POTENTIAL FRICTION OF THE ROCKS IN THE CORES.
FRICTION IS THE RESISTANCE TO MOVEMENT THAT HAPPENS WHEN TWO OBJECTS TRYING TO MOVE PAST EACH OTHER RUB AGAINST EACH OTHER. THE FRICTION SLOWS OR STOPS THE MOVEMENT.
THE AMOUNT OF FRICTION IS NOT THE SAME FOR EVERY OBJECT. FOR EXAMPLE, IF YOU SLIDE ACROSS A HARDWOOD FLOOR WEARING SOCKS, YOU CAN GO A GOOD DISTANCE BEFORE THE FRICTION BETWEEN YOUR SOCKS AND THE FLOOR SLOWS YOU DOWN.
Wheee!!
BUT TRY SLIDING ACROSS THE FLOOR WITH SAND PAPER GLUED TO YOUR FEET.* THE FORCE OF FRICTION BETWEEN THE SANDPAPER AND FLOOR IS STRONG AND YOU WILL HARDLY GO ANYWHERE.
Ahhhh!!
* ACTUALLY, DO NOT TRY THIS. MY CLIENT DOESN'T NEED YOUR GUARDIANS SUING HIM TO COVER ANY INCURRED SANDPAPER-FROM-FEET-REMOVAL FEES OR HARDWOOD-FLOOR-REFINISHING FEES. -LEGAL LUCIA (KEVIN'S LAWYER)
SCIENTISTS ON THE JAPAN TRENCH EXPEDITION WANTED TO SEE HOW MUCH FRICTION THERE WOULD BE BETWEEN THE MOVING ROCKS AND SEDIMENT AROUND THE FAULT, SO THEY DID EXPERIMENTS WITH THE CORES TO MEASURE THE FRICTION.
Looks like core C0019E-17R1 has less friction!
WELL, NOT EXPERIMENTS LIKE THAT!
ONE OF THE ACTUAL EXPERIMENTS THAT THE SCIENTISTS DID WAS THEY TOOK SAMPLES OF ROCK AND SEDIMENT FROM THE CORES THEY DRILLED AND SIMULATED A DEEP SEA EARTHQUAKE ON THEM USING A DEVICE THAT LOOKS LIKE THIS. THEY CREATED DEEP SEA PRESSURE BY SQUEEZING THE CORE MATERIALS IN A VICE. THEY ALSO HAD TWO METAL RAMS PUSH THE SIDES OF THE CORE MATERIALS. THEN THEY USED A MOTOR ON ONE OF THE RAMS TO MAKE IT TRY TO MOVE PAST THE OTHER SIDE.
WHAT THEY FOUND WAS THE ROCKS AND SEDIMENT AT THE FAULT WHERE THE EARTHQUAKE OCCURRED HAD MUCH LESS FRICTION THAN THE SCIENTISTS HAD EXPECTED. IN FACT, THEY WERE VERY SLIPPERY.


ONE OF THE REASONS THE ROCKS AND SEDIMENT AROUND THE FAULT HAD SUCH LOW FRICTION IS BECAUSE IT HAD A LOT OF CLAY IN.
IF YOU HAVE EVER MADE A PINCH POT IN ART CLASS, YOU KNOW THAT WET CLAY CAN BE VERY SLIPPERY.
Ms. Art Teacher! Ms. Art Teacher! Look a my projec-whoops!
THE LOW FRICTION CLAY WAS ONE OF THE REASON THE EARTHQUAKE WAS SO BIG. ITS SLIPPERINESS HELPED THE PLATES TO SLIDE 165 FEET (50 METERS) PAST EACH OTHER, WHICH IS A HUGE JUMP FOR AN EARTHQUAKE.
THAT IS ALSO WHY IT CREATED SUCH A BIG TSUNAMI. A LOT OF ROCK WAS ABLE TO MOVE VERY QUICKLY AND PUSH A LOT OF OCEAN WATER TO THE SURFACE.
EARTHQUAKE
10 20 30 40 50 40 30 20 10
FRICTION IS NOT THE ONLY FACTOR THAT CAN INFLUENCE THE INTENSITY OF AN EARTHQUAKE.
EXPEDITION 375, WHICH HAD THE LESS CATCHY NAME OF "HIKURANGI SUBDUCTION MARGIN CORING, LOGGING, AND OBSERVATORIES," DRILLED INTO THE HIKURANGI SUBDUCTION ZONE WHERE A SLOW EARTHQUAKE HAS BEEN HAPPENING.
NEW ZEALAND
HIKURANGI SUBDUCTION ZONE
EXPEDITION 375 HAPPENED DURING 2018.
THE CORES THAT WERE DRILLED THERE REVEALED A VARIETY OF ROCK TYPES AROUND THE TRENCH.
THE SCIENTISTS THINK THAT HAVING ALL THESE DIFFERENT ROCKS MAY MAKE SLOW EARTHQUAKES MORE LIKELY TO HAPPEN.

