Riss or Würm?

By F. E. Zeuner, London

Zusammenfassung. Die Klimaschwankungen des jüngeren Pleistozäns werden anhand von drei unabhängigen Gruppen von Beobachtungsmaterial besprochen, nämlich von Schwankungen des Meeresspiegels, den Terrassenunterkanten der Themse und den fossilen Böden der Lößzone von Nordfrankreich bis Niederösterreich. Die gleiche Abfolge von Klimaphasen ergibt sich in jedem Falle. Das Letzte Interglazial weist in der Mitte eine leichte Schwankung auf und war zeitweilig sommer-wärmer als heute. Die folgende Kaltphase war kurz, aber intensiv (Meeresspiegel ca. —100 m), und auf sie folgte eine Warmphase mit durchaus gemäßigtem Klima (Halling-Stage der Themse), welche oft mit dem Letzten Interglazial verwechselt wird. Auf diese Phase folgt die Vereisungsgruppe Weichsel-Würm. Die vorausgehende Kaltphase wird oft als Jungriß bezeichnet, doch ist Würm I vorzuziehen, da das vorausgehende Interglazial länger war als das Interstadial zwischen der fraglichen Phase und dem jüngeren Würmkomplex.

Sommaire. La succession des phases climatologiques du Pleistocène supérieur est discuté aux points-de-vue des occillations du niveau de la mer, des niveaux d'abrasion fluviatiles de la Tamise, et des sols fossiles qui se trouvent dans des coupes de loess du nord de la France, du bassin de Mayence, la Bohème et l'Autriche. Ces témoignages étant d'accord, on obtient une succession générale comme suit: Après l'avant -dernière glaciation, le dernier interglaciare avec une oscillation légèrement froide au milieu, mais autrement tempéré et même plus chaud que le climat récent pendant l'été. Il suit une glaciation, la phase qu'on a appelée aux Alpes ou Würm I ou Jeune-Riss. Après cette période froide, une interstadiaire parfaitement tempéré qui la sépare du complexe würmien proprement dit. On a souvent pris cette phase interstadiaire (Halling stage de la Tamise) pour le propre dernier interglaciaire. C'est comme ça qu'on est errivé à l'appellation Jeune-Riss au lieu de Würm I qui est préférable, l'interglaciaire entre Riss et la phase froide en question ayant été plus long que l'interstadiaire qui le sépare du Würmien plus récent.

In all areas where conditions of observation are favourable, geologists agree that the four major glaciations recognized by Penck can be subdivided into phases. This applies in particular to the Alps. Corresponding evidence has come forth in the periglacial zone where both river terraces and weathering horizons have revealed sequences of climatic fluctuations more complicated than the original scheme of Penck. This multiplicity of cold phases has inevitably raised the problem of their correct assignment to major glaciations, and the controversy which has in the last few years developed over the assignment of a certain glacial phase to the Riss Glaciation or the Würm Glaciation is merely an illustration of the difficulties which are bound to arise. Since the forelands of the northern Alps are the typical area for the subdivision of the Pleistocene glaciations, for it was here that Penck defined the terms Günz, Mindel, Riss and Würm, the uncertainty as to what should be called Riss and what Würm is a serious matter.

That this problem is not confined to the Alpine sequence is indicated by similar complications that have arisen in other areas. On the margin of the Scandinavian ice-sheet, the chronological position of the Warthe phase has caused considerable difficulty. In Denmark the connection of the Skärumhede series with boulder clays is open to discussion. In the loess zone of western Europe, a loess occurs which has occasionally been assigned to the Younger Loesses by one group of investigators and to the Older Loesses by another, for instance at Achenheim in Alsace (Zeuner 1952, p. 157, p. 407; 1954), In eastern England there is unvertainty about the Little Eastern Glaciation of Solomon, and in the Mediterranean basin the relation of certain eustatic terraces with interstadials of Last Glaciation age or with the Last Interglacial has been worrying some investigators, as illustrated

