Paleogene and Neogene Periods of the Cenozoic Era. A formal proposal and inclusive solution for the status of the Quaternary

by

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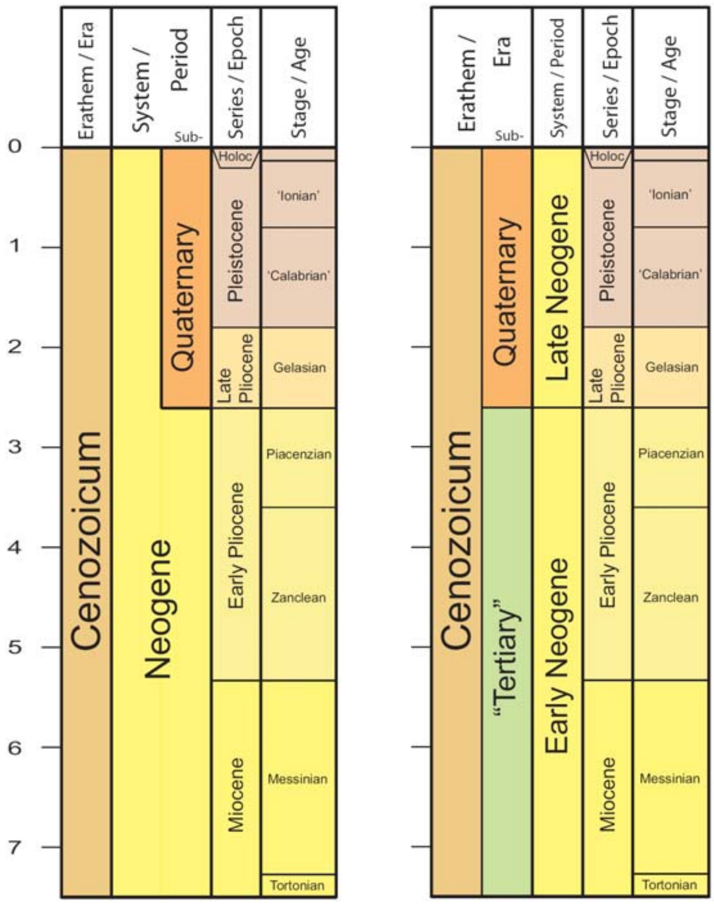

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Abstract

We propose that the Cenozoic Era comprises the Paleogene and Neogene Periods and that the Quaternary be a Sub-Period spanning the past 2.6 Myr. Our objective is an inclusive compromise respecting *both* the predominantly marine tradition of the Neogene, well-established as spanning the Miocene-Recent, *and* the predominantly continental tradition of the Quaternary, recently the subject of another expansion back in time, this time to 2.6 Ma (base of Gelasian Age).

There are several solutions, as tabulated here, but there are broadly three alternatives. (i) The Quaternary is equivalent to the Late Neogene. (ii) In a flexible chronostratigraphic hierarchy, the Quaternary (and Tertiary, if retention of this obsolete entity is desired) is (are) elevated to Sub-Era whilst the Paleogene and Neogene are Periods of the Cenozoic, not of the Tertiary. (iii) The Neogene comprises only the later Tertiary (Miocene and earlier Pliocene).

Our objectives, of respecting the two traditions, of inclusive compromise, and of conserving both Neogene and Quaternary, are met in both options (i) and (ii). Option (iii), favoured in the Quaternary community, meets none of our objectives and renders the Neogene irrelevant.

Although we reject that option of a decapitated Neogene, we appreciate those arguments by the Quaternarists based on Quaternary being very special - emergence of *Homo* (Pleistocene), explosion in technology and society (Holocene), even human impact (Anthropocene); and the correspondingly exponential increase in publications and citations as we approach the present. These very arguments can ensure that chronostratigraphic precedent and stability are not threatened by arrangements in the youngest 0.07% of the stratigraphic record, such as the flexible hierarchy in option (ii).

However, we recommend option (i) in this proposal. The Pliocene/Pleistocene boundary remains at 1.80 Ma as currently defined but the Pliocene Epoch is split into an Early Pliocene and a Late Pliocene Epoch reminiscent of Lyell (1833). This action maintains hierarchy in the global chronostratigraphic scale.

Introduction

In GTS2004 (Gradstein et al., 2004), the Quaternary was eliminated from the standard geological time scale while, at the same time, the Neogene was extended to the Recent. This elimination of the Quaternary, even though it had never been formally defined, raised a storm of protest and triggered an unprecedented reaction by the Quaternary community to have their claims of a Neogene/Quaternary boundary at 2.6 Ma coincident with the Gelasian GSSP and a lowered Pliocene/Pleistocene boundary formally accepted (e.g., Gibbard et al., 2005; Head et al., 2008).

Meanwhile, proposed compromise solutions kept both the dominantly marine Neogene tradition and the dominantly continental Quaternary tradition intact. The first of these proposals included the Quaternary as Subperiod of the Neogene, acknowledging the unique character of the Quaternary for the youngest time interval covering the last 2.6 million years (Pillans and Naish, 2004). Alternatively, Aubry et al. (2005) presented a solution in which the Quaternary and Tertiary were elevated to Subera status while the Paleogene and Neogene were retained as Periods of the Cenozoic, not of the Tertiary. This compromise was approved by ICS at the meeting held in Leuven in 2005, but was found unacceptable by INQUA-IUGS on three main grounds: the non-hierarchical structure, the decoupling of the Quaternary from the Pleistocene and the extension of the Neogene. In response, ICS (under pressure of IUGS and INQUA) put forth a proposal that is similar to the current proposal from the Quaternary community (e.g., Head et al., 2008), except for the exclusion of the Tertiary and with Paleogene and Neogene periods below the Quaternary Period (see Ogg and Pillans, 2008). This proposal was not ratified by IUGS (which now requires full formal proposals for deliberation and subsequent vote).

