

GENERAL FEATURES OF QUATERNARY VOLCANISM IN CENTRAL-SOUTH CHILE*

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Petrology

The most striking feature in this region is the abundant occurrence of high-alumina basalt associated with andesite and dacite of the calc-alkaline series, while rhyolite is rarely found (Larsson, 1940; Katsui and Katz, 1967; Katsui and González, 1968; Vergara and Katsui, 1969; González y Vergara, 1970; González, 1972; Katsui, 1972; Vergara and González, 1972; Moreno, 1974, 1975, 1977).

Tholeiitic basalt, however, does not occur in this region, although Kuno (1966) supposed that most of the southern Andean rocks are of tholeiitic derivation.

According to Moreno (1974) typical calc-alkaline character of volcanism prevails up to the latitude of Chillan volcanic area ($37^{\circ}00'$), further to the south, mainly rocks related to the high-alumina basalt series can be found in the west Andean volcanic range.

On the other hand, in dacites Na_2O content increases from north to south, while K_2O content decreases in basalts, andesites and dacites.

Besides, it is necessary to point out that the thickness of the crust is around 65 km thick at the latitude of Santiago ($33^{\circ}30'$ south latitude) and only 25 to 30 at the latitude of Puerto Montt. On the other hand, subduction angle of Benioff plane is around eighteen degrees at the latitude of Santiago while in Puerto Montt seems to be no subduction angle at all (Kausel and Lomnitz, 1968; Dragicevic, 1970, 1974).

These facts indicate that there probably exists a close relationship between chemical composition of volcanism, thickness of the crust and the subduction angle of Benioff plane (Moreno, 1974).

