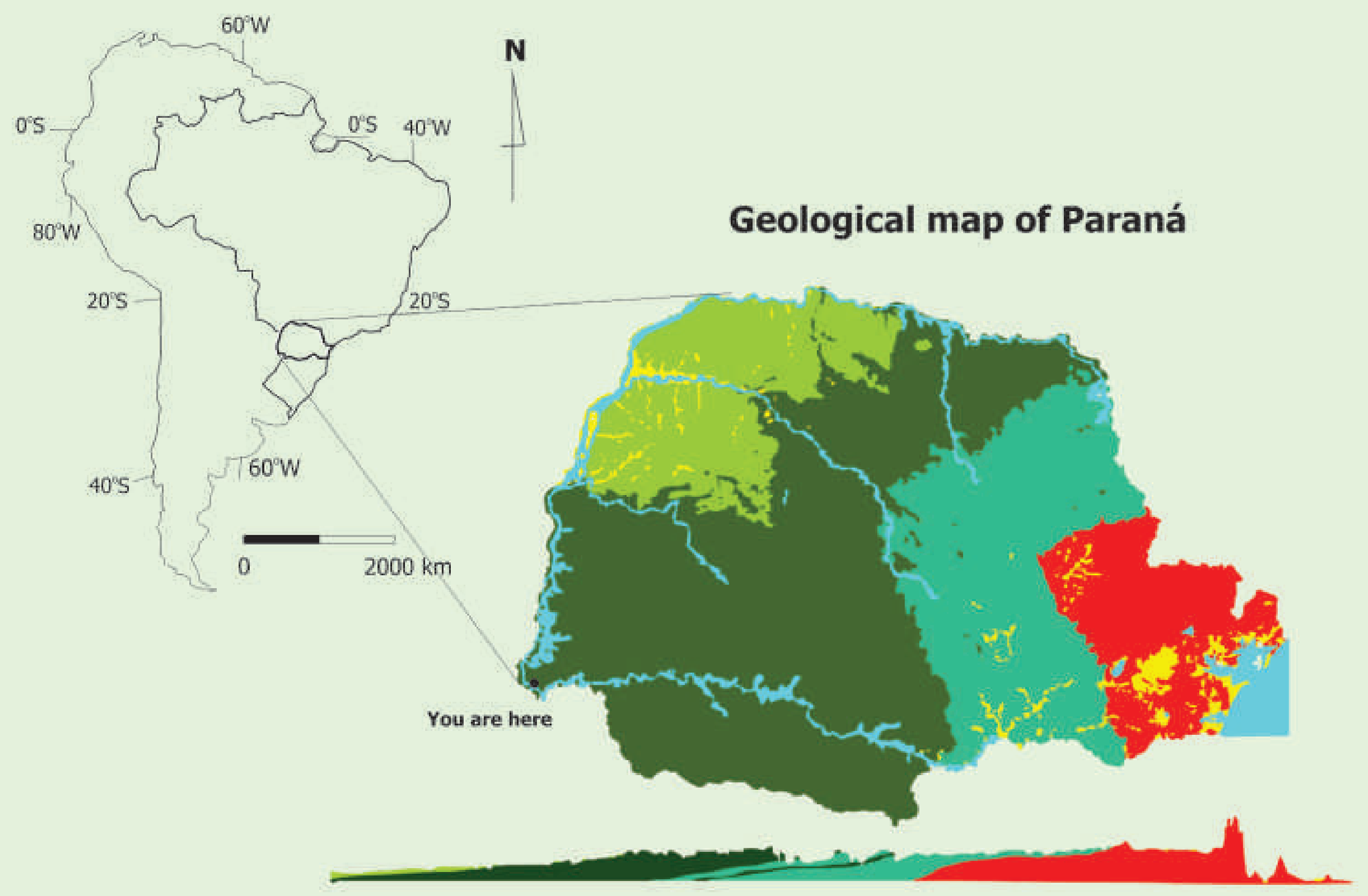
Iguaçu National Park

Geological Site

Geology of Paraná



EON	ERA	PERIOD	EPOCH	Age (million years)	Features	Geology
Phanerozoic	Cenozoic	Quaternary	Holocene	Today	Mankind, Northern Hemisphere glaciation	Sediments
				1,1		
			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	Paraná Basin: Sedimentary rocks; Magmatic rocks
		Jurassic		206	First birds and mammals appear	Paraná Basin: Sedimentary rocks
		Triassic		248	First Dinosaurs appear	Paraná Basin: Sedimentary rocks
	Paleozoic	Permian		290	Trilobites disappear	Paraná Basin: Sedimentary rocks
		Carboniferous		354	Reptiles, primitive large trees appear	Paraná Basin: Sedimentary rocks
		Devonian		417	Amphibians appear	Paraná Basin: Sedimentary rocks
		Silurian		443	Terrestrial plants appear	Paraná Basin: Sedimentary rocks
		Ordovician		495	First fishes	Paraná Shield
		Cambrian		545	First shells; trilobites prevail	Paraná Shield
Precambrian	Proterozoic			2500	First pluricellular organisms	Paraná Shield
	Archean			4000	First unicellular organisms	
	Hadean			4560	Earth forms	

Formation of the basaltic rocks

Formation of the Iguaçu Falls

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, the region being 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.

