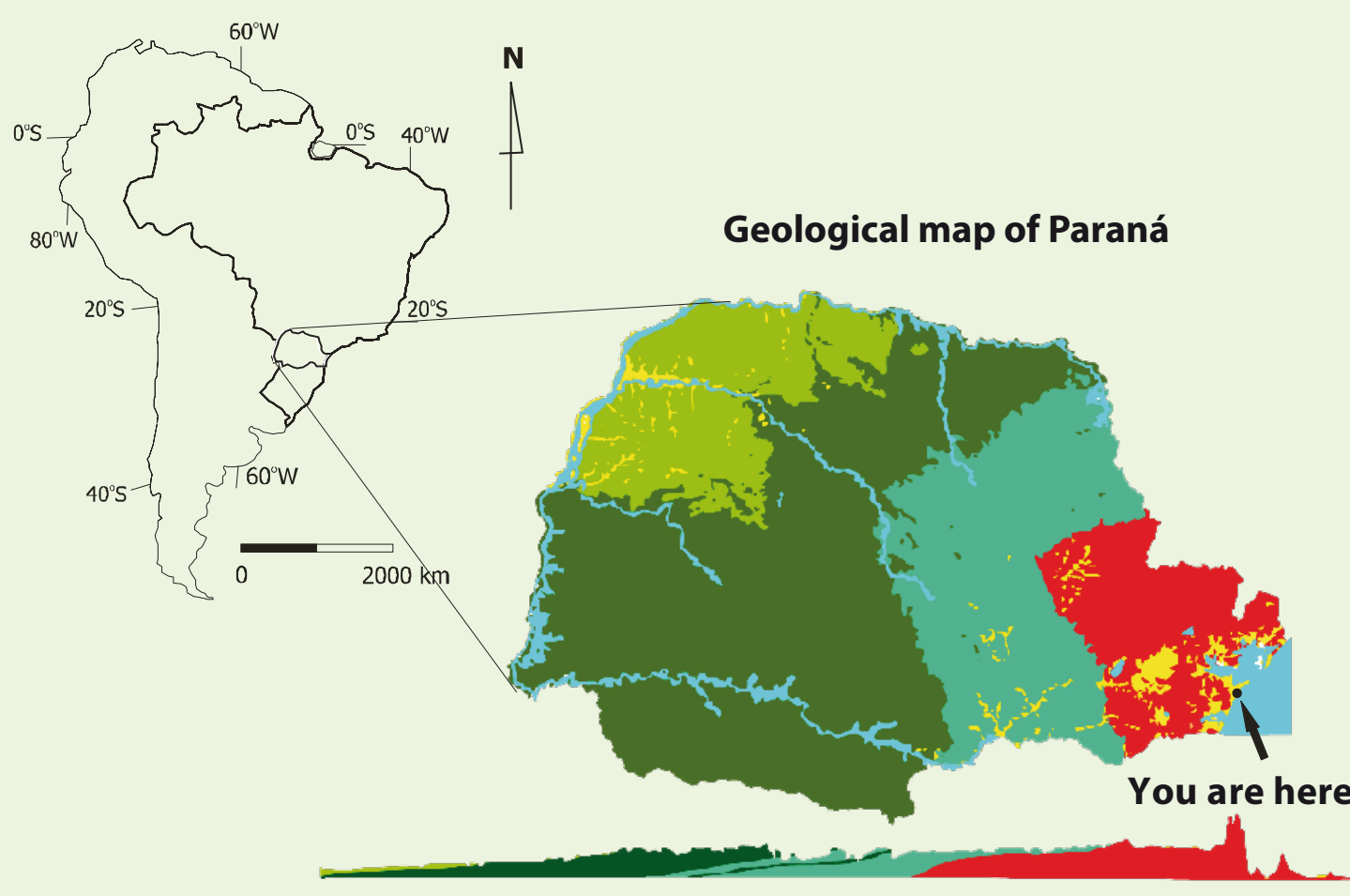


# Geology of Paraná



EON	ERA	PERIOD	EPOCH	Age (millions of years)	Features	Geology
Phanerozoic	Cenozoic	Quaternary	Holocene	Today	Human, Northern Hemisphere glaciation	Sediments
			Pleistocene	1.1		Sediments
			Pliocene	1.8		Sediments
			Miocene	5.3		
			Oligocene	23	Primates proliferate	
		Tertiary	Eocene	34		
			Paleocene	51		
			Cretaceous	65	First horses appear	
			Jurassic	152	Dinosaurs appear; flowers	
			Triassic	208	First birds and mammals appear	
	Paleozoic	Permian	252	First Dinosaurs appear		Sedimentary rocks
			Carboniferous	290	Trilobites disappear	
			Devonian	364	Reptiles, primitive target fish appear	
			Silurian	417	Amphibians appear	
			Ordovician	443	Terrrestrial plants appear	
			Cambrian	488	First trilobites	
			Cambrian	545	First shells; trilobites prevail	
Precambrian	Archean	Hadean	Proterozoic	2500	First pluricellular organisms	Paraná Shield
			Archean	4000	First unicellular organisms	
			Hadean	4550	Earth forms	

- Formation of the sandy sediments in the coastal plains
- Formation of the diabase dike
- Formation of the migmatites that sustain the coastal lowlands

The geological evolution of Paraná is followed when the state is crossed westward. The oldest rocks, formed more than three billion years ago, are found on the coastal plain. There, and all over Serra do Mar and the First Paraná Plateau, igneous and metamorphic rocks of Archean to early Paleozoic age outcrop in the region known as the PARANÁ SHIELD, whose strong relief reflects how resistant to weathering its rocks are.

From the Devonian scarp known as São Luiz do Purunã to the western border of the state, the PARANÁ SHIELD is overlain by the PARANÁ BASIN, a massive sequence of sedimentary and volcanic rocks of Silurian to Cretaceous age that sustains the state's Second and Third plateaus. In the early stages of the basin's evolution, South America and Africa were still unseparated parts of a supercontinent named Gondwana, and their geographic locations were very different from today's.

