= Irruputuncu =

Irruputuncu is a volcano in the commune of Pica , Tamarugal Province , Tarapacá Region , Chile , as well as San Pedro de Quemes Municipality , Nor Lípez Province , Potosí Department , Bolivia . The mountain 's summit is 5 @,@ 163 m (16 @,@ 939 ft) high and has two summit craters ? the southernmost 200 m (660 ft) -wide one has active fumaroles . The volcano also features lava flows , block @-@ and @-@ ash flows and several lava domes . The volcano is part of the Andean Central Volcanic Zone (CVZ) .

The volcano has been active during the Pleistocene and Holocene , with major eruptions occurring 258 @.@ 2 ± 48 @.@ 8 ka ago , between 55 @.@ 9 ka and 140 ka ago and 1570 ± 900 BP (380 ± 900 AD) , which were accompanied by the formation of ignimbrites . Historical volcanic activity is less clear ; an eruption in 1989 is considered unconfirmed . Plumes linked to phreatomagmatic eruptive activity were observed on 26 November 1995 and 1 September 2003 . Seismic activity is also observed on Irruputuncu , and ongoing fumarolic activity releasing 21 ? 50 t / d (0 @.@ 24 ? 0 @.@ 57 long ton / ks) of sulfur dioxide has left sulfur deposits in the active crater .

The Central Volcanic Zone is thinly inhabited and most volcanoes are not under reconnaissance , but Irruputuncu is watched by the Chilean SERNAGEOMIN geologic service . The possibility of geothermal energy production from the volcano has been examined .

= = Etymology and alternative names = =

The name Irruputuncu derives from Aymara iru spiny Peruvian feather grass and phutunqu a small vessel or a hole , pit , crater . Alternative names are Irruputunco and Iruputuncu .

= = Geography and geology = =

= = = Regional setting = = =

The subduction of the Nazca plate and the Antarctic plate beneath the western side of South America has generated a belt of volcanic activity named the Andean Volcanic Belt . The belt is separated in a number of volcanic zones by segments lacking recent volcanic activity ; in these segments , shallow subduction of the plates presumably displaces the asthenosphere away from these segments . The segments with active volcanism are the Northern Volcanic Zone (NVZ) , the Central Volcanic Zone (CVZ) , the Southern Volcanic Zone (SVZ) and the Austral Volcanic Zone (AVZ) . The " Volcanoes of the World " catalogue counts about 575 eruptions in the entire volcanic belt .

Volcanic activity in the belt is usually linked to the dehydration of the subducting slabs , which causes water and other subducted components to be added to the overlying mantle . In the case of the CVZ , this addition generates magmas that are further modified by the thick crust in the area , forming andesites , dacites and rhyolites .

= = = Local setting = = =

Volcanism in the CVZ is linked to the subduction of the Nazca plate beneath the South America plate . This subduction within the past c . 27 @.@ 5 mya has triggered a thickening of the crust and orogeny . Approximately 44 volcanic centres that are either active or potentially active are found in the CVZ . Some centres are fumarolically active ; these include Alitar , Lastarria and Tacora . Irruputuncu and other volcanoes including Guallatiri , Isluga , Lascar and San Pedro have displayed phreatic or magmatic @-@ phreatic activity . The arid climate of the area has led to good preservation of volcanic structures .

A small gap about 100 km (62 mi) wide , which is known as the " Pica gap " but includes the Pliocene @-@ Pleistocene Alto Toroni volcano that features vigorous seismic activity , separates

Irruputuncu from Isluga in the north . Irruputuncu is part of an elliptical alignment of volcanoes that extends to the east , which may be linked to a cup @-@ shaped intrusion in the crust . Older Pliocene volcanoes around Irruputuncu are Laguna volcano to the northeast and Bofedal to the southeast . Irruputuncu lies at the end of a chain of volcanoes that trends northeastward away from it .

The volcanic complex sits on top of ignimbrite layers , the Miocene Ujina and Pleistocene Pastillos Ignimbrites . These ignimbrites are c.150 m (490 ft) and 20 ? 90 m (66 ? 295 ft) thick , the former is a welded ignimbrite that was erupted 9 @.@ 3 ± 0 @.@ 4 mya and the latter in two stages 0 @.@ 79 ± 0 @.@ 2 - 0 @.@ 73 ± 0 @.@ 16 mya and 0 @.@ 32 ± 0 @.@ 25 mya . In terms of composition , the Ujina is pink @-@ grey crystals and pumice and the Pastillos a gray @-@ white pumice forming the lower member and the upper member of the Pastillos contains cinerites with accessory claystones , siltstones and diatomites . Further volcanic rocks beneath Irruputuncu are hydrothermally altered dacites that may be part of an older now deeply eroded edifice .

