= Cerro Blanco (volcano) =

Cerro Blanco is a caldera in the Andes of the Catamarca Province in Argentina . Part of the Central Volcanic Zone of the Andes , it is a volcano collapse structure located at an altitude of 4 @,@ 670 metres (15 @,@ 320 ft) in a depression . The caldera is associated with a less well defined caldera to the south and several lava domes .

The caldera has been active for the last eight million years and eruptions have created several ignimbrites . One of the most recent eruptions occurred 73 @,@ 000 years ago and formed the Campo de la Piedra Pómez ignimbrite layer . About 5 @,@ 000 years ago , the largest volcanic eruption of the Central Andes with a volcanic explosivity index of 7 occurred at Cerro Blanco , forming the most recent caldera as well as thick ignimbrite layers . About 110 cubic kilometres (26 cu mi) of rhyolite were erupted then . The volcano is dormant since then with some deformation and geothermal activity . A major future eruption would put local communities to the south at risk .

The volcano is also known for giant ripple marks that have formed on its ignimbrite fields . Persistent wind action on the ground has shifted gravel and sand , forming wave @-@ like structures . These ripple marks have heights up to 1 metre (3 ft 3 in) and are separated by distances up to 30 metres (98 ft) . Unlike dunes , they do not migrate with the wind and are stationary . These ripple marks are among the most extreme on Earth and have been compared to Martian ripple marks by geologists .

= = Geography and geology = =

= = = Regional setting = = =

The Central Volcanic Zone of the Andes is an area between 14 ? 28 ° southern latitude where volcanic activity dates to the Eocene . Ignimbritic activity has occurred over the whole area , particularly north of 25 ° southern latitude where the Altiplano ? Puna volcanic complex is situated . Ignimbrites are primarily rhyolite and rhyodacite and subordinate shoshonite . The more southern ignimbrites are felsic and have a low crystal content . With the exception of the Luingo caldera and Cerro Galán , most volcanism south of 25 ° southern latitude is of low volume . After a phase of pyroclastic activity in the Antofalla area during the Eocene , a number of volcanoes formed from calc @-@ alkaline magmas during the Miocene . Changes in subduction geometry including the removal of continental crust from the boundary 8 @-@ 3 mya have caused a thickening of the crust as well as an eastward shift of the volcanic front . Huaynaputina volcano in Peru is part of the Central Volcanic Zone and had a major eruption in 1600 .

Most ignimbrites of the southern sector have volumes of 50 cubic kilometres (12 cu mi) or less and are associated with stratovolcanoes and small calderas . They are derived from fractional crystallization of andesitic magmas with variable crustal input .

= = = Local setting = = =

Cerro Blanco is part of the Central Volcanic Zone and is located at the southern limit of the Puna . It forms a volcanic unit together with the Aguada Alumbrera ignimbrite , at the eastern edge of the Cordillera de San Buenaventura . Rocks beneath this unit include dacitic ? trachyandesitic volcanites 9 ? 7 mya old and an igneous @-@ metamorphic granitic basement containing orthogneiss , quartz of Neoproterozoic @-@ early Paleozoic age , containing paleozoic mafic to ultramafic volcanic inclusions . The Cordillera de San Buenaventura is formed from lava domes and volcanic complexes of intermediary composition of Upper Miocene ? Quaternary age . During the Miocene @-@ Pleistocene , the isotope and chemical composition of areal magmas has moved away from arc like magmas to distinctly water @-@ poor and unoxidized petrologies . This finding is consistent with a hot mantle forming after delamination of the crust and migration of the arc .

