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Palynological Evidence for Increased Aridity on the Central Chilean Coast during the Holocene

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The late Quaternary vegetation of the semiarid coast of central Chile is inferred from the palynological analysis of profiles from Quereo (31°55'S) and Quintero (32°47'S). Prior to 11,400 yr B.P., wet conditions are suggested by the abundance of pollen indicators of swamp and aquatic taxa, such as Cyperaceae and *Myriophyllum*, and by the presence of traces of arboreal pollen. Since ca. 10,000 yr B.P., a trend toward increasingly drier conditions is implied by the almost complete absence of arboreal and aquatic taxa, and a general decrease in the diversity of the semiarid shrubland indicators. From 3000 yr B.P. onward, the pollen records show the reappearance of swamp and aquatic taxa, presumably associated with wetter conditions, which led to recolonization by forest taxa at 1720 yr B.P. in Quintero. The drier climate detected along the semiarid coast of central Chile during most of the Holocene extended inland to the Andean foothills, within the present mediterranean-type climate zone of Chile, and also affected the distribution of the winter-deciduous *Nothofagus* forests and the northern boundary of the temperate rain forests.

INTRODUCTION

The vegetation of the mediterranean-climate zone of central Chile (30–38°S) represents the transition between the semiarid scrubland and the southern temperate rain forest. Consequently, this transition zone should be particularly sensitive to climatic changes that affected the Chilean territory during the Quaternary. The present mediterranean-type climate of central Chile, with winter rains and summer drought, is mainly determined by the quasi-permanent influence of the South Pacific subtropical high which has a conspicuous annual cycle of latitudinal displacement in accordance with other large-scale systems, such as the Intertropical Convergence and the North Pacific subtropical high. During the austral winter, rainfall in central Chile appears related to northward displacement of the South Pacific subtropical high which favors frontal activity associated with the westerlies of mid-latitudes. During the austral summer, southward displacement of the South Pacific subtropical high, to an average position of ca. 40°S, generates a stable system which is associated with a southward contraction of the westerlies belt that causes dry conditions in central Chile (Aceituno, 1988).

Winter-deciduous *Nothofagus*-dominated forest, sclerophyllous forest, *Acacia caven* matorral, and several scrub formations are all found within this region. North of 30°S, climatic conditions remain dry throughout the year and the vegetation changes gradually from a semiarid scrub, between 27° and 30°S, to an absolute desert north of 27°S. South of 38°S, precipitation falls throughout the year and evergreen rain forests become dominant (Schmithüsen, 1956). Along the coast of central Chile, the strong oceanic influence determines a permanently high level of humidity and cloudiness. The occurrence of isolated patches of evergreen rainforests, dominated by *Aextoxicon punctatum* and *Nothofagus obli-*

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qua, on the hilltops and ravines of the coastal range may be attributed to these conditions.

Small patches of swamp forest are also found discontinuously along the coastal plains of central Chile and in the Norte Chico from 30° to 34°S. The stable humidity of the soils of these swamp forests is related to block tectonics which determined the relief, the filling of the basins, and the underground and surface water drainage (Varela, 1979, 1981). The swamp forest patches are floristically homogeneous over their geographical range. Dominant tree species are *Drimys winteri, Luma cheguen,* and *Myrceugenia exsucca* (Villagrán, 1982). A floristically similar type of swamp forest community has been described for wet sites in the Central Valley of southern Chile between 38° and 42°S (Ramirez *et al.*, 1983).

In this paper we examine the late Quaternary history of the coastal semiarid vegetation of central Chile, based on pollen analysis from two localities presently supporting typical swamp forests, Quebrada Quereo and Quintero. Very few palynological data are available for central Chile (Heusser, 1983; Villagrán, 1982).

STUDY AREA

The geographic locations of swamp forest stands in central Chile and that of the two pollen profiles studied are shown in Figure 1. The regional climate can be classified as mediterranean, semiarid, with maritime influence (Di Castri and Hajek, 1976). This climate is characterized by low precipitation, concentrated in winter (Fig. 1), and by high air humidity and cloudiness directly associated with the oceanic influence (Fuenzalida, 1965).

The Quereo site, located 5 km south of Los Vilos at ca. 25 m altitude, has been the site of multidisciplinary studies concerned with the remains of paleoindian hunter–gatherer communities in relation to the extinction of the local megafauna during the late Pleistocene (Nuñez *et al.*, 1983).

The forest at Quebrada Quereo (31°55′S; 71°30′W) is located near two streams that form the upper catchment of the watershed, about 500 m from sea. The hydrographic system of Quebrada Quereo develops a funnel-type drainage that concentrates the underground and surface waters of a relatively wide region. The present forest occurs at the convergence point of this hydrographic system, near the mouth of Quebrada Quereo (Varela, 1981). The vegetation is dominated by *L. cheguen,* associated with *D. winteri, Escallonia revoluta, Schinus latifolius,* and *Cissus striata* (Villagrán, 1982).

