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Making North America: Origins

KIRK JOHNSON *(Sant Director, Smithsonian National Museum of Natural History)***:** *North America, the land that we love: it looks pretty familiar, don't you think? Well, think again! The ground that we walk on is full of surprises, if you know where to look.*

00:25

As a geologist, the Grand Canyon is perhaps the best place in the world. Every single one of these layers tells its own story about what North America was like when that layer was deposited.

So, are you ready for a little time-travelling?

00:38

I'm Kirk Johnson, the director of the Smithsonian National Museum of Natural History, and I'm taking off on the fieldtrip of a lifetime,…

00:50

Look at that rock there. That is crazy!

…to find out, "How did our amazing continent get to be the way it is?"

EMILY WOLIN (Geophysicist)**:** Underneath Lake Superior, that's about 30 miles of volcanic rock.

KIRK JOHNSON: *Thirty miles of volcanic rock?*

How did the landscape shape the creatures that lived and died here?

Fourteen-foot-long fish, in Kansas. That's what I'm telling you!

01:14

And how did we turn the rocks of our homeland…

Ho-ho. Oh, man!

…into riches?

This thing is phenomenal.

In this episode, we hunt down the clues to our continent's epic past.

01:26

You can see new land being formed, right in front of your eyes.

Why does this golf course hold the secret to the rise and fall of the Rockies? What forces nearly cracked North America in half? And is it possible that the New York City skyline…

I've always wanted to do this.

01: 45

…was once dominated, not by skyscrapers, but by towering mountains?

We're uncovering secrets hiding in our own backyard.

Peel it back!

Woo hoo! That is unbelievable!

Making North America: Origins*, right now, on NOVA.*

03:38

North America: our continent, filled with all these spectacular landscapes. They look like they've been here forever, but they are anything but permanent. The truth is, our continent has had its ups and downs, literally. It's an epic tale of creation and destruction, playing out over thousands, millions, even billions of years.

Wow!

We're going to trace this story back to the very beginning, to the origins of North America.

Our journey starts here, in the American Southwest. This place is a paradise for geologists and one of our national treasures. It is, of course, the Grand Canyon.

That is a big hole!

05:25

And it gets me every time.

Wow! This is absolutely awesome!

The landscape is breathtaking and so much more.

As a geologist, the Grand Canyon is perhaps the best place in the world. It's this incredible 300-mile-long slice through the earth, and you can see layer after layer after layer of sedimentary rock.

Each layer is a time capsule, with a slice of our continent's epic history locked inside, stretching hundreds of millions of years into the past.

Every single one of these layers tells its own story about what North America was like when that layer was deposited. So, here, in one place, you have this incredible story of our continent, laid out for your viewing pleasure.

06:27

But, to really tell that story, I've got to step out of my comfort zone.

So, are you ready for a little time-travelling?

I'm going to rappel down the cliff to get up close and personal with these rocks.

So, it looks like I'm good to step off the edge of the Grand Canyon. I can't believe I'm doing this.

I really don't like the fact that you've put a cactus right here.

This is the moment of truth! Oh, baby! This is not the easiest thing to do, especially in a-hundred-degree heat, but it's worth it.

Every foot I descend transports me further back in time.

07:28

The first layer you come to, in this part of the canyon, is this pinkish rock I'm hanging next to right now. It's called the "Esplanade" layer, and like all the rocks in the Grand Canyon, it's an ancient landscape frozen in time.

Three-hundred-million years ago, this place, and all of the American Southwest, was a vast sea of sand. Hot, dry winds sculpted an immense desert landscape of endless dunes. Over time, the sand compressed and transformed into the sandstone that forms the top ledge of the Grand Canyon, here, today.

Further down, there's evidence of a very different landscape. About a thousand feet below the rim of the canyon, the rock changes to limestone, loaded with fossils.

I've got a little fossil coral in my hand. And it's fossils like this that tells ***<VERIFY "FOSSILS…TELLS">****us that this whole landscape was once under water. Three-hundred-forty-million years ago, a warm shallow sea covered all of the American Southwest. Its waters were teeming with trillions of microscopic marine organisms. When they died, their skeletons piled up on the seafloor and compressed into limestone, forming layers that are hundreds of feet thick.*

And so it goes: layer after layer of rock, telling us the story of long lost landscapes, each one, once the surface of our continent.

