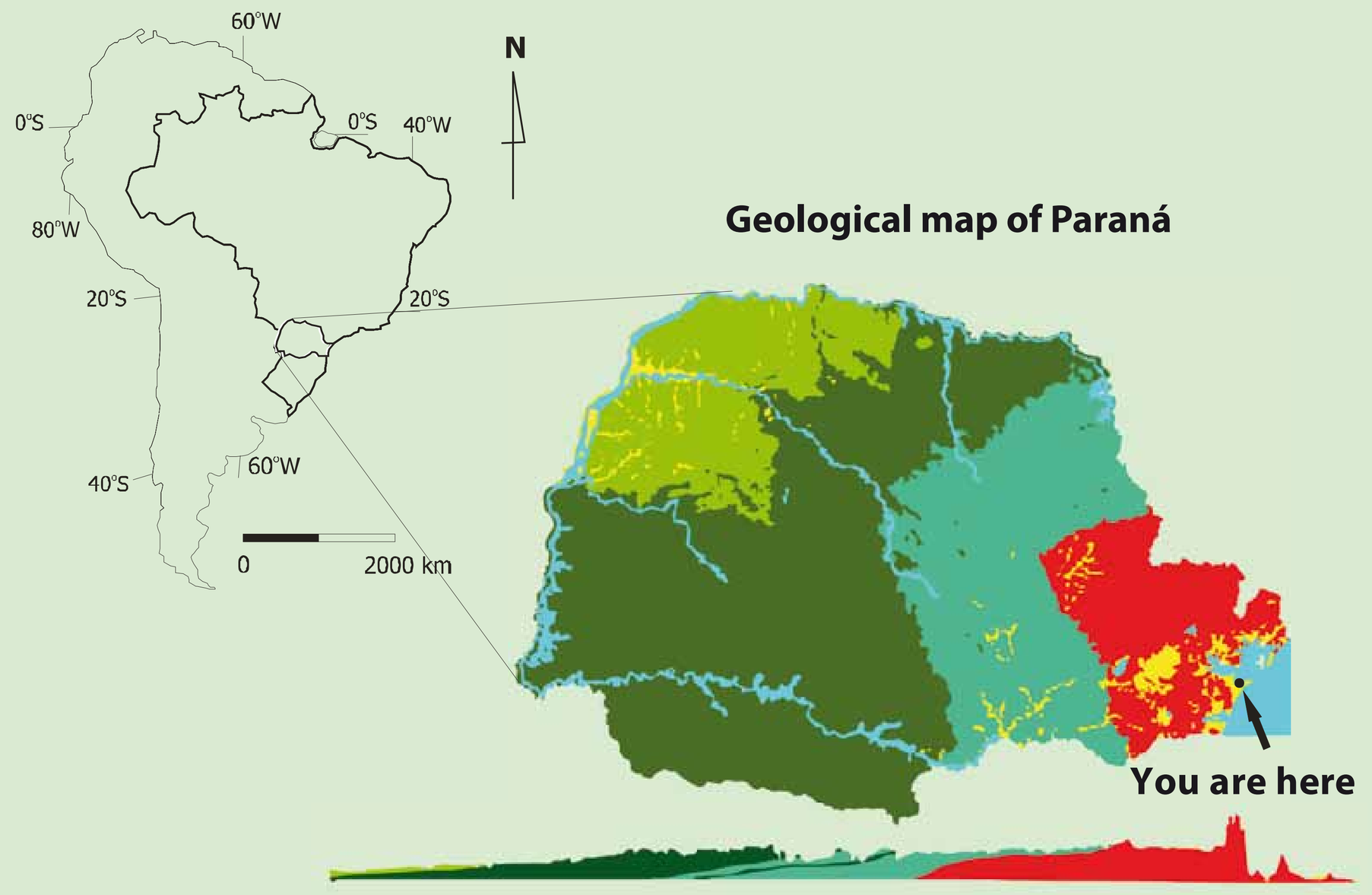
Geology of Paraná



EON	ERA	PERIOD	EPOCH	Age (million years)	Features	Geology
Phanerozoic	Cenozoic	Quaternary	Holocene	Today 1,1	Mankind, Northern Hemisphere glaciation	Sediments
			Pleistocene	1,8		
		Tertiary	Pliocene	5,3		Sediments
			Miocene	23		
			Oligocene	34	Primates proliferate	
			Eocene	53		
			Paleocene	65	First horses appear	
	Mesozoic	Cretaceous		142	Dinosaurs appear; flowers	Sedimentary rocks / Magmatic rocks
		Jurassic		206	First birds and mammals appear	Paraná Basin: Sedimentary rocks
		Triassic		248	First Dinosaurs appear	
	Paleozoic	Permian		290	Trilobites disappear	
		Carboniferous		354	Reptiles, primitive large trees appear	