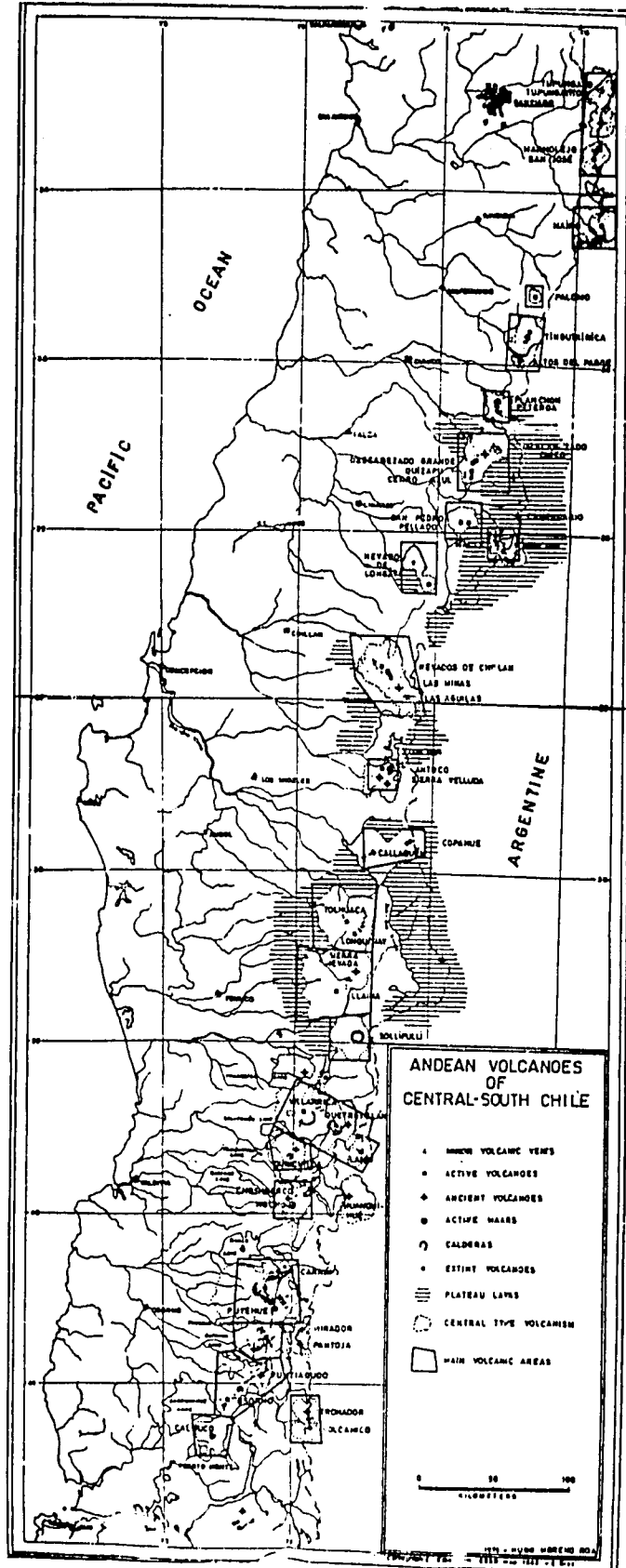
Tectonism

A remarkable tectonic control of volcanism is evident throughout the entire region. (Figure 3.)

From the latitude of Santiago (33° S) up to Valdivia (40° S) volcanic activity is controlled by N-S and NW-SE fractures and faults (González and Vergara, 1962; González, 1970; Katz, 1970; Vergara and González, 1972; González, 1972; Moreno, 1974).

(*) Partly extracted from: Hugo Moreno, 1974. Airplane flight over active volcanoes of Central-South Chile. International Symposium on Volcanology. Guide Book - Excursion D-3. IAVCEI.

FIGURE 3.



Between 40° S and $40^{\circ}40'$ S there is a transition zone in which the eruptive centers alignments are NW-SE; NE-SW and N-S (Katsui and Katz, 1967; Katz, 1973; Moreno and Parada, 1974; Moreno, 1974).

Further south from $40^{\circ}40'$ S, volcanic vents are controlled exclusively by NE-SW and N-S fractures and faults (Katsui and Katz, 1967; Moreno, 1974).

The N-S fracture and fault system is related to the general rise of the Andes since Pliocene time (Klohn, 1955; Aguirre and Levi, 1964; Corvalán and others, 1967; Katsui and Katz, 1967; González, 1969, 1970; Katz, 1970; Vergara and González, 1972; Katsui, 1972; Moreno and Parada, 1974; Moreno, 1974).

Volcanic Areas

The description of volcanic areas will be limited to the most important centers which are closely related to volcanic ash soils in South Chile. These areas are: (Figure 4.)

1. Antuco - Sierra Velluda
2. Llaima - Sierra Nevada
3. Villarrica - Lanin
4. Mocho - Choshuenco
5. Puyehue - Carrán
6. Antillanca
7. Osorno - Puntagudo
8. Calbuco

1. Antuco - Sierra Velluda

Location: $37^{\circ}22'$ to $37^{\circ}35'$ South latitude
 $71^{\circ}15'$ to $71^{\circ}30'$ West longitude

