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MAJOR EVENTS AT THE TRANSITION FROM EARLY TO MIDDLE PLEISTOCENE

A. Azzaroli
Università di Firenze, Dipartimento di Scienze della Terra
with the cooperation of G. Ficcarelli and D. Torre

ABSTRACT - *Major events at the transition from early to middle Pleistocene* - Il Quaternario, **4**(1a), 1991, p. 5 -11 - The Pleistocene climatic fluctuations were accompanied by world-wide eustatic oscillations of sea level and by extensive changes in marine and continental faunas and in vegetation. The most drastic change in average ocean temperature and in the pattern of temperature fluctuations took place at O^{18} isotope stage 22 and was preceded by dramatic revolutions in continental faunas and floras, which have been recognized in Eurasia and South America; similar changes may presumably be detected in other continents if time scales with adequate resolution will be made available.

It is suggested that the Cassian sea level drop of the Mediterranean, equivalent to the first Illinoian cycle in North America, may correspond to stage 22 and at the same time may provide a reliable criterion for a limit between early and middle Pleistocene. We recognize that the matter requires closer investigation and suggest to select a suitable section for the definition of the limit.

RIASSUNTO - *Eventi maggiori alla transizione tra Pleistocene inferiore e Pleistocene medio* - Il Quaternario, **4**(1a), 1991, p. 5 -11 - Le fluttuazioni climatiche del Pleistocene furono accompagnate da oscillazioni eustatiche del mare, estese a tutta la Terra, e da cambiamenti di grande portata nelle faune e nella vegetazione dei continenti. Il cambiamento più drastico nella temperatura media degli oceani e nella modalità delle fluttuazioni marine avvenne in corrispondenza dello stadio 22 degli isotopi dell'ossigeno e fu preceduto da estese rivoluzioni nelle faune e nelle flore dei continenti, cambiamenti che sono stati evidenziati in Eurasia e nell'America meridionale. Cambiamenti analoghi potranno eventualmente essere evidenziati in altri continenti qualora scale cronologiche ad adeguata risoluzione siano rese disponibili.

Viene avanzata l'ipotesi che la regressione Cassia nel Mediterraneo, equivalente a l primo ciclo regressivo correlato con l'Illinoian nell'America settentrionale, possa corrispondere allo stadio 22 e nelle stesso tempo possa offrire un criterio attendibile per il limite tra Pleistocene inferiore e Pleistocene medio. Si riconosce che l'argomento richiede un'indagine più approfondita e si propone di scegliere una sezione idonea alla definizione del limite.

Key-words: Pleistocene, stratigraphy and subdivisions
Parole chiave: Pleistocene, stratigrafia e suddivisioni

1. CENTRAL ITALY - HISTORICAL

In the excursions guidebook of the IV INQUA Congress, Rome 1953, Blanc, Tongiorgi and Trevisan described the richly fossiliferous Pliocene and Pleistocene deposits of the Rome area. Pliocene sediments are marine and were described as *faciès Plaisancien*. Early Pleistocene sediments are also marine, ending with littoral facies, while younger deposits are fluviatile and deltaic and form the delta of the Tiber. The higher part of the series contains volcanic intercalations at various levels.

Blanc and collaborators remarked that the sequence is discontinuous, characterized by a series of sea regressions and ingressions which evidence eustatic cycles. Later studies (Blanc, 1955; Blanc, Cova *et al.*, 1955; Blanc, Lona *et al.*,1955) showed that regression phases were linked with climatic coolings evidenced by fossils and by sedimentary features, and Blanc proposed to designate them with the names of *periodo glaciale dell'Acquatraversa* (the oldest), *periodo glaciale Cassio, periodo glaciale Flaminio* and *periodo glaciale Nomentano*. A younger cold period, *periodo glaciale Pontino*, was based on evidence from plants. Names were derived from typical exposures in the surroundings of Rome: Fosso dell'Acquatraversa, a little creek near Monte Mario; Via Cassia, Via Flaminia, Via Nomentana, Agro Pontino. It was perhaps a chance, but time succession of these events coincides with their alphabetic order.