		Devonian		417	Amphibians appear	
		Silurian		443	Terrestrial plants appear	
		Ordovician		495	First fishes	Paraná Shield
		Cambrian		545	First shells; trilobites prevail	
Precambrian	Proterozoic			2500	First pluricellular organisms	
	Archean			4000	First unicellular organisms	
	Hadean			4560	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.

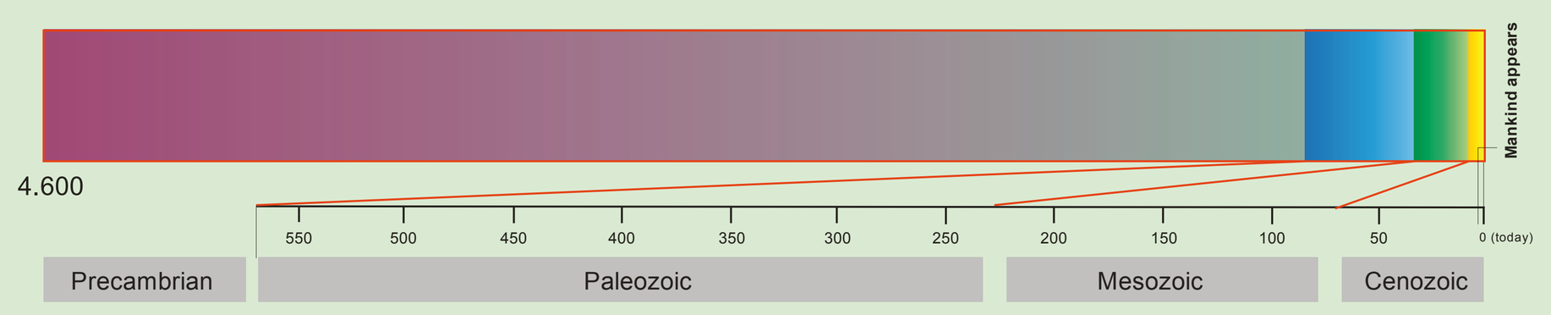
In Jurassic times, a desert named Botucatu, that spread for more than 1,500,000 km2, covered parts of southern Brazil, Paraguay, Uruguay, and Argentina.

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 km2 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.



