VOYAGE OF THE CONTINENTS
SOUTH AMERICA
Script - 52'

10 00 03 00 : Narration
Since its formation, our planet has undergone constant transformation.
10 00 12 00
Stupendous collisions have created continents. Colossal forces have raised up ocean floors, forming dramatic mountain ranges.
10 00 27 00
These movements on the Earth's surface can be seen today in (the form of) volcanic eruptions, earthquakes and tsunamis.
10 00 38 00
Tectonics sculpt our landscapes, modify the climate, displace oceans, and can even influence the living world.

10 00 56 00 : Narration
South America has the longest mountain range, and the densest forest,

10 01 04 00
the most powerful river, and the greatest biodiversity on the planet.

10 01 10 00
It's a world of great beauty and infinite variety, forged by the energy contained within the Earth itself, shaped and moulded by earthquakes and erosion.

10 01 21 00
This turbulent past has left traces in rocks and cliffs. From the heart of the Amazon jungle to the lofty moutain peaks, scientists attempt to resolve the mysteries of the South American continent. One more tale in the never-ending story of the voyage of the continents.

10 01 37 00

Opening titles

<u>Séquence 1 – In the beginning: Columbia</u>

10 01 57 00 Narration :
When it was born, some 4.6 billion years ago, our planet was a gigantic ball of fire. Then it cooled, giving way to the first oceans… and the first embryonic continents.

10 02 10 00
As time passed, the emerging land masses came closer together, forming vast islands of terrestrial crust.

10 02 19 00
Two billion years ago, one of these continental masses, known as the 'Amazonian craton', became the cornerstone of the future South America.

10 02 35 00 Narration :
Nelson Reis works for the Brazilian geology service, and is one of the leading experts on the history of the Amazonian craton.

10 02 45 00
He's working in the north of Brazil, in the Tepequem region. It is here that the last vestiges of this original land can be found, remaining unchanged since they were created.

10 03 00 00 : Narration
He explores the regionrelentlesly, looking for rocks that were part of the craton.

10 03 09 00
It's a delicate mission, as the elements have changed the landscape over millions of years.

10 03 18 00
Ancestral lands lie on the slopes of moutnains with flattened tops, that the Indians call 'tepuy'.

10 03 34 00
For Nelson Reis, these rocky peaks provide valuable testimony for a better understanding of the origins of the South American continent.

10 03 56 00
Over time, the Amazonian craton moved on the Earth's surface and collided with other land masses. 1.8 million years ago, it was trapped within the vice of a supercontinent, Columbia.

10 04 12 00
Nelson Reis :

To reconstruct the story of the Columbia supercontinent, we need to do field studies. This involves collecting rocks for dating and studying what we call paleomagnetism. The data enables us to know the age of the rocks in question and also where they were situated, in relation to the Earth's magnetic pole, at the moment they were formed.

10 04 42 00 : Narration
In recent years, Nelson Reis and his colleagues have collected and analysed hundreds of samples.

10 04 50 00
The results reveal a particularly complex puzzle.

10 04 56 00
Nelson Reis :

Here in South America, we can observe at least four cycles of supercontinent formation. The oldest led to the formation of (the supercontinent) Columbia, followed by Rodinia, then Gondwana, and the youngest of them, in the Mesozoic, Pangaea.

10 05 22 00 : Narration
For millions of years, through tectonic plate movements, the future South America was therefore at the centre of various, differently shaped supercontinents.

10 05 35 00
Today, the history of these successive assemblies is still little known. The surface of the planet has retained little evidence of these extremely ancient events.

Sequence 2 – The dislocation of Rodinia

10 05 53 00 : Narration
But at the University of Tucson in Arizona, one rather adventurous geologist has decided to investigate, in order to reconstruct the various phases in the evolution of South America.

10 06 07 00
He is Martin Bailey Pepper, a geologist and a motorbike fanatic.

10 06 14 00
For several years, he has been exploring South America by bike, collecting unusual samples. Zircon… A mineral present in sand grains, with the quality of being extremely stable.