The PARANÁ BASIN evolved for more than 300 million years, in long transgression-regression cycles of an ancient sea that surrounded Gondwana. These cycles, immensely slow as compared to human lifetime, resulted in different marine, lacustrine, fluvial, and glacial rocks in Paleozoic times.

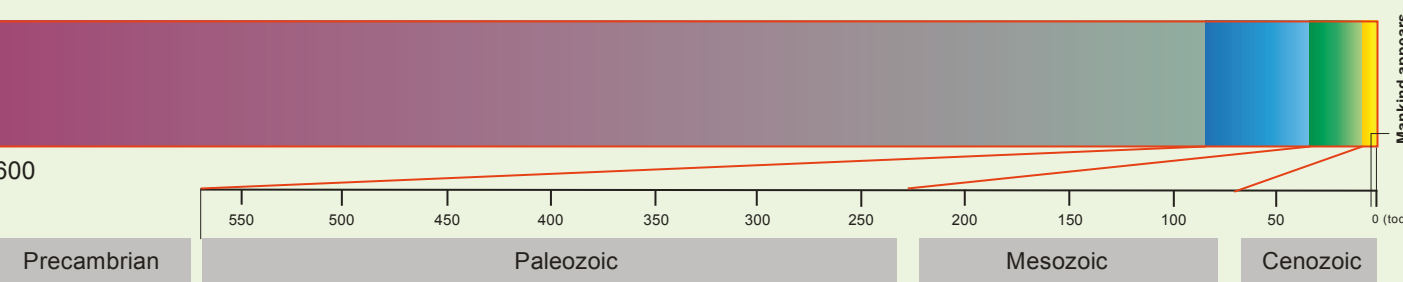
In Jurassic times, a desert named Botucatu, that spread for more than 1,500,000 km<sup>2</sup>, covered parts of southern Brazil, Paraguay, Uruguay, and Argentina.

The breakup of Gondwana, and the consequent separation of South America and Africa as the South Atlantic Ocean spread, took place in the Cretaceous. As part of the breakup process, extensive, up to 1,500 m of superpose basalt flows covered more than 1,200,000 km<sup>2</sup> of the Paleozoic sedimentary rocks of the Paraná Basin. The remarkably fertile soil known as Terra Roxa derives from weathering of such basalt flows. By the end of the Cretaceous, desertic terrains (the Bauru Basin) spread over the basalt flows in northwestern Paraná as recorded by the Caiuá sandstone. Unlike the Terra Roxa, however, soils formed from these rocks are poorly fertile and highly susceptible to erosion.

The youngest geological units in Paraná are sediments of Quaternary age. Most representative examples are those generated under arid to semi-arid conditions over parts of Curitiba and Tijucas do Sul, those formed from weathering of crystalline rocks along the Serra do Mar range, marine sand deposits along the eastern coast, and also countless alluvial deposits along water streams in the state.