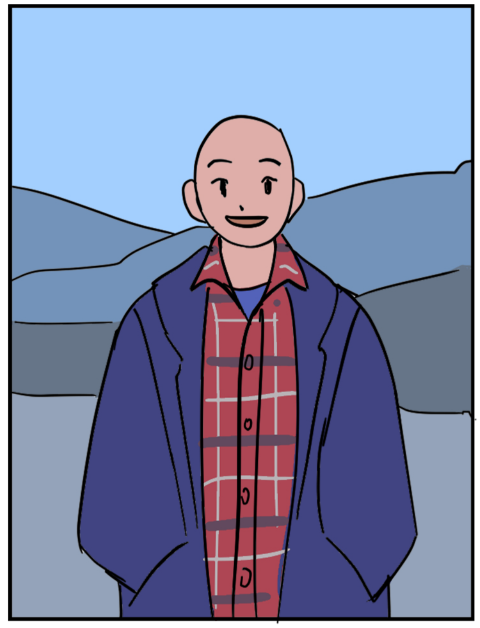

THEIR HYPOTHESIS IS THAT EACH ROCK TYPE HAS DIFFERENT CHARACTERISTICS FROM THE OTHERS, WHICH MAKES EACH OF THEM ACT DIFFERENTLY WHEN TECTONIC PLATES MOVE.
ROCKS IN AN EARTHQUAKE IN THE JAPAN TRENCH SUBDUCTION ZONE ACT LIKE THIS.
BECAUSE OF THIS, TRYING TO ORGANIZE AN EARTHQUAKE IN A SUBDUCTION ZONE LIKE HIKURANGI IS KIND OF LIKE HERDING CATS. ALL THE ROCKS DO THEIR OWN THING AND THIS PREVENTS THE EARTHQUAKE FROM RELEASING ALL ITS ENERGY IN ONE QUICK, TREMENDOUS JOLT.
ROCKS IN AN EARTHQUAKE IN THE HIKURANGI SUBDUCTION ZONE ACT LIKE THIS
IN 2016 DURING EXPEDITION 362: SUMATRA SEISMOGENIC ZONE, SCIENTISTS LOOKED AT EVEN MORE EARTHQUAKE ORIGIN FACTORS. THE JOIDES RESOLUTION DRILLED INTO THE SUMATRA SUBDUCTION ZONE WHERE A HUGE EARTHQUAKE (MAGNITUDE 9.2) AND TSUNAMI DEVASTATED INDONESIA AND OTHER COASTLINES ALONG THE INDIAN OCEAN IN 2004.
INDIA
SRI LANKA
MALAYSIA
INDONESIA
SUMATRA SUBDUCTION ZONE
THE SUMATRA SUBDUCTION ZONE IS BURIED IN A SURPRISINGLY THICK AMOUNT OF SEDIMENT AND ROCK DEPOSITS.
SUMATRA SUBDUCTION ZONE
OVER 3 MILES (5 KILOMETERS) THICK!
THE SCIENTISTS STUDIED THE CORES THEY DRILLED TO DETERMINE WHERE ALL THIS SEDIMENT CAME FROM. THEY FOUND MUCH OF IT CAME FROM MT EVEREST AND THE OTHER HIMALAYAN MOUNTAINS, EVEN THOUGH THESE MOUNTAINS ARE ABOUT 1,250 MILES (2,000 KILOMETERS) AWAY FROM THE TRENCH.
HIMALAYA MOUNTAINS
SEDIMENT FLOW
BAY OF BENGAL
SUMATRA SUBDUCTION ZONE
JUST LIKE GRAVITY PULLS THE DANDRUFF ON YOUR UNCLE BRIAN'S HEAD TO HIS LOWER-ELEVATION SHOULDERS, OVER TIME, GRAVITY PULLED THE HIGH ELEVATION HIMALAYAN SEDIMENT (USUALLY MIXED WITH WATER) TO THE DEPTHS OF THE SUMATRA SUBDUCTION ZONE.
THE HIMALAYAN SEDIMENT FLOWS EVEN BROUGHT SOME TREES WITH IT.
PETRIFIED WOOD IN A SUMATRA SEISMOGENIC ZONE CORE