10 06 30 00

Martin B. Pepper :
What I really love about geology is that you can pick up just, let's say a handful of sand here. (It's not only taken millions of years to get this of the tops of these mounts) but the geologists using the right tool you can get in and just look at a single grain like a zircon. You can take that single grain and you can zoom into that and get a whole story of non only when this formed but you go back farther what fluids were there before this formed. You can also go forward and figure out so much information about the time it took to slowly come out of the deep mantle.
As these rivers remove more and more after tops of these mountains bringing this up from hundred of kilometers deep, finally get into the surface. There's so much information into one of this grains of sand, and yet that's almost the biggest thing we have when we go back billions of years to figure out what happen to things in Rodinia or farther back to Colombia, or farther back to the beginning of the earth itself.

10 07 37 00 : Narration
Martin has already covered some 50,000 kms, from Patagonia to Ecuador.

10 07 47 00
He's collected more than 8000 samples from almost every river across the continent…

10 08 00 00

Martin B. Pepper :

And so all I had to do is gointo these river valleys with a gold pan separate all the light minerals that I didn't want and take just the Zircon home, (which is just a sample about a size of a thumb, so extremely small.) And it's those Zircon that I can then take in our lab to analyse.

10 08 19 00 : Narration

In his laboratory back in Tucson, each grain of sand is washed, filtered, then analysed using a laser. This process provides the precise age and composition of each grain of zircon.

10 08 33 00

Martin hopes that he will soon manage to identify the origin of all the sediment, and thus retrace the geological history of Latin America over 3 billion years.

10 08 53 00

There are still years of work to be done… but already the first results are promising. The geologist has discovered grains of sand from every part of the continent that are some 900 million years old.

10 09 07 00

This would suggest that at the time, all the fragments of land that make up South America, were all assembled together.

10 09 18 00

Martin B. Pepper :

When I think of the earth I like to envision it as almost when I'm cooking hot cocoa. And so we have the heat underneath the pot and that causes this upwelling current, this convection cell. And the continents were really just these marshmallow bits that float around on all that convecting magma. On earth, as we know it, we see these giant continents but when you go back in time, a continent is composed of these stabilised blocks. And it's these blocks that will actually separate and collide in time. And scientists discovered that these blocks separate and collapse in supercontinents about every four or five hundred million years.

And these blocks can completely disassociatefrom what we understand as North America, South America, Europe, Asia, Africa. And so when we go to the time of Rhodenia the final assembly about 900 million years ago, many of these continental blocks that we think of associated with south America look completely different.

They were kind of in the middle of this supercontinent but they were separatedand so after 900 million years ago as all these blocks started to be ripped apart we then disassociated what something we wouldn't even recognise and then they started to coalesce into that something what we can finally say « ha ha » that look just like South America.

10 10 44 00 : Narration

900 million years ago, the dislocation of a supercontinent would therefore have given rise to the future South America.

10 10 55 00
The pieces of terrestrial crust that compose it began a long, common existence, and nothing would separate them.

10 11 06 00
But subsequently, the continent would experience other dramatic changes.

Sequence 3 – The formation of Gondwana

10 11 14 00 : Narration
About 700 million years ago, the land masses of the southern hemisphere converged, and the future South America collided with the future Africa.
This contact led to the appearance of a new supercontinent : Gondwana.

10 11 35 00
The land today can tell the story of the birth of Gondwana, a major episode in South American history.

10 11 53 00
We're in Rio de Janeiro, Brazil's second biggest city. There is a laboratory here with a very evocative name : the Gondwana lab.

10 12 07 00
It was founded by Renata Schmidt. Her objective is to understand every detail of every step in the formation of Gondwana.

10 12 20 00
A century ago, it was the first supercontinent to be recognised as such by the specialists. It confirmed the hypothesis of the existence of plate tectonics.

10 12 32 00

Renata Schmitt :
It's like a perfect puzzle which fits together so this was actually very strong evidence for the building up the theory of the continental wandering. It was in 1920 more or less and it evolved in 1950, 1960 to the theory of tectonic plates and it evolved much faster after the 60's because of all the knowledge we got from the oceans, because we didn't have access until the 50's, until the Cold War. And in the Cold War, they started to build up submarines and they started to study all the oceans of earth and then we started to get better information and then we understand that the continent actually are tectonic plates that move along the history of earth since the beginning until today.

