SOME BASIC DATA ON THE QUATERNARY GLACIATION IN THE CHILEAN LAKE DISTRICT

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Abstract Significant eight figures on the Quaternary glaciation in the Chilean Lake District are presented. They are maps showing the former ice margins of four different glaciations, stratigraphies of tephras and paleosoils, and cross sections of glacial landforms. Development of coalescent piedmont glaciers during each glaciation is clearly indicated in these figures. Description on tephra-stratigraphy and red soil must be significant to examine the chronology of these glaciations. The longitudinal profiles of outwash plains along the major rivers during the Last Glaciation can be prominent evidence to discuss the chronology in relation to the lowering of the sea level. On the basis of these profiles, the largest glacier advance during the Last Glaciation probably occurred during the isotope Stage 4.

Key words: glaciation, piedmont glacier, paleosoil, tephra. Chilean Lake District

1. Introduction

The Chilean Lake District (Fig. 1) has long been focus of researches on the Quaternary glaciation, where the best glacial record has been obtained in the west of the southern Andes. We carried out the field survey on the Quaternary glaciation in this region during December 1981 to February 1982 that was financially supported by the Grant-in-Aid for Scientific Research (Oversea Scientific Survey) of the Japanese Ministry of Education, Science and Culture (Principal Investigtor: Professor Michio Nogami, Tokyo Metropolitan University).

Although a series of compiled studies have been published after the survey (especially Clapperton, 1993), it seems to be still significant to represent our field data and some interpretations. We have so far preliminarily reported important results in some restricted occasions (*e.g.*, Nogami *et al.*, 1983; Hirakawa *et al.*, 1983; Imaizumi *et al.*, 1983; Okada *et al.*, 1983). In this report we will presnt some figures as basic data and thus briefly add some interpreted remarks.

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2. Some Remarks

Former Ice margins of Lake District (Fig. 2)

Lago Llanquihue region should be the key area to examine the glaciation, because four glaciations are recorded as terminal moraines and associated outwash plains. Those are Rio Frio, Colegual, Casma and Llanquihue Glaciations in ascending order, according to the designation by Mercer (1976). Of these Glaciations, the Llanquihue Glaciation is thought to be the South American equivalent of the Wisconsin of North America. Porter (1981) proposed a complete revision of these earlier litho-stratigraphical nomenclatures, mainly on the basis of weathering characteristics, and named earlier glaciations as Santa Maria, Rio Lico and Caracol in descending order. Concerning the Last Glaciation, tripple terminal moraines such as the Llm (Llanquihue Glaciation maximum), Ll1 and Ll2.

Figure 2 clearly shows the coalescent piedmont glaciers in the Lago Llanquihue, Seno Reloncavi and Golfo de Ancud, not only during the Last Glaciation but also during the earlier two Glaciations of the Casma and Colegual. Porter (1981) criticized that the topographic crests of earlier glacial margin indicated by Mercer (1976) could not be traced across the Rio Maullin lowland. It is, however, very obvious that they do not disappear in this region, but indicate arcuate interfluves. This is the reason why we still follow the nomenclatures by Mercer (1976).

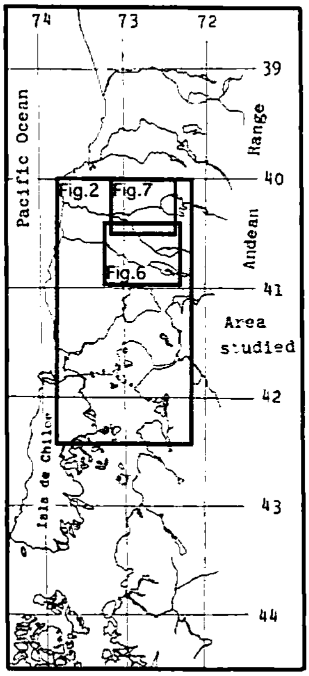

Fig. 1 Location Map of the Chilean Lake District and index for Figs. 2, 6 and 7.

