secure a better general understanding of science and a better integration of science into the culture of our time. It seems necessary first because a growing gulf of lack of understanding endangers the continued support of scientific work. Second, it seems necessary because science and engineering have become and must continue to be a fundamental support of the way of life and the type of society we wish to continue. The future of science depends largely upon public understanding and acceptance; the welfare of the world depends largely upon the future of science and the wisdom with which society handles the problems that are raised by scientific and engineering developments.

Perhaps we need another revolution in thought, a revolution led by another enthusiastic and devoted rebel who will make it his life's work to bring about the better integration of science into the complex web of modern life and culture.

Postglacial Hypsithermal Interval

Edward S. Deevey and Richard Foster Flint

It is generally agreed (*1*) that some time after about 11,000 years ago, when continental ice sheets disappeared from the more temperate parts of northwestern Europe and northeastern North America, most of the world entered a period when mean annual temperatures exceeded those of the present. We have objected (*2*) to the term *postglacial climatic optimum,* which is in widespread use for this warm climatic phase, but our suggested term, *thermal maximum* (*2*), is likewise open to objection (*3*). In both nomenclature and stratigraphy, the definition of the interval has seemed inseparable from the problem of the "Little Ice Age" (*4*), but a recent interpretation (*5*) of glacial events in the Glacier Bay district of Alaska has been helpful in clarifying our thinking.

We propose to recognize the *hypsithermal* interval, adopting the term applied by Chiarugi (*6*), but changing its spelling and redefining it as the time represented by four pollen zones, V through VIII in the Danish system. More precisely, it was the time of abundant hazel (*Corylus*) pollen in lake and bog sediments in Germany, from the first rise of hazel at the bottom of zone V to its decline (and that of *Quercus* + *Tilia* + *Ulmus* pollen) to values below 10 percent of total arboreal pollen at the bottom of zone IX (*7*). In effect, this redefinition calls for a return to the stratigraphic scheme of Rutger Sernander as modified by von Post (*8*); the interval is the equivalent of von Post's *postarktisk värmetid.*

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Stratigraphy

For the stratigraphy of the time represented by the last 12,000 years, northwestern Europe is the best-known region, and it is there that we look for a point of departure. Although the designation of a type section is customary in stratigraphic practice, we omit it through inability to choose, among several thousand published pollen sequences, a single one more suitable than a hundred others. Instead, we give in Table 1 summaries of the postglacial pollen stratigraphy of Denmark and northern Germany. The numerical system of zonation is the Danish one (*9*). The dating of the zonal boundaries is approximate, but it incorporates radiocarbon evidence (*2, 10*) as well as other data (*11*). The table also gives the dates of recurrence horizons in Swedish bogs (*12*), the radiocarbon-dated glacial maxima in the Glacier Bay district (*5*), and a generalized pollen stratigraphy of eastern North America that incorporates the recent work of Leopold (*13*).

The climatic character of the European phases is broadly but convincingly shown by the estimated displacement of the alpine timberline in Switzerland (*14*), which is also included in Table 1. With this information, as with other phytogeographic evidence, it is difficult to separate the effects of temperature from those of precipitation, but if temperature variation was primary—as much other evidence suggests (*15*), it is reasonable to apply the lapse rate in calculating the temperature anomalies. This leads to the inference that the thermal maximum of 2° to 3°C above the present occurred in sub-Boreal time in Switzerland, and that temperatures higher than today's prevailed from Boreal through sub-Boreal time.

Nomenclature

The long, warm interval spanned by Danish pollen zones V through VIII, which has been dated from approximately 7000 B.C. to approximately 600 B.C., we propose to call the *hypsithermal* interval. We have changed the spelling of Chiarugi's *ipsotermico* (*6*) to conform with the English style of Greek adjectives and to express the customary distinction between *hypsi-*, high, and *hypso-*, a height. Chiarugi's original definition was explicitly based on rock-stratigraphic units, but it included his pollen zones III through IVb, thus excluding zone Va, sub-Boreal. The exclusion seemed reasonable in the light of the pollen stratigraphy of maritime Etruria and of other facts known in 1936, but it can now be seen that it makes the hypsithermal interval too short.