Renata Schmitt
The origin of Gondwana, the word Gondwana comes from the nineteenth century when they found in India, in a region in India, Jaipur, and in this region there wasthese people which they called the "Gons" it's like an aboriginal people. And they found there a sequence of sedimentary rocks of the Carboniferous Period and within these rocks they found fossiles of Glossopteris which is a kind of plant. And the same sequence, the same floras they found in

Antarctica, they found in the basins of Africa and they found also in South America and in Australia. It is weird that how can a plant travel from all this really large distance so this mass, this continental mass should be together at some part of history of earth. And of course another very strong evidence of the Gondwana amalgamation and the Gondwana existence is the fit of the continental margin.

10 14 27 00 : Narration
For several years, Renata Schmidt and her colleagues have been studying the rocks of South America to learn more about the history of the supercontinent.

10 14 42 00
Claudio Valeriano, a geologist at the University of Rio de Janeiro, is particularly interested in the famous Sugar Loaf Mountain, which stands majestically over the bay. This granite mountain, rising up 395 metres, is the result of a violent collision between tectonic plates.

10 15 11 00

Claudio Valeriano

This is a peculiar shaped rock that was eroded from a granite, a kind of granite that formed when some old continental blocks collided about 600 million years ago. The Sugar Loaf is just an erosion form which was formed much later, when Africa and South America broke apart.

10 15 38 00 : Narration
When they collided, the rocks of the future African and South American continents folded and fractured. Magma rose to the surface, and gigantic mountain ranges emerged from the ground.

10 15 51 00
Erosion then took over… and the granite peaks that dominate the Rio bay today are all that remain of the monumental age-old relief.

10 16 05 00
After 300 million years of co-existence, Africa and South America separated. It was a brutal dislocation, traces of which are still visible in the very heart of the rock.

10 16 19 00

Claudio Valeriano

We have here in Rio de Janeiro some rocks that testify to the separation, which are the dolerite dykes. These are black rocks that filled fractures that were created about 130 million years ago. These rocks which we call dolerites filled these fractures and they can be seen all around here and in the Sugar Loaf area also.

10 16 58 00: Narration
Today, the Sugar Loaf, and the Corcovado are the best-known vestiges of that ancient collision…

10 17 10 00

On the latter's summit stands the imposing statue of Christ the Redeemer, symbol of the city, and indeed of the whole country.

10 17 22 00
On the other side of the Atlantic, the coasts of Africa have also conserved traces of Gondwana's existence.

Sequence 4 – The separation of Gondwana

10 17 39 00 : Narration
In Namibia, the town of Keetmanshoop is in the heart of the Karas region.

10 17 48 00
The landscape here was formed by the encounter between South America and Africa. As far as the eye can see, gigantic blocks of rock emerge from the plain…

10 18 02 00
This breathtaking setting is where geologist Nicole Ulrich is hard at work…

Live Nicole Ulrich : «Look at this view here… I like this »

10 18 11 00 : Narration
The rocks are strikingly similar to those found along the Brazilian coast.

10 18 28 00
Nicole Ulrich :

The granitic rocks that we see here in this beautiful valley, give us evidence of plate tectonic processes. You do find similar rocks with a similar age on the other side of the Atlantic ocean in Brazil, like for instance the world known Sugarloaf in Rio de Janeiro is built up by similar rocks. This proves that the two continents which are now separated by thousands of kilometres of ocean, have once been connected together and only later after the breakup of the Gondwana continent were separated again.

10 19 02 00 : Narration
When Gondwana broke apart, a vast ocean gradually opened up between the future Africa and South America… The Atlantic Ocean, as we know it today.

10 19 14 00
But this brutal dislocation made the Earth's crust fragile, and in places, it was torn apart. Magma rose from the depths and seeped through cracks in the rock.

10 19 30 00 : Narration
Today, these lava inclusions are visible on Namibian soil and on the Brazilian coast. They form rather unusual seams : called dolerite dykes.

10 19 45 00
It is these rocks that Nicole Ulrich is researching and analysing all along the Namibian coast.

10 19 58 00
Nicole Ulrich :

Also in South Namibia we can find evidence of the Gondwana separation. What you can see here are dolerite dykes. They occur in such great numbers that we can not distinguish a single dyke anymore and it is why the geologists speak of a dolerite swarm. Dolerite is a magmatic rock that is compared to basalt which flows out the lava on the surface, does not reach the earth surface but cools off in the earth's crust and forms long extended dykes.