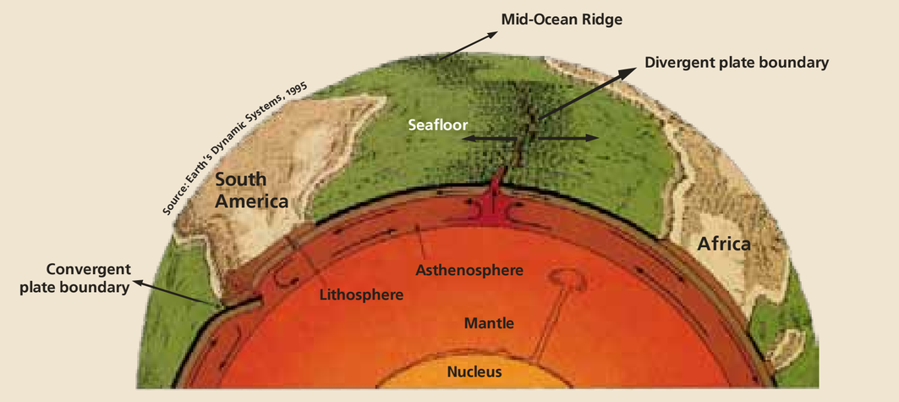
Geological Site

The coasts of Paraná

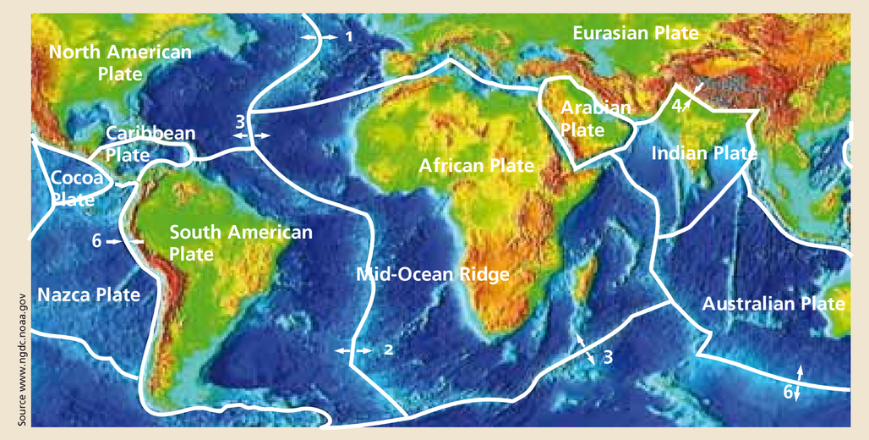
The opening of the South Atlantic Ocean

The South Atlantic Ocean started to open 150 million years ago, in the Cretaceous Period, when separation of Africa and South America begun.

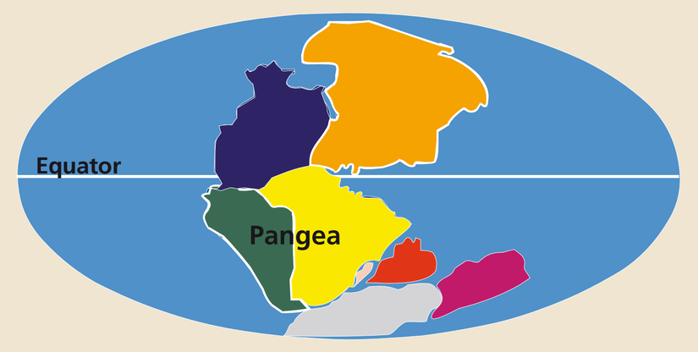
It is the horizontal displacement of tectonic plates, known as continental drift, that causes oceans and land masses to change in outline and position in the geologic time.



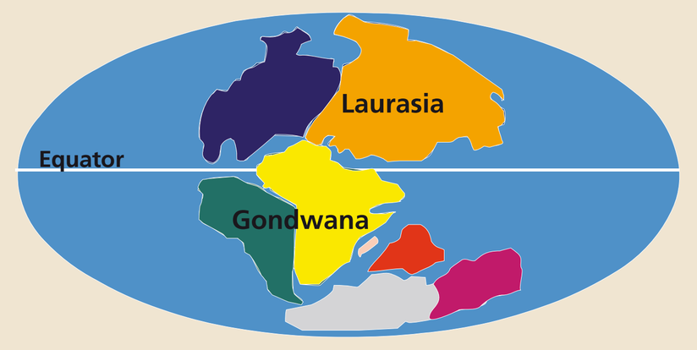
Schematic section and tectonic system of the Earth showing convergent and divergent plate boundaries



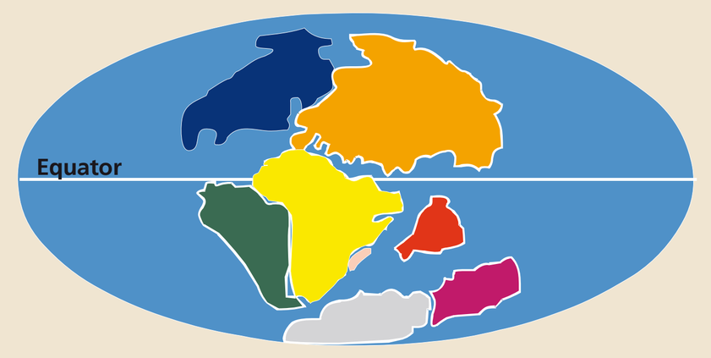
The Earth´s mosaic of tectonic plates with their respective displacement speeds in centimeters per year (2)