The Quintero site is located ca. 5 km northeast of the coastal town of Quintero (32°47′S; 71°32′W), at ca. 10 m altitude. The forest here occupies a flat area underlain by a stabilized Pleistocene dune system. The dominant trees are *M. exsucca* and *D. winteri.* The forest is surrounded by marshes with *Scirpus californicus, Typha angustifolia, Blechnum chilense,* and *Gunnera chilense.* Its flora has been the subject of studies by Looser (1944), Levi (1951), and Villagrán (1982).

STRATIGRAPHIC SECTIONS AND METHODS

The sediments from the Quereo Formation are of late Pleistocene age and have been described by Varela (1979, 1981). The Quereo deposits consist of six members (Fig. 2). Member 1, the oldest and with an unexposed base, consists of clean light-gray sands mixed with fragments of shells and with faunal remains at the top, including mastodon (Sundt, 1903), horse, swamp deer, camelids, giant sloth, feline, canid, rodents, birds, and frogs. Member 2 contains dark-gray clayey sands of lacustrine origin with dispersed osseous remains. Member 3 consists of brownish fluvial sands, somewhat clayey. At the top there is evidence of human activity associated with remains of fossil megafauna which do not differ significantly from those of Member 1. Member 4, includes light-colored calcareous lacustrine sediments associated with

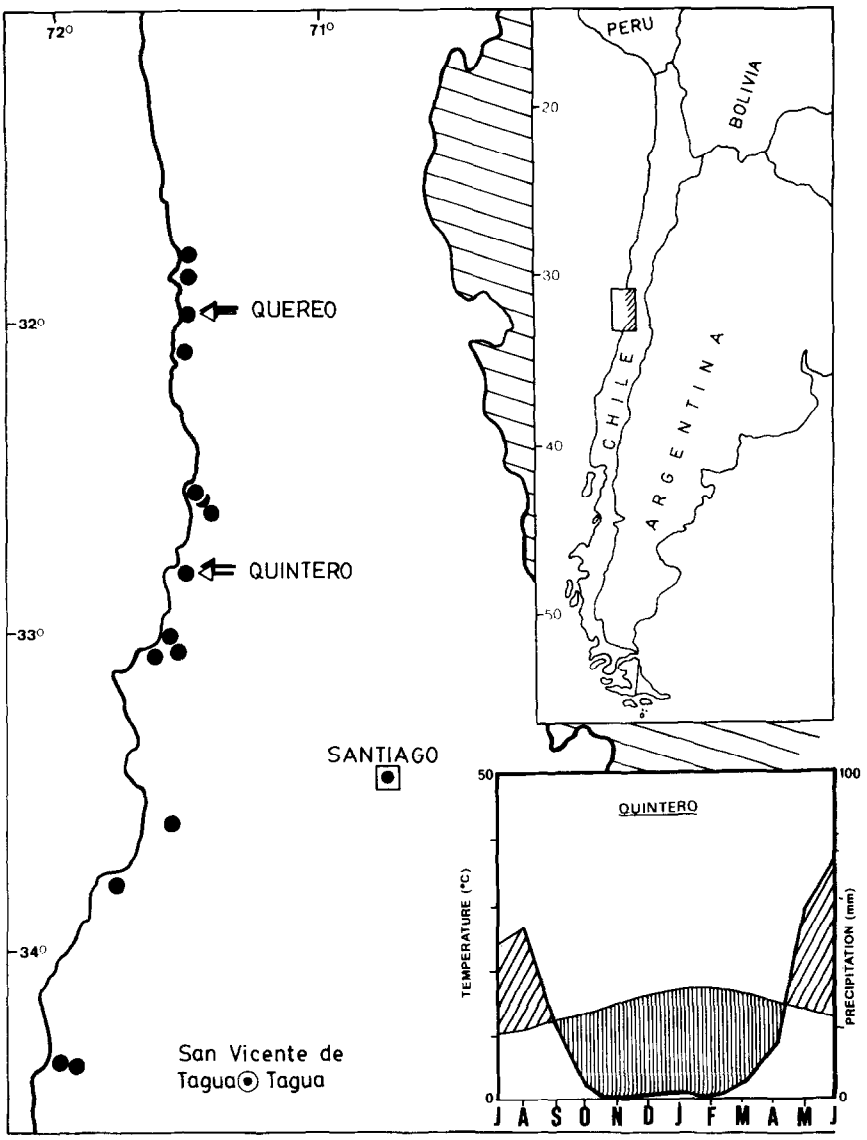

FIG. 1. Map of the semiarid coast of central Chile showing the distribution of Myrtaceae-dominated swamp forests, the geographic locations of the Quereo and Quintero profiles, and the Taguatagua glacial site. Climatic diagram for Quintero is after Castri and Hajek (1976).

freshwater peats and fluvial and eolian sands. Member 5 includes light-gray peaty calcareous sediments associated with freshwater peats. Member 6 includes yellowish to light-brownish eolian sands associated with freshwater peats and bears an incipient soil. The contacts between all the members are erosional disconformities, except between members 2 and 3 where the contact is gradational (Fig. 2).

