THE CLASSICAL LATE WEICHSELIAN CLIMATIC FLUCTUATIONS IN MEXICO

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INTRODUCTION

With respect to the classical Late Weichselian climatic fluctuations (Fig. 1) of the Netherlands and Western and Central Europe many scientists tried to establish similar chronostratigraphies of climatic variations for other parts of the world (e.g. Chile, Western North America, New Zealand, South Antarctica). Recent investigations give more and more evidence that the classical West European chronostratigraphy of the Late Weichselian in many details is a *regional* stratigraphy and cannot be transferred to other areas of the world.

Therefore it is necessary to focus our attention on many different parts of the world, especially on the tropics and subtropics in order to establish a great number of seperate chronostratigraphies. I will present here the results of investigations carried out during the last two decades in the central Mexican highland (Puebla/Tlaxcala area, Fig. 2) by many scientists which were involved in the German-Mexican "Mexico Project" of the DEUTSCHE FORSCHUNGSGEMEINSCHAFT.

The conclusions concerning the Late Quaternary climatic history of the central Mexican highland are based on the results of research in geomorphology, tephrochronology, palaeopedology, and palaeoclimatology.

I. CHRONOLOGY OF GLACIAL DEPOSITS, EASTERN CORDILLERA NEOVOLVANICA, MEXICO

In many papers I have reported on the late Quaternary chronostratigraphic situation of the central Mexican volcanoes

N.-A. Mörner and W. Karlén (eds.), Climatic Changes on a Yearly to Millennial Basis, 95–115.

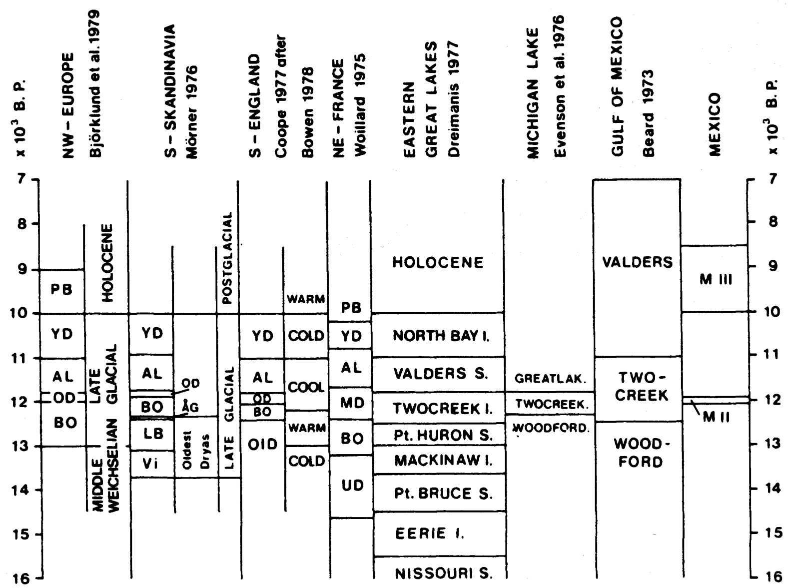


Fig. 1: Chronostratigraphy of the Late Weichselian according to various sources.
PB - Preboreal; YD - Younger Dryas; AL - Allerød;
OD - Older Dryas; MD - Middle Dryas; BO - Bølling;
I. - Interstadial; ÅG - Ågard; LB - Low Baltic;
Vi - Vintapper; OLD - Oldest Dryas; UD - Upper Dryas;
S. - Stadial

(Heine, 1975, 1978, 1980, 1983, in press). Volcanoes of the Cordillera Neovolcânica with late Quaternary glacial deposits are shown in Fig. 2. Intensive investigations concerning the glacial history of the volcanoes numbered 2 to 10 (Fig. 2) were carried out during 1971 - 1975. A summary of the palaeogeographic reconstruction of the eastern Cordillera Neovolcânica area for the time 40,000 yr BP to present is presented in Fig. 3.

The area of investigation comprises the eastern part of the volcanic belt (Cordillera Neovolcânica) that is composed of eroded late Tertiary and Quaternary volcanic and sedimentary rocks and extends for nearly 1000 kms along the 19th parallel north. The huge volcanic massifs constitute barriers which separate the valleys or basins from each other. Principal geographic features include five volcanic massifs (from west to east: Nevado de Toluca, Ajusco, Sierra Nevada with Popocatêpetl, Iztaccîhuatl, Tlâloc and Telapôn, Malinche, and Pico de Orizaba with Cofre de Perote) and four basins (basin of Toluca, basin of Mexico, basin of Puebla/Tlaxcala, and basin of El Seco/Oriental). The elevations of the basins range from about 2200 to 2600 m, whereas the

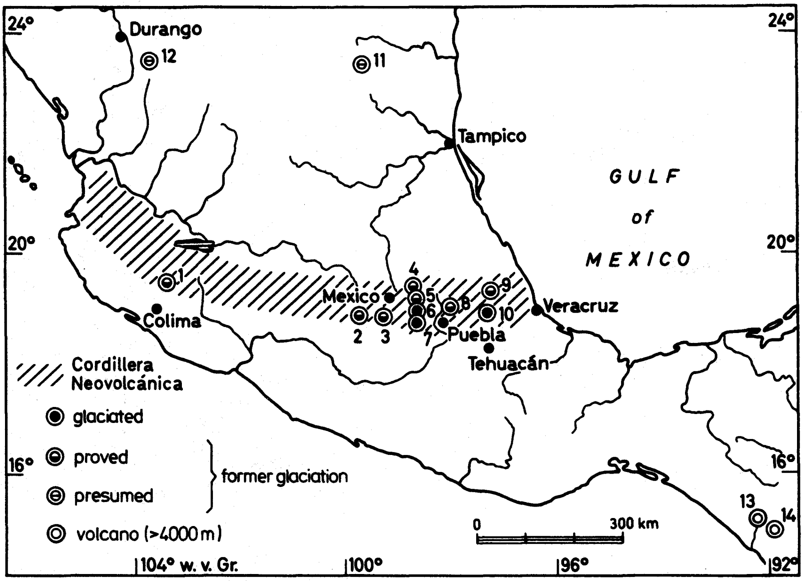


Fig. 2 : Index map of the Cordillera Neovolcânica, Mexico. Circles indicate the location of the volcanoes: 1 - Nevado de Colima, 2 - Nevado de Toluca, 3 - Ajusco, 4 - Tlâloc, 5 - Telapôn, 6 - Iztaccîhuatl, 7 - Popocatêpetl, 8 - Malinche, 9 - Cofre de Perote, 10 - Pico de Orizaba, 11 - Cerro Peña Nevada, 12 - Durango mountaneous area, 13 - Tacanâ, 14 - Tajumulco.

peaks of the volcanoes have heights between 3952 m (Ajusco) and 5700 m (Pico de Orizaba).