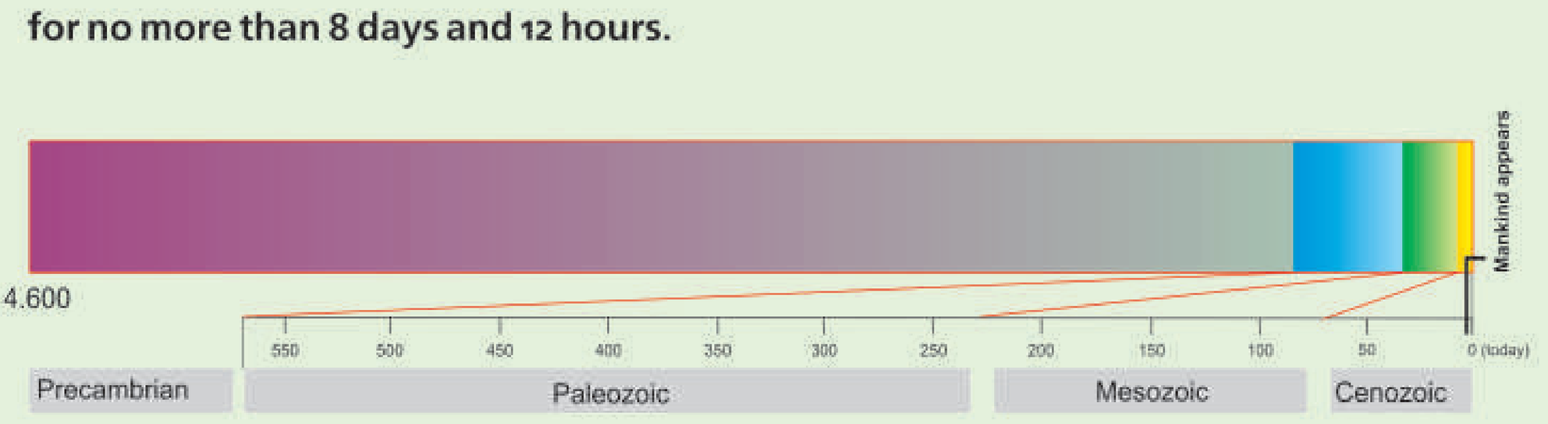
In Jurassic times, a desert named Botucatu, that spread for more than 1,500,000 km^2, covered parts of southern Brazil, Paraguay, Uruguay, and Argentina.

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 stacked basalt flows covered more than 1,200,000 km2 of the Paleozoic sedimentary rocks of the Paraná Basin. A remarkably fertile soil known as Terra Roxa resulted 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

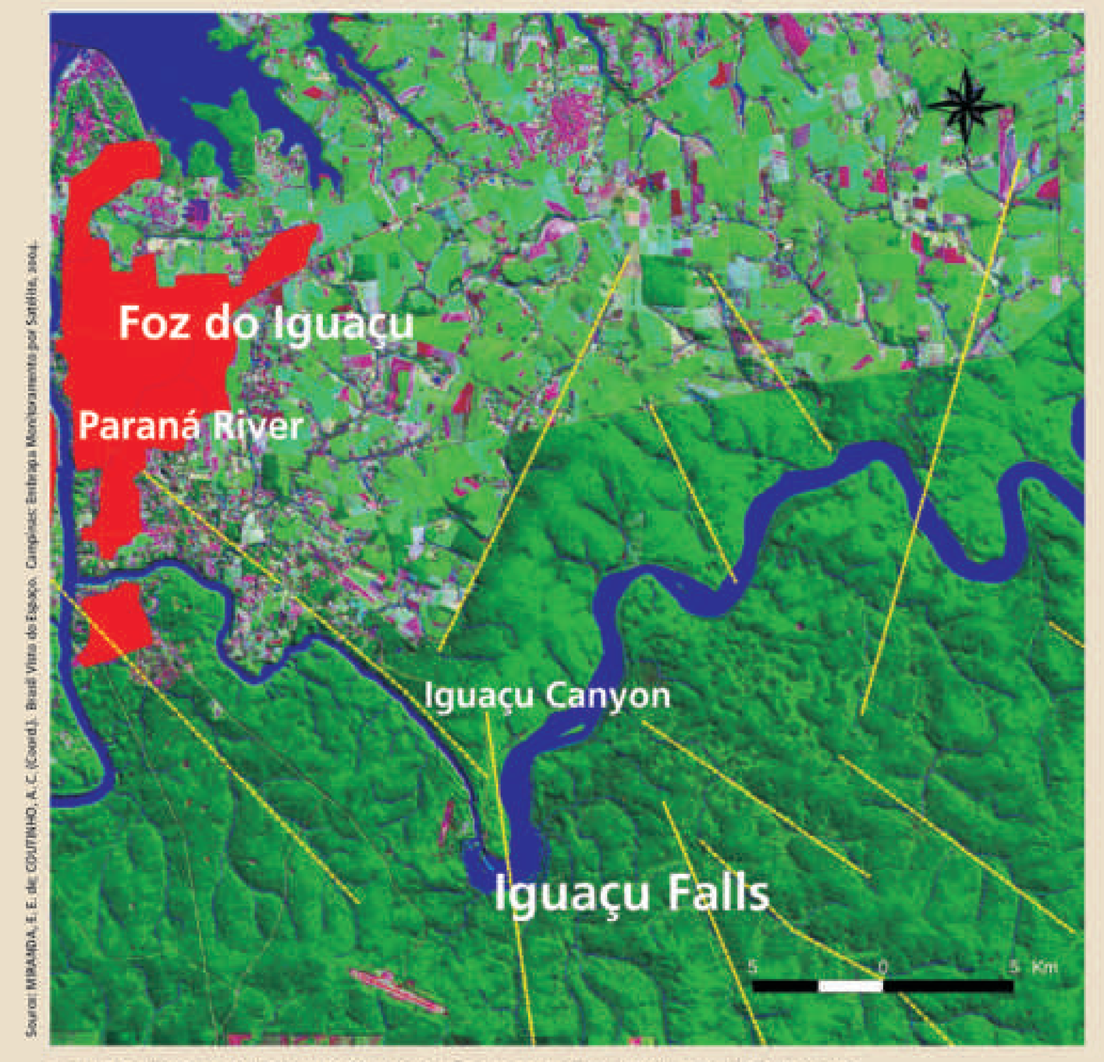
If the 4.6 billion years of geological history were scaled to one single year, Mankind would have been on Earth since 8:14 p.m. December 31 i.e., within the last 3 ours and 46 minutes. Dinosaurs, that lived for 100 million years, would have lived for no more than 8 days and 12 hours.