The base of the Quintero core (240–215 cm; Fig. 3) is composed of pale-orange to pale-yellowish-brown sands with low clay (10%) content. These sands, which are probably of eolian origin, are overlain by dusky-brown to grayish-black peats (215–0 cm) which are associated with minor sand, possibly of eolian origin, between 170 and 150, 110 and 100, and 65 and 50 cm. The pure peats between 100 and 65 cm include

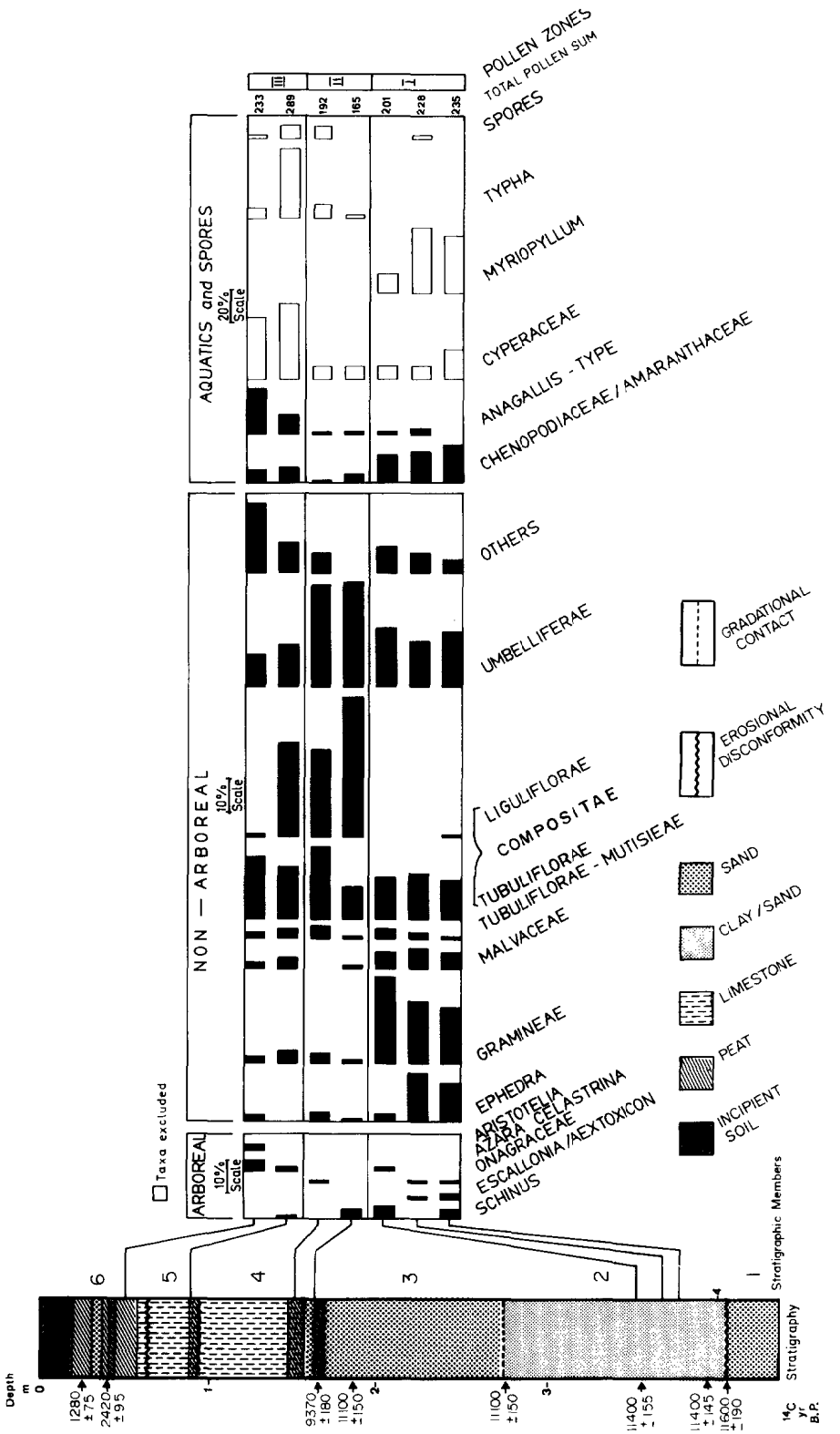

FIG. 2. Pollen diagram for Quereo, central Chile.