Different late Quaternary stratigraphic successions can be recognized within the area. The slopes of the volcanoes are dissected by barrancas (erosion gullies), radiating from the upper parts of the forest belt and descending to the basins. Thus the stratigraphic successions can easily be traced from one barranca to the other by the different layers of glacial and periglacial deposits, palaeosols, debris, fluvial gravels and sands, and loess-like so-called "toba"-sediments which are interbedded with tephra, lava flows, and ignimbrite deposits. The term "tephra" pertains to all pyroclastic fragments, such as fine and coarse ash, lapilli, volcanic bombs, and blocks.

Different tephra layers as well as some palaeosols are of great use as stratigraphic markers within the late Quaternary deposits of the volcanoes. In determining the stratigraphic succession of tephra, both field characteristics and laboratory examination were carried out. Radiocarbon dating of tephra layers has been restricted to charcoal logs and branches imbedded in the

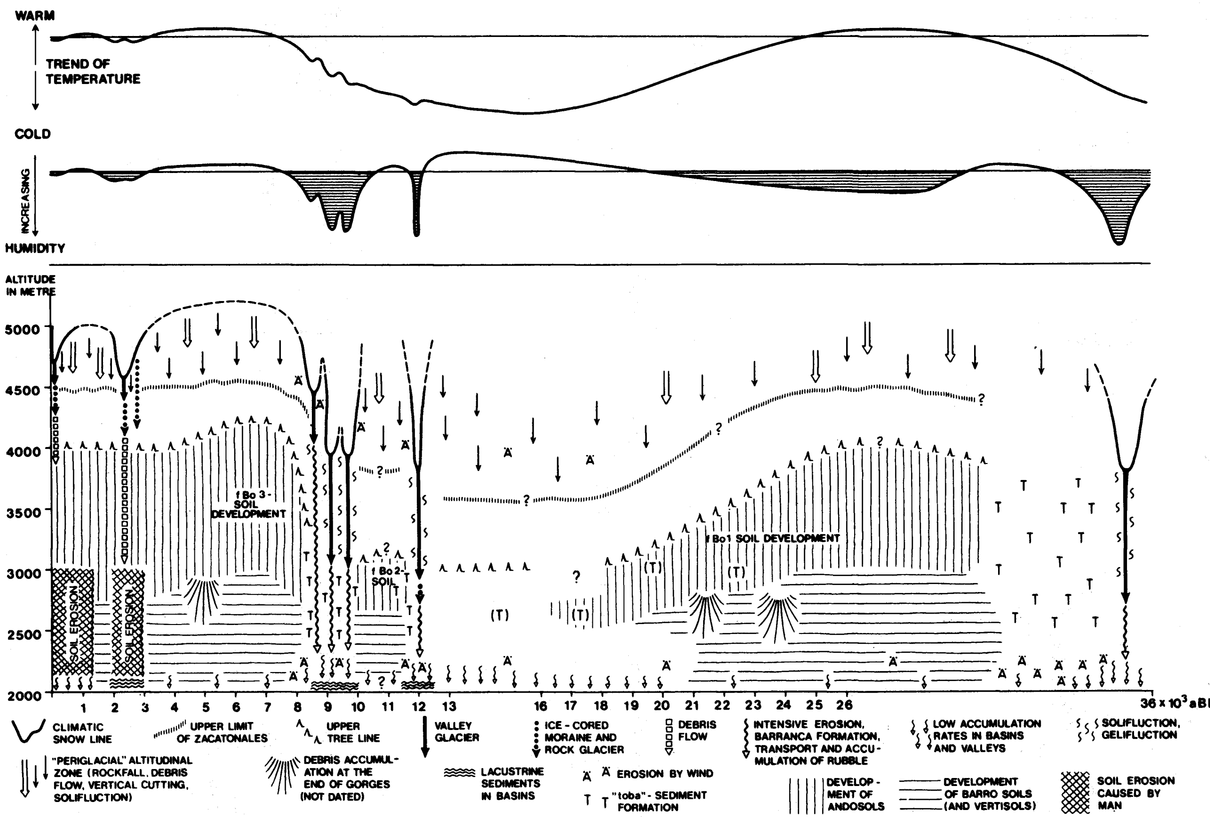


Fig. 3: Scheme of three-dimensional development of the natural environment of the central Mexican highland during the Late Quaternary.

volcanic deposits. Many samples from charcoal were dated by M.A. Geyh. In addition to these data palaeosols, wood fragments from gravels, peat, and calcrete (caliche) deposits were dated by radiocarbon. Other age determinations of the late Quaternary deposits are being attempted through studies in archaeology and prehistory. Pollen studies in cores of sediments in small volcanic craters, maars, and lakes (Ohngemach & Straka, 1983) cover the time span of approximately 35,000 to 0 yr BP. The results are compared with the chronology of the glacial deposits. Furthermore, relative age-dating methods have been used to demonstrate age differences in the till sequence; such relative dating methods include topographic position, morphologic shape of the moraines, rock-weathering parameters, thickness of aeolian "toba"-sediments, soil properties, and vegetation cover (including lichen data of Holocene glacial and periglacial deposits).

A scheme of the three-dimensional development of the natural environment of the central Mexican highland during the late Quaternary is given in Fig. 3. Periods of normal and of catastrophic processes, stability, and erosion during the past 36,000 yr BP are immediately recognizable. The processes which are controlled by the bioclimatic milieu create distinctive soils and landforms. During the past 36,000 yr BP three major periods with climatically induced high erosion intensities and glacier advances can be distinguished: (i) 36,000 to >32,000 yr BP, (ii) around 12,000 yr BP, and (iii) 10,000 to 8,500 yr BP. These periods with high erosion intensities and glacier advances coincide with climatic changes from relative aridity to greater humidity. Figure 3 shows that there is no synchroneous development of the trend of the temperature on the one hand and of the trend of the humidity on the other hand. The temperature curve for the last 36,000 yr BP is marked in the tropics of the central Mexican highland by an increase between 36,000 and 32,000 yr BP, a decrease between ca. 26,000 and ca. 16,000 yr BP (with the last glacial temperature minimum around 17,000 - 16,000 yr BP), and an increase of the temperature with minor fluctuations during the period 16,000 to 8,000 yr BP. The postglacial climatic optimum is reached 8,000 to 5,000 yr BP. During the Holocene, only between ca. 2,000 and 3,000 yr BP the climate was slightly cooler and wetter, producing a minor glacier advance.

