Article

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PALEOHYDROLOGICAL CHANGES IN JURA (FRANCE), AND CLIMATIC OSCILLATIONS AROUND THE NORTH ATLANTIC FROM ALLERØD TO PREBOREAL

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ABSTRACT Regional palaeohydrological changes recorded in the Jura lakes, France, have led to a tentative reconstruction of a fine-scale pattern of climatic changes from Allerød to the early Holocene. The Younger Dryas (YD) can be subdivided into three parts: after a first wet phase, this cool period was characterized by increasing dryness; a short rise in lake level developed during its last part. Moreover, the YD was preceded and followed by two short rises in lake-level, which interrupted the lake-level lowerings developing during the Allerød and the Preboreal. Climatic oscillations reconstructed in Jura appear to be in phase with glacier and tree-limit movements in the Alps, with fluctuations in oxygen-isotope records from the Swiss lakes and the Greenland ice sheet, and with climatic oscillations recorded in the Norwegian Sea. Other correlations between (1) these climatic oscillations, (2) ^{14}C plateaux recorded in Swiss lake sequences, and (3) fluctuations in the residual $\Delta^{14}C$, support a correlation between regional palaeohydrological changes defined in Jura and broad-scale climatic oscillations; they also support the existence of a link between climatic changes in Western and Central Europe and oceanic circulation. Moreover, as working hypothesis, these correlations suggest high-precision timing for the climatic and environmental changes occurring during the early Holocene.

RÉSUMÉ *Changements paléohydrologiques dans le Jura (France) et oscillations climatiques autour de l'Atlantique Nord de l'Allerød aux débuts de l'Holocène.* Les changements paléohydrologiques enregistrés dans les remplissages des lacs du Jura permettent de proposer une reconstitution détaillée des oscillations climatiques de l'Allerød aux débuts de l'Holocène. Trois phases sont distinguées à l'intérieur du Dryas récent : une phase à bilan hydrique déficitaire encadrée par deux phases humides. D'autre part, deux courtes phases de hausse du niveau des lacs surviennent avant et après le Dryas récent, interrompant momentanément la baisse des plans d'eau qui se développe pendant l'Allerød et le Préboréal. Ces oscillations climatiques reconstituées dans le Jura apparaissent en phase avec les mouvements des glaciers et de la limite supérieure de la forêt dans les Alpes, avec les stratigraphies isotopiques établies dans les lacs suisses et au Groenland ainsi qu'avec des oscillations climatiques enregistrées en mer de Norvège. D'autres corrélations entre ces oscillations climatiques, les plateaux du radiocarbone repérés dans les lacs suisses et les fluctuations du $\Delta^{14}C$ résiduel indiquent l'existence d'une corrélation entre les changements paléohydrologiques reconnus dans le Jura et des oscillations plus globales du climat. Elles renforcent aussi l'idée d'un lien entre la circulation océanique et les changements climatiques affectant alors l'Europe occidentale et centrale. Enfin, elles permettent de proposer des références chronologiques de haute précision pour les changements climatiques et environnementaux survenant au début de l'Holocène.

ZUSAMMENFASSUNG *Paläohydrologische Veränderungen im Jura, Frankreich und klimatische Schwankungen um den Nordatlantik vom Allerød bis zu den Anfängen des Holozän.* In den Juraseen festgestellte regionale paläohydrologische Veränderungen erlaubten eine vorläufige detaillierte Rekonstruktion der klimatischen Wechsel vom Allerød bis zum frühen Holozän. Die jüngere Dryaszeit kann in drei Phasen unterteilt werden: nach einer ersten feuchten Phase, charakterisierte sich die darauffolgende kalte Periode durch zunehmende Trockenheit; während der letzten Phase entwickelte sich eine kurze Anhebung des Seenniveaus. Außerdem gab es zwei kurze Anhebungen des Seenniveaus, eine vor und eine nach der Dryaszeit, welche die Senkungen des Seenniveaus, die während des Allerød und dem frühen Holozän auftraten, unterbrachen. Die im Jura rekonstruierten klimatischen Schwankungen scheinen mit den Gletscher- und Baumgrenze-Bewegungen in den Alpen zeitlich übereinzustimmen, wie auch mit den Fluktuationen in den Sauerstoffisotopenbelegen von Schweizer Seen und der Grønland-Eisdecke, und mit den im norwegischen Meer festgestellten Klimaschwankungen. Andere Korrelationen zwischen (1) diesen Klimaschwankungen, (2) ^{14}C Plateaux, die in Schweizer Seen-Sequenzen festgestellt wurden und (3) Fluktuationen im $\Delta^{14}C$ Rückstand, stützen eine Korrelation zwischen den im Jura festgestellten regionalen paläohydrologischen Veränderungen und globaleren Klimaschwankungen; sie stützen auch die Annahme einer Beziehung zwischen den Klimawechseln in West- und Zentraleuropa und der Ozeanströmung.

