

**NATURAL C-14 VARIATIONS  
AND CONSEQUENCES FOR SEA-LEVEL FLUCTUATIONS  
AND FREQUENCY ANALYSIS OF PERIODS OF PEAT GROWTH**

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**ABSTRACT**

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The rise in sea level during the past 18,000 years has been studied largely by means of radiocarbon dating. The question of whether small fluctuations are superimposed on the steadily rising sea level is discussed. Support for this is the observed succession of clastic deposits and peat layers, resulting from alternating periods of transgressive and regressive activity. However, irregularities in the <sup>14</sup>C time scale might not only give rise to apparent steps in the relative sea-level rise, but also to clustering of <sup>14</sup>C dates of geological finds at certain <sup>14</sup>C intervals. Therefore, until there is more evidence the succession of clastic deposits and peat layers is interpreted as caused by local disasters at certain times and random regressive peat growth during quiet periods.

**INTRODUCTION**

As the ice sheets of the last glaciation melted down the global sea level started to rise. The course of this sea-level change during postglacial times has been the object of many studies. Most of the analyses are based on the fact that any past sea-level stand, which did not change too fast during a certain period, may have left a record on the continent beaches. In areas, where local or regional tectonic effects have been absent or constant in time, these beach and river delta formations can give information about past sea-level variations, provided they can be dated. In this way an attempt to establish the average global sea-level rise during the past 18,000 years has been made (e.g. GODWIN ET AL., 1958; FAIRBRIDGE, 1961; JELGERSMA, 1966; VAN ANDEL ET AL., 1967). After a rapid rise until about 5000 years ago, the sea-level rise decreased to the present-day rate.

For the North Sea basin the observed sea-level variation can only partly be attributed to the world sea-level movement. The Netherlands and the region around the southern North Sea basin are especially affected by the Scandinavian isostatic re-equilibration and by a regional crustal down warping: the North Sea geosyncline development. This local anomaly may

have decreased in recent millennia and be small in modern times. Although in this region a temporary fall in relative sea-level during the middle and young Holocene is extremely unlikely, interpretations based on geological records show fluctuations in the relative sea-level rise during the past 8000 years. The course of these smaller changes and the question of whether they are caused by crustal warping, eustatic or isostatic fluctuations, due to worldwide climatic changes, is still under discussion.

Most of the geological records used are documented in radiocarbon years. It will be shown here that <sup>14</sup>C data should be used with the utmost care (1) in the field of sea-level studies and (2) in the field of the analysis of frequency histograms, in view of past natural variations in the atmospheric <sup>14</sup>C concentration and thus of irregularities in the <sup>14</sup>C time scale.

**CONSTRUCTION OF A SEA-LEVEL CURVE  
FROM C-14 DATA**

In order to investigate the relative sea-level rise, most of the geological records have, indirectly or directly, been supplied with a time scale based on radiocarbon dates. However, soon after the introduction of this method it was recognized by measuring known age samples, that one of the basic premises, viz. a constant atmospheric <sup>14</sup>C level, is not entirely

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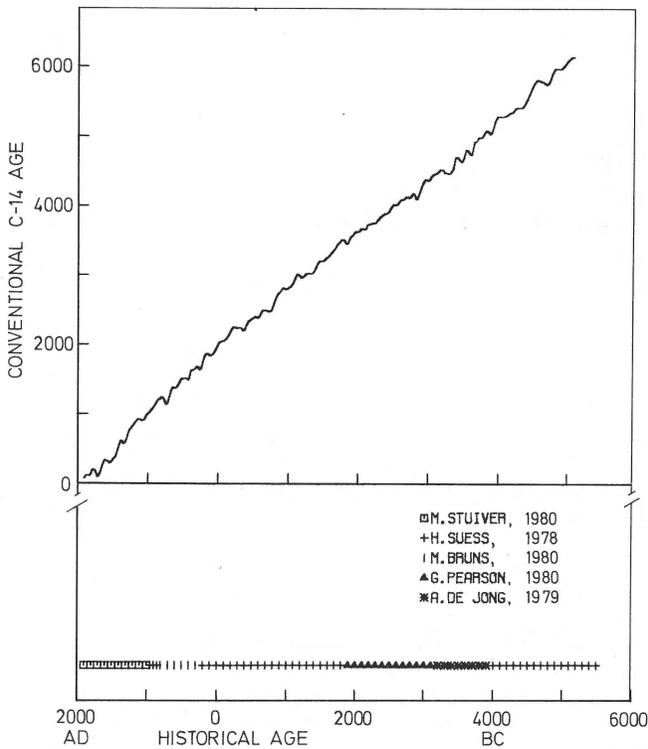