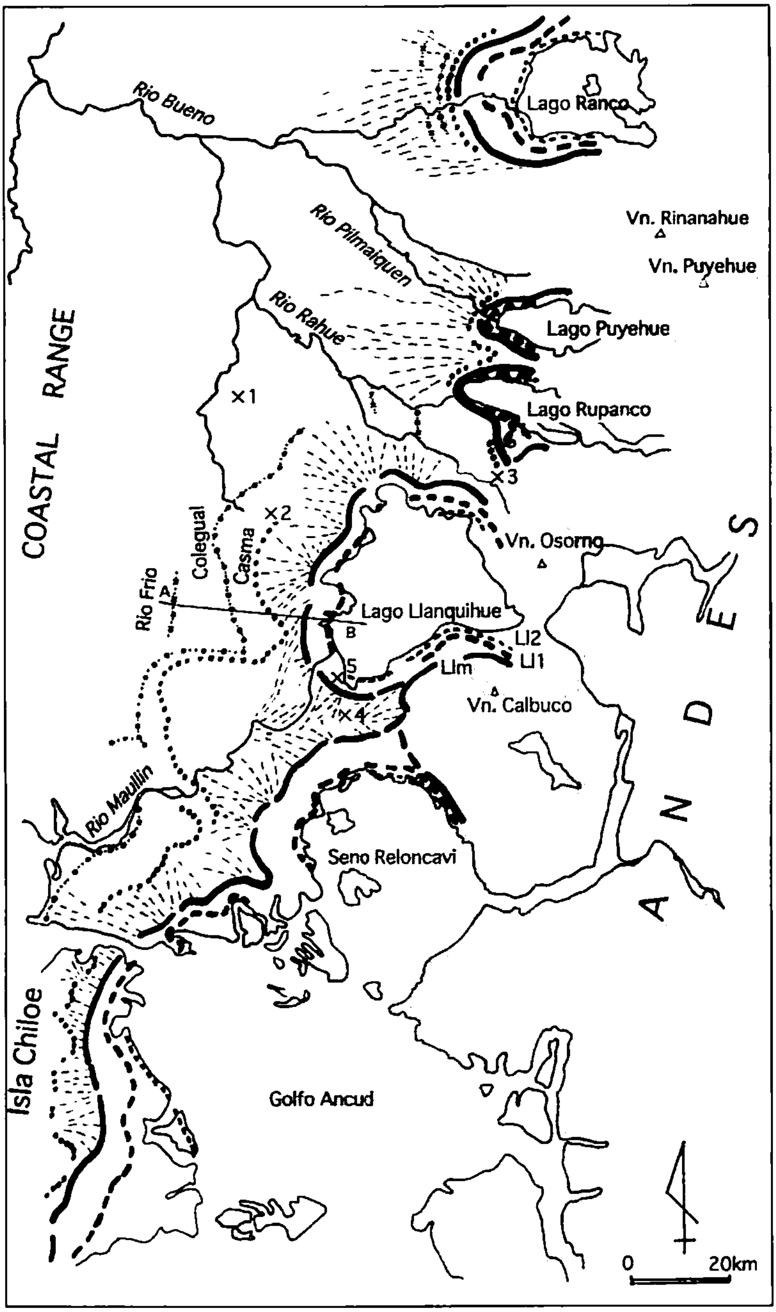

Fig. 2 Southern part of Chilean Lake District from Lago Ranco to Golfo de Ancud, showing the distribution and patterns of end moraines. The glaciations are given as Rio Frio, Colegual, Casma and Llm, Ll1 Ll2 to the west of Lago Llanquihue respectively. ×1 ~ ×5 are the localities for columnar sections of Fig. 4.