## Geological time

If the 4.6 billion years of geological history were scaled to one single year, Mankind would have been on Earth since 8:14 p.m. December 31 i.e., within the last 3h ours and 46 minutes. Dinosaurs, that lived for 100 million years, would have lived no more than 8 days and 12 hours. The coastal plain over which the urban areas of Matinhos and Guaratuba spread formed within the last 34 seconds of the hypothetical year i.e., at 11:59:26 on December 31.



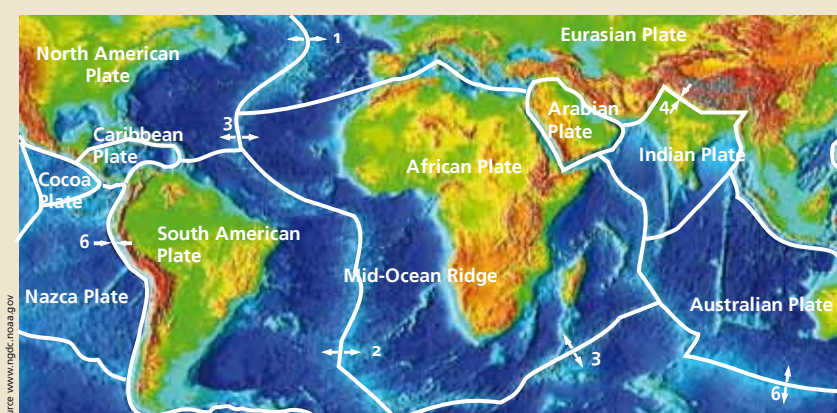
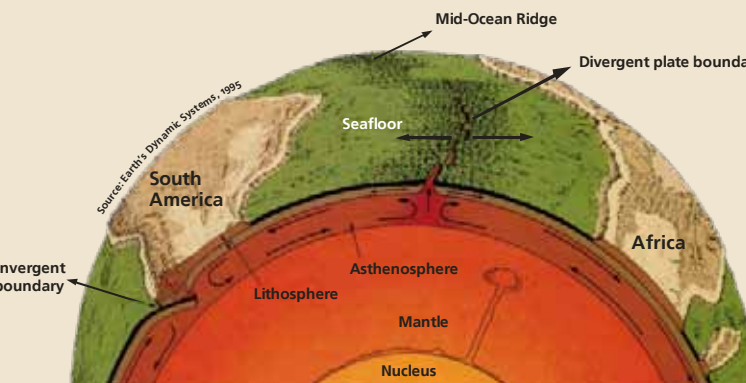
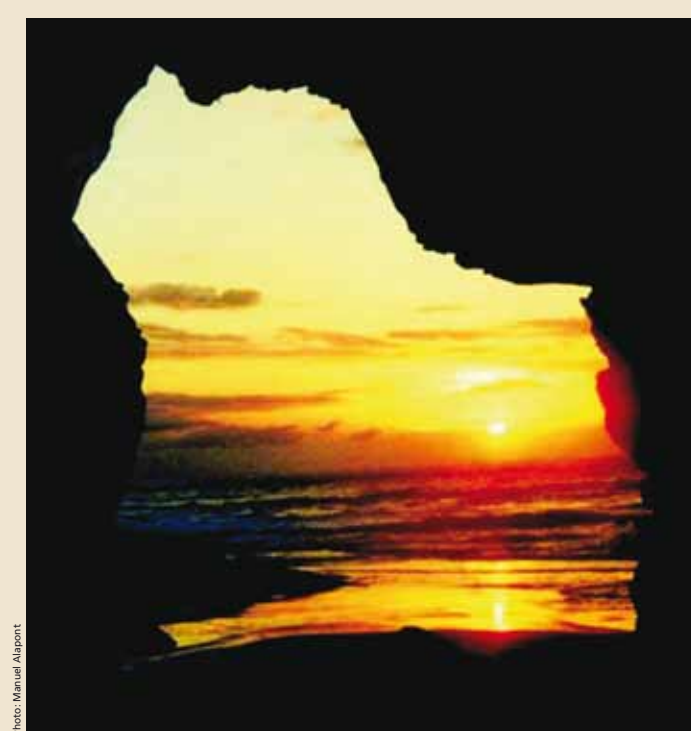
4.600

# Ilha do Mel

## The opening of the south Atlantic Ocean

The South Atlantic Ocean came into existence about 150 million years ago in the Cretaceous period, when Africa and South America began to separate.