by Caton Thompson's treatise on the Levalloisian culture in North Africa. It will take some time before a common denominator can be applied to these local or regional chronologies, and before an agreement is reached about the nomenclature to be used which is satisfactory to all. Nevertheless the Alpine problem of „Riss or Würm" being paralleled by corresponding problems elsewhere, other areas are likely to contribute information which may be helpful in the solution of Alpine problems. Broadly speaking the question is one of the length and the duration of the successive temperate phases separating the glacial phases. More information about this is available in the periglacial and pluvial zones than in the immediate vicinity of the Alpine moraines, and the present paper is intended to view the problem in the light of such non Alpine evidence.

At the outset it is essential to adopt a nomenclature for the climatic phases of the Pleistocene which is not local. In other words, in this article (as in other works of the writer) the terms Riss and Würm are restricted to the Alpine area, Saale and Weichsel being those applicable to the Scandinavian ice-sheet, and so forth, and in the general terminology, the two complexes of cold phases, with the separation of which we are concerned, are called Penultimate Glaciation and Last Glaciation. The equation Würm = Weichsel = Last Glaciation is known to be correct in a broad sense, though in detail many controversial points remain.

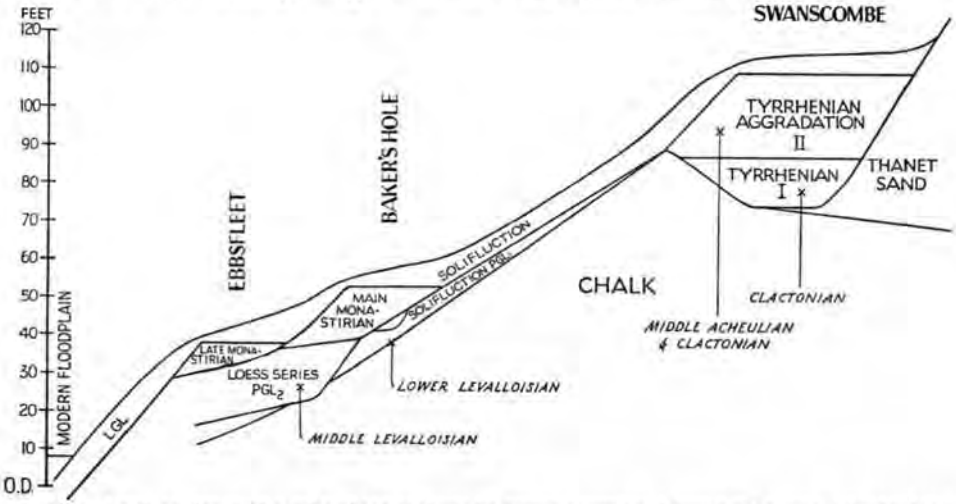

Fig. 1. Section from the Ebbsfleet Valley to Swanscombe, Lower Thames, illustrating the sequence of climatic phases from the Great Interglacial onwards.

After the cutting of the bench (G-bench) at Swanscombe, aggradition (in two stages) to Tyrrhenian sea-level of the Penultimate Interglacial (33 m above sea-level) with Clactonian II and early Middle Acheulian.

Then occurred erosion to low sea-level, and formation of Main Coombe Rock (solifluction) and of some stream-deposited gravel (Baker's Hoe) in the cold climate of the first phase of the Penultimate Glaciation, with early Levalloisian at Baker's Hole.

Partial removal of the Coombe Rock suggests a slight break in the sequence (? interstadial PGl ½ ?), which was followed by deposition of cold gravels (Middle Levalloisian) and loess (second phase of the Penultimate Glaciation).

Aggradation of river gravels to the Main Monastirian sea-level followed in the first part of the Last Interglacial (Upper Gravels at Baker's Hole).

