VIEWPOINT

What status for the Quaternary?

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The status of the Quaternary, long regarded as a geological period effectively coincident with the main climatic deterioration of the current Ice Age, has recently been questioned as a formal stratigraphic unit. We argue here that it should be retained as a formal period of geological time. Furthermore, we consider that its beginning should be placed at the Gauss-Matuyama magnetic chron boundary at about 2.6 Ma, rather than at its current position at about 1.8 Ma. The Quaternary would be formally subdivided into the Pleistocene and Holocene epochs. The global chronostratigraphical correlation table proposed is enclosed at the back of this issue.

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The Quaternary has been a familiar part of the stratigraphic column for nearly two centuries. The term, dating originally from Arduino (1760, in Rodolico 1970; Schneer 1969), and first formally used by Desnoyers (1829), precedes any serious consideration of terrestrial glaciations, arguably originating from Agassiz (1840). However, most authorities concur that it was defined and used in a chronostratigraphical sense by von Morlot (1854). In the past few decades, the complex climatic imprints within its deposits have been used as a template for the interpretation of much of the sedimentary record, and *inter alia* to help divine our own species' near future. The term 'Quaternary' has concomitantly gained wider currency within and well beyond the geological community.

The status of the Quaternary as a formal stratigraphic unit has been questioned in the past (e.g. Flint 1957: p. 281; Krumbein & Sloss 1963: p. 19). However, as part of the general reorganization of the stratigraphic column, primarily by the International Commission on Stratigraphy (ICS), the status of the Quaternary has recently come under review, with proposals for its abandonment or modification (e.g. Ogg 2004; Pillans 2004; Pillans & Naish in press; Gibbard 2004; see also Gradstein *et al*. 2004 and in press). The reason most commonly invoked for this is the fact that the term has not been rigidly defined. Given the long history of its use, the dominance of glacial phenomena in high latitudes and of the important widespread oxygen isotope variations in the oceans, we (members of the Stratigraphy Commission of the Geological Society of London) consider it important that there is discussion and feedback between the Quaternary and broader earth sciences communities on the one hand and the formal decision-making bodies on the other, before any final decision is reached on its status. This short paper is aimed at stimulating such debate, beginning with an outline of the complex history of the term, followed by an analysis of currently proposed options and ending with some conclusions. The chronostratigraphical table proposed is attached at the back of this issue of *Boreas*.

Brief history of the term 'Quaternary'

Two terms arose independently in the early to mid-19th century to encompass superficial (mostly unconsolidated) deposits in the northern hemisphere: the

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Quaternary (Desnoyers 1829) and the Pleistocene (Lyell 1839). Interestingly, both terms were originally founded on the basis of marine deposits, in the Paris basin and in eastern England, respectively, although both soon became synonymous with the Ice Age (Forbes 1846), with the remarkable 'Drift' deposits of continental mid-latitudes, and with the rise of humans. The term 'Drift' was introduced by Lyell to account for glacial deposits interpreted to have been laid down by icebergs that 'drifted' across an ice-age sea presumed to have covered Britain, a concept related to the 'Biblical flood'. However, with the recognition that the 'Drift' or 'Diluvial' deposits, so extensive in the mid-latitudes of the northern continents, represented greatly extended glaciation in recent earth history, both soon became synonymous with the Ice Age, and latterly with the evolution and dispersal of humans.

The Quaternary differed from the Pleistocene in encompassing Lyell's (1839) 'Recent' or Forbes's (1846) 'Post-glacial', a period termed the Holocene by Gervais (1867–1869), the Holocene being formally adopted by the 1885 International Geological Congress (IGC). Given the near-synonomy of the Quaternary with the Pleistocene, there followed attempts to suppress one or other of them, or to suggest alternatives such as the Anthropogene (used in the former Soviet Union) or the Pleistogene of Harland *et al*. (1990) (cf. Bourdier 1957; Nilsson 1983; Gibbard & van Kolfschoten 2005). For much of the past century, both terms have been retained: the Quaternary has generally been assigned the rank of a period within the Cenozoic Era, subdivided into two epochs: the Pleistocene and the Holocene, the latter extending to the present day. At the present time, the terms Quaternary and Pleistocene are both in widespread use.

Duration of the Quaternary and location of its Global Stratotype Section and Point (GSSP)

The duration of the Quaternary has been a vexed question. At the 18th International Geological Congress in London in 1948 it was decided to seek a location for the Pliocene–Pleistocene boundary, and concordantly the Tertiary–Quaternary boundary, in Italy. Here, continuous marine successions spanning the boundary are exposed at a level that would mark the first significant climatic deterioration (King & Oakley 1949). This deterioration was originally identified by the arrival of so-called 'cold-guest' molluscs in the Mediterranean, particularly *Arctica (Cyprina) islandica* (cf. Nilsson 1983).