Nevado Tres Cruces lies to the west and Nevado Ojos del Salado lies to the southwest of the Cerro

Blanco centre . East @-@ northeast running fault systems are controlled by local tectonics and may be responsible for the formation of the Cordillera de San Buenaventura . The 4 @-@ 3 @.@ 7 mya Laguna Amarga west of Cerro Blanco erupted rhyolites , unlike Cerro Blanco 's ignimbrites . The better known Cerro Galán caldera lies 80 kilometres (50 mi) southwest of Cerro Blanco . It forms a northwest @-@ southeast volcanic line with Cerro Blanco and Incapillo . This line was active less than 2 @.@ 5 mya ago . Another trend is defined by the Culampaja line running from Sierra Nevada over Cerro Cóndor and Cerro Peinado to Blanco . Other volcanic centres in the region are the Miocene @-@ Pliocene ignimbrites Las Juntas and Las Papas . Minor bimodal ? mafic volcanic centres during the Pleistocene ? Holocene include volcanoes in the Pasto Ventura , Salar de Carachi Pampa and Volcán Negro Peinado areals . Felsic centres include Chascón and Cueros de Purulla . Cerro Purulla lies northnorthwest of Cerro Blanco and the La Hoyada volcanic complex lies directly west . 4 @,@ 380 metres (14 @,@ 370 ft) Cueros de Purulla and 4 @,@ 290 metres (14 @,@ 070 ft) Chascón are major sources of obsidian in the Puna of Catamarca region .

The Cerro Blanco complex is formed from pyroclastic flows extending from nested calderas . The Robledo caldera is heavily eroded and has assumed a semicircular shape . The rim of the Cerro Blanco caldera proper is well @-@ preserved , with ash and block flows filling the interior . Another theory holds that the northern Cerro Blanco and the southern Robledo calderas are part of one caldera with a minimum subsidence of 700 metres (2 @,@ 300 ft) and a dimension of 13 by 10 kilometres (8 @.@ 1 mi × 6 @.@ 2 mi) . The Cerro Blanco caldera is 6 kilometres (3 @.@ 7 mi) wide . On its southern rim , surrounded by ashfall deposits , lies the Holocene Cerro Blanco del Robledo lava dome (26 ° 46 ? 51 ? S 67 ° 45 ? 27 ? W) . Some sources call the whole volcano Robledo and use Cerro Blanco to refer to the lava dome . The whole volcanic complex is formed from lava domes , ignimbrites , ash and block flows and unconsolidated deposits . Cerro Blanco is the largest lava dome and has a debris collapse deposit on its northern side . A hydrothermally altered area in the middle of the caldera has been linked to phreatomagmatic activity . The El Escondido crater northeast of the caldera is 1 @.@ 2 kilometres (0 @.@ 75 mi) wide and 40 metres (130 ft) deep . It shows a dark colour and semiannular shape in satellite images and has been interpreted as a phreatic crater . The complex is located at the southwest end of a volcano @-@ tectonic depression formed by local fault systems . These fault systems channel magma during eruptions ; usually no eruption column is formed . The formation of the depression may be influenced by the emptying of magma chambers associated with the volcano . The complex is located on 60 kilometres (37 mi) thick crust . A crustal low seismic velocity anomaly is located beneath Cerro Blanco , called the Southern Puna Magma Body .

= = = Megaripple fields = = =

Mega ripple marks formed by gravel are also found in the Cerro Blanco area and are among the most extreme on Earth . These are formed from wind @-@ driven processes acting on local ignimbrites , including saltation of fine grains and sand during wind . Ripples have amplitudes varying 0 @.@ 1 ? 2 metres (3 @.@ 9 in ? 6 ft 6 @.@ 7 in) and wavelengths of 10 ? 30 metres (33 ? 98 ft) . Coarse gravel is found at their top and more fine silt in their lower parts . Pumice blocks are found in the lee surfaces of the ripples , with the interripple areas relatively flat . Unlike dunes these structures do not migrate once stably formed . The material these structures is formed from includes lithic clasts with densities 2 @,@ 600 ? 3 @,@ 000 kilograms per cubic metre (4 @,@ 400 ? 5 @,@ 100 lb / cu yd) and pumices with densities 800 ? 1 @,@ 300 kilograms per cubic metre (1 @,@ 300 ? 2 @,@ 200 lb / cu yd) . The formation of the ripples is associated with bedrock ridges . These ripple marks have been compared to Martian ripple fields .