Several years later Ambrosetti *et al.* (1972) redescribed these episodes, which they called "erosional phases", and added an *Ostian erosional phase* (named after Via Ostiense), which follows the Nomentanan phase. Later still Arias *et al.* (1980) added an "Aullan erosional phase" inserted between the Acquatraversan and the Cassian cycles and named from Aulla, a small town in NW Tuscany near Olivola, where a characteristic fauna is intercalated in deposits indicative of intensive erosion. Sea level lowering during the Aullan cycle seems to have been of lesser amplitude than during the Acquatraversan and Cassian, and the Aullan erosional phase is not obvious, or has not yet been recognized in the Tiber delta.

2. CENTRAL ITALY AND WESTERN EUROPE - STRATIGRAPHY

In 1953 Blanc *et al.* pointed out that the oldest sea regression in the Rome area dates from the Pliocene and the others from the Pleistocene. No correlation was proposed with the classical sequence of Alpine glaciations, and this proved later to have been a wise choice.

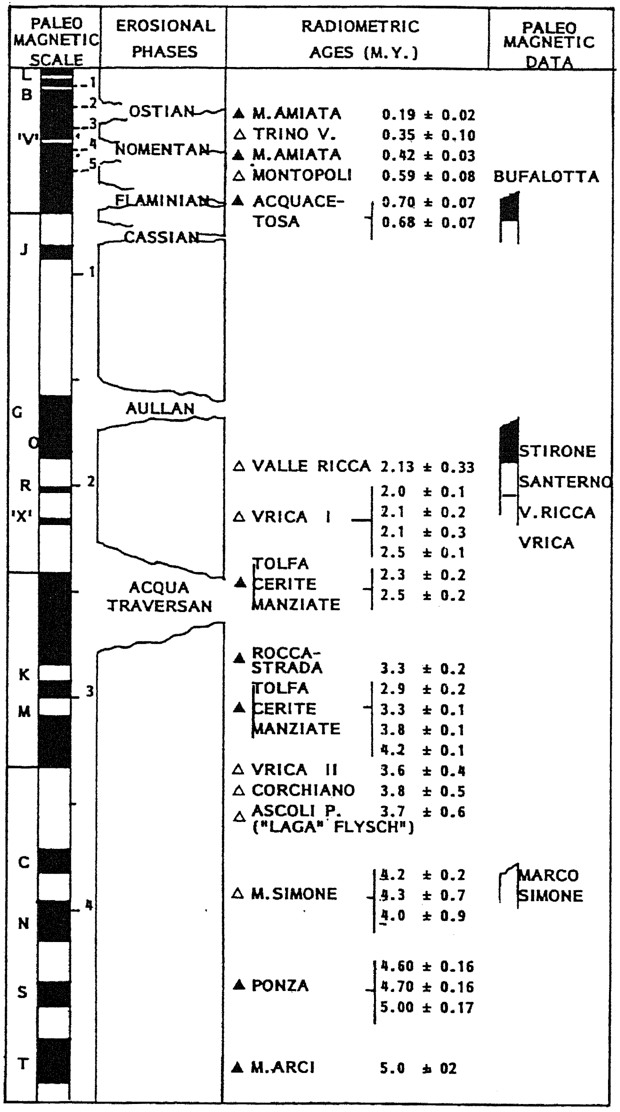

Fig. 1 - Calibration of sea level fluctuations in the Tyrrhenian area (after Arias *et al.*, 1979).

Taratura delle fluttuazioni del mare nell'area tirrenica (sec. Arias et al., *1979).*

An attempt at closer dating was made by Ambrosetti *et al.* (1972), who plotted sedimentary sequences with their fossils and discontinuities against a set of radiometric readings, mostly from volcanics of the Rome area and other sites from central Italy. Further improvement to the scale was brought by Arias *et al.* (1979), through the addition of data from palaeomagnetism and pollen analysis. Their results are summarized in Fig. 1. It may be pointed out that, in the light of later evidence, the position of the Cassian cycle is possibly too old in their synthesis.

These marine and climatic cycles, with the exception of the oldest two, were entered into the correlation chart of the special volume issued for the XI INQUA Congress, Moscow 1982 (Schanzer 1982). In particular, the Cassian cycle is correlated in this chart with the Matuyama-Brunhes palaeomagnetic transition, which also marks the transition from "Eopleistocene" to "Pleistocene" which, in the terminology of Russian authors, correspond respectively to the early Pleistocene and to the middle+late Pleistocene of western authors; but in our opinion Schanzer placed the Cassian cycle too high in his sequence.