Chronology of Late Weichselian Glacial Deposits

The chronology of the Late Weichselian glacial deposits is best known at the Malinche volcano. There, most of the late glacial tills are related to volcanic rocks and tephra as well as to organic materials that can be dated by radiocarbon. By means of tephrochronologic methods valley-to-valley correlation of tills is possible. The general distribution and dimensions of the late Quaternary glaciers of the Malinche volcano and problems associated with the identification and differentiation of each glacier advance and their age relationship were discussed by the author in previous papers (Heine, 1975, 1978, 1980, 1983). Tills with poorly preserved moraine forms are those of the M I-glacier advance between 36,000 and >32,000 yr BP and of tills deposited during the M II-glaciation about 12,000 yr BP. Lateral and end moraines deposited during the M III-glaciation between 10,000 and 8,500 yr BP show well preserved morainal forms, so do the Holocene neoglacial deposits which are divisible into two advances (M IV: 2000 - 3000 yr BP; M V: Little Ice Age). A map of the summit area of the Malinche volcano with the locations of the principal glacial and periglacial deposits is presented in Fig. 4. An outline of the local stratigraphy of the glacial deposits at the eastern slopes of the Malinche volcano (Fig. 5), based mainly on palaeosols (fBo1, fBo2, fBo3) and tephra layers (marker horizon

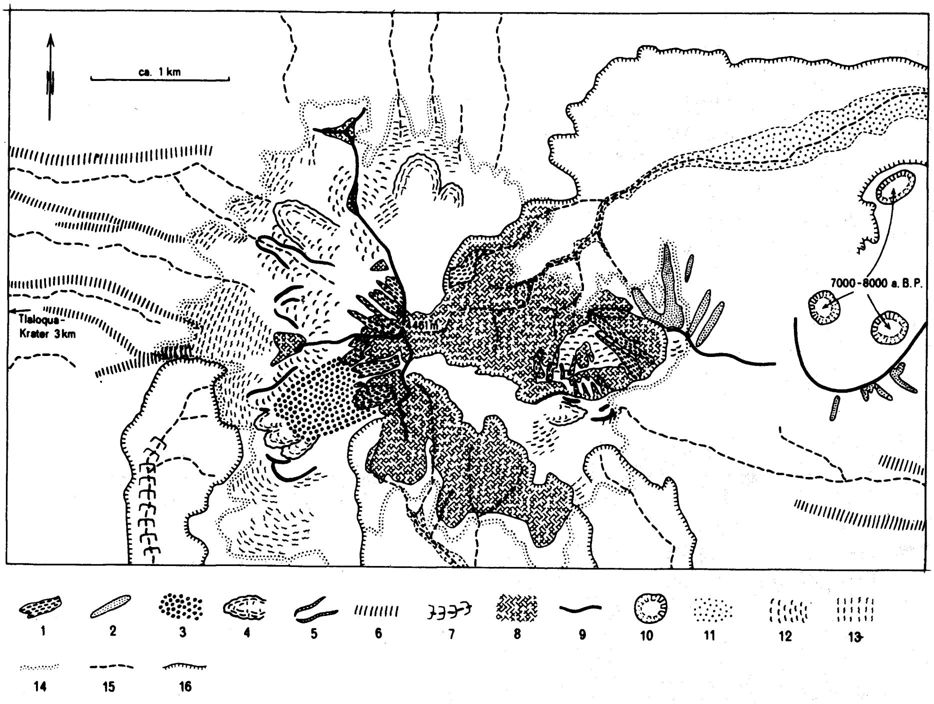


Fig. 4: Geomorphological map of the Malinche summit area.
1 - Talus debris, 2 - slope with volcanic sands, 3 - rock glacier, 4 - M IV-rock glacier, 5 - M III 3-moraine, 6 - M III 2- and M III 1-moraine, 7 - U-shaped valley, 8 - rock, 9 - crest, 10 - crater (age in ^{14}C years BP), 11 - gravel, 12 - solifluction terracette, 13 - turf exfoliation, 14 - upper timber line (ca. 3900 - 4000 m), 15 - valley, barranca, 16 - edge versus valley.

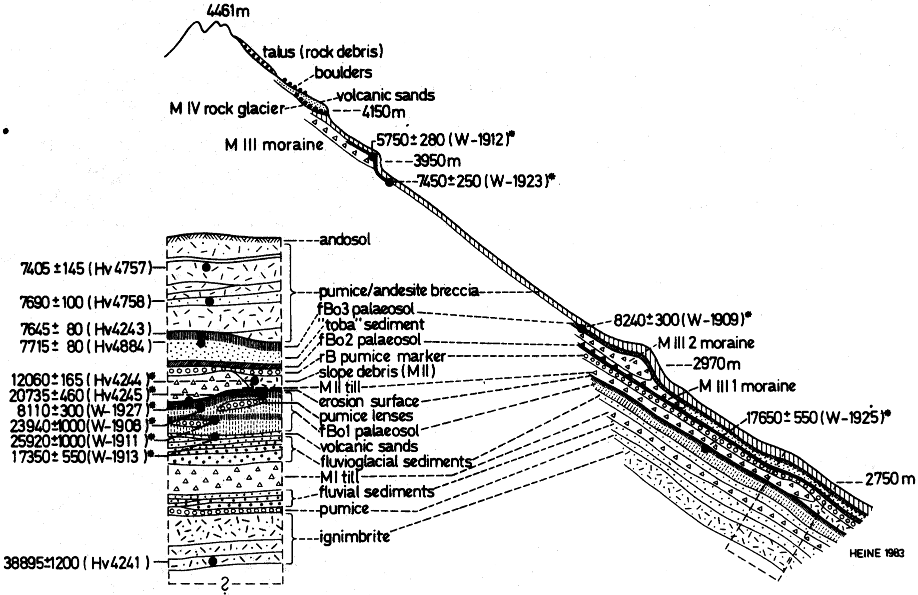


Fig. 5: Scheme of the stratigraphy of the Late Quaternary deposits at the eastern slopes of the Malinche volcano. The ^{14}C dates marked with stars refer to the western flank of the volcano.