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INTRODUCTION

Recent warming enhances an urgent need to understand the dynamics of climatic changes. The study of past climates can contribute to this understanding by offering references for natural factors controlling climatic oscillations. The abrupt cooling characterizing the Younger Dryas and the subsequent warming occurring during the early Holocene certainly constitute the most prominent broad-scale climatic events of the last 12 000 years. Thus, their study is of particular interest.

Investigations carried out in the Jura lakes, France, have recently provided high-resolution records of the time span *ca.* 11 500-9000 BP (Magny and Ruffaldi, 1995). This paper has three aims:

(1) To present a fine-scale pattern of palaeohydrological changes during the Younger Dryas and the early Holocene from the Jura lakes.

(2) To attempt correlations between this regional palaeohydrological pattern and records of more global significance, by comparing the Jurassian proxy data with data obtained from continental, ice sheet and oceanic records around the North Atlantic area.

(3) To discuss several implications of these tentative correlations, in particular with regard to the link between palaeohydrological oscillations on the European continent and changes in ocean circulation during the deglaciation.

Below, dating of palaeoclimatic events is indicated by uncalibrated radiocarbon dates: BP, and calibrated radiocarbon dates: cal. BP. Dates obtained from yearly laminated Greenland ice cores are expressed in cryo-years.

PALAEOHYDROLOGICAL CHANGES IN JURA FROM *ca.* 11 500 to *ca.* 9000 BP

The Jura range is a medium sized mountain chain culminating at 1723 m. Sedimentological and palynological analyses of stratigraphical sequences from three lakes of central Jura (Fig. 1): Onoz (560 m), Remoray (851 m) and Saint-Point (850 m) led to the reconstruction of a detailed pattern of lake-level fluctuations from the late Allerød to the early Holocene. The lake-level changes are reconstructed on the basis of the use of multiple lines of evidence, *i.e.* changes in (1) the sediment texture, (2) the sediment composition (lithology), and (3) the frequency and the types of carbonate concretions in lake marl. Hiatus evidenced by pollen stratigraphy also can give further indications (Magny, 1992a, b). Figure 2 presents the records of lake-level changes obtained at lakes Onoz, Remoray and Saint-Point (Magny and Ruffaldi, 1995). The chronology is based on a layer of Laacher See tephra (Bogaard and Schmincke, 1985) and on pollen zones; today, the lateglacial and Holocene vegetation history in the Jura mountains is well known and has benefitted from numerous radiocarbon datings (Wegmüller, 1966; Richard, 1983; Ruffaldi, 1993; de Beaulieu *et al.*, 1994) (Table I). Several rises in lake level can be distinguished as follows:

• The Allerød period corresponds to a lowering phase interrupted by a rise in lake level (the transgressive Onoz 1 phase) developing just before the Laacher See tephra deposition, *i.e.* around 11 000 BP.

• The start of the Younger Dryas (YDS) coincides with an abrupt rise in lake level (the transgressive Onoz 2 phase). Then, this period is marked by a progressive fall in the water level. This drying could correspond to the culmination of the climatic deterioration. A short transgressive phase (Onoz 3 phase) developed just before the Younger Dryas termination (YDT). By referring to a YD duration of *ca.* 1300 calendar years (Stuiver and Braziunas, 1993), the sedimentation rate shown by the stratigraphical sequence of Lake Onoz suggests that the rise in lake level corresponding to the Allerød-YD transition (*i.e.* the beginning of the Onoz 2 phase) took less than 50 years. In the same way, the Onoz 3 phase marking the last part of YD has a duration shorter than 200 years.

• The transition from the YD to the Preboreal is characterized by a fall in water level. This low lake level characterized most of the Preboreal. It was interrupted only by a short but well-recorded transgressive phase, *i.e.* the Remoray phase. By referring to a YDT dated at 11 650±250 cryo-years BP (Stuiver and Braziunas, 1993) and a Preboreal-Boreal transition dated at *ca.* 9950 cal. BP in Jura, the sedimentation rate shown by the stratigraphical sequence of Lake Remoray would suggest that this phase of rising lake level developed between *ca.* 11 110 and 10 730 cal. BP.