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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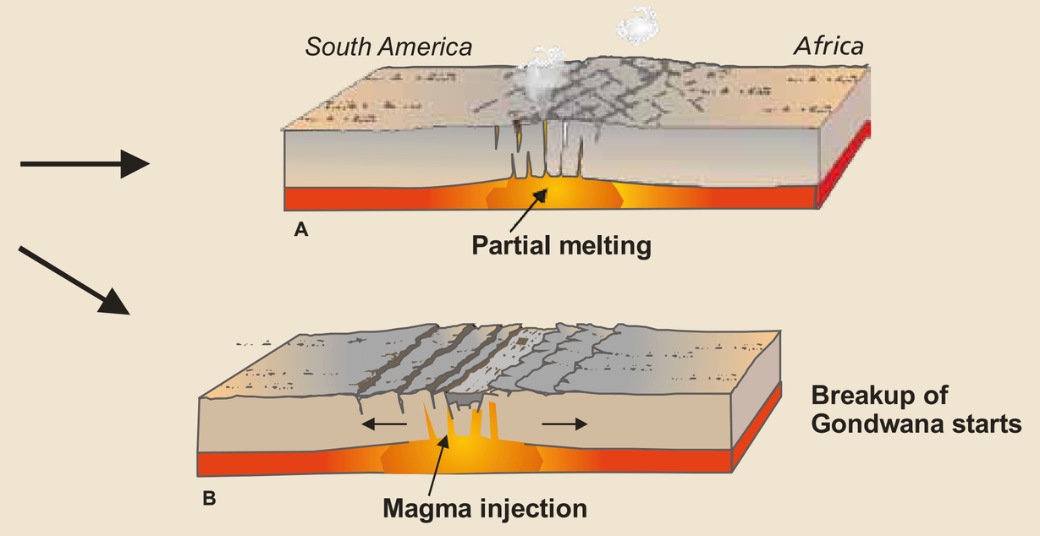
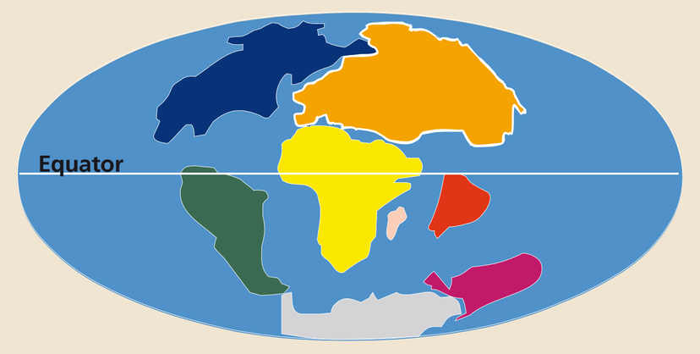
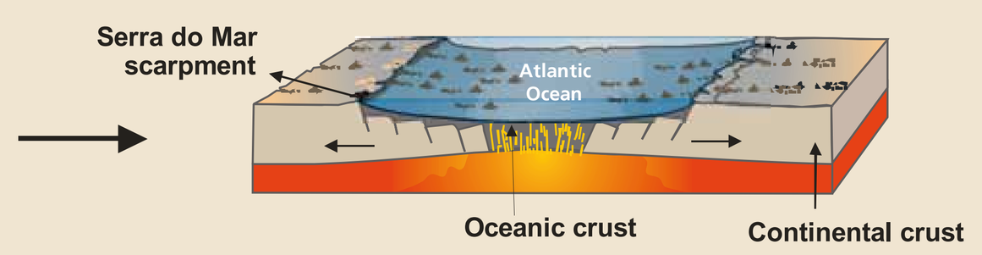
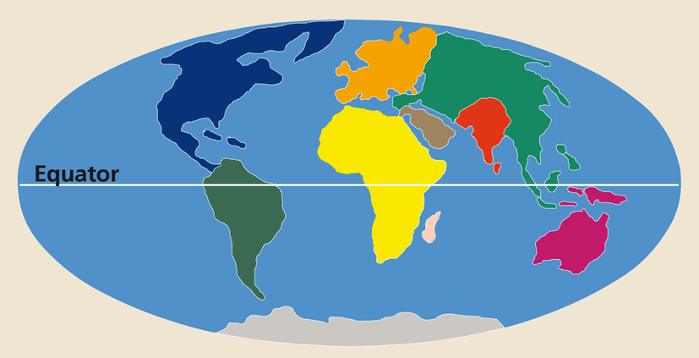