The succeeding decades saw extraordinary ferment in Quaternary stratigraphy, including the realization that the period was considerably longer than the 0.6 My originally derived from the Alpine glacial record (Penck & Brückner 1909). However, of greater importance was the revolutionary interpretation, based on the variations in oxygen isotopes obtained from deep-sea cores, that complexities of Quaternary stratigraphy were controlled primarily by variations in the Earth's spin and orbit around the Sun (Milankovitch cycles: Milankovitch 1941; Shackleton & Opdyke 1973; Hays *et al*. 1976).

By the early 1980s it was becoming clear that the major threshold of climatic deterioration in mid- to high latitudes had occurred around 2.6 million years ago, close to the boundary between the Gauss and Matuyama magnetic chrons (Suc *et al*. 1997). Nevertheless, at the 27th IGC in Moscow in 1984 (Aguirre & Pasini 1985) it was decided to place a 'golden spike' for the GSSP for the Plio-Pleistocene boundary in a section at Vrica, in Calabria, at a much younger level dated at about 1.8 Ma that was not coincident with any marked climatic change (Berggren & Burckle 1997). The decision may have been partly influenced by pressure to arrive at a conclusion to a process that had been running for nearly 20 years (van Couvering 1997; Suc *et al*. 1997).

Although the Vrica GSSP can readily be correlated with the marine oxygen isotope stratigraphy (Shackleton 1997), most of the Quaternary community place the beginning of the Quaternary at 2.6 Ma, coincident with what they also regard as the 'natural' beginning of the Pleistocene (Zagwijn 1974; Partridge 1997a; An Zhisheng *et al*. 1990). This older placement of the boundary has also been adopted by several major geological surveys (e.g. in The Netherlands, China and elsewhere).

In 1998, following debate on the issue (Partridge 1997b; van Couvering 1997), there was a formal reconsideration of the boundary by the Neogene (SNS) and Quaternary (SQS/INQUA) subcommissions of the ICS/IUGS, who are empowered to make such decisions. Fifty-one members took part in the voting: 20 from the SQS and 31 from the SNS. For decisions involving two subcommissions, votes are weighted to take into account the differences in numerical membership. The weighted result of 53%, a majority, favoured the earlier boundary, but this was 7% short of the 60% required by statute to effect the change.

Should the term Quaternary be retained as a formal unit?

Possible options for the status of the Quaternary are (Ogg 2004; Pillans 2004; Gibbard 2004):

- Removing the Quaternary altogether as a formal term (for instance, the term is not included in the current ICS stratigraphic chart: International Commission on Stratigraphy 2004).
- Retaining the Quaternary as a sub-period of the Neogene Period.
- Retaining the Quaternary as a period.

The principal arguments against retention of the term Quaternary include the following. The name itself is the last of the Primary/Secondary/Tertiary/Quaternary scheme originally suggested by G. Arduino (1760 in Rodolico 1970; Schneer 1969) and more usually ascribed to Desnoyers (1829) and von Morlot (1854). Given that the terms Primary and Secondary have been superseded, with the Tertiary being largely replaced by the Cenozoic, the retention of the term 'Quaternary' appears anomalous and anachronistic. In fact, what used to be known as the Tertiary (= Cenozoic less the Pleistocene and Holocene) is still implicitly in use, as in the K–T (Cretaceous–Tertiary) boundary.

Apart from the 10 000 ^{14}C years (or 11 500 ice-core lamina years) assigned to the Holocene, the current definition of the Quaternary is identical to the Pleistocene making the term seem unnecessary. As a period it is much shorter than any other geological period. Moreover, the climatic signals preserved within its mid- to high-latitude continental deposits can be regarded as an intensification of trends begun in the Neogene or earlier, trends which are absent or difficult to recognize in their contemporaneous equatorial equivalents. In this perspective, there is no reason to raise the Quaternary to period or sub-period status.

The counter arguments for its retention start with the purely pragmatic argument that the term 'Quaternary' has extraordinarily wide currency, both within the Earth Sciences and beyond (in our experience, it is used much more widely than the term 'Pleistocene'). Most scientists working on deposits of the last two million years or so regard themselves as Quaternary, not Pleistocene (or indeed, 'late Neogene') geologists, and this is reflected in the names of the corresponding organizations (INQUA, QRA, DEUQUA, AFEQ, AIQUA, NORDQUA, AMQUA, etc.) and scientific journals (*Quaternary Science Reviews*, *Quaternary Research*, *Journal of Quaternary Science*, *Quaternaire*, *Géographie physique et Quaternaire*). More generally, the term is used and understood by, say, engineers, land-use planners, archaeologists and a wide variety of professionals working on superficial deposits and surface processes.

