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WHAT WAS THE YOUNG EARTH LIKE?

This two-part lecture describes the early Earth and the forces that have shaped the planet as we know it now. Jump in a time machine to visit the early Earth, a hot and inhospitable place where the Earth's layers were just taking shape and ongoing changes to the planet's surface were set in motion. This lecture also introduces Alfred Wegener, who suggested in 1912 that the continents were in motion — a theory that was validated by later evidence for plate tectonics. After reading the text below and watching the video, you should be able to explain the Earth's layers, describe plate tectonics, and cite the evidence that supports this fundamental theory about the planet.

Key questions

1 What processes shaped the early Earth?

2 How have plate tectonics worked to shape Earth's surface as we know it today?

3 What evidence do we have for plate tectonics?

Transcript: Part 1

0:11-1:07

THE EARLY EARTH

Imagine you're in a time machine and you've traveled back 4.5 billion years. What you're doing is taking a stroll on the early Earth. What would it be like and would you be having fun? Well, the answer is I don't think you'd be having much fun.

First, you'd be walking on molten lava. Not nice. Secondly, you couldn't breathe because there's no oxygen. You'd be asphyxiating. And thirdly, you'd be ducking asteroids and meteorites that are crashing into the early Earth; lots and lots of them. And fourth, you'd probably be throwing up because of very high levels of radiation, and if you stay there too long your hair would start falling out too. So, I don't think you want to stay there too long.

1:07-1:56

A HOT EARLY EARTH

Why was the early Earth so hot? Because that's the main thing. It was really, really hot. Now, you've already got some clues as to why it was so hot and you might be able to think this through, but let me give you three of the main reasons.

First, do you remember that supernova that blew up just before the Solar System was formed? That created huge amounts of radioactive material and that radioactivity generated a lot of heat. Today a lot of it is dissipated. So today's Earth is nothing like as radioactive as it was 4.5 billion years ago.

Secondly, do you remember the process of accretion? Really violent, lots of space debris crashing into other space debris. Each collision with a meteorite or an asteroid created huge amounts of heat.

1:56-2:34

PRESSURE BUILT UP HEAT

And the third problem…the third problem is subtler because it's pressure. Do you remember those clouds that the early stars formed from? Well, as the clouds got denser, do you remember the pressure increased and they got hotter? And the same thing happened with the early Earth. As it accreted it got larger, pressure built up, and heat built up particularly at the center. So that's why the early Earth was so hot.

In fact, the early Earth got so hot it melted and that is really important because if it hadn't melted today's Earth would be very different from the way it is.

2:34-3:33

A THOUGHT EXPERIMENT ON THE EARTH'S LAYERS

To get a sense of what happened and why this was so important, let's imagine a kind of absurd experiment. So you're going to put some stuff into a sauce pan. You're going to put in some coins. You're going to put in some rice. You're going to put in some plastic. Let's add a little bit of mud. Let's put in some ice and you can chuck in one or two other things. Now we're going to heat that stuff up to several thousand degrees. Don't stir, just let it simmer.

Now, it's not going to taste good, but we may be able to learn something from this. What we'll see is that the whole thing is going to melt. The heavy stuff, such as the coins, are going to sink down to the bottom, lighter stuff is going to rise to the top, and some stuff is going to evaporate and boil above the sauce pan.

Now something very like this seems to have happened to the early Earth. It melted and because it melted it formed a series of **layers** and they give it its structure today. Let's look at the four main layers.

3:33-4:41

THREE OF THE EARTH'S LAYERS: CORE, MANTLE, CRUST

The first is at the center. It's the **core**. It's metallic. Nickel and iron — above all, iron — sank to the center of the Earth. And the fact that the center of the Earth is full of metal is really important because this gave the Earth its magnetic field and the magnetic field deflects some of the sun's rays that would be harmful to living creatures such as us. So that's the first layer, the core.

Secondly, lighter stuff — lighter rocks — float above the core and form a layer that's called a **mantle**. The mantle you can think of as sort of hot sludge of rocks. These rocks are so hot they're sort of semi-molten and they're actually moving around in convection currents inside the mantle.

Then at the very top you have a layer called the **crust**. Very light rocks such as basalts and granites reached the top, they cool, and they form this thin layer of the crust. That's where we live. The crust is pushed around by those convection currents from underneath. You can think of the crust as a tiny, thin layer a bit like sort of an egg shell.

4:41-5:07

FOURTH LAYER: THE ATMOSPHERE

Finally, the fourth layer is the **atmosphere**. Some of the gassy stuff bubbles up to the top, it evaporates. The very light gases such as hydrogen disperse into space, but a lot of other gases just hang around the Earth held by its gravitational pull and that's how the Earth acquired the structure it has today. All of this happened about 10 million years after the creation of our Solar System.