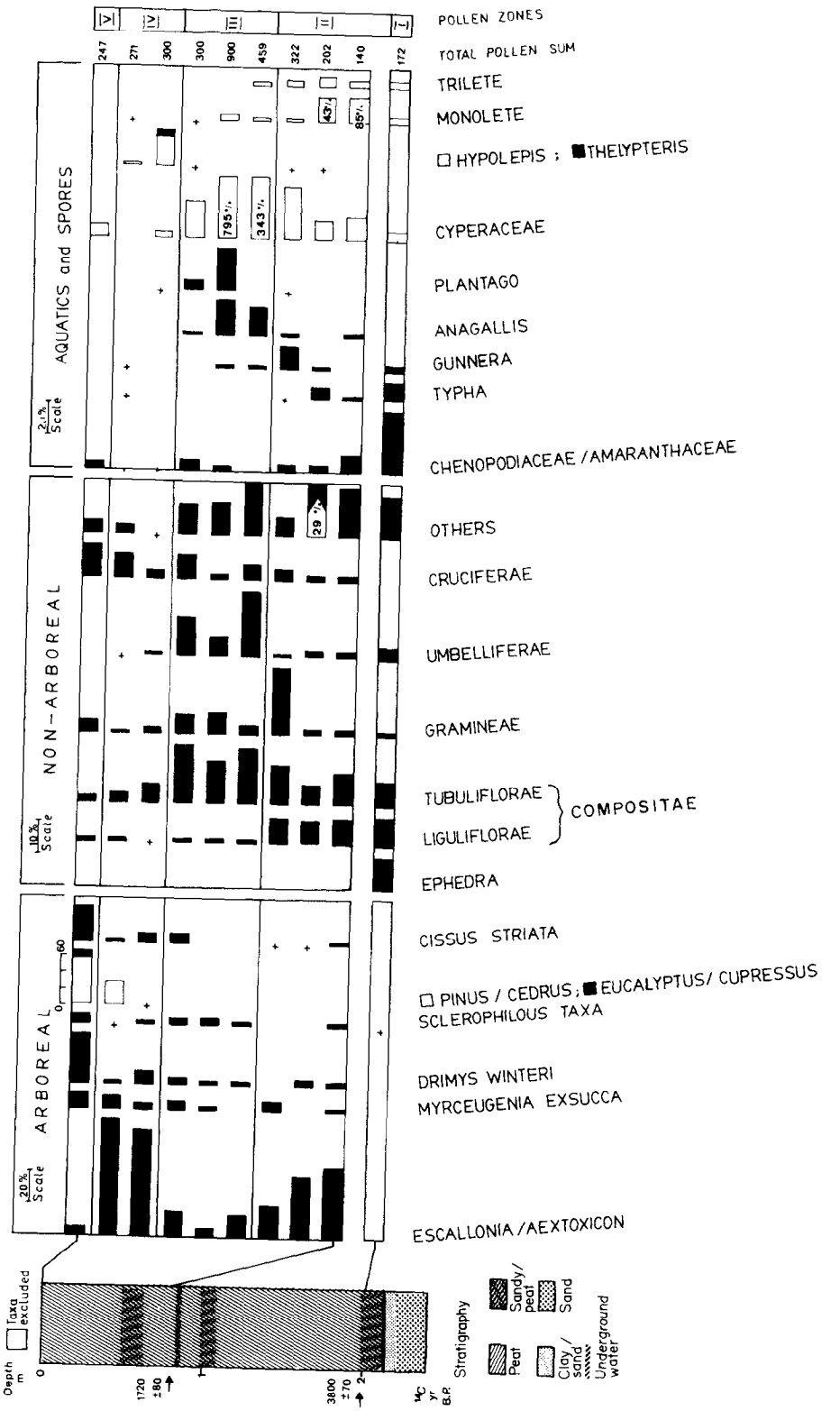

FIG. 3. Pollen diagram for Quintero, central Chile.

tests of sponges, frustules of pennate diatoms, and freshwater mollusks. The water table is found at 85 cm depth.