The lowering of lake level in Jura during the Preboreal has also been observed at two other sites: (1) In southern Jura, Richard (1991) reconstructed a similar regressive phase from the stratigraphical sequence of Lake Bart. Here, a peat layer interbedded between two lake-marl layers and dated at 9630±360 BP indicates a major lowering phase (overgrowing); moreover, this low water level is underlined

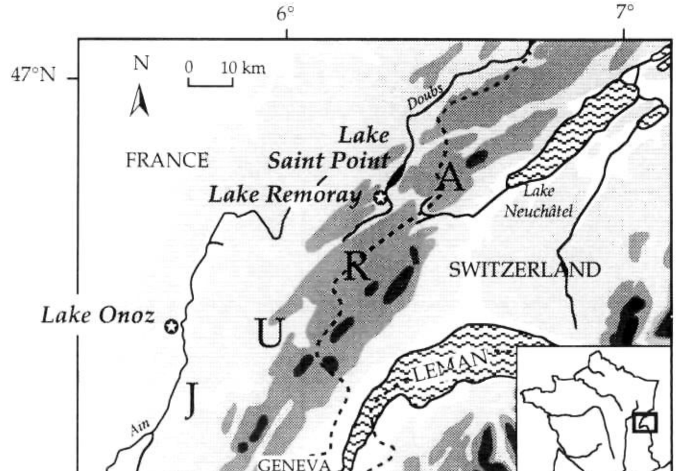

FIGURE 1. Location of the investigation area and studied sites.
Région d'étude et localisation des sites de référence.

by a hiatus in the pollen assemblages. (2) In northern Jura, in the stratigraphical sequence of Lake Chaillexon, the Preboreal also corresponds to a hiatus in sedimentation; this would suggest a major water-level lowering reaching 9 m (Di Giovanni, 1994).

- The transgressive Joux phase developing during the Boreal could have begun as early as the late Preboreal at Remoray (*i.e. ca.* 10 250 cal. BP from the sedimentation rate). It ended at *ca.* 8950 cal. BP.

The palaeohydrological pattern reconstructed from lacustrine sequences of Jura for the YD and the early Holocene is in good agreement with that established in the Alps and in other European countries for the same periods. From pollen data in Upper Valais (Switzerland), Markgraf (1969) distinguished two main phases in the YD: an older one believed to be rather oceanic and a younger one thought to be more continental. Kerschner (1980) outlined a similar climatic pattern from glaciers in the Alps during the Egesen phase (*i.e.* YD). This deficit in water balance developing during the YD cold period has also been evidenced by Guiot and Pons (1986) and Pons *et al.* (1987); using a quantitative reconstruction method from pollen time-series, they highlight a marked cooling accompanied by a large decrease in precipitation in France and eastern Spain. Hence, by referring to this palaeohydrological scheme, the increased values of *Filipendula* and *Betula* discussed by Lotter *et al.* (1992) in Swiss lakes during the PAZ CHb-4b2 should be attributed not to a wetter climate, but to a lowering of lake levels and to development of wider moist zones around these lakes.

Thus, three phases can be distinguished during the YD. The first is characterized by an abrupt cooling and by a wet climate; this is termed the Onoz 2 phase. The second is marked by a progressive drying; it could correspond to the culmination of the climatic deterioration. These first and second phases could be correlated with the two phases distinguished by Markgraf (1969) and Kerschner (1980) in the Alps. An additional third phase, evidenced from the high-resolution record of Lake Onoz and termed the Onoz 3 phase, shows increasing wetness at the YDT and could indicate a rapid inversion of the climatic trend preceding the marked climatic warming at the YD-Preboreal transition. All these Jurassian lacustrine sequences indicate that the Preboreal considered as a whole coincides with a fall of lake level, giving evidence of a significant deficit in water budget. Ammann (1989), Gaillard (1984) and Digerfeldt (1988) arrive at a similar palaeohydrological pattern in Switzerland and South Sweden. Starkel (1991) also highlights a reduction in the water discharge of the Upper Vistula in Poland during this period. The data synthetized by Gaillard (1985) support the idea that this lowering phase is a widespread European phenomenon.

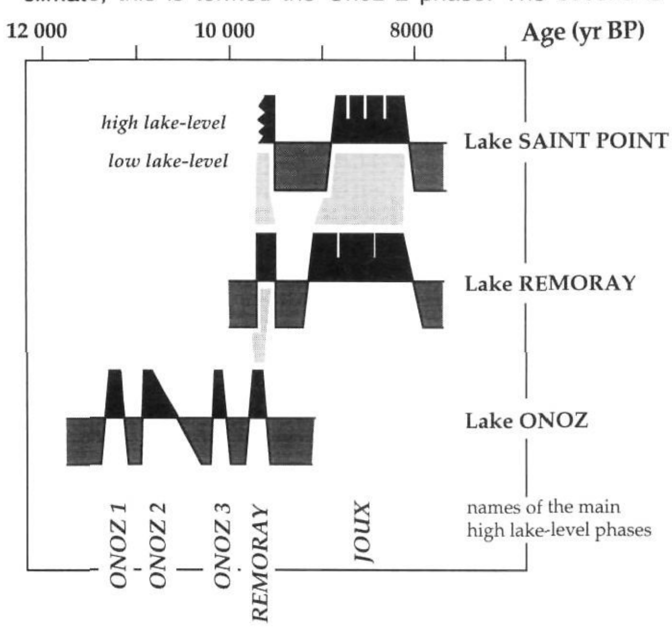

FIGURE 2. Palaeohydrological changes recorded in the lakes Onoz, Remoray and Saint-Point between 11 500 and 8000 BP.