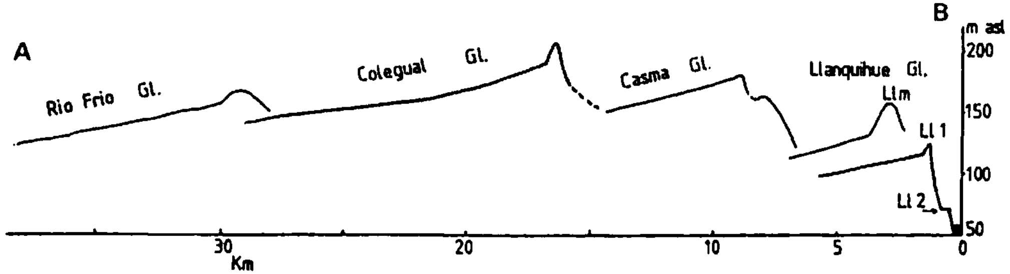

Fig. 3 Cross section showing the terminal moraines and associated outwash plains of the glaciations, west of Lago Llanquihue. Location of transect is given in Fig. 2.

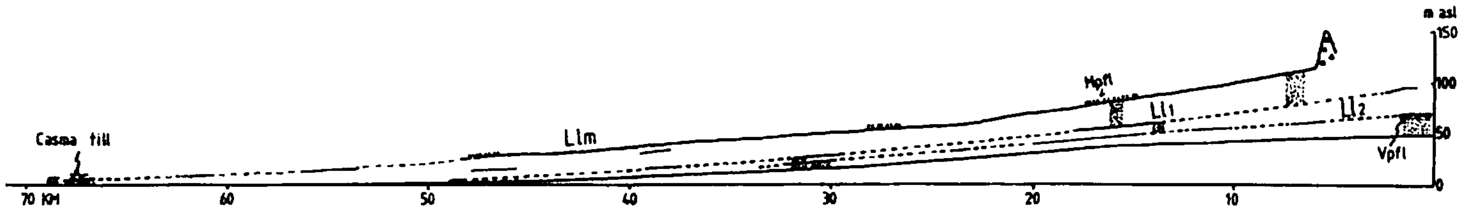

Fig. 5 Longitudinal profiles of terraced outwash plains of Last Glacial substages along the Rio Maullin, indicating the steeper gradients than the present river. Mpfl: Maullin Pyroclastic flow, Vpfl: Varas Pyroclastic flow.

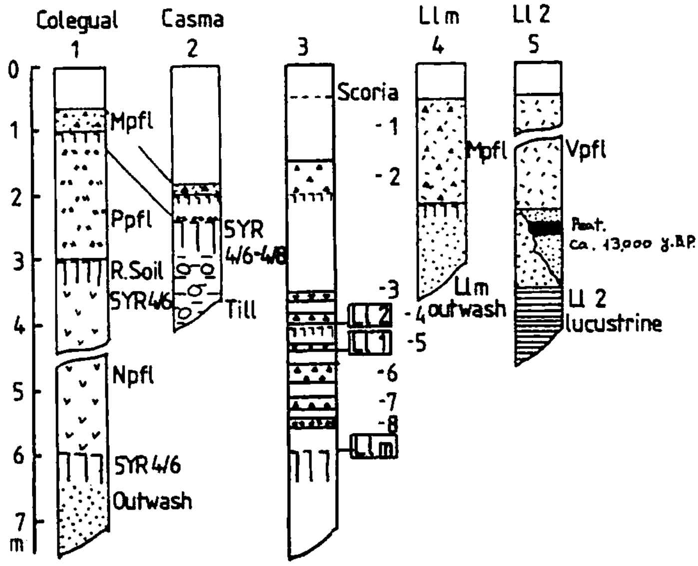

Fig. 4 Columnar sections showing the volcanic deposits and reddish~brown paleosoils overlying the glacial sediments. Localities of sections are given in Fig. 2. Npfl: Negro pyroclastic flow, Ppfl: Pilmaiquen pyroclastic flow, Mpfl: Maullin pyroclastic flow, Vpfl: Varas pyroclastic flow.