End of the Cretaceous Period, 65 million years ago





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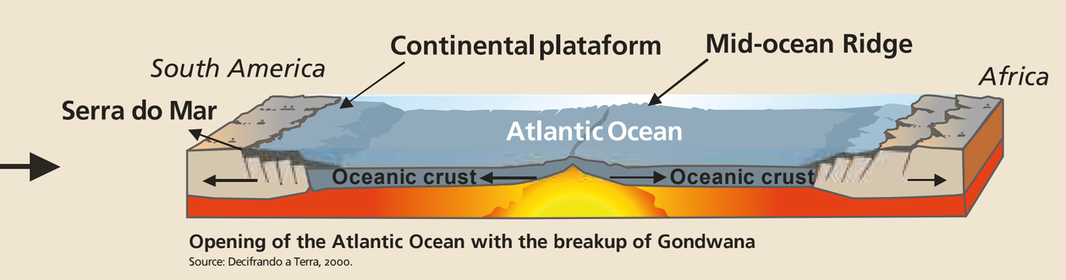


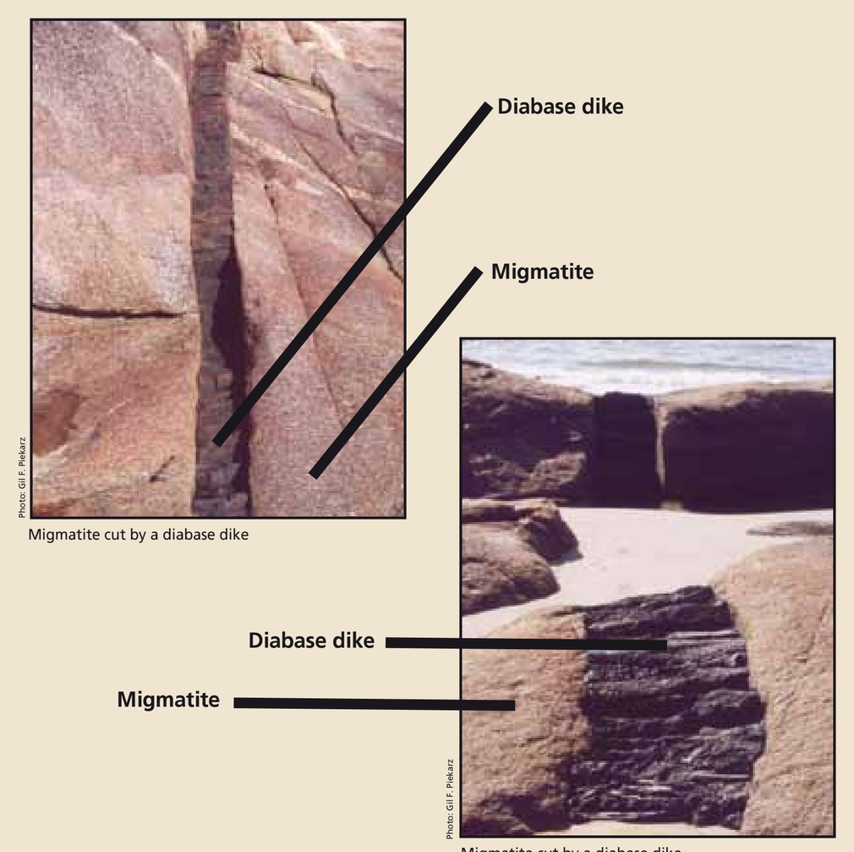
Matinhos and Guaratuba hills

The hills of the coastal lowlands of Paraná including matinhos and guaratuba hills 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 to spread.

Guaratuba hill

Caiobá hill

Guaratuba Delta



Migmatite cut by a diabase dike

Picture of a cliff. In its lower part, organic-rich sediments mark a horizon known as piçarra. The upper part consists of whitish sands with dark levels of concentrated heavy minerals (ilmenite and magnetite).

How and when the coastal plains of Paraná formed

The coastal plains of Paraná consist 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 Earths history).

During glacial periods, water that evaporates from the sea remains over continental land masses after it precipitates as snow, which causes sea level to 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 plains of Paraná formed mainly over the last two interglacial periods, whose climaxes were respectively 120,000 and 5,600 years ago.