In this formal proposal that we submit as an alternative to the proposal by the Quaternary community, we reaffirm our commitment to 1) the *original* (i.e., not decapitated, or “extended”) Neogene and 2) an inclusive compromise as presented in the Pillans and Naish (2004) and Aubry et al. (2005) papers[1]. We have modified these proposals slightly to accommodate the rigid chronostratigraphic hierarchy (Lourens, 2008) (McGowran et al. (2008) challenge the rigid hierarchy).

[1] The original inclusive solutions for the Quaternary issue were accepted by a vast majority of SNS voting members while the proposal favored by the Quaternary community was found unacceptable (outcome questionnaire linked to the ICS workshop held in Leuven, 2005).

Before detailing these inclusive solutions, we briefly summarize the concept, integrity and validity of the original (not decapitated) Neogene, and discuss the hierarchy problem. Details of the arguments underlying an inclusive solution and this formal proposal have also been presented in several accompanying papers (Lourens, 2008; Hilgen et al., 2008; McGowran et al., 2008).

Original definition, continued usage and chronostratigraphic significance of the Neogene

Original definition

One of the major objections against the Pillans and Naish (2004) and Aubry et al. (2005) inclusive solutions was the extension of the Neogene to the present, as in GTS2004. Serious doubts were raised whether Hörnes (1853) had meant such an extended usage when he first defined the Neogene in 1853 in a letter to Prof. Bronn. It is not clear from his writings how Hörnes defined an upper limit of the Neogene, nor whether he intended to define such a limit at all (Walsh, 2008; Fig. 1). Notably Bronn (1854) himself was convinced that Hörnes' Neogene extended up to the present (although excluding the alluvial) when he published his next edition of his Lethaea Geognostica. Also the actual reason why Berggren (1972; 1998) and Steininger (2002) and others arrived at the conclusion that Hörnes meant the Neogene to continue to the Recent was not invalidated by Walsh (2008; see Appendix in McGowran et al., 2008). But even in case of a Neogene/Diluvium (=Neogene/Quaternary) boundary, such a boundary would certainly not be older than 0.5 Ma according to current knowledge of the - marine - units that Hörnes incorporated in his Neogene (Fig. 1). In this respect, it is reassuring that the extended undecapitated Neogene remains at or very close to its original definition.

Continued usage of the original Neogene

The original Neogene did not gain wide acceptance initially but was included as a twofold subdivision (*"Néogénique Ancien"* and *"Néogénique Récent"*) in the time scale of Renevier (1897) that followed from the VIth International Geological Congress (Fig. 1). In it the Quaternary is shown as a synonym of the Pleistocene (Ogg and Pillans, 2008). Into and during the first half of the 20th century most authors preferred a time scale with a Neogene/Quaternary boundary (Walsh, 2008). The Neogene in its current Miocene to Holocene concept gained momentum from an article in the International Stratigraphic Lexicon (Denizot, 1957) (Fig. 1). Denizot's paper greatly influenced a new generation of stratigraphers and geologists who started to explore the deep marine archives of the Cenozoic in the middle of the 20th century (McGowran et al., 2008).

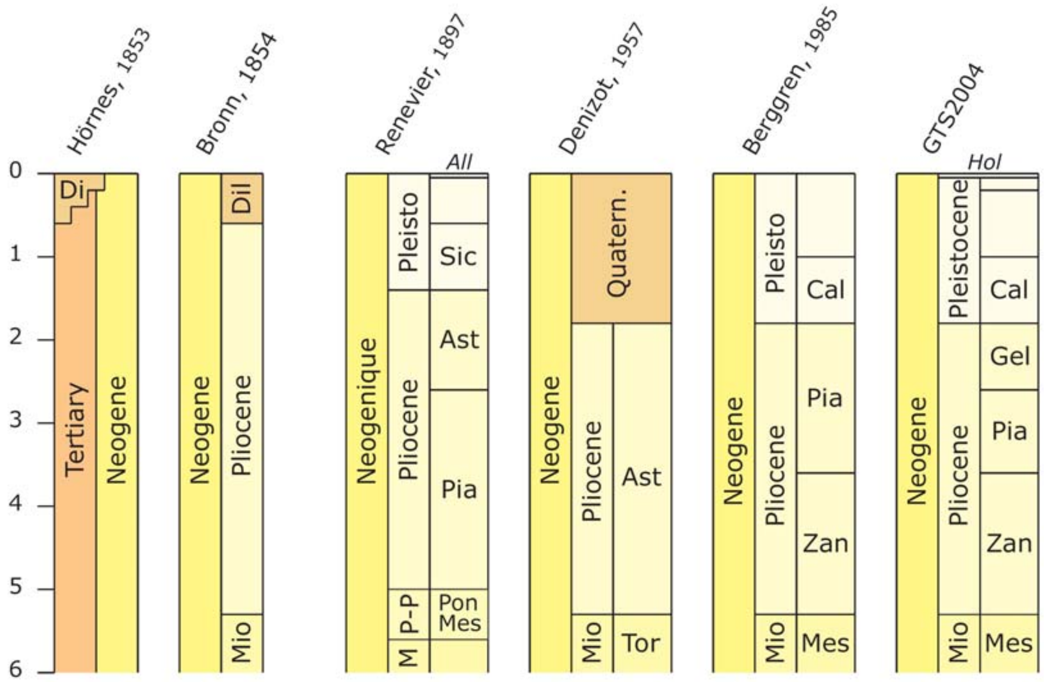

Figure 1. Original definition of the Neogene and examples of the non decapitated Neogene in Geological Time Scales. Stage abbreviations: Sicilian (Sic), Astian (Ast), Piacenzian (Pia), Pontian (Pon), Tortonian (Tor), Messinian (Mes), Zanclean (Zan), Calabrian (Cal) and Gelasian (Gel). Other abbreviations: Diluvium (Dil), Alluvium (All) and Holocene (Hol). Age shown on Y-axis in million of years (after Hilgen et al., 2008).