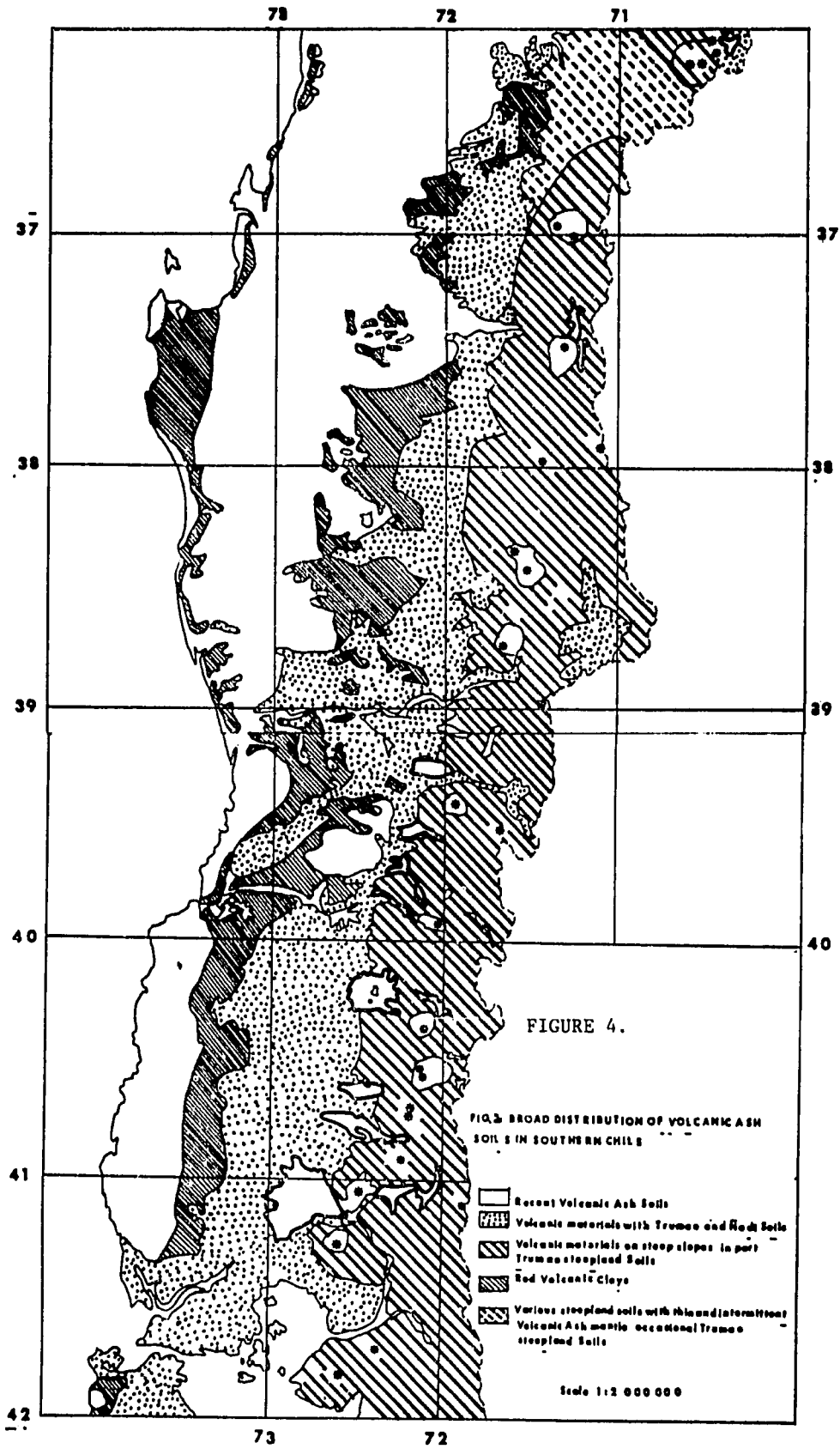
General features:

Volcanic activity since early Pleistocene up to the Present. A ruined andesitic stratovolcano of Pleistocene age represents the first stage; an eroded andesitic stratovolcano of Upper Pleistocene age performs a stage event. A final stage consists in the evolution of Antuco volcano of basaltic composition. It developed during Holocene time and consists in a somma with a central cone, lava flows, parasitic pyroclastic cones and ash deposits.

Basement is composed mainly of stratified and granitic Mesozoic rocks.

Volcanic groups:

- Antuco: composed of a somma (relict of Antuco I Caldera stratovolcano) and a central cone (Antuco II) with parasitic craters, cinder cones, pyroclastic deposits and recent lava flows.



Antuco stratovolcano (2.895 m.a.s.l.).

- Sierra Velluda - Cerro Cóndor: consist of two eroded stratovolcanoes, the older of which is Sierra Velluda volcano.

Sierra Velluda ancient stratovolcano (3.385 m.a.s.l.).

Petrography and chemical composition:

Petrography:

Andesites of Sierra Velluda - Cerro Cóndor volcanic group are aphiric and porphyric with phenocrystals of olivine, augite, hypersthene and labradorite in a hyalopilitic groundmass.

Basalts of Antuco volcanic group have olivine, augite and bytownite-labradorite phenocrysts in an intergranular to intersertal groundmass.