Thereafter the sea-level dropped again, erosion cutting through the Main Monastirian gravels and partly through the loess series. A new rise of the sea-level (Late Monastirian) brought the aggradation of the 'temperate loam' of Burchell, in the second part of the Last Interglacial. This was followed by further phases of down-cutting and solifluction during the Last Glaciation, not illustrated here, but evidenced by the three buried channel benches (see Fig. 2).

The sequence of events is perhaps most conclusively reproduced by the thalassostatic portion of the River Thames, where the sections of Swanscombe and Ebbsfleet have provided an unambiguous starting point, whilst an investigation of the longitudinal profile of the terraces carried out by the writer in conjunction with Mr. Day KIMBALL has revealed a number of rhythms of bench cutting and estuarine aggradation which can only correspond to fluctuations of the sea-level. Briefly, these sections (fig. 1; discussed in ZEUNER 1952, p. 193, and 1945, p. 127) show that following the Great Interglacial two cold phases occurred, the second of which witnessed the deposition of the major part of the loess in Kent. Following these cold phases coupled with a low sea-level, the sea-level rose to about 18 m., the Thames adjusting itself to it by the formation of the Taplow Terrace. A second high sea-level is indicated by the Upper Flood Plain Terrace at about 7.5 m. That these two correspond to the Main and Late Monastirian shore-lines recognized on the coasts of the Atlantic and Mediterranean will be difficult to refute.

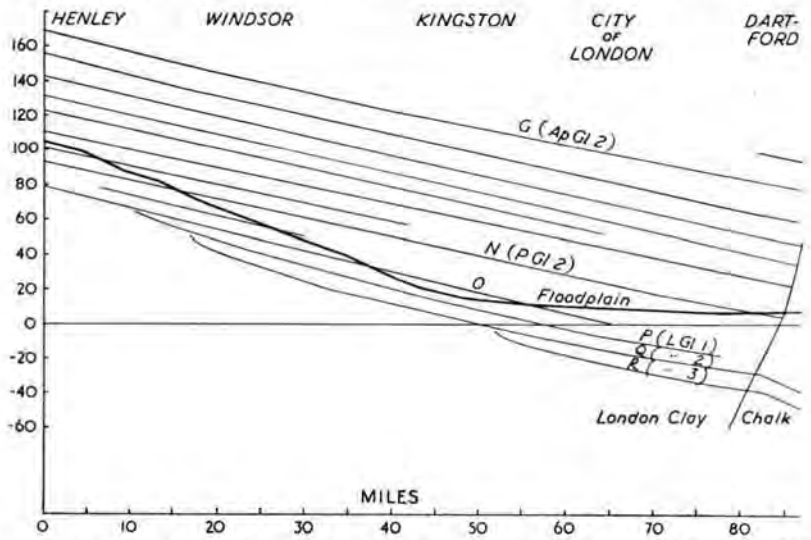

Fig. 2. The erosional benches of the Thames between Henley and Dartford. Each of these benches indicates a phase of low sea-level, i. e. a phase of climate colder than the present.

G: Swanscombe bench of Antepenultimate Glaciation 2 on which the Hornchurch boulder clay lies (probably equivalent of Elster Glaciation of Germany).

N: Taplow bench of Penultimate Glaciation 2 (probably Saale Glaciation of Germany).

This is followed by 5 benches of which the lowest 3 are the buried channel benches P, Q and R as indicated in Table 1, which correspond to the three phases of the Last Glaciation.

Now, the lower of these aggradations rests on a rock bench which has been identified over some distance along the course of the river (fig. 2). It is followed by three more rock benches all continuing to a low sea-level, the last being followed by the rise of the sea-level up to its present-day height. These are the well known „buried channel benches". That there are three, confirms the observation made elsewhere that the Last Glaciation had three cold phases. But the terraces of the Thames provide additional information of great interest. The aggradation which rests on the first of the three buried channel benches constitutes the Lower Flood Plain Terrace which always remains a few feet above the modern flood plain. This stage, the Halling Stage of KING & OAKLEY (1936), occasionally also

called the Eyot Phase, indicates a sea-level at a height of something like 3 m above the present, though because of the inevitable error of measurement and the tidal amplitude an exact figure cannot at present be given. The fact that the sea-level rose as high as this suggests that the climate of this phase was temperate.