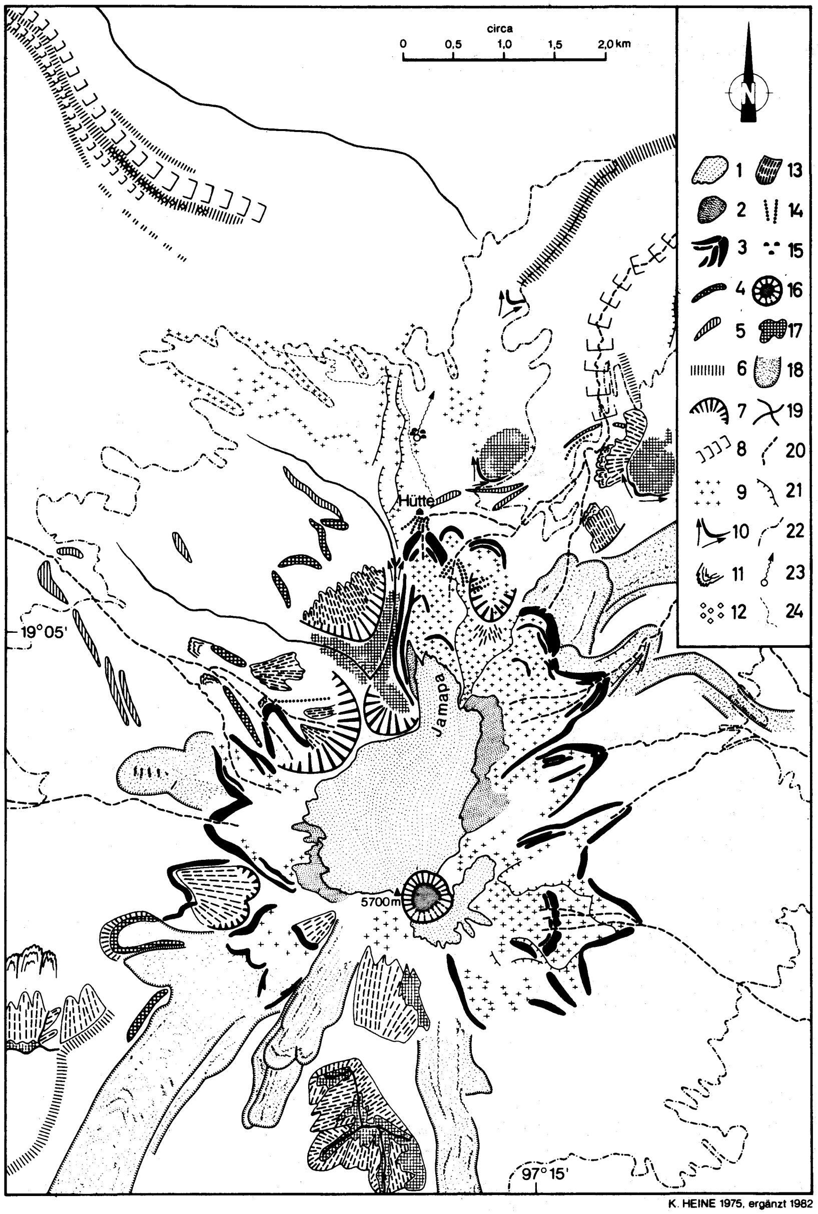
rB), provide sufficient information of how different late Quaternary stratigraphic successions have been elaborated.

From the other volcanoes of the Cordillera Neovolcánica, deposits belonging to the major glaciations of the late Quaternary are described in detail by Heine (1975). Figures 6 to 8 give evidence of the location of the glacial and periglacial deposits on Pico de Orizaba, the southern part of Iztaccīhuatl, and the Nevado de Toluca volcano. Comparable to the late Quaternary stratigraphic successions of the Malinche volcano are the glacial deposits of these other volcanoes. Apart from the M II-glaciation that did not exist at the Nevado de Toluca volcano (see Heine, 1983), five glacier advances of the late Quaternary can be traced on the slopes of Pico de Orizaba and Iztaccīhuatl, whereas on the flanks of the less high volcanoes of Nevado de Toluca and Malinche the Holocene glacial deposits of the M IV and M V phase do not occur. Instead of the glacial deposits periglacial forms and deposits developed here (rock glaciers, ice-cored moraines, rock debris).

In the correlation diagramm (Fig. 9) most geologic-climatic unit boundaries are based either on maximum or minimum radiocarbon dates or on relative criteria. In most cases radiometric controls are very reliable and the presented boundaries will likely not be shifted on the time bar.

The Period about 16,000 to 12,000 yr BP

During the period of 16,000 to 12,000 yr BP there were no major glacier advances on the central Mexican volcanoes. The soil deve-



lopment of the palaeosol fBol terminated about 16,000 yr BP according to radiocarbon dates of charcial from pumice layers

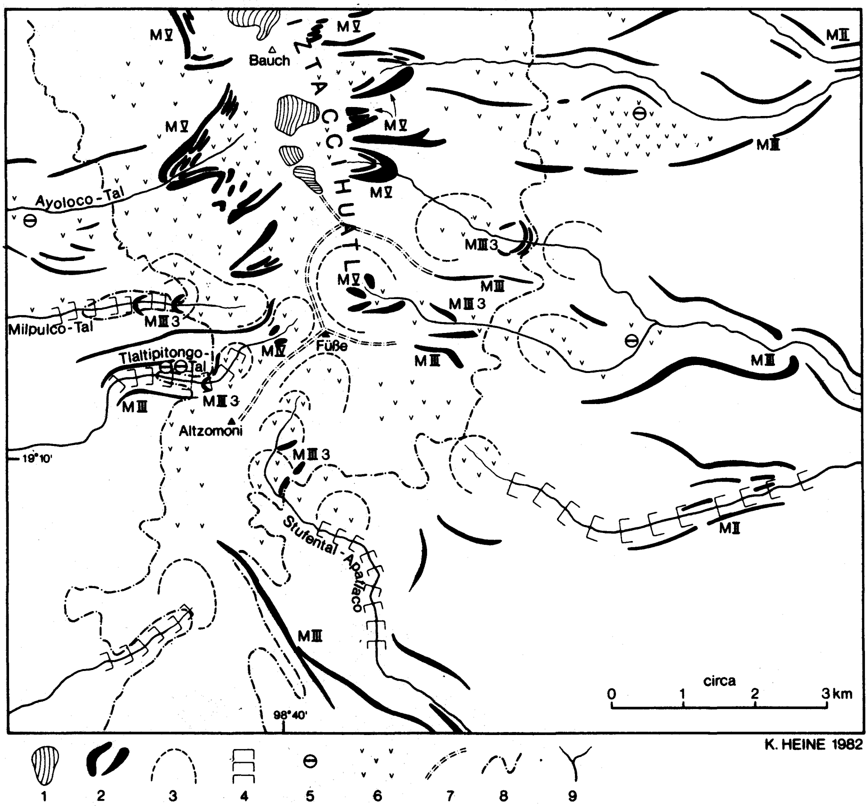
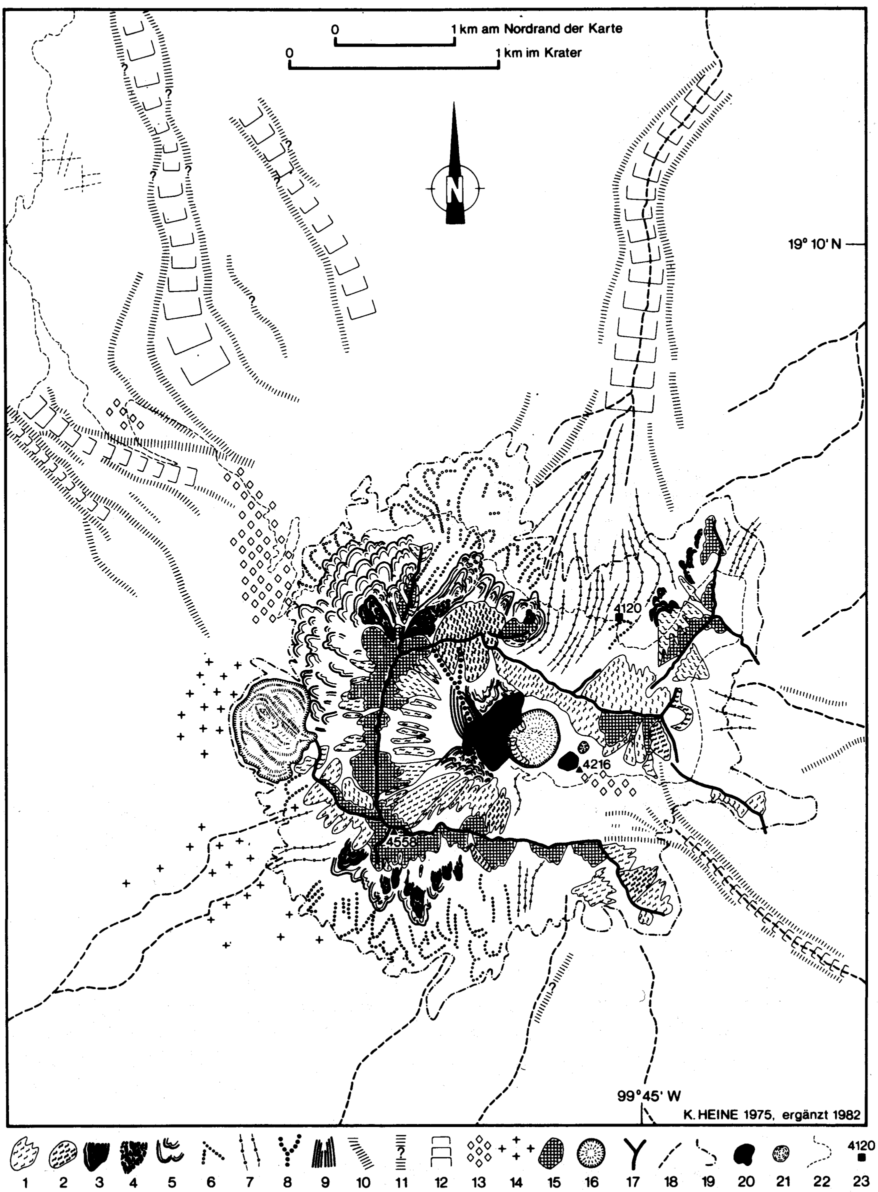


