

## 2. Some Remarks on the Pleistocene Vegetation

by BURKHARD FRENZEL, Stuttgart-Hohenheim

With 1 figure

### 1. Introduction

In contrast to the wealth of geological and geomorphological investigations which have been published since the days of PENCK & BRÜCKNER, botanical studies have only little contributed to a well founded understanding of the Pleistocene as regards the German part of the foreland of the Alp Mts. Moreover it must be regretted that paleobotanical investigations in the area studied in general only followed geological work without having special botanical aims of their own. Only during the last years this picture seems to have changed a little. This bad starting point is the reason why here only the main lines of vegetation history can be cautiously traced.

The most essential localities yielding material for an understanding of interglacial or interstadial vegetation history are shown in fig. 1. It is striking to see that more than 50 % of them are to be found within the area of the last glaciation. This means that their geomorphological situation does not help in evaluating their stratigraphical position. This is the reason why we don't know exactly the stratigraphical equivalent of the Eemian interglacial of Northern Germany. As to the older warmperiods the situation is still worse.

### 2. The Problem of the Riss/Würm Warmperiod

There, where closed basins have been investigated, lying between the end moraines of the main Riss glaciation on the one hand and those of the Würm glaciation on the other, e.g. in basins the geomorphological position of which raises no doubt as to their age, in no instance exact equivalents of the Eemian interglacial could be found as far as the development of vegetation is considered. This is striking since the postglacial vegetation history of Southern Germany in many respects resembled that of other comparable regions of Central Europe. From this it follows that one can hardly believe that the evolution of vegetation in Southern Germany followed during the last interglacial other principles than in Northern or Central Germany. The investigations just mentioned were done by GÖTTLICH & WERNER (1968 a) in the northeastern part of former Rhine glacier (Stockach and Meßkirch area: Maienberg and Waltere); by ourselves (unpublished) near Wilflingen to the west of Riedlingen on the river Danube, near Krumbach (to the west of Federsee), in the Jammertal (to the west of Biberach), in Füramoos (southsoutheast of Biberach), and in Wildmoos (to the west of Fürstenfeldbruck). In each case the basal moraine lying beneath the layers with plant remains was observed in the bore holes. In the Wildmoos and Füramoos, near Stockach-Meßkirch, at Wilflingen and Krumbach the following situation could be observed in basins which are till nowadays covered by bog vegetation: On top of an older drift and lacustrine clays, and covered by periglacial hill slope sediments organic layers of sometimes several meters thickness are found, the pollen-flora of which is characterized by *Pinus* und *Picea*, sometimes accompanied by other tree species. In general *Abies*, *Fagus*, *Quercus*, *Tilia*, *Ulmus*, and *Carpinus* were nearly lacking or they appeared only within the first part of this warm period in quantities which