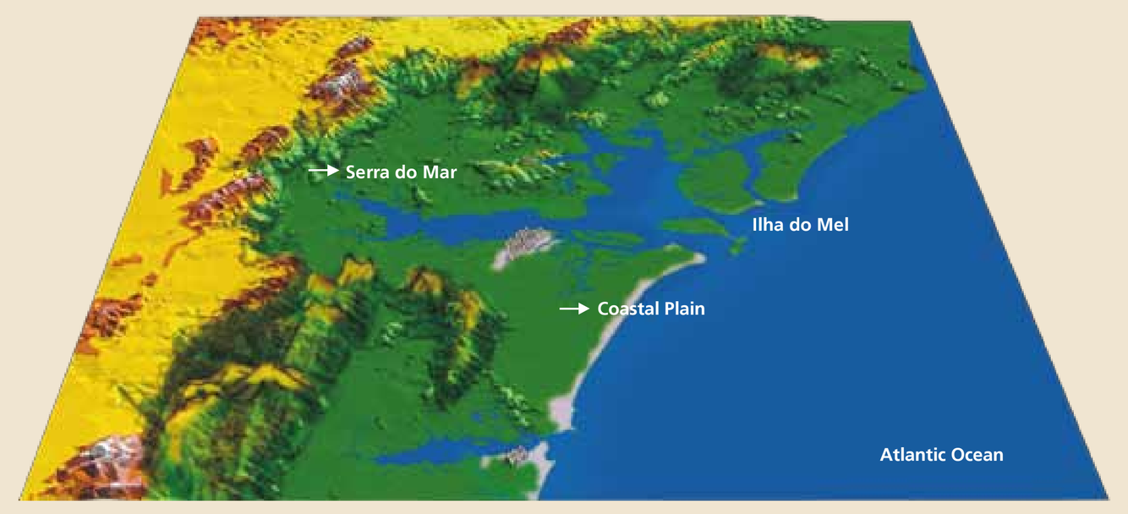
Coast of Paraná *120,000 years ago*

In the first period, 120,000 years ago, the sea level was eight meters higher than now, the coastal plain was virtually absent, and the coastline almost reached the flanks of Serra do Mar. Caiobá and Guaratuba hills would appear as two small rocky islands.

Coast of Paraná *18,000 years ago*

At the peak of the last glacial age 18,000 years ago, the sea level dropped to approximately 120 m below its current position, and extensive coastal plains cut by water streams deposited. At that time, the coastline of Paraná was over 100 km east of where it is now.

Coast of Paraná *today*



After the last glacial peak, glaciers started to melt. Five thousand, six hundred years ago, the sea level was three meters above its current position. The coastline was 2 to 5 km west of its current position. Guaratuba Bay reached then its largest extension i.e., more than twice its current extension. An outlet was present where now Guaratuba City lies. Large shoals probably formed a flood tidal delta at that time. Another bay separated from the open sea by small barrier islands was present in Matinhos.

Guaratuba bay 5,500 years ago.

Guaratuba bay today.

After 5,600 years, the sea level dropped to its current position, which has led the youngest coastal plains of Paraná to take shape. They formed eastward, by progradation of successive foredune-beach ridges. Bays became progressively smaller and shallower until they reached their current configuration, or even disappeared in some cases.

It was only very recently that the Caiobá and Guaratuba hills were linked to the coastal plains.

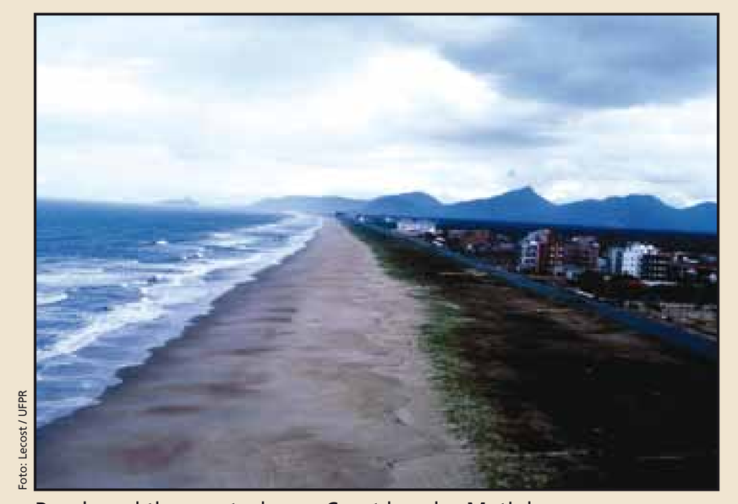
Features in the coasts of Paraná

Several geologic evironments are recognized on the coasts of Paraná, among which stuaries or bays, tidal deltas, tidal flats, beaches, and coastal dunes prevail.

