Chronostratigraphical Subdivisions of the Holocene: A review

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The INQUA Holocene Commission's Working Group on the chronostratigraphical subdivision of the Holocene was appointed in 1977 with the main aim of reviewing the principles and practice of such classifications in the Holocene. In an attempt to obtain a world coverage, many scientists were contacted and invited to contribute a brief review of the Holocene chronostratigraphy for particular geographical areas. Twentyone contributions were received, and they are published together here. The various approaches to establishing chronostratigraphical subdivisions of the Holocene are reviewed, and the advantages and disadvantages of these approaches are discussed. Formal definitions of stratotypes sensu *International Stratigraphic Guide* do not at present appear practicable for the Holocene. Of the two alternative major approaches, namely (1) the use of radiocarbon years without any formal subdivisions, and (2) the definition of chronostratigraphical units in terms of radiocarbon years, no formal recommendations are made, as both can be useful for particular purposes in Quaternary research.

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During the Xth INQUA Congress held in Birmingham, England in August 1977, the Holocene Commission appointed a Working Group to report on the chronostratigraphical subdivisions of the Holocene. The group consisted of Dr. J. Mangerud (Chairman), Dr. H.J.B. Birks, and Dr. K.-D. Jäger. The aim of the working group was to study and to review the currently used chronostratigraphical classifications of the Holocene throughout the world, and to consider the nature, historical background and development, geographical distribution, and past and present definitions of the boundaries of the chronostratigraphical units.

As the members of the working group were clearly not qualified to review the chronostratigraphical divisions used in many different parts of the world, scientists with a strong and active interest in the Holocene of particular geographical areas were invited to submit an independent contribution about the chronostratigraphical subdivision of the Holocene for their particular area. Each contributor was asked to review the *chronostratigraphy* (sensu Hed-

berg 1976) of the Holocene, although we realised that for the Holocene very few strictly chronostratigraphical subdivisions exist. Contributors were therefore asked to include any biostratigraphical, climatostratigraphical, lithostratigraphical, and morphostratigraphical subdivisions that are, in practice, used as chronostratigraphic classifications. Contributors were requested to give the original definitions and historical background for the units, to outline currently accepted (and disputed) definitions of the boundaries, to indicate the geographical extent of these units, to evaluate how the classifications work in practice, and to suggest their potential for larger geographical areas.Twentyone papers were received.

For some areas the working group was, unfortunately, unable to find anyone prepared to review the Holocene chronostratigraphy, and for other areas promised contributions were not forthcoming. The geographical coverage of the contributions is thus not complete but we feel that it is adequate to provide some basis for reviewing the chronostratigraphical subdivision of the Holocene and for considering some of the problems that are encountered in deriving such classifications.

The geographical coverage of the contributions is as follows:

1) Europe: The Nordic countries (Mangerud), British Isles (Birks), the Netherlands (de Jong), France (de Beaulieu), Alps (Bortenschlager), Bulgaria (Bozilova), Central Europe (Jäger, malacology: Ložek), USSR, including the Asian part (Neustadt, Chotinskij).

2) North America: United States and Southern Canada (Wright), Arctic Canada (Andrews).

3) South America: Argentina (Fidalgo and Tonni), Mexico and Central America (Bradbury), South America (Markgraf and Bradbury).

4) Asia: Japan (Fuji), China (Liu et al.)

5) Near East: Turkey, Iran, Iraq, Syria (van Zeist and Bottema).

6) Africa: Tropical part (Talbot)

7) Australasia: Australia (Thom and Bowler), New Zealand (Moar).

These contributions were reviewed by the working group and after revision, the papers are published in full in this special volume of *Striae*. The Working Group is extremely grateful to all the contributors for the large amount of work that they have put into preparing their reviews.

In this concluding paper we first review in brief the status and the various approaches to Holocene chronostratigraphy throughout the world based on the individual contributions. We highlight some of the most important aspects that emerge frome these papers. We then consider the general problems of the chronostratigraphy within the Holocene and of applying the *International Stratigraphic Guide* in a formal way to Holocene chronostratigraphy. We present the various alternative approaches but we do not make any definitive recommendation about chronostratigraphical procedures within the Holocene; indeed the members of the working group do not themselves agree on what procedures should be adopted, as is apparent from their own regional contributions. The choice of procedure to be adopted will inevitably depend on the aims and interests of the investigator and, in part, on whether chronostratigraphy is viewed as an end in itself or as a means to an end.