Chemical composition*:

	Antuco Average of 8 basalts	Sierra Velluda - Cerro Cóndor Average of 5 andesites
SiO ₂	51.61	56.92
Al ₂ O ₃	18.51	17.15
Fe ₂ O ₃	8.46	8.61
FeO		
MgO	6.20	2.85
CaO	8.98	6.56
Na ₂ O	3.51	4.77
K ₂ O	0.75	1.25
TiO ₂	1.01	1.29
P ₂ O ₅	0.24	0.30
MnO	0.16	0.18
H ₂ O	0.47	0.81
Total:	99.90	100.69

Historic eruptions:

Antuco Volcano: 1752, 1806, 1828, 1839, 1845, 1852, 1853
1861, 1863, 1869, 1969, 1982 intermitent fumarollic activity.

2. Llaima - Sierra Nevada

Location: 38°28' to 38°52' South latitude
71°25' to 72°00' West longitude

General features:

Volcanic activity since Pliocene up to the present.
Composed by a ruined stratovolcano deeply eroded by glaciers (Sierra

(*) Vergara y Katsui (1969); López et.al. (1981); Deruelle (1982).

Nevada) and a modern well shaped volcanic cone (Llaima) with numerous parasitic craters, pyroclastic cones, lava flows and lahar deposits. Basement consists in stratified and granitic mesozoic rocks.

Volcanic groups:

- Sierra Nevada: consists of and old Plio-Pleistocene eroded caldera stratovolcano.

Sierra Nevada stratovolcano (2.554 m.a.s.l.).

- Llaima: composed of a beautiful modern stratovolcano with fumarolic activity in its central crater, surrounded by numerous pyroclastic cones. It shows extense lava flows and lahar deposits.

Llaima stratovolcano (3.124 m.a.s.l.).

Petrography and chemical composition:

Petrography:

Lavas and pyroclastics of Llaima volcano are olivine-bearing basalts with labradorite an augite, and olivine-augite andesites with andesine.

Chemical composition*:

	Average of 7 basalts	Average of 3 andesites
SiO ₂	52.37	54.97
Al ₂ O ₃	17.31	17.26
Fe ₂ O ₃		
FeO	9.41	9.75
MgO	5.22	3.29
CaO	9.16	7.97
Na ₂ O	3.03	3.65
K ₂ O	0.67	0.77
TiO ₂	1.15	1.31
MnO	0.13	0.18
P ₂ O ₅	0.25	0.24
H ₂ O	0.22	0.13
Total:	98.92	99.52

Tectonism:

Volcanic activity is controled by N 140° E and N 15° E fracture systems.

Historic eruptions:

Llaima volcano: 1640, 1751-52, 1852-53, 1862, 1864, 1866, 1872, 1874, 1876, 1887, 1889, 1903, 1917, 1922, 1927, 1930, 1941, 1957, 1960, 1979, permanent fumarolic activity.

(*) Klerkx (1965); Deruelle (1982); López y Moreno (in prep.).

3. Villarrica - Lanín

Location: 39°15' to 39°43' South latitude
71°23' to 72°08' West longitude

General features:

Volcanic activity since Pliocene up to date. Characterized by three large stratovolcanoes aligned in a NW-SE trend. The oldest unit consists in thick piles of stratified lava flows and pyroclastics, related to old stratovolcanoes deeply dissected by glacial erosion. A number of pyroclastic parasitic cones, extense lava flows and lahars perform the youngest unit. Historic eruptions are related to Villarrica volcano, located at the NW end of the volcanic range. Volcanic materials are mainly of basaltic composition, nevertheless, andesites and dacites are also present.

Basement consists in Mesozoic granitic and stratified rocks.

Volcanic groups:

- Villarica: composed by a modern well shaped stratovolcano with a large somma displaced towards the SE. The main active cone is surrounded by several pyroclastic cones. A recent N° 30° E fracture can be distinguished at both sides of the summit, caused by the 1971 eruption.

Villarrica stratovolcano (2.840 m.a.s.l.).

- Quetrupillán: consists in a wide caldera with a central stratovolcano and numerous parasitic pyroclastic cones and craters. A ruined stratovolcano (Quinquilil) is located towards the NE of Quetrupillán volcanoes.

Quetrupillán stratovolcano (2.360 m.a.s.l.).