Based on physiography and dynamics, features on the coasts of Paraná are classified into three main categories:

Tidal flat - Guaratuba bay

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



Beach and the coasts dunes. Coast beach - Matinhos

Open coasts show typically sandy beaches and frontal dunes.

Caieiras beach

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

Coastal Care

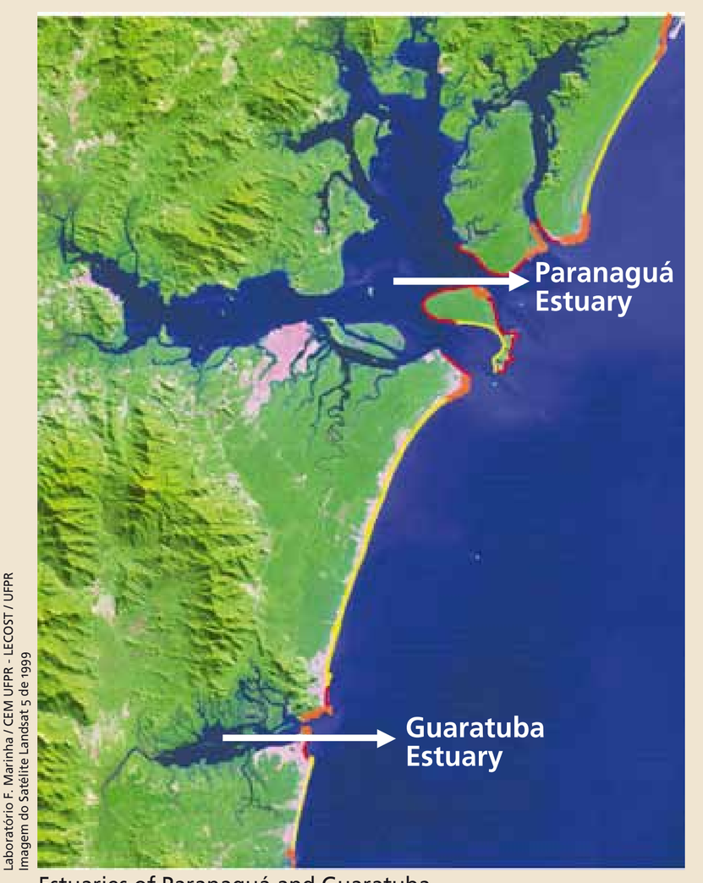
Geological history reveals that coasts are immensely dynamic, mobile regions, which poses risk to their occupation. But how to reduce such risk?

The most efficient and less costly measures are the preventive ones. One of the most efficient preventive measures is to leave an unoccupied, or only temporarily occupied, coastal stripe. The wider the stripe, the more environmentally safe it is. It is also of fundamental importance to have foredunes preserved, as these features can block wave action. Sands that accumulate along foredunes protect beaches from storm waves. Foredunes are among the most efficient erosion control structures. Where destroyed by human occupation, they should be artificially or naturally reconstructed.

Once triggered, coastal problems tend to aggravate, and their solution becomes more and more expensive and difficult. Damage prevention and morphological reconstruction are the best alternatives left.

Foredune

In Guaratuba and Matinhos, stable and unstable coasts occur. Oceanic types like those of Brejatuba or Matinhos are the more stable, and 20 to 40 m wide unoccupied stripes seem to prevent erosion. Along beach segments such as those near the Guaratuba Bay outlet, such as Caieiras and Prainha, sand accumulation and erosion are intense, and wider unoccupied stripes are necessary.



Estuaries of Paranaguá and Guaratuba

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

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

Realization:

MINEROPAR SERVIÇO GEOLÓGICO DO PARANÁ

GOVERNO DO PARANÁ SECRETARIA DE ESTADO DA INDÚSTRIA, DO COMÉRCIO E ASSUNTOS DO MERCOSUL

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