Regional approaches to Holocene chronostratigraphy

The Holocene, with a provisional lower boundary of 10,000 radiocarbon years, B.P. (Hageman 1969), is the youngest *series* and *epoch* of the Quaternary. Although Hedberg (1976) states a series need not be necessarily subdivided, various attempts at chronostratigraphical subdivisions of the Holocene have been made.

In Australia, Thom and Bowler (this volume) make no attempt at chronostratigraphical subdivisions because of the shortage of data from this vast and varied country. Holocene research is in its infancy in Australia, and the emphasis has been on local detailed studies, which has provided impressive evidence for environmental changes in some parts of Australia from lithostratigraphy, biostratigraphy and changes in lake-levels and in inland-dune activities. Thom and Bowler conclude that "the magnitude of climatic change in many areas in Australia is relatively low and terrestrial vegetational change may not always be marked. Therefore a broader spread of research on Holocene problems is required before the extent of geomorphic and ecologic changes in this period can be determined. Until more research is undertaken, a firm basis for chronostratigraphical division of the Australian Holocene will not be possible."

The situation is similar in New Zealand (Moar, this volume) with a diverse array of biostratigraphical, lithostratigraphical, morphostratigraphical and climatostratigraphical evidence from a country of very considerable topography, ecology, and climate. Moar sees climatic change as the most useful basis for chronostratigraphical subdivisions of the Holocene but feels that present knowledge in New Zealand is too limited to warrant a Holocene subdivision. Moar concludes his paper as follows, "there have been great advances in our knowledge of Aranuian events in New Zealand during the last twenty years. Despite these advances it is inappropriate to offer a formal chronostratigraphical subdivision . . ., indeed this may never be necessary in view of the use of radiocarbon dating for correlation purposes . . . In the meantime the various chronologies should stand, and whenever possible, be compared or integrated with each other. In an oceanic country of such diverse topography, and spanning many degrees of latitude, the solution to this problem is not likely to be reached quickly, although the evidence available supports the view that subdivision based on climatic change is the most appropriate."

Tropical Africa (Talbot, this volume) is in many respects similar to Australia and the tropical Americas, being a large and geographically varied continent with an extremely rich flora. In contrast to these other areas, however, tropical Africa is one of the few places where some attempt has already been made to produce chronostratigraphic subdivisions for the Holocene, including the

designation of some stratotypes. Although never intended for use on a continental scale, this system has gained a certain degree of acceptance, mainly amongst French-speaking geologists working in West and Central Africa. Talbot also reviews some of the more important sources of palaeoclimatic data. He shows that pollen sequences are never likely to provide viable chronostratigraphic markers in a region as floristically varied as tropical Africa, but suggests that synchronous, continent-wide climatic events may be recognisable from lake level evidence. Talbot concludes that, in keeping with many other areas, radiocarbon dating is likely to remain the principal chronostratigraphic tool.

For China Liu et al. (this volume) briefly describe the different lithostratigraphical, biostratigraphical, and climatostratigraphical sequences in that vast country with its large number of sedimentary (and tectonic) environments. The chronostratigraphy is based on numerous radiocarbon dates, and the Holocene is subdivided into Early, Middle, and Late. "The time-limits between them are based on sedimentological characteristics, climatic changes and radio-carbon dates, as well as their world-wide correlations, it is an approximate recognition, and exact subdivision will be made after more work is done".

Fuji (this volume) discusses the complex lithostratigraphy, morphostratigraphy, and to a lesser extent, biostratigraphy of the Japanese islands. He describes the Holocene climatic development of Japan and correlates it with NW-Europe, but not chronostratigraphical subdivision is established in Japan.

Based on their pollen-analytical studies in the Near East, van Zeist and Bottema (this volume) demonstrate that the vegetational histories of Iran, Syria, and Turkey differ considerably and that there are no synchronous expansions or reductions of forest or steppe vegetation in the Holocene. Whilst they acknowledge that the Holocene of the Near East can be arbitrarily divided into two or more units, such a subdivision would not coincide with the available evidence. They thus conclude that a chronostratigraphical subdivision of the Holocene in the Near East that attempts to reflect regional environmental change is not possible.

