

## THE DEFINITION OF THE QUATERNARY SYSTEM/ERA AND THE PLEISTOCENE SERIES/EPOCH

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### ABSTRACT

The Quaternary is characterised by the development of widespread glaciations in temperate northern regions, and by associated physical and biotic readjustments. As a chronostratigraphical term it has attracted considerable debate. There has long been acceptance that the Quaternary should begin at the first indication of refrigeration in the Mediterranean region, which for spurious reasons was placed at 1.8 Ma. Following protracted discussions, led by the International Subcommittee on Quaternary Stratigraphy (ISQS) and supported by the International Union for Quaternary Research (INQUA), the International Commission on Stratigraphy has now officially agreed that the Quaternary will henceforth begin at 2.6 Ma within a 2.8-2.4-Ma interval of profound change in Earth's climate system. The base of the Gelasian Stage (previously Pliocene) at 2.588 Ma offered an existing global stratotype section and point (GSSP) to define the base of the Quaternary. However, adopting this measure also necessitated lowering the base of the Pleistocene from its previously defined 1.8 Ma to that of the Quaternary to maintain hierarchical order. Acceptance of this proposal recognises the distinctive qualities of the Quaternary, complies with the hierarchical requirements of the geological time scale, and respects the historical and widespread current usage of both terms Quaternary and Pleistocene.

### RÉSUMÉ

#### DÉFINITION DU QUATÉNAIRE EN TANT QUE SYSTÈME/ÈRE ET DU PLÉISTOCÈNE EN TANT QUE SÉRIE/ÉPOQUE

Le Quaternaire est caractérisé par le développement de glaciations majeures sur les régions septentrionales tempérées, et par les effets physiques et biotiques associés. En tant que terme chronostratigraphique il a fait l'objet d'un important débat. Pendant longtemps il a été admis que le début du Quaternaire coïncidait avec les premiers indices de refroidissement de la région méditerranéenne, qui pour des raisons fallacieuses ont été placés à 1.8 Ma. Après de longues discussions, menées par la Sous-commission Internationale de Stratigraphie du Quaternaire (ISQS) elle-même soutenue par l'Union Internationale pour la Recherche sur le Quaternaire (INQUA), la Commission Internationale de Stratigraphie (ICS) a maintenant officiellement reconnu que désormais le Quaternaire commence à 2.6 Ma durant un intervalle de profond changement du système climatique terrestre entre 2.8 et 2.4 Ma. La base de l'étage Gélasien (auparavant Pliocène) à 2.588 Ma présente l'avantage de correspondre à un point de référence établi (GSSP) sur un stratotype global pour la définition de la base du Quaternaire. Cependant, adopter cette mesure implique également d'abaisser la limite inférieure du Pléistocène depuis sa précédente position à 1.8 Ma jusqu'à celle du Quaternaire afin de respecter l'ordre hiérarchique des divisions. L'acceptation de cette proposition reconnaît les qualités distinctives du Quaternaire, est en accord avec les exigences hiérarchiques de l'échelle stratigraphique des temps géologiques, et respecte l'usage historique et couramment répandu des termes Quaternaire et Pléistocène.

### 1 - INTRODUCTION

The Quaternary is youngest in a four-cycle division of earth history proposed by G. Arduino in 1759 (Arduino, 1760). Although he never used the term "quaternario", referring instead to his "fourth order" (Schneer 1969; Ellenberger 1994, p. 261; Vaccari, 2006), his concept was reinvoked by J. Desnoyers (1829) to encompass *Tertiaire récent*, and finally defined by H. Raboul (1833, p. 1-2) as "*la période dont les terrains sont caractérisés par les espèces animales et végétales semblables aux êtres actuellement vivants dans les mêmes lieux*". This term has continued in use to the present day. Until the events reported here, the official status of the Quaternary was that of period/system with a base at 1.8 Ma (Cowie & Bassett, 1989; Remane, 2000; Head, Gibbard & Salvador, 2008a, Fig. 1B). Nonetheless, the Quaternary

was omitted from the influential time scale of Gradstein *et al.* (2004, Fig. 1A) because, they argued, the term represented an outdated concept. This action immediately sparked vigorous debate about the nature, duration and chronostratigraphical status of the Quaternary. Indeed, the recent time scales of Gradstein *et al.* (2004, 2005), while officially sanctioned by neither the International Commission on Stratigraphy (ICS) nor the International Union of Geological Sciences (IUGS), have stimulated productive discussions about the status of the Quaternary, and indeed its equally legitimate sister, the Tertiary.