10 20 31 00 : Narration
Over thousands of years, erosion has brought the dykes to the surface. Today, they rise up towards the skies, like rocky icebergs in the middle of the steppe.

10 20 42 00
They remind us that Africa and South America were once brutally broken apart.

10 20 51 00 : Narration
After this separation, the South American continent began a long, solitary journey.

10 20 57 00
It drifted slowly to the west, pushed by tectonic forces.

10 21 04 00
But as it progressed, it encountered the gigantic Pacific Ocean plate. This new collision was not without consequences…

Sequence 5 - The uplift of the Andes

10 21 18 00 : Narration
Along the whole western face of South America, huge mountains rose from the earth. It was the birth of the Andes…

10 21 28 00
Stretching over 7000 kms from Venezuela to Chili, the Andes form the longest mountain range on the planet.
They mark out the precise zone where the plates collided some 100 million years ago.

10 21 44 00
It is in the central part, straddling Peru, Chile and Bolivia, that the range is the most imposing.

10 21 54 00
It is over 6000 metres high and 1700 kms long.

10 22 02 00
It is also the focus of attention for Thierry Sempere, a geologist from the Earth Siences Institute in Grenoble, in France.

10 22 13 00
He is heading for Tacna, in the extreme south of Peru, to retrace the region's geological history in as a detailed manner as possible.

10 22 22 00
The land here has been stripped bare by centuries of erosion.
For Thierry, the thousands of overlying strata are like the pages of a history book, an open-air geological archive.

10 22 35 00

Thierry Semperé :

So here we have some of the strata. As you can see, it's markedly stratified, with sediments deposited on a sea bed. The sediments are very fine, very well stratified, on the bed of a sea at least 1000 metres deep. We're at an altitude of 2000 metres, and we can see that well before the Andes existed, we were, in fact, in an oceanic trench.

10 23 08 00 : Narration
For a long time, the subduction of the Andes posed a problem for geologists. How did such marine sediments end up at an altitude of 2000 metres ? And, above all, in what way could such high mountains be formed along a continent's border with an ocean ?

10 23 28 00

Thierry Semperé :

It's true that most mountain ranges that have been studied in the past result from collisions, like the Alps, the Himalayas and others. Here, that's not at all the case. Throughout the region, the strata have not been deformed very much, they're like I'm doing with my hands, with a few undulations, but there are no folds, which would be like this. In the Alps, there are folds, and thrust faults, and ancient rock that covers more recent rock, and in this part of the Andes, in the western part, we don't see that.

10 24 01 00 : Narration
Most mountain ranges on the planet were created by the coming together of two continental plates. The Andes result from a very different phenomenon.

10 24 13 00

Thierry Semperé :

Everyone knows that the Earth is a ball, a sphere, that's not exactly spherical, but almost. In its centre, is what we call the core, which is composed of iron, mostly in liquid form. Around the core is a kind of pulp, cvalled the mantle, and this mantle is covered over several tens of kilometres by a crust. In fact, the crust floats on the mantle, and so the crust is subjected to Archimedes principle. This means that the thicker it gets, the more it rises up, and that creates mountains. When the crust thickens, there's a substantial part we don't see, beneath us, a bit like an iceberg, and there's a part that rises. And it rises at least 3 kms. These 3000 metres that we've gained here are 3000 metres that were produced by the thickening of the crust beneath our feet. And that thickening, with a rough calculation, would be of around 20 kms.

10 25 09 00 : Narration
In fact, the South American plate came into direct contact with the Pacific plate. As the latter was denser, it slid into the depths of the mantle. But the sediments that had accumulated on the ocean floor remained on the surface, and were deposited along the junction of the two plates.

10 25 25 00
This phenomenon led to the thickening of the continental crust… which then gradually rose.

10 25 36 00
In the Andes, this terrestrial crust is now more than 70 kms thick in places. Almost twice its normal depth…

Sequence 6 - Torres del Paine

10 25 56 00 : Narration
In the continent's extreme south, in the region of Torres del Paine, in Patagonia, the Andes landscape is very different…

10 26 06 00
Majestic peaks rise above deep valleys. The relief is chaotic, and the rock is a brownish colour, its intensity contrasting with the hues of the northern Andes.