How and when the falls formed?

About 1 to 1.5 million years ago, Iguaçu Falls lay where now waters of the Iguaçu and the Paraná rivers meet. From the Devils Gorge on, the Iguaçu River runs for 21 km down a 80 to 90 m wide, 70 m deep canyon sculptured by regressive erosion of fault and fracture planes in the bedrock.

Because of its higher erosion potential, the Paraná River has a deeper channel than its tributaries, and it is depth difference that determines the presence or not of waterfalls at each tributary mouth. Each waterfall lies at a certain distance from the rivermouth: from a few hundred meters upstream minor tributaries to 21 kilometers upstream the Iguaçu River. An unarmed eye could not perceive the slow erosional processes that cause the waterfalls to recess (average 1.4 to 2.1 cm/year for Iguaçu Falls, the recession being recorded as the Iguaçu Canyon itself).



Satellite image of the waterfalls showing geological faults and/or fractures. Note that the Iguaçu Canyon extends along one such structure.

Photo: Apolonio Nelson Rodrigues

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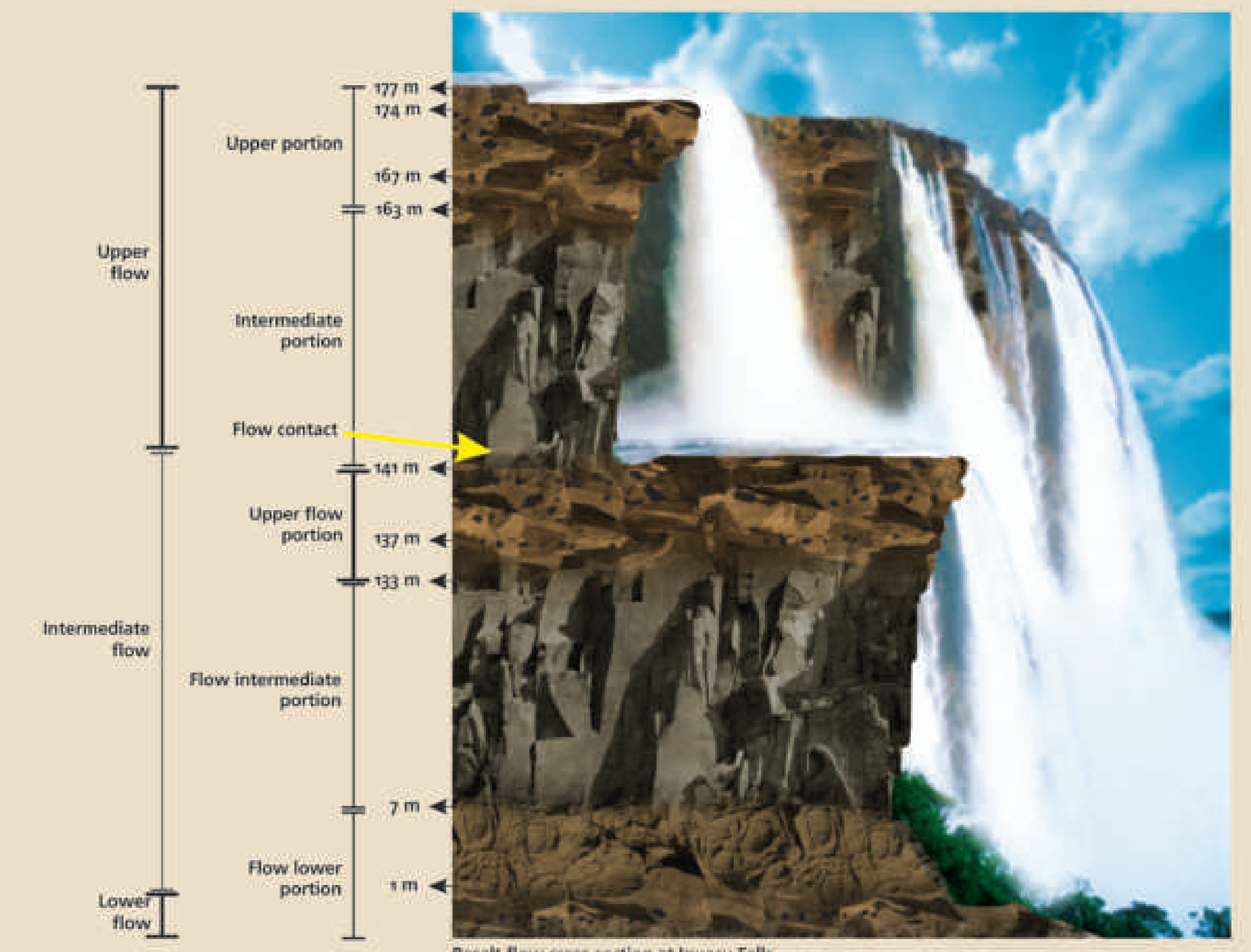
Why are the falls step-like?