Fig. 7: Geomorphological map of the southern part of the Iztaccīhuatl massif. 1 - glacier, 2 - M V-moraine, 3 - cirque, 4 - U-shaped valley, 5 - striated ground, 6 - roche moutonée, 7 - crest, 8 - upper timber line, 9 - brook (periodic).

Fig. 6: Geomorphological map of the Pico de Orizaba. 1 - glacier, 2 - fossil ice beneath debris, 3 - M V-moraine, 4 - M IV-moraine, 5 - M III 3-moraine, 6 - M III 2- and M III 1-moraine, 7 - cirque, 8 - U-shaped valley, 9 - roche moutonée, 10 - ice-free crest during maximum glaciation, 11 - rock glacier (Little Ice Age), 12 - striated blocks on moraine, 13 - talus, 14 - debris flows, 15 - thufur, 16 - crater, 17 - steep walls, 18 - lava flow, 19 - crest, 20 - valley, barranca, 21 - edge versus valley, 22 - upper timber line (ca. 4000 m), 23 - well with brook, 24 - path.

covering the A_h-horizon of the palaeosol fBol. No traces of erosion on the slopes of the volcanoes are visible. If the preservation of the topsoil of the palaeosol fBol during the period 16,000 to 12,000 yr BP is taken to be an evidence for relatively weak erosion and denudation on the mountain flanks, then the climate must have been relatively dry and cool compared with today.



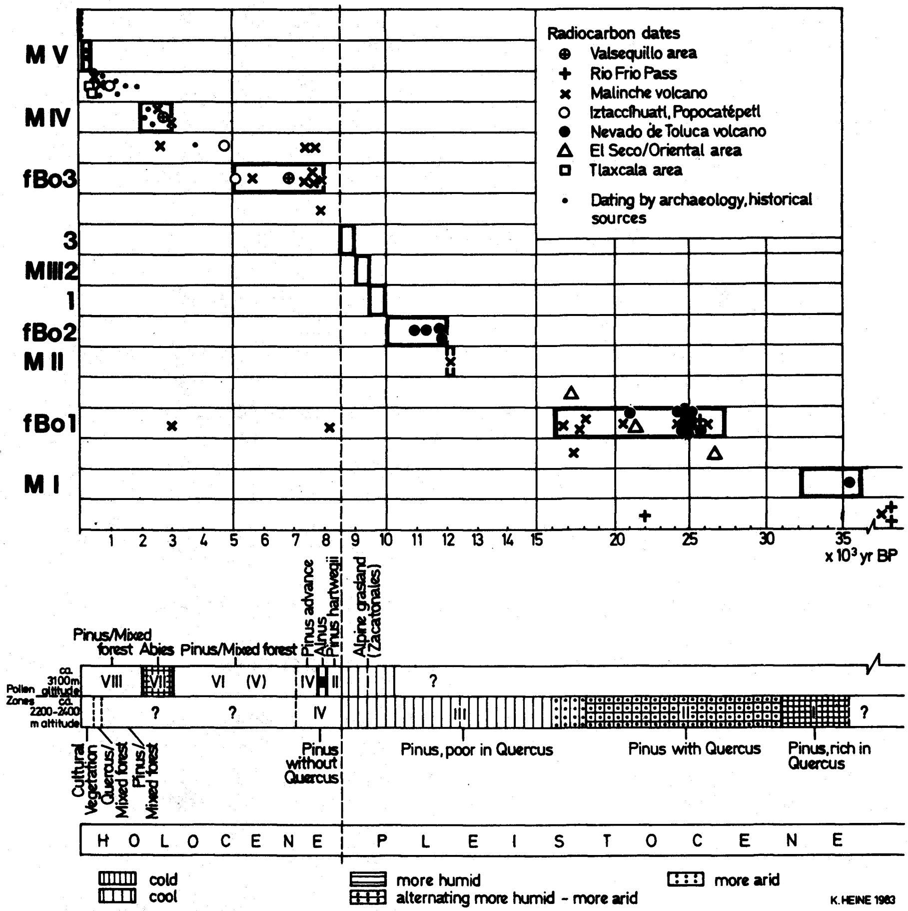


Fig. 9: Correlation diagram. Geologic-climatic unit boundaries are based on radiocarbon ages, tephrochronologic correlations, soil development, pollenanalyses, sedimentologic criteria, and topographic position. The pollen zones refer to Ohngemach & Straka (1983).