ALL THIS EXTRA SEDIMENT SITTING ON THE SUBDUCTION ZONE CHANGED THE PRESSURE AND TEMPERATURE OF THE SEDIMENT AND ROCKS AT THE FAULT.
THE SCIENTISTS STUDIED HOW THE SEDIMENT IN THE CORES HAD BEEN CRUSHED TOGETHER BY THE PRESSURE AND ALSO WHERE WATER WAS FOUND IN THE CORES.
THEY SAW THAT THE INCREASED PRESSURE AND TEMPERATURE PRETTY MUCH SQUEEZED ALL THE WATER OUT OF THE ROCKS. THIS MADE THE ROCKS EASIER TO BREAK APART. ROCKS AT A FAULT THAT ARE EASY TO BREAK APART ALLOW PLATES TO MOVE LONGER DISTANCES DURING EARTHQUAKES. THE MORE THE FAULT SLIPS ALL AT ONCE, THE MORE DESTRUCTIVE THE EARTHQUAKE AND TSUNAMI TEND TO BE.
SO, THERE IS NOT ONE THING THAT CAUSES EARTHQUAKES AND TSUNAMI IN SUBDUCTION ZONES TO BE MORE DESTRUCTIVE THAN OTHERS. MANY FACTORS AFFECT THE INTENSITY OF THESE EARTHQUAKES, AND WE'RE STILL FIGURING OUT WHAT THEY ALL ARE.
THE AMOUNT OF SEDIMENT PUTTING PRESSURE ON THE FAULT
THE NUMBER OF DIFFERENT ROCK TYPES
THE PRESENCE OF CLAY
BUT THAT IS HOW SCIENCE WORKS. IT IS KIND OF LIKE PUTTING TOGETHER A PUZZLE WHERE YOU DON'T HAVE A BOX WITH A PICTURE SHOWING WHAT THE PUZZLE IS GOING TO LOOK LIKE AND ALL THE PIECES ARE HIDDEN IN RANDOM PLACES.
SEISOMETER
EACH PIECE YOU FIND GIVES YOU A BETTER IDEA OF WHAT THAT BIG PICTURE WILL BE. WHEN YOU FIND ENOUGH PIECES, YOU CAN MAKE AN EDUCATED GUESS OF WHAT THIS PUZZLE IS SHOWING, BUT YOU NEED TO KEEP LOOKING FOR MORE PIECES UNTIL YOU HAVE ENOUGH THAT EVERYONE CAN LOOK AT THE PIECES YOU HAVE AND AGREE THE PUZZLE IS SHOWING US THIS PICTURE.
EACH OF THESE SUBDUCTION ZONE EXPEDITIONS HAS PROVIDED ONE OR MORE PUZZLE PIECES HELPING US FIGURE OUT WHAT CAUSES COLOSSAL EARTHQUAKES AND TSUNAMI IN THE OCEAN. NEW EXPEDITIONS WILL FIND EVEN MORE PIECES.
BY DOING THIS, WE NOW HAVE MORE KNOWLEDGE TO HELP US PREDICT WHEN AND WHERE THE NEXT BIG OCEAN EARTHQUAKE AND TSUNAMI WILL OCCUR.
WE HAVE A BETTER UNDERSTANDING OF HOW PLATE TECTONICS AND SUBDUCTION WORK THAT CAUSE HUGE EARTHQUAKES AND TSUNAMI.
WE HAVE ALSO LEARNED HOW DIFFERENT ROCK TYPES AND OTHER CONDITIONS IN A SUBDUCTION ZONE INFLUENCE THE INTENSITY OF EARTHQUAKES.
PLANS TO MAKE DISASTER CITY MORE EARTHQUAKE-PROOF
THIS ALLOWS US TO BETTER DETERMINE WHICH COASTAL COMMUNITIES ARE MOST SUSCEPTIBLE TO THE BIGGEST EARTHQUAKES AND TSUNAMI, SO THOSE COMMUNITIES CAN BETTER PLAN TO BE READY FOR THE NEXT "BIG ONE" SO IT CAUSES LESS HARM.
SO, ULTIMATELY, READING ROCKS CAN HELP SAVE LIVES.
BET YOU DIDN'T SEE THAT COMING WHEN YOUR TEACHER MADE YOU READ THIS.
NEXT ISSUE: CAN READING ROCKS HELP US FIGURE OUT THE CAUSES AND EFFECTS OF CLIMATE CHANGE? IT SURE CAN!

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 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

STAR REN IS AN ARTIST AND ANIMATOR BASED IN BROOKLYN, NEW YORK, WHO FREELANCES FOR VARIOUS INDIE GAMES, FILMS, MUSIC VIDEOS, AND COMICS.

LEARN MORE AT WWW.STARAPTURE.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.

THANK YOU TO DR. PATRICK FULTON FOR REVIEWING OUR WORK TO MAKE SURE WE ARE STAYING TRUE TO THE CURRENT SCIENCE. ANY ERRORS AND INACCURACIES LEFT IN THE BOOK ARE THE AUTHOR'S ALONE.

How To
READ A ROCK Vol. 2

A Graphic Novel About Earthquakes, Tsunami, Volcanoes, Plate Tectonics, and the Scientists who Love Them

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 STORY, TOLD IN THE GOOFIEST WAY POSSIBLE, OF HOW SCIENTISTS READ ROCKS FROM UNDER THE SEAFLOOR TO HELP US LEARN MORE ABOUT EARTHQUAKES, TSUNAMI, AND VOLCANOES.