09:41

And, right at the bottom, you find the granddaddy of Grand Canyon rocks, granodiorite. This rock is more than 4,000 feet below the rim of the canyon, and it's one of the oldest rocks of them all. By measuring the radioactive elements in this granodiorite, the rock here at the bottom, geologists have figured out that it formed 1.7-billion years ago; old for sure, but not the oldest rock on our continent, in fact, not even close.

10:20

The first rocks on our planet formed over four-billion years ago. Back then, the whole thing was a lump of molten rock, under constant fire from asteroids. Eventually, the bombardment slowed, and the earth cooled. It formed a hard, rocky crust. And, as water seeped from the rocks, oceans soon covered almost the entire planet. Under an orange methane atmosphere, there was hardly any land in sight. So, how did North America, and its fellow continents, get started?

11:22

To see what the very first land might have looked like, I'm heading to a place far from our continent, right in the middle of the Pacific Ocean: Hawaii. Here, you can witness a force of nature that creates land from scratch.

This is amazing. We're flying over this Hawaiian rainforest, just this verdant rainforest, with its vigorous ferns and trees. From up here, it looks like paradise, but there's an inferno bubbling under the surface. This forest is doomed.

Just below us, lava is pouring right out of the mountainside. Here comes an amazing flow. I'm going to open the door now and take a look what's going on here.

Oooh! What is that? Sulfur dioxide? Wow.

There's a vent blowing lava out the window right there. Spattering right below us.

12:25

I'm flying over Mount Kilauea, one of the most active volcanoes on Earth.

What's so cool about volcanoes is that they actually happen on a human timescale. Most other geologic things happen so slowly that it's hard to imagine them happening at all.

Erupting since 1983, Mount Kilauea has spewed out 10-billion tons of lava and resurfaced 50 square miles of land.

This is part of the volcano where you can actually see liquid lava, 1,500 degrees, coming out of the ground, flowing down towards the sea, solidifying and making new land. It's one of these ***<THE?>****few places where you can see new land being formed, right in front of your eyes.*

13:13

All land on our planet started out like this, as lava, cooling and turning into dark, heavy volcanic rock. It would take a dramatic transformation to turn volcanic islands like this into the first continents.

I've got two kinds of rocks here. The first one is this dark, heavy stuff, called basalt. This is the kind of rock you find on ocean floors and ocean crust and ocean islands, like Hawaii.

The second kind of rock is lighter in color, and it's lighter in weight. It's called granite, and rocks like this form the stuff of our continents. You can find granite all over the place in North America, from the Appalachians on the east coast, to the sheer rock faces of Yosemite and the towering peaks of the Rockies. Without granite and other light rocks there might not even be any continents, because at one time the only rock on the face of the earth was volcanic rock, like basalt.

The trick is how do you get the granite in the first place, if you start out with only basalt?

Under the ancient oceans, our whole planet was covered in basalt, broken into large chunks, called plates. Deep beneath them, the heat of the earth softens the rocks and moves them, like a giant conveyor belt. This pushes and pulls the plates of basalt along the surface and sometimes even drags them down, triggering a reaction in the red hot rocks below. The lighter stuff melts, floats upwards and cools into granite, gradually building up a thick layer of light buoyant rock. And this is how you turn heavy volcanic rock into the rock that makes continents, including our own.

15:42

In southern Canada, just north of Lake Superior, I'm on the hunt for some of the oldest rocks on our continent.

I'm Kirk Johnson, here to see Cameron Maclean.

GATEKEEPER <NEEDS CONTEXT. WHAT GATE IS THIS PERSON KEEPING?>:
Okay. On you go.

KIRK JOHNSON: *Thanks, very much.*

This is Lac des Iles, a mine in Thunder Bay, Ontario. This huge open pit is just the tip of the iceberg. I'll be going way deeper.

16:18

How deep are we going right now?

CAMERON McLEAN (Exploration Manager)**:** We're going to the 740 level, so, about 740 meters.

KIRK JOHNSON: *Over 2,000 feet, something like that.*

We're going down. Way down. Way down!

16:36

At the bottom, nearly half a mile down, I realize the full scale of the mining operation. Every day, they blast out 3,000 tons of rocks to find a treasure that formed a long time ago.

CAMERON McLEAN: Here, we've got a pile of ore that was just blasted this morning.