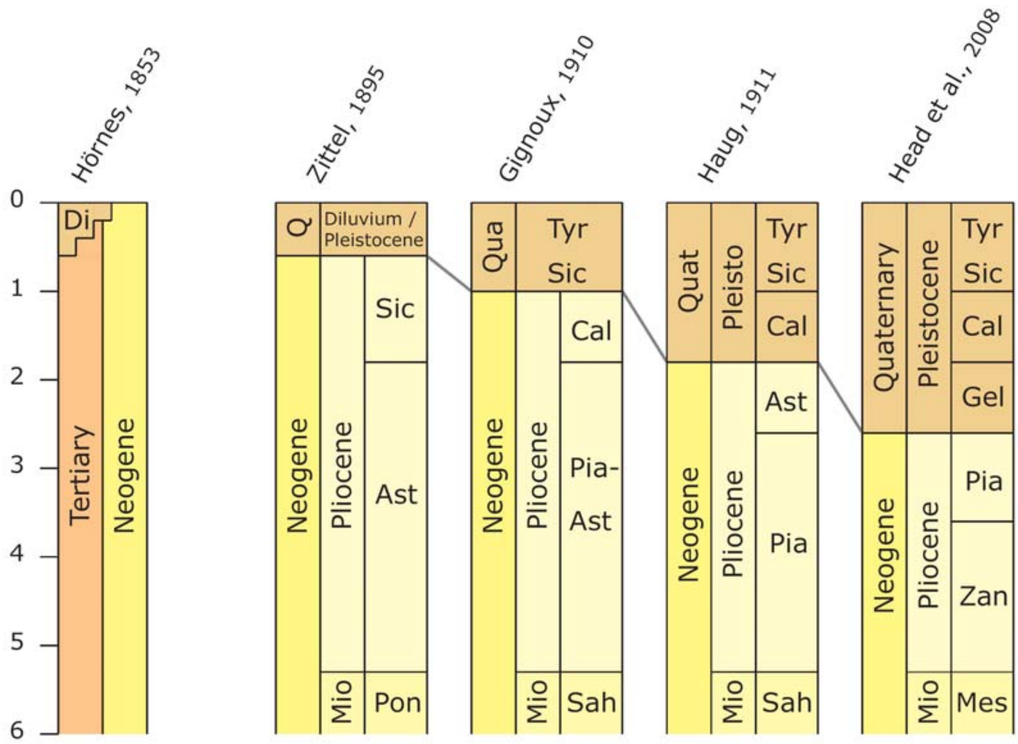

Figure 2. Selected examples from the literature of the chronostratigraphic subdivision of the youngest part of our time scale showing the progressive lowering of the base of the Quaternary. Extra abbreviations: Tyr (Tyrrhenian), Sah (Sahelian). Slightly modified after Hilgen et al. (2008).

However, a contrasting development took place during the 20th century in which the base of the Quaternary - and Pleistocene - was lowered stepwise as to encompass successively older stages that originally belonged to the Pliocene (Fig. 2). Each step involved a “redefinition” of other chronostratigraphic units, in particular the Pliocene, Pleistocene, Neogene and Tertiary. In the most recent development the Quaternary community seeks **to incorporate the next subjacent stage - the upper Pliocene Gelasian - into both the Quaternary and the Pleistocene** (Fig. 2). One might surmise that this be the final step to have the Quaternary defined as a climato-stratigraphic unit with special chronostratigraphic significance. However, for others, this is little more than a metaphor for more than a century of extended, divisive (and indecisive) debate about the chronostratigraphic subdivision of the youngest part of the Cenozoic time scale.

However, the principles of chronostratigraphy require that subsequently discovered older glacials be automatically placed in the next older chronostratigraphic unit. Strict application of this principle would thus place the base of the Quaternary at ~0.8 Ma, coincident with the Brunhes/Matuyama boundary and the onset of peak glacials (corresponding to MIS 2, 6, 12 and 16) that left their marked surface (i.e., sedimentary, geomorphologic) expression in NW Europe upon which the Diluvium (Quaternary) was originally based, as argued by Lourens (2008).

Marine tradition of the original Neogene

The tradition of the original Neogene was thus carried on by marine stratigraphers when they set out from the mid-20th century onwards to explore the deep marine Cenozoic record. It was employed in numerical codifications of standard, low-latitude biozonal schemes with P and N denoting Paleogene and Neogene (Figure 3 in Hilgen et al., 2008). This system was first used by Banner and Blow (1965) to denote their standard planktonic foraminiferal zones with the argument that they “would prefer not to employ formally the terms “Tertiary” and “Quaternary” for the interval we group as Cainozoic; [because] the history of these terms and their present disputed application is so confused that we believe their use to be both inadvisable and unnecessary” (Blow and Banner, unpubl. ms.). The original Neogene was embraced by the DSDP/ODP community and incorporated in the integrated magnetobiochronostratigraphic scales of the second half of the 20th century (e.g., Berggren et al., 1985; 1995a). Numerous publications show that the original Neogene was not only adopted by marine biostratigraphers but by a whole community of Earth scientists aiming to reconstruct Earth history, especially its climate history, in unprecedented detail (e.g., Wei and Kennett, 1983; Pisias et al., 1995; O’Brien et al., 2007). Finally the undecapitated Neogene is employed in a standard text books about Earth history and their publication precedes that of GTS2004 (e.g., Stanley, 1999; see also Hilgen et al., 2008).

