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CLIMATIC AND VOLCANIC INFLUENCES ON THE LATE PLEISTOCENE AND HOLOCENE LACUSTRINE SEDIMENTATION IN THE SOUTHERNMOST ANDES (53°S)

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INTRODUCTION

The southernmost Andes (53°S) are whole-yearly influenced by the southern hemispheric westerlies. These westerlies are connected with the Antarctic climate and the Trans Antarctic Ocean Current, from which the Humboldt Current branches towards the north along the west coast of southern South America (Fig. 1). In the southernmost Andes the westerlies produce the most pronounced climate devide of the world with very narrow vegetation zones. The precipitation and the resulting sediment transport are strongly related to the intensity of the westerlies (Fig. 2). Consequently, Late glacial and Holocene climate changes in the southern hemisphere may have left telltale signs in the southern Andes by changing erosion, sedimentation rates and zonation of the vegetation. Disturbances caused by e.g. volcanic eruptions and human interference may also be archived.

In October 1989 we started an interdisciplinary project, investigating the recent climate as well as highly resolving climate and environmental archives of the Gran Campo Nevado area, like peat bogs and lake sediments (3) as well as tree rings (4). Here we report first results of the geochemical

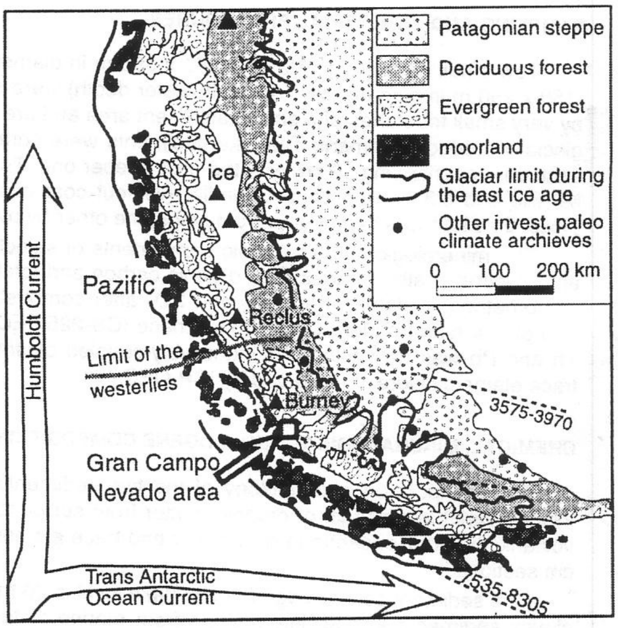

Fig.1. Southernmost South America with the area of investigation at the Gran Campo Nevado, the zonation of the vegetation (1) and the distribution of the volcanic eruptions from the Mt. Burney volcano (2). Ocean currents and the northern limit of the whole-yearly distribution of the westerlies are also shown.

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record in two lake sediment cores (8.6 m and 6.5 m lengths) which document environmental and possibly climatic changes during the last 14 000 years (http//www.geologie.uni-freiburg.de/projekte/patagonien).

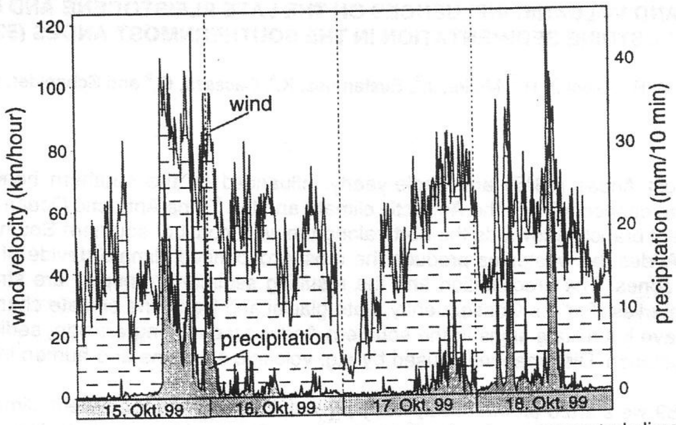

Fig. 2. Wind velocities and precipitation measured in intervals of 10 min. at our automated climate station during a south polar-derived storm in October 1999, indicating the strong positive correlation between wind velocities and precipitation.