KIRK JOHNSON: *So we're in the ore now?*

CAMERON McLEAN: Yep.

KIRK JOHNSON: *So, basically: shovel it out, grind it up and process it. What do you get?*

CAMERON McLEAN: We get this: Palladium.

KIRK JOHNSON: *Every day, miners extract nearly 400,000 dollars' worth of Palladium from these rocks. This silvery metal makes our car's catalytic converter function.*

Palladium ***<IS?>****35 times more rare than gold.*

17:45

But, to me, the most valuable thing down here is the rock the miners throw away. Geologists have dated the rock here in Lac des Iles and figured out that it formed nearly three-billion years ago, which is just mind-blowing. That's almost a billion years older than the oldest rock at the bottom of the Grand Canyon.

Lac des Iles sits in an ancient chunk of continental crust, one of the oldest building blocks of North America, cooked up nearly three-billion years ago. It merged with other chunks about 1.7-billion years ago, to build the very first version of our continent: Laurentia.

18:42

To this day, the ancient rocks of Laurentia form a solid foundation, reaching about a hundred miles deeper into the earth than the rest of North America.

Building Laurentia was a huge step forward in the making of our continent, but there was some trouble ahead. A-hundred-and-fifty miles *farther south, the peaceful shores of Lake Superior hold traces of a cataclysmic event that very nearly ripped Laurentia apart.*

I've always loved beachcombing. You find amazing things on beaches, and one thing, as a geologist, you learn, very quickly, is that every single pebble tells a story. And on this beach, I'm looking for a very particular kind of pebble.

19:53

Ah, here's one. That's excellent. It doesn't look like much on the backside of it, but, if you turn it over, you can actually see this incredible banded structure. And this is a classic, beautiful Lake Superior agate. And agates form in cavities in rocks made by gas bubbles. And the result is this incredible banded semi-precious gemstone.

Where you find agates, volcanoes, the source of the gas bubbles, are usually not far away. And just a stone's throw from the beach, at Gooseberry Falls, I find a landscape made of nothing but volcanic rock.

That tells me that this place was not always as serene as it looks today. A billion years ago, it was a hellish scene, and geophysicist Emily Wolin has the evidence.

20:57

EMILY WOLIN: These falls are the record of a series of volcanic eruptions that happened in this area. So, we have five steps in these falls, and you can think of each of those steps, each of these layers, as another volcanic eruption. We have flow after flow of lava coming out. And, believe it or not, what we're seeing here, this huge stack of basalt is really only the tip.

KIRK JOHNSON: *Ha! So it goes deep into the ground below us?*

EMILY WOLIN: It goes much deeper into the ground.

KIRK JOHNSON: *So, just how deep does this volcanic rock go? Emily has brought a piece of equipment that can help us see below the surface. It's an array of seismic sensors that you simply pin into the ground.*

Emily is part of a team that has deployed similar sensors all around Lake Superior.

21:52

Shall we test this now?

EMILY WOLIN: Absolutely. Go for it.

KIRK JOHNSON: *I'm setting off little earthquakes. This is great.*

Did that work?

EMILY WOLIN: Looks good.

So, the key to this is that seismic waves travel at different speeds through different kinds of rock.

KIRK JOHNSON: *The waves will travel at different speeds through soil and granite and basalt?*

EMILY WOLIN: Exactly, yes.

We've put seismometers all around Lake Superior, and that tells us the kind of material that's far, far below our feet, without actually having to drill down.

KIRK JOHNSON: *How much basalt is down there?*

EMILY WOLIN: Underneath Lake Superior, this basalt, and other volcanic rocks associated with it, stretch 55 kilometers into the crust. That's about 30 miles of volcanic rock.

KIRK JOHNSON: *Thirty miles of volcanic rock, straight down, that's a lot of volcanic rock. That is a huge pile of volcanic rock.*

22:48

This rock is what remains from one of the biggest volcanic eruptions in the history of our planet. Where the water runs today, there once flowed a sea of fire.

A little more than a billion years ago, Gooseberry Falls was the scene of one of the most violent events in North America's history. Huge torrents of lava poured from the earth, off and on, for about 20-million years. And it wasn't just burning up what's now Minnesota.