Basalt flow cross-section at Iguaçu Falls

Adapted from: Geografia Física do Estado do Paraná by Reinhard Maack, 1968. Drawing by Marcelo Marini. Edited by Paula Xisto

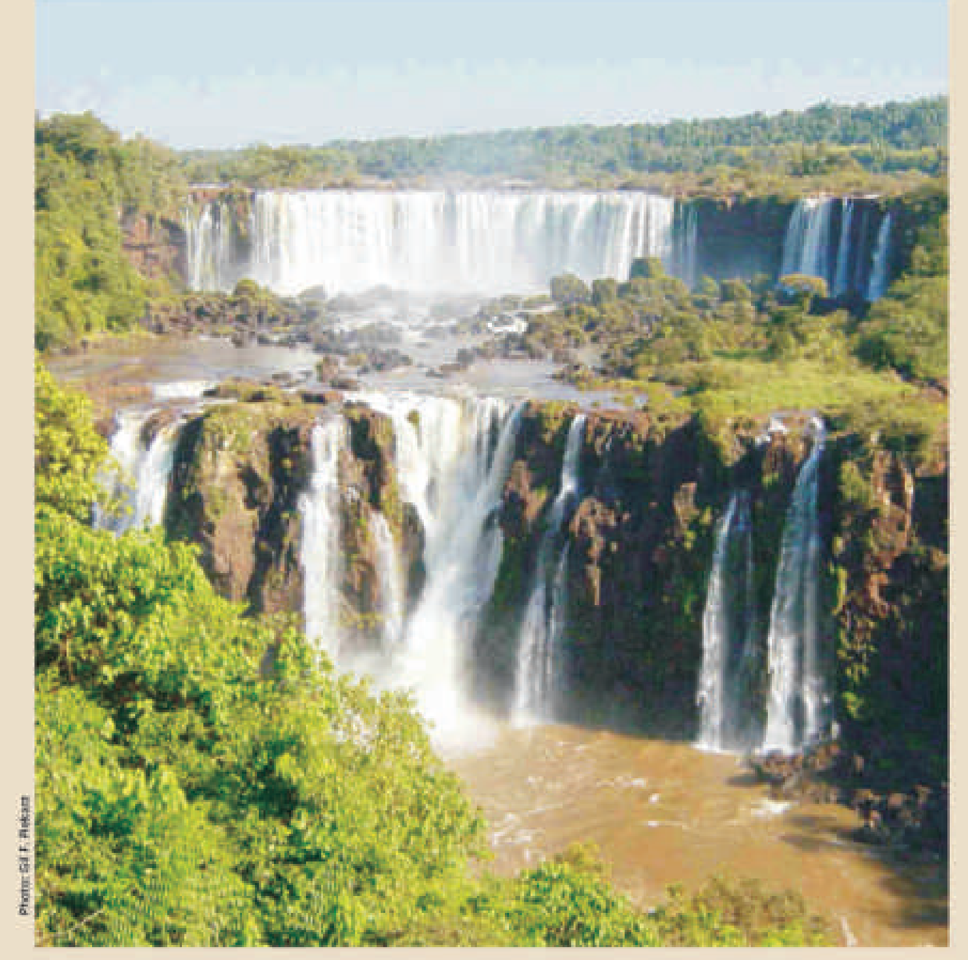


Photo: Gil F. Piekarz

The step-like nature of the falls is determined by the architecture of the underlying rocks. Three superimposed basalt flows can be noticed in the images above, the contact between the upper and intermediate ones marking a sharply defined level at which the more pronounced erosion forms recesses and grottos.

As erosion of the contact zone progresses, columnar massive blocks of the upper flow collapse ontop of the flat platform represented by the more resistant basaltic breccia and vesicular basalt of the intermediate flow. The waterfalls remain vertical, which is typical of those developed from basalt.

Rocks at Iguaçu Falls

A record of the separation of South America and Africa

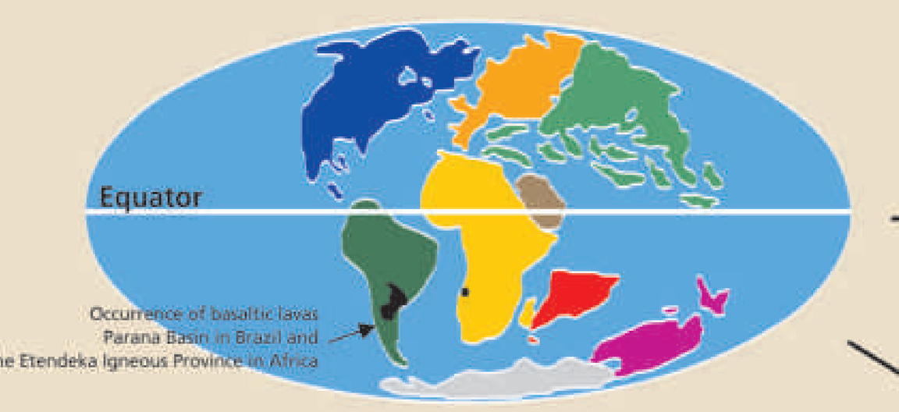
The rocks underlying Iguaçu Falls record the largest basalt flood event in Earth's history, which took place 120 to 130 million years ago during the Cretaceous.