Recent proposals regarding the status of the Quaternary have included treating it as an informal chronostratigraphic unit, and formally as a sub-period, period, or sub-era (see Pillans and Naish, 2004; Gibbard *et al.*, 2005; Aubry *et al.*, 2005; Walsh, 2006; Bowen and

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| Gradstein <i>et al.</i> (2004) |          |             |          | IUGS pre-2009 status quo |            |             |          | ICS-approved 2009 Quaternary (SQS/INQUA) proposal |            |                  |             |           |             |       |       |   |  |
|--------------------------------|----------|-------------|----------|--------------------------|------------|-------------|----------|---|------------|------------------|-------------|-----------|-------------|-------|-------|---|--|
| ERA                            | PERIOD   | EPOCH       | AGE      | ERA                      | PERIOD     | EPOCH       | AGE      | ERA   | PERIOD     | EPOCH & SUBEPOCH | AGE         | AGE (Ma)  | GSSP        |       |       |   |  |
| CENOZOIC                       | NEOGENE  | HOLOCENE    |          | CENOZOIC                 | QUATERNARY | HOLOCENE    |          | CENOZOIC  | QUATERNARY | HOLOCENE         |             |           |             |       |       |   |  |
|                                |          | PLEISTOCENE | Upper    |                          |            | PLEISTOCENE | Upper    |   |            |                  | PLEISTOCENE | Upper     |             |       | 0.012 | ← Vrica, Calabria<br>Monte San Nicola, Sicily |  |
|                                |          |             | Middle   |                          |            |             | Middle   |   |            |                  |             | Middle    |             | 0.126 |       |   |  |
|                                | Lower    |             | Lower    |                          | Lower      |             |          |   | 0.781      |                  |             |           |             |       |       |   |  |
|                                | PLIOCENE | Gelasian    | PLIOCENE |                          | Gelasian   | Ng          | PLIOCENE |   | Gelasian   |                  | PLIOCENE    | Early     | 'Tarantian' |       |       |   |  |
|                                |          | Piacenzian  |          |                          | Piacenzian |             |          |   | Piacenzian | M                |             | 'Ionian'  |             |       | 1.806 |   |  |
|                                |          | Zanclean    |          |                          | Zanclean   |             |          |   | Zanclean   | Late             |             | Calabrian |             |       | 2.588 |   |  |
|                                |          |             |          |                          |            |             |          |   |            |                  |             | Gelasian  |             |       | 3.600 |   |  |
|                                |          |             |          |                          |            |             |          |   |            |                  |             |           |             | 5.332 |       |   |  |

**Figure 1: Comparison of late Cenozoic time scales. A: the Gradstein *et al.* (2004) time scale which, although influential, was sanctioned by neither ICS nor IUGS. B: the most current previous IUGS-sanctioned time scale showing the Quaternary in place (Remane, 2000). C: the current (2009) scheme proposed by SQS and INQUA and newly approved by ICS, in which the Quaternary and Pleistocene are co-terminus with the base of the Gelasian Stage at 2.6 Ma (modified from Head *et al.*, 2008a). Stage names and boundary ages are from the ICS website in 2008, with the provisional Ionian Stage following Cita *et al.* (2006, 2008) and the provisional Tarantian Stage following Cita (2008, and references therein). The subdivision of the Pleistocene is based on Head *et al.* (2008a). Currently defined GSSPs are indicated by arrows. Ng = Neogene. The illustrations are not scaled to geological time.**

*Figure 1: Comparaison des échelles stratigraphiques de la fin du Cénozoïque. A: Echelle stratigraphique de Gradstein et al. (2004), bien qu'influente, cette proposition n'a été approuvée ni par l'ICS ni par l'IUGS. B: précédente échelle stratigraphique montrant le Quaternaire en place (Remane, 2000), cette proposition la plus communément admise a été approuvée par l'IUGS. C: proposition présentée par le SQS et l'INQUA (2009) et récemment approuvée par l'ICS, dans laquelle le Quaternaire et le Pléistocène ont une base commune avec le Gélasién à 2.6 Ma (modifié d'après Head et al., 2008a). Les noms des étages et la chronologie des limites ont été tirés du site web de l'ICS en 2008, sont mentionnés l'étage temporaire Ionien d'après Cita et al. (2006, 2008) ainsi que l'étage temporaire Tarentien d'après Cita (2008 et citations incluses). La subdivision du Pléistocène est basée sur Head et al. (2008a). Les GSSP actuellement définis sont signalés par des flèches. Ng = Néogène. Les illustrations ne tiennent pas compte de l'échelle géologique.*

Gibbard, 2007; and Pillans, 2007 for reviews). Objections to its classification as an informal term include its precise, formal and widespread use in the literature and among technological as well as scientific communities (Salvador, 2006a, b). Claims based on historical interpretation that the Neogene Period should extend to the present day, thereby rendering the term Quaternary superfluous (e.g., Berggren, 1998; Aubry *et al.*, 2005; Lourens *et al.*, 2005), have been refuted (Walsh, 2006, 2008). Proposals for both sub-era and sub-period status denied the Quaternary its ubiquitous usage, and failed to respect the hierarchical nature of the stratigraphic time scale, when adopting a 2.6 Ma inception for the Quaternary.

