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THE VOLCANOES OF SOUTHERN CHILE.

WITH PLATES XIV-XIX AND MAPS XX-XXI.

Introduction and acknowledgments.

In the summer of 1929 the writer, then in Peru, was appointed a Research fellow of the Hawaiian Volcano Research Association for the purpose of reconnoitering the volcanoes of southern Chile The especial object of the undertaking was to determine which if any of the Chilean volcanoes is the most suitable location for a volcanological observatory and what local conditions or interests may favor the establishment of an observatory. The writer landed at Valparaiso an November 6, 1929 and sailed from there at the end of his work on February 12, 1930.

Everywhere in Chile the writer met with a courteous and helpful reception. Dr. Juan Brueggen, Professor of Geology, and Dr. Carlos Bobillier, Chief of the Seismological Service, both of the School of Engineering in Santiago, aided in planing the writer's trip to the south of Chile Mr. Fernando Orrego, Director of the Tourist Section of the Ministry of Commerce (Ministerio de Fomento), to whom the writer was introduced by the Embassy of the United States, gave him a letter adressed to the Prefects of the several provinces recommending the writer to their assistance. In the provinces of Nuble, Bio-bio, and Cautin, where this letter was presented, the response of these officers of the Cuerpo de Carabineros, the military police of Chile, was so ready and ungrudging as to arouse a strong liking and admiration for the efficient body that they represent. Further acknowledgements for hospitality are due to Mr. Ernesto Behnke Vergara of Cherquenco and Dr. Federico Reichert of the University of Buenos Aires, Argentina and of Cayutue, Chile. Professor E. Porter of Santiago allowed the writer to publish a note explaining his mission in the "Revista Chilena de Historia Natural".

Area considered in this report.

The area considered in this report is a narrow strip along the west flank of the Andes extending from about the city of Talca (lat 35° 25' S) to the Fjord of Reloncavi (lat 41° 40' S) near Puerto Montt. (See pl. XX.) Within this area there are 9 volcanoes known or reported to have been active on the last century and many others only recently extinguished. Active volcanoes are not confined however to the part of Chile discussed here. In nothernmost Chile the volcano Ollagua on the Bolivian border was active in 1927, and recent earthquakes (1930) in the province of Arica have been attri-

buted to the volcano Tacora. There are accounts of activity of several other volcanoes in northern Chile, and active volcanoes are known in the Cordillera east of Santiago. A few other volcanoes lie far to the south in the region of the canals or fjords. On page 85—86 of this paper, all known volcanoes between Lat. 30 S. and Lat. 45 S. have been listed.

Altho the south-central part of Chile is nowhere more than 140 miles wide, it is further divided topographically into three still narrower strips: the coast range, the longitudinal valley, and the western slope of the Andes[1].

General features of the volçanoes.

The volcanoes of southern Chile belong to a type that combines explosive eruptions with lava flows, altho explosive activity predominates. In size they cannot compare with such giants as Mauna Loa and Mauna Kea in Hawaii, but Osorno rising 8560 feet above Lake Llanquihue is a mountain of notable size as are also Llaima and Villarica. Their shape due to a predominance of explosive eruptions from a central vent tends to be steeply conical with concave slopes Villarica, Osorno and Antuco, especially when viewed from certain directions, are beautifully symmetrical. (See pl. XIV fig. 11.)

The Chilean volcanoes seem to be approaching extinction. Many are long dead and already partly destroyed by erosion, others show only by their undissected form and the emission of steam that they are still potentially active, and only a few have been active in the last century. For one of these volcanoes to have been active more than once or twice in twenty years is most unusual and in the area under consideration only the cone "Quizapu" and the volcano Llaima have been so active in the last century. On the other hand, the geological record, which is especially well exposed at Antuco and Calbuco, shows that during an earlier epoch eruptions of much greater violence took place. The extent and thickness of the older volcanic deposits point not only to much greater eruptions but also more frequent ones.

The modern eruptions for which there are any data, have been short and quite mild. They have at times been accompanied by earthquakes but only feeble and very local ones, altho an apparent connection has several times been noticed between the outbreak of a volcano and one of the destructive earthquakes which occur so frequently a little farther north. The most dangerous feature of the eruptions is the possibility of sudden floods caused by the melting of the cover of ice and snow which caps most of the volcanoes. Little damage to human beings has been done by ash falls, and none so far as known by lava flows.