Fig. 8: Geomorphological map of the Nevado de Toluca volcano. 1 - talus, 2 - 'Glatthang' (straight smooth slope), 3 - rock glacier (phase I), 4 - rock glacier (phase I), 5 - rock glacier (phase II), 6 - rock glacier (phase III), 7 - valleys in debris, 8 - debris flow, 9 - debris flow lobe, 10 - M III-moraine, 11 - M III-moraine, not clearly identified, 12 - U-shaped valley, 13 - till, 14 - roche moutonée, 15 - rock, 16 - volcanic plug, 17 - crest, 18 - valley, barranca, 19 - upper timber line (ca. 4000 m), 20 - crater lake, 21 - dry lake, 22 - road, 23 - hut with altitude in meter.

Relative dry conditions are indicated by the preservation of the palaeosol fBo1. Relative cool conditions are indicated by the termination of the development of the palaeosol fBo1, because the soil formation and the soil properties only depend on climate and altitude (Miehlich, 1974). It is significant that the period 16,000 to 12,000 yr BP is not represented by any radiocarbon date obtained from deposits of the slopes of the volcanoes (Fig. 9).

The M II-Glacier Advance at about 12,100 yr BP

The M II-glacier advance occured around 12,100 yr BP, but only on the high volcanoes east of the basin of Mexico M II-moraines extend down to lowest elevations of less than 2750 m in huge valleys of the Malinche and Pico de Orizaba. Above 3000 to 3300 m they are covered by a mantle of volcanic tephra, debris, and younger glacial and periglacial deposits, so that the erosion of the barrancas do not reach the M II-morainic material; therefore nothing is known about the upper limit of M II-tills on the mountain slopes. The M II-glacial episode is characterized by a short duration of presumably less than 200 years according to investigations of the moraines and other glacial, periglacial, and fluvial sediments (Heine, 1983). The M II-glacier advance was caused by intense precipitation rather than by a temperature decrease. This increase in precipitation has been observed in various sediments from sites of the Sierra Nevada, the Malinche, and the Pico de Orizaba. It is not represented by any deposits east of the basin of Mexico, e.g. at the Nevado de Toluca, which I believe marks the influence of the Gulf of Mexico in respect to the short but intense increase in precipitation around 12,100 yr BP.

The Period from 12,000 to 10,000 yr BP

The period between about 12,000 and 10,000 yr BP is characterized by soil formation on the slopes of the high volcanoes. The palaeosol fBo2 was developed. According to the altitudinal belt of the formation of the palaeosol fBo2 the climate must have been relatively cool compared with today.

The M III-Glacier Advances between 10,000 and 8,500 yr BP

During the period between 10,000 and about 8,500 yr BP the complex of the M III-moraines were formed. The first and second advances of the M III-glaciation led to the formation of huge lateral and end moraines (see Fig. 4 - 8). These moraines extend from below the present tree line about 4000 m down to around 2900 m (first advance: M III 1) and 3000 m (second advance: M III 2) respectively. Recessional moraines of the M III-glaciation (M III 3) are found at about 4000 m altitude at the Malinche, whereas moraines of this advance reach farther downvalley on the flanks of the Sierra Nevada and the Pico de Orizaba, because of the greater extent of the zone of net accumulation above the firn line during the M III 3-glacier advance (Fig. 10). It is interesting to note that during the M III 3-glaciation the formation

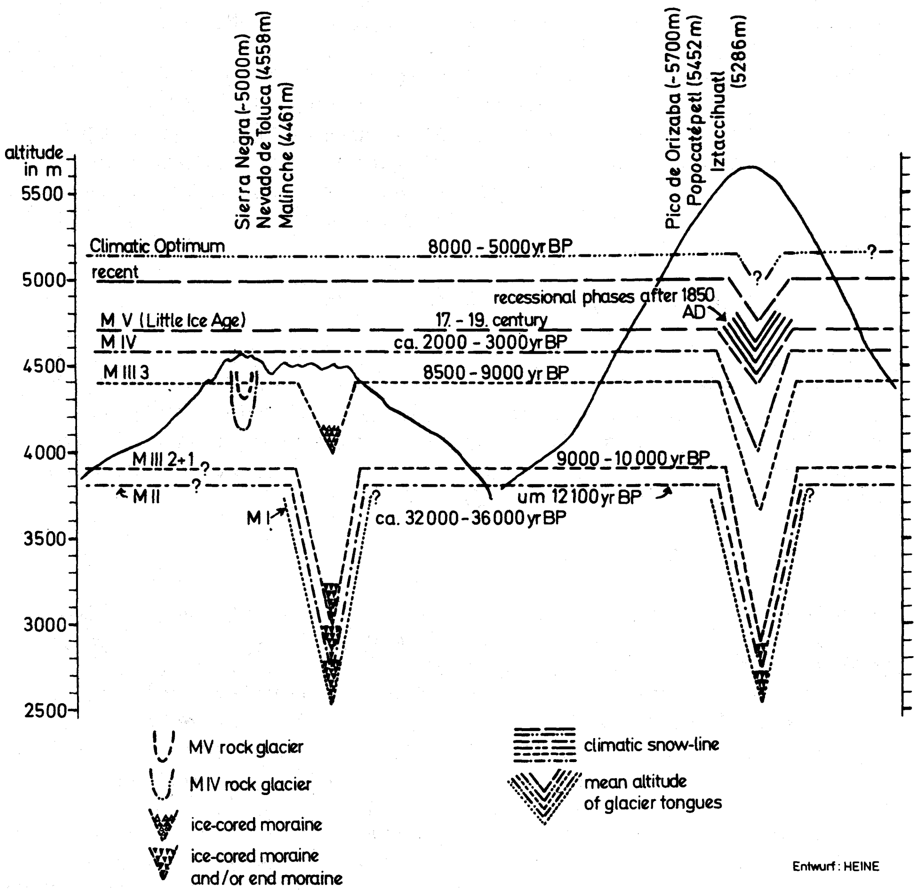


Fig. 10: Climatic snow lines reconstructed for the different Late Quaternary glacier advances.

of ice-cored moraines was very common on the Nevado de Toluca (Fig. 8) (Heine, 1976). The M III-glacier advances reflect a lowering of the climatic snowline during the period 10,000 - 9,000 yr BP of approximately 800 m in reference to the snowline of 1850 AD.

Since about 9,000 yr BP the mean annual temperatures increased so much that the relationship between temperature and precipitation led to a rapid shift of the climatic snowline to higher elevations. Only a few recessional moraines give evidence of minor glacier fluctuations during the period 9,000 to 8,500 yr BP.