Before such monumental basalt flood took place, all landmasses in the world formed one single supercontinent called Pangea, whose southern part, Gondwana, would now comprise South America, Africa, Australia, India, and Antarctica altogether.

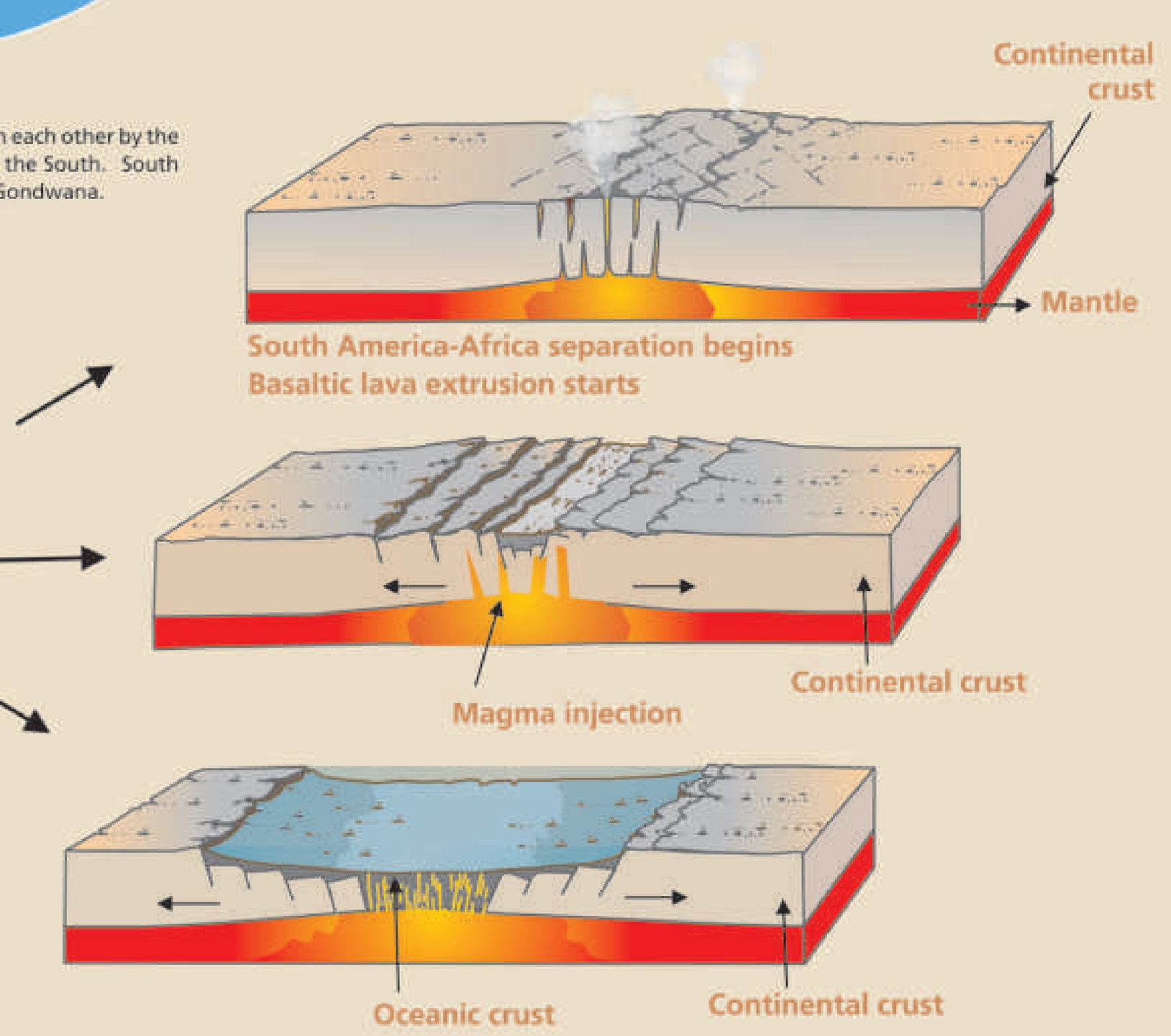
In Late Cretaceous, the region where Iguaçu Falls lie was part of a large desert called Botucatu, which covered extensive areas of Africa and South America that separated with the spreading of the South Atlantic Ocean after the breakup of Gondwana.

The basalt flows from which Iguaçu Falls take shape are consequence of the breakup of Gondwana. They formed as melted preexisting materials reached the surface from deep inside the Earth's crust and below through distension fractures. The immense, up to 1,500 m thick volcanic sequences cover an area of 1,200,000 km^2. More than 50 superimposed individual flows can be observed at some places. The desertic conditions persisted during the volcanic event, as evidenced by the presence of interflow aeolian sandstone layers.