Changements paléohydrologiques enregistrés dans les lacs d'Onoz, de Remoray et de Saint-Point entre 11 500 et 8000 BP.

In Jura, as already mentioned, this Preboreal phase of negative water budget appears to be interrupted by a short phase of positive water balance, termed the Remoray phase. From a pollen/mollusc/ostracod sequence in South Wales (UK), Walker *et al.* (1993) reconstructed similar warm and dry conditions for the Preboreal and identified a short-lived climatic cooling in the middle of the tenth millennium BP. In Scania, records from lakes Torreberga (Digerfeldt, 1971) and Krageholmssjön (Gaillard, 1984) also show a phase of increased lake level occurring between 10 000 and 9500 BP.

The lake level lowering observed in Jura during the Preboreal is synchronous with a general retreat of glacier tongues in the Austrian and Swiss Alps (Patzelt, 1977; Zoller, 1977). It marks the climatic warming developing after the YD. Moreover, the short-lived climatic oscillation, termed the Remoray phase in Jura, can be correlated in the Alps with a similar cold event marked by a glacier advance (Patzelt, 1977; Zoller, 1977) and a tree-limit decline, termed the Palü phase by Burga (1988). In the same way, the

TABLE I

Correlation of the Jura pollen-zone system to ^{14}C chronology (conventional and calibrated).

Pollen zone	Age (yr BP)	Age (cal. yr BP)
	8 000	8 850
Boreal		
	9 000	9 980
Preboreal		
	10 000	*11 150*
Younger Dryas		
	11 000	*12 920*
Allerød		
	12 000	*13 990*

From De Beaulieu *et al.* (1994).
Italics indicate calibrated dates by comparision of the U-Th and ^{14}C ages of the Barbados corals.

transgressive Joux phase coincides with a glacier advance and a tree-limit decline in the Alps, termed the Venediger-Schams phase (Patzelt, 1977; Zoller, 1977) (Fig. 5).

CLIMATIC OSCILLATIONS, OXYGEN-ISOTOPE STRATIGRAPHY AND RESIDUAL $\Delta^{14}C$ RECORD

The palaeoclimatic pattern previously reconstructed from Jura lakes and Alpine sites matches with that evidenced by Lotter *et al.* (1992) for the Swiss lakes and with the correlations they make with the Greenland ice sheet (Fig. 3). The oxygen-isotope stratigraphies obtained in Swiss Plateau and in Greenland highlights that the Younger Dryas is preceded and followed by two distinct short climatic oscillations, respectively termed the Gerzensee and the P fluctuation (*i.e.* Preboreal fluctuation). Thus, the Onoz 1 phase appears to be synchronous with the Gerzensee fluctuation also occurring shortly before the deposition of the Laacher See tephra; the Remoray phase (Fig. 2) can be correlated with the P oscillation (Fig. 4).

The palaeoclimatic pattern established from Jura, the Swiss Plateau and the Alps can be also correlated with the curve of the residual $\Delta^{14}C$ recently extended back to 11 400 cal. BP (Stuiver *et al.* , 1993) from tree-ring series. Figure 5 shows tentative correlations between (1) the residual $\Delta^{14}C$ curve as published by Stuiver and Reimer (1993) and (2) the Jurassian and Alpine glacier records (Magny, 1995). The palaeoclimatic events were dated in solar years by calibration of their radiocarbon chronology from Stuiver and Reimer (1993). Despite the uncertainty inherent in the radiocarbon method (standard deviation), the Jurassian lakes, the Alpine glaciers and the $\Delta^{14}C$ record display fluctuations showing a similar *rhythm* : the rises in lake level in Jura and the glacier advances in the Alps appear to be synchronous with $\Delta^{14}C$ maxima, and inversely. Stuiver and Braziunas (1993) suggested that during the early Holocene, the $\Delta^{14}C$ oscillations reflect an oceanic forcing. $\Delta^{14}C$ maxima should be linked to changes in thermohaline circulation: a reduced upwelling of ^{14}C-deficient water increases surface ocean and atmospheric $\Delta^{14}C$ levels. Thus, the phases characterized by low lake level in Jura, glacier retreat and rise in tree limit in Alps would be associated with a strengthened North Atlantic Deep Water (NADW) flow, and the phases marked by rises in lake level in Jura, glacier advance and tree-limit fall in the Alps would be associated with a smaller NADW flow. From the $\Delta^{14}C$ residual curve, the YD-Holocene transition and the climatic improvement following the Palü/Remoray phase does coincide with two noticeable drops in $\Delta^{14}C$ values inducing ^{14}C plateaus in palaeoenvironmental records. From a detailed lateglacial and early Holocene radiocarbon stratigraphy established by Ammann and Lotter (1988) and Zbinden *et al.* (1989) for the Swiss Plateau, three ^{14}C plateaux have been highlighted at *ca.* 12 700, 10 000 and 9500 BP. The first and the second coincide respectively with the Oldest Dryas-Bølling transition and the YD-Holocene transition. The third appears to be synchronous with the P oscillation. The correlations between palaeoclimatic data and $\Delta^{14}C$ falls appear to be in agreement with the ^{14}C plateaus defined for the same periods in Switzerland.