The Period from 8,500 to 5,000 yr BP

The rapid deglaciation terminated ca. 8,500 yr BP. According to the radiocarbon dates of the palaeosol fBo3 that developed either on the M-III-tills and/or on volcanic tephra of post-Pleistocene age (Fig. 5) the period between 8,000 and 5,000 yr BP was slightly warmer than recent times; the development of andosols took place even in areas up to 4200 m altitude (today andosol development is restricted by low temperatures over 4000 m altitude). The postglacial climatic optimum is documented in the central Mexican highland by the palaeosol fBo3.

The Period from 5,000 yr BP to Recent Times

During the last 5,000 years, two periods with glacier advances occurred. The M IV-glaciation is dated to about 2,000 to 3,000 yr BP. A minor glaciation can be correlated with the Little Ice Age. Since about 1850 AD to 1972, the ice caps and glaciers of the Iztaccîhuatl, Popocatêpetl, and Pico de Orizaba were reduced to small remnants of ice (Heine, 1983b).

Palynologic Analyses

Palynologic, sedimentary, and radiocarbon analyses of gyttja, clay, sand, ash, lake marl, and other deposits, formed in small craters and maars, provide a palaeoenvironmental and palaeoclimatic record of approximately 35,000 yr BP for the eastern Cordillera Neovolcânica (Ohngemach & Straka, 1983; Heine & Ohngemach, 1976). Of special interest is a pollen sequence of the Tlaloqua crater which is situated at an altitude of about 3100 m on the western slope of the Malinche volcano (Fig. 11).

During the M III-glaciation (lower part of the diagram, Fig. 11) the upper zone of the forest certainly consisted of pines just as today, for pine pollen mostly accounts for more than 80 % of the pollen during the time rich in NAP. *Alnus* and *Quercus* play a comparatively minor part (Ohngemach 1977). Of particular interest is the occurrence of *Picea*, a genus encountered in Mexico today only at a few relict stations. The nearest site of *Picea chihuahuana* is situated 900 km north-west of the Malinche volcano, *Picea mexicana* is found some 700 km to the north. The pollen of *Picea* occurs below about 2 m in every sample, above the 2 m level, *Picea* is no longer found. The extinction of *Picea* coincides with the rapid decrease of the NAP curve (Ohngemach, 1977). According to Heine (1975, 1980, 1983a; see Fig. 3) the climate was cooler and more humid than today during the M III-glacial advances. Such a climate may have been the precondition for the former presence of spruce at the Malinche volcano and the basin of El

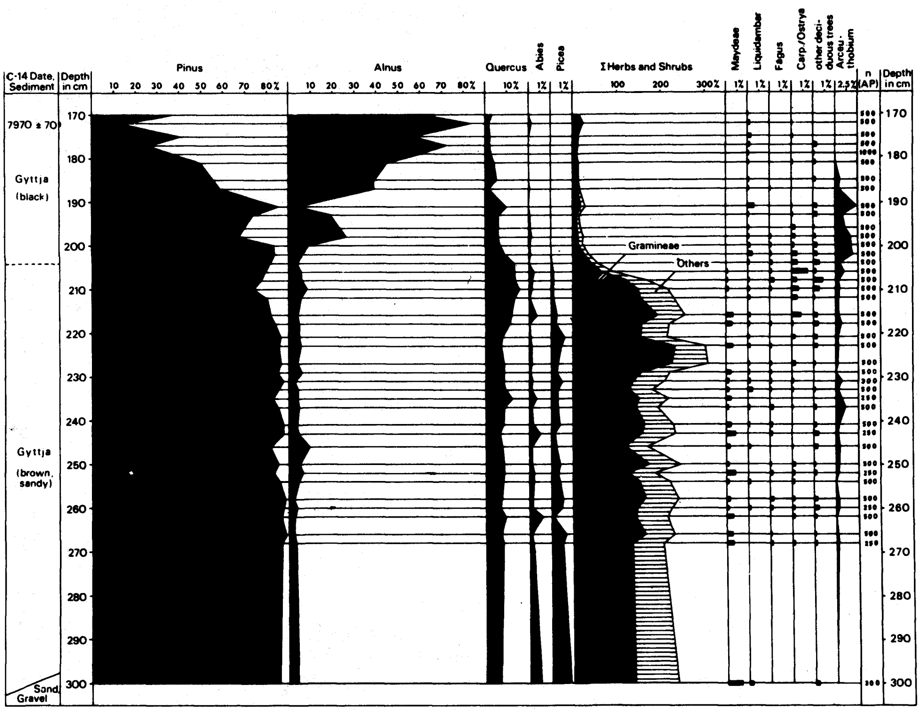


Fig. 11: Pollen diagram of the Pleistocene/Holocene boundary at the Malinche volcano, Mexico (after Heine & Ohngemach, 1976 and Ohngemach & Straka, 1983).

Seco/Oriental (Ohngemach & Straka, 1983). When the climate became drier and warmer after the M III-glaciation, *Picea* was not able to persist any longer and dies out (Ohngemach, 1977; Heine & Ohngemach, 1976). The level marked by the extinction of *Picea* is taken as the boundary between Pleistocene and Holocene vegetation. Provided that the diagram (Fig. 11) starts shortly after the beginning of M III-glaciation at 10,000 yr BP, one reaches an age of some 8,500 yr BP for this transition, if one takes further into account a radiocarbon date (ca. 8,000 yr BP) for the *Alnus* maximum at 1.7 m together with the supposition of a constant sedimentation rate (Ohngemach 1977). This agrees well with the fixation of the Pleistocene/Holocene boundary based on geomorphologic, palaeopedologic, and palaeontologic evidence (Heine & Ohngemach, 1976).

The region around the Tlaloqua crater was only a transit station to higher elevations for the *Pinus hartwegii* forest that succeeded the late Weichselian alpine grassland after about 8,500 yr BP (see also Fig. 9). Ohngemach (1977) and Ohngemach & Straka (1983) infer the presence of *Pinus hartwegii* from the occurrence of the parasite *Arceuthobium globosum* ssp. *graudicaule* by which *Pinus hartwegii* is preferably infected.

According to the pollen diagrams of Ohngemach & Straka (1983) no noticible deterioration in temperature occurred during the Late Weichselian and early Holocene trend of warming (16,000 to 8,000 yr BP). On the other hand, the M I-glaciation, the M III-glacier advances, and the M IV-glaciation are well recorded in the pollen diagrams.