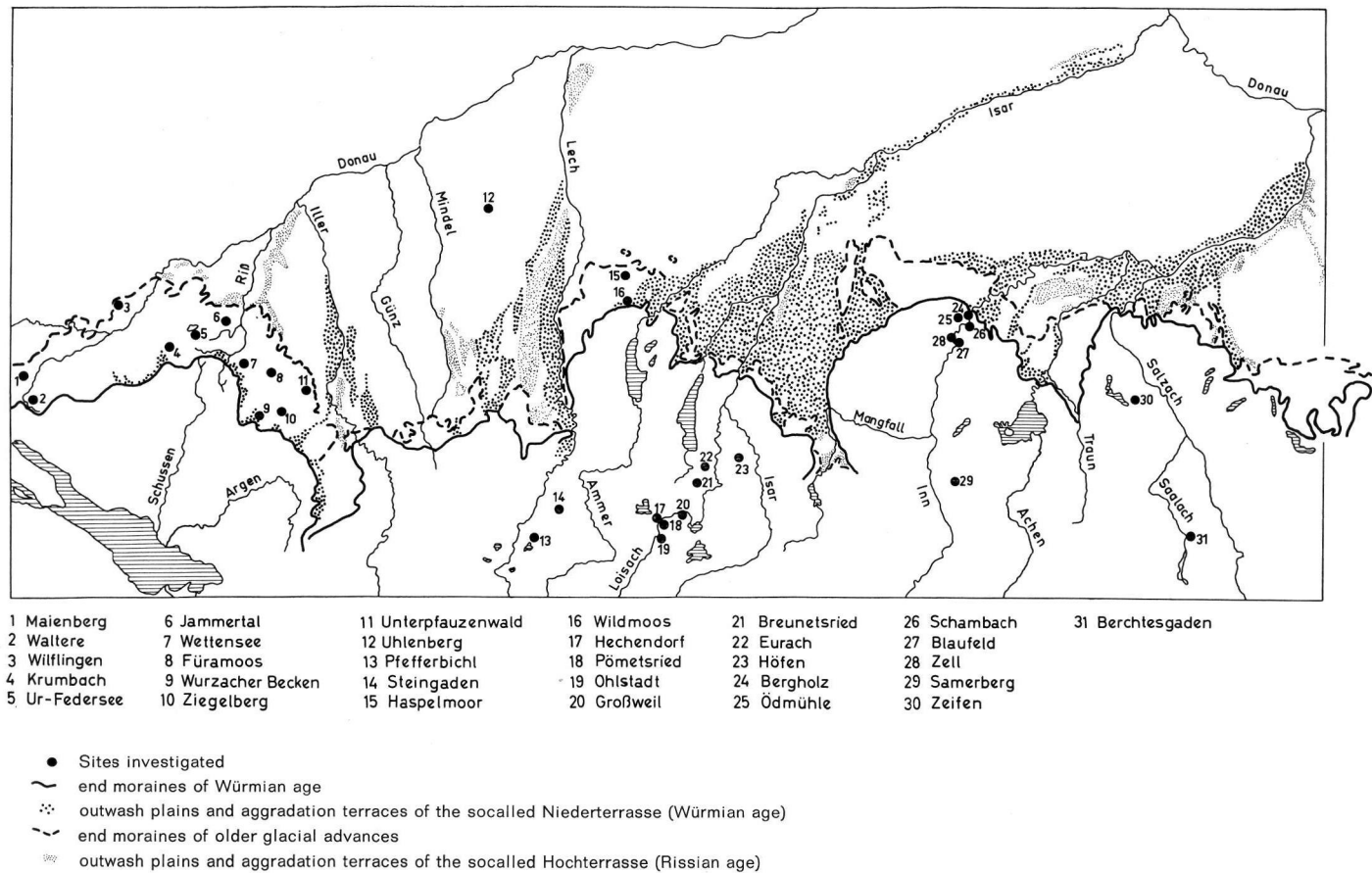


Figure 1. Geomorphological situation of the sites discussed in this paper.

changed strongly. The great amount of *Corylus* seems to show that the forest cover was not closed. Later on the coniferous forests became still more open in consequence of increasing severity of climate. At Maienberg and Waltere the organic sediments could be  $^{14}\text{C}$ -dated, yielding indefinite ages of more than 42 900 or 41 500 years before present (b.p.), and more than 24 700 or 23 300 b.p. respectively (GÖTTLICH & WERNER 1968). Since the organic sediments discussed are not overlain by interglacial layers and since these sediments were found in basins which up till now are still existing so that an erosional removal of formerly existing interglacial sediments can be ruled out, the organic sediments just mentioned must have been formed after the last classical interglacial period, i.e. after the Eemian interglacial. But still another point of interest exists: Beneath the sediments under consideration an older drift always follows. Since the sites of investigation are all situated between the end moraines of Rissian and Würmian glaciation respectively this older drift must be of Rissian age. From this it follows that the Rissian glaciation was younger than the Eemian interglacial of Northern Germany. Against this conclusion the following arguments must be raised:

a) Those aggradation terraces, which are connected with end moraines of Rissian age, are in general covered by a fossil forest soil (Braunerde or Parabraunerde). This soil is strongly altered by cryoturbation and is covered by loess layers.

b) The area of Rissian drift is nearly completely lacking in lakes. From this only very rare exceptions do exist. This means that the Rissian drift, there where it forms the land surface, belongs to the geomorphological type of old, weathered moraines.

To the validity of these arguments the following objections must be taken into consideration:

a) It should be argued that a pine-spruce forest which seems to have lasted for an appreciably long time, should have thrived on a forest soil of Braunerde or Parabraunerde types.

b) Already WEIDENBACH in 1936 has pointed out that the area of Rissian drift in the vicinity of Biberach on the river Riss resembles strongly the landscape of the last glaciation. Moreover during our own investigations it could be shown that the Jammertal and Wettensee basins still during late glacial or even late postglacial times were covered by lakes. If these observations hold true for other comparable basins of the former Rhine and Ammersee glaciers, too, it must be concluded that these regions up till very recent times resembled strongly the type of young moraines, though they were already altered by weathering and downslope movements as compared with the area of maximal Würm glaciation.

In my opinion the warm period between the Rissian and the Würmian glaciations respectively should be regarded as "Füramoos warmperiod" without synchronizing it with the Eemian interglacial.

Within the area of Rissian drift of the so-called Ammersee glacier to the northwest of Fürstenfeldbruck the Haspelmoor is situated in a comparable geomorphological situation like that of Jammertal in the area of former Rhine glacier. PAUL & RUOFF stressed in 1932 that the basin of the Haspelmoor was formed by drowning a Rissian age valley by outwash sediments of Würmian age being derived from the end moraines of Fürstenfeldbruck—Jesenwang. Since early postglacial bog sediments were still inundated during the Boreal period of postglacial times, the outwash sediments just mentioned are held to have been accumulated up to this time. During our own investigations in the Haspelmoor under 5,5 m of peat 6,5 m of lacustrine clays, rich in shells, could be found without reaching the basal moraine or gravel layers. Moreover the accumulation of the outwash plain of Jesenwang must have ended at the latest when the glacier front retreated from the Ebersberger

end moraine ridge, that is to say at the very beginning of the glacier's retreat. From this it follows that the explanation given by PAUL & RUOFF can't be held any longer. On the contrary it must be stressed that here, too, an old and deep lake existed up to postglacial times. Since in the vicinity of the Haspelmoor the so-called Wildmoos was covered by a lake, too, up to the end of preboreal times of the early postglacial, it must be admitted that the area of Rissian drift within this part of former Ammersee glacier resembled more the conditions of young than those of older moraines.