The Halling stage was followed by two cold phases separated by a less cold interval (Ponders End aggradation) during which the sea-level never rose to the present height (ZEUNER 1945, p. 130).

This evidence from the Lower Thames suggests that following the two Monastirian sea-levels, three cold phases occurred. The first and second of these were separated by a mild phase as temperate as the present day climate, in other words, of a fully interglacial character. The oscillation between the second and third, however, never led to a deglaciation comparable with that of the Postglacial. It is unlikely, therefore, that during this second mild phase the climate assumed a temperate character.

As a fossil shore-line, the Halling stage has been found in a large number of places on the south coast of western England. Its transgression platform occurs at Lannacombe (South Devon) for instance, where it is covered with thick solifluction deposits proving that this level cannot be of Postglacial age. It also occurs in Jersey (Channel Islands), at Gibraltar, Arab's Gulf (west of Alexandria), the Atlantic coast of Morocco and elsewhere (ZEUNER 1953).

The climatic sequence supplied by this evidence, therefore is as follows: —

1) Two phases of the Penultimate Glaciation.

2) The Last Interglacial, with two warm phases represented by sea-levels at 18 and 7.5 m above the present and separated by a slight oscillation.

The warm character of these two phases is evidenced by their *Strombus* fauna in the Mediterranean which corresponds to the Eem fauna of the North Sea.

3) A cold phase with low sea-level.

4) The Halling phase with sea-level rising to about 3 m above the present, of a temperate character.

5) Two cold phases separated by an oscillation during which the sea-level remained below present height and the climate of which never became typically temperate.

6) The Postglacial.

Turing now to the loess belt, it is remarkable that the same sequence of climatic phases is exhibited by the Younger Loesses, though not everywhere. Three Younger Loesses have been established in the Mainz basin, in Alsace, in Czechoslovakia and in Lower Austria. To find them, therefore, it appears that one has to go to areas where the summer is comparatively warmer and where the climate has continental tendencies. Farther west, especially in France, the Third Younger Loess appears to be absent, which is not surprising, since during that last phase of the Last Glaciation, which was the weakest of the three, the influence of the ocean made itself most strongly felt. The division between the Second and Third phases of the Last Glaciation, however, is evidenced by soils occuring between solifluction levels in several French sites, as it is, incidentally, at the Petersfels in southern Germany.

The evidence from the Mainz Basin has been studied by SCHÖNHALS (1950, 1951a, b) from the pedological point of view. Whilst the Last Interglacial soil is usually a chernozem, the soil between the First and Second Younger Loesses is a brownearth. Similarly the soil between the Second and Third Younger Loesses has brownearth characteristics, but it is thinner and less deeply weathered.

At the prehistoric site of Achenheim situated on the French side of the southern Rhine Rift, the presence of the three Younger Loesses has been suggested on the