Chronostratigraphic significance of the original Neogene

The open deep marine record is superior to shallow marine and continental archives to *formally* define *global* chronostratigraphic units, as also expressed in the guidelines for defining GSSPs (Remane et al., 1996). In this respect, it is not simply the “desire [of the marine Neogene community] to establish a monopoly for marine biostratigraphy in the definition of standard global chronostratigraphic boundaries” as stated by Walsh (2008). Indeed a clarification is useful here: what is perceived as a *desire for monopoly* is a genuine and logical consequence of the nature of biostratigraphy as a superior guide to stratigraphic classification. It is no surprise that Lyell (and other authors for the Mesozoic and Paleozoic eras) used biostratigraphic assemblages to establish the temporal subdivision of the Cenozoic era, two of which (Pliocene and Pleistocene) we defend here, for biostratigraphy is the only truly non-iterative tool that contributes to deconstruct time’s arrow (Aubry et al., in prep.).

The key significance of the open marine sedimentary archives lies in the fact that it is essentially continuous, providing us with an uninterrupted record of Earth history. This continuity was decisive in reaching a breakthrough in unravelling the history of the Ice Ages (e.g., Hays et al., 1976) leading to the confirmation of the Milankovitch theory of the Ice Ages and the construction of the standard SPECMAP oxygen isotope (astro)chronology and time scale. The latter proved instrumental as an accurate and precise temporal framework to which all other archives were correlated. The approach of what is now called orbital tuning was extended into the Miocene (Fig. 3), using oxygen isotope stratigraphy and sedimentary cycles (Shackleton et al., 1990; 1995; Hilgen, 1991; Berggren et al., 1995b), and beyond (Pälike et al., 2006; Westerhold et al., 2008; Kuiper et al., 2008).

The resulting astrochronology has played a crucial role in revolutionizing (global) chronostratigraphy. It led to a *stable* geological time scale to which integrated magnetobiochronostratigraphic frameworks are tied via first-order correlations. Neogene GSSPs are all defined in tuned sections that underlie the - age calibration of the - standard geological time scale. In GTS2004, the Neogene time scale is a fully orbitally tuned time scale (Lourens et al., 2004). The innovative approach also led to a modified unit-stratotype approach for global stages, the (proposed) introduction of astronomically controlled cycles as formal chronostratigraphic units of minor rank (chronozones; Hilgen et al., 2006), and the intercalibration of astronomical and radio-isotopic dating (Kuiper et al., 2008). This revolution in (global) chronostratigraphy and numerical dating is directly linked to the marine tradition of the Neogene but is independent from the dominantly continental tradition of the Quaternary. Hence to favour insertion of the Quaternary as a *global* chronostratigraphic unit to the expense of the original Neogene would be unjustified.