It is the horizontal displacement of tectonic plates, known as continental drift, that causes oceans and land masses to change in outline and position in the geologic time.



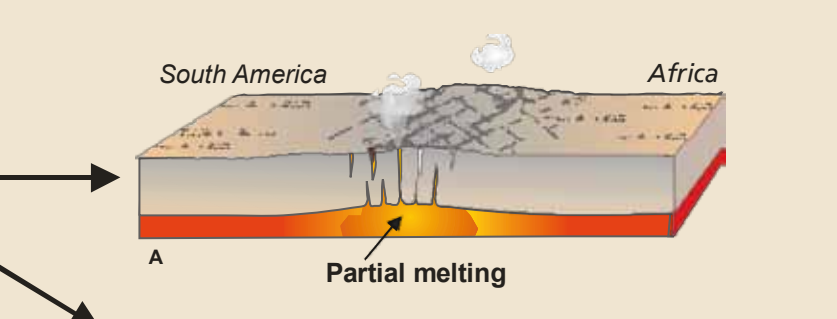
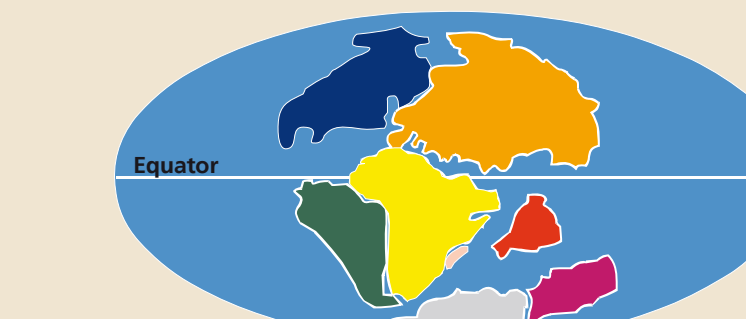
The Earth's mosaic of tectonic plates with their respective displacement speeds in centimeters per year (z)



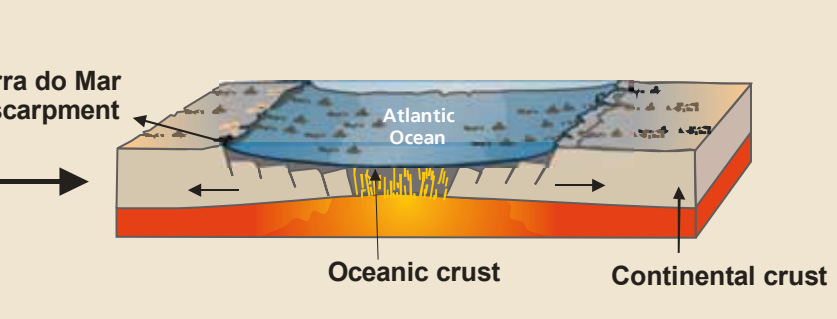
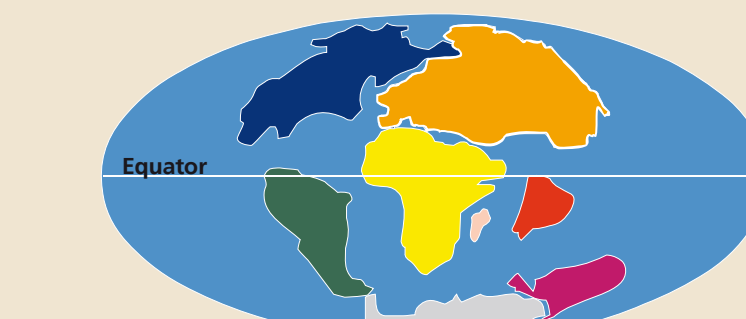
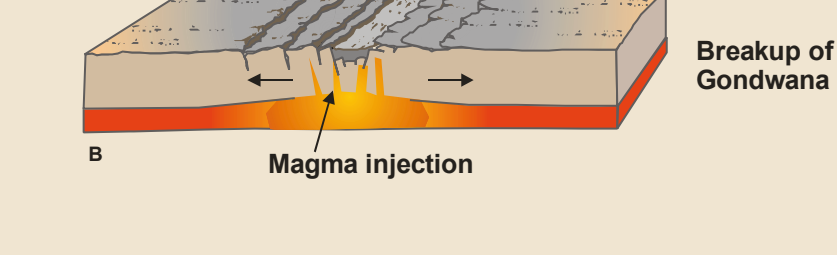
Twenty-five hundred million years ago in late Paleozoic, all landmasses on Earth aggregated into a single supercontinent called Pangea.