- Lanín: composed by a large stratovolcano partly dissected by glaciers.

Lanín stratovolcano (3.774 m.a.s.l.).

Petrography and chemical composition:

Petrography:

Basalts have Mg-olivine, labradorite and augite in an intergranular groundmass with pyroxene and iron ore.

Andesites have andesine-labradorite, olivine, augite and hypersthene in a groundmass with grains of plagioclase, pyroxene and iron ore.

Dacites have oligoclase-andesine, augite, hypersthene and occasionally Fe-olivine in a vitrophyric groundmass with grains of plagioclase, pyroxene and iron ore.

Chemical composition*:

	Villarrica		Quetripillán-Lanín
	Average of 10 basalts	Average of 7 andesites	Average of 8 dacites
SiO ₂	51.59	55.85	64.05
Al ₂ O ₃	18.00	16.79	15.21
Fe ₂ O ₃			
FeO	9.10	8.69	5.75
MgO	5.71	4.48	1.28
CaO	8.94	6.44	3.54
Na ₂ O	3.47	4.10	4.65
K ₂ O	0.86	1.18	2.86
TiO ₂	1.12	1.11	1.06
HnO	0.12	0.11	0.11
P ₂ O ₅	0.28	0.29	0.40
H ₂ O	0.68	0.61	0.70
Total	99.87	99.65	99.61

Tectonism:

Volcanism in this area is controlled by a NW-SE fracture system.

Historic eruptions:

Villarrica volcano: 1640, 1806, 1860, 1869, 1874, 1875-76, 1877, 1883, 1893-94, 1908, 1910, 1920, 1948, 1950, 1964, 1971, fumarollic activity today.

4. Mocho - Choshuenco

Location: 39°49' to 40°05' South latitude
71°51' to 72°11' West longitude

General features:

Volcanic activity since Middle Pleistocene up to the Present. Characterized by stratovolcanoes, a ruined caldera, pyroclastic cones, explosion craters and lava flows. Volcanic materials are of basaltic, andesitic and dacitic composition, they rest with unconformity upon mesozoic and paleozoic bedrock which consists mainly of granitoides and related rocks.

Volcanic groups:

- Mocho - Choshuenco: stratovolcanoes, a ruined caldera and a central pyroclastic cone. Parasitic explosion craters and pyroclastic cones.

Mocho volcano (central pyroclastic cone: 2.430 m.a.s.l.).

(*) Klerkx (1965); Deruelle (1982); Moreno y López (in prep.).

- Fui: numerous pyroclastic cones and lava flows.

Petrography and chemical composition:

Petrography:

Basalts have Mg-olivine, augite and labradorite in an iron-rich groundmass with clinopyroxene and andesine. Dacites have clinopyroxene and andesine. Dacites have clinopyroxene and oligoclase in a felsic groundmass with clino and ortopyroxene, oligoclase and iron ore.

Chemical composition*:

	Choshuenco Average of 4 basalts and basaltic-andesites	Mocho Average of 2 dacites	Fui Average of 2 basaltic-andesites
SiO ₂	53.16	64.30	54.72
Al ₂ O ₃	19.07	15.66	16.23
Fe ₂ O ₃	8.88	6.46	10.56
FeO			
MgO	3.99	1.57	3.34
CaO	8.70	3.16	7.67
Na ₂ O	3.40	5.10	3.99
K ₂ O	0.71	1.61	0.86
TiO ₂	1.06	0.94	1.42
MnO	0.16	0.17	0.20
P ₂ O ₅	0.19	0.29	0.28
ppc	0.55	0.56	0.59
Total:	99.87	99.82	99.86

Tectonism:

Two trends of volcanic centers alignment indicates a tectonic control of volcanism: N 140° E, N 60° E.

Historic eruptions:

Mocho volcano: 1864.

5. Puyehue - Carrán

Location: 40°16' to 40°40' South latitude
71°55' to 72°35' West longitude

General features:

Volcanic activity since Late Pliocene up to date. Characterized by stratovolcanoes, ruined calderas, fissural volcanic ranges and numerous pyroclastic cones, maars, lava-domes, lava flows and pyroclastic deposits widely spread. Volcanic materials are of basaltic, andesitic and dacitic composition, and they rest in unconformity upon Mesozoic and Paleozoic bedrock which consists mainly of granitoids and related rocks.