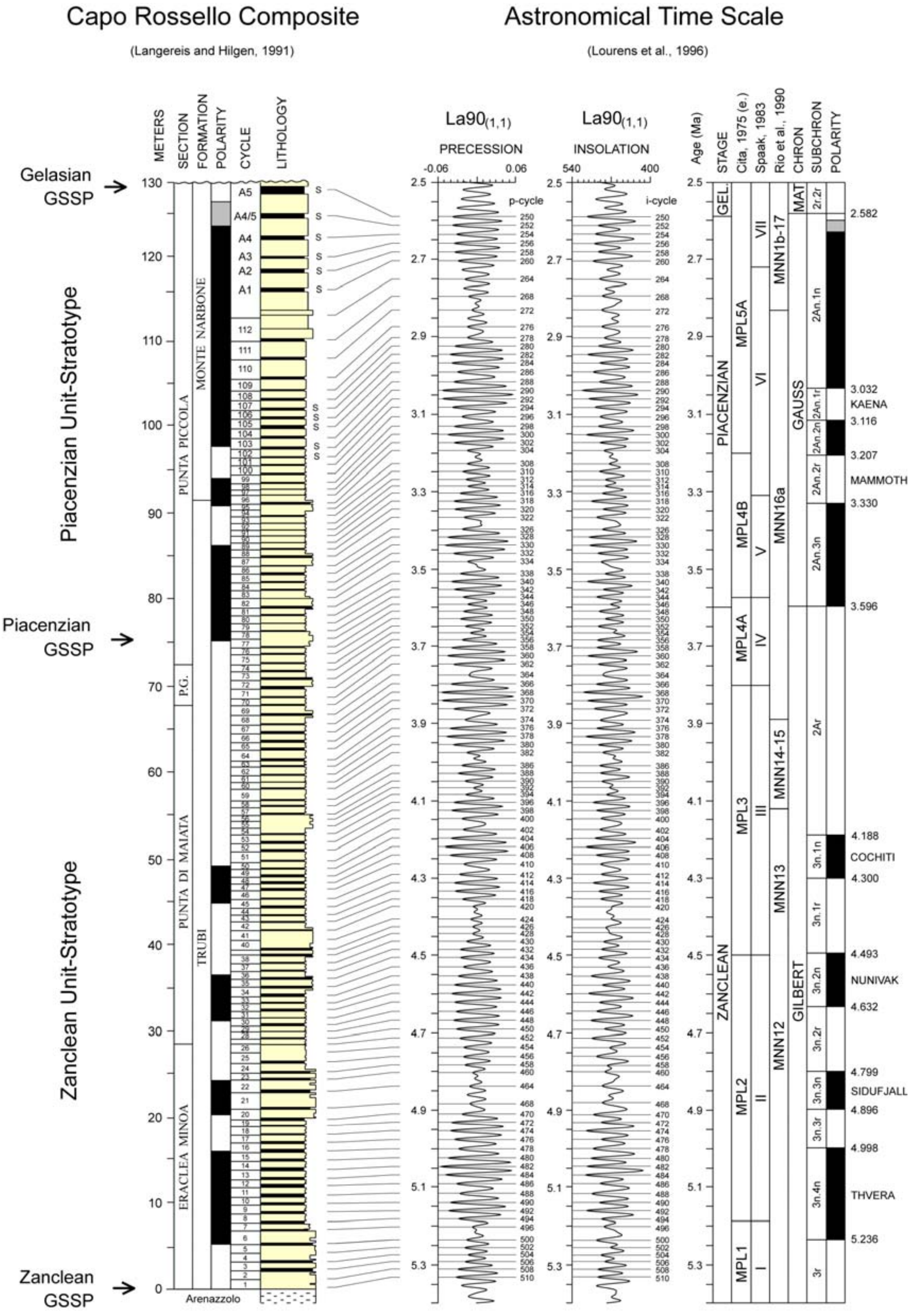

Figure 3. Orbitally tuned carbonate cycles in the Capo Rossello Composite section (Sicily) resulting in an astronomical time scale for the (Mediterranean) Pliocene. Also shown are the Zanclean, Piacenzian and Gelasian GSSPs defined in this section (or at San Nicola), the potential Zanclean and Piacenzian Unit Stratotypes and Milankovitch chronozones (modified after Hilgen et al., 2006).

Hierarchy of the standard chronostratigraphic scale

Another important argument against the inclusive solutions of Pillans and Naish (2004) and Aubry et al. (2005) is the lack of strict hierarchy in the resulting chronostratigraphic scheme, as ardently argued especially by Walsh (2006). The conventional ranked hierarchy in chronostratigraphy/geochronology is one in which each unit (except the highest) is entirely incorporated within the next higher ranking unit. However, one can argue whether such a rigid and strict hierarchy, if mandatory at all, is necessary in the special case of the Quaternary (McGowran et al., 2008). Following Aubry et al. (2005), alternative pathways are offered from Era to Epoch in the Cenozoic, i.e. either the route via Tertiary and Quaternary Suberas, or the route via Paleogene and Neogene Periods (McGowran et al., 2008). This option conserves the real Neogene and conserves the Quaternary at a high level, and the special case of the Quaternary at the young end of the time scale poses no risk of precedence and instability further down the column.

Although we are of the opinion that a rigid hierarchy is not strictly necessary, we nevertheless proposed a solution to overcome the hierarchy problem in the Pillans and Naish (2004) and Aubry et al. (2005) compromise solutions (Lourens, 2008). Reminiscent of Lyell (1833), the Pliocene is split into an Early and Late Pliocene Epoch, with the Late Pliocene corresponding to the Gelasian Stage, a solution that harks back to the Older and Newer Pliocene of Lyell (1833). Moreover, in case of the Aubry et al. (2005) proposal, the Neogene is divided into an Early and Late Neogene Period (Lourens, 2008).

Inclusive solutions

We have refuted the two main points of criticism on the inclusive compromise solutions of Pillans and Naish (2004) and Aubry et al. (2005), namely by 1) showing the validity of the concept of the original undecapitated Neogene, its continued usage through time and its significance in terms of global chronostratigraphy, and 2) formulating an acceptable solution to the hierarchy problem. Below we will provide arguments for which inclusive solution we find the most appropriate for the formal subdivision of the youngest Cenozoic part of the global time scale.

The original inclusive compromise solutions of Pillans and Naish (2004) and Aubry et al. (2005) are shown in Figure 4; their modified versions that take the proposed solution for the hierarchy problem into account are shown in Figure 5. In addition to the Subperiod option of Pillans and Naish (2004), we also show alternative options for the status of the Quaternary, namely as Period synonymous to the Late Neogene and as Superseries.