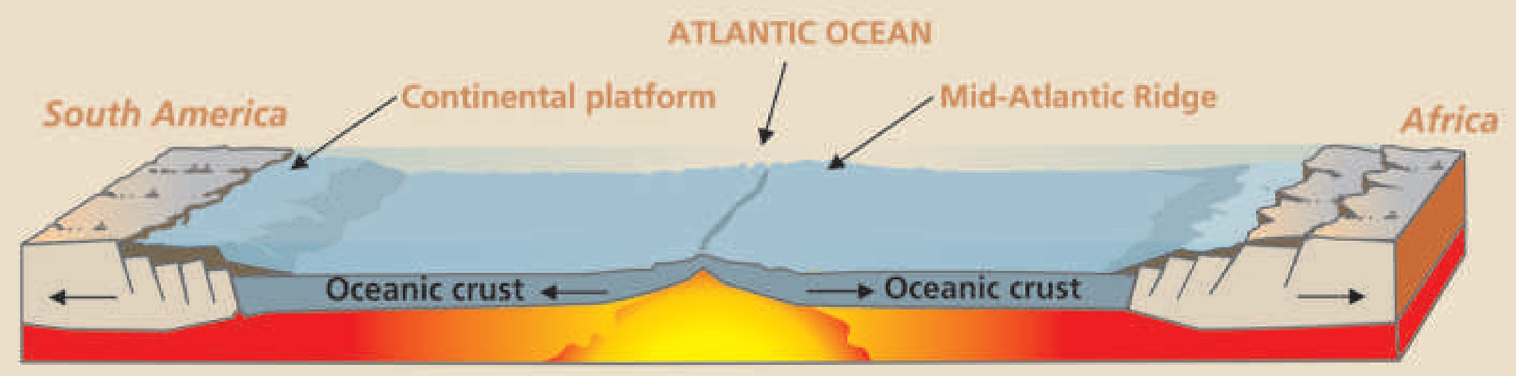
Jurassic begins 195 M.y
Dinosaurs climax. Only two continents separated from each other by the Tethys Sea: Laurasia to the North and Gondwana to the South. South America, Africa, Australia, India and Antarctica form Gondwana.



Cretaceous 140 to 65 M.y
Breakup of Gondwana. Separation of South America and Africa as the South Atlantic Ocean starts to spread. Extrusion of the lava from which derive the basalt underlying Iguaçu Falls.

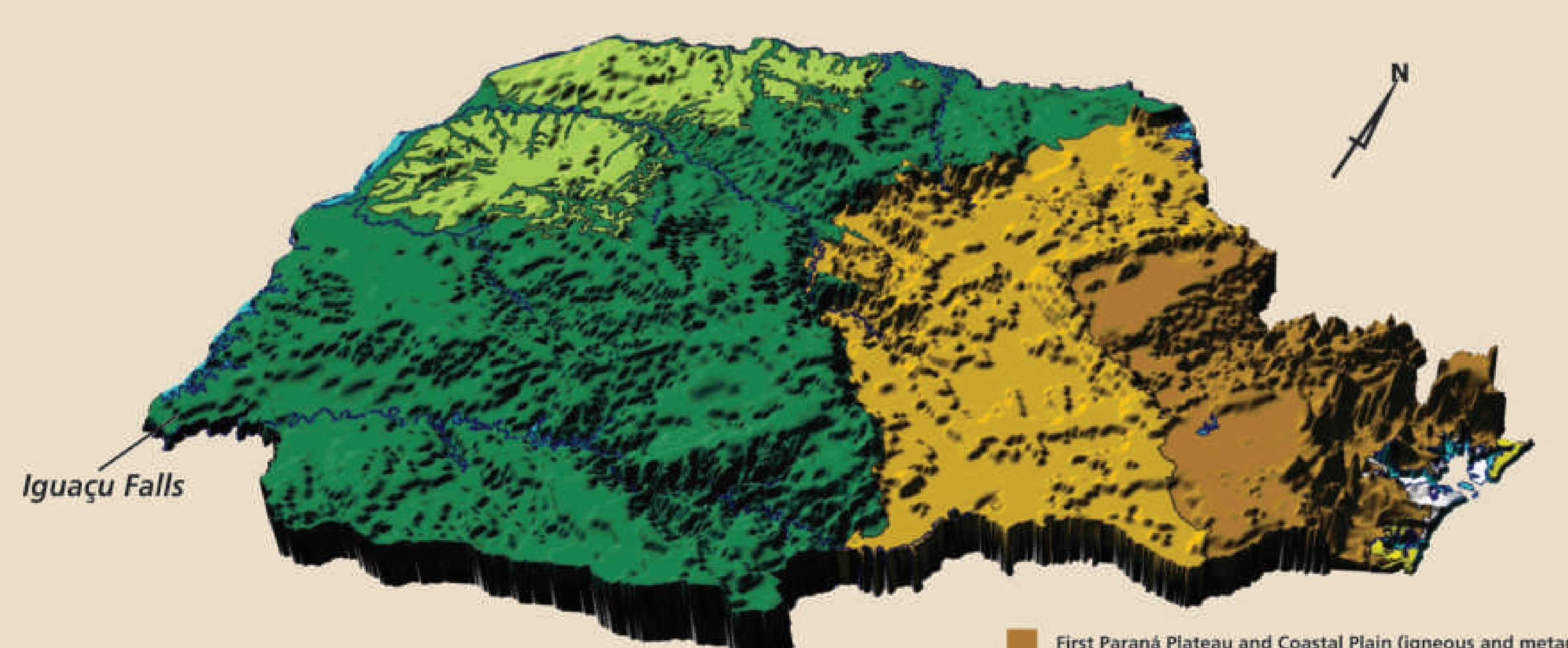


Present
A new continental collision cycle begins, which in 250 million years will result in a new supercontinent. Global temperature increases as the last glaciation, the "Age of Ice" recedes from its climax 10,000 years ago and increasing atmospheric emissions follow human activity.