Fig. 1  
Spline function through the best available  $^{14}\text{C}$  analyses on dendrochronologically dated wood. The dates have been obtained from different laboratories, covering different intervals as demonstrated in the lower part. The bristlecone dates of Suess are corrected to the proper standard activity ( $0.95 \times \text{NBS oxalic acid}$ ). The original data (De Jong et al., 1979) have been slightly revised (De Jong & Mook, 1980).

correct. Due to a changing earth magnetic field the atmospheric  $^{14}\text{C}$  concentration varies sinusoidally in time, which results in a deviation from sidereal years up to 800 years around 5000 BC (BUCHA, 1970). Apart from this it has now definitely been established that smaller deviations with amplitudes of approximately 200 years occur, superimposed on this trend (DE JONG ET AL., 1979). Although a generally accepted calibration curve has not yet been established, a reliable curve, suitable for demonstrating the effects of these medium-term  $^{14}\text{C}$  variations, can be constructed (Fig. 1). Only  $^{13}\text{C}$ -corrected radiocarbon data, measured on dendrochronologically dated tree rings, are included with a standard deviation of less than 50 years. All measurements were carried out on tree-ring increments of less than 20 years, in order to obtain sufficient resolution. Through this set of data a cubic spline function has been constructed using the Reinsch algorithm, where the smoothing parameter is not too small in order to avoid an oscillating solution. Although any mathematical procedure introduces specific frequencies, it has been shown on white noise series that this algorithm acts as an ideal low-pass filter (NEFTEL ET AL., 1981).

Based on the general trend of the relative sea-level rise in the Dutch North Sea area and neglecting any form of compaction, figure 1 can now be converted into a depth/time

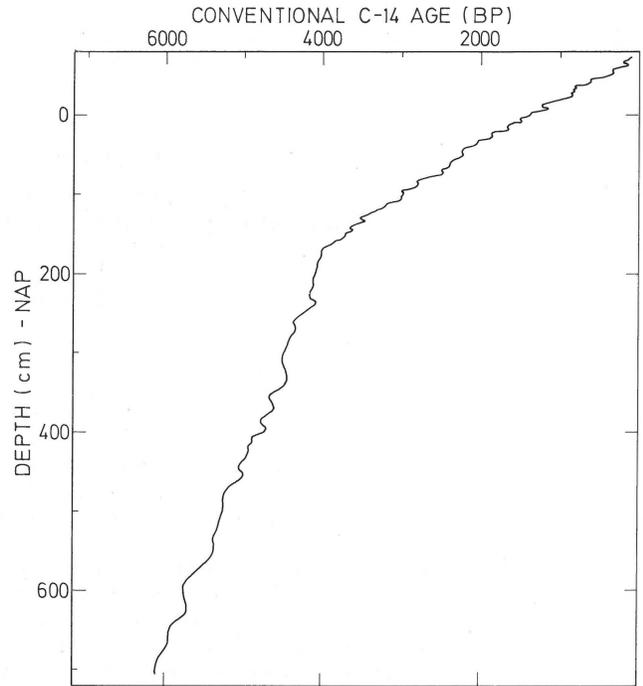


Fig. 2  
Apparent variations in the relative sea-level rise during the past 6000 years, as constructed from figure 1. A constant relative sea-level rise has been assumed of 5 cm/100 yr for the recent period back to 4000 BP and 20 cm/100 yr prior to this.

curve. To a first approximation the relative sea-level rise is assumed to be 5 cm/100 yr for the recent period back to 4000 BP and 20 cm/100 yr for the period prior to this. The resulting sea-level curve (Fig. 2) shows steps, which are in accordance with the medium-term radiocarbon variations.