The largest field is named Campo Piedra Pómez (centered 26 ° 36 ? 17 @.@ 30 ? S 67 ° 34 ? 50 @.@ 46 ? W) and covers a surface area of 600 square kilometres (230 sq mi) , descending from 3 @,@ 800 metres (12 @,@ 500 ft) at La Hoyada in the south to 3 @,@ 000 metres (9 @,@ 800 ft) Carachipampa volcano in the north . The megaripples in this field are dark , formed from older ignimbrites and lavas of the 70 @,@ 000 @-@ year @-@ old Piedra Pómez ignimbrite . Northwest of Cerro Blanco caldera and towards Laguna Purulla lies another field (centered 26 ° 39 ? 49 @.@

97 ? S 67 ° 48 ? 55 @.@ 83 ? W) with a surface area of 127 square kilometres (49 sq mi) , It has a dark colour from andesitic lava and falls down from 4 @,@ 100 metres (13 @,@ 500 ft) altitude at La Hoyada to 3 @,@ 700 metres (12 @,@ 100 ft) at Laguna Purulla . Reddish @-@ brown Rosada ignimbrites and white basement material are also components of this field . Other fields are the 12 square kilometres (4 @.@ 6 sq mi) Campo Purulla (centered 26 ° 37 ? 12 @.@ 27 ? S 67 ° 46 ? 00 @.@ 66 ? W) field downslope of Cerro Purulla with a distinct albedo from the 13 @,@ 000 years old Purulla ignimbrite , and the 54 square kilometres (21 sq mi) Salar de Incahuasi (centered 26 ° 31 ? 53 @.@ 61 ? S 67 ° 41 ? 36 @.@ 93 ? W) field from the Piedra Pómez ignimbrite of a brown colour .

= = Climate = =

The Puna climate in the area is a high desert climate with high insolation and long @-@ term aridity . The desert environment of the Puna results in low levels of erosion . Plant growth is minor . Wind speeds of 33 kilometres per hour (21 mph) are regularly found and may play a role in the formation of megaripples . While there are no meteorological data for the Piedra Pómez area , a similar climate is found in Salar del Rincón where in 2014 temperatures ? 19 @.@ 6 ? 22 @.@ 9 ° C (? 3 @.@ 3 ? 73 @.@ 2 ° F) were recorded . Recorded precipitation amounted to 7 @.@ 1 millimetres (0 @.@ 28 in) with evaporation rates of 764 @.@ 5 millimetres (30 @.@ 10 in) .

A weather station (26 ° 28 ? 58 @.@ 6 ? S 67 ° 41 ? 1 @.@ 3 ? W) was run from March to November 2013 in the Salar de Incahuasi , at 3 @,@ 300 metres (10 @,@ 800 ft) altitude . Winds recorded there are mostly northwestern and southwestern and have gusts of > 59 kilometres per hour (37 mph) every month . Stronger average winds are found during spring .

= = Eruptive history = =

Human research in the San Buenaventura area goes back to Stelzner 1885 , mineral @-@ focused research in 1895 and Penck 1920 . The La Hoyada Formation was identified 1963 and reinterpreted as the La Hoyada volcanic complex in 2000 . General geological research in the region occurred 1988 , 2000 and 2006 , and research focused on Cerro Blanco was done by Arnosio et al . 2005 and 2008 .

Activity of Cerro Blanco goes back 8 mya , when the Maricunga Belt in the west was active . The volcano is responsible for a large Holocene eruption with a Volcano explosivity index 7 , the largest in the Andean Central Volcanic Zone for 5000 years . It is comparable to Santorini and Tambora 's large eruptions .

= = = Pre @-@ Holocene = = =

The Aguada Alumbrera Ignimbrite is a white @-@ rosa ignimbrite composed from two units , 7 @.@ 14 mya Unidad Blanquecina and 13 @.@ 57 mya Unidad Rojiza . The Blanquecina unit is of white to white @-@ rosa colour and contains amphibole , biotite and quartz crystals . It contains lithic fragments of dacitic composition . The groundmass of the ignimbrite is grey in colour and contains glass and phenocrysts . Next to Laguna Aguada Alumbrera it is 100 metres (330 ft) thick . The ignimbrite is unconformably overlaid by ignimbrites from La Hoyada volcano and overlies the basement . There are fluvial deposits contained within the Blanquecina ignimbrite , suggesting that sedimentation occurred between the eruptions . The other subunit Rojiza is of white colour and is rich in biotite and quartz . It is mostly buried by other deposits ; south of Aguada Alumbrera the principal deposit is 40 metres (130 ft) thick . This ignimbrite crops out south of Cerro Blanco .