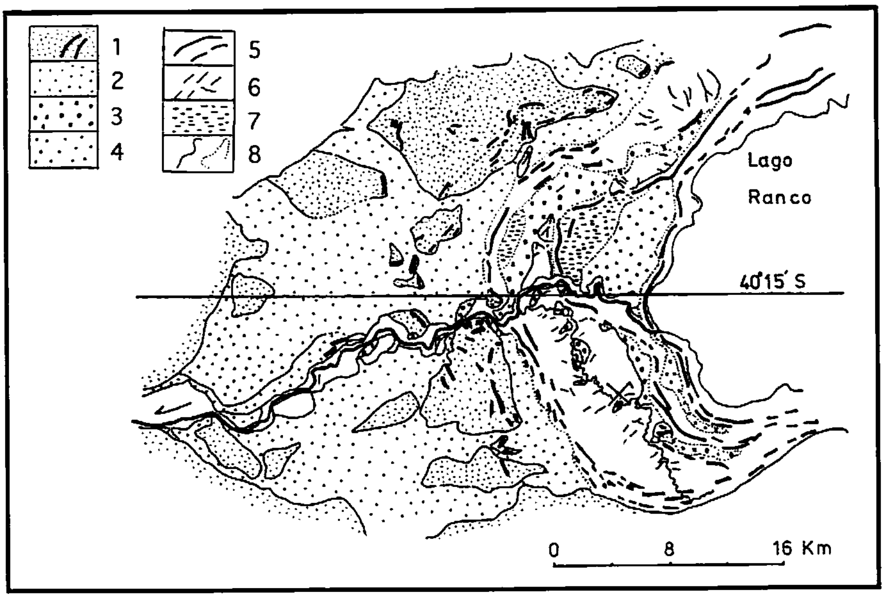

Fig. 7 Glacial landforms showing the terminal moraine ridges and associated outwash plains around the Lago Ranco. 1: Moraine ridges and outwsh plains of the older glaciations than the Last Glaciation, 2: Outwash plain of Llm substage, 3: Outwash plain of Ll1 substage, 4: Outwash plain of Ll2 substage, 5: Moraine ridge of Ll1 substage, 6: Ridges on the till plain, parallel to the flow direction of associated glacier, 7: Lacustrine plain, 8: Boundary of landforms.