SAMPLING AND ANALYTICAL PROCEDURES

Tow small lakes, Lago Martillo (350 x 550 m in diameter with 10-12 m water depth) and Lago Chandler (150 x 250 m in diameter with 15-16 m water depth) were selected for drilling. These lakes are characterized by very small tributaries of a small catchment area and are surrounded by rainforest, peatland and uncovered glacially eroded basement. The lake sediments were cored stepwise by means of a 2 m long piston corer, each core overlapping 30 cm with the next deeper one. Total core lengths of 8.6 m were obtained from Lago Martillo and 6.3 m from Lago Chandler (without core overlapping; Fig. 3). The cores were cutted into half pipes. One half was sampled in 2 cm steps, the other by overlapping 14 cm long pieces for thin sections.

The mineralogical and biogenic components of selected samples were investigated by X-ray diffraction and electron scatter images. The organic carbon and total sulfur content of the samples was determined by photometric (IR) detection of CO_2 and SO_2 after combustion of the homogenized dried and ground sample (0.5 g) in a high frequency induction furnace (CS-225 LECO). The content of the rare earth elements and U, Th and Pb was determined by inductively-coupled plasma mass spectrometry (ICP-MS). Major and some trace elements were investigated by ICP-OES.

CHEMICAL, MINERALOGICAL AND BIOGENE COMPOSITION

The composition and lithology of the two sediment cores is illustrated in Fig. 3. The lake sediments include variable amounts of organic matter from surrounding peat soils, basement weathering products and volcanic ashes. Concentrations of major and trace elements, sulfur and organic carbon were analyzed in 10 cm sections.

The sediment core of Lago Martillo (lake level is 20 m above N.N.) is characterized by partially laminated clayey sediments and an interchange from marine to terrestrial sedimentation at about 11 000 to 10 000 years B.P., whereas the sedimentation at Lago Chandler (lake level is 70 m above N.N.) was terrestrial since the Late Glacial (> 13 000 years). The two sediment cores and especially that of Lago Chandler are characterized by pronounced changes of some chemical components, related to two Holocene eruptions of the Mt. Burney volcano (2). The chemical variations are illustrated in Fig. 4 at the case of sediments from Lago Chandler.

The Ti and Al contents which may reflect the terrigenous sediment input remain nearly constant throughout the whole Late glacial and Holocene sedimentation period, whereas S and C as well as such elements which can be transported in water solutions of lacustrine environments show significant variations which are explained in the following (Fig. 4).