10 26 18 00
The story of the Andes' formation here is more recent and, above all, much more complex.

10 26 26 00
As it travelled to the west, the South American continent first of all encountered the Pacific plate.
But a few tens of millions of years later, the southern tip found itself in a tight spot, where the Pacific and Antarctic plates were already face to face.

10 26 44 00
The earth's crust was therefore compressed, and vast quantities of magma rose to the surface.

10 26 54 00
These infiltrations considerably raised the temperature of the surrounding rock, giving them this very particular colour.

Sequence 7 – Pacifique versus Am Sud

10 27 06 00 : Narration
The eternal voyage of the plates on the Earthh's surface continues to change the face of Latin America even today. The continent continues to drift slowly westward,

and its confrontation with the Pacific Ocean regularly causes the earth to shake and move along the coast.

10 27 38 00
This is notably the case in the region of Ilo in southern Peru.

10 27 47 00
For several years, this small coastal town and the surrounding area have been carefully monitored by a team of scientists.

10 27 55 00
Anne Socquet is a geologist from the Earth Sciences Institute in Grenoble, and works in collaboration with the Peruvian geology institute.

10 28 05 00
She is studying the movements of the Earh's crust, thanks to a vast network of sensors installed along the coast.

10 28 15 00
Today, she's on her way to inspect one of the GPS stations with a colleague, Nathalie Cotte.

10 28 21 00

Nathalie Cotte:
Here we are !

Nathalie Cotte:
This is the GPS antenna. So, on this site at Playameca, we've set up a relay next to this house, which is under surveillance, so there's no risk for the equipment.

Anne Socquet :
The fact of having a station on the rocks is really good, to be sure that the type of readings we get are actually measuring the movement of the Earth's crust itself, and not just a superficial landslide or something that has nothing to do with what's happening with the subduction underground.

10 28 57 00
Narration :
The antenna is linked to a GPS station, which picks up the ground movement data in real time. This is then safely guarded in a local fisherman's home.

10 29 08 00

Man
Hello. Welcome to my home.

Anne Socquet
Hello sir! How are you?

Nathalie Cotte :
Hello! Thank you.

Anne Socquet :
Where is the station now?

Nathalie Cotte :
Here it is. Thank you, sir.

Anne Socquet :
Thanks very much.

Nathalie Cotte :
So let's take a look inside…

10 29 26 00 : Narration
The apparatus is located just above the subduction zone, where the Pacific plate slides under the South American continent.
The slightest movement, even minute, can therefore provide the geologists with valuable information.

10 29 42 00
Anne Socquet :
The aim, in fact, is to look at the deformation generated by this subduction.The subduction involves a fault, which is blocked between two earthquakes, so it can generate huge quakes, mega quakes of a magnitude of 8 or even 9. Between two quakes it's blocked, in what we call the interseismic phase. During this phase it's very important to measure the deformation, and I think here on this coast, we should have deformation of around 2 cms per year. So, in fact, during the interseismic phase, the coast is moving towards the Andes mountains, and during the coseismic phase there's an elastic rebound, and we'll see a sudden deplacement of around 5 metres, sometimes more.
So, we'll collect the data…

Nathalie Cotte :
Yes, let's do that…

10 30 35 00 : Narration
Between earthquakes, energy builds up in the depths of the earth, until it's released.
But even today, predicting seismic events is an inexact science. Experts can't give a precise date for the next earthquake…
But one day, they are certain, the ground will shake again along the Peruvian coast…

10 30 55 00
At the same time, more than 100 kms from the coast, Anne Socquet and her team are studying another phenomenon.

10 31 05 00
The subduction of the Pacific plate has created countless volcanos here.

10 31 15 00
Many of them are still active today, and pour out torrents of lava at regular intervals.

10 31 05 00
The town of Candarave, in southern Peru, lives constantly under the threat of the volcano Yucamane, which rises up some 5500 metres.

10 31 59 00

Anne Socquet :
This volcano is actually still active… and there's no doubt it presents quite a considerable risk for the town of Candarave which is just below it.

Nathalie Cotte :
Like all the volcanos here in southern Peru.