The most pronounced steps occur in the intervals:  
5300-5000 BP,  
4700-4500 BP,  
4400-4100 BP.  
They seem to result in an apparent sea-level rise of only 3 cm/100 yr, 17 cm/100 yr less than the assumed constant rise of 20 cm/100 yr. On the other hand, the intervals 4100-4000 BP and 4500-4400 BP suggest an apparent rapid relative sea-level rise of approximately 60-70 cm/100 yr. The slower rise of the relative sea-level after 4000 BP compresses the radiocarbon variations, resulting in less pronounced steps. Nevertheless some apparently faster rises can be observed in the intervals:  
~ 3000 BP  
2400-2200 BP  
~ 800 BP

Hence, a set of radiocarbon dates, derived from peat and corresponding with a constant sea-level rise can be interpreted as a succession of periods with successive slow and fast relative sea-level rises.

The opposite situation occurs if one wants to translate a set of  $^{14}\text{C}$  dates from a sequence of peat layers into historical ages

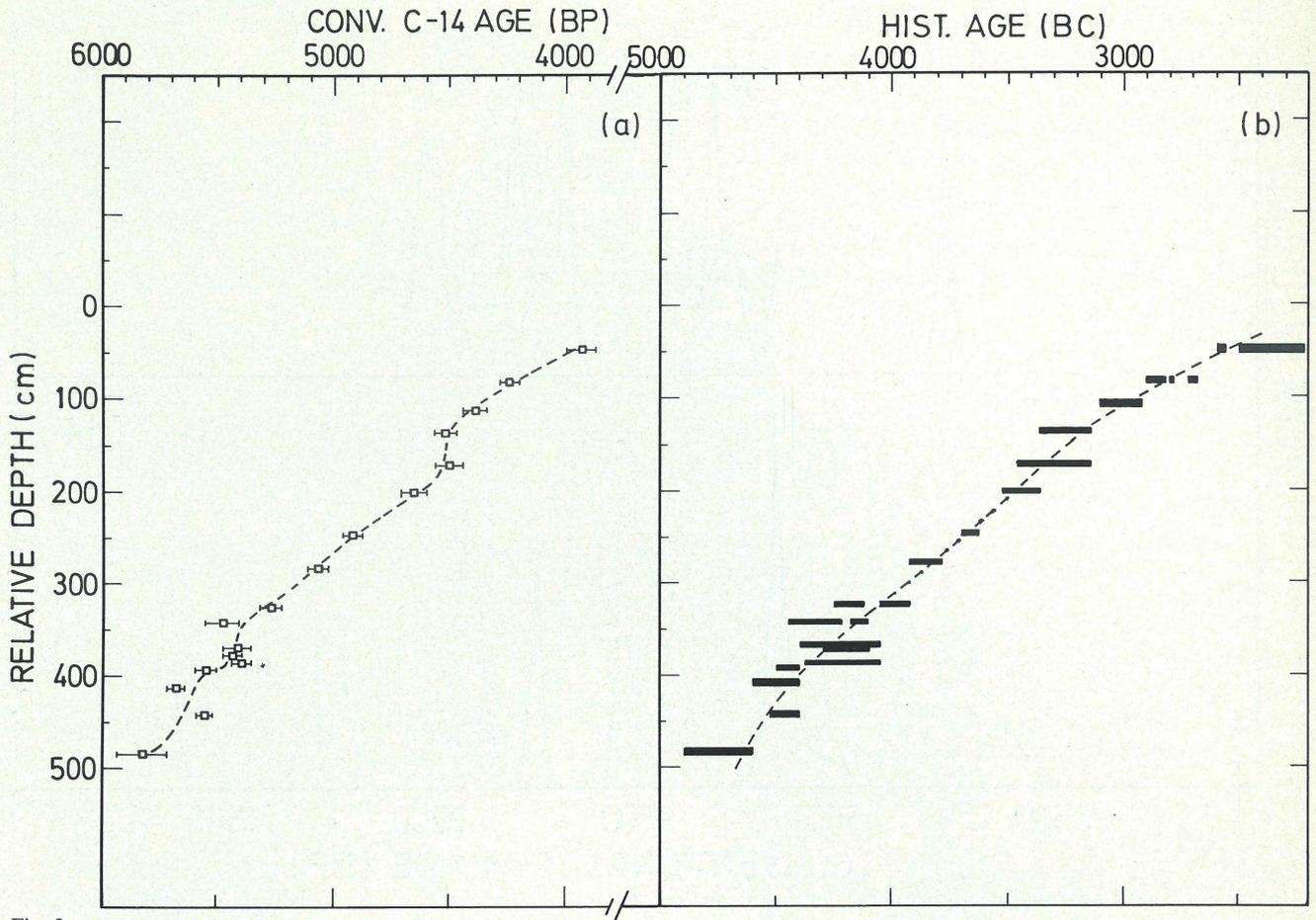


Fig. 3 A set of <sup>14</sup>C dates from a sequence of peat layers (3a) converted into historical ages (3b). The bars indicate the historical time intervals from which the peat might have originated.

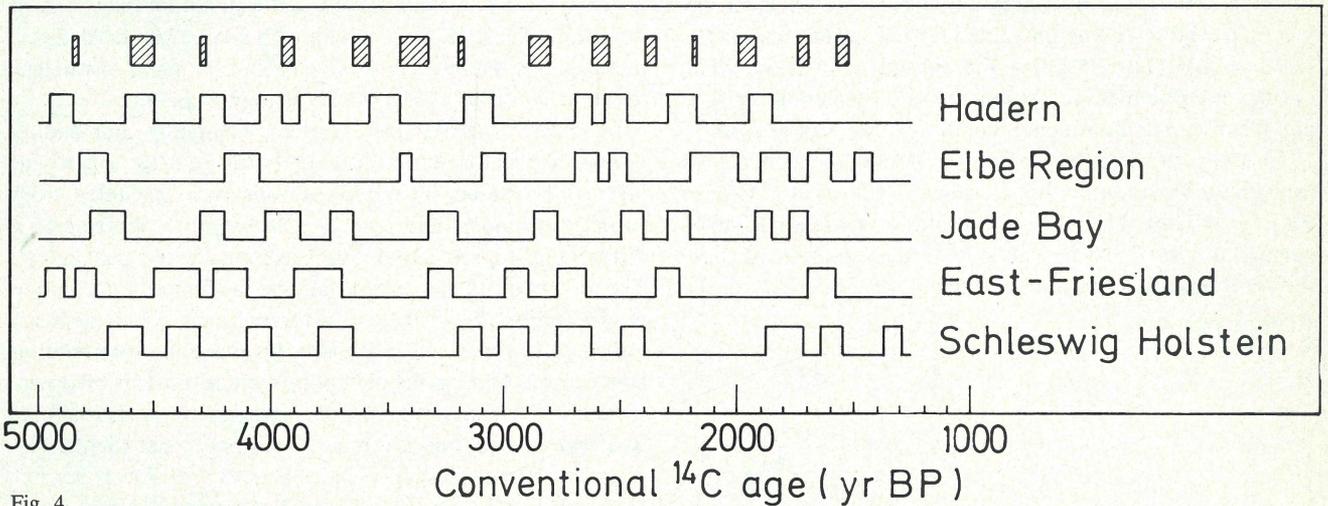


Fig. 4 Diagram of simplified histograms of <sup>14</sup>C dates for five regions of the North Sea coast in West Germany as demonstrated by Geyh (1980). Periods of assumed coinciding gapes are indicated by the dashed areas.

(Fig. 3a). The historical periods in which the peat might have grown are indicated by the bars in figure 3b. Through these bars a curve can be drawn indicating a relative sea-level rise without any significant variation.