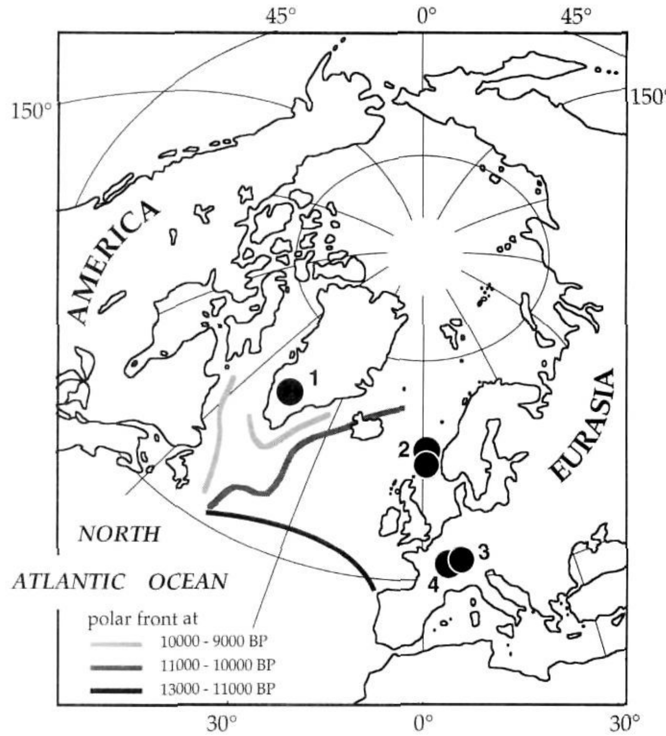

FIGURE 3. Reference sites around the North Atlantic: (1) Dye 3, Greenland (from Dansgaard *et al.*, 1989); (2) Cores HM 79 6/4 (from Karpuz and Jansen, 1992) and Troll 3.1 (from Lehman and Keigwin, 1992); (3) Swiss Plateau and Alps; (4) Jurassian lakes. The successive positions of the polar front are drawn from Ruddiman and McIntyre (1981).

Position des sites de référence autour de l'Atlantique Nord : (1) Dye 3, Groenland (d'après Dansgaard et al.*, 1989); (2) Sondages HM 79 6/4 (d'après Karpuz et Jansen, 1992) et Troll 3.1 (d'après Lehman et Keigwin, 1992); (3) Plateau et Alpes suisses; (4) lacs jurassiens. Les positions successives du front polaire sont indiquées d'après Ruddiman et McIntyre (1981).*

PALAEOCLIMATIC RECORDS FROM THE NORWEGIAN SEA

The correlations just proposed between palaeoclimatic records in Jura, the Swiss Plateau and the Alps and changes in oceanic circulation by referring to the residual $\Delta^{14}C$ curve appear to be supported by the results obtained by Lehman and Keigwin (1992) from the Norwegian Sea (Fig. 6). Faunal analyses of oceanic cores led these authors to distinguish in particular an Intra Allerød Cold Period (IACP) and a Preboreal oscillation (PB) respectively preceding and following the Younger Dryas. They correlated these climatic oscillations with those defined from oxygen-isotope stratigraphy in the Swiss lakes and interpreted them as sudden changes in thermohaline circulation.

The diatom record established by Karpuz and Jansen (1992) from two other cores from the Norwegian Sea presents strong similarities with that of Lehman and Keigwin. They distinguish a brief cooler condition occurring between 9900 and 9600 BP, termed the second YD; moreover, despite some chronological discrepancies, the Younger Dryas also appears here to be preceded by several short-lived