23:30

The devastation spread much farther. Evidence of the immense scale comes from surveys, like an ambitious project called the USArray. It's a huge network of 400 movable seismic sensors. In the last eight years, scientists have deployed these across the United States, providing the first complete picture of the rocks that make up our continent, almost like a 3D M.R.I. scan of North America, revealing an ancient geological wound.

I'm looking at a map of the midwest United States, and what I'm seeing is the distribution of these basalt flows. They stretch all the way through Iowa, up into Minnesota, into Lake Superior, and then back down to Lake Michigan. It's a huge area, about a thousand miles long.

24:25

And this map is really revealing, because it shows a tremendous scar across the North American continent. The scar is the result of a huge rift that opened up, in the heart of Laurentia, over one-billion years ago.

Torrents of lava poured from the earth. It was a gash more than a thousand miles long that threatened to split our budding continent apart. But the rift mysteriously stopped. Today, all that's left of this gaping wound is the scar tissue, the basalt we find under Gooseberry Falls and right through the Midwest.

What happened that kept our young continent whole? What was it that stopped the rift?

25:25

No one knows for sure, but it could have been our neighbors. A billion years ago, some of the other continents on Earth converged on North America to form a supercontinent, called Rodinia. It was a titanic group-hug, and when it broke up, the rift had healed. North America was safe but far from finished.

26:01

Our continent now had a stable core, but to build its coastlines, east and west, our continent would have to take a beating that went on for hundreds of millions of years.

Making the east coast we know today is an epic story of heat and collisions. Today, I'm hunting for relics of this continental makeover, in Manhattan.

Apartment block, apartment block…Wow! No apartment block here. Rock!! All over the city, you can see outcrops of bedrock. It's called Manhattan schist, and it's a clue to how the city and the whole east coast was made.

These rocky outcrops in Central Park don't really show up in too many guidebooks, but they are as important to New York's history as the Statue of Liberty or the Empire State Building.

27:25

Here in the heart of Midtown, a brand new apartment complex will soon rise up from the rocks. To build the foundation, the crew's had to dig a pit deep into the Manhattan schist.

So, what's the toughest thing about drilling into this rock?

A.B OLEVIC (**<BUILDING?>**Project Superintendent)**:** This rock is very solid. We've been beating it for 10 weeks, and so far, we went down about three feet.

KIRK JOHNSON: *Wow. And you're just pounding away with those rock hammers?*

A.B OLEVIC: Drilling and hammering away, yeah.

KIRK JOHNSON: *Can I have a try? Can I try one of the machines?*

A.B OLEVIC: Absolutely, here's your chance.

KIRK JOHNSON: *All right, let's go do it, man.*

This is great! I've always wanted to do this. Takes a little concentration, but it's pretty straightforward. Up, down, backwards and then down and then hammer.

This is incredibly hard rock. I mean, I could sit in this cab for hours pounding away, and it would take a long time to make even a couple of inches of progress.

28:30

It's the tough Manhattan schist that's allowed the city's skyscrapers to soar. And the thing about schist is that it started its life as mud. What could have turned mud into this beast of a rock?

I've found some evidence at the bottom of this construction pit. You can see that the rock has a particular shine to it. This is a mineral called muscovite. And muscovite forms in big, platy crystals. Here's one that's almost an inch in diameter. And what's cool about this stuff is that it forms in even larger sheets. And in Moscow, where the word "muscovite" comes from, they used to use sheets of muscovite as window glass.

Muscovite forms at over 500 degrees, and some of the surrounding schist formed at even higher temperatures. That gives me an idea of what happened here that turned soft mud into hard rock.

29:29

About a half-a-billion years ago, a chain of volcanic islands headed towards North America, riding the earth's conveyor belt. These islands bulldozed mud from the seafloor, dumped it onto the east coast and buried it.

29:57

Over time, the mud compressed and baked into the hard bedrock, or schist, that's shaped the face of New York City.

The skyline of New York City is so familiar. It's got this incredible group of tall buildings in the ***<"the midtown" is fine, but if "the" is not actually in the audio than Midtown should be capitalized>****midtown, and then, far to the south, down in downtown Manhattan, there's a second clump of skyscrapers, and in between, there's much smaller buildings.*

And what's going on here, is that, in Midtown, the Manhattan schist comes near the surface, and that allows the builders of the skyscrapers to attach their foundations firmly to bedrock. The same thing happens to the far south, in downtown, and, in between, the bedrock dips deep below the surface, where it's covered by gravels and sands. And there's not so many skyscrapers there; it's much smaller buildings. So, it's actually the geology that gives this very American city its very particular look.