### 3. The Question as to the Eemian Warmperiod

That what has been stressed hitherto as to the character and age of the Füramoos warmperiod does not necessarily mean that in Southern Germany sediments of Eemian age are completely lacking. On the contrary JUNG, BEUG & DEHM (1972) have described at Zeifen, 7,75 km to the west of Laufen on the river Salzach, sediments of a very interesting warm period. Here the warm period lacustrine layers are situated within a 6 m deep basin, being deepened into gravels and being capped by younger gravels. The younger gravels are looked upon as equivalents of the so-called "Laufenschotter", though the base of Laufenschotter at its type section, only 7 km apart, is to be found 30 m deeper. According to the character of the evolution of the interglacial vegetation, the remains of which could be detected in the lacustrine clays and marls, these sediments are held to be of Eemian age, thus enabling the authors to date the older gravel as belonging to the Rissian glaciation since the Rissian and the Saalian glaciations be equivalents. But it must be stressed that this hypotheses cannot be proved by geological facts. According to the micro and megafossils the evolution of interglacial vegetation here followed several steps:

- a) period without forests;
- b) pine-birch period;
- c) pine-birch-elm period;
- d) oak-elm-esh period;
- e) hazel-mixed oak forest period;
- f) hazel-mixed oak forest-spruce period;
- g) *Taxus* period;
- h) hazel-mixed oak forest-*Taxus* period;
- i) spruce period;
- k) hornbeam period;
- l) fir-hornbeam period.

It must be admitted that this trend in the evolution strongly resembled that of the Eemian period in Northern Germany, with the exception of the linden period (*Tilia*) which is lacking at Zeifen. So the authors seem to be right in regarding the warm period of Zeifen as equivalent of the Eemian. But from this it cannot be concluded that the Riß/Würm warmperiod of Southern Germany was of the same age like that of the Eemian since this synchronization can neither be shown by geomorphological nor by geological evidence. Moreover it must be admitted that the character of the warm period just described and that of the Füramoos warmperiod are not comparable with one another. So one may argue that the Zeifen warmperiod was indeed the equivalent of the Eemian interglacial, but the stratigraphic position of this warm period within the pleistocene of Southern Germany is still open to debate.

This being so I prefer to call the warm period of Zeifen only the "Zeifen warmperiod" but not Eemian interglacial. Perhaps further arguments in favour of a better understanding of the real age of the "Zeifen warmperiod" may result from investigations which are now being done by GRÜGER on sediments of a warm period in the Samerberg (near

Nußdorf on the river Inn), and by BEUG on sediments of Eurach (to the north of Penzberg). But unfortunately these two locations, the age of which seems to be the same (BEUG & GRÜGER, papers during DEUQUA-session, 1972) are only situated within the area of the last glaciation. The same holds true for sediments near Berchtesgaden, described by GANSS (1953).

#### 4. The Problem of the so-called Schieferkohlen

Within the formerly glaciated area to the north of the Alp Mts. heavily pressed peat layers can be found at several localities. They are called Schieferkohlen. Several papers discuss the age of these coal layers, most of all that of Schambach on the river Inn. There micro- and macrofossils of beech (*Fagus*) were found by several authors (FRITZ 1970). In Central Europe beech seems to have disappeared at the end of the first warm periods of the pleistocene (on the beech problem see FRENZEL 1968). This being so the strong amount of beech pollen in the "interglacial" coal layers of Schambach (according to FIRBAS up to 60% of the arboreal pollen sum) was striking. During our own geological investigations (drilling) on the Schambach section (unpublished) it could be shown that the coal layers of Schambach are situated at the very base of a huge earth slide, caused by lateral erosion of the river Inn. As has been observed earlier, the coal layer of Schambach is strongly disrupted. In one place where the organic sediments had a thickness of 140 cm the pollen flora showed to be of iron or Roman ages. This is corroborated by two <sup>14</sup>C-datings: 2160 ± 110 years b.p. (Hv 4842; 515 cm); 4830 ± 190 b.p. (Hv 4843; 585 cm). So the Schieferkohlen of Schambach on the river Inn can no longer be held to be of interglacial age. On the contrary they were formed during postglacial times within a small bog which was fossilised by an earth slide some 2000 years ago. Comparable to the situation of the Schambach Schieferkohlen, roughly at about the niveau of the river Inn to the north of Wasserburg at several other places Schieferkohlen can be found, too. These coals are much stiffer than those of Schambach. According to their vegetation history the Schieferkohlen mentioned can be divided into two types. There are those which were formed in a pine-spruce or spruce-pine forest (Zell, according to oral communication by O. FRÄNZLE, and Bergholz), and those of a forest-less cold climate (coals of Blaufeld and of Ödmühle; the latter some 42 m above the river Inn; JOCHIMSEN & FRENZEL, unpublished). FRÄNZLE (in litt.) has shown that the coal layers of Zell have an age of 57 000 ± 900 b.p. (GrN-4742) and of 65 400 <sup>+ 3500</sup> <sub>- 2600</sub> b.p. (GrN-4104). Of course none of these organic layers can be looked upon as being an indication of interglacial climate. Moreover it is open to debate, whether or not both types of vegetation (coniferous forest and open vegetation) belonged to one interstadial period only, nor is it clear whether similar vegetation types were indeed formed simultaneously. This scepticism is strengthened by the fact that in Blaufeld in a situation, the real stratigraphic position of which is questionable (but in all probability above the coal layer) a well preserved molar of *Mammontheus trogontherii-primigenius* was found (determination by K. D. ADAM). Perhaps this shows that the coal layer of the Blaufeld is much older than it was hitherto thought. Besides the coal layers just mentioned those of Großweil, Ohlstadt, and Hechendorf in the vicinity of Murnau and those of Pfefferbichl near Füssen are thought to be of Riss-Würmian age, the beginning of the last glaciation included (REICH 1953; FILZER 1967). This dating is based on palynological work done by REICH on the Großweil Schieferkohlen. Here the succession of vegetation types (from oldest to youngest) is as follows:

- h) spruce pine pollen assemblage;
- g) pine with spruce pollen assemblage;
- f) spruce-pine pollen assemblage;

- e) pine with spruce pollen assemblage;
- d) spruce pollen assemblage;
- c) spruce-fir pollen assemblage;
- b) spruce-alder-hornbeam pollen assemblage;
- a) spruce-hazel-mixed oak forest pollen assemblage.