[1] For a general description of Chile, see Martin, Carl, Landeskunde von Chile, Hamburg, L. Friederichsen & Co., 1923.

Lava flows have not been common during modern eruptions. One was reported at Llaima in 1927 and a small one at Calbuco in 1917. Lava has commonly been present in the craters during eruptions, however, as is shown by the mention of glow and "columns of fire" in the accounts of the eruptions. Bombs and fragments of bombs are found abundantly on the slopes of Llaima and Osorno, and basaltic scoriae were produced at Llaima in 1927 and at Puyehue in 1922. No unquestionable bombs were found among the ejecta of the eruption of Calbuco of 1929 and samples of the ash have not yet been examined microscopically. The craters of Antuco, Villarica, Osorno, and Calbuco are partly surrounded by rims of spattered slaggy lava. The eruptions appear to be of magmatic origin and not of the phreatic type of the Kilauean eruption of 1924.

The volcanic rocks of the southern Chilean volcanoes were all classified in the field as olivine-poor basalts. Quartz was not found in a single specimen, including not only those collected but also many more examined in the field. Biotite was also completely absent, as was hornblende with the doubtful exception of one fragment from the older tuffs of Antuco. Feldspar phenocrysts were found in all specimens except in a few almost wholly glassy lavas, and olivine was found with the hand-lens in nearly all. Some of the lavas may contain hypersthene. The textures of the rocks range from glassy to almost wholly crystalline. The presence of a remarkable proportion of large plagioclase phenocrysts in some flows is notable. More extended and detailed remarks on these Chilean lavas will be made after microscopic study.

The lavas occur as flows, as fragmental products derived from older flows, and to a smaller extent as scoriae and bombs. By far the prevailing type of flow is typical aa. Not a single typical pahoehoe flow was seen, altho a very rough type of pahoehoe was noted in one flow on the north slope of Villarica. Some old flows of Osorno and Calbuco now appear as columnar lavas and many originally have had pahoehoe tops. Consideration of the southern Chilean volcanoes as a group and also of the local geology of individual volcanoes shows that activity has declined greatly from a maximum, probably in the Tertiary, and that the present-day activity is but the dying flicker of this epoch of volcanism in the Chilean Andes. Further points of interest in this connection are the predominance of explosive eruptions at these basaltic volcanoes, the unusual crystallinity of many of the flows (shown as a crowding of large plagioclase phenocrysts), and the almost universal development of aa lava.

Whether or not the character of the eruptions has changed since the period of greatest activity could not be determined by the reconnaissance studies made by the writer. Lava flows are interbedded with the oldest tuffs, buth they are also found on the surface of most of the modern cones, altho few have been erupted in historic times. Likewise ejected blocks and ashes are found in the deposits of all ages. If any change can

be recognized from these reconnaissance studies, it is in the direction of greater explosiveness. The infrequent and rather insignificant recent eruptions suggest that volcanoes of southern Chile are connected only with small magma reservoirs. In these small residual reservoirs the magma has been cooling for a long period and may be expected to be in a partially cristalline state. This crytallinity is shown by the large proportion of intra-telluric crystals appearing as phenocrysts in many of the recent flows. Advancing crystallinity may have so increased the viscosity of the magmas and the resulting lavas that the eruptions are increasingly explosive. The explosive nature of volcanoes having stiff siliceous lavas is often remarked, but it seems possible that thru advancing crystallization basaltic lavas may reach a similar stage of viscosity and so favor explosive eruptions.

When poured out on the surface, the partly-crystalline magmas produce aa flows. It has been shown that if crystallization be promoted, lavas tend to take the aa structure.[1]

In the case of the Chilean volcanoes cristallization has been able to proceed under conditions of long cooling in a magma reservoir. In the case of the long flows of Mauna Loa which issued as pahoehoe, cristallization proceeded on the surface so that at a distance from its source the lava turned to aa. The hypothesis of intra-telluric crystallization is not a universal explanation of aa structure; it is only one of the methods by which crystallinity may become so advanced that a lava on eruption will take the aa form.

Possibilities for an observatory.

The two volcanoes of southern Chile most suitable as sites for a volcanological observatory are Llaima und Calbuco.