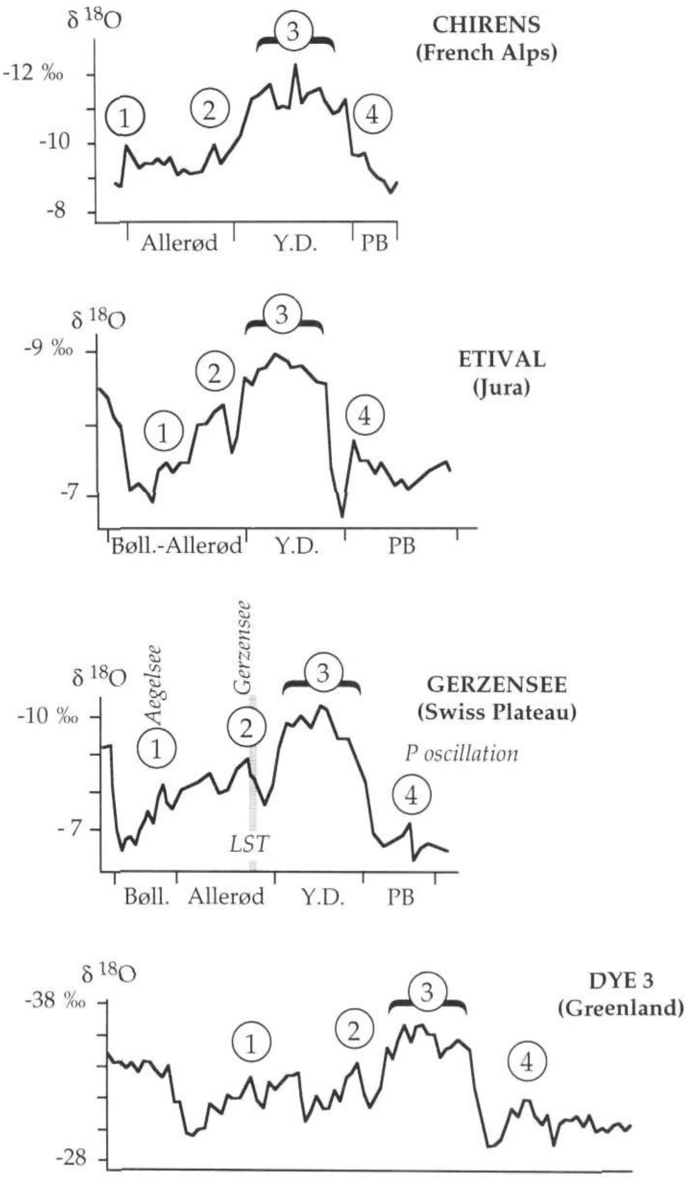

FIGURE 4. Tentative correlations between oxygen-isotope stratigraphies of sites from the French Alps (Chirens, from Eicher, 1987), Jura (Etival, from Campy *et al.*, 1983), Swiss Plateau (Gerzensee, from Lotter *et al.*, 1992) and Greenland (Dye 3, from Lotter *et al.*, 1992). LST: Laacher See Tephra. Oscillation 3 corresponds to the Younger Dryas. The abscissa axis corresponds to a depth scale; pollen analysis provides additional chronological references at lakes Chirens, Etival and Gerzensee.

Essai de corrélation entre les stratigraphies isotopiques de sites des Alpes françaises (Chirens, d'après Eicher, 1987), du Jura (Étival, d'après Campy et al., *1983), du Plateau suisse (Gerzensee, d'après Lotter* et al., *1992) et du Groenland (Dye 3, d'après Lotter* et al., *1992). LST : Laacher See Tephra. L'oscillation 3 correspond au Dryas récent. L'axe des abscisses correspond à une échelle de profondeur. Dans le cas des sites de Chirens, Etival et Gerzensee, l'analyse pollinique livre des références chronologiques complémentaires.*