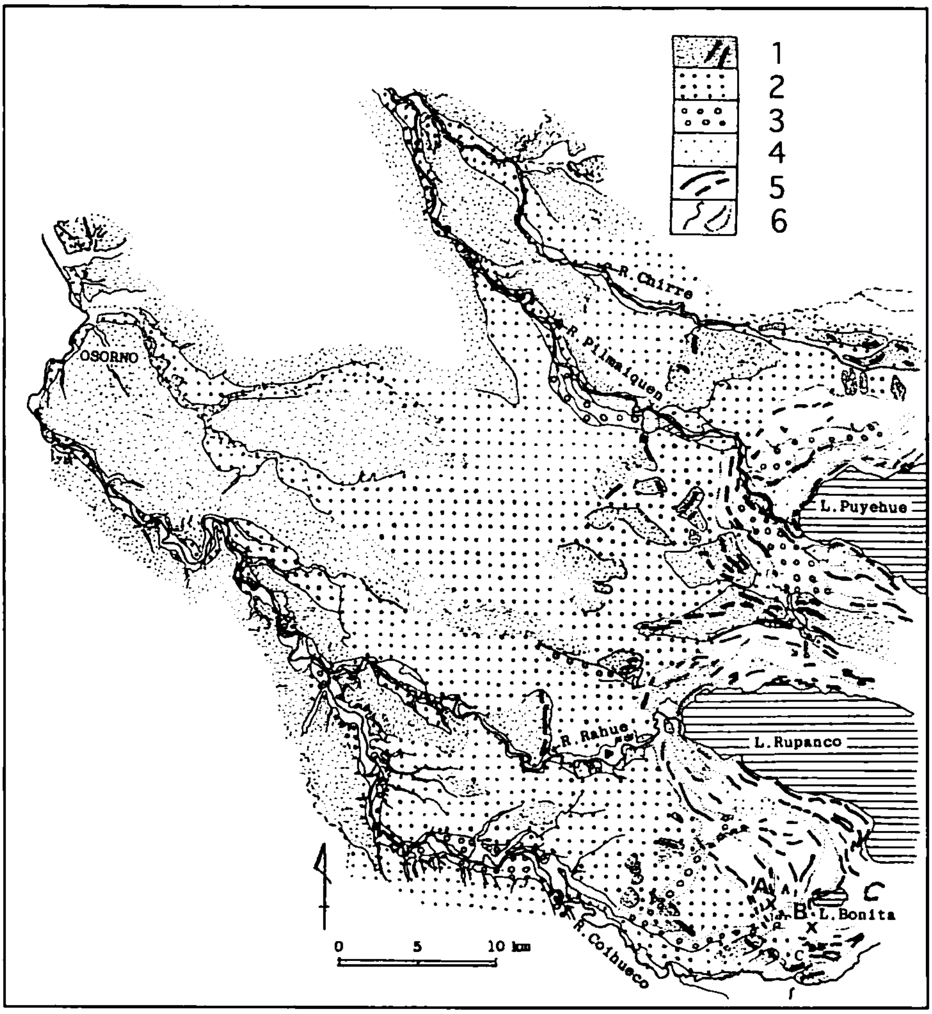

Fig. 6 Glacial landforms showing the terminal moraine ridges and associated outwash plains around the Lago Rupanco and Lago Puyehue. 1: Moraine ridges and outwash plains of the older glaciations than the Last Glaciation, 2: Outwash plain of Llm substage, 3: Outwash plain of Ll1 substage, 4: Outwash plain of Ll2 substage, 5: Moraine ridge of Ll1 substage, 6: Boundary of landforms.

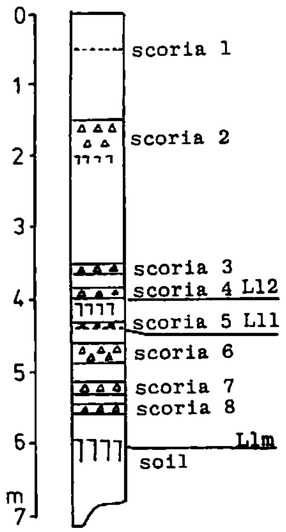

Fig. 8 Columnar section showing the volcanic scorias and brown soils in relation to the stratigraphical positions of Llm, Ll1 and Ll2 substages, south of Lago Rupanco. Locality (×B) is given in Fig. 6.

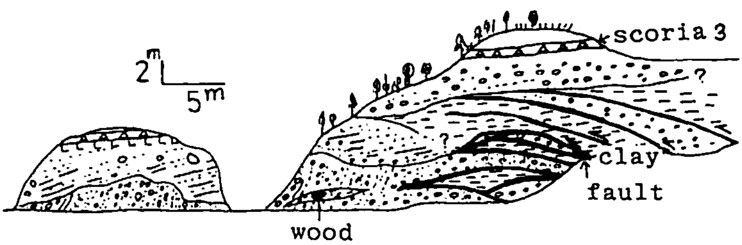

Fig. 9 Sketch showing deformation and dislocation mainly by reverse faulting due to the subglacial tectonics, south of Lago Rupanco. Locality (×A) is given in Fig. 6.

Transect of Lago Llanquihue moraine belts (Fig. 3)

Transect westwards from Lago Llanquihue represents the geomorphological evidence of systematic succession of moraine belts and associated outwash plains for each glaciation including the Last Glaciation. This figure is based on aerial photo interpretation, contour lines of 1:50,000 topographical maps and field survey. It is significant that each moraine belt indicates the typical glacial landforms surrounding the former ice margin. Therefore each of these moraine belts might represent the full glaciations, referring to the above paleosoil development.