The spruce-hazel-mixed oak forest pollen assemblage is held to be the equivalent of the mixed oak forest-hazel period and of the linden period (*Tilia*) of Eemian time, whereas the spruce-alder-hornbeam pollen assemblage is thought to be synchronous with the hornbeam phase of the Eemian. Some <sup>14</sup>C-datings, later on done on material of the last two spruce-pine pollen assemblages at Großweil seemed to corroborate this view (GROSS 1960: assemblage f: 59 000 b.p.; assemblage h: more than 50 000 b.p.). From this it follows that the organic sediments of the surroundings of Murnau should be the equivalents of the Zeifen warmperiod. But the vegetation types and their mode of evolution were in the two areas compared quite different from one another. BEUG (in JUNG, BEUG & DEHM, 1972) feels that this might be the effect of the coals of the Murnau area lying roughly 200 m higher than those of Zeifen. This difference might have been strengthened by the situation of former sediment accumulation: Near Murnau *Picea* is held to have colonized the bogs, thus contributing much to their pollenflora, whereas in the former lake of Zeifen this could not happen. In favour of the contemporaneity of the two coal areas discussed according to BEUG speaks the fact that in both regions at comparable phases of the vegetation's history *Taxus* was of great importance, as new pollen counts in the coal layers of Großweil have shown. It may be that BEUG is right, but the age problem of the coals of Großweil and that of the adjacent places is obscured by the fact that only one profile of the Großweil coals shows the beginning of the warm period, these layers being strongly pressed (only 20 to 25 cm). All the other pollen profiles of this region only depict the end of the warm period. We have begun investigations on the vegetation history of the warm period sediments of Großweil but the results are still too meager to be discussed here (PESCHKE, unpublished). So I think it would be best to speak of this warm period as of the "Großweil warmperiod" without synchronizing it too early with other warm periods.

According to REICH (1953) and FILZER (1967) the coal layers of Pfefferbichl near Füssen are held to be synchronous with those of the surroundings of Murnau. BRUNNACKER (1962) described the geological setting of the Pfefferbichl quarry and coal pit as follows: A basal moraine is covered by lacustrine clays which may reach a thickness of up to 25 m. On top of the clays Schieferkohlen follow (about 4—5 m), which are capped by a periglacial gravel. This gravel is overlain by very compact cemented gravels, on the surface and in fissures of which remains of a fossil forest soil can sometimes be observed. This fact, hitherto unknown to BRUNNACKER, was first observed by JERZ. Later on J. SCHRÖPPEL and I could make comparable observations. Some time later the cemented gravel and the fossil soil were capped by the youngest moraine. On this new drift, which contains remnants of the destroyed fossil soil the Parabraunerde of today is developed. After having gathered a huge quantity of coal seam, fossil wood and firmly pressed peat VODIČKOVA (pollenanalyses) and BUCHLOH (bryoflora) could check the older investigations on the Pfefferbichl Schieferkohle. Now we can trace the vegetation history (from oldest to youngest) in the following steps:

- 6) *Pinus-Picea-Betula* pollen assemblage;
- 5) *Abies-Picea* pollen assemblage;
- 4) *Picea-Abies-Carpinus* pollen assemblage, with *Buxus*, *Ilex*, *Vitis*, *Juglans*, *Carya*, *Hedera*, *Quercus*, *Ulmus*, *Tilia*, and in general with *Fagus*, too;

- 3) *Picea-Abies* pollen assemblage; thermophilous deciduous tree species are nearly lacking;
- 2) *Corylus* pollen assemblage, with much *Picea*, together with *Ulmus*, *Quercus* and *Tilia*, and with only small amounts of *Abies* and *Fagus*;
- 1) *Picea-Ulmus-Tilia* pollen assemblage, rich in *Corylus*; small amounts of *Abies* and *Fagus*.

The vegetation's history here is striking in respect to its strong influence of thermophilous tree species during the time of the *Picea-Abies-Carpinus* pollen assemblage. Another point of interest are the *Abies-Picea* and *Picea-Abies* pollen assemblages bracketing the time, when *Carpinus* was able to spread, together with quite a lot of other thermophilous species. It must be stressed that these peculiarities in the evolution of vegetation can no longer be compared with the interglacial history of vegetation at Zeifen. Whether or not a comparison with the Großweil warmperiod is warranted, cannot be answered in view of the bad representation of the first steps of the Großweil warmperiod. But it is possible to synchronize the warm period sediments of Pfefferbichl with those that were described by GERMAN, FILZER, DEHM, FREUDE, JUNG & WITT (1968) at the southwestern rim of Wurzacher Becken at a depth of 95,0 to 94,7 m. There, too, *Abies* and *Picea* were strongly represented during the second half of a warm period, before *Carpinus* spread. Comparable to the situation of Pfefferbichl fir had in the Wurzacher Becken immigrated very early, i.e. early during the phase of spruce and mixed oak forests which were rich in hazel. By these characteristics the two warm period layers can be synchronized with one another. I should like to name the corresponding warm period the "Pfefferbichl warmperiod". It is noteworthy to state that it was of different age as compared with the Zeifen warmperiod.