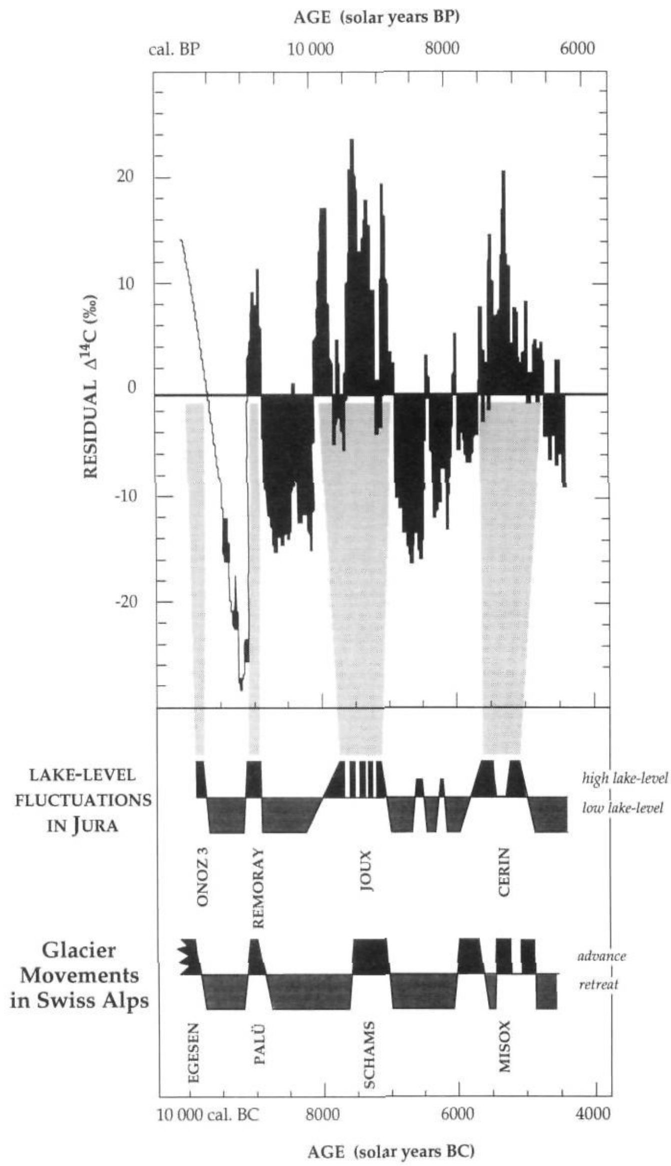

FIGURE 5. Tentative correlations between the curve of the residual $\Delta^{14}C$ (from Stuiver and Braziunas, 1993), the level fluctuations of the Jurassian lakes (from Magny, 1995) and the movements of the glacier and timberline in the Swiss Alps (from Zoller, 1977 and Burga, 1988).

Essai de corrélation entre la courbe du $\Delta^{14}C$ résiduel (d'après Stuiver et Braziunas, 1993), les fluctuations du niveau des lacs jurassiens (d'après Magny, 1995) et les mouvements des glaciers et de la limite supérieure de la forêt dans les Alpes suisses (d'après Zoller, 1977 et Burga, 1988).

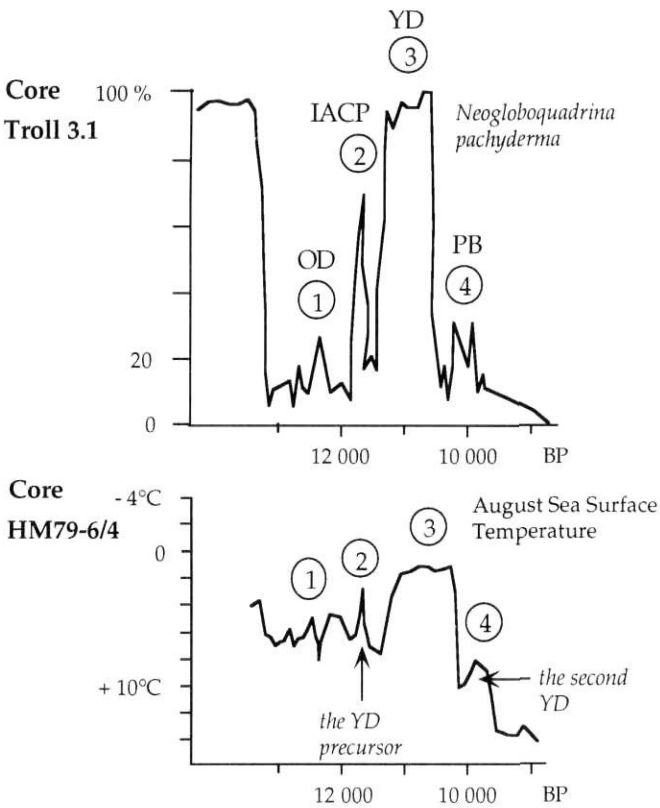

FIGURE 6. Tentative correlations between environmental changes recorded in oceanic cores from the Norwegian Sea (Lehman and Keigwin, 1992; Karpuz and Jansen, 1992). Oscillation 3 corresponds to the Younger Dryas.

Essai de correlation entre les changements environnementaux reconstitués à partir de sondages océaniques en mer de Norvège (Lehman et Keigwin, 1992 ; Karpuz et Jansen, 1992). L'oscillation 3 correspond au Dryas récent.

climatic oscillations, which could be correlated with the OD (*i.e.* Older Dryas) and IACP (*i.e.* Intra-Allerød Cold Period) fluctuations defined by Lehman and Keigwin, with the Aegelse and Gerzensee fluctuations defined by Lotter *et al.* (1992) in the Swiss plateau, or with the Onoz 1 phase defined in Jura during the Bølling-Allerød interstade.

DISCUSSION

The proxy data presented here from continental, ice sheet and oceanic sites around the North Atlantic suggest to recognize the existence of a similar *rhythm* in climatic oscillations between *ca.* 12 000 and 9000 BP and to propose a consistent fine-scale pattern of climatic changes for this time span. The Younger Dryas major cold event appears to be preceded and followed by minor short-lived oscillations well recorded in high-resolution stratigraphical sequences in different types of environment. Thus, the Killarney oscillation recognized from multiple lines of evidence in Eastern Canada (Cwynar *et al.* 1994), appears to be an equivalent to the Onoz phase 1, also termed Gerzensee phase in the Swiss Plateau and IACP in the Norvegian Sea. The magnitude of the cold events increases before and decreases after the Younger Dryas. Oxygen-isotope records display most often stepwise decreasing temperature via several climatic oscillations during the Bølling-Allerød interstade, and a more rapid warming at the YD-Holocene transition.