The Rosada Ignimbrite is located next to Cueros de Purulla and has a rosa colour , due to fiamme formed from welded pumice . The pumice contains biotite , hornblende and quartz . It also contains lithic fragments from the basement and from vulcanites . Two dates of 6 @.@ 3 and 7 @.@ 3 mya have been obtained ; the younger age is likely the result from argon loss and less accurate . It and the Aguada Alumbrera ignimbrites are coeval but different compositions indicate that they derive

from separate eruptions . The Rosada ignimbrite 's main minerals are biotite , quartz , plagioclase and sanidine . It has a volume of 50 cubic kilometres (12 cu mi) .

A lava dome (26 ° 40 @.@ 26 ? S 67 ° 45 @.@ 90 ? W) formed 7 @.@ 3 ± 0 @.@ 5 mya and red ignimbrite 8 @.@ 1 ± 0 @.@ 5 mya . 2 @.@ 3 ? 1 @.@ 3 mya an east @-@ northeast chain of andesitic lava domes was formed , with the youngest dome (26 ° 40 @.@ 63 ? S 67 ° 45 @.@ 1 ? W) being 1 @.@ 3 ± 0 @.@ 4 mya old and located next to Cerro Blanco . 0 @.@ 8 mya mafic andesite was erupted south and west of Carachipampa (26 ° 28 @.@ 251 ? S 67 ° 24 @.@ 94 ? W) and Laguna de Purulla (26 ° 39 @.@ 3 ? S 67 ° 52 ? W) . The Cueros de Purulla obsidian lava dome (26 ° 34 @.@ 06 ? S 67 ° 44 @.@ 97 ? W) formed 0 @.@ 4 ± 0 @.@ 1 mya .

The Barranca Blanca and Carachi Ignimbrites are covered by lavas from Volcán Carachipampa and are thus older than 0 @.@ 75 mya . They contain pumices of various colours and lithic fragments , including mylonite and schist . The Barranca Blanca ignimbrite is white in colour and contains rhyodacitic white pumice with subordinate amounts of grey trachyandesitic pumice . The Carachi Ignimbrite overlies the Barranca Blanca ignimbrite . It is weakly welded and contains white pumice and crystals with fiamme . Both of these are pyroclastic density currents that were still hot at the time of deposition .

The Campo de la Piedra Pómez ignimbrites (26 @.@ 65 ° S 67 @.@ 71 ° W ? / -26.65 ; -67.71) have a surface area of 261 @.@ 83 square kilometres (101 @.@ 09 sq mi) . They have a volume of 17 cubic kilometres (4 @.@ 1 cu mi) and are separated in two layers which form one cooling unit despite their different colour and mineral composition . They both contain pumice and lithic fragments and are poor in crystals . Both have a pyroclastic texture with pumices bearing a porphyritic texture . Dating techniques yield different ages ; the most reliable one (argon ? argon dating on sanidine) indicates that these ignimbrites were erupted 73 @,@ 000 ± 23 @,@ 200 years ago . Other proposed dates go as far back as 0 @.@ 555 ± 0 @.@ 11 mya . They do not cross topographic surfaces and were generated by tranquil release from the ground rather than through the collapse of an eruption column . The surface has been exposed to wind erosion , forming yardangs and ripple marks . The source of this eruption is unknown ; the Robledo caldera may be the origin of this eruption but this is controversial . The ignimbrites of Piedra Pómez are covered with a desert varnish similar coating , some bearing signs of endolithic lifeforms .