Two radiocarbon ages from Quintero were determined by Beta Analytic, Inc., Florida: 1720 ± 80 yr B.P. (β-3406; 75–85 cm), and 3800 ± 70 yr B.P. (β-3407; 200–220 cm). For Quereo, the radiocarbon dates were obtained from the Rikagaku Kenkyusho Laboratory (N), Japan. Duplicates of the same samples were cross-checked at the Smithsonian Institution (SI), and the dates provided by the latter laboratory are indicated in parentheses where available. Two samples from Member 6 were dated: 1280 ± 75 yr B.P. (QR-1/N-2960) (SI-3398: 985 ± 60 yr B.P.) and 2420 ± 95 yr B.P. (QR-2/N-2961) (SI-3390: Idem.). Two samples from the peat layer at the base of Member 4 were dated: 9370 ± 180 yr B.P. (QR-0/N-2483) and 9370 ± 180 yr B.P. (QR-0/N-2484). A sample from the top of Member 3 was dated 11,100 ± 150 yr B.P. (QR-9/N-2962), and four samples from Members 2 and 1 had ages of 11,100 ± 150 yr B.P. (QR-13/N-2963), 11,400 ± 155 yr B.P. (QR-14/N-2964) 10,925 ± 85 yr B.P. (SI-3391), 11,400 ± 145 yr B.P. (QR-12/N-2966), and 11,600 ± 90 yr B.P. (QR-15/N-2965). The erosional disconformity between Members 1 and 2, and the possibility that the percolation of groundwater may have introduced younger carbonates into the samples, mean that the last four radiocarbon ages may be older than calculated.

Both sections contain very little pollen. In Quereo, we studied seven levels down the stratigraphic column (Fig. 2). The top sample was taken at 50 cm depth, from the sands and peats of Member 6. The next sample was taken from Member 5, at 91 cm depth. The following two samples were taken from basal peats of Member 4, at 1.52 and 1.63 m, respectively. The three basal samples were taken from clayey-sandy sediments of Member 2, between 3.05 and 4.04 m depth. In Quintero, samples for pollen analysis were taken at 10-cm intervals, from the surface down 75 cm depth. Not enough pollen for analysis was detected farther down, except within the sandy peats at the base of the profile where one sample (at 200 cm depth) was taken for analysis.

Samples were treated with 5% KOH solution, hydrofluoric acid, and acetolysis and mounted in a glycerine gelatin medium. For the Quereo samples, the proportions of all taxa were calculated from a basic pollen sum of 150 grains. In Quintero, the basic pollen sum considered was 200 grains, except at intervals 35, 45, 65, 75, and 200 cm where pollen concentration was quite low and the basic pollen sum was only 100 grains. Aquatic (Cyperaceae, *Myriophyllum, Typha*) and spore-producing taxa were excluded from the basic pollen sums in both profiles. The total pollen sums are shown in Figures 2 and 3.

RESULTS

Quereo Profile (Fig. 2)

Zone I. The three levels studied were dated at ca. 11,400 ± 155 yr B.P. As mentioned earlier, the ages determined for Members 1 and 2 appear underestimated. Varela (1979, 1981) has estimated an age range between 11,500 and 21,000 yr for these sediments, corresponding to the last glacial age (isotope stage 2). Predominant taxa of this zone are Gramineae (up to 26%), Compositae–Tubuliflorae (up to 13%), Umbelliferae (up to 18%), *Ephedra* (10%), Malvaceae (up to 6%), *Puya* (up to 3%), and traces of Cactaceae, Liliaceae, and Cruciferae, all indicative of a semidesert scrub. Traces of arboreal pollen and high proportions of wetland and aquatic taxa (Cyperaceae up to 17%, *Myriophyllum* up to 40%) suggest humid conditions with development of lakes surrounded by wetlands and small woodlands. High representation of saltflat indicators (Chenopodiaceae/Amaranthaceae, up to 25%), suggest that the lake level was low.

Zone II. The base of the Zone II was dated 9370 ± 180 yr B.P. According to the

chronosequence proposed by Varela (1979, 1981), the two levels studied in this zone, near the base of Member 4, should represent the early Holocene. Umbelliferae (up to 32%) and Compositae (Liguliflorae up to 43%, Tubuliflorae up to 25%) characterize the pollen spectrum of this zone. Pollen of tree species and wetland taxa is practically absent, and the overall species richness of scrub indicators decreases, thus suggesting increased aridity and sparse vegetation during this period.

Zone III. The top of this zone was dated at 2420 ± 95 yr B.P. Varela (1979, 1981) considered the two levels studied as Members 5 and 6, corresponding to the transition between the European Sub-Boreal and Sub-Atlantic. Pollen of Compositae and Umbelliferae remain dominant, but Malvaceae (4%) and traces of *Puya,* Convolvulaceae, Portulacaceae, and Solanaceae are also present. These taxa confirm a richer, semiarid vegetation. Arboreal pollen, including taxa presently occurring in the forest, is represented by traces of *Schinus, Azara,* and *Aristotelia.* Increased rainfall may be inferred from the higher representation of wetland taxa, such as Cyperaceae (up to 45%), *Typha* (up to 42%), and *Anagallis*-type (up to 28%).