Irruputuncu is a relatively small , 5 @,@ 163 m (16 @,@ 939 ft) high volcano , which covers a surface area of 23 @.@ 861 km2 (9 @.@ 213 sq mi) with a volume of 4 km3 (0 @.@ 96 cu mi) and has two summit craters , of which the 200 m (660 ft) -wide southwestern one is fumarolically active . Crater II , the youngest crater , is surrounded by the Crater lava flows that form lava domes and seven short lava flows 0 @.@ 54 ? 0 @.@ 94 km (0 @.@ 34 ? 0 @.@ 58 mi) long , 68 ? 107 m (223 ? 351 ft) thick and with a total volume of 0 @.@ 042 km3 (0 @.@ 010 cu mi) emitted from it . They have weakly developed ogives and there is no evidence of glacial activity anywhere on the volcano . The current edifice is constructed within a collapsed amphitheater of an older edifice . Overall , the volcano has a pristine morphology . Block @-@ and @-@ ash flows and thick lava flows of high viscosity form the stratocone . A rhyolitic ignimbrite is found southwest of the volcano . The oldest lava flows on the northern and eastern side of the volcano were erupted from a northeastern crater named Crater I and are 35 ? 113 m (115 ? 371 ft) thick with erosional features and preserved ogives . They have a volume of around 0 @.@ 097 km3 (0 @.@ 023 cu mi) .

The younger flows are known as Queñoas lava flows ; they form six distinct flows on the western sides of the volcano . They have different appearances depending on the side ; the northwestern flows form lateral lava levees and ogives and reach thicknesses of 117 ? 180 metres (384 ? 591 ft) while the other flows have lobate structures with thicknesses of 23 ? 95 m (75 ? 312 ft) . These thicknesses may be the result of high @-@ viscosity magma and / or low eruption rates . A major block @-@ and @-@ ash deposit with the volume of 0 @.@ 023 km3 (0 @.@ 0055 cu mi) covers a surface area of 11 @.@ 333 km2 (4 @.@ 376 sq mi) ; it was highly mobile considering the distances it reached from the volcano on all three sides of the younger crater . It contains large blocks and has long flow ridges . A second block @-@ and ash flow formed by the collapse of lava domes covers 0 @.@ 801 km2 (0 @.@ 309 sq mi) . Its blocks are somewhat smaller and its ridges are poorly developed . Fissure eruptions have generated large lava flows from the flanks . The El Pozo ignimbrite covers a surface area of 0 @.@ 02 km2 (0 @.@ 0077 sq mi) northwest of the volcano with a thickness of 50 m (160 ft) , an approximate volume of 0 @.@ 001 km3 (0 @.@ 00024 cu mi) and is probably linked to Irruputuncu , in which case it would be the volcano 's oldest unit .

Irruputuncu underwent a flank collapse that subdivides the volcano into two edifices , the older Irruputuncu I and the younger Irruputuncu II , about 140 ± 40 ka ago . This flank collapse extends 6 @.@ 3 km (3 @.@ 9 mi) southwest from the older crater I and is about 10 m (33 ft) thick . It was formed by the collapse of the southwestern flank and forms three distinct units formed by hummock @-@ forming lava blocks and flow ridges up to 1 km (0 @.@ 62 mi) long . Each stage is associated with an individual crater named Crater I and Crater II . The flank collapse was probably produced by oversteepening of the volcano or by asymmetric growth . Subsequent activity of the volcano has completely filled the scarp . The lack of ground deformation during eruptive activity suggests the magma chamber of Irruputuncu may be more than 7 ? 15 km (4 @.@ 3 ? 9 @.@ 3 mi) deep , which may be linked to the thickness of the crust beneath the Central Andes , ranging 50 ? 70 km (31 ? 43 mi) .

Irruputuncu displays vigorous fumarolic activity that occupies about half the summit crater and is

visible within several 10 km (6 @.@ 2 mi) . The 200 m (660 ft) high fumaroles have temperatures of 83 ? 240 ° C (181 ? 464 ° F) and are composed mainly by sulfur dioxide , followed by minor amounts of hydrogen sulfide , hydrogen chloride , hydrogen fluoride , methane , nitrogen and oxygen . In addition , argon , carbon monoxide , helium , hydrogen and sulfur are found . The temperatures of the fumaroles are comparable with or exceed the boiling point at such altitudes . ASTER imagery indicates Irruputuncu 's fumarole field has a small surface area with high temperatures . Total sulfur dioxide flux from the volcano is between 21 ? 50 t / d (0 @.@ 24 ? 0 @.@ 57 long ton / ks) . The fumarolic activity has left sulfur deposits on the volcano . Sulfur deposits are found in the youngest crater in an area of about 0 @.@ 011 km2 (0 @.@ 0042 sq mi) , and also form small sulfur flows with pahoehoe @-@ type morphology . Deposits are generally yellow but close to the fumaroles they display different colours depending on their temperatures . Gravel and eolian deposits form sedimentary units around the volcano .