Direct correlations between continental and oceanic sequences support the idea of a link between (1) thermal and palaeohydrological oscillations on the European continent and Northern high latitudes, and (2) changes in oceanic circulation (Lehman and Keigwin, 1992). This link is also supported by the correlations observed between (1) palaeoclimatic records from Jura lakes and Alpine glaciers and (2) the residual Δ^{14}C record. Direct stratigraphical correlations observed between ^{14}C plateaus and palaeoenvironmental changes in Swiss sequences corroborate this pattern.

No tree-ring record is available to extend the residual Δ^{14}C curve beyond 11 400 cal. BP. The ^{14}C curve reconstructed from Swiss lake records by Zbinden *et al.* (1989) and the proxy data from continental and oceanic records tentatively suggest similar correlations between changes in residual Δ^{14}C, oceanic circulation and climate during the Bølling-Allerød interstade. From Zbinden *et al.* (1989), the climatic warming at the oldest Dryas-Bølling transition is well marked by a ^{14}C plateau, and then the stepwise cooling developing during the interstade is synchronous with an increase in the Δ^{14}C values. It can be speculated that the Aegelsee and the Onoz 1-Gerzensee oscillations could correspond to (minor?) peaks of Δ^{14}C and that the abrupt YDS could coincide with a similar strong rise in residual Δ^{14}C.

The palaeoclimatic records from the Jura lakes show that *broad-scale* climatic fluctuations can induce different types of palaeohydrological changes on a *regional scale*. Minor and short-lived climatic coolings coincide with rises in lake level. The Younger Dryas major cold event shows a more complex picture: the YDS and the YDT correspond to transgressive phases, but the culmination of the cooling occurred during a well-marked drying. Ruddiman and McIntyre (1981) associated the YD with a readvance of the North Atlantic polar front (Fig. 3); this readvance reached its most southward position between 11 000 and 10 000 BP. This southward position could have induced the water deficit evidenced in Jura between the Onoz 2 and 3 phases, due to a combination of several factors such as (1) a development of a continental high-pressure cell in Eurasia, (2) more frequent incursions of dry and cold polar air into Western Europe, and (3) a weaker evaporation on the cold North Atlantic. The Onoz 1-2-3 and Remoray phases could be associated with less southward readvances of the polar front explaining a positive water budget in Western and Central Europe. The deficit in water budget developing during the early Holocene between *ca.* 10 000 and 9000 BP and inducing a low lake level in Jura and glacier retreat in the Alps marks the climatic improvement following the YDT. It also reflects the summer-insolation maximum characterizing the early Holocene (Berger, 1979; Harrison, 1988) and effects of residual ice sheets on the atmospheric circulation (COHMAP, 1988; Harrison *et al.*, 1992).

The fine-scale palaeoclimatic pattern outlined suggests that the early Holocene was still marked by abrupt climatic changes synchronous with changes in the oceanic circulation (Bard *et al.*, 1987; Mörner, 1993; NASP Members, 1994). By referring to the residual $\Delta^{14}C$ curve, the climatic oscillation termed the second YD, PB or P oscillation, Remoray or Palü phase, could be precisely dated between 10 950 and 10 750 cal. BP. Moreover, by reference to (1) stratigraphical correlations between palaeoenvironmental changes and ^{14}C plateaus and (2) the residual $\Delta^{14}C$ curve, the YD-Holocene transition can be situated at *ca.* 11 650 cal. BP in agreement with the observations of Stuiver and Braziunas (1993). Karpuz and Jansen (1992) proposed that the increased meltwater flux at meltwater pulse IB (Fairbanks, 1989) might have been the cause of the "second YD". This pattern appears to be consistent with the large drop of residual $\Delta^{14}C$ before 11 150 cal. BP. But, as discussed by Stuiver and Braziunas (1993), some uncertainties still persist concerning the precise chronological position of the meltwater pulse IB.

Difficulties with the fine-scale reconstructions arise from the lack of absolute chronological references. The standard deviation in the radiocarbon datings leads to insufficient time accuracy in comparison with the need to correlate short-term events reported by continental and oceanic records. Ash layers can offer further high-precision but only relative references. In this context, correlations can be attempted by reference to *rhythm* and *magnitude* reconstructed in sequences of environmental changes and to *coherence* of the patterns reconstructed by assemblage of different types of palaeoclimatic records. Despite these difficulties, tentative fine-scale reconstructions of past climatic changes need further development to assess at what time scale natural factors interact in climate dynamics. Moreover, the previous discussion would suggest interesting hypothesis for dating palaeoenvironmental changes during the early Holocene in calendar years by correlations with the fluctuations of the residual $\Delta^{14}C$.

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