30:59

While other factors are involved, today, these steel and concrete giants dominate New York's skyline. But 440-million years ago, they would have been dwarfed by something else.

The same collision that created the Manhattan schist turned a flat coastal plain into something that's very hard to believe: a mountain range, standing almost 10 times taller than any skyscraper in New York today, the Taconic Mountains.

The ancient Taconic Mountains were really big. They were the size of the Alps, maybe 13,000 feet tall.

Today, very little remains. So where did they go?

In Manhattan, they eroded away, leaving only bedrock. And this reveals one of the great geologic truths. No landscape is permanent.

32:14

The formation of New York and the east coast was just the first in a series of gigantic continental collisions that would transform not just North America, but the entire planet. Evidence of this great clash of continents is hidden in one of the most spectacular vistas of North America.

DAVID LOOPE (Sedimentologist)**:** Over here, Kirk. This is one of the best spots, over here.

KIRK JOHNSON: *Wow. What a spot this is! This is incredible.*

This is Zion Canyon. Its 2,000-foot sandstone cliffs are among the tallest of their kind on the planet. Locked inside them are the remnants of a lost world.

33:20

DAVID LOOPE: Put yourself back in the Jurassic.

KIRK JOHNSON: *Two-hundred-million years ago, these rocks were endless dunes, in a vast desert, covering much of the West.*

DAVID LOOPE: So, this sandstone means that we had nothing but sand, being blown over a **<AN?>**almost lifeless desert. And you piled up more and more and more, dune after dune.

KIRK JOHNSON: *So, these great cliffs of Zion, these great sandstone cliffs are actually the stacked, fossilized, ancient sand dunes?*

DAVID LOOPE: That's it.

KIRK JOHNSON: *The rocks, here in Zion, bear witness to a traumatic phase in our continent's history.*

34:14

More than 300-million years ago, all the continents on Earth came together into the biggest landmass ever: the mega-continent Pangea. A towering mountain range rose in its center, disrupting the climate and turning great swaths of North America parched and dry.

DAVID LOOPE: It was a huge desert. Everything was so far from a source of moisture that you couldn't get rainfall; no moisture in the air.

KIRK JOHNSON: *So what happened to this giant desert? Why did it disappear?*

35:02

David has brought me here to look for clues in the rocks beneath our feet, but they're not easy to spot.

DAVID LOOPE: All right, Kirk. We're getting close, here.

KIRK JOHNSON: *And they'll be round? Or are they irregular?*

DAVID LOOPE: They'll look like circles on the rock surface. Always takes me a little while to get tuned in.

KIRK JOHNSON: *Is this one, over here? This thing?*

DAVID LOOPE: Yep. You got it.

KIRK JOHNSON: *There's that one. So, they're in a row? You got a scale?*

What we've found are ***<WORD MISSING?>****of strangely regular circles in the sandstone. Some of them lined up like a string of pearls. What could have made them?*

DAVID LOOPE: I ruled out tracks, and I ruled out burrows, and then, when I saw the near perfect alignment of these in lines and how they cross cut several different dune deposits, the light finally came on, and I realized it's got to be earthquakes.

KIRK JOHNSON: *Earthquakes? How could these little circles have anything to do with earthquakes?*

36:24

Turns out the mega-continent Pangea was too big for its own good. Trapped heat rising from the earth caused enormous stress under the gigantic landmass sending earthquakes shuddering across the land. When they hit the deserts of Zion, streams of groundwater shot up through the dunes and erupted in mini-volcanoes of quicksand.

So, you're telling me that there'd be geysers of sand shooting out of these holes?

DAVID LOOPE: That's what I'm telling you.

37:06

KIRK JOHNSON: *Pangea ruled the earth for a hundred-million years, but finally this monster of a continent couldn't hold it together, and it cracked apart. The sea flowed into a rift between the continents to form the Atlantic Ocean. North America drifted northward and as the climate changed, it became green again. Finally, our continent was free.*

The breakup of Pangea more or less much ***<IS "MUCH" CORRECT HERE?>****marks the moment that North America became a continent in its own right, with the newly formed Atlantic on one side, what would become the Pacific on the other side, and a shape we'd recognize today.*

37:57

Still, one very important thing was missing: the Rocky Mountains. Miles high, stretching all the way from New Mexico to Canada, you'd think they've been here forever, but you would be wrong. These majestic mountains have come and gone, several times.