Following the largest survey of researchers' opinions ever undertaken, the International Union for Quaternary Research (INQUA) jointly with SQS, in March 2006 notified the ICS of its requirements: that the Quaternary be of period status with its base at the GSSP of the Gelasian Stage (2.6 Ma), and that the base of the Pleistocene should also be lowered from 1.8 Ma to coincide with that of the Quaternary. In May 2007, the ICS voted in favour of the INQUA proposal, but the International Union of Geological Sciences (IUGS), while approving the ICS's request to accept the Quaternary as a formal period, noted in correspondence to the ICS (in May 2007) that the base of the Pleistocene could not be moved until a 10-year moratorium had expired (in January 2009). This had come about because the IUGS (but not the ICS) had voted in January 1999 to uphold the base-Pleistocene GSSP after a joint Quaternary-Neogene task

group reconsidering the level of the Pliocene-Pleistocene boundary was unable to reach a supermajority (60 %) recommendation (Remane and Michelsen, 1998). The IUGS imposed a 10-year moratorium on the earlier base-Pleistocene decision, thereby delaying further consideration of a definition for the Quaternary and associated shifting of the Gelasian Stage to the Pleistocene until after January 2009. This was the situation before the most recent voting round that was completed on 22 May 2009.

A difficulty that hindered all discussions concerning the definition and duration of the Quaternary has been the 1985 decision to place the Pliocene-Pleistocene boundary near the top of the Olduvai Subchron. This boundary, dated astronomically at 1.806 Ma (Lourens *et al.*, 2005), was defined by a global stratotype section and point (GSSP) at Vrica in Calabria, south-eastern Italy (Aguirre and Pasini, 1985; Cita, 2008), and reaffirmed by the IUGS in 1999 in spite of numerous objections (Partridge, 1997; Suc *et al.*, 1997; Gibbard *et al.*, 2005; Bowen and Gibbard, 2007). Among these was that fundamental geological changes did not take place at or even near the chosen boundary. Indeed, some of the so-called "northern guests", cold-tolerant migrants into the Mediterranean used as indicators of cooling at the boundary (Aguirre and Pasini, 1985), have since been found to have arrived in the Mediterranean earlier than 1.8 Ma (e.g. Aiello *et al.*, 1996): an age of c. 2.5-2.7 Ma is more appropriate (e.g. Suc *et al.*, 1997). It is now well known that major cooling events in the Mediterranean occurred between about 2.8 and 2.5 Ma (e.g. Versteegh,

1997; Monegatti and Raffi, 2001; Roveri and Taviani, 2003), which coincide with the widely agreed base of the Quaternary.

This was the basis for the repeated and longstanding demands from the Quaternary community for lowering the basal boundary of both the Quaternary and the Pleistocene when the current round of discussions were initiated at the 33<sup>rd</sup> International Geological Congress (IGC) held in Oslo, August 2008. There was overwhelming support for the Quaternary to be recognised as a full period/system extending from 2.6 Ma to the present day, and that the base of the Pleistocene be lowered to that of the Quaternary in order to maintain hierarchy (Ogg and Pillans, 2008; Head *et al.* 2008a).

## 2 - BASE OF THE QUATERNARY

While the Quaternary is generally characterised by widespread Northern Hemisphere mid-latitude glaciation, cooling was both global and episodic. Multiple major cooling phases occurred between 2.8 and 2.4 Ma (MIS G10 to MIS 96), and their expression varied according to region (North Atlantic ice-rafted debris at 2.74 Ma, loess-palaeosol accumulation in China at 2.6 Ma, severe cooling in NW Europe at 2.54 Ma, incoming sub-Antarctic molluscs to Wanganui Basin in New Zealand at 2.4 Ma [Pillans and Naish, 2004]). No single global event emerges as triggering the change. Given that boundaries must be

recognised unambiguously and widely, it was noted that the Gauss-Matuyama polarity boundary at 2.581 Ma (or 2.610 Ma, with a transition of 1.5 kyr, according to Deino *et al.*, 2006), falls near the mid-point of this interval of global cooling. The base of the Gelasian Stage, defined by a GSSP at Monte San Nicola in Sicily, has an astrochronological age of 2.588 Ma. It corresponds to MIS 103 and is located about 1 m (20 kyrs) above the Gauss-Matuyama boundary (Rio *et al.*, 1998). Given the close proximity of this existing GSSP to the Gauss-Matuyama boundary, and its calibration to the astrochronological time scale, the base-Gelasian GSSP is evidently well characterised also to define the base of the Quaternary.