Key tephras and soils (Fig. 4)

Volcanic pyroclastic deposits provide key beds for understanding the chronology and regional correlation of these glaciations. Landforms of the Colegual Glaciation are covered with two remarkable pyroclastic flow deposits of Npfl (Negro pyroclastic flow) and Ppfl (Pilmaiquen pyroclastic flow), while landforms of the Casma Glaciation are covered only by the Ppfl. Concerning the Llanquihue Glaciation, eight volcanic scoria layers probably supplied from the Osorno Volcano are useful for the subdivision and correlation in the northern area of Lago Llanquihue, while two pyroclastic flow deposits of the Mpfl (Maullin pyroclastic flow) and the Vpfl (Varas pyroclastic flow) probably from the Calbuco Volcano along the southern coast of Lago Llanquihue to the Rio Maullin river valley.

Figure 4 contains also the data on buried soils: orange~reddish brown soil indicating 5YR4/6~6/8 in Munsell notation seems to be very effective to examine the chronological issue of glaciation. As indicated in the columnar sections 1 and 2 in Fig. 4, the cover deposits on the Colegual outwash contain two well developed red soil horizons, while those on the youger Casma glacial deposits develop only one red soil horizon.

The Llanquihue glacial deposits are not covered with any red soil, but with more weakly developed brown soil of 7.5 YR. The most advanced substage of the Llanquihue Glaciation (Llm) is characterized by the cover deposits including two brown soil horizons, while the younger Ll1 dposits is covered with one horizon of more weakly developed brown soil.

Stratigraphy and type of paleosoil might resolve the issue on the relative age of glaciation. The well developed reddish brown soil possibly indicates an interglacial, while brown soil could be formed during an interstadial. This issue on paleosoil stratigraphy should be examined more detail.

Longitudinal profiles along the Rio Maullin (Fig. 5)

The Valley of Rio Maullin is situated in the geomorphologically significant area indicating the outwash plain of the piedmont glaciers of Lago Llanquihue, Seno Reloncavi and Golfo de Ancud particularly during the Last Glaciation (Fig. 2). We should discuss the issue how the Rio Maullin had responded to the lowering of sea level during the Last Glaciation. The longitudinal profile of the Llm terraced outwash plain is steeper than that of the present Rio Maullin and significantly gentler than those of the Ll1 and Ll2 outwash plains on the other hand. In particular the Ll1 is buried beneath the present (Holocene) alluvial plain at ca. 50 km upstream from the present river mouth. Ll1 outwash plain geomorphologically appears to have been formed in response to the lowest sea level of the Last Glaciation. Therefore the outermost glacial advance of Llm should have occurred during isotope Stage 4, as concluded by Mercer (1983).

Glacial landforms around other lakes (Figs. 6 and 7)

Glacial landforms around Lago Rupanco, Puyehue and Ranco north of Lago Llanquihue show almost the same characteristics and development. Tripple terminal moraines of the Last Glaciation (Llm~Ll2) and associated outwash plains can be easily identified. We can obtain the same longitudinal profiles of these outwash plains as those along Rio Maullin mentioned above. The older terminal moraines and outwash plains probably consist of two or three different glaciations, which are not seperately illustrated in figures.

Subdivision of the Last Glaciation (Fig. 8)

As for the subdivision and precise correlation of the Last Glaciation, tephra-stratigraphy is effective also in the area to the south of Lago Rupanco, as shown in the columnar section 3 in Fig. 4 for Lago Llaquihue . Llm terminal moraine is covered with eight volcanic scoria layers, while Ll1 and Ll2 are with five and four scoria layers respectively. In addition, a brown soil characterizes the Llm substage also in this area.

Deformed and dislocated glacial deposits (Fig. 9)

At Loc. A in Fig. 6. glacial deposits are highly deformed and dislocated by many reverse faults. They must have occurred through the subglacial tectonics. We could examine a subglacial condition and deformation processes of the piedmont glacier during the maximum stage of the Last Glaciation on the basis of more detailed observation. Further observation is still needed for this discussion.

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