According to GERMAN et al. (1968) the interglacial sediments of the Wurzacher Becken are held to be the equivalents of the Eemian interglacial. But here several discrepancies must be taken into consideration: First the Zeifen warmperiod may be correlated with the Eemian interglacial, as has been already shown; but the Pfefferbichl and the Zeifen warmperiods do not resemble each other. Moreover the coal layers of Pfefferbichl are not only divided from the recent soil by cold climate sediments (periglacial gravels and moraine) but by a strongly developed forest soil, too (Braunlehm-type). So it must be admitted that the Pfefferbichl warmperiod is older than the Eemian interglacial. On the other hand there do exist floristical and vegetational affinities to the Holsteinian interglacial of Northern Germany.

At several localities in the environments of Penzberg pleistocene coal layers can be observed, too, outcropping in gravel pits (e.g. Höfen and Breinetsried, STEPHAN 1970). They reach a thickness of some 20 to 30 cm and are covered and underlain by outwash sediments. Since the organic sediments of Höfen are situated on a nearly horizontal fossil land-surface some 35 m above the bottom of the recent Wolfratshausener Becken, it must be concluded that the topography during the formation of this fossil peat layer differed strongly from that of today. As to the original topography of the coal layers of Breinetsried nothing is known, because the coals and the thick gravel layers containing them were later on faulted and dipped (perhaps glacier activity?). The former bog of Höfen developed at  $66\,400 \pm 2000$  b.p. to  $69\,300 \pm 2000$  b.p. respectively within a forest community dominated by pine and spruce. Fir and larch were always present, but only in very small amounts. At the very beginning of the peat accumulation *Quercus*, *Ulmus*, *Carpinus*, and *Corylus* seem to have been present nearby as scattered trees, too. In contrast to this the bog of Breinetsried was formed at  $46\,1000 \pm 900$  b.p. to  $49\,400 \pm 900$  b.p. (GROOTES, in litt.), and  $42\,570 \pm 1160$  b.p.,  $42\,170 \pm 1400$  b.p. (VOGEL & WATERBOLK, 1972) within an open

woodland of pine with scattered spruce and birch. Thermophilous tree species were lacking (PESCHKE, unpublished). The much younger datings for this coal layer given earlier by STEPHAN (1970) must now be corrected. It is noteworthy that the two coal layers discussed, which differed in their ages as well as in their floristical composition, were bracketed by phases during which very thick layers of outwash sediments were accumulated. Does this mean that here we have to deal with glacier advances before  $69\,300 \pm 2000$  and between  $66\,400 \pm 2000$  and  $49\,400 \pm 900$  respectively? Whether or not these fossil peat bogs can be connected with the "interstadial" sediments of Steingaden (HÖFLE 1969) or those of Pömetsried (REICH 1953; PESCHKE, unpublished) or even those of the surroundings of Wasserburg discussed earlier, cannot be answered.

### 5. Older Pleistocene Warm Periods

In bore holes of the Federsee Becken (Ur-Federsee 2; GERMAN, BORNEFF, BRUNNACKER, DEHM, FILZER, KÄSS, KUNTE, MÜLLER & WITT, 1967) organic sediments were found at a depth of 92—123 m and 127—145 m respectively. They are underlain and covered by sand, clay, silt and gravel. The older organic sediments were said to belong to the so called Buchau 1 — warmperiod, the younger ones to the Buchau 2 — warmperiod. Buchau 1 is characterized by 8—10% of *Pterocarya* and 7—8% of *Fagus*. Moreover *Picea* (*Pc. omoricoïdes* included), *Abies*, *Ulmus*, *Quercus*, and *Corylus* are worth noticing. With 25—30% of the general pollen sum the amount of nonarboreal pollen was always very high. The authors believe that Buchau 1 is of Cromerian age or that it may be even older. A reliable dating seems to be very difficult in view of the always very small pollen sum (in general per horizon 64 pollen grains). To me it seems striking that the character of the Buchau 1 warm period is identical with that of the Tertiary Obere Meeresmolasse, the topmost horizons of which are held by the authors to belong to Buchau 1. This being so I feel that it might be much better to regard Buchau 1 as Tertiary or even redeposited Tertiary sediments than as indications of an early pleistocene warm period (as to the megafossil floras of the younger Tertiary in this area see JUNG, 1968, 1970).

Buchau 2 (92—123 m) is regarded to be of interglacial age, too. It is characterized by the dominance of *Picea*, *Pinus*, *Larix*, and *Abies*, with only small amounts of thermophilous deciduous trees. Here, too, the very small number of pollen grains counted impedes a precise interpretation (in general per horizon only 52 pollen grains counted). The contemporaneous mollusk fauna seems to warrant an old pleistocene age. Moreover this age is accepted by the authors since the pollenflora of the much younger layer Buchau 5 (clay with sand and gravel) is dominated by *Fagus* (roughly 15%), with spruce and pine and only 8% of *Corylus*. The other thermophilous tree species are lacking or are only irregularly documented. To the authors it seems reasonable to compare Buchau 5 by its high amount of beech pollen to the "interglacial" layers of Schambach on the river Inn, which were hypothetically correlated by REICH (1953) with the Holsteinian warmperiod of Northern Germany. This interpretation can no longer be accepted as was shown earlier. Moreover the very small amount of pollen grains counted in the layers of Buchau 5 (per horizon roughly 61 pollen grains) renders a reliable evaluation as to character and age of the then vegetation very difficult. This must be stressed even more since two diagrams of the same layer differ from one another remarkably. The layers discussed were won in one core each only. Isn't it reasonable to think that the core with relatively much beech was polluted a little?