Eustatic cycles correspond with closer or broader approximation with changes in climate, vegetation and faunas. Rio *et al.* (1990) described a marked extinction event in marine Mediterranean faunas around 3.2 Ma and a more severe one at 2.5 Ma, and Azzaroli called attention on a drastic revolution of mammalian faunas in Italy and Western Europe during the Pliocene, at the transition from the Triversa to the Montopoli faunal unit (Azzaroli 1977; 1983): an event which was dated by Lindsay *et al.* (1980) to 2.5 Ma, with good approximation. The time correspondence of these events with the Acquatraversa marine cycle is apparent. It may be added that the Montopoli local fauna, which marks the "elephant-*Equus* event" in central Italy, falls in the retreating phase of this cycle.

Eustatic cycles similar to those of the Rome area were also observed farther N on the Tyrrhenian coast, in the lower reaches of the valleys of the Arno and Cecina rivers, where the Pleistocene sea made an ingression of limited extent after the great Acquatraversan retreat (Bossio *et al.*, 1986). Correlations with the Tiber delta sequence were not proposed and are somewhat uncertain because of the dearth of fossils in the higher parts of the sequence.

Bossio *et al.* recognized:

a) A first Pleistocene sedimentary cycle, referred to the Santernian-Emilian, with marine fossils: *Arctica islandica, Mya truncata, Hyalinea baltica.* It may be remarked that fossils seem to rule out a Santernian age and speak in favour of Emilian-Sicilian in the sense of Ruggieri;
b) Unconformity (hereafter indicated as unconformity 1);
c) A second marine cycle referred to the early Pleistocene, "small *Gephyrocapsa* zone of Garther 1977";
d) Unconformity (2);
e) A third, so-called early Pleistocene cycle with pebble culture, referred incorrectly to the Sicilian;
f) Unconformity (3);

g) Conglomerates and sands, mostly fluviatile, referred to the "Mindel-Riss";
h) Unconformity (4);
i) Red sands, weathered.

The series continues with late Pleistocene deposits and terraces.

Unconformity 1 may possibly be correlated with the Cassian retreat, unconformity 2 with the Flaminian (but the position of the "small *Gephyrocapsa* zone" is anomalous; are the fossils reworked ?). Unconformity 3 may correspond to the Nomentanan, unconformity 4 to the Ostian.

Outside Italy, a faunal turnover similar to the one evidenced in Italy around 2.5 Ma (elephant-*Equus* event) took place in France, with the transition from the Vialette and Etouaires local faunas ("Triversa faunal unit" of Azzaroli, 1977) to the Roca Neyra local fauna, which marks the oldest record of *Equus* in France and was dated 2.5 Ma or younger on K/Ar readings (Bout, 1970; Savage and Curtis, 1970). In Spain the first occurrence of *Equus* was dated around 2.5 Ma (Alberdi *et al.*, 1983; Leone, 1985).

The "wolf" event (Azzaroli, 1983), which marks the transition from the Saint Vallier to the Olivola faunal unit, may correspond to the Aullan cold cycle and was less spectacular than the elephant-*Equus* event.

The Cassian cycle corresponds, with rather close approximation, but as it seems not exactly, with the "end-Villafranchian" event in mammalian faunas (Azzaroli and Napoleone, 1982; Azzaroli, 1983; Azzaroli *et al.*, 1988). This event marked the deepest faunal turnover in the whole continental Pleistocene of Eurasia, with extinctions, evolutionary changes, migrations which led to the formation of a more cold-resistant fauna.

3. WESTERN EUROPE - VEGETATION

More or less at the time of the Acquatraversa marine cycle a marked climatic shift was observed at the transition from the warm Reuverian to the cooler Praetigiglian in Dutch pollen sequences (Zagwijn, 1974). Recent age determinations place this shift shortly after the Gauss-Matuyama palaeomagnetic inversion (Zagwijn and Suc, 1984). A second cold cycle, the Eburonian in Duth pollen sequence, may be correlated with the Aullan cycle (less than 2.12+0.33 Ma in Arias *et al.*, 1979).

The Olivola local fauna, interbedded in a sedimentary sequence indicative of strong erosional conditions (Arias *et al.*, 1980) is younger than the Tegelen fauna of the Netherlands (De Giuli *et al.*, 1983; Torre, 1987; Azzaroli *et al.*, 1988) and may be correlated with the Eburonian (younger than the Olduvai, Zagwijn and Suc, 1984). The Aullan sea level drop may therefore be correlated with good approximation with the Neogene/ Quaternary boundary as agreed in the XI INQUA Congress (Moscow, 1982).