Llaima has been more frequently active than Calbuco, and its eruptions as shown by geological evidence as well as by the scanty history of its recent activity are commonly accompanied by lava fountains and flows, whereas Calbuco is almost purely an explosive volcano. The greater activity of Llaima which recommends it as an observatory station is, however, offset by the far greater accessibility of Calbuco.

Cherquenco, the nearest village to Llaima, is connected to Temuco by good train service over standard gauge tracks. Because of its height of 10000 feet Llaima is covered the year around by snow and ice, and during the long rainy winters the snow extends down the slopes well below timber line. Even in summer the ascent of the volcano requires ice-picks and ropes.

Calbuco volcano is near the little city of Puerto Varas, the center of a prosperous German farming district. Ensenada at the southeast corner of Lake Llanquihue is con-

[1] Emerson, O. H.: The formation of aa and pahoehoe. — Am. Journ. Sci. 1926, 12, 109—114.

nected to Puerto Varas by regular service of small steamers, and is also joined to Osorno by a fairly good auto road.

Calbuco is only 6600 feet high so that it is almost bare of snow in the summer at that time the ascent is easily made from Ensenada. During the winter, snow covers most of the mountain but does not often stay on the ground at the elevation of Puerto Varas and Ensenada. An observatory near the lake would be able to keep fairly close watch of the volcano, except for the frequent clouds, and by some work on the trails could make the trip to the summit easy in summer and probably possible in winter.

Calbuco is rarely in eruption and perceptible earthquakes are uncommon in the strict. There are hot springs low down on the mountain that might give valuable information, and the immediate district contains many volcanic features including Osorno a quiescent volcano, and Puntiagudo, a dead and partly dissected one. With an observatory at Calbuco as a base it would be easy to establish local seismograph stations at Villarica and Llaima, and possibly farther north also.

The cost of construction of a well-made wooden building with concrete fundations of the size of the Kilauea observatory at Ensenada would be between $ 2000 and $ 2500.

The moral and scientific support of about a dozen local scientists can be counted on, and they with a few merchants and hotel keepers migth form the nucleus of a society like the Hawaiin Volcano Research Association.

The Volcanoes.

List of the volcanoes between the latitudes of 30—45° South

The following list gives all volcanoes between the latitudes of 30 and 45° south, which are named as such on the map of Chile (scale 1 : 500000) issued by the Ministerio Fomento, Departemento de Tierras y Colonizacion in 1928. The positions and heights of the volcanoes are taken from the same source. The brief dates on the activity of the volcanoes are derived mostly from Martin.[1]

Tupungatito[2]	5640 m,	lat. 33° 24' S.,	long. 69° 49' W
San José[2]	5830 m,	lat. 33° 47' S.,	long. 69° 55' W
Maipo[4]	5290 m,	lat. 34° 10' S.,	long. 69° 50' W
Tinguiririca	4280(?)m,	lat. 34° 49' S.,	long. 70° 21' W
Volcancito[5]	3615 m,	lat. 34° 32' S.,	long. 69° 59' W

[1] Martin, Landeskunde von Chile, pp. 81–90, 1923.
[2] Probably active within the last century.
[3] Active in 1822 and 1895.
[5] Extinct.
[6] In the Argentine Republic May [illegible]