GENERAL NOMENCLATURE		SEA-LEVELS	LOWER THAMES	LOESS OF North FRANCE	LOESS OF MAINZ BASIN	LOWER AUSTRIA	ALPS	PREHISTORIC INDUSTRIES
POSTGLACIAL		FLANDRIAN	TILBURY STAGE	FORMATION DE SOL	BRAUNERDE	WEATHERING	WEATHERING	MESOLITHIC
LAST GLACIATION 3		C. — 30 M.	THIRD BURIED CHANNEL (R)		JÜNGERER LÖSS III	YOUNGER LOESS III	WÜRM	MAGDALENIAN
L. GL. 2/3		C. — 10 M.	PONDERS END AGGRADATION		BRAUNERDE	PAUDORF PHASE		MAGDALENIAN
LAST GLACIATION 2		C. — 70 M.	SECOND (PONDERS END) BURIED CHANNEL (Q)	LOESS RECENT II	JÜNGERER LÖSS II	YOUNGER LOESS II		AURIGNACIAN GRAVETTIAN
L. GL. 1/2		EPI-MONASTIRIAN + 3 M.	HALLING STAGE, LOWER FLOODPLAIN TERRACE	SOL	BRAUNERDE	GÖTTWEIGER PHASE	TEMPERATE PHASE	MOUSTERIAN BEING REPLACED BY UPPER PALAEOLITHIC
LAST GLACIATION 1		C. — 100 M.	FIRST (HEDGE LANE) BURIED CHANNEL (P)	LOESS RECENT I	JÜNGERER LÖSS I	YOUNGER LOESS I	"JUNGRISS"	MOUSTERIAN
LAST INTERGLACIAL	TEMPERATE	LATE MONASTIRIAN + 7·5 M.	UPPER FLOODPLAIN TERRACE	ARGILE ROUGE	SCHWARZERDE	DEEP WEATHERING	LAST INTERGLACIAL	LEVALLOISIAN TAYACIAN MICOQUIAN & UP. ACHEUL.
	COOL	LOWER	BENCH O					
	TEMPERATE	MAIN MONASTIRIAN + 18 M.	TAPLOW TERRACE AGGRADATION					
PENULTIMATE GLACIATION		C. — 200 M.	TAPLOW BENCH (N)	LOESS ANCIEN (PART)	ÄLTERER LÖSS	OLDER LOESS	RISS	LEVALLOISIAN

TABLE 1

evidence of mechanical analysis by DE FERRIERE and confirmed by the writer. Again the upper intermediate soil is weaker than the lower.

In Bohemia and Moravia a number of sections with three Younger Loesses have been described by LAIS (1951) and SCHÖNHALS (1951). One of these is Sedlec, near Prague, another Dolní Věstonice in Moravia. The work of LAIS (his manuscript was completed in 1944) inspired BRANDTNER (1950) to search for similar evidence in Lower Austria, where the soil between Younger Loesses I and II is called the Göttweiger loam or Hollabrunner humus zone, whilst that between Younger Loesses II and III is known as the Paudorf horizon. These names were coined by BAYER and GÖTZINGER some twenty years ago, which shows that the evidence was there and only waiting to be correctly interpreted. LAIS, SCHÖNHALS and BRANDTNER agree in regarding the temperate period between Younger Loesses I and II as longer than that between Younger Loesses II and III. Pollen-analytical evidence has defined the difference between the two interstadials still further (BRANDTNER 1949, 1950, p. 104). The First Interstadial has so far yielded pine, spruce, birch, willow, alder, hazel, elm, oak and lime. This is an association representing a fully developed temperate forest. In samples from the Paudorf horizon, however, the more or less cold-resisting species dominate, whilst the climatically more sensitive like hazel, elm and oak appear more sporadically and the most warmth requiring species, lime, is absent altogether. Moreover, density of the forest in the Göttweiger Interstadial was greater (herbaceous and grass pollen about 100%) than in the Paudorf Interstadial (non-tree pollen nearly 300%).

This evidence from the Mainz Basin and Rhine Rift, Czechoslavakia and Lower Austria proves that the three cold phases which followed the Last Interglacial were separated by two interstadials, the first of which was fully temperate, whilst the second did not attain such condition, except possibly for a brief period not normally recorded in geological evidence. There is plenty of other pedological evidence which supports this conclusion, especially regarding the cool character of the Second Interstadial (ZEUNER 1953).

