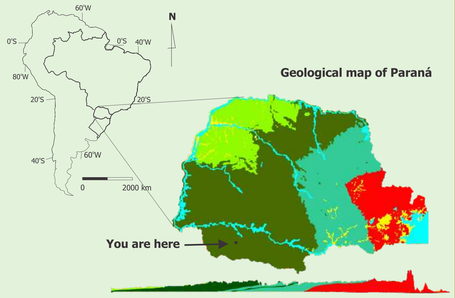
Geology of Paraná



EON	ERA	PERIOD	EPOCH	Age (mill. 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			Dinosaurs appear; flowers	Sedimentary rocks Intrusive rocks
				142		
		Jurassic			First birds and mammals appear	Paraná Basin
				206		
		Triassic		248	First Dinosaurs appear	Sedimentary rocks
	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	
Pre-cambrian	Proterozoic			2500	First pluricellular organisms	
	Archean			4000	First unicellular organisms	
	Hadean			4560	Earth forms	

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.

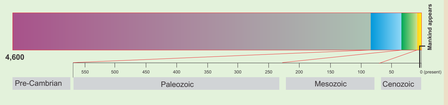
In Jurassic times, a desert named Botucatu, that spread for more than 1,500,000 km^2, covered parts of southern Brazil, Paraguay, Uruguay, and Argentina.

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 superposed basalt flows covered more than 1,200,000 km^2 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. Serra do Mar as it presents itself today would have arisen within the last 5 minutes of the year.



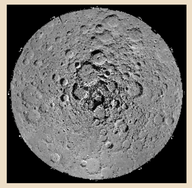
Geological site

The Vista Alegre impact crater

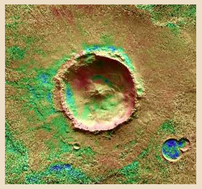
What is an impact crater?

Impact craters are formed when a planetary body (such as the Earth or the Moon) is hit by another body of smaller dimensions. These smaller bodies are usually meteorites, asteroids or comets, which travel through the interplanetary space. Meteorites and asteroids are rocky fragments, whereas comets are formed by a mixture of rocky fragments, dust and ice.

The marks left by these interplanetary collisions are the impact craters. However, not many of these craters are seen on the Earth's surface. The reason is that, along geologic time, erosion, sedimentation and the dynamics of the Earth's crust (such as the movement of tectonic plates), tend to erase the marks left by impacts on the surface of our planet. In other planetary bodies, like the Moon or Mars, this does not occur.



The north pole of the Moon, with its multiple impact craters.



Bacolor crater in Mars.

What does it happen when there is an impact and how frequent do they occur?

! Impacts of large bodies release gigantic amounts of energy and their effects may be extremely destructive to the surface of our planet and its inhabitants.

One of the youngest craters known on Earth, the Meteor (or Barringer) Crater in Arizona, USA, was formed about 50,000 years ago. It has a diameter of 1,200 meters, it is 190 meters deep and very well preserved from erosion. The amount of energy released by the impact that formed Meteor Crater was equivalent to 2,000 atomic bombs similar to the one that destroyed the city of Hiroshima in Japan during World War II.

Craters larger than Meteor Crater were formed on Earth during the last hundreds of million years. One of the largest craters known on Earth is located in the Gulf of Mexico, in the Yucatán Peninsula. Its formation, around 65 million years ago, may have been responsible for the extinction of the dinosaurs and many other life forms that existed at the time. It is known as the Chicxulub Crater, with a diameter of 170km.

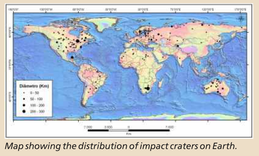
To the benefit of the human beings, these phenomena are very rare and the chances that our civilization come to experience an impact of large proportions are extremely reduced.

The Meteor Crater, Arizona, USA.

Where are the impact craters on Earth and in Brazil?