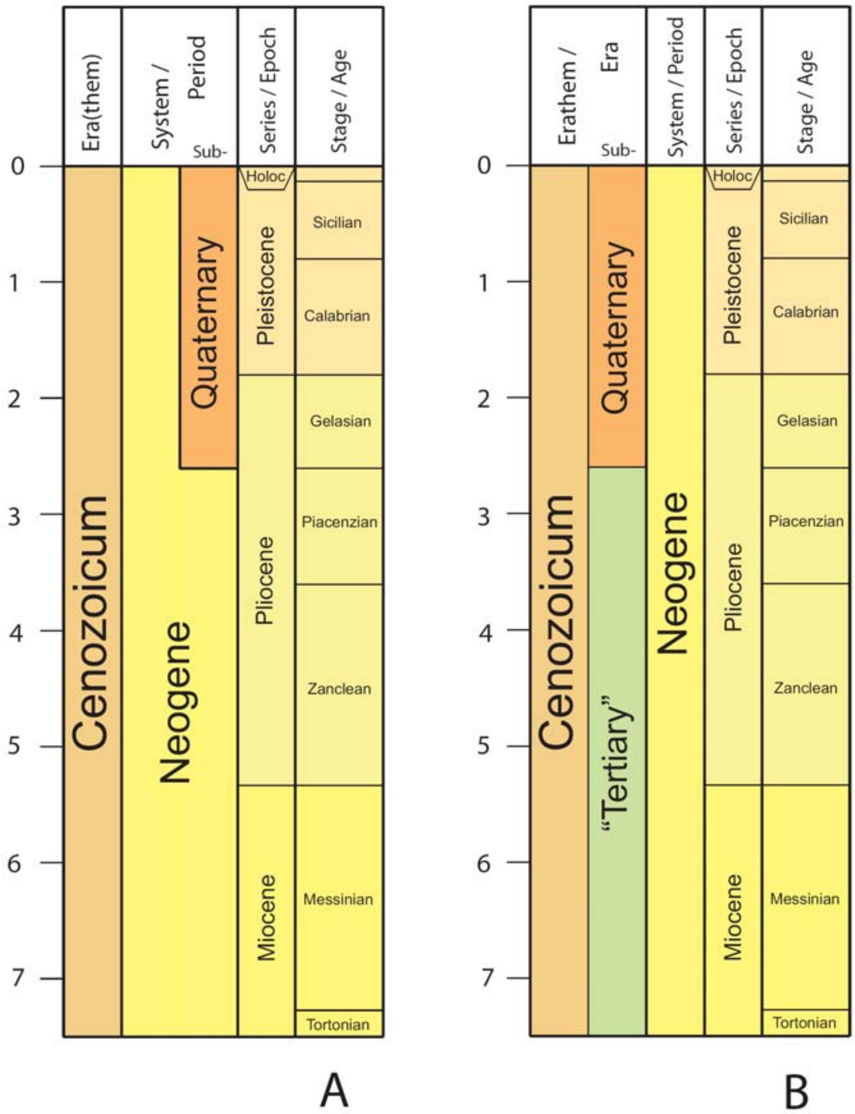

Figure 4. The original inclusive compromise solutions as informally proposed by Pillans and Naish (2004; A) and Aubry et al. (2005; B).

The Pliocene/Pleistocene boundary

In all our options the base Quaternary is defined at 2.6 Ma coincident with the GSSP of the Pliocene Gelasian Stage. We thus keep the Pliocene/Pleistocene boundary as defined, namely at the top of sapropel *e* in the Vrica section dated astronomically at 1.80 Ma. For complementarity we also show the inclusive solutions with the Pliocene/Pleistocene boundary at 2.6 Ma. Such a lowering is preferred by the Quaternary community, but is unacceptable to us. It starts from the postulation that the base Quaternary and the Pliocene/Pleistocene boundary are coincident, but this need not be the case. In our opinion the already disproportionate change in the original

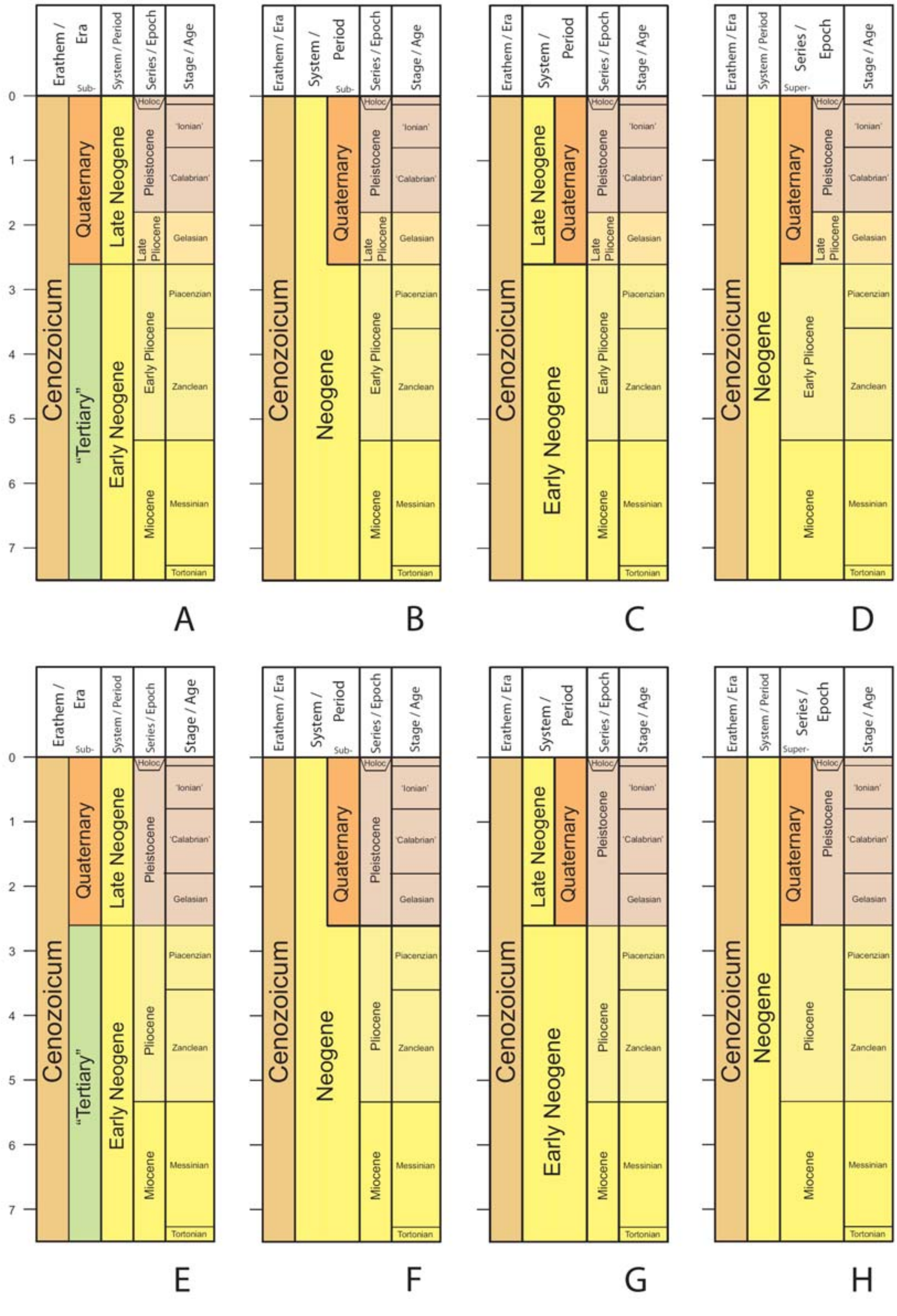

Figure 5. The original inclusive compromise solutions of Aubry et al. (2005) and Pillans and Naish (2004), slightly modified following Lourens (2008) to restore the hierarchy in the chrono-stratigraphic scheme (A,B). Options for the Quaternary as Period and as Superseries are also shown (C,D). Finally, the same 4 options are shown with the base Pleistocene and thus the Pliocene/Pleistocene boundary lowered to 2.60 Ma (E-H).