GÖTTLICH & WERNER described 1967 and 1968 fossil peat layers, met with in bore holes at Unterpfaufenwald and at Ziegelberg. Both these layers were held to belong to the last but one interglacial period, which is thought to be the equivalent of the Mindel/Riss warmperiod. But it must be admitted that the published results of pollenanalytical



investigations on this material do not warrant this interpretation, nor is it possible to conclude from this that the penultimate warmperiod of Southern Germany was indeed the Mindel/Rissian or Holsteinian warmperiod of Northern Germany, as the authors seem to think.

Doubtless of Old Pleistocene age are organic sediments of the so-called Uhlenberg on the Zusamplatte, only some km to the north of Dinkelscherben. Here, at about 529 m o. d. firmly pressed coal seams and wood layers lie on fluvioglacial gravels, fine sand, silt, and clay. The fluvioglacial gravel at the base of the exposure is looked upon by FILZER & SCHEUENPFLUG (1970) as belonging to the early Pleistocene Donau glaciation. The coal layers are covered by 2,5 m of loam. The pollenflora of the organic sediment and the clay just beneath of it is always dominated by spruce and pine (70 cm of the profile were analysed). At the bottom of the profile alder, hemlock (*Tsuga diversifolia* and *Ts. canadensis* types), and chestnut are represented, too. Several times, but always only in small amounts, *Pterocarya*, cf. *Ostrya*, *Quercus*, *Tilia*, *Ulmus*, and *Abies* were observed. An analysis of the macrofossils by JUNG (excursion of DEUQUA, 1972) revealed the presence of *Picea omoricoïdes* (the pollen of which was found by FRENZEL, unpublished, too) and of *Chamaecyparis* cf. *pisifera* vel cf. *obtusa*. This shows that these sediments indeed were formed during the Older Pleistocene. But the findings do not warrant an exact dating (from a botanical point of view a period from the end of the Pliocene up to an early Middle Pleistocene age is possible), nor is it possible to discriminate between the end of an interglacial or a warm interstadial period. So it seems appropriate to use a neutral term only, as for instance "Uhlenberg warmperiod".

## 6. Periods of Cold Climate

Up till now the vegetation thriving in Southern Germany during glacial or cold climate times has not been investigated systematically. There do exist only cursory indications as to its character, won during botanical work on the beginning or the end of warm periods. In this respect (from youngest to oldest) the following papers can be mentioned: GÖTTLICH & WERNER 1968 (Waltere); FRENZEL, unpublished (Füramoos); PESCHKE, unpublished (Wildmoos, Höfen, Breinetsried, Pömetsried); GÖTTLICH 1960 (Muttweiler, Biberach County; Dürmentingen, Saugau County); FRENZEL, unpublished (Blaufeld, Ödmühle); JUNG, BEUG & DEHM 1972 (beginning and end of the Zeifen warmperiod); PESCHKE, unpublished (beginning of the Großweil warmperiod); REICH 1953 (its end); REICH 1953, FILZER 1967, VODIČKOVA, unpublished (the end of the Pfefferbichl warmperiod). The remarks on the Old Pleistocene cold period vegetation as revealed by deep borings in the Federsee-Becken (Ur-Federsee 2, GERMAN et al., 1967) don't warrant a precise evaluation of the then prevailing conditions. In general the vegetation of early-, full- and lateglacial times (for each cold period considered separately) was an open one, with scattered stands of cold resistant trees or even lacking tree growth completely. Besides of aquatic plants, such as *Batrachium*, *Pediastrum*, *Thalictrum*, *Filipendula* and Cyperaceae, members of steppe- or tundra-communities were regularly present: *Artemisia*, Chenopodiaceae, Caryophyllaceae, *Ephedra distachya*, *E. fragilis*, *Selaginella selaginoides*, *Armeria*, *Ranunculus*, *Anemone*-type, Campanulaceae, Cerealia-type, *Botrychium* and others. Juniper, willow and *Hippophaë* were in general only rarely to be found. It is generally accepted that this type of vegetation is characteristic for late-glacial conditions only. But in view of its long and strong occurrence in undoubtedly full glacial sediments (e.g. Füramoos) this vegetation type can no longer be used as a means for the dating of late glacial sediments; its occurrence depended on certain ecological conditions as was already shown earlier, when the fossil loess flora of Northern and Eastern Austria was investigated (FRENZEL 1964). These conditions could prevail near the Alp Mts. at several times, irrespectively of a certain phase in the evolution of a glacial period.

Up till now it is impossible to discern cold climate vegetation types which were characteristic for one cold- or glacial period only so that they could be used as a stratigraphical means; and it must be regretted that the oldest reliable indications as to the cold period vegetation date from the end of the Pfefferbichl warmperiod only.

## 7. Discussion

In the foregoing we have discussed the stratigraphic position of warm period sediments sometimes in quite another way than it is hitherto accepted in general. On the contrary the sediments described are elsewhere dated as follows:

a) The coal layers of Schambach and Zell on the river Inn are looked upon as belonging to one interglacial only (Schambach hypsithermal; Zell anathermal). This interglacial is thought to have been the Eemian or the Holsteinian respectively.

b) It is thought that during the Riss/Würmian interglacial, which is held to be the equivalent of the Eemian period, were formed the coal layers of Großweil, Ohlstadt, Hechendorf, and Pfefferbichl; the lacustrine sediments of Zeifen, Wurzacher Becken; the peat layers of Waltere and Maienberg.

c) The coal seams of Breinetsried and Höfen are interpreted as belonging to one Würmian interstadial only, lasting from about 40 000 to 30 000 b.p.

d) Buchau 5 and the organic sediments of Ziegelberg and Unterpfaufenwald are regarded as accumulations of the Mindel/Rissian warmperiod, which is thought to have been contemporaneous with the Holsteinian interglacial.

e) Buchau 1 and 2 as well as the sediments of the Uhlenberg are said to date from early pleistocene times.