For South America Markgraf and Bradbury (this volume) and Bradbury (this volume) similarly emphasize inferred climatic change as the basis for Holocene chronostratigraphy. Such climatic changes can only be inferred from well-dated and carefully studied glacial features, pollen stratigraphy, faunal assemblages, lake level changes, etc. Lithostratigraphical, soil stratigraphical, and geomorphologial changes are often poorly defined and difficult to date and may be of little regional significance. Fidalgo and Tonni (this volume) emphasise the local significance os such changes in their discussion of the Holocene lithostratigraphy of Argentina. Rather than establishing an arbitrary chronostratigraphical subdivision of the Holocene, Markgraf and Bradbury attempt to define the timing of climatic change locally according to the available stratigraphical evidence. They review data from various areas from Mexico, Central America, and South America and they show broad similarities of climatic change but of different magnitudes and character at different latitudes. They feel that the "establishment of chronostratigraphic subdivisions within the Holocene is premature for Central America" and emphasise that the "scarcity and the complications involved in their interpretation suggest that the timing and nature of Holocene climatic variation in this region is poorly understood."

Moving northwards to North America, the contributions by Wright (this volume) for the United States and southern Canada and Andrews (this volume) for Arctic Canada highlight the problems of deriving a regionally applicable chronostratigraphy for the Holocene. Wright emphasises that although climatic change forms the real basis of any Quaternary subdivisions, the geological record of climatic change is time-transgressive. He illustrates this view with reference to the so-called hypsithermal interval within the Holocene of Minnesota and adjacent states, of New England, and of the south-eastern United States, and emphasises that although "these remain keen subjects for research . . . it is premature to formalize Holocene subdivision on a continental scale". Wright also discusses the Neoglacial interval and the Little Ice Age, as delimited on the basis of glacial changes in the mountains of the western United States. Although these events are well documented in some areas, they are often poorly dated. Wright emphasises that "the evidence and its dating are still uncertain enough that identification of chronostratigraphic units is inappropriate". Wright questions the usefullnes of establishing and extending chronostratigraphical subdivisions of the Holocene, as he does for the entire stratigraphical column (Watson and Wright 1980). For the Holocene he suggests direct use of radiocarbon years for chronological control and correlation.

Andrews (this volume) proposes, on the other hand, that there is now considerable evidence from Arctic Canada to indicate major changes in marine, terrestrial, and cryosphere systems and that this evidence provides a basis for a chronostratigraphy of the Holocene. He introduces a geochronological/chronostratigraphical subdivision of the Holocene on the abovementioned changes, but with the boundaries defined in conventional radiocarbon years, following the practice in Norden of Mangerud et al (1974). In doing so, he also discusses whether a chronostratigraphical subdivision of the Holocene is desirable, and says that it is a matter of preference and no great moment, but "I do so for the pragmatic reason that appropriate use of such divisions assists the process of communications and understanding." Andrews argues against using climatic changes for defining chronostratigraphical units, because "Climatic change is an event and Climatostratigraphy is not a stratigraphy at all but an interpretation of changes in the litho- or biostratigraphy of rock sequences", and it "is not explicit itself."

Andrews recognizes that any of the boundaries he proposes for the last 5 000 years are bound to conflict with one or more records. "However, geochronologic/chronostratigraphic boundaries are, by definition and intent, isochronous and hence must cross-cut time-transgressive events which characterize much of the Holocene on a continental scale". He also states that we do not lose the ability to recognize timetransgressive changes by the establishment of chronostratigraphical divisions.

There are several contributions from Europe and most of them reflect the strong tradition and importance of pollen-stratigraphy in Holocene studies and also a parallel development in many countries of the application and discussion of pollen-zones, the Blytt-Sernander terminology and other subdivisions to the Holocene stratigraphy.

