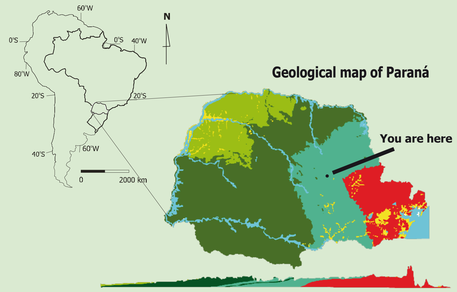
Geology of Paraná



EON	ERA	PERIOD	EPOCH	Age (Mya=Years ago)	Features	Geology
Phanerozoic	Cenozoic	Quaternary	Holocene	Today	Man enters the atmosphere	Sediments
			Pleistocene	1,1 1,8		
		Tertiary	Pliocene	5,3		Sediments
			Miocene	23		
			Oligocene	34	Primates proliferate	
			Eocene	53		
			Paleocene	65	First horses appear	
	Mesozoic	Cretaceous			Dinosaurs appear; flowers	Sedimentary rocks; Magmatic rocks
				142		
		Jurassic			First birds and mammals appear	Paraná Basin: Sedimentary rocks
				206		
		Triassic		248	First Dinosaurs appear	
	Paleozoic	Permian		290	Trilobites disappear	
		Carboniferous		354	Reptiles and primitive large	
		Devonian		417	Amphibians appear	
		Silurian		443	Terrestrial plants appear	
		Ordovician		495	First fishes	
		Cambrian		545	First shells; trilobites prevail	Paraná Shield
Pre-cambrian	Proterozoic			2500	First photocellular organisms	
	Archean			4000	First unicellular organisms	
	Hadean			4550	Earth forms	

Age of diabase dykes formation and South America-Africa separation

Beginning of sandstone deposition of Furnas Formation (canyon walls)

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 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 called 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.

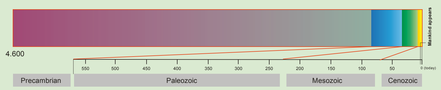
In Jurassic times, a desert named Botucatu, that spread for more than 1,500,000 km2, covered parts of southern Brazil, Paraguay, Uruguay, and Argentina.

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 superposed 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.



Geological Site

The Guartelá Canyon

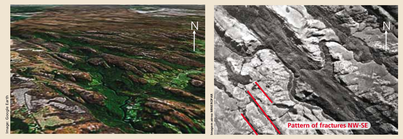
How was the Guartelá Canyon formed?

Extending for 30 kilometers, the Guartelá Canyon is a gorge carved up to 450 meters deep through geological fractures and faults by the Iapó River. It is considered to be a record of the separation of Africa and South America back in the Age of Dinosaurs, in the Mesozoic Era, when the South Atlantic Ocean started to spread.

At approximately 120 to 130 million years ago, the Guartelá region was affected the Ponta Grossa Arch, a very large structure that resulted from the action of crustal forces that lead to the separation of Africa and South America. In the beginning of the separation process, massive basalt flows ascended from long NW-SE fractures in the arch.

Sealed with volcanic rock after magma ceased to flow, these fractures now host diabase dykes. The Guartelá Canyon developed along the Ponta Grossa Arch axis, where the largest of the diabase dyke occurs. A remarkable aspect of this dyke is its flourishing vegetation, that contrasts with the short one over the surrounding sandstone substrate.

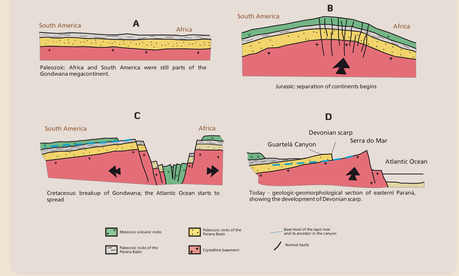
General view of the canyon with the Iapó River on the background and Lapa Ponciano, where rupestrian paintings are found



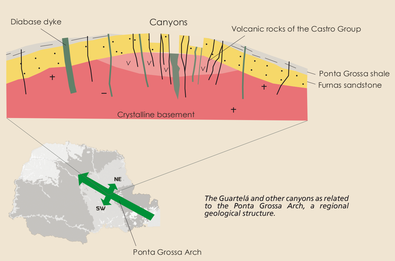
Tridimensional aerial photograph showing the Guartelá Canyon, the general NW-SE trend of the geological structures present, and the different rock types (sandstone walls; volcanic bottom). The bi-dimensional aerial photograph on the right shows the vegetation contrast between these two rock types: dark along the diabase dyke and pale over the less fertile sandstone.

Millions of years passed, with the westward Iapó River flow being controlled by these fractures. It is along these fractures that the river's main straight segments fit, the whole sandstone section being carved down to older underlying volcanic rocks of the Castro Group by the continuous erosional action of water (see "The Rocks of this region").