Attempting to revise the stratigraphic position of the warmperiod sediments just mentioned I used the principle, generally accepted by geologists, that the biostratigraphy of the Pleistocene must be based on sediments the stratigraphic position of which is proven by their geomorphologic and/or geologic settings. I feel that one should hesitate to synchronize geological events of two or more regions merely by biostratigraphical means if the geological situation does not render this possible (e.g. if it is not proven that a certain moraine belongs to the Rissian glaciation it seems to me impossible to date this moraine merely on the grounds of organic sediments, which have the character of Eemian type, thus stating that the Riss/Würmian warmperiod of Southern Germany must be the equivalent of the Eemian of Northern Germany. The same holds true for the Mindel/Rissian and the Holsteinian respectively). Moreover it is evident that the stratigraphic interpretation given here is at first only applicable to the regions investigated. It is true that we have included, thanks to the cooperation of Prof. FINK (Vienna) and Prof. KOHL (Linz), the Northern part of Austria, too, into our investigations, but the results are till now not worth discussing them.

1) If it be accepted that in closed basins between the end moraines of the Rissian and the Würmian glaciations respectively the sediments of the Riss/Würmian warmperiod must be the oldest warmperiod sediments, one should expect to find Eemian pollen assemblages, if the Eemian did indeed correspond to the Riss/Würmian. In this context the possibility must be ruled out that the times of Riss/Würmian and Eemian warmperiods corresponded each other but that the character of their vegetation did not: Since Eemian age sediments can easily be dated by their vegetation character in such a vast area as from Western to Eastern and even to the southern part of Central Europe (Zeifen), the main trends in the evolution of vegetation must everywhere have been the same. If this

be accepted it can't have been the work of chance only that nowhere between the end moraine ridges of Rissian and Würmian ages sediments could be found the vegetation history of which resembled that of the Eemian. But everywhere only sediments of the Füreamoos warmperiod were found. If one should not think of young tectonical movements forming the small basins investigated, it follows from this that at least the major part of the Rissian glaciation and the Füreamoos warmperiod happened only after the end of the Eemian warmperiod. Whether the Füreamoos warmperiod was one warmth oscillation only or whether in this name are lumped together formations of different ages cannot be evaluated today exactly. At any rate it must be admitted that the topography of Rissian drift resembled that of young moraines up till recent times strongly, since several lakes were filled by organic and anorganic sediments only some thousand years ago. Whether or not this depended on human activities must further be investigated.

2) As may be remembered, the warmperiod sediments of the Wurzachener Becken and of Pfefferbichl can easily be connected with one another, this the more if our new pollen-analytical evidence is used. But this Pfefferbichl warmperiod differed strongly from the Zeifen warmperiod. Since moreover between the Pfefferbichl warmperiod and postglacial times not only followed the time of accumulation of two different gravel layers and of one moraine, but also the formation of a deeply developed fossil soil, it follows, that the Pfefferbichl warmperiod is relatively old. So it may be argued that the Zeifen warmperiod was the connecting link between the Pfefferbichl warmperiod and postglacial times.

3) The stratigraphic position of the Pfefferbichl and Zeifen warmperiods (the Großweil warmperiod included, which was possibly contemporaneous with the Zeifen warmperiod) as to the pleistocene history of the Alp Mts. is not known.

4) Since the coal layers of Schambach on the river Inn date from postglacial times and since those of Zell were formed some 60 000 years ago, they both cannot belong to one warmperiod only. Moreover it is not possible to correlate the coal layers of Breinetsried and of Höfen with the Stillfried B-interstadial of Austria, since both are definitely older than this interstadial and since they have different ages as compared with one another. Their exact stratigraphical position and their possible correlations with the warmperiod sediments of Zell, Bergholz, Pömetsried and Füreamoos are still open to debate.

## 8. Conclusions

If the still existing great difficulties and uncertainties be duly considered the following preliminary stratigraphical division as to biostratigraphic observations may be given:

Postglacial

Würmian coldperiod

Füreamoos warmperiod: Wildmoos, Füreamoos, Krumbach, Wilflingen, Waltere

Rissian coldperiod (completely or only parts of it?)

? Zeifen warmperiod (possibly corresponding to the Eemian and to the Großweil warmperiods): Zeifen, Samerberg, Eurach

?

Pfefferbichl warmperiod (possibly the equivalent of Holsteinian warmperiod): Pfefferbichl, Wurzachener Becken

unknown number of warm and coldperiods

Uhlenberg warmperiod

Donau coldperiod (completely or only parts of it?)