The faunal revolution of the end-Villafranchian event had its counterpart in vegetation. Pollen sequences were elaborated in detail in the Netherlands (Zagwijn, 1974) and a long record was obtained from boreholes in the Hungarian plain (Cooke, 1981).

The history of vegetation is marked by a succession of associations characteristic of warm climate alternating with temperate and cold associations. In the long record from Hungary Cooke (1981) dated to the end of the Jaramillo palaeomagnetic episode the first appearance of associations characteristic of a cold dry, *i.e.* glacial climate.

4. MEDITERRANEAN AREA

In the marine section of Ficarazzi near Palermo, Sicily, a marked drop of sea level is evidenced by a calcarenitic level with pteropods indicative of a climatic cooling. The calcarenite overlies the "small *Gephyrocapsa* zone" of nannoplancton stratigraphy (Rio *et al.*, 1990) and may tentatively be correlated with oxygen isotope stage 22, the beginning of the so-called "glacial Pleistocene" of Shackleton and Opdyke 1976 (Ruggieri *et al.*, 1984). Time correspondence with the Cassian eustatic cycle is too close to be fortuitous.

5. OTHER CONTINENTS - CONTINENTAL SEQUENCES

The Atlantic coast of Morocco is characterized by a series of marine ingressions and regressions which were described in detail by Biberson (1971). Correlation with European sequences is unfortunately difficult because of the endemic character of continental faunas, and indicative chronometric ages reported by Biberson are given with broad error margins. The chronology of this sequence needs closer investigation. It may turn out to be of high interest as the area was tectonically stable during the Pliocene and Pleistocene.

It may be remarked that the intra Pliocene faunal revolution (elephant-*Equus* event of Eurasia) matches a similar event in South African mammalian faunas (Partridge, 1985; Vrba, 1985; Wesselman, 1985) and Turner (1985) described a dispersal event of hominoids and carnivores from Africa to Eurasia at the time of the end-Villafranchian event. In India the elephant-*Equus* event was dated by Lindsay *et al.* (1980) to the same time as in Europe, although different faunas were involved.

Vegetation and faunas of central and northern Asia, *i.e.* with the exclusion of the Indian subcontinent, interacted extensively with vegetation and faunas of Europe. Several localities, dispersed over most of Asia, yielded

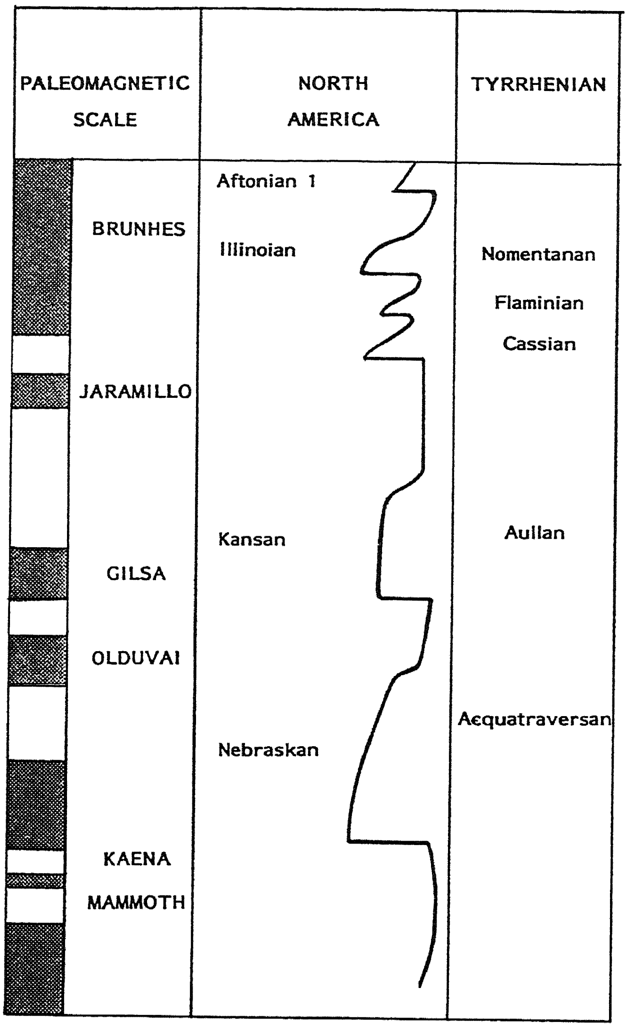

Fig. 2 - Correlations of sea level fluctuations and glacial periods in North America (after Bear *et al.*, 1982) and erosional phases in central Italy.