faunal-based definitions of the Pliocene and Pleistocene by the stepwise lowering of the base Quaternary (not to be expected were they normal global chronostratigraphic units) argues strongly against a further revision of the boundary. In the marine (Neogene) community the notion that major northern Hemisphere glaciations already occurred during the Late Pliocene is widely if not unanimously accepted. However, in part to meet the wishes of the Quaternary community, we have split the Pliocene Epoch into Early and Late Pliocene Epochs to emphasize the difference between the Gelasian and the older Pliocene stages (Lourens, 2008). Thus in our inclusive solutions the Quaternary spans the Late Pliocene, Pleistocene and Holocene Epochs. This has the additional advantage that the Quaternary is not merely synonymous with the Pleistocene (and the – of very limited duration – Holocene).

Aubry et al. (2005) inclusive compromise and the retention of the Tertiary

Contrary to Pillans and Naish (2004), Aubry et al. (2005) assigned the Quaternary a higher status than the Paleogene and Neogene (Subera versus Periods) and preserved the Tertiary as a formal chronostratigraphic unit, i.e. as a Subera of the Cenozoic below the Quaternary (Fig. 4B). Several objections have been raised against the Aubry et al. (2005) compromise solution.

IUGS argued against the addition of an extra category, the Subera, in the global chronostratigraphic scheme. The Subera category was indeed left empty in GTS2004, but was for instance employed in the widely used Harland et al. (1990) time scale, with Paleogene and Neogene as Periods of the Tertiary Subera. As with the hierarchy problem, we are of the opinion that this argument should not stand in the way of an acceptable solution for the Neogene-Quaternary issue, but realize that Suberas are only rarely used and are also not mentioned in the International Stratigraphic Guide (Hedberg, 1976; Salvador, 1994). In addition the chronostratigraphic scheme in the Aubry et al. (2005) compromise is not rigidly hierarchical. The modified solution is hierarchical (Fig. 5A) but a split Neogene Period into Early (Lower) and Late (Upper) is needed in addition to a split Pliocene to restore it.

It is arguable whether the Tertiary should be retained and whether the Quaternary and Tertiary should acquire higher status than the Paleogene and Neogene. The Tertiary and Quaternary are relics of an antiquated neptunian system for classifying the rock record. This neptunian, lithology-based system was established before stratigraphers discovered the power of fossils for correlation and age-determination. This shift is embodied by the replacement of the Primary and Secondary by the Paleozoic and Mesozoic. The (final!) abandonment of the Tertiary and Quaternary in favour of the Paleogene and Neogene would be a logical step, as argued already for more than a century (Berggren, 1998 and references therein). The Quaternary has been given a modern climate connotation, but the Tertiary is a hangover, signifying little beyond being "not Quaternary" since the latter became climatostratigraphic, and marked by its disproportionate length compared to the Quaternary (i.e. Tertiary 63.5 Myr versus Quaternary 2.6 Myr). The reasons for retaining the Tertiary are not very convincing, to put it mildly. The widespread use of "Tertiary" is due to inertia, habit and convenience (as in mapmaking and colouring). Similarly the Primary and Secondary were still widely used when they were abolished and replaced by the Paleozoic and Mesozoic having a (more) modern connotation.

Climatostratigraphic criteria for defining global chronostratigraphic boundaries

This brings us to the benefit and appropriateness of climatostratigraphic criteria both to characterize/correlate global chronostratigraphic units and to establish a major twofold subdivision of the Cenozoic. Hedberg argued against using climatic criteria (i.e. part of the phenomenon category of McGowran et al., 2008) to subdivide the chronostratigraphic scale because of the "mingling of chronostratigraphy with one's perception of the nature of the stratigraphic record and what it might be telling us about Earth history" (McGowran et al., 2008).

We reiterate our support to this philosophy. Chronostratigraphic units are defined by stratigraphic horizons, and remain different from other stratigraphic units whatever their type (bio, magneto-, climato-, etc.). Geochemical signatures are increasingly valuable in chrono-stratigraphic correlations. However, even when these signatures are used as proxies for climate change (e.g., large amplitude $\delta^{18}O$ shifts indicative of significant cooling or warming), their application in chronostratigraphy does not imply that chronostratigraphic units are transformed into climatostratigraphic units. The use of an oxygen isotopic event for correlation (not definition) of a GSSP does not transform a chronostratigraphic unit into a climatostratigraphic entity anymore than the use of a biostratigaphic criterion for correlation of a GSSP transforms a chronostratigraphic unit into a biostratigraphic one.

Thus, the use of, respectively, oxygen isotope shift Mi3b (indicative of major cooling associated with glaciation of East Antarctica; Miller et al., 1991) and the base of the Carbon Isotope Excursion (CIE) associated with Eocene Thermal Maximum (ETM) 1 as primary means of correlation of the Serravallian and Eocene GSSPs (Hilgen et al., in press; Aubry et al., 2007) do not convert Serravallian and Eocene into climatostratigraphic units, and accompanying magnetostratigraphic and biostratigraphic events are necessary for their proper identification and correlation on a global scale. Similarly, the Quaternary, once defined by the top of the Nicola Marker Bed at the base of the Gelasian Stage, will become in form and in intent a stable chronostratigraphic unit correlatable by a geochemical signature (i.e. oxygen isotope shift) regardless of the climatic significance that the latter may convey.