38:32

Just outside the Mile High City, of Denver, Colorado, you can see that, for the Rocky Mountains, ups and downs were par for the course.

This is an embarrassingly manicured landscape for a geologist, but I'm heading to the 14th hole, where there's some pretty amazing evidence for the forces involved in the uplift of the Rocky Mountains.

Hey, Jon, how are you?

Drone expert Jon Fredericks and I are going to take his state of the art "eye in the sky" for a little spin.

JON FREDERICKS <(Drone expert?)>: All right. Let's take off.

39:38

KIRK JOHNSON: *The drone camera reveals a bizarre landscape: jagged slabs of sandstone jutting out of the ground.*

Oh, look at that! Incredible!

Just a beautiful landscape there.

39:59

This is like being a bird. And that's what geologists want to do. They want to get up in the air and look down on these rocks, and I can see just a beautiful perspective.

These are layers of sandstone. They started off as sand, which means they were originally horizontal. Now, they're tilted up. It's the kind of landscape you look at and you wonder, "What happened here?"

If you take a closer look at the sandstone slabs, you'll find some clues to how they got here. Mixed in with the finer sand grains are big pebbles with sharp edges.

These are way too big to have been blown by wind. And given the size of these particles and how angular they are, there's probably only one way to get this kind of sediment moved along, and that's by a river. And fast-flowing rivers begin in big mountains.

So, I'm thinking I'm looking at a sandstone that was formed near a mountain range.

40:59

But what mountains? It can't be the Rockies. This sandstone formed way before they even existed. So what's the story?

Standing here, 300-million years ago, I'd be witnessing the birth of a long-lost mountain range. Called the "Ancestral" Rockies, they were nearly as high as the Rockies we see today.

Over millions of years, rivers and rain ground down these ancient mountains and reduced them to sand and gravel, which eventually compressed into sandstone. So, the slabs we see on the golf course are all that's left of this long-forgotten mountain range.

But how come these layers that were once horizontal are now standing on their heads?

42:09

*What was the force that was strong enough to push up hundreds of feet of layered rock up****<VERIFY THAT HE SAYS "UP" IN BOTH PLACES IN THIS SENTENCE>*** *into the sky?*

Seventy-million years ago, the rock that makes our modern Rockies was deep under ground and covered by 10,000 feet of layered rock. But then something happened, hundreds of miles away, on the western edge of

North America. A slab of ocean floor, diving deep into the earth, suddenly starts attacking our continent, bulldozing right through its foundations.

43:51

Far inland, this forced up a massive mountain range, the Rockies 2.0.

They lifted up the 10,000 feet of layered rock above them, tilting that ancient layer of sandstone, which erosion then sculpted into sharp, angled slabs, the jagged red monoliths that make this golf course so special.

The colossal mountains that created them eventually eroded down. But then, about 10-million years ago, the entire region was lifted a mile above sea level, giving us the spectacular Colorado Rockies we see today, a true signature landscape of the American West. They're still under construction, pushing up from below, even as erosion keeps carving away at their majestic peaks.

Now, there's just one more big piece to add to our continental puzzle: the magnificent landscapes of the west coast, like Big Sur, the snow-capped volcanoes of the Pacific Northwest and the fjords and islands of British Columbia and Alaska.

44:48

To find out what made these landscapes, I'm going to have to crack open a few rocks.

To help me, I've brought a crew of fossil hunters to this remote beach.

So what time is it?

<WHO IS THIS?>: I think the tide has probably turned: 7:41.

KIRK JOHNSON: *So, we have about three hours, right?*

So, I'm going to turn you guys loose on this outcrop. And just scream, if you find something good, all right?

<WHO IS THIS?>: We'll scream at the top of our lungs.

KIRK JOHNSON: *I've been here before, and I really wanted to come back.*

<WHO IS THIS?>: Nothing. It's just rock.

KIRK JOHNSON: *You've got to break a lot of rock to find fossils.*

There's nothing quite like splitting open slabs of rock. You never know what you will find hidden inside.