Correlazioni fra fluttuazioni del livello del mare e periodi glaciali nel Nord America (sec. Bear et al.*, 1982) e fasi erosive nell'Italia centrale.*

faunas which may be correlated with either Villafranchian or Galerian faunas of Europe (Azzaroli *et al.*, 1988), but transitions between the two faunal assemblages can seldom be detected.

Evidence for the beginning of the great faunal revolution of the end-Villafranchian event comes from the cold environments of north-eastern Siberia (Sher, 1971, 1987; Azzaroli *et al.*, 1988). The first representatives of the new assemblages (Olyorian of NE Asia; see Sher, 1987) appeared in the late Matuyama chron. Some were recorded from the latest period of reversed magnetic field, some during the Jaramillo normal episode, others still (*Equus verae, Lemmus* sp.) even before the Jaramillo. In spite of differences due to climatic factors, Olyorian assemblages are easily correlated with Galerian faunal complexes of western Europe.

Other typical elements of the Galerian fauna appeared in the same time interval in Tadjikistan: *Equus altidens* at the base of the Jaramillo, *Equus caballus* at its top (Azzaroli, in Azzaroli *et al.*, 1988), alongside primitive megacerids, carnivores (*Canis lupus* cf. *mosbachensis*, *Xenocyon lycaonoides*, primitive giant deer etc.; Nikiforova and Vangengeim, 1988).

The end-Villafranchian event coincides with good approximation with a rejuvenation of erosion and the onset of strong tectonic movements in the Himalayan fold belt (Azzaroli and Napoleone, 1982). According to Dodonov (1987) a marked increase in loess sedimentation took place in central Asia in two phases: the first around 2.4 Ma (but Kukla and An, 1989, date the beginning of loess deposition in China to 2.5 Ma) and the second in the late Matuyama, between the Jaramillo episode and the Brunhes epoch.

A spectacular change took place in the vegetation of Japan at the beginning of the Jaramillo episode, with the appearance of a flora of alpine type (Suzuki and Manabe, 1982), in good agreement with the end-Villafranchian dispersal event.

In view of all this, it appears strange that nothing like the elephant-*Equus* event, nor like the end-Villafranchian event, which have been recognized in several parts of the old World, has yet been recorded in vertebrate faunas of the western Hemisphere: the more so as these events appear to be more or less closely linked with world-wide sea level falls and climatic fluctuations. This may possibly be because, although American mammalian stratigraphies are established on solid bases, their time resolution does not seem to be as high as in mammalian stratigraphies of western Europe. This may also be the case for pollen stratigraphies, but an exception in this field is provided by the long record of the sedimentary basin of Bogota, Colombia. Hooghiemstra (1989) recognized a distinct change in the features of climatic cycles at 2.5 Ma, from high-frequency, low amplitude to low-frequency, high amplitude cycles; and oak (*Quercus*) appeared in the area around 1 Ma, drastically changing the aspect of Andean forests (Hooghiemstra's age determinations are somewhat broadly approximated: Kukla, 1989).

6. OTHER CONTINENTS - MARINE SEQUENCES

Comparison with marine areas in other parts of the world is instructive. Stipp *et al.* (1967) brought evidence for a succession of eustatic cycles in the western coast of New Zealand, North Island, the oldest of which dates from 2.4÷2.6 Ma, and proposed to take this event as the Neogene/Quaternary boundary. This is the age of the Acquatraversa cycle of Blanc. Although the XI INQUA Congress, Moscow 1982, decided otherwise on the conventional boundary, the oldest cycle described by Stipps *et al.* is by far the major event in the marine Pliocene

(Shackleton and Opdyke, 1977; Stanley, 1982; Thunell and Williams, 1983; Raffi *et al.*, 1990; Rio *et al.*, 1990). The diagram of Stipps *et al.* illustrates five more eustatic cycles, the last of which corresponds to the end of the Pleistocene.