Schematic representation of the breakup of Gondwana and the spreading of the Atlantic Ocean

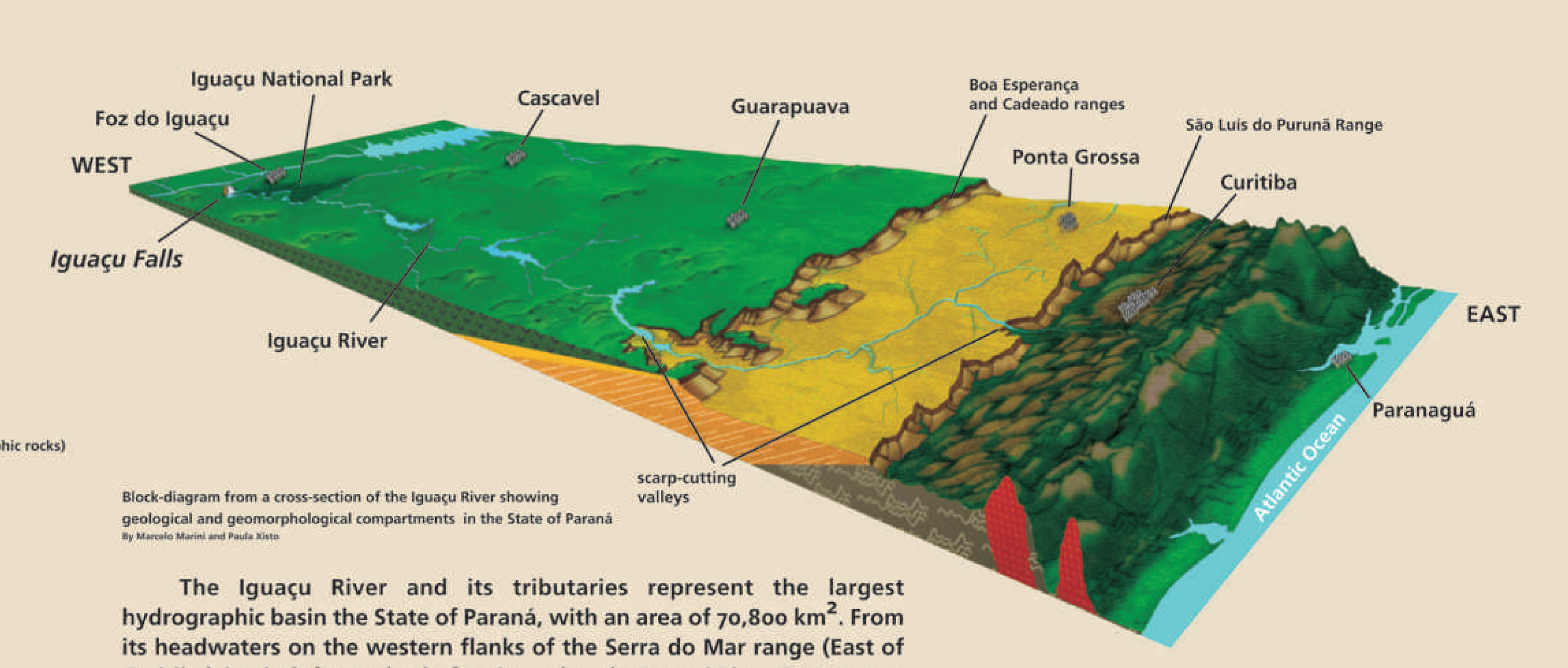
Why does the Iguaçu river flow inward the continent?



Geological-geomorphological map of Paraná
Source: MINEROPAR, by Otávio A. B. Licht

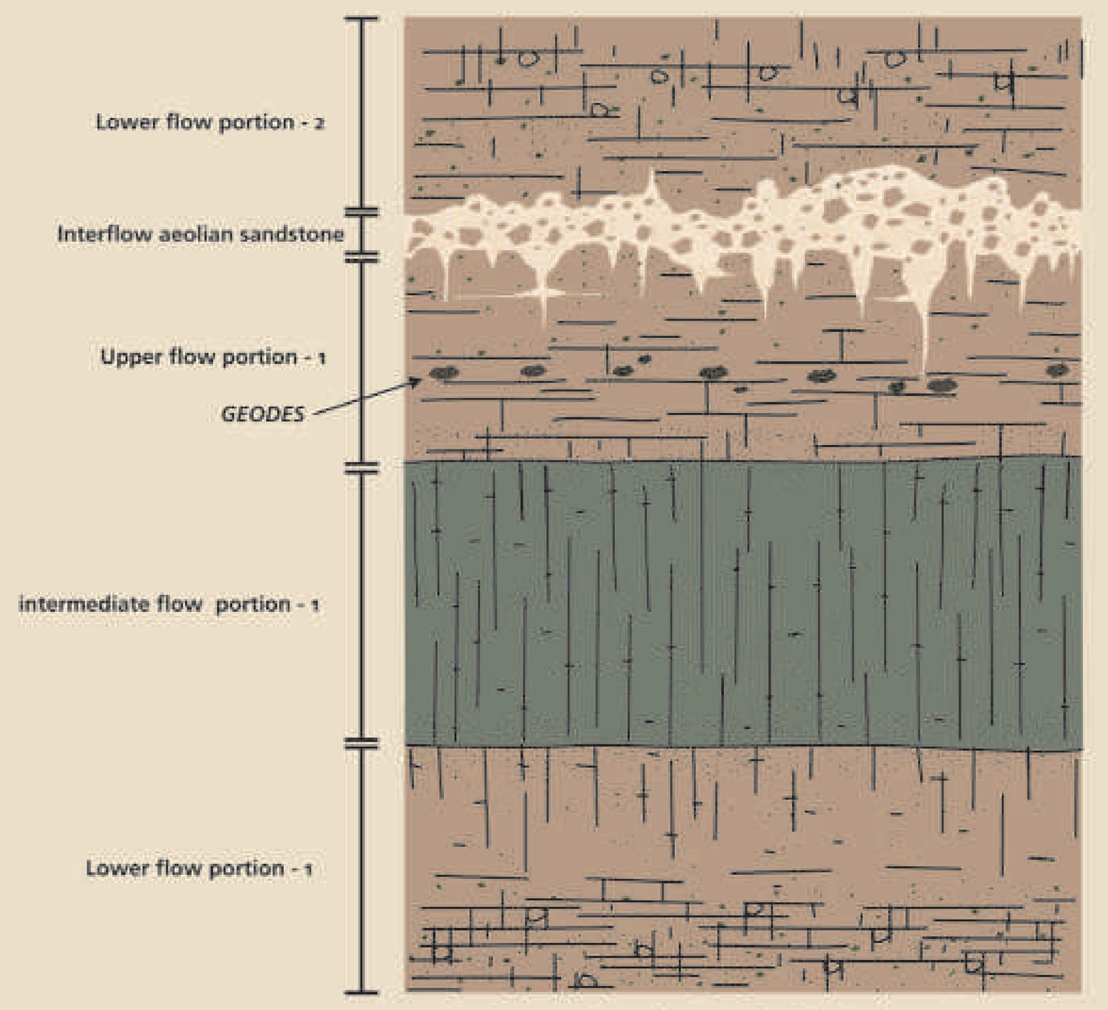
- First Paraná Plateau and Coastal Plain (igneous and metamorphic rocks)
- Second Paraná Plateau (sedimentary rocks)
- Third Paraná Plateau (basaltic volcanic rocks)
- Third Paraná Plateau (sedimentary rocks)