## 3 - FORMAL PROPOSALS

Following public discussions at the Oslo IGC in 2008, the incoming ICS President, Stanley Finney, asked each of the competing proponents, the Subcommissions of Quaternary and Neogene Stratigraphy (SQS, SNS) to submit formal proposals on which the ICS voting membership could comment and ultimately vote.

The “formal request to ICS that the base of the Quaternary System/Period be lowered to the Gelasian Stage GSSP (at 2.588 Ma), and that the base of the Pleistocene Series be lowered to the same position”, submitted by Philip Gibbard & Martin J. Head on 1 September 2008 on behalf of the Subcommission on Quaternary Stratigraphy is given in Box 1 and Fig. 1.

### **Box 1 Formal request to ICS that the base of the Quaternary System/Period be lowered to the Gelasian Stage GSSP (at 2.588 Ma), and that the base of the Pleistocene Series be lowered to the same position.**

The International Subcommission on Quaternary Stratigraphy formally requests to the ICS that the base of the Quaternary System/Period be lowered to the Gelasian Stage GSSP (at 2.588 Ma) and that the base of the Pleistocene Series be lowered to the same position. The Quaternary is already recognised by the IUGS as having System/Period status and succeeding the Neogene, but with its base currently defined by the Pleistocene System GSSP at Vrica (at 1.806 Ma). The specific details of this request are that:

1. The base of the Quaternary System be lowered to the GSSP of the Gelasian Stage (currently the uppermost stage of the Pliocene Series) at the base of Marine Isotope Stage 103, which has a calibrated age of 2.588 Ma.
3. The base of the Pleistocene Series be lowered to coincide with that of the Quaternary System boundary (the Gelasian GSSP).
4. The Vrica GSSP (the present Quaternary and Pleistocene basal boundary) be retained as the base of the

Calabrian Stage, the second stage of the revised Pleistocene Series.

This request follows a previous ICS proposal, dated 13 May 2007, which was supported by a separate request directly to IUGS by the INQUA Executive Committee. It was subsequently supported by a unanimous vote of the INQUA General Assembly at the INQUA Congress in Cairns, in Australia in August 2007.

#### **Supporting case**

Thank you for this opportunity to present our final case for the Quaternary as a period/system with its base defined by the base-Gelasian GSSP at Monte San Nicola, Sicily, which has an astronomical age of 2.588 Ma. On hierarchical, as well as scientific grounds, this definition requires that the base of the Pleistocene Epoch/Series be lowered from its present GSSP at Vrica, Calabria, Italy (dated astronomically at 1.806 Ma) to the GSSP at Monte San Nicola. The Vrica GSSP would, however, remain to define the base of the “Calabrian”

Age/Stage. This proposal moreover reflects widespread current and historical usage of the term Quaternary, and is supported by INQUA, the SQS, and the outgoing ICS for 2004-08. This position has been summarised recently by Head *et al.* (2008) and Ogg & Pillans (2008). We welcome this opportunity also to address opposing views by Lourens (2008) and Hilgen *et al.* (2008) including their desire to extend the Neogene to the present day.

1. The Quaternary was first proposed as a concept by Arduino in 1759 and was used formally by Desnoyers in 1829, predating both the terms Pleistocene (Lyell 1839) and Neogene (Hörnes 1853).

2. The traditional and current view (and that of the IUGS) is that the Neogene represents the Miocene and Pliocene, and that the Quaternary represents the Pleistocene and Holocene, as any wide perusal of the current literature shows.

3. Claims that the Neogene should be extended to the present day are based on flawed historical interpretation. Hörnes was vague about where his Neogene should end but it is clear that he did not intend it to extend to the present day or indeed include parts of the Pleistocene (Walsh, 2008).

4. Assertions that the Holocene should be treated as a subdivision of the Pleistocene, rendering the Quaternary superfluous, deny the unique qualities of the Holocene and its pervasive use in the literature. Furthermore, the argument is now moot – the Holocene having been ratified as an epoch /series within the Quaternary Period/System by the IUGS earlier this year (Walker *et al.* 2008; 2009).