Apart from its priority, we prefer this term to others because (i) *optimum* is subjective and, when it is applied interchangeably in arid and humid countries, ambiguous; (ii) *thermal maximum,* as Antevs (*3*) has stated, applies to a stratigraphic horizon or to a point in time, not to a zone or its time equivalent; (iii) *xerothermic* usually implies too much that is unknown and is at best of local application; (iv) *altithermal* (*16*) is an etymologic hybrid and its stratigraphic basis has never been defined—as it is dated, it applies to only part of the zone in question; (v) *megathermal* (*17*), although correctly formed, is uninformative as to how "big" or "mega-" was the temperature; was the interval, for instance, more megathermal than the warmest part of the Sangamon interglacial?

By broadening the stratigraphic definition to include pollen zones V through VIII in the German and Danish sequences, we emphasize the fact that the hypsithermal interval, though prevailingly warmer than the present, included several thermal maxima with intervening cooler phases. Some may quarrel with the inclusion of all of zone V, which was laid down when the climate was warming rapidly, but this is a matter of convenience: it is easier to obtain agreement on the lower boundary of a pollen zone than it is to decide the precise time at which rising temperature equaled that of today.

By including zone VIII, the sub-Boreal, we express dissent from a common misconception—that, because conditions in Fennoscandia were optimal for elm and linden during Atlantic (Littorina) time, the postpluvial arid phase of the American Southwest must have been of Atlantic age. In particular, by keeping in mind the recurrence horizons of bogs and their climatic implication that several oscillations of atmospheric moisture were superposed on the postglacial thermal variation, we begin to understand the confusing fact that parts of the hypsithermal interval were warmer than others. Among the warmer episodes, the run of dry, hot summers immediately preceding 600 B.C. in northwest Europe is especially notable; it led to the oxidation of peat under recurrence horizon III, the classic *Grenzhorizont* of C. A. Weber, and was responsible for Sernander's interpretation of the end of the "warmth period" as catastrophic.

Matthes (*4*) introduced the term *Little Ice Age* for an episode of renewed glaciation that began sometime after the driest part of postglacial time and culminated in or shortly before the 18th century A.D., since which time glaciers in many parts of the world have been shrinking. The renewed glaciation appears to have been restricted to mountains; it has not been manifested by continental ice sheets, at least in temperate latitudes. Antevs' dating (*16*) of the "altithermal" (5000–

Table 1. Late-glacial and postglacial stratigraphy of northwestern Europe and northeastern United States, including recurrence horizons in Swedish bogs; alpine timberline in Switzerland according to Lüdi (*14*); glacial episodes at Glacier Bay, Alaska, according to Yale radiocarbon dates (*5*).

Years B.P.		Zones	Pollen sequence, Denmark	Pollen sequence, North Germany	Alpine timberline (meters above present)	Sweden (Recurrence horizons in Swedish bogs)	Alaska (Glaciations in Glacier Bay area)
2,000	Postglacial	IX	SUB-ATLANTIC BEECH, OAK	SUB-ATLANTIC BEECH, OAK	X YOUNGER SUB-ATLANTIC ±0; IX OLDER SUB-ATLANTIC +100 -200	I, II	V, IV
4,000	Postglacial; Hypsithermal	VIII	SUB-BOREAL OAK, ASH, LINDEN	SUB-BOREAL OAK, BEECH	VIII SUB-BOREAL +300 -400	III, IV, V	III, II
6,000	Postglacial; Hypsithermal	VII	ATLANTIC OAK, ELM LINDEN, IVY	ATLANTIC OAK, ELM LINDEN	VII YOUNGER ATLANTIC +200 -300		I
8,000	Postglacial; Hypsithermal	VI	(TRANSITION)		VI OLDER ATLANTIC +100 -200		
	Postglacial; Hypsithermal	V	BOREAL PINE, HAZEL	BOREAL PINE, HAZEL	V BOREAL +100		
10,000	Postglacial	IV	PRE-BOREAL BIRCH, PINE	PRE-BOREAL BIRCH, PINE	IV PRE-BOREAL ±0		
	Late-glacial	III	YOUNGER DRYAS BIRCH, PARK-TUNDRA	YOUNGER DRYAS PARK-TUNDRA	III YOUNGER DRYAS -800		
12,000	Late-glacial	II	ALLERÖD BIRCH, PINE, WILLOW	ALLERÖD PINE, BIRCH	II ALLERÖD -500		
	Late-glacial	Ic	OLDER DRYAS TUNDRA	OLDER DRYAS TUNDRA	I OLDER DRYAS		
	Late-glacial	Ib	BÖLLING BIRCH PARK-TUNDRA	BÖLLING PARK-TUNDRA			
14,000	Late-glacial	Ia	OLDER DRYAS TUNDRA	OLDER DRYAS TUNDRA			