COMPARISON OF REGIONAL RE- AND TRANSGRESSIONAL PHASES

The succession of clastic deposits and peat layers found along

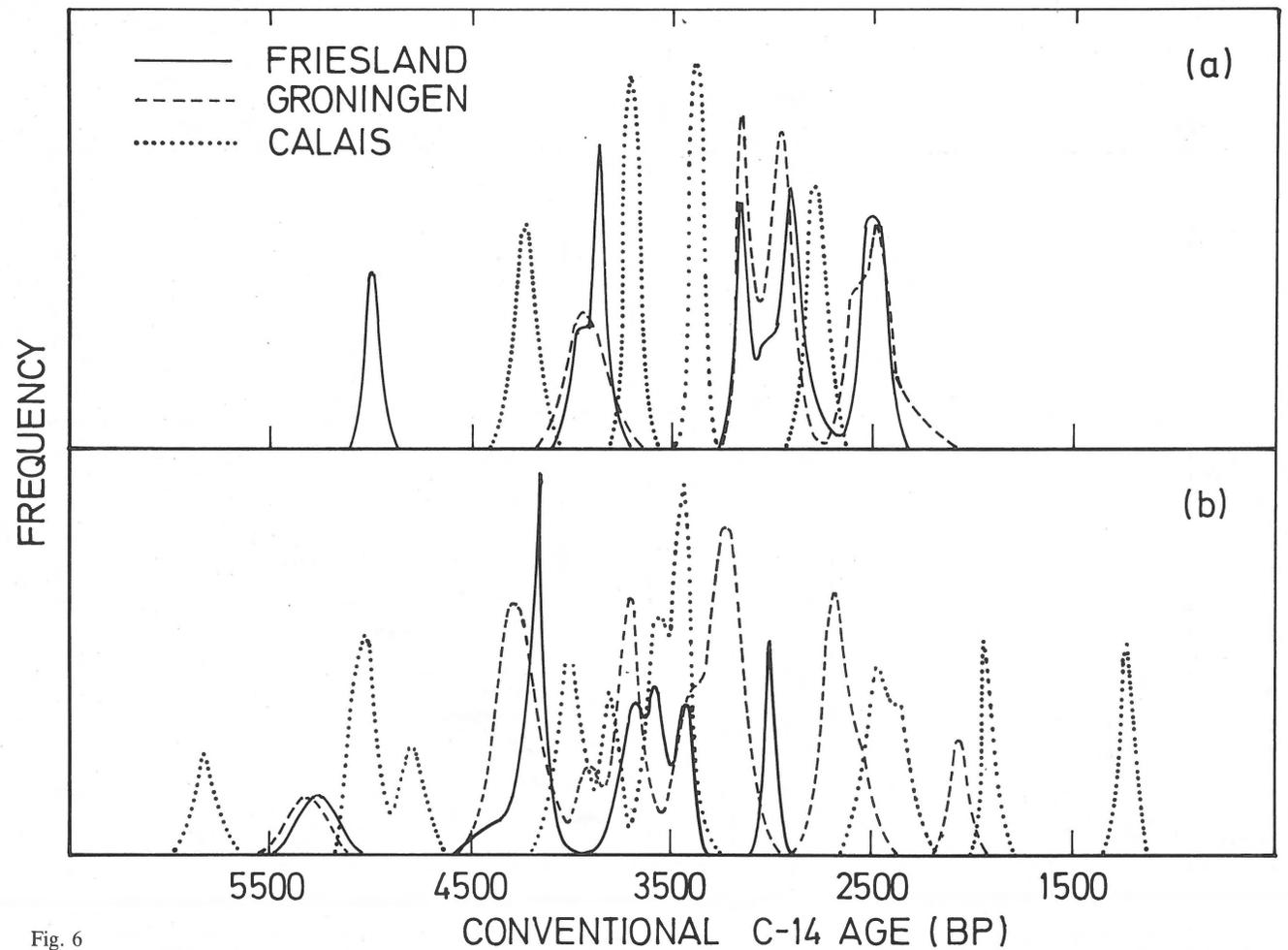


Fig. 6 Histogram as constructed from radiocarbon dates from top (6a) and base (6b) of peat layers in the Dutch provinces of Friesland and Groningen.

the North Sea coast was assumed to be caused by transgressions and regressions, occurring roughly synchronously throughout the area. Fluctuations in the relative sea level may have caused this. It is assumed that during a transgression the sea level rose fast, flooding the coastal peat areas, while during the subsequent regression the rate decelerated, resulting in sufficiently continental conditions for peat growth.