Mangerud (this volume) reviews the development in

Norden (Denmark, Finland, Iceland, Norway, Sweden) where the Blytt-Sernander classification and Jessen's pollen zones were originally defined. In Norden a formal chronostratigraphical subdivision was introduced by Mangerud et al. (1974), by redefining the Blytt-Sernander terms as units whose boundaries were defined as radiocarbon years. According to Mangerud "the main argument for the introduction of a strict chronostratigraphic subdivision of the Holocene was to have one classification with time–horizontal boundaries to correlate the many different bio-, climatic-, and morphostratigraphic subdivisions with metachronous boundaries."

Within Norden this proposal has been used by practically all Quaternary scientists, and Mangerud states that "it has worked reasonably well." He summarizes some arguments for and against this classification. The main arguments against are that all geology disappears from the definitions, that no special terms are needed to describe time in years, and that Blytt-Sernander terms are used with different meanings in other regions. The main argument for their use is that experience shows that if a chronostratigraphical classification does not exist, other subdivisions with metachronous boundaries are in practice used as chronostratigraphical subdivisions, indicating that the former is desirable in practice.

In Central Europe the Blytt-Sernander classification has been widely adopted but as pointed by de Jong (this volume) in his contribution about the Netherlands the Blytt and Sernander names are used there with a different meaning compared to Norden. This is also reflected by the contribution of Bortenschlager (this volume) about the Alps. For this region he proposes a chronostratigraphy of the Holocene based on inferred climatic changes derived from pollen stratigraphy and glacial fluctuations. He follows the approach of Mangerud et al. (1974) in Norden by defining the boundaries in terms of radiocarbon years. Bortenschlager, however, uses the same chronozone names as Mangerud et al., even though some of the boundaries are defined differently. This is against the rules of the International Stratigraphic Guide (Hedberg, 1976), and can only create confusion. On the other hand, it is a consequence of another regional tradition of applying Blytt-Sernander terms. These terms have become widely adopted in Mid-European Holocene research but have been changed to fit the regional differences in geological and vegetational development. This means that also in Central Europe the Blytt and Sernander terms have in practice been used in a mainly chronological sense. What has been transferred from Norden to Central Europe is not their chronological range but a comparable geological content which because of the metachroneity of vegetational and other changes, occupies different chronological positions compared to Norden.

As Ložek (this volume) demonstrates, the Blytt-Sernander terms are a suitable tool for characterizing the main units of regional Holocene development based not only on pollen analyses but also on molluscan faunas, which are significant for examining the Holocene development of dry environments and sediments where pollen analysis is not applicable because of poor conditions for pollen preservation. Summarizing the Mid-Europe situation there has mainly been a chronological use of the Blytt-Sernander terms, but the chronological meaning is different from that in Norden. This may be the reason why Firbas (1949, p. 52) tended to avoid the use of the Blytt-Sernander terms in only chronological sense. Reviewing this situation Jäger (this volume) concluded that "it seems to be the best way to permit a different chronological implication of the Blytt-Sernander terms according to various regional traditions". This conclusion corresponds with that of Bozilova (this volume) who summaries the subdivisions used in a wide range of sedimentary environments in Bulgaria. Her contribution is representative for the situation in South-Eastern Europe as a whole. There both regional subdivisions and references to more general schemes are used. Her review concludes that "the application of regional schemes is useful for the more detailed precision of the palaeoecological and palaeoclimatological situations. It is obvious on the other hand that the application of such regional schemes impedes the classification of general regularities, and this implies the use of an uniform biostratigraphic scale supplemented by regional stratigraphy".

Different uses of the Blytt-Sernander terms are also clearly demonstrated by the two contributions from Soviet Union. There, Chotinskij (this volume) favours the use of Blytt-Sernander terms based on climatic stratigraphy, and, consequently, these considerations lead to regionally differing chronological meanings of these terms. Neustadt (this volume) describes the different types of subdivision of the Holocene which are used in the Soviet Union, among them a subdivision into Old Holocene (12000–10000 B.P., and thus pre-Holocene if the lower boundary of 10000 B.P. is used), Early Holocene, Middle Holocene and Late Holocene, which may be globally used. For the Blytt-Sernander terms he proposes to omit the Preboreal, introduced by Erdtman, but for the other boundaries he supports the definitions in radiocarbon years proposed by Mangerud et al. (1974).