Northeastern United States	Zones		Years A.D./B.C.
SUB-ATLANTIC OAK, CHESTNUT	C3	Postglacial	0
SUB-BOREAL OAK, HICKORY	C2	Postglacial; Hypsithermal	2,000
ATLANTIC OAK, HEMLOCK	C1	Postglacial; Hypsithermal	4,000; 6,000
BOREAL PINE	B	Postglacial; Hypsithermal	
PRE-BOREAL SPRUCE, FIR PINE, OAK	A L IN MAINE	Postglacial; Late-glacial, Maine	8,000; 10,000
YOUNGER HERB ZONE PARK-TUNDRA	T3	Late-glacial, Maine	
PRE-DURHAM SPRUCE SPRUCE, PINE, BIRCH	T2	Late-glacial, Conn.	
OLDER HERB ZONE TUNDRA	T1	Late-glacial, Conn.	12,000

2500 B.C.) is based on the belief that warm dry conditions ended in the Southwest when the "Little Ice Age" (his "medithermal") began, roughly 4000 years ago according to indirect evidence (the age of certain modern salt lakes).

More direct dating, by radiocarbon, of glaciations in Alaska and British Columbia shows that several (probably five) glacial episodes have occurred in Alaska since 5000 B.C. (*5*). The oldest of these, which has been dated to the time of the Boreal-Atlantic transition, may prove to be of Long Draw (= Cochrane?) age (*18*); it antedated the "Little Ice Age" as dated by Matthes and as currently understood. A later glacial advance, dated between 2380 and 1340 B.C., may represent Matthes' "Little Ice Age"; it was followed by others about 600 B.C., about A.D. 400, and about A.D. 1200. Thus, some of the glaciations overlap some of the warmest parts of hypsithermal time, as do some of the bog-recurrence phenomena. We therefore consider that the glacial chronology of Alaska and the Cordillera must no longer be allowed to obscure understanding of better-known regions. Our hypsithermal unit begins and ends at identifiable levels in stratigraphic sections, as the "Little Ice Age" does not, and the overlying zone, although its plant assemblages imply cooler climate, is nonglacial.

Reemphasizing the fact that any geologic time interval must have a basis in stratigraphy, we must face the semantic problem raised by the term *zone*. The code of the Committee on Stratigraphic Nomenclature (*19*) accepts *zone* as a time-stratigraphic unit of lower rank than *stage*, but provides no time equivalent, as *age* is the time equivalent of *stage*. Some authorities consider that as *zone* is strictly defined by fossils, not by lithology, it is an aberrant kind of rock-stratigraphic unit (such as *bed*) and needs no time equivalent. Dunbar and Rodgers (*20*) point out, however, that all time-stratigraphic units (*stage, series, system*) are, or should be, defined by included fossils, and consider that *zone* is the same kind of unit, but usually finer and more likely to be local. They urge the use of H. S. Williams' (*21*) term *chron* and its compounds as the time equivalent for *zone*, but these terms (*palynochron* would be the appropriate term for the time of a pollen zone) will probably not find favor with pollen stratigraphers, few of whom have troubled to inform themselves of stratigraphic procedures. We have used the informal term *interval* in designating the time equivalent of the four pollen zones that comprise the hypsithermal; for the time equivalent of a pollen zone, we (*2*) have previously proposed *climatic phase*. The hypsithermal time-stratigraphic unit may not often need a name above and beyond its component zones, but when it does, logic and usage agree in suggesting that the term is *substage*, not *superzone*.

Conclusion

Restricting the previously proposed term, *postglacial thermal maximum*, to a time-stratigraphic horizon or a point in time, we adopt Chiarugi's term *hypsithermal* as a substitute for *climatic optimum* and other unsuitable terms. Defining the stratigraphic unit whose time was hypsithermal, we assign to it four pollen zones, V through VIII in the Danish system, Boreal through sub-Boreal in the Blytt-Sernander terminology, dated approximately from 7000 to 600 B.C. Stratigraphic-chronologic sequences expressing fluctuations of atmospheric moisture (for example, recurrence horizons in bogs) or of glaciation in mountains (for example, the "Little Ice Age") are held to be independent and are not allowed to obscure the importance of temperature variation as an important basis of Pleistocene (including postglacial) stratigraphic subdivision.

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