To study the possible existence of periods with a high probability of widespread peat growth, radiocarbon dates of the base and top of peat layers from different areas have to be compared (GEYH, 1980). The statistical evaluation of these radiocarbon dates is presented in histograms. In this paper the

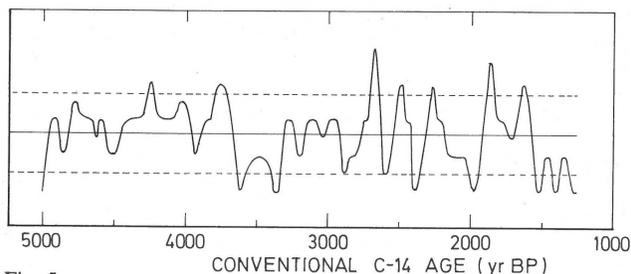


Fig. 5 Simplified histograms as constructed from figure 4; each time interval with peat growth is given the same height. For a random distribution of 52 events over a period of 4000 yr, approximately 8 statistically created gaps must be expected below 70% of the mean height.

histogram is a superposition of radiocarbon dates, each represented by a Gaussian distribution of the same area. The width of each Gaussian curve is determined by the standard deviation of the  $^{14}\text{C}$  date: a date with a large standard deviation is presented by a Gaussian distribution with a low height and thus contributes less to the histogram peaks.

In order to distinguish between beginning and ending periods of peat formation, dates of the base and the top of peat layers have to be separated. Results were excluded from suspected samples and contaminated samples referring to a different geological context, such as transgressive peat layers. The total number of available dates is too limited for a unique interpretation. Nevertheless, if the peat and clastic deposits are caused by more than random, local events, a correlation between the histograms of separate areas must be obvious.

First we evaluated the conclusions drawn by GEYH (1980) for five regions near the German North Sea coast (Schleswig-Holstein, East-Friesland, Jade Bay, Elbe River region, Hader). For the construction of histograms from peat layers in these areas he did not separate dates from the top and the base. Therefore, in his diagrams the number of peaks exceeds the number of peat layers. The histograms are depicted by a simplified diagram in figure 4 for the period after 5000 BP. Although each region shows an individual gap and peak distribution, which are not well correlated, Geyh's conclusion