5. Ratified in 1983, the base-Pleistocene is defined by the Vrica GSSP at a position now dated astrochronologically at 1.806 Ma. This position was incorrectly thought to represent the first climatic deterioration in the Italian Plio-Pleistocene. For example, the ostracod *Cytheropteron testudo*, a “northern guest” singled out as having special significance for recognising the Vrica GSSP, has since been recorded at 2.4 Ma within the Monte San Nicola section in Italy (Aiello *et al.*, 1996). Consequently, the Vrica GSSP has poor potential for correlation and, in retrospect, provides an arbitrary rather than descriptive means to subdivide geological time. This boundary is inappropriate and unworkable for defining the base of an epoch, let alone a period.

6. The first significant cluster of cooling events within the Italian Plio-Pleistocene and elsewhere extends from 2.7 to 2.4 Ma. Earlier cooling events, such as the Mammoth cooling event (3.3 Ma), are best viewed as precursor occurrences. Fundamental changes to the Earth’s climate system and associated biotic response make this episode the logical start of the Quaternary. The

Monte San Nicola GSSP dated at 2.588 Ma occurs conveniently at the approximate mid-point of this cooling interval, and within 1 m of the Gauss-Matuyama Chron boundary. The fact that this GSSP occurs in a warm event (MIS 103) has little overall consequence for the widely agreed concept of the Quaternary, namely the onset of major glaciation in the Plio-Pleistocene. The wide support for this boundary recognises that the Quaternary must be defined by scientifically meaningful as well as practical criteria.

7. Although it coincides with a period of significant global cooling, the Gelasian GSSP, which serves to define the base-Quaternary and base-Pleistocene boundary, was selected and approved as a globally correlative chronostratigraphical horizon by marine geochronologists of the Neogene Subcommittee (Rio *et al.*, 1998). Thus, the Quaternary and Pleistocene, if redefined at this boundary, will not be climatostratigraphical units as some have suggested but biochronologically defined divisions.

8. INQUA and common usage both assert the need for the Quaternary to remain at its present IUGS-sanctioned rank of period/system; a status confirmed twice by formal ICS votes in 2005 and 2007. For reasons of hierarchy and common sense, the base of the Pleistocene should therefore be lowered to that of the Quaternary. Although the Vrica GSSP was re-ratified in 1999 (by minority vote), there has been unremitting dissatisfaction with this boundary from a substantial community since its inception in 1983 and indeed before. As has been demonstrated by the voting of the INQUA members, most recently and unanimously at the 2007 INQUA Congress in Cairns, an overwhelming majority of Quaternary / Pleistocene workers want the units changed. Moreover, because INQUA now has adopted the definitions proposed here, which currently differs from that accepted by ICS and IUGS, the present situation generates great confusion.

The vague term “Plio-Pleistocene” has become the legacy of the existing Vrica boundary, which has little meaning beyond the local Mediterranean area. Lowering the base-Pleistocene to the Monte San Nicola GSSP will align it with the base-Gelasian and base-Quaternary. This also brings the lowered Pleistocene into better accord with the 1948 IGC decision that the Pleistocene should include the Villafranchian regional mammal stage, the base of which is now known to extend beyond 1.806 Ma.

9. A base-Quaternary boundary at 2.6 Ma will strengthen recognition within terrestrial as well as marine sections owing to major global changes in the terrestrial biota, including humans, and in sedimentation particularly with respect to loess deposition across northern Eurasia. Such major global changes are lacking around 1.8 Ma.

10. Although the SQS and Subcommittee on Neogene Stratigraphy (SNS) are equal members under the ICS, and IUGS and INQUA equal members under the International Council for Science (ICSU), the user base for the geological time scale should also be carefully considered. The current INQUA-SQS position has the overwhelming support of users – the large global population of Quaternary scientists that have resulted in INQUA being the only geological period to have its own union under the ICSU.

11. The suggestion by Lourens (2008) to lower the base-Quaternary and base-Gelasian to 2.72 Ma (rather than our 2.6 Ma) would weaken its potential for correlation owing to a significantly increased distance from the Gauss-Matuyama Chron boundary. Furthermore, relegating the Quaternary Period to be a subperiod of an extended Neogene Period runs counter to an enormous literature and the weight of current opinion, and would be unnecessarily disruptive. Moreover, termination of the Neogene at 2.6 Ma is logical given the fundamental changes to Earth's climate system at around this time.

12. Sanctioning two independent geological time scales, one for the Quaternary and another showing an extended Neogene, as suggested by Hilgen *et al.* (2008, p. 30), would be confusing, divisive and only defer a decision that should be made now. It would be the worst of all possible compromises. INQUA, SQS and the 2000-2004 ICS have accepted an existing GSSP (the Monte San Nicola GSSP) to define the base-Quaternary as a compromise in the interests of expediency and stability.