= = = Holocene = = =

2 @,@ 300 ± 160 BCE a large Plinian eruption occurred at Cerro Blanco . Rhyolites with a volume of 110 cubic kilometres (26 cu mi) generated ashfalls and ignimbrites , forming the largest known eruption in the Central Andes during the Holocene . These Purulla / El Médano ignimbrites (26 @.@ 85 ° S 67 @.@ 72 ° W ? / -26.85 ; -67.72) cover an area of 51 @.@ 61 square kilometres (19 @.@ 93 sq mi) and are dated to have occurred less than 12 @,@ 200 years ago on the basis of radiocarbon analysis of organic material contained between various ignimbrite layers . One layer in La Hoyada is dated between 8 @,@ 830 and 5 @,@ 480 BP . Other data attribute the Purulla ignimbrites to 22 @,@ 000 years ago . The date of the major Holocene eruption is constrained to between 5 @,@ 500 and 4 @,@ 000 years ago . Based on stratigraphic relationships , the Cerro Blanco caldera formed during this eruption . The location of the vent did not change during the course of the eruption , indicating that the annular fractures around the caldera were possibly uninvolved in the process . The low population density in the Fiambalá valley south of the volcano during the 10 @,@ 000 ? 3 @,@ 000 B.P interval is ascribed to this eruption .

The ignimbrites from the caldera @-@ forming eruption have a volume of 17 cubic kilometres (4 @.@ 1 cu mi) and cover a surface area of 527 square kilometres (203 sq mi) south , north and east of the caldera . They are partly welded and contain fiamme and lithic fragments . The material is vitreous and may have been fluid at the time of deposition . Breccia derived from column collapse are also found . The deposits are microcristalline with much glass . A few kilometres from the calderas they abruptly turn into medium @-@ sized pumice deposits . Some ignimbrites from this stage are derived from the lava domes placed within small depressions , the largest of which is 1 @.@ 3 kilometres (0 @.@ 81 mi) wide . Aeolian erosion has reworked the ashes generated by the

eruption , generating dunes .

The Purulla / El Médano ignimbrites have a precaldera lower layer that various methods have dated 20 @,@ 000 to 5 @,@ 000 years ago . This stage was effusive and accompanied by the emplacement of lava domes . A postcaldera stage is represented by lava domes on the southeast edge of the caldera , as well as block and ash flows inside the caldera . These are rhyolitic in composition . Their age is unknown , but postdates the caldera formation .

= = = Recent unrest and threats = = =

There are no reports of historical activity . A small geothermal field is associated with the volcanic complex , consisting of fumaroles , mud volcanoes and thermal anomalies .

The caldera floor has been subsiding in the 1990s according to satellite images . The diametre of the deformation region is less than 30 kilometres (19 mi) and the deformation occurs at depths of less than 4 @.@ 8 kilometres (3 @.@ 0 mi) . The deflation speed has been decreasing from more than 2 @.@ 5 centimetres per year (0 @.@ 98 in / year) between 1992 and 1997 over 1 @.@ 8 centimetres per year (0 @.@ 71 in / year) between 1996 and 2000 and 1 @.@ 2 centimetres per year (0 @.@ 47 in / year) between 2003 and 2007 to 0 @.@ 87 centimetres per year (0 @.@ 34 in / year) between 2005 and 2010 . This deformation is centered between the Robledo and Cerro Blanco calderas and is accompanied by an uplift to the northwest . The deflation has been interpreted to depend on a magma chamber with a diametre of 17 kilometres (11 mi) but is unlikely to be caused by magma withdrawal or tectonic expansion . It may be linked to hydrothermal effects however . A seismic swarm was noted at 15 kilometres (9 @.@ 3 mi) depth in 2007 and 2009 .

Evidence indicates that such calderas can fill in within a timespan of hundreds to thousands of years . Two possible scenarios of an eruption are the formation of Plinian eruption columns or more tranquil subhorizontal eruption of pyroclastic flows from vents . Given the low population density of 0 @.@ 06 people per 1 square kilometre (0 @.@ 39 sq mi) , the impact of the eruption on local population will be small . Westerly winds may cause larger impact west of the centre , with air travel particularly affected . The community of Bolsón de Fiambalá 50 kilometres (31 mi) south of the caldera is beneath the level of Cerro Blanco and connected to it by valleys . In a future eruption , pyroclastic currents and less dense clouds associated with them from Cerro Blanco might reach the community .