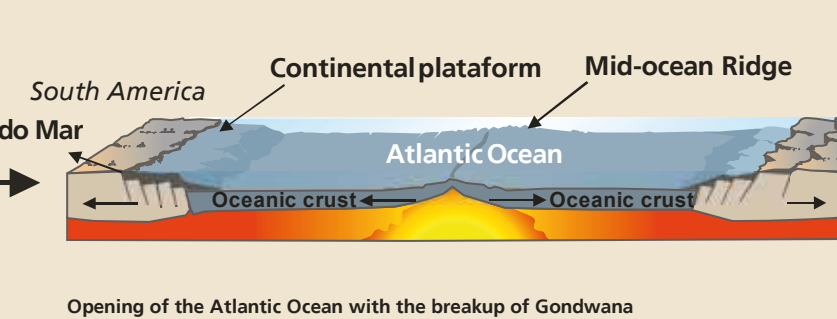
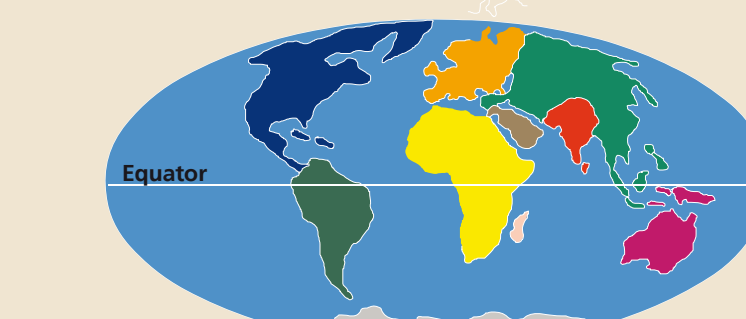
In the Triassic Period, the fragmentation of Pangea began, which in its first stages led to the formation of two continents, Laurasia in the north and Gondwana in the south. Gondwana would later break up to form South America, Africa, Antarctica, Australia, and India.



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End of the Cretaceous Period, 65 million years ago



Present

## Ilha do Mel hills and the Encantadas grotto

The hills of the coastal lowlands of Paraná and Ilha do Mel are formed of Precambrian gneisses and migmatites younger than 550 million years. These rocks are cut by 130 million year old diabase dikes emplaced when the South Atlantic Ocean started spreading.

The Encantadas grotto was carved from one such dike by differential marine erosion because diabase is less resistant than gneiss.

If the whole Earth history was scaled to one year, Ilha do Mel as it presents itself today would have arisen within the last 34 seconds i.e., at 11:59:26 pm on December 31.