Contrary to this, Birks (this volume), in his review of the Flandrian (Holocene) of the British Isles, criticises the continued use of the Blytt and Sernander terms, even when they are explicitely defined as, for example, by Mangerud et al. (1974) because the terms can, through nearly ninety years of use, convey palaeocological or palaeoclimatic connotations to some investigators that may be erroneous or misleading.

Moreover, Birks in his contribution (this volume) discusses the problems of defining Holocene chronozones sensu Hedberg (1976) within the British Isles in the absence of a stratotype. He also reviews the time-transgressive nature of pollen zone boundaries within the British Isles and the impossibility of using pollen zones as chronostratigraphical units. This view is shared by de Beaulieu in his contribution (this volume) reviewing the use of pollen zones in France. He discusses how different pollen-zonation schemes have come to be used in France, a situation similar to that in Central Europe (Jäger, this volume). Therefore, de Beaulieu (loc.cit.) discusses the importance of establishing local pollen zonations. Such local zones can then be related to previously defined chronozones such as those defined by Mangerud et al. (1974) in Norden, or to a chronostratigraphy of radiocarbon years, assuming that sufficient dates are available.

The latter is the view of Birks (l.c.) who emphasizes that for many palaeoecological and palaeoclimatic purposes, the most useful approach is to order locally and regionally defined pollen-assemblages zones in space and time (by

radiocarbon dating) without reference to chronozones, stratotypes, or formal chronostratigraphy.

Another view is proposed by Jäger (l.c.) who accepts the usefulness and possibility of establishing chronozones. He, however, suggests that their definition and terminology should be independent of the Blytt-Sernander classification. On this basis the procedure of defining such chronozones as suggested by Mangerud et al. (1974) is principally supported but it should be carried out in any way that does not conflict with the various regional traditions of using the Blytt-Sernander terms in Europe. He recommended that the discussion and establishment of such system should be taken over by the Holocene Commission of INQUA in the near future. Another recommendation addressed to this Commission is proposed by Neustadt (l.c.). He suggests that a working-group of experts from different countries should undertake a careful reinvestigation of the Scandinavian peatbogs on which the scheme of Blytt and Sernander is based.

Thus, reviewing the discussion for Europe three main arguments can be emphasized:

1) The utility of a chronostratigraphical subdivision of the Holocene is discussed with reference to the specific suggestions of Mangerud et al. (1974) in Norden.

2) The problems are outlined that arise by various regional traditions adopting the "classical" Blytt-Sernander system of Holocene subdivisions.

3) The use of only radiocarbon years is favoured by some authors.

In summary the approaches presented in and the general conclusions of the various contributions from all over the world fall into three major categories. Firstly, currently available geological, palynological, and/or radiometric data may be too few or too limited to permit the delimitation of any Holocene chronostratigraphical subdivisions (e.g. Australia, New Zealand, South America, Japan). Secondly although detailed data are available along with a reliable radiocarbon chronology, the patterns of inferred environmental change are so variable in space or are so indistinct in time that the authors find little value in defining a chronostratigraphy (e.g. United States and southern Canada, tropical Africa, Near East, British Isles). Instead the use of radiocarbon dates to order observed geological and biological evidence is advocated. Thirdly, Holocene chronozones defined in terms of radiocarbon years are proposed for Norden, Arctic Canada, the Alps, the Soviet Union and in principle for the Central Europe.

Discussion and conclusions

The contributions in this volume, and also the other literature on Holocene stratigraphy in the last decade, demonstrate an increasing concern for the principles of stratigraphical subdivision. There has been a movement towards a more strict application of the general rules of stratigraphic classification, most recently expressed in the "International Stratigraphic Guide" (Hedberg 1976). In our opinion this is a sound and important development. Particularly important is that now clear distinctions are made between the different categories of subdivision, for example lithostratigraphy, biostratigraphy, morphostratigraphy, soilstratigraphy, climatostratigraphy and chronostratigraphy. The concern of this volume is, however, only chronostratigraphical subdivision, and we will restrict our discussion to that.