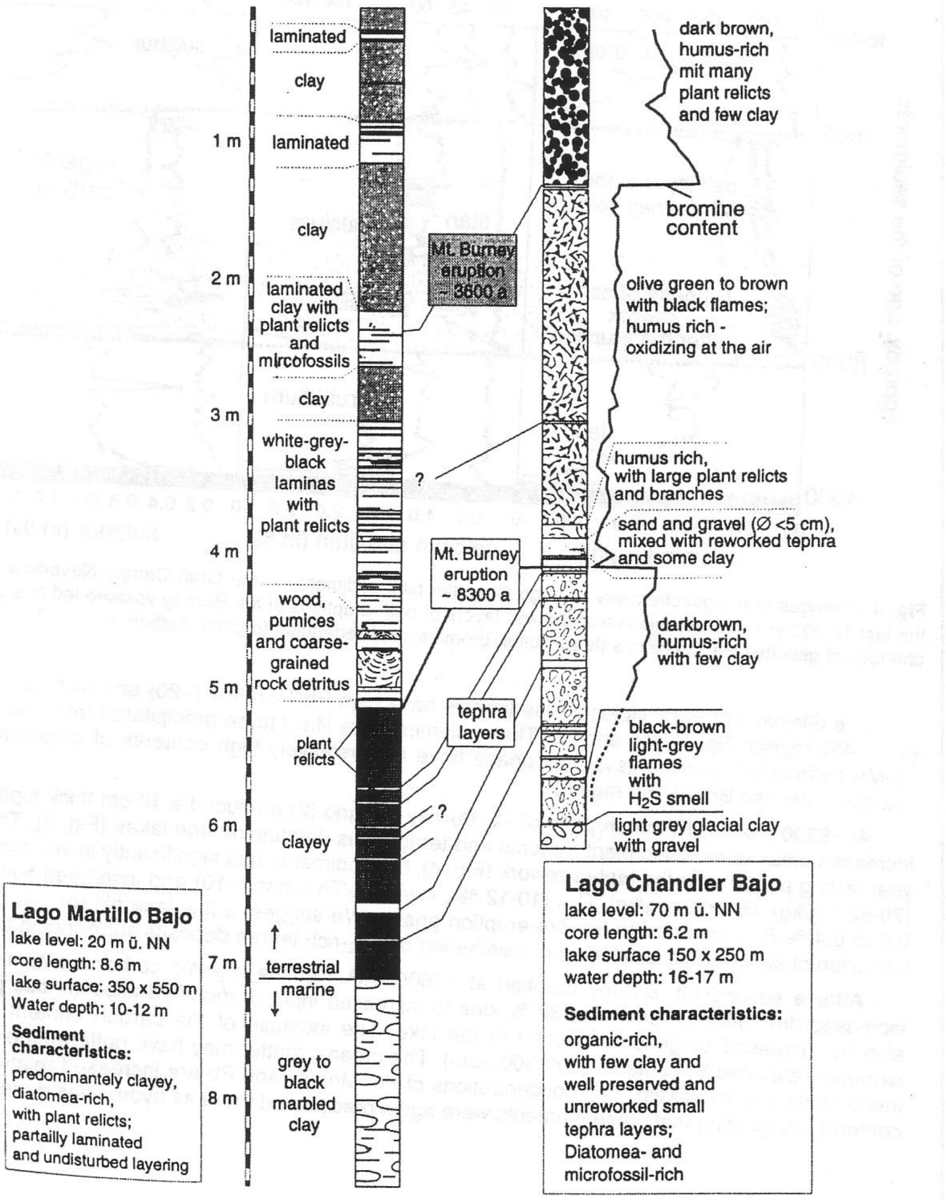

Fig. 3. Schematic lithology of the sediment cores from Lago Martillo Bajo (left) and Lago Chandler (right), located near the Gran Campo Nevado area (Fig. 1)

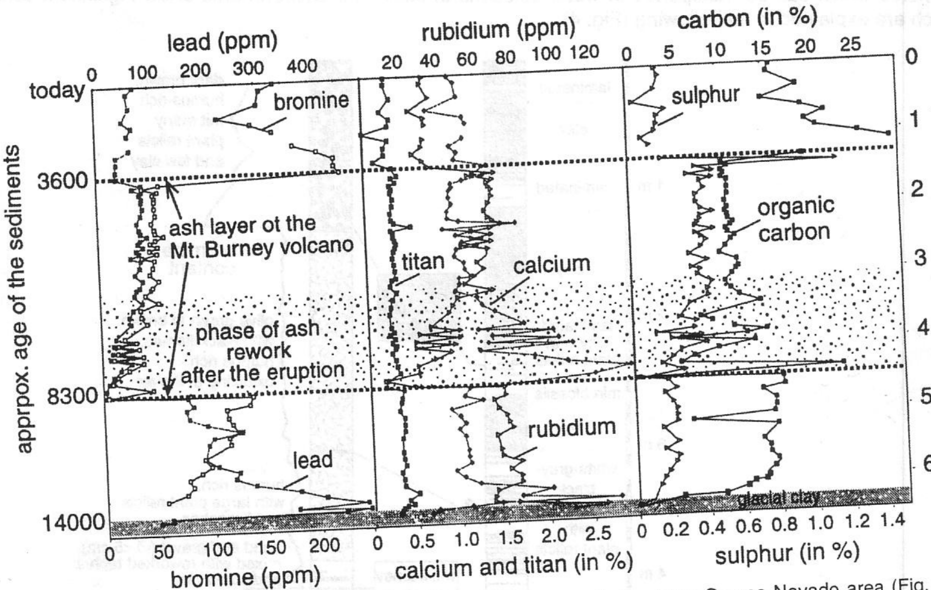

Fig. 4. Changes in the geochemistry of Lago Chandler lake sediments in the Gran Campo Nevado area (Fig. 1) during the last 14 000 years. It is obvious that the ash layers of both eruptions of Mt. Burney volcano led to significant long-term changes of geochemical conditions (lead, sulfur, bromine) and vegetation (organic carbon).