(*) Di Biase (1976); Deruelle (1982).

Volcanic groups:

- Carrán - Los Venados: stratovolcanoes, maars and numerous pyroclastic cones and lava flows.

Carrán Maar (300 m.a.s.l.).

- Mencheca: relicts of an old fissural volcanic range, an eroded caldera, volcanic necks and modern well preserved maars.

Mencheca volcano (1.840 m.a.s.l.).

- Puyehue - Cordón Caulle: stratovolcanoes (caldera), fissural volcanic ranges, domes and numerous pyroclastic cones, viscous lava flows and extense pumice deposits.

Puyehue volcano (2.236 m.a.s.l.).

- Cordillera Nevada: ancient ruined caldera with lava flows and old eruptive centers inside.

Cordillera Nevada volcano (1.799 m.a.s.l.).

Petrography and chemical composition:

Petrography:

Basalts have Mg-olivine, augite and labradorite in an iron rich groundmass with clinopyroxene, olivine and labradorite.

Andesites have andesine-labradorite, augite and sometimes hypersthene.

Dacites and rhyolites have augite, Fe-olivine, hypersthene and oligoclase in a felsic groundmass with oligoclase, iron ore and some trydimite.

Chemical composition*:

	Carrán - Los Venados Average of 5 basalts	Cordón Caulle Average of 14 dacites-rhyolites	Puyehue Average of 10 dacites-rhyolites
SiO ₂	52.56	69.98	67.66
Al ₂ O ₃	18.56	14.12	14.68
Fe ₂ O ₃	2.87		
FeO	8.03	4.53	5.50
MgO	4.34	0.40	0.77
CaO	7.00	2.12	2.83
Na ₂ O	3.83	5.09	4.94
K ₂ O	0.69	2.74	2.47
TiO ₂	1.33	0.61	0.71
MnO	0.19	0.12	0.14
P ₂ O ₅	0.13	0.12	0.17
ppc	0.98	-	-
Total:	100.51	99.83	99.87

Tectonism:

The tectonic control of volcanism is evident. The main trends of vent alignments are: N 120° - 130° E, N 60° E, N 5° - 10° E.

Historic eruptions:

- 1893(?) : Cordón Caulle (fissural eruption).
 1907 : Corral Quemado or Riñinahue (maar explosive eruption with lava outpouring).
 1921-22 : Cordón Caulle - Cordillera Nevada (fissural eruption).
 1929 : Cordón Caulle (pumice eruption).
 1934 : Cordón Caulle (fissural eruption).
 1955 : Carrán, Nilahue or Pillanilahue (maar explosive eruption).
 1960 : Cordón Caulle (fissural eruption).
 1979 : Mirador, a pyroclastic cone of Carrán - Los Venados (pyroclastics and lava flows).

At present with solphataric, fumarollic and geyser activity.

6. Antillanca

Location: 40°40' to 40°52' South latitude
 72°05' to 72°25' West longitude

General features:

Volcanic activity since late Pliocene up to Holocene time. Characterized by numerous pyroclastic cones and maars well preserved, stratovolcanoes and ruined calderas. Volcanic materials are of basaltic composition and they rest in unconformity upon Mesozoic and Paleozoic bedrock which consist mainly of granitoids and related rocks.

(*) Moreno (1974); Gerlach (in prep.).

Volcanic groups:

- Antillanca: stratovolcanoes, pyroclastic cones, lava flows and maars.

Casablanca volcano (1.990 m.a.s.l.).

- Fiucha: stratovolcanoes (eroded caldera) lava flows and pyroclastic cones.

Fiucha caldera (1.481 m.a.s.l.).

- Sarnoso: stratovolcanoes (volcanic ruin), pyroclastic cones, lava flows and maars.

Sarnoso volcano (1.630 m.a.s.l.).