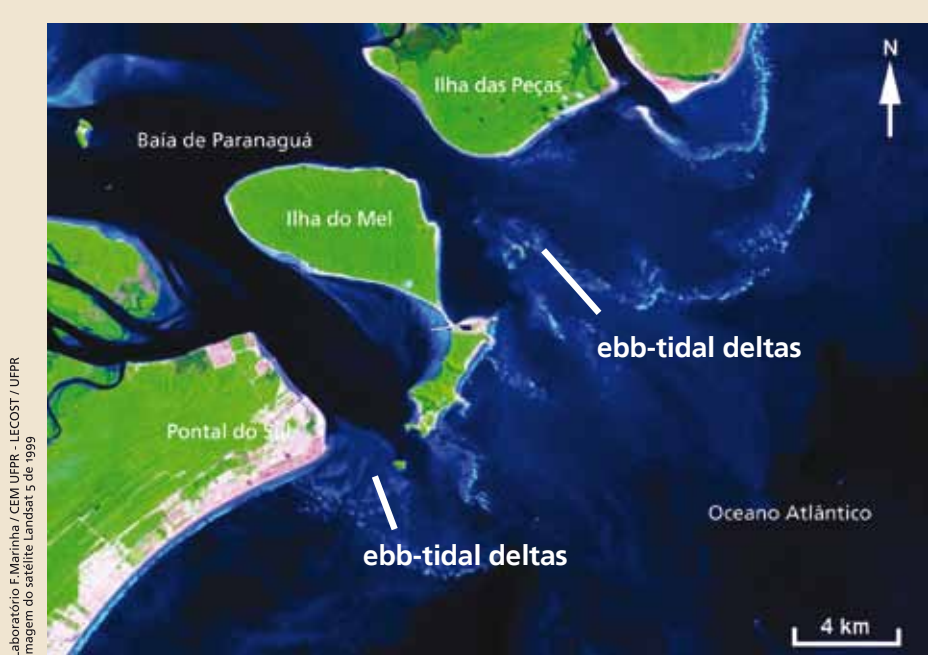


## Coastal stability

Because coastal stability depends largely on the dynamics of estuary mouths and their associated features, especially in ebb-tidal deltas, the coastal areas of Paraná can be classified as stable, moderately stable, and unstable.

The satellite image shows coastal areas of Paraná according to their stability.

- Stable areas
- Moderately stable areas
- Unstable areas



Paraná Estuary mouth with banks and break zones that correspond to ebb-tidal deltas.

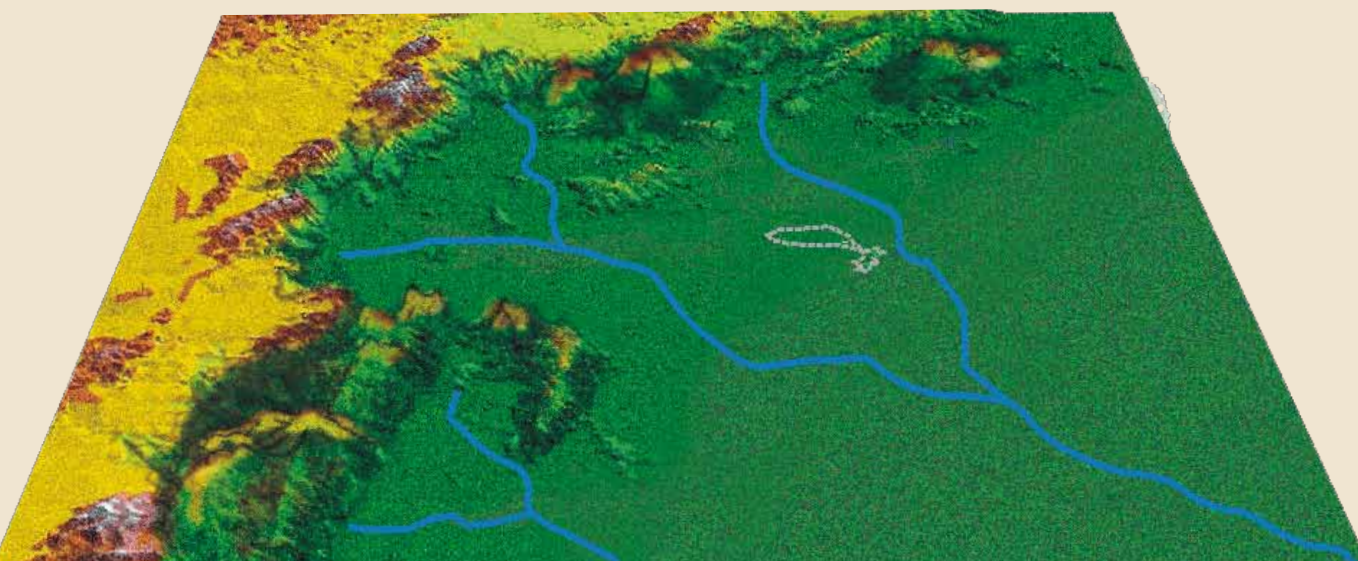
## How and when Ilha do Mel and the coastal plains formed

The coastal plain of Ilha do Mel consists of sandy, younger than 120,000 years marine sediments deposited during cycles of large sea level variation that marked transitions between glacial (cold) and interglacial (warm) periods in the Quaternary (the last 1.8 Ma in Earth's history).

During glacial periods, water that evaporates from the sea remains over continental land masses after it precipitates as snow, which causes sea level drop. In interglacial periods, when temperature is higher and glaciers melt, sea level raises again. The Earth now experiences an interglacial period, with the highest sea levels in Quaternary. The coastal plain of Paraná formed mainly over the last two interglacial periods, whose climaxes were respectively 120,000 and 5,600 years ago.

At the climax of the last glacial period 18,000 years ago, the sea level was approximately 120 m lower than now, and extensive coastal plains cut by water streams were present.