Overo[6]	4550 m,	lat. 34° 34' S.,	long. 70° 02' W.
Planchon	3970 m,	lat. 35° 14' S.,	long. 70° 36' W.
Peteroa[7]	4090 m,	lat. 35° 16' S.,	long. 70° 35' W.
Descabezado Chico[8]	3250 m,	lat. 35° 31' S.,	long. 70° 39' W.
Descabezado Grande[8]	3830 m,	lat. 35° 35' S.,	long. 70° 47' W,
Cerro Azul[8]	3810 m,	lat. 35° 39' S.,	long. 70° 46' W.
Las Yeguas or San Pedro	3500 m,	lat. 35° 39' S.,	long. 70° 52' W.
Chillan[8]	3000 m,	lat. 36° 50' S.,	long. 71° 30' W.
Antuco[9]	2990 m,	lat. 37° 25' S.,	long. 71° 20' W.
Copahue	3010 m,	lat. 37° 50' S.,	long. 71° 11' W.
Callaquen (or Callaqui)	3090 m,	lat. 37° 56' S.,	long. 71° 27' W.
Trolguaca	2780 m,	lat. 38° 18' S.,	long. 71° 39' W.
Lonquimai[8]	2890 m,	lat. 38° 23' S.,	long. 71° 35' W.
Llaima[8]	3060 m,	lat. 38° 42' S.,	long. 71° 44' W.
Villarica[8]	2840 m,	lat. 39° 25' S.,	long. 71° 56' W.
Quetrupillan[9]	2360 m,	lat. 39° 31' S.,	long. 71° 43' W.
Lanin[10]	3740 m,	lat. 39° 39' S.,	long. 71° 30' W.
Shoshuenco	2360 m,	lat. 39° 55' S.,	long. 72° 02' W.
El Mocho[11]	2430 m,	lat. 39° 56' S.,	long. 72° 01' W.
Puyehue[12]	2240 m,	lat. 40° 35' S.,	long. 72° 07' W. (about)
Puntiagudo[13]	2490 m,	lat. 40° 58' S.,	long. 72° 16' W.
Osorno[12]	2660 m,	lat. 41° 07' S.,	long. 72° 29' W.
Calbuco[12]	2015 m,	lat. 41° 20, S.,	long. 72° 39' W.
Yate[14]	2010 m,	lat. 41° 45' S.,	long. 72° 26' W.
Hornopieren	1670 m,	lat. 41° 53' S.,	long. 72° 32' W.
Huequen (or Huequi)[15]	1050 m,	lat. 42° 20' S.,	long. 72° 40' W. (about)
Minchinmavida[16]	2470 m,	lat. 42° 48' S.,	long. 72° 27' W. (about)
Yelcho	2020 m,	lat. 43° 09' S.,	long. 72° 33' W.
Corcovado	2300 m,	lat. 43° 10' S.,	long. 72° 48' W.
Yanteles[17]	2050 m.	lat. 43° 26' S.,	long. 72° 54' W.

[6] In the Argentine Republic.
[7] Active in 1762, 1835. 1837, 1878, 1889, 1890,
[8] Notes on activity in the text.
[9] Extinct.
[10] Long extinct and partly dissected.
[11] Shoshuenco and El Mocho are sometimes known together as the volcano" Rinihue". Reported active in 1907.
[12] Notes on activity in the text.
[13] Long extinct and deeply dissected.
[14] Not a volcano according to Prof. F. Reichert.
[15] Active in 1906.
[16] Active in 1834—35.
[17] Active in 1834—35.

Cerro Azul and "Quizapu".

History — According to Astaburuaga (Martin p. 85) Cerro-Azul commenced eruption on Nov. 1847. Later travellers have reported that this eruption marked the birth of a new volcano on the north slope of Cerro Azul. Later eruptions were reported in 1912, 1921, 1922, 1923, 1927, 1928 and 1932[2].

Descabezado Grande and Descabezado Chico.

Location — Northeast of Cerro Azul are two extinct volcanoes Descabecado Grande ("the big beheaded one") 12,500 feet high and Descabecado Chico, 10,650 feet high[1]. As their names imply they are squarely truncated cones. In the region around them are many hot-springs, and a little farther north stands the volcano Peteroa which was active in the 18th and 19th centuries.

Chillan.

Location — The volcano of Chillan is not shown on the map of the Departemento de Tierras y Colonizacion. It is in the province of Nuble, southeast of the provincial capital, Chillan. (Pl. XIV, Fig. 2).

History — Chillan is reported to have been smoking in 1750 and was in eruption from 1861 to 1865 commencing a few months after a destructive earthquake near Mendoza in the Argentine Republic and the simultaneous extinguishing of the volcano Antuco (Martin p. 85).

It became active again on Aug. 6, 1906 and remained active for about four months according to the mayordomo of the Thermas (Hot Springs) de Chillan, a man who has known the region for 50 years. During this eruption the volcano ejected ash and glowing stones, but there were no lava flows. A glow could be seen over the crater at night but no flames. A dull roar accompanied the eruptions. No earthquakes were felt at the hotel at the Termas at this time, and in general earthquakes there are rare, being only the feeble echoes of earthquakes felt more strongly in Chillan. On the 16 th of Aug., 1906 occurred the terrible earthquake which destroyed most of Valparaiso.