II. PALAEOCLIMATIC INTERPRETATION

In the central Mexican highland, the Late Weichselian (ca. 16,000 to 8,500 yr BP) is characterized by increasing temperatures without the well-known sudden deteriorations of temperature during the Older and Younger Dryas periods. Apart from the 12,000 yr BP event (Heine, 1983a) that seems to be triggered by an enormeous increase in precipitation rates mainly in the regions facing the Gulf of Mexico-coast, only the period 10,000 to 8,500 yr BP shows climatic conditions favorable for greater glaciations on the high mountains. This Late Weichselian climatic fluctuation is caused by higher precipitation during a period with increasing temperatures between the relatively cold phase of oxygen isotope stage 2 and the warm postglacial climatic optimum of oxygen isotope stage 1. The palynologic evidence indicates, too, that the Pleistocene/Holocene boundary is dated to about 8,500 yr BP in the central Mexican Highland. Different pollen diagrams from the area prove that no abrupt climatic fluctuations in temperature comparable to the Older and Younger Dryas periods occurred. Even the 12,000 yr BP event cannot be traced in the pollen diagrams, presumably because of the short duration of the 12,000 yr BP event of less than 200 years (Heine, 1983a).

The classical Late Weichselian climatic fluctuations of the central Mexican highland are (i) with respect to the temperature; increasing temperatures without any major variations and/or abrupt fluctuations, and (ii) with respect to the precipitation: a short but great increase of precipitation about 12,000 yr BP and a period with higher precipitation between 10,000 and 8,500 yr BP. Yet, until today we cannot estimate the absolute amount of precipitation during the various Late Weichselian glaciations. The pollen studies show that the Late Weichselian fluctuations in precipitation in the basins must have been of no significant influence for the vegetation. We might conclude, because of this, and because of the shrinkage of the glaciers since the Little Ice Age maximum glacier extent in 1850 AD that took place without any significant variations in temperature and/or precipitation, that the Late Weichselian glaciations were due to only slightly altered conditions in humidity.

III. CORRELATION WITH LATE QUATERNARY EVENTS IN OTHER REGIONS

The late Quaternary environmental history of Lake Valencia/Venezuela (Bradbury et al., 1981) obtained by chemical, palaeontological, and mineralogical analyses of a 7.5 m core from the lake allows a tentative correlation with the situation in central Mexico. The data show that dry climates existed in the Lake Valencia region from at least 13,000 yr BP (= the base of the core) until about 10,000 yr BP. The Lake Valencia Basin was occupied by intermittent saline marshes at that time. During the period 13,000 to 10,000 yr BP only the pollen record gives evidence for a minor increase in moisture by a small amount of arboreal pollen (*Spondias* and *Bursera*) at a depth of 6.4 m (Bradbury et al., 1981). If one takes into account a constant sedimentation rate of the 13,000 to 10,000 yr BP deposits, the increase in moisture in what otherwise was an arid climatic period can be compared to the M II-glaciation of Mexico. About 10,000 yr BP, a permanent Lake Valencia of fluctuating salinity formed and arboreal plant communities replaced the earlier dominant xeric herbaceous vegetation and marsh plants. This zone 2 of the Lake Valencia core correlates with the M III-glaciation period of central Mexico. By 8,500 yr BP, Lake Valencia reached moderate to low salinities and discharged water; the modern vegetation became established at that time. After 8,500 yr BP, the lake twice ceased discharging as a result of reduced watershed moisture (Bradbury et al., 1981). The stratigraphic record from Lake Valencia is important because it contains a continuous, well-dated, and well-documented palaeoenvironmental history of a low-latitude, low elevation site from the late Pleistocene to the present. Table 1 is a tentative correlation of palaeoenvironmental interpretations from the Lake Valencia record with the Mexican data.

The most important conclusions from Table 1 are the coincidence of the central Mexican late Quaternary chronostratigraphy with the Lake Valencia core and the evidence that the Younger Dryas period did not exist, neither in Mexico nor in Venezuela.

yr BP x 10^3	Central Mexico this paper	Lake Valencia Bradbury et al. 1981	
1	M V	zone 3	Climate generally similar to that of today
2–3	M IV		
4–8			
9–10	M III	zone 2	Humid
11		zone 1	More arid than today
12	M II		More moisture
13–14		zone 1 ? ? ?	More arid than today

Table 1: Tentative correlation of palaeoenvironmental interpretations from the Lake Valencia record with the Mexican data

The stratigraphic records from Mexico and Venezuela cannot be correlated with late Quaternary glaciations in Central and South America; the principal difficulty is the lack of adequate radiocarbon time control in most studies (Bradbury et al., 1981; Heine, 1975, 1983c). According to Mercer (1983), in the South American tropics, interpretations of past variations of glaciers in terms of climate is difficult; owing to the intensity of solar radiation year-round, the glaciers are very sensitive to changes in cloudiness and albedo of the glacier surface. Mercer (1983) reports that in Peru by 12,200 yr BP the Quelccaya Icecap was not much larger than it is today and that a later readvance that was in progress soon after 11,500 yr BP culminated after 11,000 yr BP. The icecap then shrank rapidly and shortly after 10,000 yr BP was little or no larger than it is today. The dating of the readvance after 11,500 yr BP suggests that it preceded the European Younger Dryas stade by a few centuries, but it does not preclude the possibility that they were simultaneous (Mercer, 1983). In southern South America no glacial geological evidence has been found anywhere for a readvance at the time of the Younger Dryas period (Mercer, 1983), although severe cooling and a rise in precipitation have been inferred from the pollen record (Heusser et. al., 1981). The analyses of fossil beetle assemblages through the Late Glacial of southern Chile implies a relative stable climate, too, and does not support, like the geomorphological evidence, the assumption of a major climatic deterioration about the same time as the Younger Dryas in Europe (Ashworth & Hoganson, 1983).

IV. CONCLUSIONS

The palaeonvironmental data from Mexico, Venezuela, and Chile support the hypothesis that Late Weichselian climates in the tropics of America were more arid than today. The classical Late Weichselian climatic fluctuations of the Older and Younger Dryas periods did not occur. There is evidence that these Late Weichselian climatic deteriorations are best documented in Scandinavia (Berglund et al., 1983; Berglund & Mörner, 1983) although even for middle Sweden Björck & Digerfeldt (1983) postulate that either many significant events occurred during Younger Dryas or hardly nothing at all, perhaps not even the 'famous' drainage of the Baltic Ice Lake at the northern point of Mt. Billingen. If we move away from Scandinavia to the Alps then the Older Dryas nearly disappers (de Beaulieu et al., 1983; Ammann et al., 1983) and the Younger Dryas cooling cannot have been very strong (Ammann et al., 1983). Observations from the Alps and Switzerland show that the Older Dryas stade can only be traced by 'reworked material' and not by pollen evidence (de Beaulieu et al., 1983) or as a somewhat 'drier phase' (Ammann et al., 1983). In the Alps, the Younger Dryas was more pronounced by palaeoenvironmental changes at greater heights, whereas on the Swiss Plateau the Younger Dryas climatic deterioration was less severe.

From the 'tropical point of view' we should not only look for evidence for the Older and Younger Dryas stades, but also for evidence for the non-existence of these climatic fluctuations. The low-latitude stratigraphies experience a Late Weichselian transition from full glacial dry and cold/cool climate to postglacial conditions *without* significant cold temperature anomalies.

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