Petrography and chemical composition:

Petrography:

Mainly basalts with phenocrysts of Mg-olivine, augite and labradorite. Iron-rich groundmass with clinopyroxene, olivine and labradorite.

Chemical composition*:

Antillanca Group Average of 6 basalts	
SiO ₂	51.21
Al ₂ O ₃	19.55
Fe ₂ O ₃	2.37
FeO	6.46
MgO	5.62
CaO	8.76
Na ₂ O	3.26
K ₂ O	0.58
TiO ₂	0.95
P ₂ O ₅	0.15
MnO	0.13
H ₂ O	0.60
Total:	99.64

Tectonism:

A tectonic control of volcanic activity is evident. Trends of alignment are: N 130° E, N 45-60° E, N 80° E, N 5-10° E.

History eruptions:

No record, but recent activity is evident.

(*) Moreno (1975); Pino (in prep.).

7. Osorno - Puntíagudo

Location: 40°52' to 41°13' South latitude
72°09' to 72°41' West longitude

General features:

Volcanic activity since late Pliocene up to the Present. Characterized by stratovolcanoes, an ancient fissural volcanic range and well preserved pyroclastic cones. Volcanic materials are mainly of basaltic composition and they rest in unconformity upon Mesozoic and Paleozoic bedrock which consists mainly of granitoids and related rocks.

Volcanic groups:

- Osorno: modern stratovolcano with a somma and numerous parasitic pyroclastic cones and lava flows.

Osorno volcano (2.652 m.a.s.l.).

- La Picada: stratovolcano (eroded caldera) with parasitic crater.

La Picada volcano (1.715 m.a.s.l.).

- Puntíagudo - Cordón Cenizos: stratovolcanoes (eroded), ancient fissural volcanic range and numerous pyroclastic cones with lava flows.

Puntíagudo volcano (2.493 m.a.s.l.).

Petrography and chemical composition:

Petrography:

Mainly basalts with phenocrysts of Mg-olivine, augite and labradorite. Iron-rich groundmass with clinopyroxene, olivine and labradorite.

Chemical composition*:

	Osorno Average of 4 basalts
SiO ₂	50.62
Al ₂ O ₃	20.23
Fe ₂ O ₃	1.43
FeO	7.91
MgO	3.65
CaO	11.31
Na ₂ O	2.78
K ₂ O	0.48
TiO ₂	0.64
P ₂ O ₅	0.16
MnO	0.14
H ₂ O	0.65
Total:	100.00

Tectonism:

Main trend of alignment is N 50-60° E.

Historic eruptions:

Osorno volcano and parasitic pyroclastic cones of SW:
1719, 1790, 1834, 1835, 1850. Scarce fumarolic activity on the summit.

8. Calbuco

Location: 41°13' to 41°26' South latitude
72°30' to 72°45' West longitude

General features:

Volcanic activity since Pleistocene up to the Present. Characterized by a typical stratovolcano evolution, whose different stages were separated by glacial erosion. The final stage is represented by an active central cone with related lava flows and extensive laharic deposits, volcanic materials are basaltic and andesitic; they rest in unconformity upon granitic mesozoic bedrock.

Calbuco volcano (2.015 m.a.s.l.).

Petrography and chemical composition:

Petrography:

Basalts have augite, hypersthene, labradorite and little olivine as phenocrysts.

Andesites have hypersthene, augite and labradorite-andesine as phenocrysts.

(*) Moreno et.al. (1979).

Chemical composition*:

	Calbuco	
	Average of 2 basalts	Average of 2 andesites
SiO ₂	51.10	56.18
Al ₂ O ₃	20.25	18.42
Fe ₂ O ₃	8.20	8.13
FeO		
MgO	4.26	3.89
CaO	8.86	7.52
Na ₂ O	4.07	3.93
K ₂ O	0.82	0.67
TiO ₂	0.85	0.90
MnO	0.12	0.13
P ₂ O ₅	0.15	0.18
H ₂ O	1.24	0.15
Total:	99.92	100.10

Historic eruptions:

Calbuco volcano: 1837-38, 1906, 1909, 1912, 1917, 1929, 1961, 1974.

(*) Klerkx (1965); Deruelle (1982).