On Nov. 20, 1929 two small plumes of steam were seen issuing from the cone built in 1906 and called "El Volcan Nuevo". The volcano of Chillan can best be reached from the city of Chillan.

Local Geology — At the station of Esperanza the river is in a narrow valley between walls capped by lava flows. From Esperanza to Recinto outcrops of lava are seen along the track. The road from Recinto crosses over to the Rio del Renegado. This

[1] Serv. Sismol. Chile, Bol. 19, p. 21, 1927.

[2] See also Z. f. V. 1933, 15, 100 and 105 [illegible] 14, 300. D. Red.

stream occupies a wide glaciated valley floored by postglacial aa flows. Where the road swings in against the side of the valley near the Termas, outcrops of ligth-colored granitic rocks appear. Among the flows of the valley floor one consists of black glass with phenocrysts of feldspar.

The volcano of Chillan consists of two small cones about half a mile apart standing on a deeply dissected and glaciated platform of ancient (Tertiary?) lavas. There are said to be five or six old craters in the immediate vicinity. The volcan Nuevo is a low, broad, black cone. The crater within is said to be yellow and to show much sulphur. The volcan Viejo is a similar but less perfect cone farther to the southeast.

The hot springs issue from the older lavas in a little gully just above timber-line. The springs most used and nearest to the hotel give very hot waters, some heavily charged with iron and others smelling and tasting strongly of sulphur. Light-yellow coatings are deposited by the waters. Higher up in a branch of the gully are a group of small furiously boiling fumaroles issuing from yellowed lavas containing disseminated pyrite.

Antuco.

History — According to Martin (p. 86) Antuco erupted some time in the early 19th century.

The present inhabitants of the region know of no eruption of Antuco. The volcano was steaming slightly in Nov. 1929, and some bluish vapor was seen in the north part of the summit crater (Pl. XV, Fig. 3). There are hot spots around the rim of the crater, and Martin points out that the cone in spite of its height has little or no permanent snow.

Local Geology — The region around Antuco shows a long and complex history of volcanism. A basement of granitic and metamorphic rocks is seen between the village of Antuco and Trumbuleo. Above this basement comes the great pile of interbedded lava flows and pyroclastic rocks cut by a few dikes that forms the Sierra Velluda. This range is deeply eroded and glaciated so that it no longer presents the outward shape of a volcano (Pl. XVI). Much younger than these oldest volcanics but apparently older than the cone of Antuco is the great accumulation of ejecta in the valley of the Rio de la Laja. Explosive craters probably existed in the northwest slope of the Antuco mass, and a segment of an old rim can be seen northeast of the present cone.

The cone of Antuco is largely covered (as far as could be seen with much snow on the ground) by aa flows, many of which originated near the summit crater. The crater is now occupied by rough aa, which overflowed thru a break in the east rim. A horseshoeshaped cone low down on the west slope was the source ot the freshest flow seen. All of the flows and fragments examined are basalts, mostly containing olivine. A common type is a vesicular basalt with abundant placioclase phenocrysts and a few oli-

vine phenocrysts. The old flows of the Sierra Velluda were not seen close at hand except as they are represented by fragments in the later pyroclastics.

The Lago de la Laja, east of Antuco, is an interesting example of lake formed by a volcanic dam as has been pointed out by Brüggen.[1]

Pl. XVII, Fig. 7 shows the drowned valleys that were formed when Antuco volcano grew up in the old river valley.

Lonquimai.

History — According to Martin (p. 86) Lonquimai erupted in 1853 and later in June 1887 and December 1889.[2] The volcano is a fine truncated cone which from a distance shows little dissection by erosion. About seven miles northwest of Lonquimai is the volcano Trolguaca, a truncated cone like Lonquimai but more eroded. It has no record of activity. Both volcanoes are easily accessible from Curacautin.

Llaima.

History — According to Martin (p. 86) Llaima was active from 1862 to 1865, and emitted high smoke clouds in 1864. On may 12, 1903 another eruption occurred in which lava masses were poured out that could be seen from Temuco. This eruption lasted two days and changed the shape of the volcano. (This agrees with the statement made to the writer in Cherquenco that the southeast summit cone first appeared "about twenty years ago".) Llaima was also active 1912 and 1917.