As regards the distinctiveness of the palaeoenvironmental signal, the Quaternary, while continuing climatic trends established in the late Neogene, marks a significant intensification of the cooling that transformed the landscape, and processes of sedimentary deposition, across large parts of the globe, especially in the northern latitudes. The extent of Quaternary ice sheets and periglacial conditions, and associated interglacial/interstadial deposits, especially in the northern hemisphere, produced changes of such magnitude that the early concept of a catastrophic 'Deluge' or 'Biblical flood' was entirely understandable by the founders of our science. While the duration of the Quaternary is short, the geographical extent of the deposits (covering most of the planet), their thickness (reaching hundreds of metres) and their position (at, or near, the current-day surface of the Earth), means that they are of great geological and socio-economic importance.

The distinctiveness of the Quaternary record is not confined to glaciated regions, e.g. the periglacial regolith deposits of Europe, Asia and North America, the loess of China, and the glacio-eustatically driven changes in marine sedimentation provide striking signals of an environmental change which, we argue, would represent a major transformation of the earth system even if viewed from far into the geological future, being likely comparable with the climatic signals and global reorganizations of the end-Ordovician and end-Mississippian. This view still holds in spite of recent evidence that long-term climate deterioration was clearly in progress through the later Neogene and specifically from *c*. 4 million years ago (Ravelo *et al*. 2004). The beginning of the Quaternary coincides with the development of the modern biota and, more anthropocentrically, with the rise of *Homo* spp.

Furthermore, abandonment of the Quaternary as a unit unifying the Pleistocene and Holocene would not reflect the strong connection between these two epochs, as the Holocene simply represents the latest in a long succession of interglacial phases (albeit that whose deposits are by far the most widespread and of most societal relevance). Many scientists, and many texts, deal with both Pleistocene and Holocene phenomena, and, in the absence of the formal linking term 'Quaternary', communication would be significantly hindered.

We find the arguments for retaining the Quaternary as a term outweigh the arguments for its suppression.

What should be the formal status of the Quaternary?

It is a truism that knowledge of the past declines exponentially with time. It is therefore to be expected that the nearer one is to the present day, the greater is the information available and the more refined is the time scale needed to classify and evaluate it. One measure of this knowledge is the number of references dealing with a particular topic. For example, the number of GEOREF items listed in the past 7 years with Palaeocene, Eocene and Oligocene in their titles totals about 4200; with Miocene and Pliocene it is about 5200 and with Pleistocene and Holocene about 7700. Thus Pleistocene and Holocene are almost as important in terms of the work conducted on them as the whole of the 'Tertiary' (= Cenozoic era without the Pleistocene and Holocene). More interesting is the fact that over 4100 references have Holocene in their title

and over 3600 have Pleistocene (while over 4000 have Quaternary).

These numbers suggest that, despite its very short duration, the Holocene receives almost as much attention as the Palaeogene, with the Pleistocene not far behind. That the Pleistocene and Quaternary have an almost identical duration is therefore not an argument for rejecting the term Quaternary, because this similarity conceals the enormous interest in the Holocene. The simplest view is that the amount of information in Quaternary research is more than twice that in the Pleistocene alone and that it is useful to have a term that implicitly recognizes this fact. The evidence suggests that the Pleistocene and Holocene should have the same status as Palaeogene and Neogene, and that the two together, i.e. the Quaternary as currently used, should be given the status of a period.

Location of the beginning (GSSP) of the Quaternary

If the term Quaternary is retained, then the current options for defining the beginning of the Quaternary are twofold (see correlation chart at the back of this issue of *Boreas*):

- The current GSSP in the Vrica section at about 1.8 Ma.
- Redefined as the current GSSP of the Gelasian, coincident with the Gauss/Matuyama boundary at about 2.6 Ma (Pillans 2004; Pillans & Naish in press).

The current GSSP for the start of the Quaternary has been placed at a level corresponding to about 1.8 Ma at Vrica, Italy. As noted above, though formally defined, many Quaternary workers regard this definition as unsatisfactory and ignore it.