Transcript: Part 2

5:11-6:02

SHIFTING CONTINENTS

Now, I want you to hop back in that time machine, and what I want you to do is to take off from your backyard and hover over your hometown. Now I want you to put the time machine into fast motion so it's moving rapidly back through time and you're going to see something really weird. What you're going to see is that the land is going to start buckling and shaking and moving like a huge monster.

This looks weird to us simply because we don't live long enough to see that the Earth is in fact changing all the time. Now, in fact, some scholars began to notice this as early as the 16th century when they studied the first world maps that were ever produced. Some of them noticed odd things like the fact that West Africa seems to fit well into Brazil. I mean, look at a modern map and you'll see the same thing.

6:02-7:04

ALFRED WEGENER'S THEORY

PANGAEA: A SINGLE SUPERCONTINENT

In the early 20th century, a German meteorologist called **Alfred Wegener** found lots of evidence to suggest that the **continents** had in fact once been connected. For example, he found very similar geological strata in West Africa and in Brazil. And during World War I, he wrote a book arguing that once all the continents on Earth had been united in a single supercontinent that he called **Pangaea** after the Greek goddess Gaia, for the Earth.

SCIENTISTS DOUBT WEGENER

Now, what did the other geologists think of this great idea? They were not impressed. Here's the problem. Wegener came up with heaps of evidence to show that the continents seemed once to have been linked. What he couldn't do was explain how the continents moved around the Earth. So when they said, "Okay Alfred, how do you tow a whole continent around the Earth?" he couldn't explain it, and as a result of that his great idea was ignored for almost 40 years.

7:04-7:57

SONAR TECHNOLOGY REVEALS SURPRISES AT THE OCEAN FLOOR

We saw when looking at astronomy that quite often new technologies can generate new evidence which changes our understanding of the science, and something very like this happened in geology. During World War II, **sonar** technologies were developed to track submarines and after World War II some geologist used that technology to try to map the ocean floor. When they started doing this they found something that really surprised them.

UNDERSEA VOLCANOES SPREAD THE SEA FLOOR

Through many of the Earth's oceans they found huge chains of volcanos and what's happening is that lava is coming out from the mantle. It's rising up, it's forming mountains, and it's pushing apart the old oceanic crust. In the center of the Atlantic Ocean, for example, there's a huge chain of these mountains and what they're doing is they're pushing the Atlantic apart. So the Atlantic is actually getting wider and wider at about the speed that your fingernails grow.

7:57-8:48

Now, some geologists thought okay, does this mean that the Earth as a whole is just getting bigger and bigger and bigger like an inflating balloon? But they soon realized that elsewhere in the Earth crust was going back into the mantle, which balanced what was happening in the Atlantic.

TWO TYPES OF CRUST VARY IN WEIGHT AND MOBILITY

WHEN A SECTION OF CRUST SLIDES BENEATH ANOTHER IT'S CALLED SUBDUCTION

Let me explain how it works. Now, to understand this you need to think of two basic types of crust. There's **continental** crust, which is the land that we walk on, and then there's oceanic crust, the land beneath the oceans. In general, continental crust is lighter. It tends to be made of granites. **Oceanic crust** tends to be heavier, made of basalts. Okay? Now once you've got that, think of two bits of crust colliding — continental and oceanic. What's going to happen?

8:48-9:59

Well, what's going to happen is that the heavier oceanic crust is going to dive beneath the continental crust. Now, think of this. It's grinding against the continental crust. It's creating huge friction and lots of heat and it melts part of the continental crust and punches up whole mountain chains. That basically is how the Andes mountain chain was formed.

HOW MOUNTAINS FORMED

Mountains can also form when portions of continental crust collide with each other, but this time because both portions have about the same density they don't dive beneath each other, but they crumple up to form huge mountain chains. That's basically how the Himalayas were formed about 50 million years ago when India crashed into the mainland of Asia.

THE CAUSE OF EARTHQUAKES

There's another type of relationship between different parts of crust. Sometimes you get two bits of crust that are moving in opposite directions past each other. What happens is that the friction holds them, but the pressure builds up and then suddenly they slip. This is what's happening along the San Andreas fault in California. It is that slippage that creates earthquakes.

9:59-10:58

PLATE TECTONICS

Okay, these are the basic ideas of the modern theory of plate tectonics, and the theory of plate tectonics is the fundamental idea of modern geology and Earth sciences. Just as Big Bang cosmology is the fundamental idea of modern astronomy.

It explains a huge amount about how the Earth works, just as Big Bang cosmology explains how the Universe works. It explains, for example, why all around the Pacific you get a ring of volcanoes and earthquakes. It explains why the Earth is broken up into a series of plates like a broken egg shell and why it's around the edge of those plates that you get violent activity such as volcanoes and earthquakes. It explains how mountains form. It explains all the fundamental features of our Earth, and also how the continents move. It explains what Wegener couldn't explain. So the theory of plate tectonics is now the most fundamental idea in modern Earth sciences.