In 1927 Llaima was active from Oct. 5 to 8 and again from Nov. 27 to Dec. 5th.[3] At the town Cherquenco 15 miles from the crater witnesses say there were no earthquakes, but the eruption was accompanied by a subterranean roar likened to the distant sea. The southeast crater was the more active altho the northwest cone smoked. The eruptions built up the southeast cone noticeably. At night fountains of fire and incandescent rocks were thrown into the air, and a "river of fire" ran down the south slope. The writer could find no sign of a recent lava flow under the snow on the southern foot of the summit cone, but there may have been a flow farther around to the east. Two or three inches of fresh black scoriae lay on the ice on the south slope. It may have come from the summit crater or from a fountain at the source of a flow.

During the eruption of 1927 ash and lapilli up to about 2 cm in diameter fell at the sawmill of Casimiro Escribano, three to five miles from the summit on the north side of the volcano. Earthquakes were felt at the sawmill. One was strong enough so that a cross-cut saw leaning against a house alarmed the foreman by clapping against the wall.

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[1] Brüggen, J.: Über den Ursprung der Chilenischen Seen. Deutsche Wiss. Ver. Santiago 1920, 6, 21-22. — See also Z. f. V. 1930, 13, 102. D. Red.

[2] See also Z. f. V. 1933, 15, 195. D. Red.

[3] Serv. Sismol. Chile, 1927, 19, p. 27, 29, 32.

In December 1929 Llaima was emitting dense wite smoke from both summit craters.[1] (See pl. XVII, fig. 8).

Local Geology — No plutonic or metamorphic rocks were seen near Llaima. Most of the upland around Cherquenco is covered by deep soil but in remarkable deep, straight-sided gorges cut by many of the streams, cross-bedded volcanic sands are exposed, and along the Rio Quepe below Cherquenco there are cliffs of columnar lavas. The double cone of the volcano stands on a wide platform composed largely of aa flows. One large cinder cone at the west edge of this platform consists of black or locally red basaltic scoriae and many broken bombs. A line of large old cones extends off to the northeast, and other cones were seen to the southeast. Where the surface of the volcanic platform is not covered by aa flows, it has a covering of ejected blocks, pieces of bombs, ash, and black scoriaceous pumice. The glaciers formerly extended lower down and have left polished flows on the northwest slope and moraines on the southwest to mark their position.

All lavas seen or collected on Llaima are basalts. Those with recognizable phenocrysts generally show feldspar and olivine

Villarica.

History — According to Martin (p. 86) Villarica erupted lava in 1640, and in 1876 its glow could be seen far over the land and even from the ocean. Mr. Otto Gudenschwager, manager of a hotel at Pucon, says that the volcano had been active for about a year when in 1910 there was a great spout of fire that caused an avalanche or flood of rock, snow and ice from the glacier on the east side of Villarica. The flood reached Lake Villarica at Pucon. There was no earthquake at this time altho there had been one in 1907.

Mr. Emilio Melcher, owner of the fundo "El Volcán" on the north slope of Villarica about four miles from the crater first came to this region in 1915 and that time a glow could be seen over the crater at night. This glow could be seen until about 1918, and after it disappeared there was white "smoke" or steam. In that year Mr. Melcher climbed to the summit and saw an enormous open crater with smooth inside walls "like masonry". The crater was very deep, and when the smoke blew aside he could see down about 150 feet but could not see the bottom. In the spring (northern autumn) of 1920 Mr. Melcher noticed that there was no longer any smoke. On Dec. 9, 1920 a severe earthquake threw down the porch on the front of the house at the fundo and moved a large shed three inches off its foundations. Furniture in the house moved from east to west (obliquely down the mountain). There were three short strong shocks, and slight shakes

[1] See also: Z. f. V. 1933, 15, 195; 1931, 14, 79 and 300; 1930, 13, 103. D. Red.