Beard *et al.* (1982) described eustatic cycles in the Gulf of Mexico in great detail. They recognized eight cycles of regression and ingression which were correlated with North American continental glaciations. These are, from oldest to youngest; Nebraskan (duration from 2.8 to 2.0 Ma), Kansan (1.6÷1.2 Ma), then (three distinct cycles (the oldest two incorrectly called Illinoian 1 and 2) beginning in the late Matuyama and ending around 0.45 Ma); three Altonian cycles (from 0.07 to 0.035 Ma) and Woodfordian (beginning at 0.02 Ma). Possible correlation with the eustatic cycles in the Tiber delta are shown in Fig. 2. It may be pointed out that the Kansan (= Aullan) and second Illinoian (= Flaminian) cycles are of lesser amplitude than the others. The greatest sea lowering occurred at the Nebraskan (= Acquatraversan).

The frequency of cycles increased suddenly and dramatically with the Illinoian: the first three cycles occurred at average intervals of 0.7 Ma, the last six cycles are crowded in less than 1.0 Ma.

7. THE AGES OF THE END-VILLAFRANCHIAN EVENT AND OF THE CASSIAN (= OLDEST ILLINOIAN) MARINE CYCLE

A whole set of changes in faunas, vegetation, climate and sedimentary features characterize the beginning of the so-called "glacial Pleistocene" and the advent of new faunal and floral assemblages, of more modern type. As stated in the previous sections, changes on the continents and in marine environments took place in a restricted time interval but were not contemporary.

Dating of these events has been based largely on the palaeomagnetic time scale; the time involved spans the late Matuyama epoch and the beginning of the Brunhes epoch. The age of the Matuyama-Brunhes transition was determined as 0.73 Ma by Mankinen and Dalrymple (1979) through analysis of radioisotopes, but Johnson (1982) questioned the reliability of this date. Approaching the problem from a totally different side, astronomic constants of the Earth's orbit, and assuming that temperature variations of deep ocean waters followed immediately fluctuations in insolation, Johnson concluded for an age of O^{18} stage 19 (close to the Matuyama-Brunhes boundary) of 790±5 Ka. This date, as far as correct, implies a reexamination of the middle Pleistocene time scale and of the dates previously assumed for stage 22 (ca 0.8 Ma) and for the Jaramillo episode (from 0.90 to 0.97 according to Mankinen and Dalrymple, 1979).

8. CLOSING REMARKS

It is seen from this rapid excursus that changes of great moment, indeed the most dramatic changes in Pleistocene faunas and vegetation of Eurasia took place in the time interval roughly corresponding to the Jaramillo episode in western Europe, and slightly earlier in eastern Asia. A wide ranging change in vegetation took place in South America around 0.9 Ma. Changes in ocean temperatures took place with a time lag of the order of 0.1 Ma. The Cassian sea level drop may be assumed to correspond to the calcarenitic, pteropod bearing level at Ficarazzi, Sicily, and this, in turn, may correspond to oxygen isotope stage 22, *i.e.* half way between the end of the Jaramillo and the beginning of the Brunhes epoch.

During the XII INQUA Congress, Ottawa 1987, it was provisionally agreed to place the conventional boundary between early and middle Pleistocene at the Matuyama-Brunhes transition. This because the inversion of the magnetic field is a world-wide event which offers an objective basis for close correlation and is relatively easy to detect in both marine and continental sequences.

It was objected to this proposal that the Matuyama-Brunhes transition does not coincide with any appreciable event in either sedimentary features, climate, sea level fluctuations, vegetation, faunas or tectonic activity.

If the boundary between early and middle Pleistocene is to be defined in a marine section, oxygen isotope stage 22 seems to be the best choice since it corresponds to a negative eustatic event of world-wide scope, a drastic change in the pattern of climatic fluctuations and also to a change in average sea temperature (Thunell and Williams, 1983). This boundary is also close to, although distinctly younger than, the most extensive revolution in Pleistocene continental faunas and vegetation, an event which has been recognized in Eurasia and South America and may prove to have been of world-wide scope.

It may be premature to define now a conventional boundary between early and middle Pleistocene. The matter may deserve closer investigation, and this should proceed in the sense of a closer dating of eustatic cycles, higher resolution in continental stratigraphy, more accurate correlation between marine and continental sequences and the selection of a typical marine section for reference.

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