Quintero Profile (Fig. 3)

Zone I. A discontinuous stratum of the profile at a depth of 2 m is dated 3800 yr B.P. The vegetation is composed mainly of Compositae (Tubuliflorae and Liguliflorae, 17%), *Ephedra* (10%), Umbelliferae (4%), and the wetlands indicators *Typha* (12%) and *Gunnera* (3%). Tree species are lacking. The low species richness, the absence of trees, and the abundance of saltflats indicators (Chenopodiaceae/Amaranthaceae, up to 39%), as well as *Ephedra* (indicator of long-distance transport), suggest that the regional vegetation was a sparse scrubland, interrupted by desiccated lakes, in an area with semiarid climate.

Zone II. The base of this zone, with an estimated age of 1720 yr B.P., is marked by the initiation of forest development. Arboreal pollen includes mainly *Escallonia/Aextoxicon* (up to 45%) and traces of *Myrceugenia, Drimys,* and *Schinus.* With the exception of *Ephedra* and Chenopodiaceae/Amaranthaceae, most nonarboreal taxa present in the previous zone persist through this zone, with an increase in the Gramineae (up to 21%) toward the top. Among the wetland indicators, Cyperaceae (up to 32%), *Gunnera* (up to 15%), and *Blechnum chilense*-type tend to increase. The pollen spectra suggest that climatic conditions favored colonization by tree species and increase in wetlands species, i.e., humidity would have increased with respect to the previous zone.

Zone III. Cyperaceae (*Scirpus*-type), associated with other wetlands and bog taxa, such as *Anagallis alternifolia*-type (up to 24%), *Plantago* (up to 25%), Umbelliferae (*Hydrocoyle*-type, up to 20%), and Compositae-Tubuliflorae (*Moscharia* and *Cotula*-type, up to 18%), and traces of the Ranunculaceae, Rubiaceae, *Erodium*-type, and Caryophyllaceae are the dominant pollen types in this zone. The drop in arboreal pollen, as well as the increase of wetland taxa, indicates very humid conditions, probably resulting in temporally inundated sites, similar to the *Scirpus* bog, which surrounds the forest today.

Zone IV. The pollen spectrum here is similar to the modern forest. Dominant canopy and understory woody taxa are well represented, including *Escallonia/Aextoxicon* (up to 71%), *M. exsucca* (up to 7%), *D. winteri* (up to 7%), *C. striata* (up to 6%), and traces of the sclerophyllous shrubs *S. latifolius*-type and *Peumus boldus.* Two fern species, *Hypolepis rugosula* (18%) and *Thelypteris argentina* (3%), are absent in the present-day community.

Zone V. This zone represents the cultural phase, characterized by a decrease of *Escallonia/Aextoxicon* and the increase of *D. winteri* and sclerophyllous taxa, such as *Schinus, Peumus, Lithrea, Azara,* along with Cruciferae and Gramineae herbs. This

vegetation change suggests a gradual desiccation of the forest. Human impact in the vicinity of the forest is expressed by the abundance of *Pinus/Cedrus* (up to 54%), *Cupressus* (up to 5%), and *Eucalyptus* (up to 4%).

DISCUSSION

The pollen record of Quereo reveals that during the late Quaternary, shrubby and herbaceous taxa characteristic of the semiarid region, such as *Ephedra,* Gramineae, Umbelliferae, Compositae, Cruciferae, and Malvaceae, predominated along the semiarid coast of central Chile. The late-glacial/postglacial transition is marked by a sharp change in the sediments from sands to calcareous sediments, associated with the disappearance of the megafauna (Nuñez *et al.,* 1983). Prior to 11,100 yr B.P., wet conditions are suggested by the abundance of pollen of swamp and wetland indicators, such as Cyperaceae, and the aquatic taxa *Myriophyllum,* and the traces of arboreal pollen. However, the great abundance of saltflat vegetation, such as Chenopodiaceae/Amaranthaceae, interpreted as indicators of intervals of desiccation and low water level in lakes (Heusser, 1983; Markgraf, 1983), indicate an increase in temperatures at the end of late-glacial time in Quereo.

This setting agrees with that suggested by the sedimentological and micropaleontological evidence from Quereo at this time (Nuñez *et al.,* 1983) and by the geomorphic evidence of paleosols, relicts of a more humid climate, documented for the Chilean coast between 27° and 33°S at the end of the late-glacial interval (Paskoff, 1970; H. Veit, personal communication, 1989). Cold, humid climatic conditions have been suggested for the maximum of the last glaciation in the Central Depression of central Chile (Laguna Tagua-Tagua, 34°30'S) on the basis of analysis of sediments (Varela, 1976), microfossils (Covacevich, 1971), and pollen (Heusser, 1983). At the latitude of Tagua-Tagua, in the Argentinian Monte Province, the pollen diagram of Gruta del Indio (D'Antoni, 1983) shows that the greatest environmental change of the last 30,000 yr occurred some 10,000 yr ago, as the vegetation changed from a glacial Patagonian community to the present Monte formation. As in Quereo and Tagua-Tagua, the giant sloth (*Mylodon*) disappeared at the time of this environmental change.