After the breakup of Gondwana, the eastern Brazilian border underwent a slow tectonic uplift related to both the spreading of the Atlantic Ocean and the rise of the Andes. It was that uplift, which took place between Late Cretaceous and the Tertiary, that caused rivers in Paraná to start flowing inward the continent.



Block-diagram from a cross-section of the Iguaçu River showing geological and geomorphological compartments in the State of Paraná
By Marcelo Marini and Paula Xisto

The Iguaçu River and its tributaries represent the largest hydrographic basin the State of Paraná, with an area of 70,800 km^2. From its headwaters on the western flanks of the Serra do Mar range (East of Curitiba), it winds for 910 km before it reaches the Paraná River. Two scarps, São Luis do Purunã and Boa Esperança are cut by this geologically old river.



Vertical cross-section of two stacked basalt flows

Basalt flows normally 15 m present three clearly defined portions: the upper, the intermediate, and the lower ones.

Photo: Gil F. Piekarz

Landscape of stacked basalt flows

Photo: Gil F. Piekarz

The upper portion is marked by the extensive presence of vesicles and horizontal fractures in the rock. Vesicles are small hollows left as gases ascend through the solidifying lava. When filled with minerals such as calcite, amethyst, calcedony, agate, or zeolite, that cristallize from gas or liquid fluids during or after solidification, vesicles form **wonderful geodes**.

Being more subject to atmospheric conditions, the upper portions of a lava flow tend to display reddish tones due to oxidation of the iron minerals they bear.

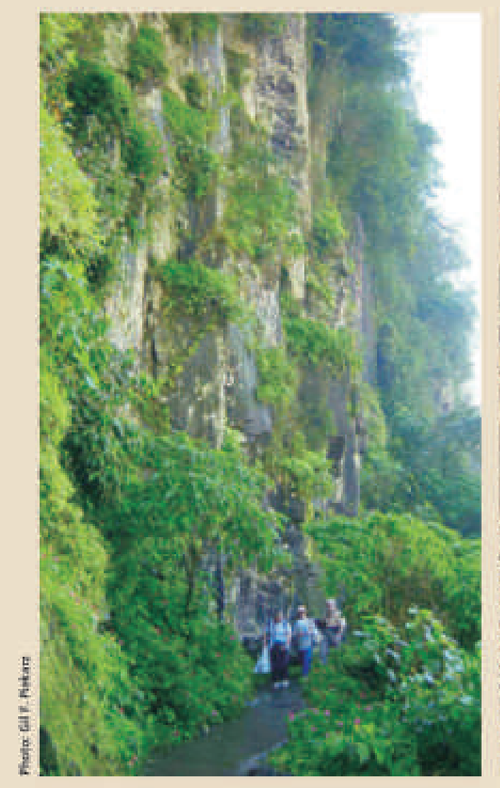


Photo: Gil F. Piekarz

The intermediate portion is characterized by massive (homogeneous) basalt formed from slower solidification. The rock is cut by a subvertical fracture system referred to as **columnar jointing**, that develops as lava solidifies.

Photo: Gil F. Piekarz

Being in direct contact with the ground surface, **the lower portion** of a basalt flow is marked by intense fracturing and horizontal lamination caused by faster solidification and flow. Such fracturing can be observed at the start of the **Macuco boat ride and at the *Campo dos Desafios* wall**, where splendid exposures of spheroidal exfoliation due to fracture-controlled weathering of basalt can be seen.

Realization:
GOVERNO DO PARANÁ
MINEROPAR MINERAIS DO PARANÁ SA
BRASIL UM PAÍS DE TODOS
IBAMA MMA

Partnership:
GOVERNO DO PARANÁ
Cultura Secretaria de Estado
SEMA
PARANÁ TURISMO
PARQUE NACIONAL DO IGUAÇU

Conception and geology: Gil F. Piekarz - MINEROPAR   Grafic design: Arno Siebert SEEC/CDG