= = = Composition = = =

Irruputuncu 's rocks consist of andesite- and dacite @-@ containing hornblende and pyroxene . The El Pozo ignimbrite is pumice @-@ rich and has a composition between trachyandesite and trachydacite . Minerals amphibole , biotite , hornblende , quartz and plagioclase comprise the rocks . The Irruputuncu I lava flows are composed of trachyandesitic with biotite and plagioclase , while the Queñoas are composed of andesite and trachyandesite . The block @-@ and @-@ ash flows and Crater lavas consist of solely trachyandesitic . Overall , these rocks belong to the potassium @-@ rich calc @-@ alkaline series typical of CVZ volcanoes . The magmas are formed by plagioclase and clinopyroxene crystallization with some mixing . Irruputuncu 's rocks show minor evidence of crustal contamination , similar to other CVZ volcanoes located within transition zones .

Water is the most important component in the volcano 's fumarolic gases , comprising 96 @.@ 05 % to 97 @.@ 95 % by volume . Examinations of deuterium and oxygen @-@ 18 content of the water have determined that like the water of fumaroles in other Andean volcanic centres , Irruputuncu water is a mixture of weather @-@ related water and water contained in andesite . The helium isotope ratios indicate the magmatic component dominates the gasses at Irruputuncu , Much of the carbon dioxide comes from subducted and crustal carbonates . The gases escape from oxidizing magma at 491 ? 781 ° C (916 ? 1 @,@ 438 ° F) and pass through a weakly developed hydrothermal system with temperatures of c . 340 ° C (644 ° F) . Argon isotope ratios appear to be radiogenic .

= = Eruptive history = =

The oldest rocks at Irruputuncu are lavas that have been dated by potassium @-@ argon dating to 10 @.@ 8 ± 0 @.@ 6 mya . The oldest component clearly belonging to the volcano is the El Pozo ignimbrite that was erupted 258 @.@ 2 ± 48 @.@ 8 ka , forming a multi @-@ layered ignimbrite that was probably generated by the injection of new , hot magma into older , cooler magma . A lava dome on the upper flank on the western side of the volcano is 0 @.@ 14 ± 0 @.@ 04 mya old . The block @-@ and @-@ ash flow between 55 @.@ 9 ka and 140 ka old , but has not been pecisely dated . The Crater lavas are 55 @.@ 9 ± 26 @.@ 8 ka old . The block @-@ and @-@ ash flow on the southwestern flank was formed 1570 ± 900 years BP .

Historical activity of Irruputuncu is unclear . An unconfirmed eruption was reported in Bolivia in December 1989 and fumarolic activity in the crater was reported on 25 March 1990 . Eruption plumes on Irruputuncu , which reached an altitude of 1 @,@ 000 m (3 @,@ 300 ft) and dispersed to the east , probably triggered by phreatomagmatic activity , were seen on 26 November 1995 . The plume 's colour changed between black and white repeatedly . Another plume was observed on 1 September 2003 ; neither of these incidents were accompnied with noticeable ground deformation . Like some other volcanoes in the area , activity at Irruputuncu has not been preceded by ground inflation during historical times . Several theories , including aliasing of the imagery , have been proposed to explain the lack of ground inflation .

Ongoing seismic activity at a rate of about 5 ? 6 earthquakes per 10 days recorded in two separate phases , November 2005 @-@ March 2006 and April 2010 @-@ February 2011 respectively and including one seismic swarm during the first measurement period , has been recorded at Irruputuncu . Some of this activity may be caused by mine blasts from nearby mining projects . Geothermal anomalies of about 9 K (? 264 @.@ 15 ° C ; ? 443 @.@ 47 ° F) have been noted , including hot springs west and northwest of the volcano .

= = Threats and geothermal prospecting = =

With the exception of Peruvian volcanoes such as Misti , most of the volcanoes of the CVZ are in remote areas and are not closely watched . Irruputuncu is a remote volcano ; a road between Iquique and the Collahuasi mine is the main infrastructure that could be affected by future activity . In Chile , Irruputuncu is surveilled by SERNAGEOMIN , which produces regular status reports .

Irruputuncu has been examined as a potential location for a geothermal energy project involving a company named Minera Doña Inés de Collahuasi . A geothermal prospect made at the base of Irruputuncu indicated the presence of water at temperatures of up to 220 ° C (428 ° F) in a deep reservoir .