The region of Ilha do Mel did not actually correspond to an island, and the coastline was more than 100 km east of its current position.



Coast of Paraná 120,000 years ago

After the climax of the last glacial period 5,600 years ago, glaciers started to melt and the sea level rose rapidly to 3 m above its current position. The coastline was 2 to 5 km west of where it is now.

Ilha do Mel would again appear as a small rocky archipelago. A narrow stripe of sand connected Bento Alves and do Meio hills, and the Encantadas region corresponded to two small sand terraces.



Coast of Paraná 18,000 years ago

## Environmental Care of Ilha do Mel and the shore



It was only recently that the large sand plain in the central part of Ilha do Mel deposited. Now it has been eroded by waves and tidal currents to a narrow isthmus that almost disappeared in the nineties.



Sand plain near the lighthouse (Farol das Conchas), Ilha do Mel



Erosion between the isthmus and Fortaleza, Ilha do Mel

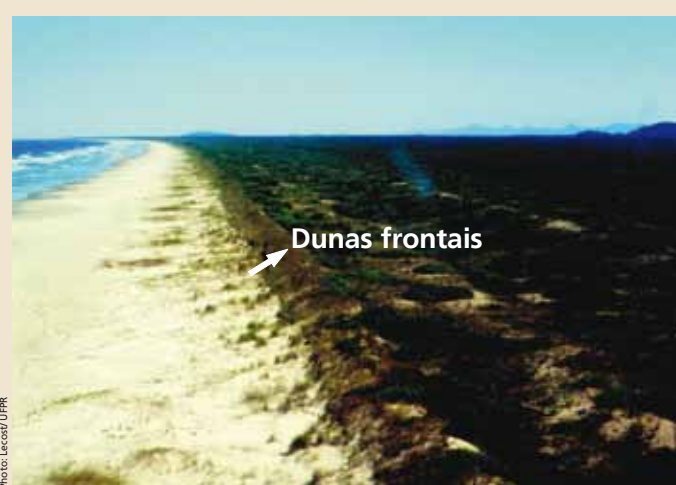
Because of its location at the mouth of Paranaguá Bay, the coasts of Ilha do Mel are highly mobile and subject to intense sedimentation (sand accumulation) and erosion (sand removal). Both processes can be modified by human activities such as coastal development, destruction of frontal dunes, erosion control works, or dredging of navigation channels. In the nineties, an extensive plain deposited rapidly near the lighthouse (Farol das Conchas), probably due to accumulation of sands dredged from the channel that leads to Paranaguá Port. The accretion of a sand plain, that is still in process, changed the orientation of waves near the coast. This has led to intense erosion of the isthmus and the area between the lighthouse and Fortaleza.

Coastal development implies risks, especially in mobile coasts. Undeveloped areas and, moreover, preservation of frontal dunes, can minimize problems brought about by coastal erosion.

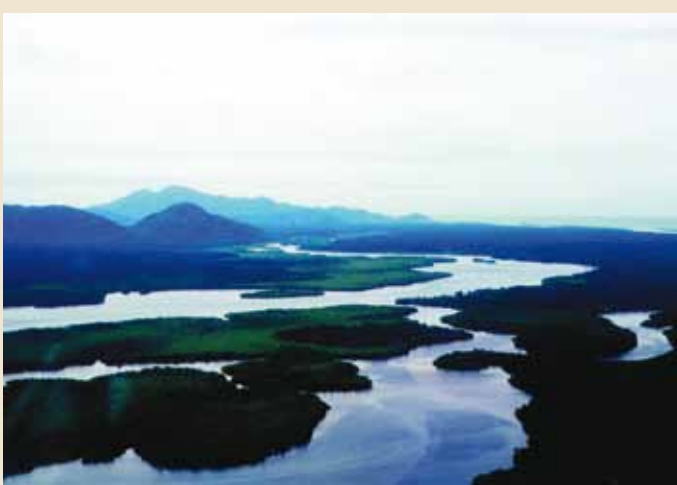


Estuarine areas show beaches and frontal dunes too, but are dynamically more complex than open coasts.

Open coasts show typically sandy beaches and frontal dunes.



Beaches and coastal dunes (Superagui Beach)



Tidal flat (Pinheiros Bay)

Estuarine coasts occupy the inner parts of a bay and show characteristically sandy-muddy tidal flats covered by mangrove vegetation and salt marshes.

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