The bigger the slab you can lift up the better, because you just can't…I can't emphasize it enough…

45:51

<WHO IS THIS?>: I think you've been emphasizing it quite a bit.

KIRK JOHNSON: *We've been cracking rocks* ***<FOR?>****hours, and we're running out of time.*

<WHO IS THIS?>: The tide is coming in, guys, about 20 feet behind us.

I have the **<THIS?>**rock. You take that rock.

Peel this one back.

KIRK JOHNSON: *And no fossil!*

Big split, no fossil. Big nothing!

With the tide on our heels, we get one last shot.

46:27

You're on it. My fingers! Okay, we're…whoa. Oh, yes! Okay, now, get this edge right here, and just peel it back real slow. One, two, three. Woo hoo! Look! There it is. Oh, my god. We've hit the jackpot: a fossilized palm frond!

That is unbelievable! That, my friends, is a palm frond. The reason I'm so excited is we're not on the sunny shores of California, we're in Alaska!

What's a palm leaf doing so far north?

I'll tell you what. If you have a palm tree, the ground doesn't freeze. This palm grew here when the climate in Alaska and the rest of the world was much warmer.

But there's something else going on here, because we've also found fossilized corals on a neighboring island, and they're much older than the palm frond.

47:47

We know these corals lived near the equator, so how did their fossils wind up here, in Alaska? Turns out the corals hitched a ride on strings of islands moving up from the Pacific, smacking into North America over millions of years.

These travelling landmasses radically re-shaped our Pacific coastline. Imagine an island the size of Japan, and imagine that island, off the coast of North America, drifting towards the coast at about three inches a year.

Then imagine this field of logs is like lots of little Japans, log after log, smacking in and sliding north, smacking in and sliding north.

And you start to see a model for how the west coast of North America grew.

48:47

It was a titanic geological logjam that grafted thousands of miles of new coastline onto our continent and still had enough power to push up the spectacular coastal mountain ranges of Alaska and British Columbia.

The west coast is the most recent addition in the great continental construction project that built North America, but it's far from complete. On the coast of California, it's easy to find the signs of ongoing work.

49:29

Just 30 miles north of San Francisco, Tomales Bay is one of the most enigmatic places on the west coast and a favorite spot for geologist Lisa White.

LISA WHITE (University of California Museum of Paleontology)**:** Growing up in San Francisco, I always loved this area so much.

It's really a curious situation here, because the rocks on that side of the bay, that whole peninsula, has been moving, for millions of years, from an area further south. And part of the puzzle is we're standing on the San Andreas Fault.

KIRK JOHNSON: *Hidden deep under this bay is an enormous crack in the earth.*

50:14

This is the San Andreas Fault. It cuts right through Tomales Bay and runs 800 miles through California, separating two huge chunks of the earth's crust: the Pacific plate and the North American plate, which are sliding in opposite directions.

LISA WHITE: We're sitting on the North American plate, and the Pacific plate, over there relative to where we're sitting, is moving to the northwest.

KIRK JOHNSON: *So that whole peninsula is moving along. How fast is it going?*

LISA WHITE: That whole peninsula is moving about the speed that our fingernails grow, so, couple of inches every year.

51:09

KIRK JOHNSON: *Tension in the San Andreas can trigger violent earthquakes, like the one that devastated San Francisco in 1906, and many others since.*

LISA WHITE: 1906, 1989, 1993, you name them. Pretty much, most decades, we can think of significant earthquakes that happened.

KIRK JOHNSON: *The power of the moving plates constantly changes the face of California, with surprising long-term results.*

So, what this is means is that sooner or later Los Angeles is going to pull up right next to San Francisco. The view from the Hollywood Hills will be very different.

LISA WHITE: Imagine that! Two towns that don't even like each other very much **<WILL>** be neighbors.

But what understanding the geology of California really illustrates is just how dynamic the state is.

52:10

KIRK JOHNSON: *California is one of those places where the forces under our feet really make themselves known. Our wild ride across North America and back in time reveals **<THAT?>**these forces are relentlessly at work. Continent building never ends, because we know one thing for sure in geology: nothing ever stays the same for very long.*

North America has seen some amazing transformations. It took billions of years to take the shape it is today, but far from reaching the end of our story, we're really just embarking on the next chapter: how geology shaped life on our continent.