13. The proposed changes will affect both the Quaternary and Neogene communities. However, since Quaternary workers have long favoured the 2.6 Ma boundary, and many indeed have applied this boundary for decades already, the impact for them will be slight. For Neogene workers the effect will be greater because of the reattribution the Gelasian Stage to the Quaternary, but this stage was ratified only 10 years ago by the Neogene community in acknowledgement of important changes occurring at *ca.* 2.6 Ma. Hence, we consider any confusion regarding the reallocation of the Gelasian to be short lived.

Source: Gibbard & Head (2009).

A competing proposal was submitted on behalf of the Neogene Subcommittee by Frits Hilgen in November, 2008 which effectively split the Pliocene Series into two

parts: a Lower Pliocene Series that was excluded from the Quaternary, and an Upper Pliocene Series included within a Quaternary Subperiod (Box 2: Fig. 2A).

### Box 2. Paleogene and Neogene Periods of the Cenozoic Era. A formal proposal and inclusive solution for the status of the Quaternary

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 [*sic*], 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).

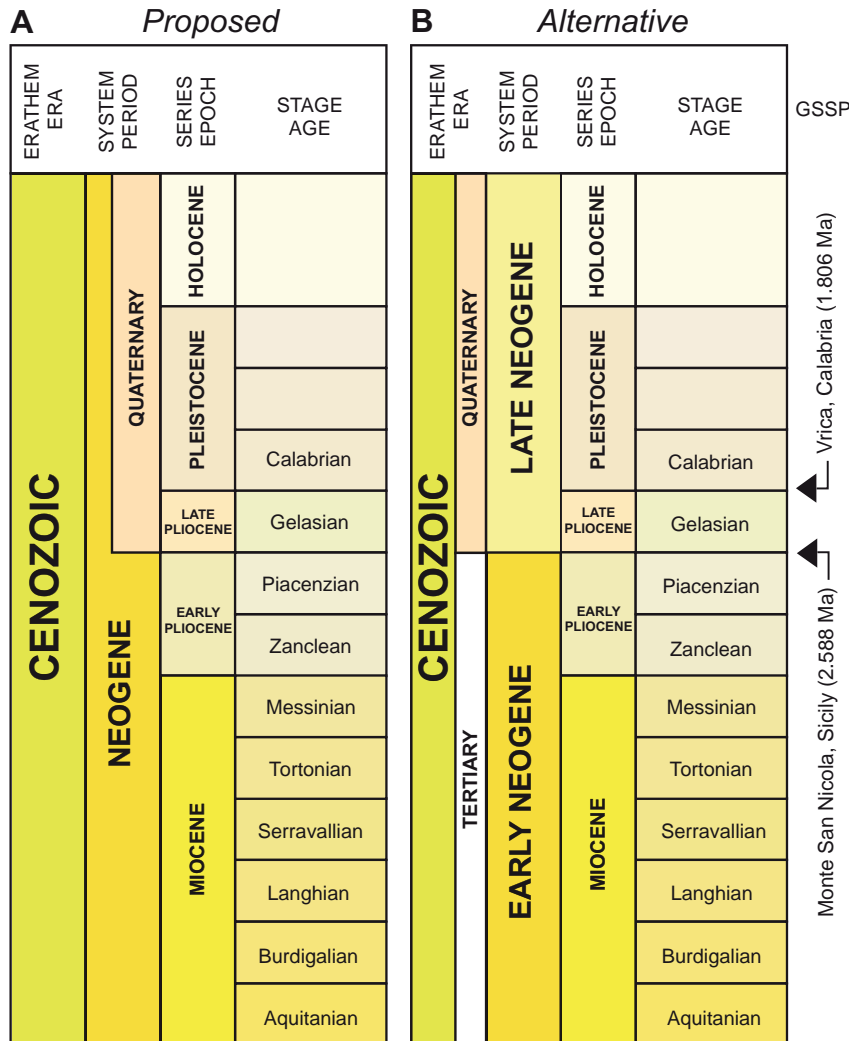
Our objectives, of respecting the two traditions, of inclusive compromise, and of conserving both Neogene and Quaternary, are met in both options (i) and (ii).

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) (Prat 2007), 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. Source: Hilgen *et al.* (2009).

## Schemes advanced by the Subcommission on Neogene Stratigraphy



**Figure 2:** The alternative late Cenozoic time-scale counter-proposals advocated by the ICS' Subcommission on Neogene Stratigraphy (Hilgen *et al.*, 2009, adapted from Aubry *et al.*, in press). The proposed scheme (A) was defeated in the first round of the 2009 ballots, and the alternative scheme (B) was not presented for voting. See Box 2 and Fig. 1 for explanation of details.