Anne Socquet :
There's a subduction zone, with volcanos behind it, except in a few places, so it's all part of the Pacific Ring of Fire.
Why do we call it the Pacific Ring of Fire ? It's because the Pacific is completely surrounded by subductions, and there are volcanos all around the Pacific. But with these subductions, what they do, in fact, is make the oceanic plates disappear.
So gradually, as they make the oceanic plates disappear, the Pacific will end up by closing, and as a result, North America and South America will come and join Japan and the Philippines, etc, and so the Pacific will disappear ; it will be a new Pangaea.

10 32 59 00: Narration
This theory concerning the disappearance of the Pacific in a few million years is a controversial hypothesis within the scientific community.
But for the moment, the Pacific Ocean continues to be slowly swallowed up in the depths of the earth's mantle.
All along the Andes, the encounter of the plates makes the ground quake, and the volcanos rumble.

10 33 22 00
On the way back, Anne Socquet and her colleague stop off a few kms from the coast. Once again, an analysis of the ground demonstrates that subduction is still going on.

10 33 35 00
At this precise point, the ocean floor dives beneath the continental plate, and sediment has built up over the millenia.

10 33 44 00
Anne Socquet :
In fact, about 40 kms beneath our feet, there's a subduction zone which generates earthquakes. But it doesn't just generate earthquakes, it also participates in raising up the Andes. We're very close to the coast here, and what we can see are different layers of different types of sediment, and when we take a closer look at these sediments, we'll see that there are shells…

which were deposited by the sea. And here we're several tens, if not several hundreds of metres above sea level. So this shows that the subduction zone constantly generates deformation, and this constant deformation plays a part in raising up the coast. Perhaps we can go and take a closer look at these deposits…

Anne Socquet :
Have you seen it ? It's really thick, it's more than 50 cms…

Anne Socquet :
Yes…so you can see here, there are lots of shells, mostly bivalves. These deposits are quite recent, in geological terms, between a few tens and a few hundred thousand years.
So the sea was here tens or hundred thousand years ago. What's pretty here in northern Chile and southern Peru is that all along the coast, we can see the uplift, like this. There's a kind of coastal escarpment all along the coast in northern Chile which continues here in southern Peru. This coastal escarpment can be several hundred metres high, and in some places it's even a kilometre high, so that's quite considerable… and it shows that there was substantial uplift here, up to one kilometre, in the past 3 million years. So this is associated with the subduction, and we really have considerable interaction between the great subduction fault, which passes beneath our feet, and the coastal morphology, and the beginning of the Andes' deformation.
Great… we've got a 10,000 year-old scallop (shell)…

Sequence 8 - Altiplano

10 35 50 00 : Narration
A little further north, the geological history of the Andes is marked by another rather particular phenomenon.
In the central sector, at an altitude of 4000 metres, a vast plain has formed in the heart of the mountains. This is the Altiplano, the world's second highest plateau after the one in Tibet.

10 36 11 00
We meet up again with geologist Thoerry Semperé, who's continuing his research into the region's history.

10 36 25 00
He comes regularly to the shores of Lake Titicaca, on the border between Bolivia and Peru, to study the origin and evolution of this unique ecosystem.

10 36 45 00
Around a picnic, he explains some of the background to his young colleagues.

10 37 00 00
Thierry Semperé :
Do you know the twin, or the species that's the closest cousin to the tomato ?

Mélanie :
No.

Thierry Semperé :
It's the potato, because when the Andes rose up, the two species diverged. The tomato stayed lower down, and the potato adapted to the altitude, and invented a new strategy for reproducing, which is the tuber, which is actually a clone… because it's cold on the Altiplano at night, and especially in winter, and in case the plant might die of cold, the tuber is always in the ground and can grow again. So that's one example, of many throughout the world and so, when you form mountain ranges, you create whole new ecosystems.

10 37 47 00 : Narration
Located 3812 metres above sea level, Lake Titicaca is one of the highest navigable lakes in the world. It's in the heart of the Altiplano, trapped between two mountain ranges.

10 38 06 00
Thierry Semperé and his team criss-cross the region, taking extensive rock samples. For it's in the depths of the Earth's crust that can be found precious indications to the formation of this high plateau.