Until now, 172 craters have been found on Earth. In Brazil there are only 5 impact craters. Vista Alegre crater was discovered in 2004 by geologists from the State University of Campinas, having joined the other Brazilian craters of Araguainha Dome (MT/GO), Riachão (MA), Serra da Cangalha (TO) and Vargeão Dome (SC). The latter is located only 100 km from Vista Alegre, arousing the possibility of being "twin craters", formed when a single comet or asteroid split into two or more smaller fragments when entering the Earth's atmosphere.

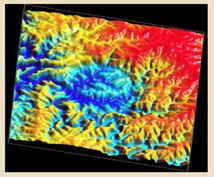
Map of the Brazilian impact craters.



Map showing the distribution of impact craters on Earth.

Vista Alegre Crater

The Vista Alegre district, in the town of Coronel Vivida, is located in the interior of a circular depression which represents the remnants of an impact crater formed several million years ago. The erosion along the geologic time resulted in the landforms which currently constitute Vista Alegre Crater. When viewed on satellite images, the topography of the region shows a clear circular depression, with a diameter of 9.5km, surrounded by steep hills. These hills correspond to the borders of the crater, with a topographic gradient of over 100 meters between the bottom of the depression and the top of the hills.



Tri-dimensional model of the topography of Vista Alegre Crater in an image produced by NASA's Endeavour space shuttle. Red colors correspond to higher elevations, gradually passing into lower elevations depicted in blue colors.

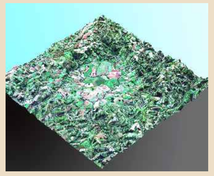
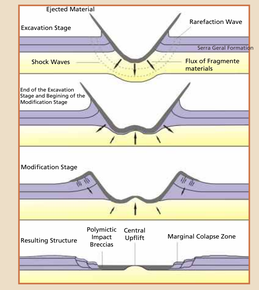


Image of the Landsat satellite combined with the tri-dimensional model of the relief, showing the Vista Alegre Crater in a perspective view.

How and when did this impact occur?

The precise time the Vista Alegre impact occurred is not yet known. However, when the celestial body which formed this crater collided against the Earth, the rocks that existed on the surface of this region were the basalts of the Cretaceous period, belonging to the Serra Geral formation. These are volcanic rocks of dark gray colors, originated when the South American continent started to drift from the African continent, forming the Atlantic Ocean. The maximum age of these basalts was established in 128 million years, the Vista Alegre Crater being therefore younger than this.



Formation model of the Vista Alegre Crater. Modified of French, 1998.

What modifications did the impact cause?

Asteroids travel through space at very high speeds, usually between 4,000 a 26,000 km/h. For this reason, the energy released by an impact is tremendous. It can be estimated that, in order to form the Vista Alegre Crater, the required amount of energy is equivalent to over 250 thousand bombs similar to the one that destroyed Hiroshima. The basaltic rocks were extremely deformed as a consequence of the energy released by the impact.

Another effect of the impact was the uplift of the bottom of the crater excavated by the impact, similarly to what happens just after a stone falls into water. In Vista Alegre, this phenomenon caused the ascent of layers of sandstone from the Botucatu formation, located several hundreds meters below the current surface. Fragments of these white-colored sandstones may be eventually found in some places within the crater.

What happened to the rocks that existed in Vista Alegre?

The pre-existing rocks at the local of the impact, together with the hitting asteroid, were deeply transformed as a consequence of the shock. They were almost instantly fragmented, shattered, pulverized or melted, forming a cloud that was ejected into the air. Most of this material was scattered throughout the area surrounding the crater, whereas part of it was deposited in the bottom of the newly-formed crater. These deposits formed a new type of rock called "impact breccia", comprising fragments of the local rocks (basalts and sandstones), some of them severely deformed and even melted, together with rock dust.

Part of these impact breccias were preserved from erosion and may be seen today in some places within the crater, as in the small quarry located near the access to the Vista Alegre district. These impact breccias are the main source of information that allows geologists to determine the origin of Vista Alegre Crater and to study how it was formed.

Impact breccia formed by fragmentation of pre-existing basalts and sandstones as a consequence of the impact.

Shatter cones in fragments of sandstone within the impact breccia. The striated cones are formed by the passage of the shock waves produced by the impact through the country rocks.

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