Moreover, where exposed, the soil of the temperate phase preceding the formation of the Three Younger Loesses is thicker than any of the soils that follow and tends to be climatically somewhat warmer than that between Younger Loesses I and II. In northern France, this Last Interglacial soil is well known as a r g i l e r o u g e, because of its slightly reddish colour indicating temperatures somewhat higher than the present. Soils of this type are now formed in the brownearth zone south of the Loire, but not in north France where a r g i l e r o u g e is common in the basins of the Somme and Seine. In southern England, similar conditions appear to have prevailed as suggested by the Last Interglacial soil of Ebbsfleet, Kent (ZEUNER 1945, p. 128). In the Mainz Basin, the a r g i l e r o u g e is replaced by a well developed chernozem (SCHÖNHALS 1951) which is consistent with the continental character of this area. This evidence suggests that the „warm" character of the Last Interglacial was in the main due to elevated summer temperatures as distinct from a higher annual mean.

Now, it must be admitted that the agreement of the climatic succession deduced independently from the sea-level fluctuations on the one hand and from weathering horizons on the other, is so close that it cannot be ascribed to mere coincidence. Following the Penultimate Glaciation, both sequences provide for

a Last Interglacial with temperatures somewhat higher than present,
a cold phase,
a period of fully temperate climate,
another cold phase,

a period with climate only moderately temperate,
a third cold phase,
followed by the Late Glacial and Postglacial.

From the point of view of nomenclature, the longest and warmest period should be regarded as the Last Interglacial. The three cold phases that follow would then represent the three phases of the Last Glaciation which have been recognised by many workers in the Alpine and periglacial areas.

A very remarkable feature, however, is now emerging. The interstadial between the first and second phases of the Last Glaciation was fully temperate. Though shorter than the Last Interglacial, it was quite as temperate as the Postglacial. If, therefore, deposits belonging to the First Interstadial of the Last Glaciation are found unassociated with formations of the Last Interglacial, such deposits will automatically be interpreted as Last Interglacial by most authors. Evidently the distinction between formations of the Last Interglacial and the First Interstadial is a difficult matter unless exceptionally complete sections are available. To make matters even more difficult, deposits of the First Interstadial of the Last Glaciation are likely to be preserved frequently, since they are younger than those of the Last Interglacial. In many districts, therefore, it must be considered as a serious possibility that evidence for the First Interstadial has been misinterpreted as Last Interglacial.

The facts briefly discussed in this paper throw fresh light on the question of what should be regarded as Riss and as Würm respectively in the Alpine area of glaciation. In recent years some investigators have commenced to use the term „Jungriss" for a glacial phase which they found to be comparatively well separated from the later complex of Würm moraines. It now appears likely that this is the phase Last Glaciation I of the general nomenclature, its clear separation being due to the temperate interstadial $LGI_{1/2}$. Since, however, the mild period preceding the cold phase in question is known to have been longer and warmer than $LGI_{1/2}$, it is inadvisable to transfer the term Last Interglacial to $LGI_{1/2}$. A great deal of confusion would thus be caused. Whilst, to the best of my knowledge, nobody has yet suggested this in so many words, it is unfortunately implied in the use of the term J u n g r i s s . Geologists not acquainted with the problem would inevitably take J u n g r i s s to mean that this phase was in time more closely linked with the Riss Glaciation and that it was followed by the main Last Interglacial. What has happened is, of course, merely that a glacial phase, the equivalent of which in the periglacial zone has often been called Würm I, has now proved to be well separated from the Alpine Würm complex, though even so it is closer to the Würm than to the Riss complex. There appears to be little enthusiasm among Alpine geologists for continuing to call this phase Würm I, a term preferable to J u n g r i s s . The best way out may well prove to be the introduction of a completely new name. The attached table is intended to summarize the evidence as it stands, in the hope that it may prove useful as a basis for discussion of the nomenclatorial problem. As to the facts, I have the impression that a large measure of agreement already exists among the investigators concerned, though local details remain to be worked out.

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Anschrift des Verf.: Prof. Dr. F. E. Zeuner, Univ. of London, Institute of Archaeology, Inner Circle, Regent's Park, London NW 1.