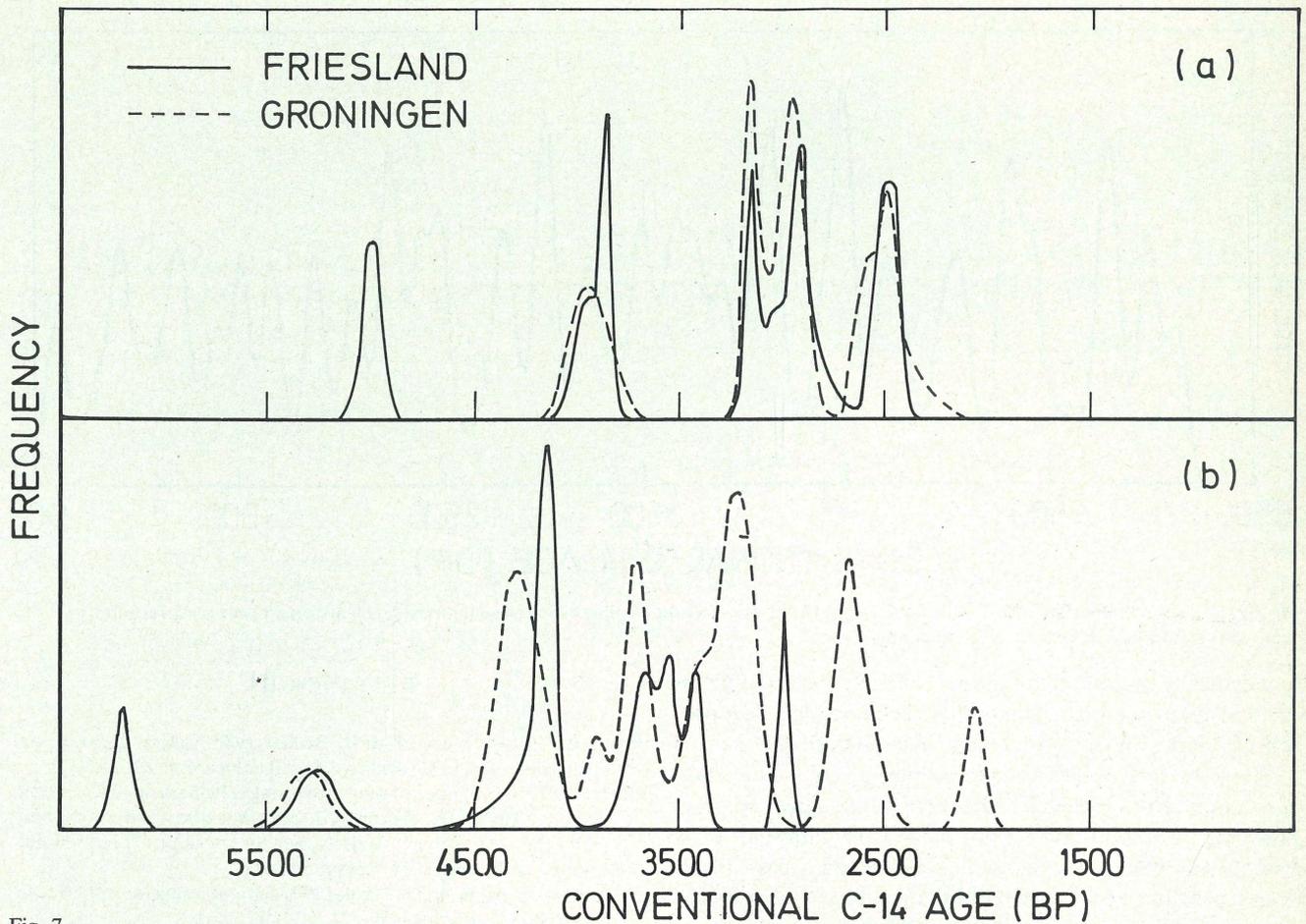


Fig. 7  
Comparison of histograms constructed for peat layers along the Strait of Dover near Calais with the histograms of figure 6. Data from the top (7a) and the base (7b) of the peat layers have been separated.

is that there are synchronous gaps in all histograms (dashed areas). To investigate the significance of the correlation between gaps and peaks in the simplified histograms of these five separate regions, a new histogram was constructed. Every period with peat growth was given the same height to avoid apparently significant peaks in the resulting overall histogram due to non-correlating high peaks in the individual histograms (Fig. 5). It can be seen that there are no significant peaks and gaps above or below the random distribution level which might be caused by taking the base and top dates together.

Therefore, we investigated radiocarbon dates from peat layers in the Dutch coastal provinces of Friesland and Groningen. For the construction of these histograms dates from the base and top of the peat layers were separated. Samples, which were possibly contaminated by roots were excluded. In contrast with earlier constructions for these areas (ROELEVELD, 1974; GRIEDE, 1978) the dates from the beginning of the basis peat formation were omitted (Fig. 6). Figure 6a shows that the top dates of both areas correlate rather well, as opposed to the periods of beginning peat growth (Fig. 6b). Comparison with histograms, constructed for peat layers along the Strait of Dover near Calais, shows the absence of a correlation (Fig. 7). We thus have to conclude that wider than

regional synchronism in peat growth cycles is very unlikely.

Also GEYH (1980) recognized the possibility of clustering of radiocarbon dates on random peat growth, due to the non-linearity of the radiocarbon calibration curve. This effect is

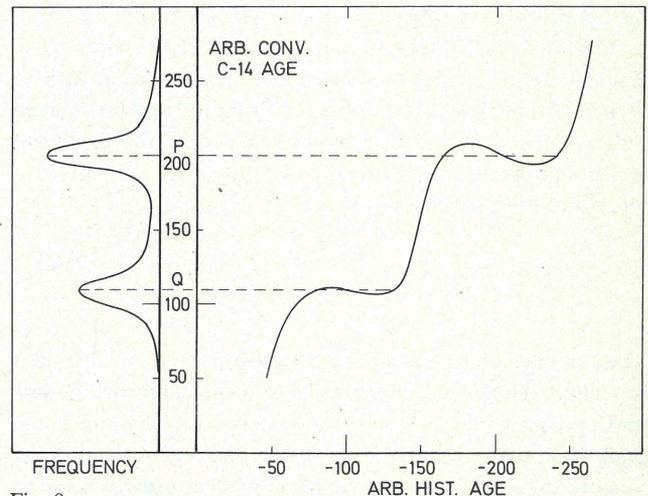


Fig. 8  
The effect of clustering of radiocarbon dates upon histograms. The left curve represents a histogram with peaks, which are only caused by the non-linearity of the arbitrary radiocarbon curve at the right.