## Literature

- BRUNNACKER, K.: Das Schieferkohlenlager vom Pfefferbichl bei Füssen. — Jahresber. u. Mitt. d. Oberhein. Geolog. Ver. **44**, 43—60, 1962.
- FILZER, P.: Das Interglazial Riß-Würm vom Pfefferbichl bei Buching im Allgäu. — Vorzeit **1—4**, 3—18, 1967.
- FILZER, P. & SCHEUENPFLUG, L.: Ein frühpleistozänes Pollenprofil aus dem nördlichen Alpenvorland. — Eiszeitalter u. Gegenwart **21**, 22—32, 1970.
- FIRBAS, F.: Über das *Fagus*-Vorkommen im „Interglazial“ von Wasserburg am Inn. — Veröff. d. Geobot. Inst. Rübel, Zürich, **33**, 81—90, 1958.
- FRENZEL, B.: Über die offene Vegetation der letzten Eiszeit am Ostrande der Alpen. — Verh. d. Zool. Bot. Ges. in Wien, **103—104**, 110—143, 1964.
- : Grundzüge der pleistozänen Vegetationsgeschichte Nord-Eurasiens, **I**, 323 S., Franz-Steiner-Verlag, 1968.
- FRTZ, A.: Die pleistozäne Pflanzenwelt Kärntens mit einem Beitrag zur pleistozänen Verbreitungsgeschichte der Rotbuche, *Fagus sylvatica* L. in Europa. — Naturwiss. Beitr. z. Heimatkde. Kärntens, **29**, Sonderheft der Carinthia II, Mitt. d. Naturw. Ver. f. Kärnten, 63 S., 1970.
- GAUSS, O.: Ein fossilführendes Interglazial in den Berchtesgadner Alpen. — Geologica Bavarica, **19**, 340—345, 1953.
- GERMAN, R., FILZER, P., DEHM, R., FREUDE, H., JUNG, W. & WITT, W.: Ergebnisse der wissenschaftlichen Kern-Bohrung Würzacher Becken 1 (DFG). — Jh. Ver. vaterl. Naturkde. Württemberg, **123**, 1—68, 1968.
- GERMAN, R., BORNEFF, J., BRUNNACKER, K., DEHM, R., FILZER, P., KÄS, W., KUNTE, H., MÜLLER, G. & WITT, W.: Ergebnisse der wissenschaftlichen Kern-Bohrung Ur-Federsee 2. — Oberrhein. geol. Abh., **16**, 45—110, 1967.
- GÖTTLICH, K.: Beiträge zur Entwicklungsgeschichte der Moore in Oberschwaben. Teil I: Moore im Bereich der Altmoräne und der Äußeren Jungmoräne. — Jh. d. Ver. vaterl. Naturkde. Württemberg, **115**, 93—174, 1960.
- GÖTTLICH, Kh. & WERNER, J.: Ein Pleistozän-Profil im östlichen Rheingletscher-Gebiet. — N. Jb. Geol. Paläont. Mh., **4**, 202—216, 1967.
- : Zwei wahrscheinlich letztinterglaziale Torfvorkommen im Gebiet von Stockach-Meißkirch. — Eiszeitalter u. Gegenwart, **19**, 175—182, 1968 a.
- : Ein vorletztinterglaziales Torfvorkommen bei Hauerz (Landkreis Wangen im Allgäu). — Jh. geol. Landesamt Baden-Württemberg, **10**, 73—78, 1968 b.
- GROSS, H.: Die Bedeutung des Göttweiger Interstadials im Ablauf der Würm-Eiszeit. — Eiszeitalter u. Gegenwart, **11**, 99—106, 1960.
- HÖFLE, Chr.: Ein neues Interstadialvorkommen im Ammergebirgsvorland (Obb.). — Eiszeitalter u. Gegenwart, **20**, 111—115, 1969.
- JUNG, W.: Pflanzenreste aus dem Jungtertiär Nieder- u. Oberbayerns und deren lokalstratigraphische Bedeutung. — Ber. d. Naturwissenschaftl. Ver. Landshut, **25**, 43—72, 1968.
- : Eine reiche Fundstelle obermiozäner Pflanzenreste in der Oberen Süßwassermolasse Südbayerns. — N. Jb. Geol. Paläontologie, Monatsh. **1970**, 542—548, 1970.
- JUNG, W., BEUG, H.-J. & DEHM, R.: Das Riß-Würm-Interglazial von Zeifen, Landkreis Laufen a. d. Salzach. — Bayer. Akad. d. Wiss. Mathem. — Naturw. Kl., Abh. N. F. **151**, 130, 1972.
- PAUL, H. & RUOFF, S.: Pollenstatistische und stratigraphische Mooruntersuchungen im südlichen Bayern. II. Teil: Moore in den Gebieten der Isar-, Allgäu- u. Rheinlandvorgletscher. — Ber. d. Bayer. Bot. Ges. München, **20**, 264 S., 1932.
- PENCK, A. & BRÜCKNER, E.: Die Alpen im Eiszeitalter, I—III, 1042 S., Leipzig, Chr.-Herm. Tauchnitz, 1901—1909.
- REICH, H.: Die Vegetationsentwicklung der Interglaziale von Großweil-Ohlstadt und Pfefferbichl im Bayerischen Alpenvorland. — Flora, **140**, 386—443, 1953.
- STEPHAN, W.: Frühwürmzeitliche Schieferkohlevorkommen im Bereich des östlichen Isar-Vorlandgletschers. — Geologica Bavarica, **63**, 217—230, 1970.
- WEIDENBACH, F.: Erläuterungen zur geologischen Spezialkarte von Württemberg, Blatt Waldsee Nr. 164, 130 S., 1936.

Manuscript received June 7, 1973.

Address of the author: Prof. Dr. B. Frenzel, Lehrstuhl Botanik der Universität Hohenheim, 7 Stuttgart 70, Kirchnerstraße 5.