The Vrica GSSP does not coincide with any distinctive threshold in the marine isotope stratigraphy and in the continuous marine record the position of any Pliocene/Pleistocene boundary may be argued to be arbitrary (Shackleton 1997). However, widespread ice-rafted debris first appears on mid-latitude ocean floors at *c*. 2.6 Ma and marks a significant event. On land, the Quaternary record is quite different from the pre-Quaternary record, as sedimentary and biotic systems adjusted to the new climatic regime. These changes were effectively worldwide, even including the tropics (see Pillans & Naish in press); they were marked across North America and Europe, and included the transition from red clay to loess deposition in China (An Zhisheng *et al*. 1990).

The GSSP for the beginning of the Gelasian Age, Monte San Nicola in southern Sicily, is placed at the Gauss/Matuyama boundary and correlated with the peak of Marine Isotope Stage (MIS) 103 (N.B. not with its base). It can be applied in marine sections as readily as the Vrica GSSP. In terrestrial successions the Gauss/Matuyama boundary is global in extent, precisely defined and more readily recognized than the Olduvai Subchron, within which the Vrica GSSP lies. Overall, the biostratigraphical signals at the Gelasian GSSP are clearer (Partridge 1997a; Suc *et al*. 1997). According to the International Commission on Stratigraphy website (2004), the Gauss/Matuyama boundary is recorded as 2.588 Ma, MIS 103, base Magnetic Polarity Chronozone C2r and base calcareous nannofossil CN12c Zone. The date for the Vrica boundary is determined by extrapolation from the age of the end of the Olduvai Subchron, currently dated at 1.77 Ma, which it 'just' pre-dates (van Couvering 1997).

In passing, we note that if the beginning of the Quaternary is placed at 2.6 Ma, a 'power of ten' perspective of the world's strata brings one to the Palaeogene/Neogene boundary at *c*. 23 Ma, the Permian/Triassic boundary at *c*. 250 Ma and the Archean/Proterozoic boundary at *c*. 2500 Ma.

Status of the Pleistocene and Holocene and location of the Pleistocene GSSP

The three main options are:

- Remove the Quaternary and make the Pleistocene and Holocene epochs part of an extended Neogene Period (the situation shown, for instance, on the current ICS stratigraphic chart – International Commission on Stratigraphy 2004; Ogg 2004).
- Retain the Quaternary as a sub-period of the Neogene Period with a Gelasian GSSP; the Pleistocene and Holocene Quaternary would be epochs of the Neogene, of equal status, with the beginning of the Pleistocene at the Vrica GSSP (Pillans 2004; Pillans & Naish in press).
- Retain the Quaternary as a period with a Gelasian GSSP, and regard the Pleistocene and Holocene as Quaternary epochs of equal status. This is the situation effectively in use by a substantial majority of Quaternary workers.

The first option has already been discussed and rejected. The second option gives rise to several problems. For example, the separation of the beginning of the Quaternary from the beginning of the Pleistocene is a major departure from historical and current usage, and would cause considerable confusion in the short and medium term. There would be, additionally, a formal problem in that the lower rank boundary between the Pliocene and Pleistocene would not coincide with the higher rank boundary at the base of the Quaternary Sub-period. On these grounds, this option is rejected.

The third option is our preferred solution.

Conclusions

On balance, we propose that:

- The Quaternary should be retained as a formal chronostratigraphical unit.
- The Quaternary should be given the status of a period, rather than a sub-period.
- The Quaternary Period should be subdivided into the Pleistocene and Holocene epochs.
- The research information on the Holocene probably exceeds that for the Pleistocene. Thus, despite its short duration (*c*. 10^4 years), it should be given equal status with the Pleistocene.
- The beginning of the Quaternary and of the Pleistocene should coincide and should be placed at the Gauss/Matuyama chron boundary of the Gelasian GSSP, rather than at the current position at the Vrica GSSP.
- Proposals to define the beginning of the Quaternary at a different stratigraphic level to the beginning of the Pleistocene do not accord with the rules of stratigraphic nomenclature.
- The re-defined Pleistocene Epoch would include the Gelasian Age.

We realize that to submit the question of the Plio-Pleistocene boundary to another vote, so soon after the last one, would probably be a controversial procedure. Furthermore, to extend the Quaternary (and Pleistocene) intervals has obvious implications for their formal subdivision. Nevertheless, we consider that our preferred combination of options is the one most likely to achieve long-term clarity and stability.

We may be wrong. Hence, we encourage debate on this issue, not least to enable the weight of opinion among Quaternary workers, and across the Earth Sciences as a whole, to be made more evident and for the resulting balance of opinion to be more effectively transmitted into the decision-making process.

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