Most, but not all, Quaternary scientists consider the Holocene to be the youngest series (epoch) of the Standard Global Chronostratigraphic (Geochronologic) Scale (Hedberg 1976 pp. 78–79). Thus, the Holocene could be subdivided into regional and/or world-wide stages. However, the proposals in this volume mainly consider subdivisions into units of a lower rank, such as regional chronozones. This is the basis for our discussion, even though most of the arguments are also valid for discussions on a world-wide scale. We will discuss three alternative approaches for establishing formal chronozones of the Holocene that are valid for small or large regions. These are by means of 1) stratotypes, 2) inferred climatic changes and 3) radiocarbon ages. We will also discuss a fourth alternative, namely the use of radiocarbon years directly, without any subdivision into named units.

There appears to be general agreement that stratotypes at present are not useful for delimiting chronozones within the Holocene. We therefore leave this question for future re-evaluation.

Climatic changes, either directly or indirectly, are the overriding causative mechanism for most of the large-amplitude environmental changes during the Pleistocene, and possibly for many of the smaller amplitude changes during the Holocene, and thus for many of the observed changes (biostratigraphical, lithostratigraphical etc.) in Quaternary stratigraphical sequences. Climatic changes, and their geological implications, are therefore an obvious, major goal for most Quaternary research. The geological records of climatic changes is also the basis for climatostratigraphical subdivisions. Both on theoretical and empirical grounds it has been demonstrated repeatedly that climatic changes and especially the geological records of climatic change, are time transgressive or diachronous (e.g. Mangerud et al. 1974, Watson & Wright 1980).

Climatic changes should therefore not be used for defining chronostratigraphical units. However, it would be in accordance with the International Stratigraphic Guide to select the level that records the stratigraphical response to a climatic change in one particular sequence as a stratotype for a chronostratigraphical boundary, but accept that in other sequences a similar response might be found above or below that chronostratigraphical boundary. This is the general procedure for the Pleistocene.

The third possible approach for the Holocene is to define the boundaries of chronozones in radiocarbon years, as done by Mangerud et al. (1974, see also Mangerud, this volume), Andrews (this volume), Bortenschlager (this volume) and partly for Africa (Talbot, this volume). This approach is not very different from using stratotypes. One finds a stratigraphical level where it is useful and desirable to define a chronostratigraphical boundary. Instead of selecting a stratotype to defining that level, the boundary is

simply defined by its age. As stated in the preliminary edition of the *Stratigraphic Guide* (Hedberg 1979, 15) and discussed by Mangerud et al. (1974, 114) this approach accords closely with the concept of chronostratigraphy. The main advantage of this approach is that it maintains the idea of chronostratigraphical units with isochronous boundaries, against which biostratigraphical and other units with time-transgressive boundaries can be displayed. As mentioned above, experience in Norden is generally positive, even though there are some arguments against this procedure.

The fourth approach is to use radiocarbon years simply to order lithostratigraphical changes, biostratigraphical changes, glacial advances, etc. within the Holocene, as advocated by Wright (this volume, see also Watson & Wright 1980), Birks (this volume) and Talbot (this volume). Many of the arguments for this solution are arguments against the basic principles of chronostratigraphy (Watson & Wright, 1980). However, even if chronostratigraphical subdivisions are generally accepted, there are strong arguments for the use of only radiocarbon years for the Holocene. As Birks (this volume), discusses, there are few, if any, widespread, unambiguous stratigraphical events that can be used to provide a basis for a useful chronostratigraphical division. The duration of the Holocene is less than one per mil. of the duration of each Series (Epoch) in the Tertiary, and ten thousand years may simply be too short for any useful and geographically widespread chronostratigraphical subdivision to be established. Also, within the Holocene it is possible to express the ages directly in radiometric years, thus making the naming of time-units superfluous.

We conclude that within the Holocene it is clearly possible, and in the opinion of some also desirable, to work without any chronostratigraphical subdivision, and simply express the ages in radiocarbon years. If an actual subdivision is wanted, definition of the boundaries in terms of radiocarbon years seems, at present, the most practical approach. These two approaches are broadly similar in their aims, and also in their requirements as estimates of the radiocarbon age of the sediment concerned are essential.

Chronostratigraphy is a form of classification and as such its value should be judged by its usefulness and its relevance to the purposes for which it is required. The working group encourages all scientists working on the Holocene to consider critically these questions and to evaluate the value and usefulness of all chronostratigraphical subdivisions of the Holocene.

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