Since near the end of the Pleistocene, ca. 10,000 yr B.P. onward, a trend toward drier conditions is implied by the almost complete absence of arboreal and aquatic taxa, and a general decrease in the diversity of the semiarid shrubland indicators. H. Veit (personal communication, 1989) has also suggested, on the basis of geomorphic evidence, that dry, warm conditions prevailed along the coast of the semiarid region during the climatic optimum.

From ca. 3000 yr B.P. onward, the pollen records from Quereo and Quintero show the reappearance of arboreal pollen and a sudden increase of aquatic taxa, associated with wetter conditions, leading to recolonization by forest taxa about 1720 yr B.P. in Quintero. This last profile shows optimal forest development only during the last millennium. Stratigraphy of the Quintero profile reveals a change from an eolian phase, represented by basal sands, to a pluvial phase, represented by peats, at 3800 yr B.P. Because of the semiarid climate of the region, this event likely represents a dramatic change in climate during the equivalent of European Sub-Boreal/Sub-Atlantic transition. This is because sea-level oscillations would not play a very relevant role in generating and closing eolian phases. Estimations of sea-level oscillation for the Holocene are about 2 m above or below the present level (Nuñez *et al.,* 1983). In addition, the steep coastline of north-central Chile would have reduced the potential impact of sea-level expansions. However, other factors such as subsidence of the coastal areas cannot be ruled out. We are currently investigating other profiles to verify the geographical extent and probable

factors which may cause this temporal sequence of eolian–pluvial phases.

Our results regarding Holocene climate in the Chilean coast are consistent with the evidence available from the Central Depression in central Chile and neighboring Argentinian Andean sites. In Laguna Tagua-Tagua (Heusser, 1983), strong dominance by Chenopodiaceae/Amaranthaceae, interpreted as indicators of warm and dry conditions, marked most of the Holocene. The upper Holocene from Tagua-Tagua shows a weak increase in arboreal, aquatic, herbaceous, and spore-producing taxa, which suggests that the wetter conditions recorded along the coast at that time did not penetrate inland, probably due to the rain-shadow effect of the coastal range. At ca. 3000 yr ago in the pollen diagram of Gruta del Indio in Argentina (D'Antoni, 1983) a decrease of riparian Monte indicators is seen, reflecting open conditions in the Monte, associated with a cooler and probably more humid climate. Two records in the Argentine Andes (Markgraf, 1983), Salina 2 (32°15′S; 2000 m) and Salado (35°10′S, 2400 m), give evidence of an environmental change at 3000 yr B.P. Prior to this time, the Monte indicators are dominated by *Ephedra,* but from 3000 yr onward pollen of Andean vegetation increased markedly. If this change is interpreted as an altitudinal decline of the limit between the Andean and the Monte vegetation, it suggests cooler temperatures.

Palynological evidence from other localities within the Chilean mediterranean region and neighboring Argentine sites also indicates a trend toward increasing aridity during the middle Holocene over a broad geographic region. This trend affected the distribution of the deciduous *Nothofagus* forest. The Vaca Lauquén profile (36°50′S), at the northern-most occurrences of *Nothofagus* forests in Argentina, shows that the northern distributional limit of several *Nothofagus* species was reached only in the last 4500 yr. During the middle Holocene, the record is primarily dominated by *N. pumilio* forest (Markgraf, 1987). The pollen diagram of Río Malleo in the Argentine Andrean *Araucaria* region (39°36′S; 1000 m) shows unusually high proportions of *Ephedra* and Umbelliferae prior to 3000 yr ago, suggesting a drier climate (Heusser *et al.,* 1988).

Where were the deciduous *Nothofagus* species during this dry period of the Holocene? The Chilean record of Rucañancu (39°33′S; 290 m) shows that winter-deciduous *Nothofagus obliqua*-type achieve dominance with Gramineae from about 8000 until about 5000 yr ago. Only in the late Holocene did the Valdivian rainforest indicator *N. dombeyi*-type prevail (Heusser, 1984).

Four Andean profiles from Vicente Pérez Rosales National Park in Chile (El Frutillar, Derrumbes I and II, and La Cumbre; 41°03′–41°12′S, ca. 900 m) show that *N. procera/obliqua* dominated in this area until about 3000 yr ago. After this time, north-Patagonian forest indicators are abundant (Villagrán, 1980). The Mallin Book site, at the same latitude in the Argentine Andes, shows a decrease of the evergreen *Nothofagus* species and the appearance of both deciduous species, *N. antarctica* and *N. pumilio* from 8500 until 3000 yr ago (Markgraf, 1983).