A natural twofold subdivision of the Cenozoic

The 2.6 Ma option for a natural twofold subdivision of the Cenozoic may seem appropriate from the continental perspective but it is not from the marine perspective. In the marine record, Cenozoic climate evolution is dominated by the transition from the Greenhouse World of the Paleocene and Eocene to the Icehouse world of today (e.g., Zachos et al., 2001), i.e. consistent with a subdivision into Paleogene and Neogene (McGowran et al., 2008), itself also reflected in major turnovers and radiations in the biotic realm, among protists, invertebrates (in particular molluscs), vertebrates (in particular mammals and birds) and plants, (Stanley, 1999; Aubry et al., in prep).

But, looking *back* in time from a Quaternary predominantly *continental* perspective, the major break seems to occur at 2.6 Ma. And yet, as reconstructed from the marine archives, this event only marks the *onset of major* northern Hemisphere glaciations and an intensification of the Icehouse world that was *already under way for more than 30 million years*. Hence it seems logical that if one aims for a higher-level natural twofold subdivision of the Cenozoic, the more rational choice is to opt for the Paleogene and Neogene rather than the Tertiary and Quaternary. At the same time this would eliminate the problem of the disproportionate difference in duration between the Tertiary and the Quaternary. One should recall that it is the marine perspective or tradition that is embodied by the Paleogene and Neogene, and it is the marine record that is preferentially used to define *global* chronostratigraphic units, as explained in the International Stratigraphic Guide (Hedberg, 1976) and in several papers by members of our group. So, apart from the *unique continental* character of the Quaternary, this line of reasoning also points to a higher status of the Paleogene and Neogene. This brings us to the modified Pillans and Naish (2004) inclusive solution.

Pillans and Naish (2004) inclusive compromise

Pillans and Naish (2004) proposed a Quaternary Subperiod as part of the Neogene Period, spanning the last 2.60 Myrs with its base coincident with the GSSP of the Late Pliocene Gelasian Stage (Fig. 4A). The older part of the Neogene is not occupied by a Subperiod. Although this may be criticised on purist and pedantic grounds, it actually emphasizes the unique character of the Quaternary. The split Pliocene of Lourens (2008) restores again the hierarchy in the chrono-stratigraphic scheme, as shown in Figure 5B. (It must be noted here that other Subperiods are present in GTS2004, namely the Mississippian and Pennsylvanian of the Carboniferous Period [Gradstein et al., 2004]. The International Stratigraphic Guide (Salvador, 1994) states that subperiods (and superperiods) have occasionally been used).

Alternative solutions other than the Subera and Subperiod options for the Quaternary are also presented in Figure 5, with the Quaternary either as Period or Superstage. In Figure 5C, the Quaternary is a Period equivalent to a split (Late) Neogene. This option does justice to the two main marine and continental traditions in subdividing the youngest part of the chronostratigraphic scale and meets the Period status for the Quaternary preferred by the Quaternary community. In this case, a split Pliocene and Neogene are both necessary to maintain hierarchy and the solution results in two different Period names for the same interval. This somewhat artificial scheme and the absence of an Early Neogene Subperiod in the modified version of Pillans and Naish (2004; Fig. 5B) are both overcome in the last option shown in Figure 5D. In this case the Quaternary is shown as Superseries that includes the combined Late Pliocene, Pleistocene and Holocene Series. This option is probably less acceptable to the Quaternary community. The International Stratigraphic Guide states that superseries (and subseries) have been used infrequently.

Combining all arguments, we favour 1) incorporation of the Quaternary as a Subperiod with the base at 2.6 Ma, defined by the GSSP of the Late Pliocene Gelasian Stage, and 2) retention of the Neogene Period extending to the present. We emphasize to the stratigraphic community that the inclusive compromise of a Quaternary Sub-Period was proposed by Pillans and Naish in 2005, as the first response to the Neogene-Quaternary controversy following the publication of GTS2004. Brad Pillans is the current chair of the INQUA Commission on Stratigraphy and Chronology, and was also co-author of the inclusive Subera solution of Aubry et al. (2005). So it is very difficult to imagine that he and other members or sectors of the Quaternary community are not willing to accept the inclusive proposal that they actually proposed themselves initially.

Conclusions

Clearly the introduction of an extended Neogene in an ICS-supported time scale (GTS2004) was not a novelty, but the recognition of a long-standing usage by the scientific community at large. This essentially marine Neogene tradition clashes with the predominantly continental tradition of the Quaternary, and resulted in a request by the Quaternary community to adjust the base of the Quaternary at 2.6 Ma coincident with the Pliocene-Pleistocene boundary, and with the top of the Neogene (truncated at a Neogene/Quaternary boundary). We show here that the latter request has no cogent or historical basis.

All arguments considered, the most elegant and satisfactory solution to resolve the clash between the two traditions is that of Pillans and Naish (2004) in which the Quaternary be denominated a Subperiod, and the Pliocene split so as to maintain the hierarchy of chronostratigraphic classification. We do not consider a serious drawback the fact that the entire Neogene is not subdivided into Subperiods. On the contrary this gives special status to the unique character of the Quaternary as a formal chronostratigraphic unit covering the last 2.6 Myrs! But if necessary, this potential problem can be solved by giving the Quaternary Superseries status, although such a status may be less acceptable to the Quaternary community.

Our second option is the inclusive solution of Aubry et al. (2005). The third, the downgrading of the Neogene to include only the Miocene and a remnant of the Pliocene (Head et al., 2008), is an exclusive, and thus unsatisfactory, option.

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