Figure 2: Propositions alternatives d'échelles stratigraphiques de la fin du Cénozoïque défendues par la sous commission de Stratigraphie du Néogène de l'ICS (Hilgen *et al.*, 2009, adapté de Aubry *et al.*, sous presse). Le schéma proposé (A) a été battu au premier tour de vote en 2009, le schéma alternatif (B) n'a pas été présenté au vote. Voir l'encart 2 et la Figure 1 pour les explications de détail.

Curiously the "Neogene" proposal reinvoked a request already rejected by the IUGS in May 2007 since it suggested that the Quaternary be classified as a subdivision of the Neogene Period. An alternative proposal advanced by the Neogene community (Aubry *et al.*, in press; Fig. 2B) assigned the Quaternary as Sub-erathem/Sub-era, although this proposal was ultimately not included in the vote. Both proposals (Fig. 2A and B) show the Neogene Period extending to the present day. Yet more surprisingly, the SNS on the 20<sup>th</sup> March 2009, just days before ICS voting was due to commence, asked to withdraw its proposal(s) in favour of one that excluded the Quaternary completely, essentially returning to the proposal of Gradstein *et al.*

(2004; Fig. 1A). In view of the short notice given, this request was not granted. However, it is probable that any of the SNS Neogene proposals, had they been accepted by the ICS membership, would have been rejected by IUGS, further delaying final settlement of the controversy.

Following submission of these proposals, they, together with supporting documentation (a total of 27 documents), were circulated to the ICS voting membership (comprising 18 individuals, the chairs of the subcommissions and the ICS officers). The full documentation can be viewed on the ICS ([www.stratigraphy.org](http://www.stratigraphy.org)) and SQS ([www.quaternary.stratigraphy.org.uk](http://www.quaternary.stratigraphy.org.uk)) websites.

#### 4 - RECOMMENDATION

In the “Quaternary” proposal, the Quaternary Period/System, Pleistocene Epoch/Series, and Gelasian Age/Stage share the same GSSP at the base-Gelasian, which is dated at 2.588 Ma. The Holocene had already been regarded officially as an epoch distinct from the Pleistocene, in recognition of the fundamental impact made by modern humans on an otherwise unremarkable interglacial (Walker *et al.*, 2008, 2009). Consequently the terms Pleistocene and Quaternary are both essential. However, on hierarchical considerations, the ICS supported SQS’s and INQUA’s recommendation to lower the Plio-Pleistocene boundary while accepting that the Vrica GSSP continues to define the base of the Calabrian Stage (Cita *et al.*, 2008). The SQS accepted the Gelasian Stage as a useful and already familiar term, and by extension generally supports use of the provisional large-scale (“super-”) stages Calabrian, Ionian, and Tarantian (Cita *et al.*, 2006, 2008; Cita, 2008). The proposed scheme (Fig. 1C) met INQUA requirements, obeyed the principles of a hierarchical time scale, and respected historical precedents and established usage for the term Quaternary.

#### 5 - VOTING

The first-round ballot was sent out on 23 March 2009 with 30 days allowed for voting. The first ballot listed the

“status quo” (i.e. the Quaternary /Pleistocene defined at 1.8 Ma), “Quaternary”, and “Neogene” proposals to which each voting member was required to vote yes, no, or abstain on each proposal. Those proposals receiving a majority of affirmative votes on the ballots submitted, if more than one, were to be listed on a second-round ballot.

In the second round of voting, each member was directed to vote in favour of only one of the proposals or to abstain. The proposal receiving the majority of votes would then be subject to a third-round ballot on which there would be only one proposal, if necessary. For the proposal that then received at least a 60 % majority of “yes” votes, a formal decision will have been made, and it would be forwarded to the IUGS for formal ratification.

If only one proposal received a majority of “yes” votes on the first round, then it would stand alone on a second-round ballot for approval by a 60 % majority (S. Finney, written communication 23 March, 2009).

The results of the first ballot were announced on 22 April and are given in Table 1. Only the Quaternary proposal received a majority of affirmative votes, causing the ballot for the second round of voting to include only the Quaternary proposal. It needed to receive at least a 60 % majority of “yes” votes among the ballots submitted for it to be approved by ICS and