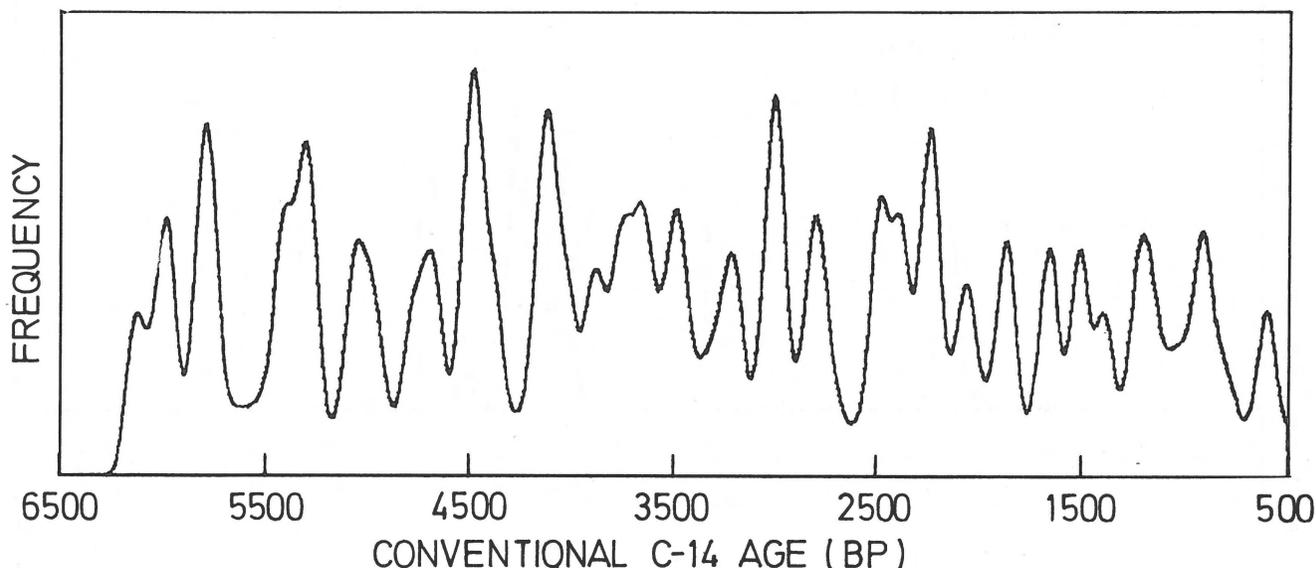


Fig. 9  
Histogram constructed from a 40-year moving average of the radiocarbon spline function of figure 1. Each historical year is represented by a  $^{14}\text{C}$  date with a standard deviation of  $\pm 40$  years.

schematically presented in figure 8. The left curve is a histogram, constructed by assuming that each historical year presents a sample which is  $^{14}\text{C}$  dated with a standard deviation of  $\pm 40$  years. Obviously the chance of obtaining radiocarbon ages around P or Q is much higher than for the other radiocarbon time periods. Radiocarbon dates from different areas will, therefore, give rise to synchronous maxima in the histograms, provided peat growth is random and evenly distributed over the historical time scale. In order to investigate this effect realistically, we constructed a histogram from a 40-year moving average of the radiocarbon spline function of figure 1, in order to take into account the accumulation of material in one peat sample (MOOK ET AL., 1979). Again each historical year is represented by a  $^{14}\text{C}$  date with a standard deviation of  $\pm 40$  years (Fig. 9). This histogram can only be compared with histograms derived from peat samples covering approximately 40 years. Otherwise another smoothed version of the spline function of figure 1 has to be used. Due to lack of sufficient radiocarbon dates for the Friesland and Groningen areas, it is, however, not yet possible to decide whether or not a correlation exists between the maxima in the wiggle histogram and the peat histograms.

### CONCLUSIONS

The evidence of synchronous peat growth over a wide area is too slight. This is partly due to insufficient radiocarbon data and –possibly– by a truly non-synchronous beginning and ending of peat growth over a wider spread region. Until there is more evidence, the interruptions of peat growth must be interpreted as caused by local catastrophic floods at certain times, after which the peat started to grow randomly, depending on local conditions and environment.

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