Late Glacial and Early Holocene sediments have high Pb/Th ratios (~20) and high concentrations of Pb (up to 450 mg/kg; Fig. 4), Mn and Fe. These elements are likely to be precipitated from the water column as Fe-Mn hydroxides. Sediments of this phase have also relatively high contents of organically-bounded and sea spray-derived Br (70-150 mg/kg).

At ~8300 years B.P. the eruption of Mt. Burney volcano (2) produced a 10 cm thick tephra layer, causing increased influx of mortified plant material and terrigenous detritus into the lakes (Fig. 3). Throughout a 4000 year lasting period after the tephra rework (Fig. 4), the sediments had significantly lower concentrations of Pb (70-82 mg/kg), Br (~50 mg/kg), C_{org} (10-12 %), lower Pb/Th ratios (~10) and increased sulfur contents (from 0.2 to 0.4 % S), compared to the pre-eruption phase. We suggest a low lake pH for this period, due to the formation of sulfuric acid as a result of weathering of SO_2-rich tephra deposits surrounding the lake.

After a second Mt. Burney eruption at ~3600 B.P. (2), the organic carbon content in the sediments increased dramatically from 10 to 30 %, due to increased input of mortified allochtonous plant material, but also by increased biogene production in the lake. The increase of the carbon content is correlated with extremely elevated Br contents (200-500 ppm). The organic matter may have buffered the lake pH (relatively low S content of the lakes). The concentrations of Fe, Mn, Cu and Pb are increased relative to the Ti and A contents, suggesting that these elements were again precipitated more as hydroxides during this period.

ENVIRONMENTAL CHANGES BY VOLCANISM

The two major Holocene eruptions of the Mt. Burney produced tephra layers of 5 to 12 cm thickness in the Gran Campo Nevado area. The older eruption (~8300 B.P.; 2) was followed by extended plant decay, probably due to the acidity of the tephra deposits. The destruction of big trees, as observed in the lake sediments after this eruption, was followed by an extended erosion. The second eruption of Mt. Burney ~3600 B.P. was less destructive and probably less acid. The long term increase of allochtonous organic matter in the lake sediments could have been produced by ash manuring of the flora silvestre.

Our results show that volcanic eruptions affected the lake pH. The lake pH was lowered over a long period after the first Mt. Burney eruption, due to long-term weathering of SO_2-rich tephra deposits. On the other hand the lake pH was possibly buffered after the second Mt. Burney eruption through increased organic matter influx. These variable lake pH conditions control the mobility of heavy metals as well as organically bounded bromine.

CLIMATE IMPLICATIONS

The amount of bromine fixed in the organic matter of sediments and peat may depend on one hand from the amount of sea spray (strong winds and storm), but on the other hand on the acidity of deposited organic matter. Therefore, we are trying to monitor the paleo pH conditions of the lakes by e.g. diatomea systematics, to understand the pH dependents of the bromine fixation. This should enable us to use the bromine content as a climatic tool. The relation between terrigenous (eg. Ti, Al) biogenic (organic carbon) components of the sediments show dramatic changes during the last 14 000 years. They reflect either climate variations or manuring of the biosphere by e.g. volcanic ashes. A synthesis of various proxy data which we are recently producing should enable us better constrains on the palaeoclimatic conditions.

GLACIOISOSTASY

The interchange from marine to terrestrial sedimentation in the Lago Martillo between 11000 and 10000 B.P. suggests a faster glacio rebound-induced uplift of the southern Andes compared to the global Late and Post Glacial see level upraise (~120 m: 5). The Andean uplift must have been also very limited during the Holocene. The Lago Chandler which is recently located 70 above N.N. was characterised by lacustrine sedimentation since the glacial retreat about 14 000 years B.P. which is documented by glacial-derived clay a the bottom of the Chandler core (Fig. 3). This limits the total Andean uplift of this area since the last ice age to less than 190 m.

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