| Name – position                    | Status Quo | Quaternary | Neogene   |
|------------------------------------|------------|------------|-----------|
| Finney – ICS Chair                 | Abstain    | Yes        | No        |
| Peng – ICS Vice Chair and Cambrian | No         | Yes        | No        |
| Bown – ICS Sec.-Gen.               | Yes        | No         | No        |
| Gibbard – Quaternary               | No         | Yes        | No        |
| Hilgen – Neogene                   | No         | No         | Yes       |
| Molina – Paleogene                 | Abstain    | No         | Yes       |
| Primoli Silva - Cretaceous         | Abstain    | Yes        | No        |
| Palfy – Jurassic                   | No         | Yes        | No        |
| Balini – Triassic                  | No         | Yes        | No        |
| Henderson – Permian                | Yes        | Yes        | No        |
| Richards – Carboniferous           | No         | Yes        | No        |
| Becker – Devonian                  | No         | Yes        | No        |
| Melchin - Silurian                 | No         | Yes        | No        |
| Harper – Ordovician                | No         | Yes        | No        |
| Gehling – Neoproterozoic           | No         | No         | Yes       |
| Van Kranendonk - Precambrian       | No         | No         | Abstain   |
| Pratt – Strat Classif              | No         | Yes        | No        |
| Ogg – Strat Inf. Serv.             | No         | Yes        | No        |
| <b>Total Yes</b>                   | <b>2</b>   | <b>13</b>  | <b>3</b>  |
| <b>No</b>                          | <b>13</b>  | <b>5</b>   | <b>14</b> |
| <b>Abstain</b>                     | <b>3</b>   | <b>0</b>   | <b>1</b>  |

**Table 1. Results of the first round of voting by ICS members. All ballots received and votes compiled on 22 April, 2009 by S. Finney. The Quaternary proposal received a 72 % majority of “yes” votes. The “Status Quo” and “Neogene” proposals failed to receive a majority of “yes” votes. Therefore, the second round of voting included only the “Quaternary” proposal. Abbreviations: Sec. Gen = Secretary General; Strat. Classif. = Stratigraphic Classification; Strat. Inf. Serv. = Stratigraphic Information Service.**

*Tableau 1 : Résultats du vote des membres de l'ICS du premier scrutin. Tous les bulletins ont été reçus et dépouillés par S. Finney le 22 Avril 2009. La proposition des quaternaristes a été approuvée à la majorité avec 72 % de votes favorables. Les propositions du « Statu Quo » et du Néogène n'ont pas été créditées d'un vote majoritaire favorable. En conséquence le deuxième tour de scrutin a porté seulement sur la proposition des quaternaristes. Abréviations : Sec. Gen = Secrétariat Général ; Strat. Classif. = Classification Stratigraphique ; Strat. Inf. Serv. = Service d'Information Stratigraphique.*

| Name – position                    | Yes       | No       | Abstain  |
|------------------------------------|-----------|----------|----------|
| Finney – ICS Chair                 | X         |          |          |
| Peng – ICS Vice Chair and Cambrian | X         |          |          |
| Bown – ICS Sec.-Gen.               | X         |          |          |
| Gibbard – Quaternary               | X         |          |          |
| Hilgen – Neogene                   |           | X        |          |
| Molina – Paleogene                 | X         |          |          |
| Primoli Silva - Cretaceous         | X         |          |          |
| Palfy – Jurassic                   | X         |          |          |
| Balini – Triassic                  | X         |          |          |
| Henderson – Permian                | X         |          |          |
| Richards – Carboniferous           | X         |          |          |
| Becker – Devonian                  | X         |          |          |
| Melchin - Silurian                 | X         |          |          |
| Harper – Ordovician                | X         |          |          |
| Gehling – Neoproterozoic           | X         |          |          |
| Van Kranendonk - Precambrian       |           | X        |          |
| Pratt – Strat Classif              | X         |          |          |
| Ogg – Strat Inf. Serv.             | X         |          |          |
| <b>Total</b>                       | <b>16</b> | <b>2</b> | <b>0</b> |

**Table 2. Results of the second round of voting by ICS members. All ballots received and votes compiled on 22 May, 2009 by S. Finney. The “Quaternary” proposal was approved by an 89 % majority “yes” vote.**

Tableau 2 : Résultats du second tour de scrutin des membres de l'ICS. Tous les bulletins ont été reçus et dépouillés par S. Finney le 22 avril 2009. La proposition des quaternaristes a été approuvée à la majorité avec 89 % de votes favorables.

forwarded to the IUGS Executive Committee for ratification. A deadline of 22 May 2009 was set for the return of second-round ballots (S. Finney, written communication, 22 April, 2009).

The results of the second ballot were announced on 20 May and are given in Table 2. S. Finney (written communication, 21 May, 2009) commented “The Quaternary proposal was approved by an 89 % majority yes vote. The Quaternary proposal will now be forwarded to the IUGS Executive Committee for ratification.” Ratification is the final stage in the process. Once the proposal has been ratified by the IUGS Executive Committee, the definition is finally officially accepted. There can be no modification of this decision and there is a moratorium on changes or challenges to the definition of 10 years (i.e. January 2019).

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