10 38 20 00

Thierry Semperé :
Oh, that's not bad… and there should be quite a lot of information inside, if we can get the grains out, which will help to date it.

Thierry Semperé :
On the Altiplano, the lowest regions are occupied by lakes, because the Altiplano is a sort of closed basin. The rain that falls on the Altiplano doesn't go to either the Pacific or the Atlantic, but to the lakes that are scattered around the Altiplano. The biggest of them is Lake Titicaca, which is in the lowest region in this part of the Altiplano.

Thierry Semperé :
What we have to understand too, is that when we go down, beneath my feet, for example, after 10 kilometres down, maybe 10 or 12 kms down… the earth's crust is fragile, and cracks on the surface, but after that depth it becomes soft, and plastic. We say that it's ductile, and so consequently it behaves like plasticine, and it spreads out. It spreads out, and so as a result the surface of the crust we're standing on naturally becomes flatter. The relief becomes less steep, because we're on a kind of mattress, a mattress made up of 50 kilometres of plastic crust.

10 39 40 00 : Narration
The Central Andes were (in reality) formed in several stages.

10 39 47 00

When the Pacific plate dips beneath the South American plate, it raises up the continental crust, which is gradually deformed. An initial mountain range rises from the ground : the eastern Andes.

10 40 02 00
Then, along the edge of the South American plate, subduction heats up the terrestrial crust to the point of melting it. This fluid and malleable terrain enables the Altiplano to form and rise over millions of years.

10 40 16 00
Later on, intense volcanic activity causes the uplift of a second mountain range, the western Andes. The Altiplano is therefore now locked in on the western side.

10 40 32 00

Thierry Semperé :
We can clearly see behind me these very flat plains, where people have settled… we have the water of Titicaca, and it's all surrounded by mountains, which are not very high, quite flat, we might say… and right in the background you can no doubt see the eastern Andes, and you have to imagine that behind those snow-capped summits, we go very quickly down towards Amazonia, towards the Amazon forest…

10 41 02 00 : Narration
The majestic landscapes of the Altiplano and the Andes mountains demonstrate to what extent tectonic forces model and shape the land's destiny…

10 41 13 00
But in turn, these mountains impose a considerable influence over the surrounding regions, and in particular, over the Amazonian forest.

Sequence 9 – The Amazonian basin

10 41 23 00 : Narration
The small town of Contaman, in Peru, is in the heart of the Amazon basin. It is here that a team of French paleontologits has set up their base camp.

10 41 51 00
Every morning, the scientists respect the same ritual ; a 30 minute boat ride before setting off into the jungle on foot.

10 42 08 00
The team leader is Pierre-Olivier Antoine, from the Evolutionary Science Institute in Montpellier, in France.He's been exploring western Amazonia for a number of years, studying the exceptional biodiversity here.

10 42 29 00
With an area of over 6 million square kms, this tropical forest is the vastest and most diverse on the planet.

10 42 42 00
Experts say it is home to 1.4 million species of plants and animals, half of all species so far recorded around the world.

10 43 03 00
On the ground, Pierre-Olivier analyses sediment strata to see how the water-course has eveolved over time.

10 43 09 00

Pierre Olivier Antoine :
This is an extremely interesting site, which is unusual for the large variety of environments concerning the deposits we've noted. Here, we have a first river coming in, which has very little energy, it would have been very calm, with just a few ripples… and then the energy level goes down further, and we basically find a marshland, a marsh with animals and plants that are typical of a marshland. And then quite suddenly, the energy changes, and there's a watercourse coming in with quite a strong current. So there we have a lot of detritus laid down, with larger elements forming a conglomerate. This lasts for about 2 metres, and above those two metres we actually have a torrent, with large rocks washed along it, like this, so there was a very strong current. This current required relief, so obviously, for that relief, we think of the Andes.

10 44 06 00 : Narration
The scientists methodically examine the ground, looking for fossils.

10 44 12 00
Tiny clues, hidden in the ground, which could provide a detailed account of the history of the Amazon basin.

10 44 20 00

Pierre-Olivier Antoine :
Here, in fact, we have an illustration of what we're after… meaning that we come to look for fossils, but these fossils have a particular interest, which is to gain a better understanding of the Amazonian ecosystem under the influence of the environment, and in particular, this environment which is linked to the Andes and Andean tectonics.