An important factor in the evolution of the Guartelá Canyon is the rock's resistance to weathering. The diabase substrate along the canyon's axis is less resistant than the sandstone of the scarps, and hence the marked relief difference between them. Down along the canyon, where the diabase is hosted by shales of the Ponta Grossa Formation, the similar resistance to weathering of these two rock types leads to the absence of scarps, and the canyon reaches its end.



Coastal evolution of Paraná showing the continental breakup, the Guartelá Canyon carving, and the sculpturing of the Devonian scarp.



The Guartelá and other canyons as related to the Ponta Grossa Arch, a regional geological structure.

Relief features of the Guartelá

Among the most remarkable sights along the Guartelá Canyon are the relief features resulting from weathering of Furnas sandstones.

Bizarre feature sets including anastomosed alveoli and tunnels, and also riverbed hollows, are easily seen. Such feature sets are known as ruiniform relief, and are formed when weathering is controlled by preexisting sedimentary structures.

Whether directly along rivers, or indirectly through rain infiltration and chemical dissolution, the causal agent of virtually all such relief forms is water.

Hollow formed by the erosive action of water on sandstone

Bird figure in sandstone

Pedra Furada ("Hollowed stone"): example of ruiniform relief

Dissolution alveoli in sandstone

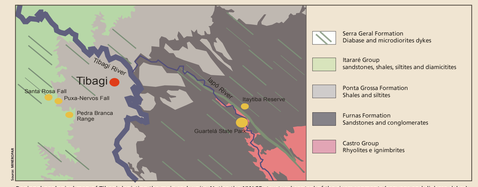
The Rocks of this Region

Over the Ivaí diamictites, massive beds of whitish conglomerate and sandstone of the Furnas Formation deposited. The Guartelá Canyon walls consist of such rocks, the most widespread ones in the region and that are substrate for the of Paraná's second plateau.

Above Furnas Formation are the fossile-rich marine shelf shale and siltite bodies of the Ponta Grossa Formation. Both Furnas and Ponta Grossa formations constitute the Devonian (or Silurian, according to some researchers) Paraná Group. These 410 to 360 million year-old rocks suggest the presence of a sea inlet into the region at that time.

Above the Paraná Group rocks are those of the Itararé Group, of Permocarboniferous age (300 million years). Again rocks formed from a glacial environment, in this case represented by reddish sandstones and diamictites. These rocks outcrop away from the canyon, like along the Pedra Branca Range near Tibagi.

All rocks in the region are cut by Mesozoic diabase dykes that resulted from volcanism episodes related to the separation of Africa and South America.



Regional geological map of Tibagi depicting the main rock units. Notice the NW-SE structural control of the rivers segments (canyons and diabase dykes).

Block and scarp on the Furnas sandstone background

Geological contact between sandstone (above) and ignimbrite (below)

Ignimbrite on the Iapó riverbed

Spheroidal exfoliation of diabase

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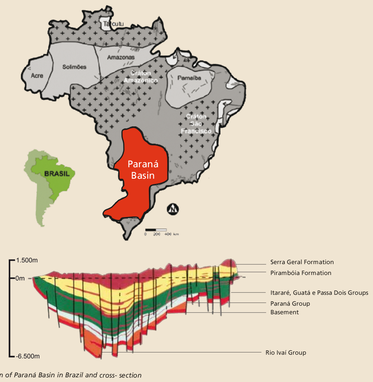
The Paraná Basin

The Paraná Basin is a vast elongated depression filled with sediments piling up to six kilometer thick in some places. Part of its total extension of approximately 1,400,000 km2 correspond to the second and the third plateaus of the State of Paraná. Early in the evolution of the basin, the global distribution of continents was quite different from the current one. The landmasses now corresponding to South America and Africa were still parts of a megacontinent named Gondwana.

The long and relatively calm evolution of the Paraná basin allowed sediments to deposit from a variety of environments such as marine, deltaic, lacustrine fluvial, glacial, and desertic ones. When Africa and South America separated, most of he basin's extension was covered with basaltic lava flows.

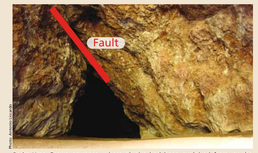


Location of Paraná Basin in Brazil and cross- section

Pedra Ume Grotto

The Pedra-Ume Grotto was a mining gallery carved into Castro Group ignimbrite near the bottom of the canyon, from which alunite used to be exploited. Ignimbrite is a type of rock that forms from sedimentation of volcanic ashes at temperatures as high as 1,000 to 1,100 °C.

Alunite, a whitish mineral known as alum and used e.g., in the softening and tanning of leather, occurs through the fault plane (see photograph). It resulted from alteration of the ignimbrite by fluids that percolated the rock at the time of faulting.



Pedra-Ume Grotto entrance, where alunite had been exploited from, at the bottom of the canyon near the Iapó River.

Alunite specimen found at the Pedra-Ume Grotto, developed from hydrothermal alteration of Castro Group ignimbrite.

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