followed all the night of the ninth at intervals of about five minutes with ... shake about every half hour. At another "fundo" houses and stables were knocked ... Early in the morning of the tenth began an explosive eruption whose cannonading ... led the windows in the house and lasted for about 36 hours. In the night of the ... a great fountain of fire was seen, but on reconnoitering next day Mr. Melcher found ... no ejecta had reached the snow line altho he could see that the snow near the summit was blackened. In 1921 the crater was nearly all filled with broken rock but smoke was issuing from a small crater which could not be approached. In December 1929 Villarica was giving off a thin cloud of white fume in which only sulphur dioxide could be detected by smell. The fume was sufficiently dense at the summit on Dec. 27 as to be very unpleasant when brought over one by the changing wind. The crater in 1929 was much as described by Mr. Melcher for 1918. The inner crater was 200 or 250 feet across and at least 150 feet deep altho the bottom could not be seen. The outer rim, where not covered by snow consisted of slaggy lava mostly bleached or reddened.[1] (Pl. XVIII)

Local Geology — Like most of the big lakes of southern Chile Villarica was formed by glaciers rising in the cordillera to the east. The west shore of the lake and the surrounding country is of moraine and outwash material. The east shore and the little island in the middle of the lake are of ice-polished volcanic rocks. The pre-glacial lavas in the point at Pucon are slightly tilted. Some wooded hills south and southeast of Pucon are also composed of volcanic rocks, probably of the same series.

Approaching the volcano from the north, one rides up a valley floored with fairly recent flows and volcanic sands. The sides of the valley, especially the west side, are steep, but no ridges are developed along the inter-stream divides, instead the valley is entirely sunk below the surface of the volcanic cone and strongly suggests a radial lava trough.

Most of the surface between timber line and snow line is covered by aa flows, there are a few rough pahoehoe flows. Basalts with abundant and conspicuous feldspar phenocrysts are common, and some unusual glassy flows were seen.

Puyehue.

History - Very little could be learned about Puyehue (Map XXI). There seem to be no one main crater, but several cones of about equal size can be seen from a distance and there are said to be many craters. In 1922 a crater in the vicinity of Puyehue or Cauye threw pumice over the surrounding country. The surface of Lake Puyehue was covered, and pumice reached Lake Todos los Santos[2].

[1] See also: Z. f. V. 1933, 15, 195. D. Red.

[2] See also Z. f. V. 1929, 13

Osorno.

History — In the "Voyage of the Beagle" under the date of Nov. 25, 1834 Darwin says, "The volcano of Osorno was spouting out volumes of smoke. This most beautiful mountain, formed like a perfect cone, and white with snow, stands out in front of the Cordillera". On the night of Jan. 19, 1835 he observed an eruption of Osorno. Since about 1850 however no eruption is known, and for many years the great ice mass filling the crater has been much the same.

Local Geology — Very few lava flows are seen on the surface of Osorno, but instead it is covered by harsh pumice and angular gravels, partly thrown out by explosive eruptions and partly formed by erosion. At the west foot of the volcano on the lake shore just north of Ensenada there is an area of fairly fresh aa flows, of different ages as is shown by the size of the trees growing on them. These flows represent one of the last phases of activity and came from the lower part of a radial rift zone on the southwest slope, which is marked up to the edge of the ice cap by many large cinder and spatter cones. Not all these cones were the sources of flows, but most are covered only by basaltic cinders and a few bombs. A few inconspicuous cones are scattered over the whole mountain but do not marr its symmetry.

The top third of Osorno is completely covered by a cap of ice except in two places where a small bit of the crater's rim is exposed. The rim is of black slaggy lava. The width of the crater is between 250 and 300 meters. A small remnant of heat in the crater rim keeps the two outcrops bare and keeps open caves extending steeply down under the edges of the great heap of ice in the crater.

Pl. XIX, fig. 11 is from a photograph taken from the summit of Calbuco volcano. It shows Osorno volcano rising between the waters of Lake Llanquihue und Lake Santos, lakes once united but now separated by the long slope of lavas and ashes from Osorno. It shows also the course of the Petrohue river by which the waters of Lake Todos Santos now find their escape to the Fjord of Reloncavi after following along the hills of granite against which the lavas of Osorno abut on the south.

Calbuco.

History — In his journal for Nov. 26, 1834 Darwin noted that Osorno volcano was active and added, "Another great volcano with a saddle-shaped summit, also emitted from its immense crater little jets of steam". This second volcano was Calbuco[1]. For forty years or more before 1893 the volcano was quiet so that snow filled its crater, and a glacier lay on the south slope. In January 1893 heavy rains began to fall on the

[1] Darwin, Charles: The voyage of the Beagle. p. 292, The Harvard Classics.