On the basis of the available evidence, we infer that the drier climate detected along the semiarid coast of central Chile during most of the Holocene prevailed inland as well as in the Andean foothills, within the mediterranean-type region of Chile, and also influenced the northern boundary of the temperate rain forest. Accordingly, the South Pacific subtropical high would have had a greater influence over the Chilean territory during the Holocene, causing a decrease in the moisture coming from a southwestern source. Drier climatic conditions would have affected primarily the distribution of sclerophyllous forest in central Chile, decreasing its range and allowing an expansion of semiarid shrublands from the north. Winter-decidu-

ous *Nothofagus* could have extended its distribution southward to occupy the Andes in the Lake District, which is today dominated by the Valdivian and north-Patagonian rain forests. In that case, modern climatic conditions were reached only about 3000 yr B.P.

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REFERENCES

Aceituno, P. (1988). On the functioning of the southern oscillation in the South American sector. Part I. Surface climate. *Monthly Weather Review* **116**(3), 505–524.

Covacevich, V. (1971). "Los moluscos pleistocénicos y holocénicos de San Vicente de Taguatagua." Unpublished Geology Thesis, Universidad de Chile, Santiago.

D'Antoni, H. L. (1983). Pollen analysis of Gruta del Indio. *Quaternary of South America and Antarctic Peninsula* **1**, 83–104.

Di Castri, F., and Hajek E. R. (1976). "Bioclimatologia de Chile." Imprenta Editorial de la Universidad Católica de Chile, Santiago, Chile.

Fuenzalida, P. H. (1965). Clima. *In* "Geografía Económica de Chile" (Corfo, Ed.), pp. 98–152. Editorial Universitaria S.A., Santiago, Chile.

Heusser, C. J. (1983). Quaternary pollen record from Laguna de Tagua Tagua, Chile. *Science* **219**, 1429–1432.

Heusser, C. J. (1984). Late-Glacial-Holocene climate of the lake district of Chile. *Quaternary Research* **22**, 77–90.

Heusser, C. J., Rabassa, J., Brandani, A., and Stuckenrath, R. (1988). Late-Holocene vegetation of the Andean Araucaria Region, province of Neuquén, Argentina. *Mountain Research and Development* **8**, 53–63.

Levi, U. (1951). Esquema ecológico del bosque de Quintero. *Investigaciones Zoológicas Chilenas* **1**, 4–18.

Looser, G. (1944). Anotaciones fitosociológicas sobre la región de Quintero. *Revista Universitaria* **29**, 27–33.

Markgraf, V. (1983). Late and postglacial vegetational and paleoclimatic changes in subantarctic, temperate, and arid environments in Argentina. *Palynology* **7**, 43–70.

Markgraf, V. (1987). Paleoenvironmental changes at the northern limit of the subantarctic Nothofagus forest. *Quaternary Research* **28**, 119–129.

Nuñez, L., Varela, J., and Casamiquela, R. (1983). "Ocupación Paleoindio en Quereo: Reconstrucción Multidisciplinaria en el territorio semiárido de Chile." Imprenta Universitaria, Universidad del Norte, Antofagasta, Chile.

Paskoff, R. P. (1970). "Le Chili semi-aride." Biscaye Freres, France

Paskoff, R. P. (1971). Edad radiométrica del mastodonte de Los Vilos. *Noticiario Mensual Museo Historia Natural* **177**, 11.

Ramirez, C., Ferriere, F., and Figueroa, H. (1983). Estudio fitosociológico de los Bosques pantanosos Templados del Sur de Chile. *Revista Chilena de Historia Natural* **56**, 11–26.

Schmithüsen, J. (1956). Die raumliche Ordnung der chilenischen Vegetation. *Bonner Geographische Abhandlungen* **17**, 1–86.

Sundt, L. (1903). Restos de un mastodonte encontrado cerca de Los Vilos. *Anales Universidad de Chile* **113**, 555–560.

Varela, J. (1976). Geologia del Cuaternario de Laguna Taguatagua (Provincia de O'Higgins). *Actas del Primer Congreso Geológico Chileno*, 81–113.

Varela, J. (1979). Geología del Cuaternario de la región de la Quebrada Quereo, Los Vilos, Prov. Choapa, IV region. *Actas del Segundo Congreso Geológico Chileno* **3**, 141–159.

Varela, J. (1981). Geología del Cuaternario del área de Los Vilos-Ensenada El Negro (IV Región) y su relación con la existencia del bosque "relicto" de Quebrada Quereo. *Comunicaciones* **33**, 17–30

Villagrán, C. (1980). Vegetationsgeschichliche und pflanzensoziologische Untersuchungen im Vicente Pérez Rosales Nationalpark (Chile). *Dissertationes Botanicae* **54**, 1–165.

Villagrán, C. (1982). Estructura floristica e historia del bosque pantanoso de Quintero (Chile, 5. región) y su relación con las comunidades relictuales de Chile Central y Norte Chico. *Actas del Tercer Congreso Geológico Chileno*, 377–402