10 44 44 00 : Narration
Experts have known for a long time that the history of the Amazon forest is closely linked to that of the Andes mountains.

10 44 51 00
Pierre Olivier Antoine
It's a lower tooth…

Man
It's spectacular.

10 45 02 00 : Narration

During the growth of the mountain range, the basin was on several occasions filled with vast stretches of water. The last of which appeared about 12 million years ago. The scientists call it the Pebas sea.
Until recently, the scientific community hotly debated a key question : was it an inland salt-water sea, or a freshwater lake ?

10 45 30 00

Dialogue Pierre-Olivier Antoine and colleague :

Colleague: I can't get a GPS signal.

PO Antoine: So… do you know what that is ?

Colleague: Yes of course, they're oysters.

PO Antoine: Oysters.

Colleague: But sea oysters, right ?

PO Antoine: Yes, of course.And last year, we took sediment samples here and there were forminifera… thousands of them, thousands of foraminifera.

Colleague: I've never seen oysters here before.

10 45 52 00

Pierre-Olivier Antoine :

So we're talking about an outcrop which is extremely unusual in the Amazonian context, because it's the only outcrop that has ostrea, or oysters, throughout Amazonia. Obviously, they are fossilised oysters, marine oysters, so they resemble the oysters we eat today. They have the particularity of having been perforated by organisms, which we call lithophagous organisms, which are marine creatures.
This informs us directly that 12 million years ago, or in the past, in any case, there was a sea here. In fact, these oysters represent the final obstacle for the opponents of the Pebas sea theory, who considered it was a lake, with freshwater. Quite simply because no-one had ever found oysters in the Pebas system. But here we are, there are.

10 46 50 00 : Narration
The whole of what is today the Amazon basin was therefore covered by a vast inland sea, some 12 million years ago.

10 47 00 00
The appearance of the Pebas Sea in the middle of the South American continent is the result of plate tectonics.

10 47 12 00
It is directly linked to theuplift of the Andes mountains.

10 47 20 00
Pierre Olivier Antoine :

Through the effects of Andean tectonics, the Andes rose up, about 15 million years ago. What we call the foreland, the zone that precedes the tectonised zone, the subduction zone, underwent flexure, or folding, and moved downwards, and in doing so, it allowed the sea to move in, an ingression of the sea. This Pebas Sea then gradually withdrew, and the whole biodiversity of the Pebas, with hundreds of species of mollusks, and marine rays, and notably a whole bunch of crocodiles, which depended on that system… all these organisms would have disappeared at the same time as the system in which they lived. On the other hand, what's certain is that the disappearance of that very particular system enabled the current Amazonian system to be established.

10 48 20 00 : Narration
Through its disappearance, the Pebas Sea led to the extinction of thousands of animal species… But it gave way to the most powerful river in the world. An evolution that furthered the emergence of an incomparable biodiversity.

10 48 42 00
Pierre Olivier Antoine :
The luxuriance, the vast biodiversity of Amazonia in fact, is ultimately very young ; it's very recent, in terms of what we know today. But it's not so surprising, because that host of species was born out of tectonics, from the consequences of Andean tectonics, which over millions of years led to the separation of smaller basins, of the Amazon basin and lesser basins, and all those zones were separated slightly. They have slightly different vegetation, and slightly different climates, and so all that led to distinctions among species, what we call the phenomenon of speciation. These sister species would then be either in the north or the south, and would ultimately evolve independently and give us this whole biodiversity that we see today.

10 49 32 00 : Narration
Amazonia bears irrefutable testimony to the bonds between the living world and geology.

10 49 40 00
Unremittingly, plate tectonics shape and sculpt our planet.

10 49 49 00
It gives rise to seas and oceans, to mountains and forests…

<u>Sequence 10 - Conclusion</u>

10 49 58 00 : Narration
Three million years ago, another phenomenon radically changed the biological equilibrium of the South American continent : the closure of the isthmus of Panama, and the junction with North America.

10 50 13 00
Isolated for some 50 million years, North America was therefore colonised by new species.

Once again, the land changed shape and form… transformed by the perpetual voyage of the continents across the face of planet Earth.

10 50 34 00